2 Norwegian coastal cod[1]

A benchmark assessment (WKBARFAR) was conducted in February 2021 to address the failure of the current management plan to reduce fishing mortality on Norwegian coastal cod (NCC; ICES, 2021a). The main outcome of the benchmark was that from assessment year 2021 onwards, Norwegian coastal cod (former stock code: cod.27.1-2coast) was split into two stocks/components by 67 degrees latitude (Figure 2.0.1); 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).

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.

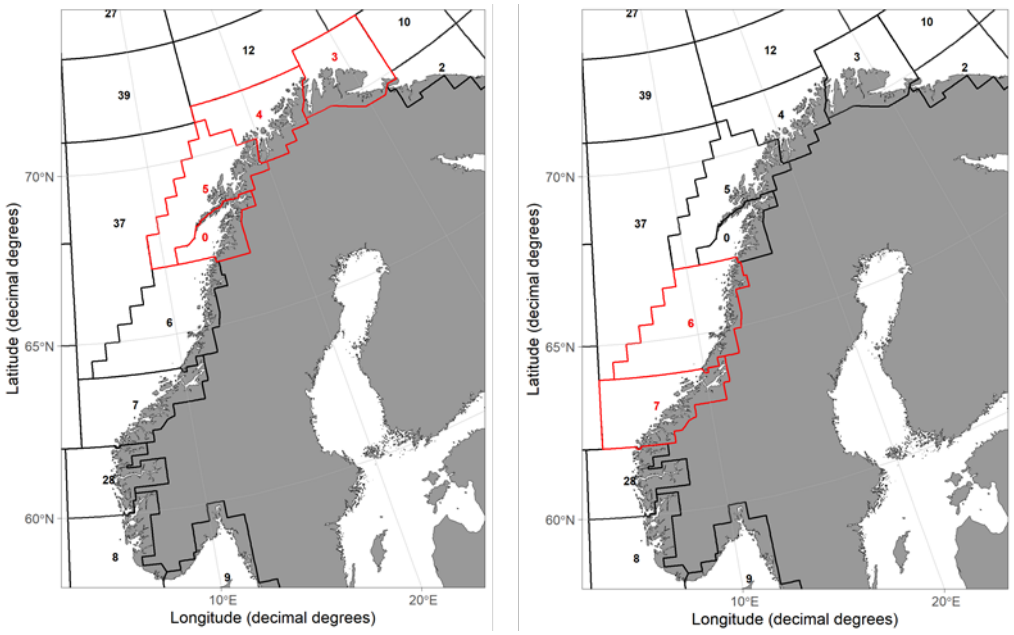

Figure 2.0.1 Norwegian catch reporting areas used to define stock distribution areas for northern Norwegian coastal cod (left) and southern Norwegian coastal cod (right).

[1] Cod (*Gadus morhua*) in subareas 1 and 2, north of 67°N (Norwegian Sea, Barents Sea), northern Norwegian coastal cod: cod.27.1-2.coastN; Cod (*Gadus morhua*) in Subarea 2 between 62°N and 67°N (Norwegian Sea), southern Norwegian coastal cod: cod.27.2.coastS.

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. Recreational catches are a much larger proportion of the total for the southern stock than for the northern stock, respectively about 50% vs. 15%. However, there are 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 2010–2019, 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 2.1.1).

The catches reported (both kept and released fish) by registered fishing businesses to the Norwegian Directorate of Fisheries in the COVID-19 years 2020–2021 were only 23% and 41% of 2019 catches, respectively. In the current assessment, the WG has taken this into account and reduced the rod and line catches from tourist boats accordingly and kept the other, Norwegian resident, recreational catches unchanged at the 2019 level. This results in 10 039 and 10 661 tonnes of recreational NCC catch north of 62°N in 2020 and 2021 (Table 2.1.1). The proportion of the recreational total caught north of 67°N vs. between 62–67°N is assumed to be the same in all years.

The total recreational catch numbers-at-age have been upscaled from the estimated catch-at-age proportions in the commercial landings (Tables 2.2.3c and Table 2.3.3).

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 (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. Commercial and recreational total catches have now been calculated back to 1977 for both stocks (Table 2.1.1, WD 03). In addition, catch-at-age in the years 1977–1993 have been estimated for the northern stock (WD 03), though it is not yet included in the assessment model.

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.

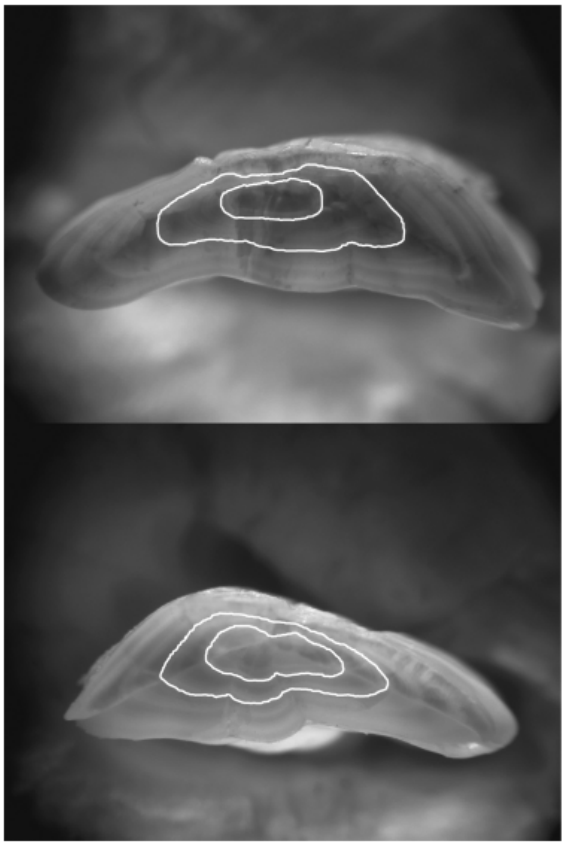

Figure 2.1.2. An image of a Norwegian coastal cod otolith (top) and a Northeast Arctic cod otolith (bottom). The two first translucent zones are highlighted. (from Berg *et al.*, 2005).

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 was lower than previous recent years due to reduced access to fish landing sites because of COVID-19, but the proportion of NCC in samples was similar. In 2021, the number of otoliths were nearly back to pre-pandemic levels; a total of 10 612 fish were aged in 2021, whereof 35% were classified as Norwegian coastal cod (Table 2.1.2).

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.

Year	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
1977	33735	9776	13831	7789	4774	12563			
1978	36413	6272	8982	7855	4814	12669			
1979	31929	8194	10745	7921	4855	12776			
1980	29792	8923	12948	8003	4905	12909			
1981	36161	10117	16551	8054	4936	12990			
1982	33361	5883	19361	8121	4977	13098			
1983	46297	5562	10616	8188	5019	13207			
1984	63305	5621	9442	8256	5060	13316			
1985	56944	7424	5786	8324	5102	13425			
1986	37359	3319	10742	8392	5143	13535			
1987	39630	5147	7731	8424	5163	13588			
1988	55602	5153	4069	8457	5183	13640			
1989	38174	6993	4277	8551	5241	13792			
1990	16707	3687	8055	9035	5538	14573			
1991	22863	3823	12331	9524	5837	15361			
1992	30110	3923	20156	10018	6140	16157			
1993	39681	6202	22814	9181	5627	14809			
1994	52579	6381	23430	9144	5556	14700			
1995	56907	8936	16981	9144	5556	14700			
1996	41820	6207	13250	9020	5480	14500			
1997	46605	4746	12695	9020	5480	14500			

Year	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
1998	45462	6200	9389	9082	5518	14600			
1999	38743	5522	7101	8646	5254	13900			
2000	33081	5838	4329	8460	5140	13600			
2001	24470	5250	3499	8335	5065	13400			
2002	32188	6937	4266	8460	5140	13600			
2003	29253	8905	3943	8646	5254	13900			
2004	31198	6866	3941	8335	5065	13400			
2005	30097	8005	1462	8211	4989	13200			
2006	36884	8612	1175	8087	4913	13000			
2007	26200	7695	2250	8087	4913	13000			
2008	27711	9889	1376	7962	4838	12800			
2009	22988	7145	2474	7900	4800	12700			
2010	34804	7634	2685	7900	4800	12700			
2011	27982	7128	7474	7900	4800	12700			
2012	26778	8187	4942	7900	4800	12700	1425	239	1665
2013	21376	5131	8395	7900	4800	12700	450	167	617
2014	22750	6244	6682	7900	4800	12700	774	229	1003
2015	34483	5004	5424	7900	4800	12700	618	226	844
2016	49503	5962	2006	7900	4800	12700	810	332	1142
2017	54273	4159	1242	7900	4800	12700	772	307	1078
2018	34532	4436	1822	7900	4800	12700	889	326	1215
2019	35861	2965	1677	7900	4800	12700	1603	339	1943
2020	43133	3481	987	6233	3806	10039	1789	347	2136
2021	38347	3696	578	6623	4039	10661	565	321	885

***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).

Year	Quarter 1		Quarter 2		Quarter 3		Quarter 4		Total		
	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
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

Year	Quarter 1		Quarter 2		Quarter 3		Quarter 4		Total		
	NCC	NEAC	NCC	NEAC	NCC	NEAC	NCC	NEAC	NCC	NEAC	%NCC
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
2021	1731	4060	956	2219	459	291	580	316	3726	6886	35
μ85–21	1126	4022	627	2091	525	467	794	838	3054	7446	29

2.2 Northern Norwegian coastal cod

2.2.1 Stock status summary

The assessment is based on the decisions of the 2021 WKBARFAR benchmark (ICES 2021a), with updates from the 2022 WKNCCHCR workshop on evaluation of Norwegian coastal cod harvest control rules (ICES 2022). The latter included changes to the assessment model as a follow-up to the benchmark in addition to reference point and HCR evaluations based on a request from the Norwegian managers.

The changes to the model included replacing the acoustic survey index by age with an aggregated biomass index due to uncertain age information, and a change to the Fbar from ages 4–7 to 4–8 to better reflect fishing pressure on the stock.

The evaluation of reference points led to the conclusion that it was not possible to set a B_{lim} with the certainty required to use it as a basis for estimating reference points in the ICES AR. Therefore, the requested HCRs (based on B_{lim}) could not be considered precautionary. As an alternative, the workshop proposed a constant fishing mortality HCR without a B_{lim}. In this HCR, target F was set to $F_{0.1}$, a conservative proxy for F_{msy}. This HCR was evaluated as precautionary for all stock sizes above B_{loss} (lowest SSB observed in last c. 20 years) at WKNCCHCR.

The HCR advice was released on 7 June 2022 and the $F_{0.1}$ HCR was adopted by the managers shortly thereafter. The revised model and new HCR were used as basis for the advice released on 15 June 2022.

The 2022 assessment shows that SSB declined from a relatively high level 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 and a slight decrease from 2020 to 2021 (3500 t). Fishing mortality mainly follows the trend in SSB, with highest F in the period with lowest estimated SSB. However, F increased from 2019 to 2020 despite increasing SSB, and decreased from 2020 to 2021 despite a small decrease in SSB. Recruitment-at-age 3 has been relatively stable over time, with somewhat higher values in the early period. There is a weak relationship between SSB and recruitment-at-age 3 despite low fishing pressure on this age.

Stock numbers-at-age 2 in 2020 were the lowest observed in the time-series, and the estimate of this cohort in 2021 is also one of the lowest in the time-series. TSB in 2021 is about 30 000 t lower than in 2020 and the lowest observed since 2006–2007. This is mainly driven by the low age 3 numbers, which were also seen in 2006–2007.

The 2021 advice for this stock was revised two times due to errors in data input, with the final quota advice released 15 June 2022 advising that 2022 catches should not exceed 12 143 t (commercial and recreational catches combined). Total landings in 2021 were ~ 45 000 t, and it is likely that 2022 landings will be at a similar level, exceeding the quota advice.

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 2021 were 38 347 t, down c. 5000 t from 2020. Of the total landings, 22% 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 area 05, using Danish seine and gillnet (Table 2.2.2). Compared to 2020, catch proportions were higher in area 05 and lower in areas 03, 04 and 00. In total, 40% of the landings were taken in gillnet fisheries and 32% in Danish seine, while longline/jig made up 16% of the landings and trawl 12%.

The estimate of recreational catch (fixed at 7900 t) was adjusted in 2020 and 2021 based on reports from tourist businesses to reflect reduced fishing tourism due to the COVID-19 pandemic.

Catch-at-age (commercial + recreational) of ages 3, 4 and 6–10+ were lower compared to 2020, while catches of ages 2 and 5 increased. The total catch in tonnes decreased by 4400 t compared to 2020.

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 for coastal cod along the Norwegian coast from the Russian border to 62°N was started in autumn 1995. In 2003, this survey was combined with a saithe survey conducted at the coastal banks and moved from September to October–November (ICES acronym for the combined survey: A6335). Since 2003, the survey therefore covered an extended area and had a more consistent design with 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. At the WKNCCHCR 2022 workshop, further quality control of the survey indices were done, resulting in a decision to change the acoustic index from an index by age to an aggregated biomass index (ICES, 2022). This was due to the index by age poorly tracking age classes, particularly after the coastal cod survey merged with the saithe survey, and that the uncertain age 2 estimates from this index had a large influence on model estimates (particularly the shape of the stock–recruit relationship). The swept-area index has generally higher internal consistency and is still included in the model as an age disaggregated index. It should be noted that the uncertainties associated with these 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 2021 survey north of 67°N are presented in Tables 2.2.5–2.2.12. Box 2.1 below details a decision that was made at AFWG to exclude the acoustic index data point from 2021 (last survey year) due to an inconsistently high value. This decision must be revisited next year when another data point is available.

Box 2.1. Decision to exclude the acoustic 2021 survey index from the 2022 stock assessment.

The 2021 acoustic survey index came in very high in relation to most previous years and compared to the 2021 swept-area index. To evaluate whether the high index reflected an actual increase in the stock or was due to an error, several checks were made before and during AFWG.

These are summarized below, and further details can be found in the presentation "Survey_data_acoustics_NCCNorth" on the AFWG 2022 SharePoint.

High acoustic values compared to trawl catches were evident both when the acoustic index was expressed as total abundance and as total biomass (Figure B2.1.1), and were seen for all age groups. Looking at internal consistency, the 2021 data point fell outside or on the very edge of the "cloud" of points for nearly all age groups. This was not the case in the swept-area index, where the 2021 data point were more consistent with previous observations.

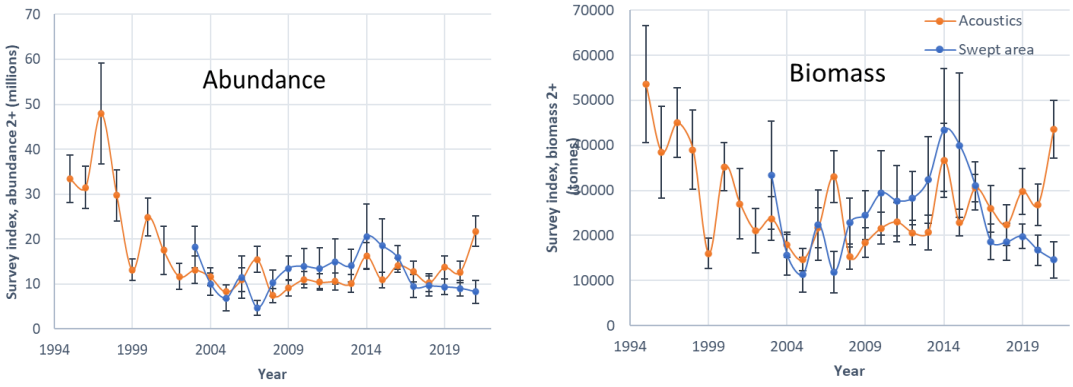

Figure B2.1.1. Swept-area (blue) and acoustic (orange) abundance indices (left, in millions) and biomass indices (right, in tonnes) for northern coastal cod. The error bars represent 95% confidence intervals around the mean. The figures show the indices after correction of stock discrimination and rescrutinization of the acoustics.

It was mainly two strata in the northeast that contributed the high acoustic values, called "Østhavet" and "Hjelmsøy Loppa". While the acoustic values were high in these strata, catch rates in the trawl were not particularly high compared to other areas. Østhavet is the strata with the largest proportion of Northeast Arctic cod in the survey, increasing the risk of misclassification between the two stocks. The area also have high abundances of other demersal fish such as saithe and haddock, increasing the risk of misclassification in the acoustic scrutinization process. Therefore, both the stock discrimination by otolith typing and the acoustic scrutinization in this area were closely examined.

In the rescrutinization, some obvious scrutinization errors were found and corrected. These mainly concerned situations where saithe had been misclassified as cod, or too large proportions of cod had been assigned to mixed demersal fish aggregations. This correction reduced the acoustic index somewhat (c. -20% for age 3, c. -10% on average).

To examine possible misclassification of stock types, a subsample of the otoliths was reread. This resulted in approximately 9% of otoliths in the sample being reclassified from coastal cod to Northeast Arctic cod. Coastal cod otoliths come in many variations (some specific to local fjords), and this level of misclassification is not unexpected even among experienced readers. Correcting the stock discrimination further reduced the survey index for some ages, but the total change compared to pre-rescrutinization of the acoustics and pre-rereading of otoliths did not exceed c. -20% for any age and the acoustic index was still unusually high compared to the swept-area index.

Next, commercial catches from the approximate time and area with high acoustic survey registrations were examined. While cod catches in October-November 2021 were actually lower than in the previous four years, catches of saithe were higher, particularly in November (Figure B2.1.2). The survey covered the area in October, not November, but the catch statistics nevertheless indicate that saithe abundance rather than cod abundance was high in the area within few weeks of the survey.

In summary, the acoustic survey index in 2021 fell outside the internal consistency "cloud" for several ages, also compared to the one other year (2007) when the acoustic index was much higher than the swept-area index. Two strata with high saithe abundances contributed the most to the coastal cod index. The high coastal cod index was caused by large acoustic registrations classified as cod that were not reflected in large survey trawl catches, or in higher commercial catches around the time of the survey. However, commercial catches of saithe were relatively high in the area at the time of the survey and some weeks after. In conclusion, some degree of misclassification between cod and saithe was strongly suspected and the expert group was not confident enough in the data to include the 2021 cod index in the assessment. Excluding it and re-evaluating this decision again when another data point is available next year was considered to be more appropriate, and a precautionary decision given that the high acoustic index had a large influence on model results (20% increase in terminal year SSB when including the 2021 acoustic data point).

Figure B2.1.2. Commercial catch (kilograms) of cod (left panels), saithe (middle panels) and haddock (right panels) in Norwegian statistical fishing area 03 by month in the years 2017–2021. The survey for coastal cod and saithe takes place in months 10 and 11 (October-November). High saithe catches in this period in 2021 are circled in red.

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

As detailed in Box 2.1, the acoustic survey index in 2021 were much higher than the swept-area index, for all age groups, and the total acoustic biomass index was nearly three times higher than the total swept-area biomass index (Tables 2.2.5 and 2.2.7).

The 2020 age 1 and 2 swept-area abundance indices were particularly low. In 2021, age 2 indices were higher than expected from the low 2020 estimate of the same year class, while the age 3 estimate were consistent with the low index for this year class in the previous year (Table 2.2.7). The age 1 index in 2021 was higher than in 2021, but still among the lowest in the time-series. Note, however, that age 1 cod are too small to be representatively sampled in the survey and that their distribution extends to shallow habitats not accessible to the research vessels. Indices

for the oldest fish (age 10+) were slightly higher in 2021 than in 2020, but the 2020–2021 indices are nevertheless much lower than those seen in 2009–2019 (Table 2.2.7).

The coefficients of variation (CVs) in both indices are generally higher for ages 8 and above where there is less data (Tables 2.2.6 and 2.2.8).

Survey mortality for age 1–2 decreased sharply in 2021 relative to 2020 as a result of the unexpectedly high estimate of age 2 in 2021 relative to age 1 in 2020 (Figure 2.2.5). Survey mortality for age 9–10 showed an opposite trend with a sharp increase. All other ages in the acoustic index had lower survey Z this year due to the high acoustic estimates, while in the swept-area index, the trends were more variable. Generally, internal consistencies are rather low in both survey indices, and consequently, the survey mortality is highly variable between years (Figure 2.2.5).

2.2.3.2 Age reading and stock separation (Table 2.2.9)

About 2400 cod otoliths were sampled north of 67°N during the 2021 survey, which slightly down from 2500 in 2020 but well above the long-term average (Table 2.2.9). The proportions of NCC at age among those otoliths were higher for older fish (age 6+) compared to the long-term average and the previous year, but within ranges previously observed (Table 2.2.9).

2.2.3.3 Length and weights-at-age (Tables 2.2.10–2.2.11, Figure 2.2.6)

There has been a trend of increasing mean length and, particularly, weight at age over the time-series for most ages, though the trend has levelled off or even reversed in the last few years. Mean lengths-at-age in 2021 were similar to previous years (Table 2.2.10), while mean weights at age decreased compared to 2020 for all ages except age 6 where it was similar (Table 2.2.11). For ages 8 and older the mean lengths and weights show larger variations, probably caused by few fish sampled in some years (Figure 2.2.6).

2.2.3.4 Maturity-at-age (Table 2.2.12, Figure 2.2.7)

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. The maturity ogive therefor includes spent/resting individuals, which gives an ogive similar to that estimated from a smaller fishery-dependent dataset, collected during the spawning season (ICES 2021a). No large changes in maturity-at-age were observed between 2020 and 2021 (Figure 2.2.7).

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 1994–2021, 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.

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. 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 total biomass index (ages 2+) and the swept-area survey index by age (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 the saithe and coastal cod surveys were combined in 2003.

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 2.2.6). 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, Figure 2.2.7)

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, Figure 2.2.8)

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 2022 assessment was run with the configuration decided upon at the 2021 benchmark (Table 2.2.16), with the necessary updates following decisions from WKNCCHCR (ICES, 2022). These decisions included replacing the acoustic index by age with a total biomass index, including age 8 in the Fbar range (previously F4–7, now F4–8), and reporting recruitment-at-age 3 (model starts at age 2).

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 5–9 in the swept-area index, 3) Separate variance parameter for age 2 in the catch, 4) AR(1)-correlation between ages in 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. The "base" model presented below refers to last year's model, which differed from the current model in using acoustic indices by age instead of aggregated biomass indices.

Model	Log(L)	#par	AIC
Current	−185.44	19	408.88
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 2.2.9–Figure 2.2.11)

A 5-year retrospective peel indicated no large problems with the estimates of SSB and Fbar, while the model have a low precision in the recruitment (age 2) estimate from 2013 onwards (Figure 2.2.9). 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, though this pattern was inversed in the last years. Mohn's rho (average 5-year retrospective bias) was 0.2 for SSB, −0.15 for Fbar, and 0.32 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 and show no concerning patterns (Figure 2.2.10). The one-step-ahead residuals (Figure 2.2.11) were also improved by introducing correlations between ages in the survey indices. Evaluation of this correlation structure should be done at the next benchmark to see if the residuals can be further improved, particularly since the correlation structure has recently been removed from the acoustic index due to the removal of age information.

2.2.5.2 Model results (Table 2.2.18–2.2.20, Figure 2.2.1)

Stock numbers-at-age 2 in 2020 were the lowest observed in the time-series, and the estimate of this cohort (age 3 recruits) in 2021 was also one of the lowest in the time-series (Table 2.2.18). SSB decreased with 3500 t from 2020 to 2021, but Fbar also decreased somewhat reflecting the decreased catches of most ages included in the 4–8 Fbar range (Table 2.2.18 and Table 2.2.3c). Fishing mortality for ages 2–5 in 2021 were slightly higher than in 2019 and 2020, while Fs for ages 6 and above were lower (Table 2.2.19). Abundances of ages 9 and 10+ in 2021 were low and slightly down from last year (Table 2.2.20). Abundances of ages 2, 5 and 8 increased compared to 2020.

2.2.6 Reference points

Reference points were evaluated at the 2021 benchmark (ICES 2021a). The estimated stock–recruitment (age 2) relationship showed increasing recruitment with increasing SSB throughout the model period, and the same pattern resulted from adding 2020 data in the assessment (ICES, 2021d). 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 indicated that the stock was below full reproductive capacity.

At the 2022 evaluation of reference points and harvest control rules, this decision was re-evaluated by looking closer at assessment data input and historical catch data. An extension of the assessment model back in time indicated that the stock had not experienced severe recruitment failure in the period examined. The stock also appeared to swiftly respond to decreased F, which would not be expected from a severely depleted stock. At the same time, simulations demonstrated a high sensitivity of the stock–recruit relationship, and therefore also B_{lim}, to small changes in the assessment model, though the estimates of SSB and F were rather consistent. The workshop therefore concluded that it was not possible to set a B_{lim} with the certainty required to use it as a basis for estimating reference points in the ICES AR. Lacking such reference points, the managers adopted a constant fishing mortality HCR (see below) in 2022.

2.2.6.1 Management plan

The Norwegian management plan was implemented in June 2022 and forms the basis for the 2022 advice (ICES, 2022). The target F in the plan is set to $F_{0.1}$, a conservative proxy for F_{msy} that is expected to drive the stock towards and above B_{msy}. This HCR was evaluated as precautionary

for all stock sizes above $SSB_{lowerbound}$ (lowest SSB observed in last c. 20 years) at WKNCCHCR (ICES, 2022). No adjustment of target F is thus applied as long as SSB is above this value. The HCR requires re-evaluation should the stock fall below $SSB_{lowerbound}$.

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. Since the fishery is not quota regulated, 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 2.2.12)

The ICES advice basis for northern Norwegian coastal cod is the Norwegian management plan. This leads to catch advice of no more than 29 347 tonnes in 2023. This catch level is expected to lead to an 8% increase in SSB relative to SSB estimated for 2022, while the same level of fishing in 2023 as in 2021 is expected to give a 1.5% decrease in SSB. Zero catch in 2023 is expected to give a 26% increase in SSB (Table 2.2.21, Figure 2.2.12).

2.2.7.3 Comparison of the present and last year's assessments

Due to the updates to the assessment model following WKNCCHCR (ICES, 2022), last year's assessment is not directly comparable to this year's assessment. However, for exploratory reasons both the old and new models were run with 1994–2020 and 1994–2021 data and the results indicated a downwards revision of SSB (and corresponding increase in F) approximately five years back in time when adding 2021 data. For 2020, the downwards revision was approximately 7000 t.

2.2.8 Comments to the assessment and the forecast

The assessment model performs rather well despite uncertainties in survey data. However, as both the stock and model are new, the assessment has so far been tested in a limited number of situations. Both the data input and configuration should be improved leading up to the next benchmark. Some areas of research that can potentially reduce uncertainty in the assessment include:

- Examining whether survey index uncertainty can be improved, e.g. by adjusting the survey design or the post-stratification applied to calculate indices.
- Rereading subsamples of otoliths from the first part of the survey (1995–2002) as these readings are expected to be less precise.
- Extending the swept-area index back to 1995.
- Re-examining the coupling of ages applied in the swept-area index observation correlation in SAM.
- Consider the new option of modelling natural mortality, stock weights, proportion mature and catch weights as processes with error (as opposed to fixed values) in SAM

2.2.9 Tables and figures

Table 2.2.1. Northern Norwegian coastal cod. Total commercial catch (t) by fishing areas in the last two years.

Year	03	04	05	00	Total in Division 1.b (NOR area 03)	Total in Division 2.a (NOR areas 04+00+05)	Total
2020	12245	12393	10832	7652	12245	30877	43122
2021	8244	6548	18542	4640	8244	29730	37974

Table 2.2.2. Commercial catch of northern Norwegian coastal cod (t) in 2021 by gear and Norwegian statistical fishing area.

Year	2021					
Area	03	04	05	00	Total north of 67°N	% by gear
Gillnet	1007	2985	7667	3352	15011	40
L.line/Jig	3578	621	1436	382	6017	16
Danish seine	2568	1633	7178	892	12272	32
Trawl	1083	1303	2258	14	4658	12
Others*	7.2	6.1	2.8	-	16	<0.1
Total	8244	6548	18542	4640	37974	

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
2021	162	408	1914	3023	1801	1270	644	177	251	38347

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

	Age									Tonnes
Year	2	3	4	5	6	7	8	9	10+	landed
2001	3	112	635	764	559	327	104	36	168	8335
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
2021	28	71	331	522	311	219	111	31	43	6623

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

	Age									Tonnes
Year	2	3	4	5	6	7	8	9	10+	landed
1998	523	1957	7718	5268	3341	1002	935	452	471	54544
1999	97	1116	4152	6040	2492	957	644	482	520	47390
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
2021	190	479	2245	3545	2112	1490	755	207	294	44970

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

	Age								
Year	2	3	4	5	6	7	8	9	10+
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
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
2021	1.189	1.847	2.513	3.360	4.387	5.442	6.391	7.285	8.998

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

	Age											
Year	1	2	3	4	5	6	7	8	9	10+	Sum	Biomass
1995	26495	8774	4974	6382	6440	4373	1309	532	319	132	59729	55126
1996	17580	9025	8592	4576	5306	2723	1022	213	32	24	49093	39263
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	481	1618	3378	3739	2025	890	522	319	85	125	12701	26878
2021	3735	4806	3597	4923	3935	2102	1143	747	231	243	21727	43863

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
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	28	16	16	12	14	14	19	27	39	57
2021	18	16	13	12	13	13	16	19	32	45

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	9072	16780
2021	1412	2531	1367	1589	1367	732	289	239	82	81	8277	14699

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

	Age									
Year	1	2	3	4	5	6	7	8	9	10
2008	15	26	21	13	11	17	15	20	37	36
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	28	14	16	13	13	16	15	19	31	41
2021	19	19	21	16	21	18	13	16	25	35

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

	Age										
Year	1	2	3	4	5	6	7	8	9	10	Total number aged
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

Year	Age 1	2	3	4	5	6	7	8	9	10	Total number aged
2006	0.98	0.93	0.94	0.83	0.75	0.71	0.68	0.68	0.57	0.00	1419
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
2021	0.97	0.93	0.85	0.84	0.76	0.79	0.81	0.83	0.84	0.83	2405
Average 95–21	0.91	0.91	0.87	0.80	0.74	0.67	0.63	0.60	0.62	0.65	2179

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

	Age									
Year	1	2	3	4	5	6	7	8	9	10+
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
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	20.8	33.2	46.9	58.3	66.5	72.3	77.4	83.9	93.2	85.3
2021	20.9	33.2	44.5	56.5	65.3	73.3	76.2	82.4	80.0	91.9

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

	Age									
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10+**
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
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	95	380	1012	1932	2963	3741	4908	6307	9287	7126
2021	79	348	853	1704	2542	3756	4421	5840	5231	7967

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

	Age									
Year	1	2	3	4	5	6	7	8	9	10+
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	0.60	0.88	0.97	0.98	1.00	1.00
2021	0.00	0.00	0.07	0.29	0.58	0.88	0.89	0.96	1.00	1.00

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

```
Norwegian Coastal cod
101
Norw-Coast-Ac-Q4-1995 (Aco)
1995 2002
1 1 0.75 0.85
-2
1 53586
1 38553
1 45079
1 39064
1 16012
1 35255
1 27051
1 21098

Norw-Coast-Ac-Q4-2003 (Aco)
2003 2020
1 1 0.75 0.85
-2
1 23749
1 17968
1 14601
1 21748
1 33075
1 15266
1 18428
1 21637
1 22991
1 20654
1 20705
1 36710
1 22892
1 30551
1 25918
1 22347
1 29829
1 26833

Norw-Coast-Ac-Q4 (BTr)
2003 2021
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	0.2	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
1	2.531	1.367	1.589	1.367	0.732	0.289	0.239	0.082	0.081

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

	Age								
Year	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10+**
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
2020	0.380	1.012	1.932	2.963	3.741	4.908	5.655	6.387	9.024
2021	0.348	0.853	1.704	2.542	3.756	4.421	6.391	7.285	8.998

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

	Age								
Year	2	3	4	5	6	7	8	9	10+
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
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	0.300	0.276	0.265	0.255	0.229
2021	0.619	0.471	0.381	0.338	0.300	0.285	0.255	0.245	0.230

Table 2.2.16. Northern Norwegian coastal cod. 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: WKNCCHCR 2022

The assessment is available at www.stockassessment.org under the name NCCN67_acotsb_2022_Excl2021acou

Configuration saved: Thu Oct 21 15:33:05 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. Negative numbers indicate that the parameter is not
included in the model
$minAge
The minimium age class in the assessment
2

$maxAge
The maximum age class in the assessment

```
 10

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

$keyLogFsta
# Coupling of the fishing mortality states processes for each age (normally only the first row (= fleet) is used). Sequential
# numbers indicate that the fishing mortality is estimated individually for those ages; if the same number is used for two or
# more ages, F is bound for those ages (assumed to be the same). Binding fully selected ages will result in a flat selection
# pattern for those ages.
  0  1  2  3  4  5  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).
# 0: independent means there is no correlation between F across age 1: compound symmetry means that all ages are equally
# correlated; 2: AR(1) first order autoregressive - similar ages are more highly correlated than ages that are further apart,
# so similar ages have similar F patterns over time. if the estimated correlation is high, then the F pattern over time for each
# age varies in a similar way. E.g if almost one, then they are parallel (like a separable model) and if almost zero then they
# are independent. 3: Separable AR - Included for historic reasons . . .  more later
 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 -1 -1 -1 -1 -1 -1 -1
  1 -1 -1 -1 -1 -1 -1 -1 -1
  2  3  4  5  5  5  5  5  6

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

$keyVarF
# Coupling of process variance parameters for log(F)-process (Fishing mortality normally applies to the first (fishing) fleet;
# therefore only first row is used)
  0  0  0  0  0  0  0  0  0
 -1 -1 -1 -1 -1 -1 -1 -1 -1
 -1 -1 -1 -1 -1 -1 -1 -1 -1
 -1 -1 -1 -1 -1 -1 -1 -1 -1

$keyVarLogN
# Coupling of the recruitment and survival process variance parameters for the log(N)-process at the different ages. It is
# advisable to have at least the first age class (recruitment) separate, because recruitment is a different process than
# survival.
 0 1 1 1 1 1 1 1 1

$keyVarObs
# Coupling of the variance parameters for the observations. First row refers to the coupling of the variance parameters for
# the catch data observations by age. Second and further rows refers to coupling of the variance parameters for the index
# data observations by age
  0  0  0  0  0  0  0  0  0
```

```
  1 -1 -1 -1 -1 -1 -1 -1 -1
  2 -1 -1 -1 -1 -1 -1 -1 -1
  3  3  3  3  3  3  3  3  3

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

$keyCorObs
# Coupling of correlation parameters can only be specified if the AR(1) structure is chosen above. NA's indicate where
# correlation parameters can be specified (-1 where they cannot).
#2-3 3-4 4-5 5-6 6-7 7-8 8-9 9-10
  NA  NA  NA  NA  NA  NA  NA  NA
 -1  -1  -1  -1  -1  -1  -1  -1
 -1  -1  -1  -1  -1  -1  -1  -1
  0   1   1   1   2   3   3   3

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

$noScaledYears
# Number of years where catch scaling is applied.
 0

$keyScaledYears
# A vector of the years where catch scaling is applied.

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

$fbarRange
# lowest and higest age included in Fbar
 4 8

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

$hockeyStickCurve
#
 20

$stockWeightModel
# Integer code describing the treatment of stock weights in the model (0 use as known, 1 use as observations to inform
# stock weight process (GMRF with cohort and within year correlations))
 0

$keyStockWeightMean
# Coupling of stock-weight process mean parameters (not used if stockWeightModel==0)
 NA NA NA NA NA NA NA NA NA

$keyStockWeightObsVar
# Coupling of stock-weight observation variance parameters (not used if stockWeightModel==0)
 NA NA NA NA NA NA NA NA NA

$catchWeightModel
# Integer code describing the treatment of catch weights in the model (0 use as known, 1 use as observations to inform
# catch weight process (GMRF with cohort and within year correlations))
 0

$keyCatchWeightMean
# Coupling of catch-weight process mean parameters (not used if catchWeightModel==0)
 NA NA NA NA NA NA NA NA NA

$keyCatchWeightObsVar
# Coupling of catch-weight observation variance parameters (not used if catchWeightModel==0)
 NA NA NA NA NA NA NA NA NA

$matureModel
# Integer code describing the treatment of proportion mature in the model (0 use as known, 1 use as observations to inform
# proportion mature process (GMRF with cohort and within year correlations on logit(proportion mature)))
 0

$keyMatureMean
# Coupling of mature process mean parameters (not used if matureModel==0)
 NA NA NA NA NA NA NA NA NA
$mortalityModel
# Integer code describing the treatment of natural mortality in the model (0 use as known, 1 use as observations to inform
# natural mortality process (GMRF with cohort and within year correlations))
 0

$keyMortalityMean
```

#
NA NA NA NA NA NA NA NA

$keyMortalityObsVar
Coupling of natural mortality observation variance parameters (not used if mortalityModel==0)
NA NA NA NA NA NA NA NA

$keyXtraSd
An integer matrix with 4 columns (fleet year age coupling), which allows additional uncertainty to be estimated for the specified observations

Table 2.2.17. Northern Norwegian coastal cod. SAM output. Estimated catchability at age for each fleet. The two parts of the acoustic biomass index have one catchability parameter each as the biomass index is not split by age. In the swept-area index, catchabilities are coupled (set equal) in the SAM configuration for ages 5–9.

Fleet/Age	2	3	4	5	6	7	8	9	10+	2+
Acoustic biomass index pt. 1	-	-	-	-	-	-	-	-	-	0.131
Acoustic biomass index pt. 2	-	-	-	-	-	-	-	-	-	0.084
Swept-area index	0.000059	0.000099	0.000141	0.000155	0.000155	0.000155	0.000155	0.000155	0.000206	-

Table 2.2.18. Northern Norwegian coastal cod. SAM output. Estimated recruitment (1000's), Spawning-stock biomass (SSB, t), average fishing mortalities for ages 4–8 (Fbar(4–8)), and Total-stock biomass (TSB, t).

Year/Age	R (age 3)	Low	High	SSB	Low	High	Fbar (4–8)	Low	High	TSB	Low	High
1994	34992	27728	44159	130993	96944	177001	0.28	0.22	0.35	319804	274928	372005
1995	41348	33622	50850	111126	83352	148154	0.37	0.30	0.45	304438	265793	348702
1996	50989	42740	60829	88896	71071	111192	0.36	0.30	0.45	250491	223931	280201
1997	61719	51220	74369	68453	55548	84356	0.46	0.38	0.56	225985	203998	250343
1998	53189	45264	62500	57631	46109	72033	0.47	0.39	0.57	239763	217051	264852
1999	54709	46415	64485	46563	38713	56004	0.43	0.35	0.53	218210	198852	239451
2000	53310	45246	62810	51115	43978	59411	0.33	0.27	0.41	229435	209257	251560
2001	45938	39048	54044	66803	59523	74974	0.27	0.22	0.33	234635	214160	257068
2002	46742	39710	55019	80746	71999	90555	0.31	0.25	0.37	252166	229999	276470
2003	47784	40608	56228	67357	59689	76011	0.30	0.25	0.36	235077	214066	258152
2004	42553	36652	49404	76698	67828	86727	0.33	0.27	0.40	237280	215168	261663
2005	43888	37773	50993	68735	60330	78311	0.29	0.24	0.35	229863	208034	253982
2006	35580	30541	41451	86978	75614	100050	0.34	0.27	0.41	239023	215690	264880
2007	33123	28438	38579	93704	80558	108995	0.24	0.189	0.29	247700	222464	275799
2008	42627	36580	49673	93726	79841	110026	0.22	0.180	0.28	264965	237448	295670
2009	40757	35217	47169	72516	60529	86876	0.19	0.149	0.23	258190	230778	288857
2010	37846	32781	43693	83864	70567	99665	0.23	0.185	0.28	270820	243344	301398

Year/Age	R (age 3)	Low	High	SSB	Low	High	Fbar (4–8)	Low	High	TSB	Low	High
2011	36999	31855	42973	94782	80225	111980	0.21	0.167	0.26	292032	262578	324790
2012	45225	39106	52300	99826	84178	118383	0.166	0.135	0.21	286213	257303	318372
2013	34861	30026	40475	100983	85441	119352	0.143	0.116	0.176	275339	247640	306137
2014	40524	35046	46858	105791	90454	123730	0.139	0.114	0.170	295707	267055	327433
2015	40680	35009	47270	97679	83546	114202	0.20	0.164	0.24	315537	285400	348856
2016	42547	35926	50387	102587	88477	118947	0.28	0.24	0.34	308133	276832	342974
2017	42932	35446	52000	86205	73511	101091	0.37	0.31	0.44	299472	264379	339224
2018	41939	33397	52665	82113	68806	97994	0.32	0.26	0.39	297859	254656	348391
2019	52186	39653	68680	71717	57570	89341	0.34	0.27	0.43	284703	235074	344811
2020	42704	30808	59193	83705	62620	111890	0.36	0.26	0.49	273050	215481	346000
2021	34086	22950	50628	80421	55386	116771	0.28	0.185	0.41	245947	182979	330584

Table 2.2.19. Northern Norwegian coastal cod. 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	0.038	0.162	0.327	0.432	0.432	0.432	0.330
1995	0.000	0.008	0.055	0.181	0.388	0.602	0.602	0.602	0.424
1996	0.001	0.018	0.091	0.227	0.396	0.551	0.551	0.551	0.424
1997	0.001	0.025	0.119	0.274	0.535	0.680	0.680	0.680	0.559
1998	0.004	0.054	0.243	0.470	0.631	0.502	0.502	0.502	0.425
1999	0.001	0.027	0.169	0.382	0.540	0.535	0.535	0.535	0.463
2000	0.001	0.016	0.127	0.323	0.403	0.403	0.403	0.403	0.414
2001	0.000	0.010	0.085	0.223	0.342	0.359	0.359	0.359	0.660
2002	0.001	0.012	0.082	0.211	0.379	0.428	0.428	0.428	0.870
2003	0.001	0.013	0.066	0.177	0.329	0.456	0.456	0.456	0.869
2004	0.001	0.008	0.050	0.144	0.326	0.555	0.555	0.555	1.001
2005	0.000	0.008	0.054	0.150	0.279	0.481	0.481	0.481	1.121
2006	0.001	0.011	0.068	0.190	0.328	0.550	0.550	0.550	1.634
2007	0.001	0.016	0.077	0.181	0.248	0.334	0.334	0.334	0.981
2008	0.001	0.018	0.073	0.205	0.259	0.287	0.287	0.287	0.650
2009	0.001	0.015	0.046	0.153	0.240	0.244	0.244	0.244	0.413
2010	0.001	0.018	0.055	0.185	0.303	0.299	0.299	0.299	0.576
2011	0.002	0.021	0.063	0.141	0.221	0.306	0.306	0.306	0.543
2012	0.006	0.038	0.078	0.129	0.184	0.220	0.220	0.220	0.449
2013	0.003	0.026	0.061	0.106	0.149	0.200	0.200	0.200	0.366
2014	0.003	0.022	0.061	0.101	0.141	0.196	0.196	0.196	0.386
2015	0.005	0.040	0.095	0.142	0.206	0.273	0.273	0.273	0.592
2016	0.003	0.030	0.097	0.155	0.282	0.443	0.443	0.443	0.810
2017	0.009	0.057	0.145	0.215	0.352	0.560	0.560	0.560	0.856
2018	0.003	0.025	0.085	0.160	0.271	0.536	0.536	0.536	0.678
2019	0.001	0.020	0.082	0.164	0.289	0.583	0.583	0.583	0.703
2020	0.001	0.017	0.090	0.192	0.357	0.579	0.579	0.579	0.598
2021	0.002	0.021	0.104	0.203	0.281	0.397	0.397	0.397	0.477

Table 2.2.20. Northern Norwegian coastal cod. SAM output. Estimated stock numbers-at-age (1000's).

Year/Age	2	3	4	5	6	7	8	9	10+
1994	83306	34992	39108	35936	17710	10156	4859	1124	3081
1995	99046	41348	21156	25103	21136	9196	4904	2426	2391
1996	122445	50989	24666	13420	14705	10279	3800	2040	2278
1997	106813	61719	29781	14775	7417	7169	4422	1665	2104
1998	109788	53189	37075	17441	7753	3140	2647	1673	1590
1999	102990	54709	31344	19796	7616	2989	1429	1217	1595
2000	87319	53310	32472	17792	9540	3182	1313	631	1351
2001	84360	45938	32944	19070	9052	4668	1581	661	1043
2002	87770	46742	28354	20764	10684	4636	2421	840	787
2003	80865	47784	29702	17439	12024	5330	2266	1202	671
2004	79982	42553	30041	18718	10327	6229	2509	1083	819
2005	63046	43888	25902	19644	11604	5441	2650	1088	718
2006	60940	35580	27501	16663	12008	6298	2525	1254	696
2007	72916	33123	22655	17391	9725	6490	2681	1128	661
2008	72708	42627	20802	14229	10443	5543	3553	1480	827
2009	68818	40757	27790	13391	8383	5924	3135	2090	1208
2010	64863	37846	25556	18703	8278	4860	3508	1883	1938
2011	79524	36999	24213	16582	11184	4537	2725	2004	1967
2012	67552	45225	23859	15880	10497	6602	2574	1518	2049
2013	74721	34861	28813	15504	10251	6472	3989	1602	1965
2014	75747	40524	21186	18945	10261	6479	3964	2525	2094
2015	78329	40680	25643	13703	12444	6653	3986	2523	2721
2016	78398	42547	25151	16357	8609	7530	3883	2323	2673
2017	76621	42932	25648	15970	10107	4889	3645	1921	2091
2018	89067	41939	26384	15213	9415	5216	2140	1603	1555
2019	77253	52186	25915	16956	9522	5308	2320	971	1358
2020	63412	42704	33048	16728	10302	5326	2260	989	947
2021	79169	34086	26829	20881	10098	5286	2294	960	842

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
$F_{ages\ 4–7}$ (2022)	0.280	F_{sq} = median fishing mortality in 2021.
SSB (2022)	86 899	Short-term forecast fishing at *status quo* (F_{sq}); Tonnes.
$R_{age\ 2}$ (2022 and 2023)	77 253	Median resampled recruitment (2012–2021). The youngest age in the model is age 2. Other reported recruitments are at age 3 when the fish enter the fishery; thousands.
Total catch (2022)	43 688	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 (last 5 year averages).

Age	Weight in catch (kg)	Weight in stock (kg)	Proportion mature	Natural mortality
2	1.313	0.425	0.005	0.586
3	1.877	1.032	0.060	0.445
4	2.545	1.936	0.275	0.367
5	3.289	2.927	0.576	0.324
6	4.135	3.815	0.822	0.298
7	5.005	4.907	0.929	0.276
8	5.896	5.896	0.987	0.261
9	6.749	6.749	0.976	0.250
10+	9.054	9.054	1.000	0.229

Table 2.2.22. Northern Norwegian coastal cod. Catch scenarios.

Basis	Total catch (2023)	F_{total} (2023)	SSB (2023)*	% SSB change**	% advice change***	% probability of SSB falling below $SSB_{lower\ bound}$ in 2023
ICES advice basis						
Management plan^	29 347	0.176	93 809	8.0	142	8.8
Other scenarios						
F = 0	0	0	109 399	26	−100	0.9
$F = F_{2021}$	44 278	0.28	85 568	−1.5	265	18.5

*** 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 2023 relative to SSB in October 2022 (86 899 tonnes).**

***** Advice for 2023 relative to advice for 2022 (12 146 tonnes).**

^According to the harvest control rule (HCR) in the MP (ICES, 2022a). The advice basis has changed compared to last year following the adoption of the harvest control rule (HCR) evaluated in ICES (2022a) by the managing body.

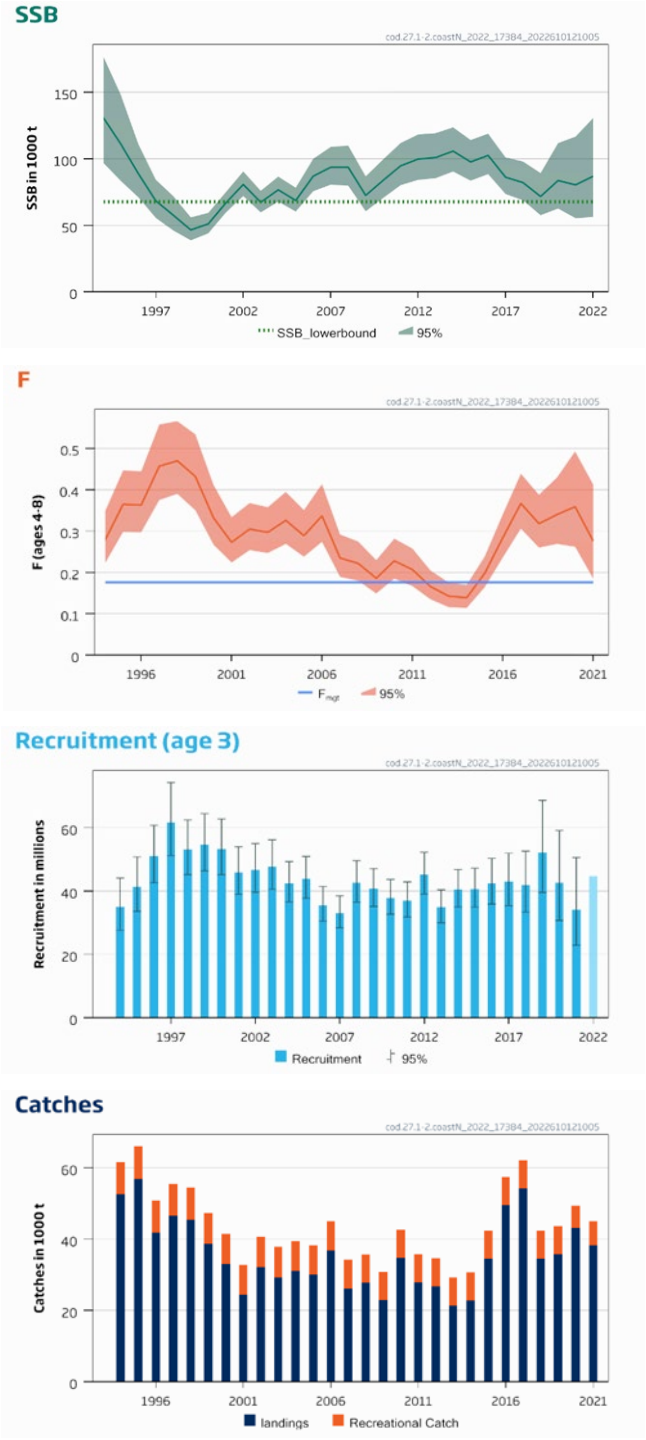

Figure 2.2.1. Northern Norwegian coastal cod. Standard figures. SAM estimates of a) SSB, b) Fbar(4–8), c) recruitment (age 2,), and d) catch input data.

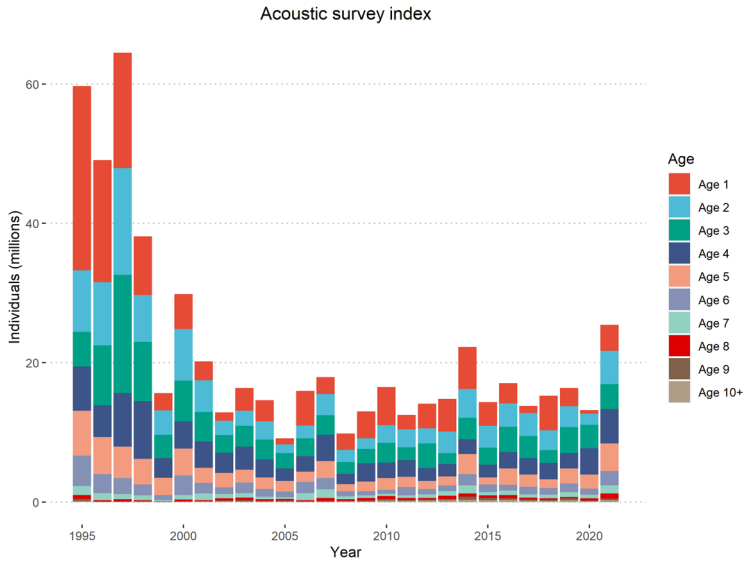

Figure 2.2.2. Northern Norwegian coastal cod. Acoustic abundance index by age (colours) from the Coastal survey in October–November (survey code A6335). Note that starting in 2022, the acoustic index is included in the assessment model as a total biomass index rather than numbers-at-age.

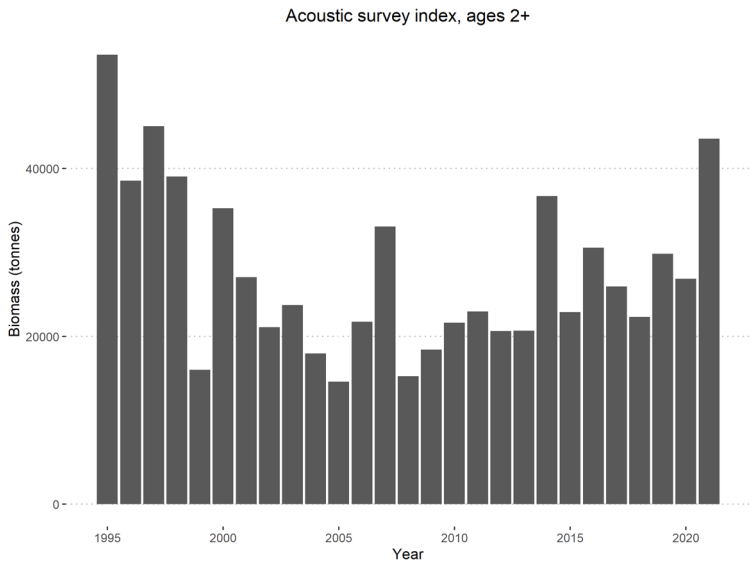

Figure 2.2.3. Northern Norwegian coastal cod. Acoustic biomass index (ages 2+) from the Coastal survey in October-November. Biomass for ages 1+ are reported in Table 2.2.5, but it is biomass for ages 2+ that goes into the assessment model due to the difficulty of distinguishing between coastal and Northeast Arctic cod for age 1. Note that the final data point (2021) was excluded from this year's assessment (see Box 2.1).

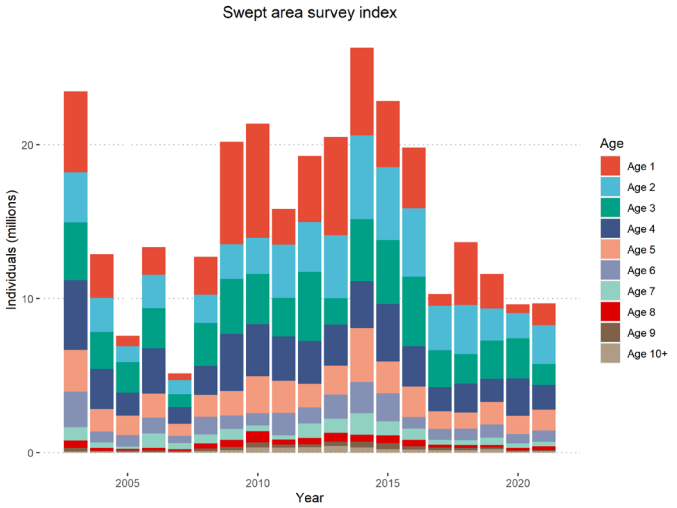

Figure 2.2.4. Northern Norwegian coastal cod. Swept-area abundance index by age (colours) from the coastal survey in October–November (survey code A6335).

Figure 2.2.5. Northern Norwegian coastal cod. 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*.

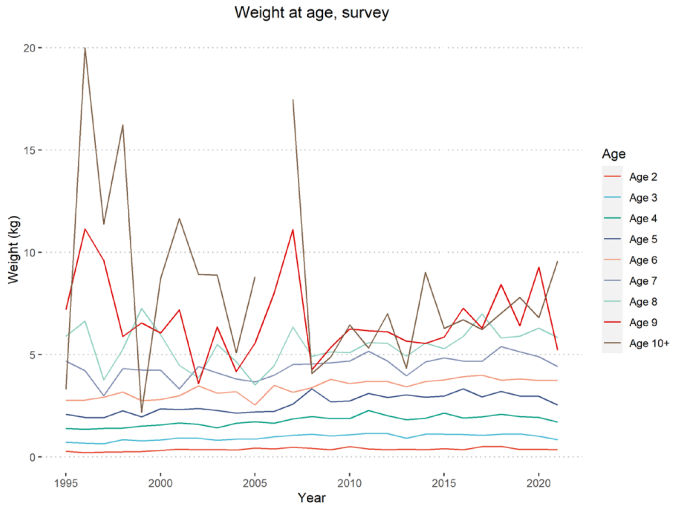

Figure 2.2.6. Northern Norwegian coastal cod. Mean weight-at-age in the coastal survey. Few individuals of ages 10+ were sampled at the beginning of the time-series, leading to extremely large variation in mean weights. In the stock assessment model, stock weights for ages 8–10+ are set equal to mean weight of these ages in the catch.

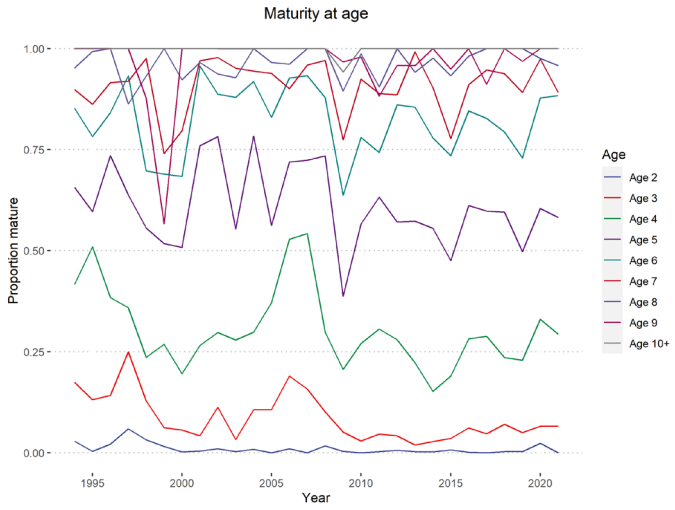

Figure 2.2.7. Northern Norwegian coastal cod. Proportions mature-at-age as observed in the Coastal survey. Since the survey takes place in October-November and the main spawning season is in March-April, spent/resting individuals are included as mature when calculating these proportions.

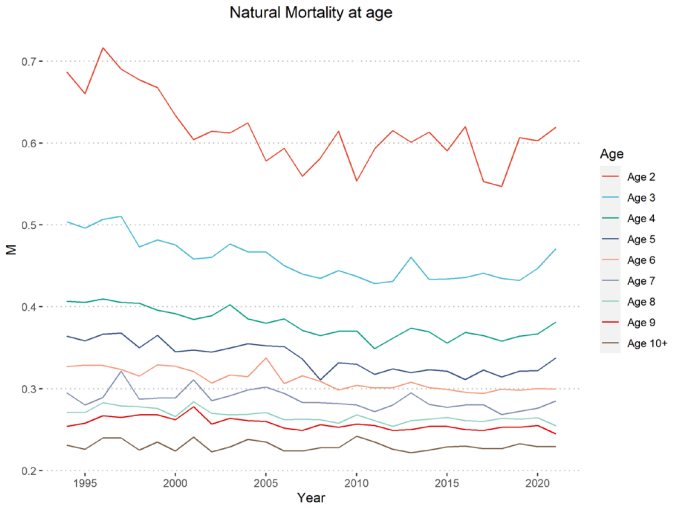

Figure 2.2.8. Northern Norwegian coastal cod. Natural mortality-at-age estimated from stock weights-at-age by the Lorenzen (1996) method.

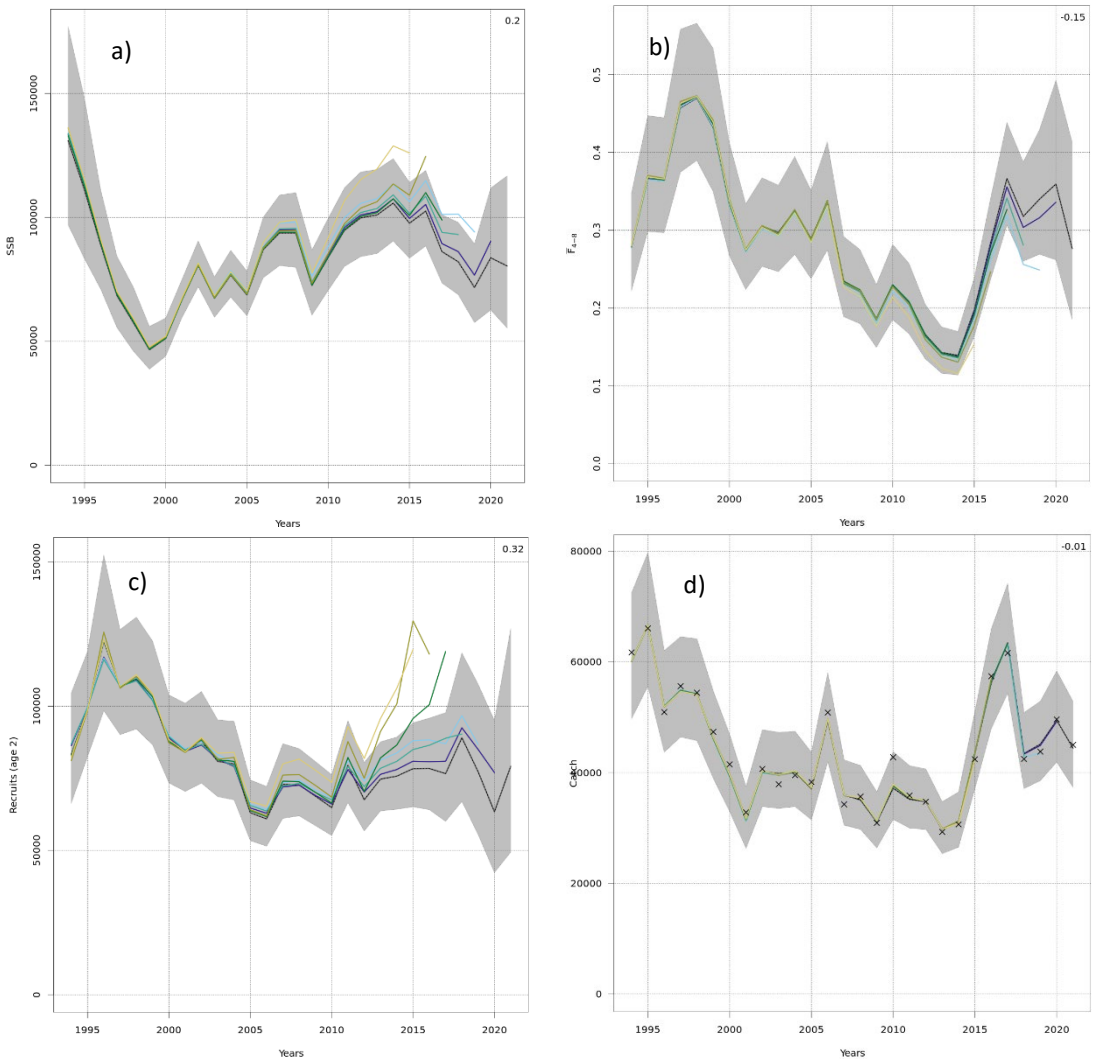

Figure 2.2.9. Northern Norwegian coastal cod. Northern Norwegian coastal cod. 5-year retrospective peel: a) SSB, b) Fbar, c) recruitment, and d) catch. The Mohn's rho value (5-year average retrospective bias) is indicated in the upper right corner of each panel.

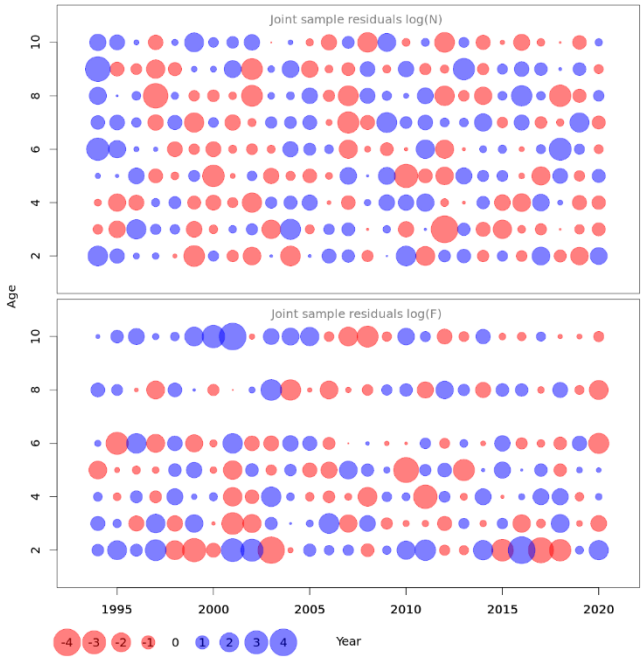

Figure 2.2.10. Northern Norwegian coastal cod. Residuals for the log(N) (top) and log(F) (bottom) process from the final SAM run.

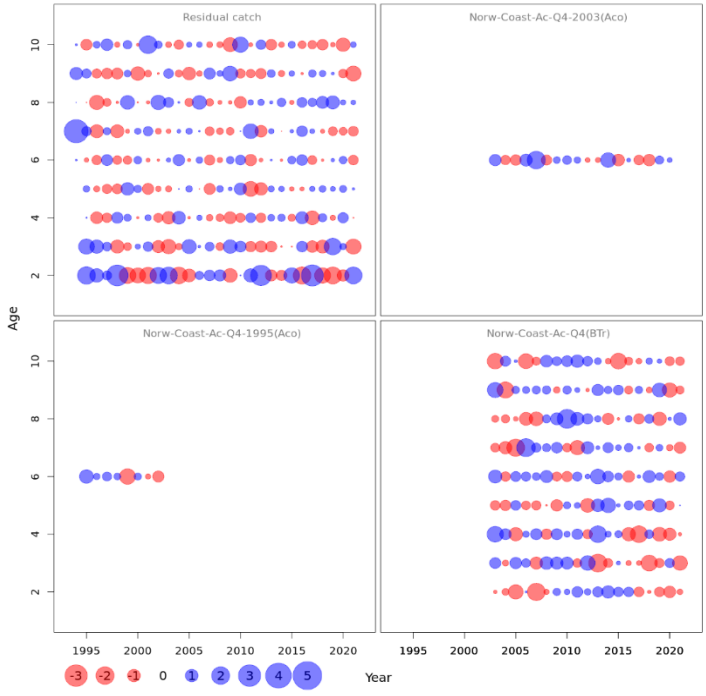

Figure 2.2.11. Northern Norwegian coastal cod. One-step-ahead residuals by fleet from the final SAM run. Blue circles indicate positive residuals and red circles indicate negative residuals. Top left: catch, top right: acoustic index pt. 2, bottom left: acoustic index pt. 1, bottom right: swept-area index.

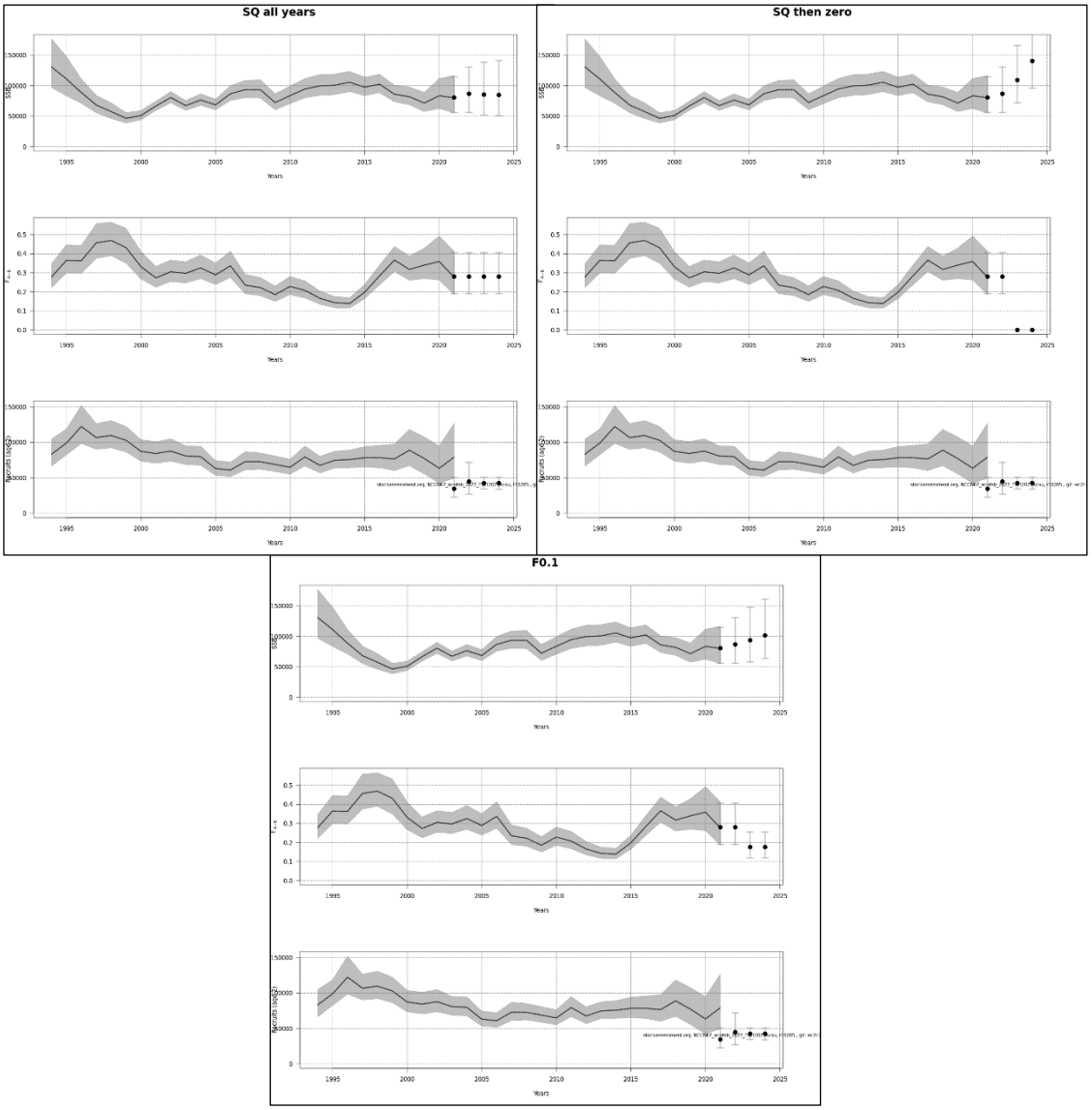

Figure 2.2.12. Northern Norwegian coastal cod. Short-term prediction. Predicted SSB (top panels), Fbar (middle panels) and recruitment (bottom panels) at status quo fishing (top left), status quo then zero fishing (top right), and fishing according to the management plan ($F_{0.1}$ = 0.176). In the forecast, recruitment is the same for all scenarios (resampled from the period 2012–2021).

2.3 Southern Norwegian coastal cod

2.3.1 Stock status summary

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

Commercial catches have decreased since 2010–2012 (Figure 2.3.1). To some extent this is explained by decreasing effort until 2013, but catches have continued to decrease after 2013 when the effort has been stable or increasing (Figures 2.3.8 and 2.3.9). The recreational fishery by tourists and Norwegian residents is assumed to catch similar amounts as the commercial fishery (Figure 2.3.1 and Table 2.3.3), and a prerequisite for more accurate future assessments is a better estimation of the recreational catches.

Catch advice for southern Norwegian coastal cod (62–67°N) follows the "rfb" rule for category 3 stocks (ICES, 2020, 2022). The "rfb" rule is primarily driven by the trend in the coastal reference fleet gillnet CPUE index (more controlled than a full fleet CPUE, Section 2.3.3). Thus, the advice depends heavily on the representativeness of the CPUE index (Fischer *et al*., 2020). The CPUE index has increased enough that the +20% stability cap was reached (Section 2.3.9, Figure 2.3.7, and Table 2.3.7).

A stochastic length-based spawning potential ratio (LBSPR) model and other length-based indicators are presented as additional information. In the previous assessment, the LBSPR was used to assess the need for a 20% precautionary buffer in the "2 over 3" rule, although ICES lacks a framework for using the LBSPR directly as a basis for catch advice. ICES recommends the use of the surplus production model SPiCT for category 3 stocks, but the SPiCT fit was determined to be unsatisfactory in the 2021 benchmark and has not been updated here (ICES 2021b).

The LBSPR model estimates that stock size is below, and fishing pressure is above, possible MSY reference points (Figures 2.3.10 and 2.3.11). From 2010–2021, the "spawning potential ratio" (SPR), i.e. the ratio between the spawning potential of the current stock and the theoretical spawning potential without fishing, fluctuated between 20–35% with an overall downward trend. SPR in 2021 was estimated as 25% (95% CI: 21–29%), which places the stock below generally accepted target values (30–40% SPR).

Additional length-based indicators depict a somewhat depleted and worsening stock status. For example, mean length and the mean length of the largest 5% of caught fish have decreased over the past decade (Figure 2.3.12). The length at 50% selectivity, i.e. first capture, has decreased from ca. 57.6 to 48.4 cm (Figure 2.3.13). About half of the catch is immature, and this proportion has increased in the last decade (Figure 2.3.14). The minimum legal size (44 cm) is well below the length at 50% maturity (62.8 cm).

Priorities for more accurate future assessments are 1) better estimation of recreational catches, and 2) re-evaluation of available survey data that could be used as indices. Possible model improvements include 1) accounting for uncertainty in the index, and 2) combining index and length data in one model.

The catch advice for 2022 was 7613 tonnes. The advice for 2023 is that catches should be no more than 9136 tonnes. Assuming recreational catches of 4420 tonnes, this implies a commercial catch of no more than 4716 tonnes.

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 1990s the average percentage share between gear types in the estimated coastal cod commercial landings was around 65% gillnet, 26% longline/handline, 8% Danish seine, and 1% bottom trawl. In 2021 this share was 50% gillnet, 15% longline/handline, 27% Danish seine, and 5% 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 2019–2021 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 2021, the recreational cod catches between 62–67°N are estimated to about 52% of total cod catches in this region (Table 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. One-third 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 Berg and Nedreaas (2021), between 2–5% was discarded in the commercial gillnet fishery in the area 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 (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 (NEA) cod in these statistical areas between 62–67°°N are shown in Table 2.1.1 and Figures 2.3.1–2.3.2.

The estimated commercial catch-at-age (2–10+) for the period 1994–2021 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, where the proportions-at-age for the recreational catch are assumed equal to those from the commercial catch. The commercial catch in 2021 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)

Mean 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 Recreational catches in 2023

To split the 2023 catch advice into commercial and recreational components, we assume continued recovery of the tourist/recreational catch towards the pre-Covid level. The assumed recreational catch in 2021 was 4039 t, and for 2022 we assume halfway between this and the pre-Covid level (4800 t), which is 4420 t.

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 in ICES 2021b).

These fleets catch cod from both coastal and NEA populations, which can be discriminated based on their otolith shape (Section 2.1.2). 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 reference fleet 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. In this update assessment, we used the models selected in the benchmark (ICES 2021b), after confirming that model diagnostics were satisfactory (Figures 2.3.3 and 2.3.5). To calculate the CPUE index between 62–67°N we only use quarters 3–4 because at that time of year there are fewer issues with mixing coastal and NEA cod (Figure 2.3.4).

2.3.4 Standardized CPUE index (Table 2.3.6 and Figures 2.3.3–2.3.7)

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.

The first step in the CPUE standardization is to estimate the proportion of Norwegian coastal vs. Northeast Arctic (NEA) cod in the catch, as these two cod stocks (ecotypes) mix in the Norwegian Sea. Our goal is to derive an index of only coastal cod abundance. We follow these steps:

1. Fit a binomial GLM to estimate the probability that cod caught between 62–67°N are coastal vs. NEA cod during the time frame of interest (quarters 3–4).
2. Fit a lognormal GLM to standardize total cod CPUE, taking into account year, gear, area, and quarter.
3. Combine the output from the previous two steps to create an index of abundance for only coastal cod.

Here we define important terms used in 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: Proportion coastal vs. NEA cod

We used all data from above 62⁰N (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. NEA cod (Section 2.1.2). Otolith types 1 and 2 were categorized as coastal cod and types 3–5 as NEA cod. Around 2500 otolith samples have been read per year since 2010. A total of 30 828 samples between 2007–2021 were included in the binomial GLM, after removing covariates that had less than three observations to ensure estimability.

We then fit a binomial model with logit link using four categorical explanatory variables: year, area, quarter, and gear, with an area-year interaction effect. In other words, the probability that individual cod i is classified as coastal, π_i, is given by:

$$Z_i \sim \text{Bernoulli}(\pi_i), \quad \text{(eq 1)}$$

$$\text{logit}(\pi_i) = \alpha + \sum_a \beta_a \text{Area}_i + \sum_y \beta_y \text{Year}_i + \sum_g \beta_g \text{Gear}_i + \sum_q \beta_q \text{Quarter}_i + \sum_y \sum_a \beta_{a,y} \text{Area}_i \text{Year}_i$$

where Z_i is a binary variable that equals 1 if cod i was coastal and 0 if not. Likewise, Area_i, Year_i, Gear_i, and Quarter_i are 1 if cod i was caught in that area, year, gear, and quarter and 0 if not.

There were no issues with the diagnostics (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 2007–2021 (Figure 2.3.4).

Step 2: Total cod CPUE standardization

The final lognormal GLMM selected in the benchmark was fitted on all cod CPUE data (no distinction between coastal and NEA cod) in areas 6–7 and quarters 3–4 between 2007–2021 (ICES 2021b). As in the benchmark, data were filtered to remove gears with less than 3 observations or only used in one year. There were only three zero catch observations out of 747, and these were removed, resulting in a final sample size of N = 744. We fit the model:

$$\log(Y_j) \sim N(\mu_j = \alpha + \textstyle\sum_a \beta_a \text{Area}_j + \sum_y \beta_y \text{Year}_j + \sum_g \beta_g \text{Gear}_j + \sum_q \beta_q \text{Quarter}_j + b_{AreaYear_j} AreaYear_j + b_{QuarterYear_j} QuarterYear_j),$$

$$b_{AreaYear_j} \sim N(0, \sigma^2_{AreaYear}), \quad \text{(eq 2)}$$

$$b_{QuarterYear_j} \sim N(0, \sigma^2_{QuarterYear}).$$

where Y_j is the CPUE of gillnet set j, β are categorical fixed effect terms for each area, year, gear, and quarter (as in equation 1), and b are random effect intercept terms for area-year and quarter-year interactions. The $AreaYear_j$ indicates that the area and year variables were concatenated into a single variable and considered as a random effect acting on the intercept, and likewise for $QuarterYear_j$. The total cod CPUE model showed reasonable diagnostics (Figure 2.3.5).

Step 3: Joining steps 1–2 to create a standardized coastal cod CPUE

The predicted proportion coastal cod, $\hat{\pi}_{y,q,a}$, and total cod CPUE, $\hat{Y}_{y,q,a}$, for each year y, quarter q, and area a combination were calculated from the two models above and combined to estimate the standardized coastal cod CPUE index, $I_{y,q,a}$:

$$I_{y,q,a} = \hat{\pi}_{y,q,a} * \hat{Y}_{y,q,a} \quad \text{(eq 3)}$$

The variance of $I_{y,q,a}$ was calculated as:

$$V(I_{y,q,a}) = (\hat{\pi}_{y,q,a})^2 V(Y_{y,q,a}) + (\hat{Y}_{y,q,a})^2 V(\pi_{y,q,a}) \quad \text{(eq 4)}$$

The resulting standardized coastal cod CPUE indices for areas 6 and 7 are shown in Figure 2.3.6, where quarters 3 and 4 are weighted equally. To combine the indices for areas 6 and 7, we weighted the indices in proportion to the surface area within 12 nm (0.587 for area 6, 0.413 for area 7). The composite standardized CPUE index for coastal cod in the entire area between 62–67°N , 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 length-based spawning potential ratio (LBSPR) model to input parameters (Hordyk *et al*., 2015b, 2015a), the AFWG developed a stochastic LBSPR approach at the last benchmark (ICES 2021b), similar to the one developed for anglerfish (Section 9). While the LBSPR assumes that key life history parameters (growth, natural mortality, and maturity; described below) are known, our approach includes uncertainty and correlation in these parameters by fitting the LBSPR model 1000 times using randomly sampled values from their estimated distributions. Observation uncertainty of the annual length distributions is also included by random resampling (bootstrapping) the length data.

Most of the parameters estimated during the benchmark do not need to be re-evaluated on an annual basis and could be randomly generated using the reported mean and standard deviation values. However, we re-estimated each of the life history parameter models selected in the benchmark with data updated through 2021 (Table 2.3.1). All parameter estimates and residual diagnostics were very similar to those from the benchmark.

2.3.5.1 Growth (k, L_{inf})

The von Bertalanffy growth model parameters L_{inf} (asymptotic length) and k (growth coefficient) were estimated using non-least-squares fit to length and decimal age data from the reference fleet. The value for the theoretical age when size is zero, t_0 = -0.0387, was borrowed from northern coastal cod (north of 67°N). To account for biases from size selective sampling, we used composite weights based on the product of 1) calibrated weights (size-selective ageing among individuals sampled for size; Perreault *et al*., 2020) and 2) weights correcting for size selectivity-at-age in the catch (loosely based on model 1 in Taylor *et al*., 2005), using selectivity parameters estimated using LBSPR and parameters borrowed from northern coastal cod.

2.3.5.2 Natural mortality (M)

One of the most critical parameters for the performance of LBSPR is M/k. For southern coastal cod we had a reasonable estimate of k but no *a priori* information on M/k. The benchmark evaluated four methods of estimating M based on life history and selected the size-varying M following Lorenzen (1996) due to its consistency with cannibalism-driven mortality in the partially sympatric NEA cod and that it estimated similar SPR and F/M to assuming M = 0.2.

2.3.5.3 Maturity (LM_{50}, LM_{95})

The maturity parameters LM_{50} and LM_{95} (length at 50% and 95% maturity) were estimated by fitting a binomial GLM with covariate length to yearly bootstrapped maturity data from the autumn coastal survey. All data north of 62°N were used because biological samples from the area between 62–67°N were scarce. For consistency with the choices made for the northern stock, resting individuals (stage 4) were considered mature.

Table 2.3.1. Life history parameter distributions estimated using data through 2021, used as inputs in the LBSPR model. Other required LBSPR parameter values not included here were left at their default values.

Parameter	Mean (sd)	Description
M	0.230 (0.001)	Natural mortality (year^{-1}) at asymptotic length (L_{inf}). Size-varying M following Lorenzen (1996) fit to resampled reference fleet commercial sampling data.
M_{pow}	0.959 (0.005)	aka exponent c, eqn. 17 in Hordyk *et al.* (2016): parameterization of the size-varying M in LBSPR, following Lorenzen (1996) fit to resampled reference fleet commercial sampling data.
k	0.255 (0.003)*	von Bertalanffy growth coefficient
M/k	0.900 (0.007)	M/k at L_{inf}, derived from the above estimates
L_{inf}	94.1 (0.455)*	Asymptotic length (cm) as defined in the von Bertalanffy growth function
t_0	-0.0388	Theoretical age when length = 0 in the von Bertalanffy growth function. Not used in the LBSPR model, but used in the estimation of k and L_{inf} (above). Borrowed from northern coastal cod.
CVL_{inf}	0.155 (0.001)	Coefficient of variation of L_{inf}, encompasses all inter-individual growth variability of LBSPR. The values used are borrowed from northern coastal cod, estimated and randomly generated on the log scale (mean = -1.862; s.d. = 0.0039).
LM_{50}	62.8 (1.842)†	Length (cm) at 50% maturity. Estimated from resampled coastal survey data (2010–2021, all data north of 67°N) using a binomial glm.
LM_{95}	79.6 (3.816)†	Length (cm) at 95% maturity. Estimated from resampled coastal survey data (2010–2021, all data north of 67°N) 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 $\Delta LM = LM_{95} - LM_{50}$.

2.3.5.4 Length distribution resampling

The LBSPR model is fitted to 1000 bootstrapped length 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 as coastal and NEA cod, using a binomial random generator based on the GAM,

```
gam(is_coastal ~ s(length) + factor(area) * factor(year) + factor(quarter) +
                 factor(gear), family=binomial(link = "logit"))
```

2. bootstrap of the length composition within each year, i.e. draw the number of individuals sampled within each year of data from step 1, with replacement.

For each of the 1000 randomized data and parameter sets, the LBSPR model estimates SPR, F/M, and the lengths at 50% and 95% selectivity, SL_{50} and SL_{95}.

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

2.3.6.1 Standardized CPUE index

In recent years, the standardized CPUE index for coastal cod based on the reference fleet gillnet data has generally increased in area 6 (northern subarea, 64–67°N) and decreased in area 7 (southern subarea, 62–64°N; Figure 2.3.6). The composite CPUE index combining areas 6 and 7 decreased from 2007–2013 and has increased since 2013, with large uncertainty (95% CIs extend to 0 in all years; Figure 2.3.7). The composite CPUE index in 2020–2021 was higher than from 2017–2019, and so the "2 over 3" ratio that largely determines the catch advice increased from last year's assessment (red lines in Figure 2.3.7). CPUE in 2020–2021 was similar to 2007–2008, the beginning of the time-series.

2.3.6.2 Effort and CPUE from official landings statistics

We have also calculated CPUE from the full fleet, although this is less controlled for fishing behaviour and uses a less precise measure of effort than the reference fleet CPUE. Still, it is valuable to consider because it covers the entire commercial fleet instead of just a few boats in the reference fleet.

Calculating fishing effort for the full fleet is much less precise than for the reference fleet, where we can calculate kg cod caught per gillnet per day. 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 therefore consider a "trip" by combining the vessel's "Registration mark" in the sales note statistics with "Last catch date", and define effort as the number of sales note trips.

	2018		2019		2020	
Vessel size group	Number of trips	Landed round weight (t)	Number of trips	Landed round weight (t)	Number of trips	Landed round weight (t)
LG1: (blank)	680	29	605	30	603	33
LG2: < 11 m	4203	229	3814	191	4311	298
LG3: 11–14.99 m	1107	129	1221	145	1125	114
LG4: 15–20.99 m	89	24	99	20	71	19
LG5: 21–27.99 m	3	2	1	1	32	15
LG6: >= 28 m	1	3	1	0	8	1

The table above shows the number of trips and cod landings (round weight in tonnes) from inside 12 nautical miles during the second half-year during 2018–2020, per vessel size group, all gears. This shows that the vessel size groups < 11 and 11–14.99 m, represented by the coastal reference fleet (Section 2.3.3), 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 group responsible for about 60% of the total annual cod commercial catches in the stock 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. The recent gillnet CPUE trends differ by vessel size group, with some increasing and some decreasing (Figure 2.3.9).

2.3.6.3 Stochastic LBSPR outputs and interpretation

Between 2010–2021, the mean SPR fluctuated between 20 and 35%, with an overall downward trend (Figure 2.3.10). In most years SPR was estimated below common target values (30–40%) and in 2019–2020 SPR was near the limit reference point (generally accepted to be 20% in the absence of further information on the stock dynamics; ICES 2018; Prince *et al*., 2020; Mace and Sissenwine, 1993). SPR in 2021 was estimated as 0.25 (95% CI: 0.21–0.29). In all years 2010–2021, the relative fishing mortality F/M was estimated above the value which achieve long-term SPR = 40%, or the more usual proxy F/M = 1 (Figure 2.3.11). F/M in 2021 was estimated as 1.28 (95% CI: 1.07–1.52). Concomitant with the decrease in SPR, the size-based indicators $L_{max5\%}$ (mean length of the largest 5% of individuals) and $\bar{L}$ (mean length) also declined from 2010–2021 (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, with 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 $B_{lim} = B_{MSY}/2$) should be SPR = 20%. A simulation function in the LBSPR package also allowed us to estimate $F_{SPR40\%}/M = 0.81$ (95% CI: 0.74–0.88), which is the F/M that leads to SPR = 40% given equilibrium and the parameter values (Figure 2.3.11). This also produces the expected mean length at SPR = 40%, $\bar{L}_{SPR=40\%}$, which could be evaluated for use as a target/reference length in the fishing pressure proxy part of the ICES 'rfb' rule (Figure 2.3.12).

2.3.6.4 Catch lengths in relation to maturity

Averaged across all years, the length at which 50% of southern coastal cod are mature, LM_{50}, was estimated as 62.8 cm (95% CI: 59.4–66.9). This is substantially higher than the minimum legal size (44 cm) or the estimated length at 50% selectivity (S_{50}; Figure 2.3.13). In addition, S_{50} has decreased in the last decade, i.e. the fishery is catching smaller fish, closer to the minimum size. This has led the proportion of immature fish in the catch to increase from about 25% in 2010 to about 50% in 2021 (Figure 2.3.14).

2.3.6.5 Total mortality (*Z*) from catch curves

Since catch numbers-at-age data are available for this stock for a longer period (1994–2021; Tables 2.3.2 and 2.3.3) 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.

We estimated the average total mortality of ages 5–14 for the years 1994–2020, not updated with 2021 data. 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 2.3.15 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 $M = 0.23$ (Table 2.3.1), this implies fishing mortality around 0.5.

2.3.6.6 Additional indices: coastal survey

The last benchmark considered and rejected indices calculated from the main survey covering coastal cod, the autumn coastal survey (Nocoast-Aco-4Q), due to concerns about poor and inconsistent coverage south of 67°N (WD33 in ICES 2021b). The reference fleet CPUE index was used instead. The reviewers commented that it was "not entirely clear that this was justified" (ICES 2021b). Given the high uncertainty in the CPUE index (95% CIs extend to 0 in all years; Figure 2.3.7), we calculated swept-area indices from the coastal survey trawl data between 62°N and 67°N for comparison (methods described for northern coastal cod in Section 2.2.3). It is possible that the coastal survey data may not provide reliable abundance-at-age indices, yet still produce a useable aggregate (across ages) biomass index.

Three alternative swept-area indices from the coastal survey are shown in Figure 2.3.16: total age-2+ biomass, total numbers age-2+, and spawning-stock biomass. There are several notable differences from the reference fleet CPUE index: 1) the survey indices extend back to 2003, whereas the CPUE index starts in 2007; 2) the 95% CIs are much smaller for the survey indices; and 3) the survey indices are relatively stable from 2003–2013 and then decline from 2013–2021, whereas the CPUE index declines from 2007–2013 and then increases. The coefficient of variation (CV) of the CPUE index is 0.7–0.85 in most years, and the survey indices CV is 0.2–0.4 (Figure 2.3.17). The correlations between the CPUE and survey indices are negative, whereas the correlations between the survey indices and SPR estimated from the LBSPR model are positive (Figure 2.3.18). In contrast to the age-aggregated swept-area indices, the index-at-age probably is too uncertain to be useful (CVs > 0.3–0.4 for most ages and years; Figure 2.3.19).

Further exploration of how to produce indices from the coastal survey data is warranted. The survey index CVs reported here may not be reliable as they do not take into account variable spatial coverage by year. Still, the consistency between the survey indices and SPR, and the lower CV of the survey indices, indicates that an age-aggregated swept-area index calculated from the coastal survey may be useful for assessing southern coastal cod.

2.3.6.7 Additional indices: shallow water survey

IMR established a shallow water survey using small, passive meshed gear in 2013 in the hope that it would provide information on fish abundance in nearshore habitat not sampled by the main coastal survey, especially for young cod ages 1–3 (Eidset 2019; WD 13).

The shallow water survey appears to provide precise enough estimates of abundance-at-ages 1–3 to generate useful indices, with CVs between 0.15–0.20 (Figure 2.3.19). CVs for ages 0 and 4 were about 0.30, and the CV for age 5 was 0.40. The survey can reasonably track cohorts—the correlations from one age/year to the next were about 0.45–0.60 for ages 0–5, with the exception of age-2 to age-3, which was about 0.15 (Figure 2.3.20). Indices for ages 2 and 3 were somewhat consistent between the coastal survey swept-area and the shallow water survey (r = 0.82 and 0.32, respectively), but not for other ages.

Both surveys estimate declining trends for all ages 1–5 over the period 2013–2021, with the coastal survey estimating steeper declines for all ages (Figure 2.3.21). The coastal survey swept-area indices-at-age were stable or increasing for all ages in the decade before the shallow water survey was initiated, 2003–2012 (Figure 2.3.21). For further details, see WD 13.

2.3.7 Comments to the assessment

The assessment remains 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 also depends on the representativeness of the

coastal reference fleet gillnet CPUE index. Gillnets are 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. Still, the reference fleet CPUE increasing trend in recent years is not consistent with decreases in the SPR, coastal survey swept-area index, or shallow water survey index.

ICES catch advice is based on the "rfb" rule for Category 3 stocks, which relies primarily on the reference fleet CPUE. While the reference fleet CPUE has increased since 2013, the SPR, coastal survey swept-area index, and shallow water survey index have decreased and are presented as additional information.

Priorities for more accurate future assessments are 1) better estimation of recreational catches, and 2) re-evaluation of available survey data that could be used as indices. Possible model improvements include 1) accounting for index uncertainty in the 'rfb' rule, and 2) combining index and length data in one model.

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 2023

The ICES Guidance for completing single-stock advice for category 3 stocks was applied (ICES, 2020, 2022). A 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 2007–2021, is used as the stock biomass index (Table 2.3.6). The advice is the previous year's catch advice multiplied by four modifiers: 1) ratio of the two latest index values (Index A) to the three preceding values (Index B), 2) length-based proxy of fishing pressure (f), 3) biomass safeguard (not applicable here), and 4) life history multiplier (m). The advice is estimated to have increased by more than 20% and thus the stability cap was applied. Discarding (of dead fish) is known to take place (2–5% in the commercial fishery and about 7% in the rod and line sector of the recreational fishery; Berg and Nedreaas, 2021), but ICES cannot quantify the corresponding catch.

The catch advice for 2023 is estimated to 9136 tonnes (Table 2.3.7). Assuming recreational catches at 4420 tonnes, this implies a commercial catch of no more than 4716 tonnes.

2.3.10 Management considerations

Applying the official ICES Guidance for catch advice results in an increase of 20%. Several caveats should be considered:

- Uncertainty of the CPUE index used in the 'rfb' rule is high, with 95% confidence intervals extending to 0 in all years (Figure 2.3.7). This is not taken into account when calculating the advice.
- The CPUE index increase is driven by area 6. The index is lower and has decreased in area 7 (Figure 2.3.6).
- The LBSPR results indicate fairly poor status: SPR = 0.25 (95% CI: 0.21–0.29) and F/M = 1.28 (95% CI: 1.07–1.52; Figures 2.3.10 and 2.3.11).
- Length-based indicators in the reference fleet data have declined over the past decade (Figures 2.3.12 and 2.3.13). Mean length has decreased from ca. 70.9 to 63.2 cm and the

length at 50% selectivity, i.e. first capture, has decreased from ca. 57.6 to 48.4 cm (averages 2010–2013 vs. 2018–2021).
- The minimum legal size (44 cm) is well below the length at 50% maturity (62.8 cm). About half of the catch is immature, and this proportion has increased in the last decade (Figure 2.3.14).
- Commercial catches have decreased over the last 10–15 years while effort has probably remained stable or increased since 2013 (Figures 2.3.1, 2.3.8, and 2.3.9).
- The coastal survey swept-area and shallow water survey indices decreased from 2013–2021, the opposite trend as in the CPUE index (Figure 2.3.21).

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.

The substantial and increasing proportion of immature fish in the catch is concerning, as well as the length at 50% selectivity being below the length at 50% maturity (Figures 2.3.13 and 2.3.14). Increasing the size of first capture closer to or above the size of maturity is worth considering, especially given the current difficulties of estimating catch and controlling fishing pressure with a quota (Prince and Hordyk, 2018).

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.

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.

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.

The catch advice for 2022 was 7613 tonnes (ICES, 2021a).

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
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

	Age									Tonnes
	2	3	4	5	6	7	8	9	10+	Landed
2020	1	46	164	140	144	79	84	37	16	3481
2021	34	173	198	228	114	78	50	27	33	3696

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
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

	Age									Tonnes	Hereof
	2	3	4	5	6	7	8	9	10+	landed	rec. (t)
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
2021	72	361	414	477	239	163	104	56	70	7735	4039

Table 2.3.4. Cod (*Gadus morhua*) in Subarea 2 between 62°N and 67°N, Southern Norwegian coastal cod. Commercial catch in 2021 by gear and Norwegian statistical fishing area. Both fishing areas lie within ICES Division 2.a.

Gear	Area 06	Area 07	Total 62–67°N	% by gear
Gillnet	996.0	835.6	1831.6	49.8
Longline/Handline	291.9	248.1	540.0	14.7
Danish seine	0.1	1004.6	1004.7	27.3
Trawl	85.7	109.7	195.4	5.3
Others	1.2	103.2	104.4	2.8
Total	1374.9	2301.2	3676.1	

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
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

CWT	2	3	4	5	6	7	8	9	10+
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
2021	1.325	2.049	2.827	3.696	4.692	5.835	6.755	7.672	11.064

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 2007–2021. SE = standard error. 95% confidence intervals (CI) calculated using the approximation CPUE +/- 1.96 SE.

Year	CPUE index	SE	CI low (2.5%)	CI high (97.5%)
2007	0.30	0.27	0	0.84
2008	0.39	0.28	0	0.93
2009	0.25	0.17	0	0.57
2010	0.16	0.11	0	0.37
2011	0.24	0.18	0	0.60
2012	0.24	0.21	0	0.65
2013	0.06	0.04	0	0.13
2014	0.13	0.09	0	0.30
2015	0.26	0.18	0	0.62
2016	0.29	0.20	0	0.68

Year	CPUE index	SE	CI low (2.5%)	CI high (97.5%)
2017	0.37	0.32	0	0.99
2018	0.14	0.11	0	0.36
2019	0.17	0.13	0	0.42
2020	0.39	0.31	0	1.00
2021	0.30	0.25	0	0.79

Table 2.3.7. Cod (*Gadus morhua*) in Subarea 2 between 62°N and 67°N, Southern Norwegian coastal cod. Values used for calculating catch advice under the ICES "rfb" rule (ICES, 2022a).*

Quantity	Value
A_y: Previous year catch advice	7613 t
Stock biomass trend	
Index A (average CPUE 2020–2021)	0.342
Index B (average CPUE 2017–2019)	0.225
r: Stock biomass trend (ratio A/B)	1.52
Fishing pressure proxy	
Mean catch length (L_{mean}= L_{2021})**	67.7 cm
MSY proxy length ($L_{F=M}$)***	66.2 cm
f: Fishing pressure proxy relative to MSY proxy ($L_{2021}/L_{F=M}$)	1.02
Biomass safeguard	
Last index value (I_{2021})	0.297
Index trigger value ($I_{trigger}$=I_{loss}×1.4)	0.058
b: index relative to trigger value, min{$I_{2021}/I_{trigger}$, 1}	1
Precautionary multiplier to maintain biomass above B_{lim} with 95% probability	
m: multiplier (generic multiplier based on life history)	0.9
rfb rule catch advice****	10 643 t
Stability cap (+20%/-30% compared to A_y, only applied if b≥1)	Applied
Discard rate	Not quantified
Catch advice for 2023	**9136 t**
% advice change^	+20%

*** 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.**

**** Calculated as per ICES (2022a), only using lengths greater than L_c.**

*** Equation A.3 in Jardim *et al.* (2015).

**** [$A_y \times r \times f \times b \times m$]

^ Advice value for 2023 relative to the advice value for 2022.

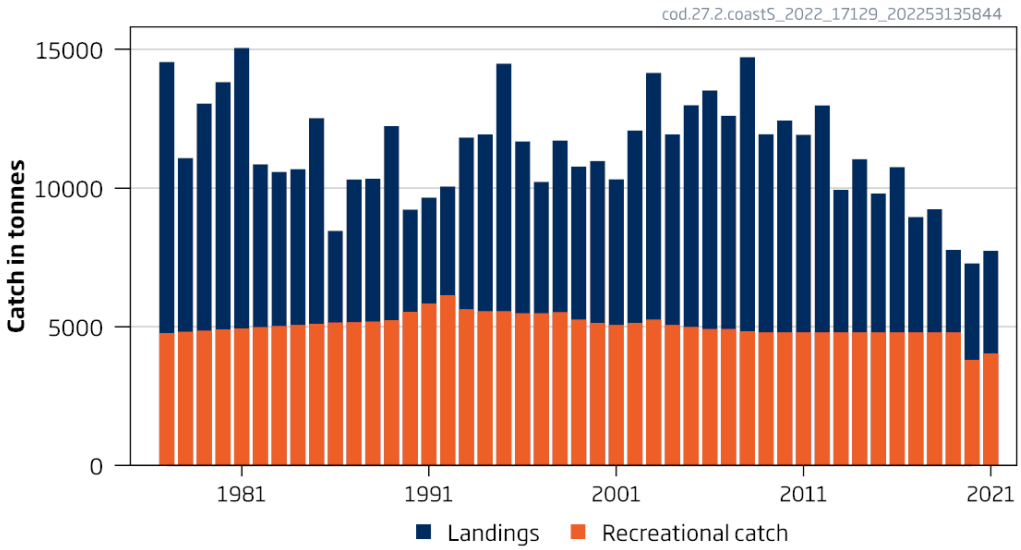

Figure 2.3.1. Cod (*Gadus morhua*) in Subarea 2 between 62°N and 67°N, Southern Norwegian coastal cod. Commercial landings and recreational catches. Recreational catches are fixed from 2009–2019 at 4800 tonnes and then reduced from 2020–2021 due to Covid-19 impacts on tourist fishing.

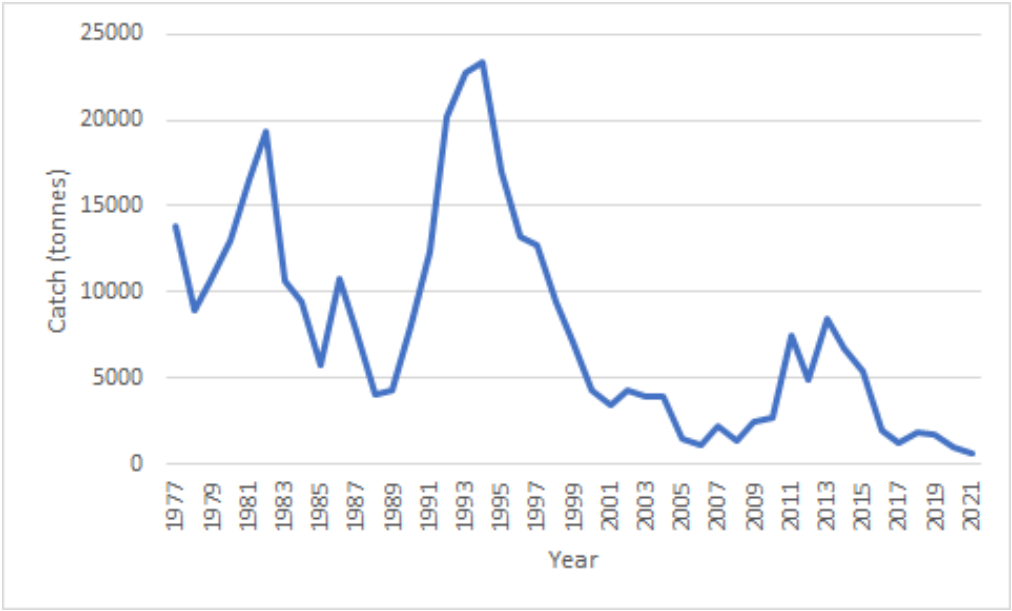

Figure 2.3.2. Estimated commercial landings of Northeast Arctic cod (*Gadus morhua*) in Subarea 2 between 62°N and 67°N.

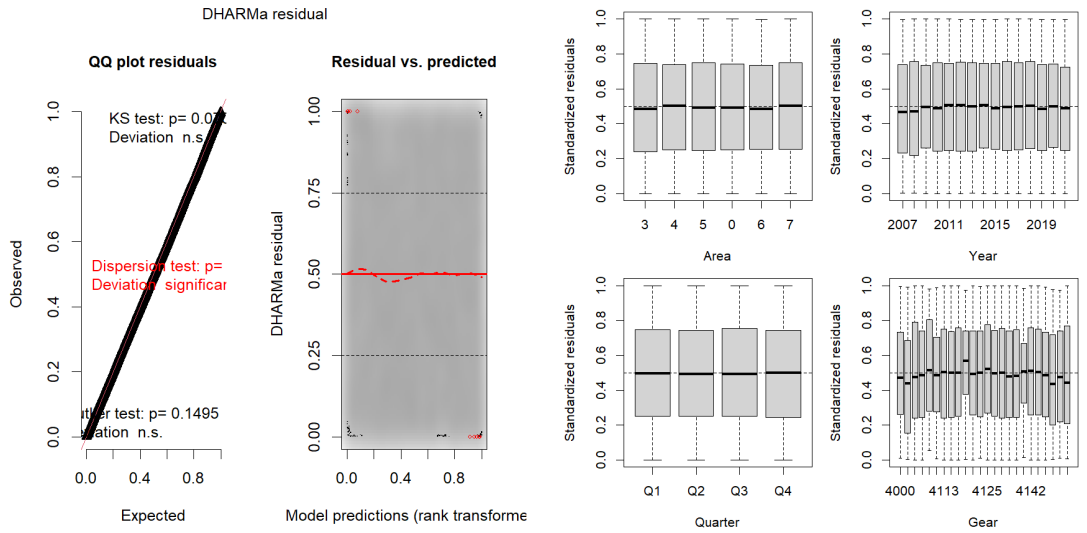

Figure 2.3.3. Residual diagnostic plots for the final binomial model to differentiate coastal cod vs. NEAC. The panel on the left is a standard output from the residual diagnostics using the R package DHARMa. The panel on the right plots the model standardized residuals against available covariates.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

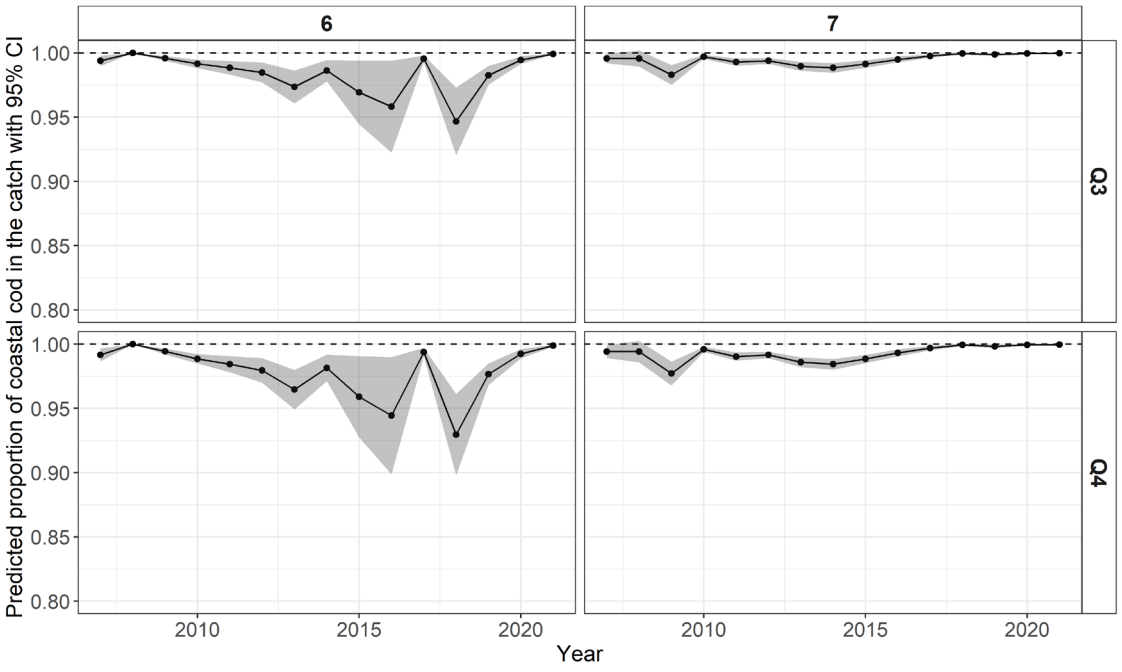

Figure 2.3.4. Predicted probability of cod being classified as coastal instead of Northeast Arctic, based on the quarter (vertical panels), area (horizontal panels), and year (x-axis within each panel). The grey shaded polygon represents the 95% confidence interval.

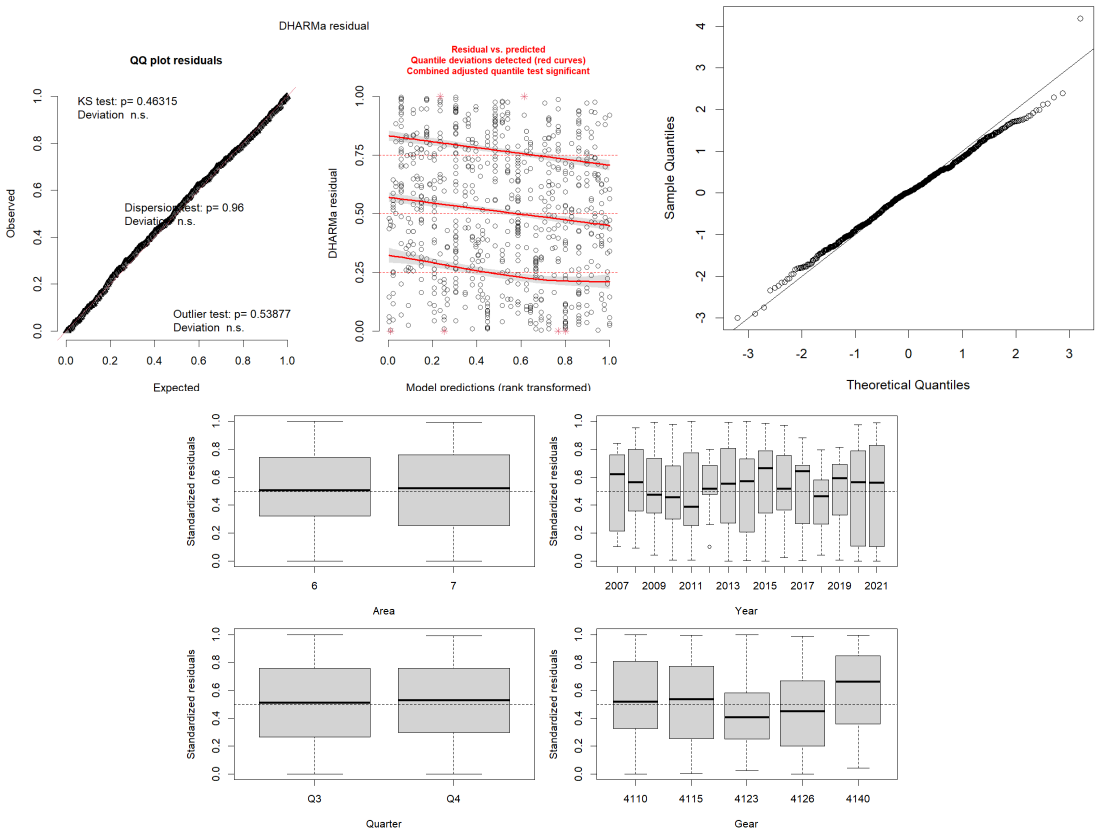

Figure 2.3.5. Residual diagnostic plots for the final CPUE model fitted to cod data in area 6 and 7, and quarters 3 and 4. Top panel left: standard output from the residual diagnostics using the R package DHARMa. Top panel right: normal QQ-plot. Bottom panel: model standardized residuals vs. available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

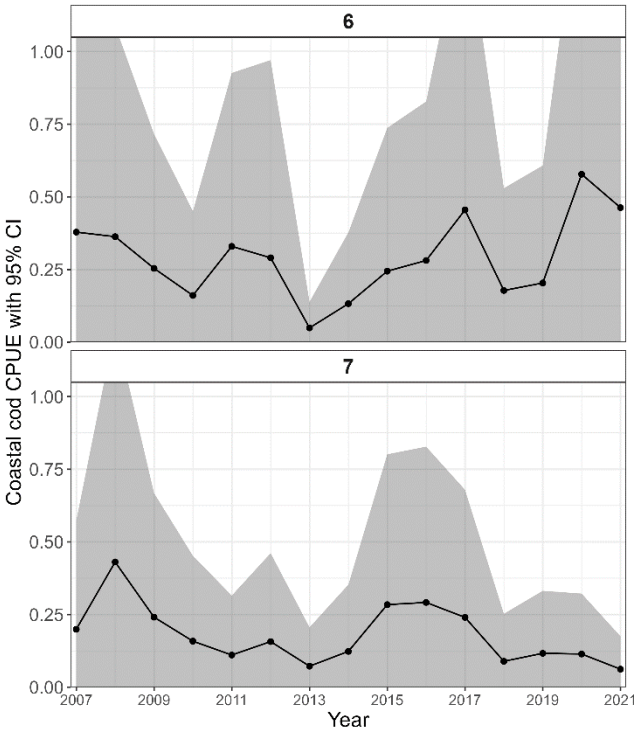

Figure 2.3.6. Standardized reference fleet CPUE (kg per gillnet per day) index for coastal cod in areas 6 and 7 during quarters 3 and 4, between 2007–2021. The grey shaded polygon represents the 95% confidence interval (calculated using the approximation: mean +/- 1.96 SE).

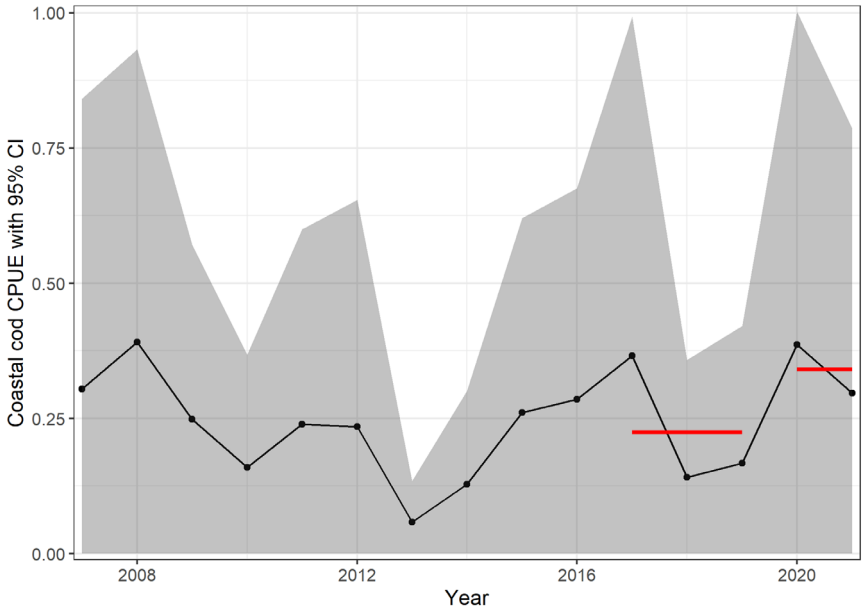

Figure 2.3.7. Composite reference fleet CPUE (kg cod per gillnet per day) index for southern Norwegian coastal cod, areas 6 and 7 combined. 95% confidence intervals are calculated using the approximation: mean +/- 1.96 SE. Red horizontal lines indicate the averages for the last 2 years (2020–2021) and previous 3 (2017–2019) used in the 'rfb' rule for catch advice (Table 2.3.7).

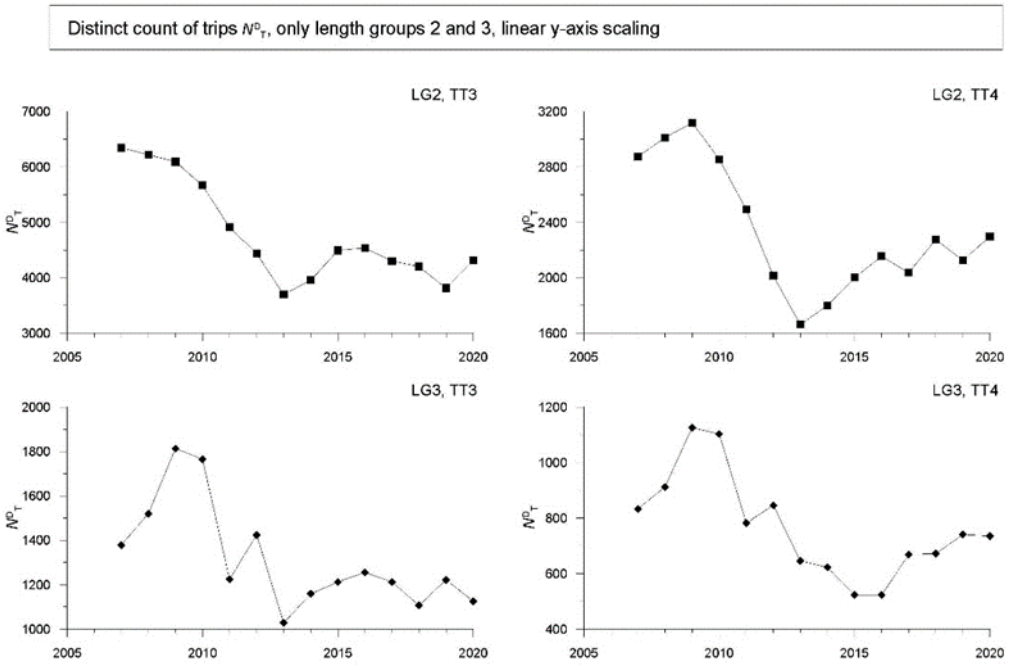

Figure 2.3.8. Full commercial fleet fishing effort presented as the number of sales note trips for two boat sizes, LG2 = <11 m and LG3 = 11–14.99 m, for areas 62–67°N in the second half of the year. Left panel: all gears; right panel: gillnet only. Note different y-axes.

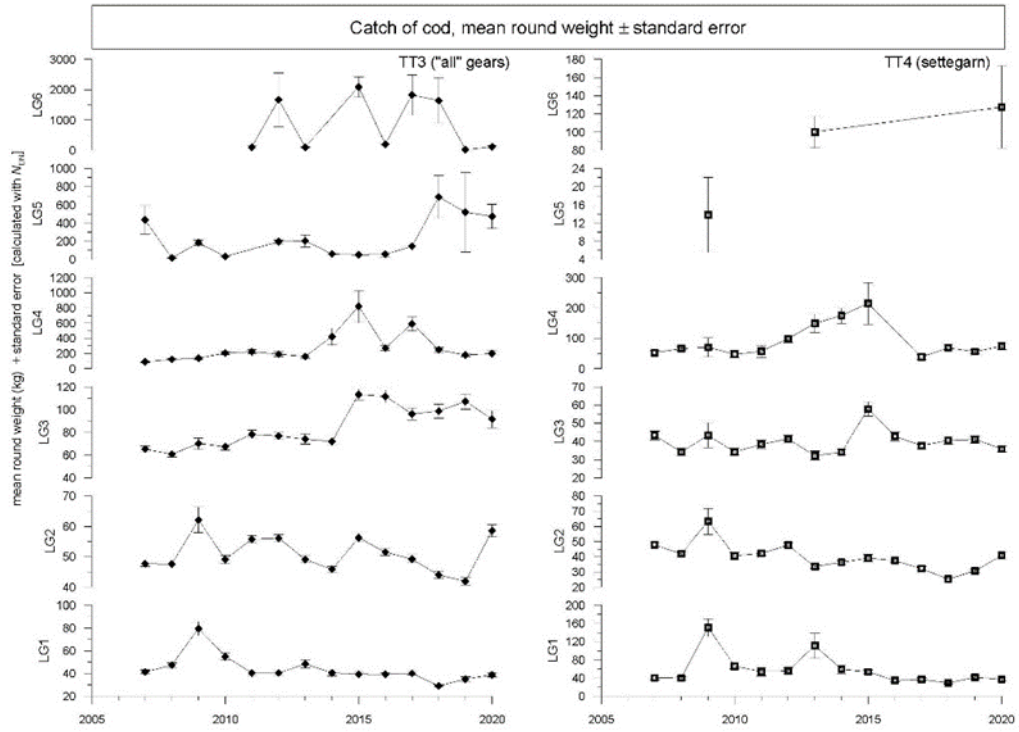

Figure 2.3.9. Full commercial fleet CPUE (kg cod per sales note trip) per boat size (LG1-LG6) for area 62–67°N in the second half of the year. Left panel: all gears; right panel: gillnet only.

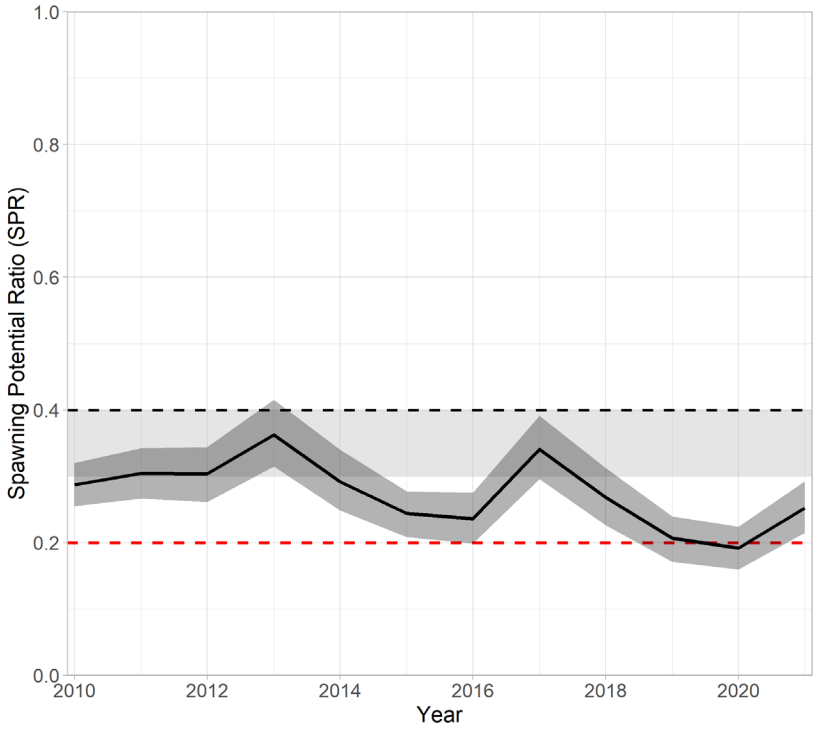

Figure 2.3.10. Spawning potential ratio (SPR) per year estimated by the length based spawning potential ratio (LBSPR) model. Mean (black line) and confidence intervals (dark shaded area, 95% interquartile range [IQR]), based on the stochastic LBSPR. The light shaded area delimits the $SPR_{30\%-40\%}$ zone (common targets) and the red dashed horizontal line the $SPR_{20\%}$ limit reference point.

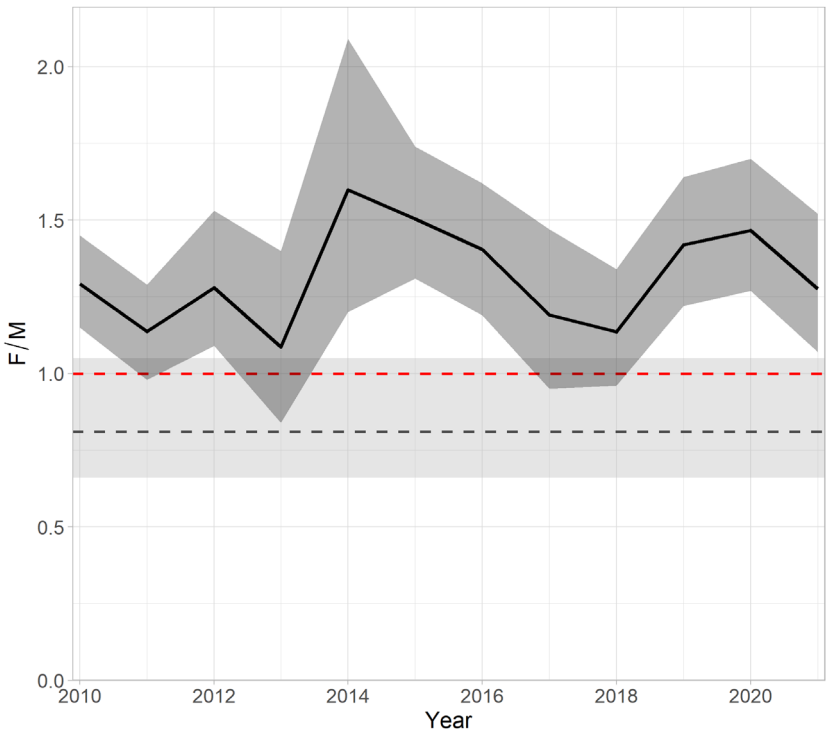

Figure 2.3.11. Estimated fishing mortality relative to natural mortality (F/M) per year estimated by the length based spawning potential ratio (LBSPR) model. Mean (black line) and confidence intervals (dark shaded area, 95% IQR), based on the stochastic LBSPR. Red dashed line indicates F/M = 1, and grey dashed line indicates $F_{40\%SPR}$/M (with 95% IQR, light shaded area), common target reference points.

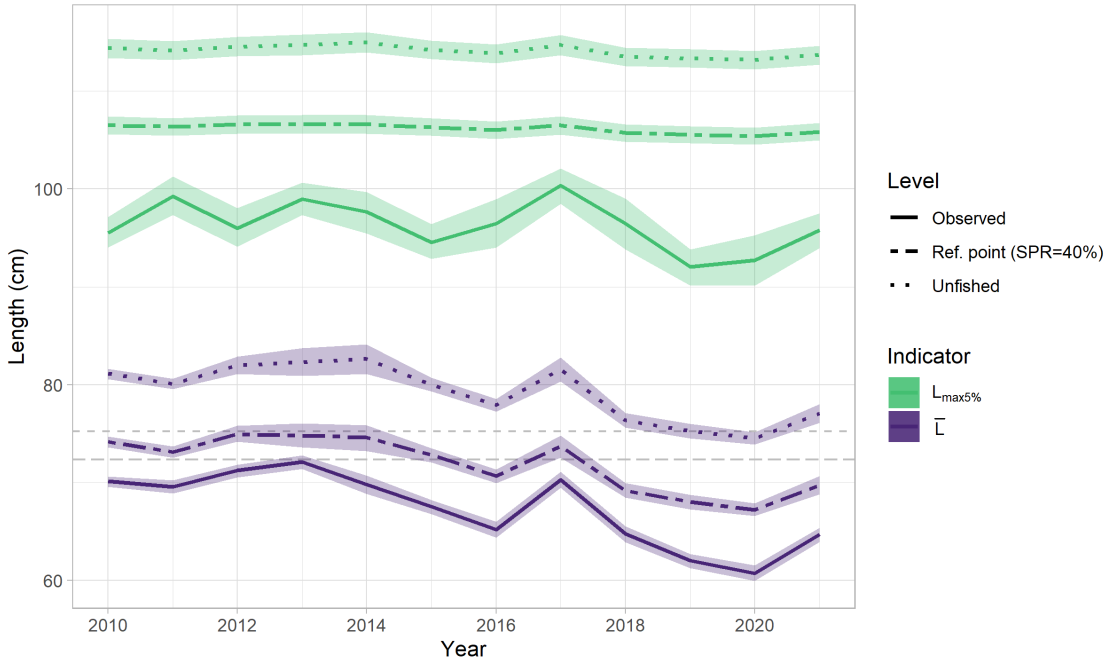

Figure 2.3.12. Length-based indicators $L_{max5\%}$ and mean catch length ($\bar{L}$) in relation to their reference points (mean and 95%CI). The reference points were estimated using the LBSPR simulation model together with the stochastic parameters detailed in Table 2.3.1 (mortality scenario following Lorenzen, 1996) and SPRs of 40% and 100% (unfished).

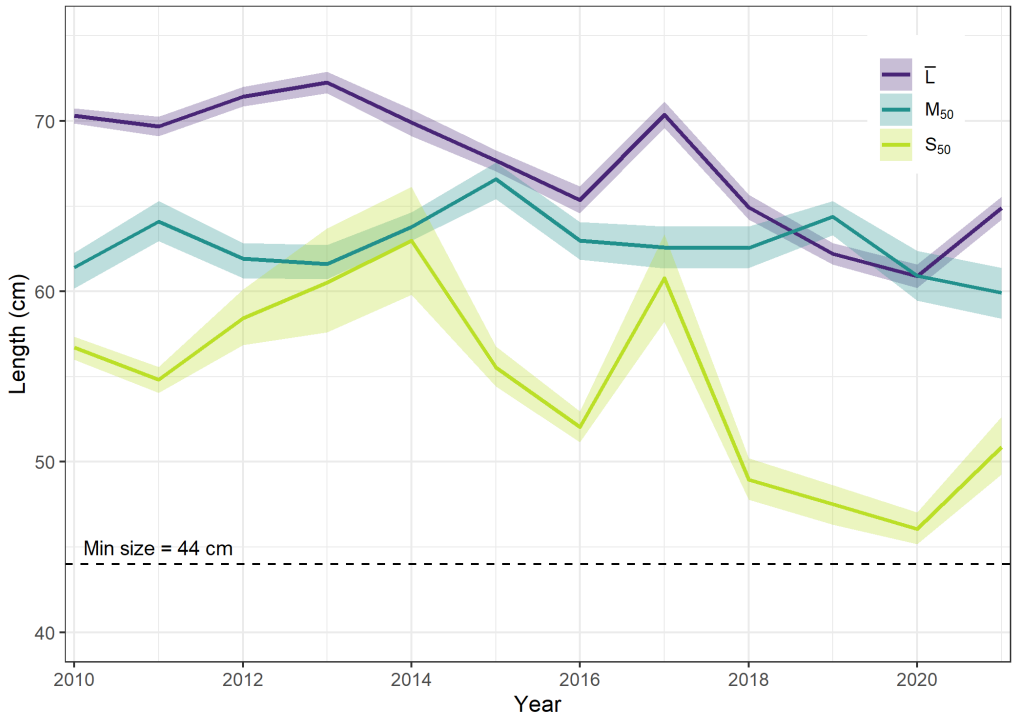

Figure 2.3.13. Length-based indicators, mean catch length ($\bar{L}$) and length at 50% selectivity (S_{50}), in relation to the minimum legal size (44 cm) and length at 50% maturity (M_{50}). M_{50} is estimated with uncertainty by bootstrapping data from the coastal survey. S_{50} is estimated by the length based spawning potential ratio (LBSPR) model, independently by year. $\bar{L}$ is calculated from the coastal reference fleet biological samples.

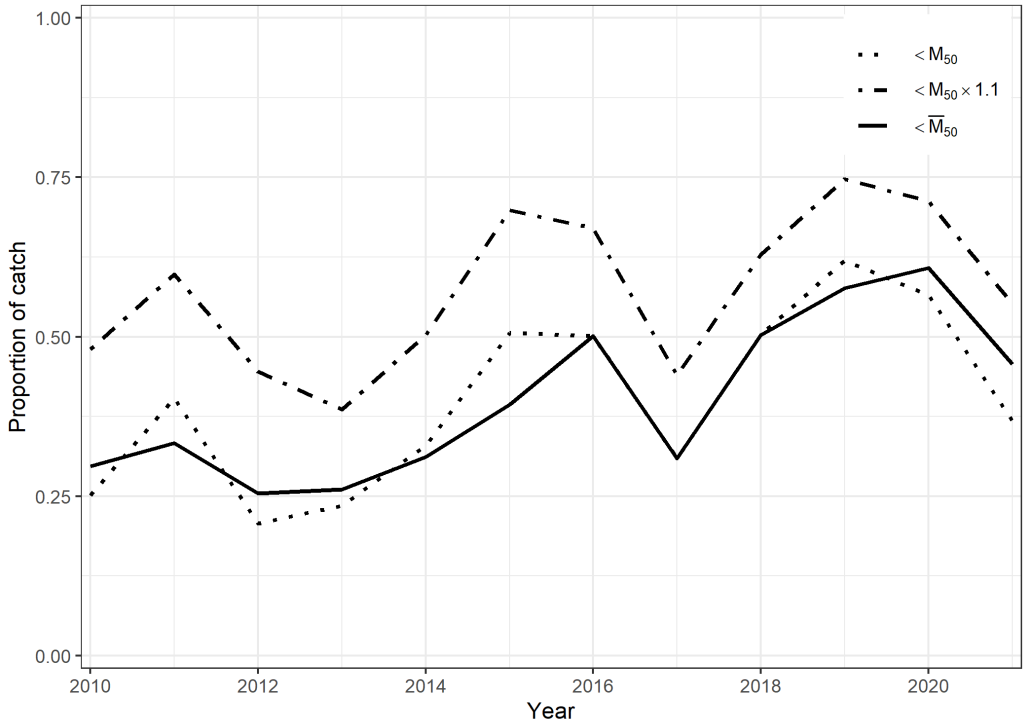

Figure 2.3.14. Proportion of the catch that is immature, southern Norwegian coastal cod. Linetype shows the proportion of cod in each year that are smaller than the yearly length at 50% maturity (M_{50}, dotted line), yearly M_{50} times 1.1 (dashed line), and average M_{50} ($\bar{M}_{50}$ = 62.8 cm, solid line).

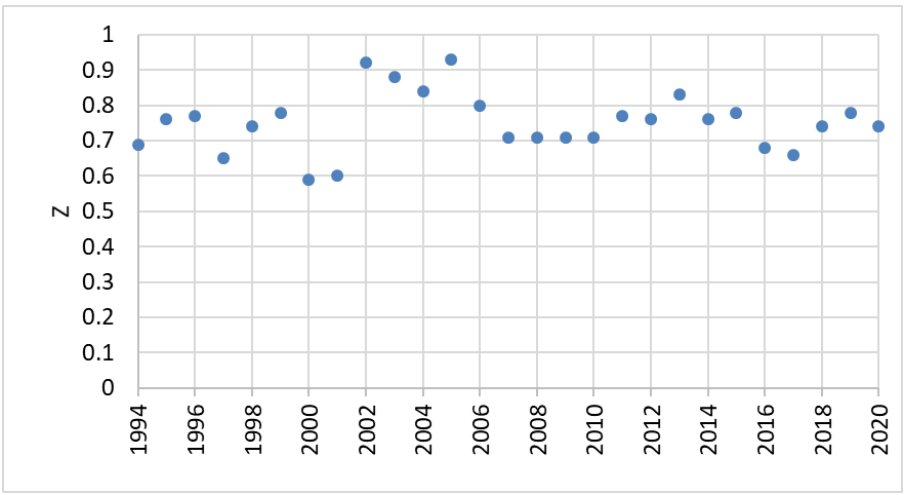

Figure 2.3.15. Total mortality (Z) estimated from catch curves (average over ages 5–14 in commercial and recreational catches) 1994–2020.

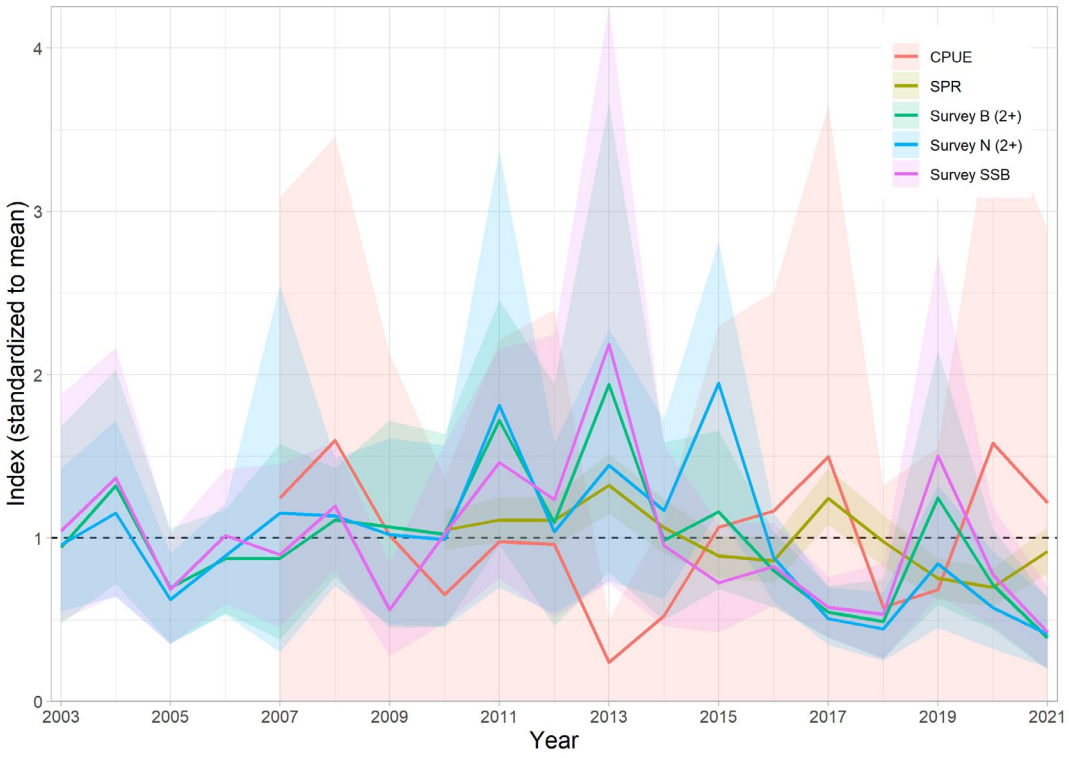

Figure 2.3.16. Coastal survey trawl swept-area indices in relation to the reference fleet CPUE index and SPR, each standardized to its mean. Three alternative indices are calculated from the coastal survey: total age-2+ biomass (Survey B 2+), numbers age-2+ (Survey N 2+), and spawning-stock biomass (Survey SSB). Shading depicts 95% confidence intervals.

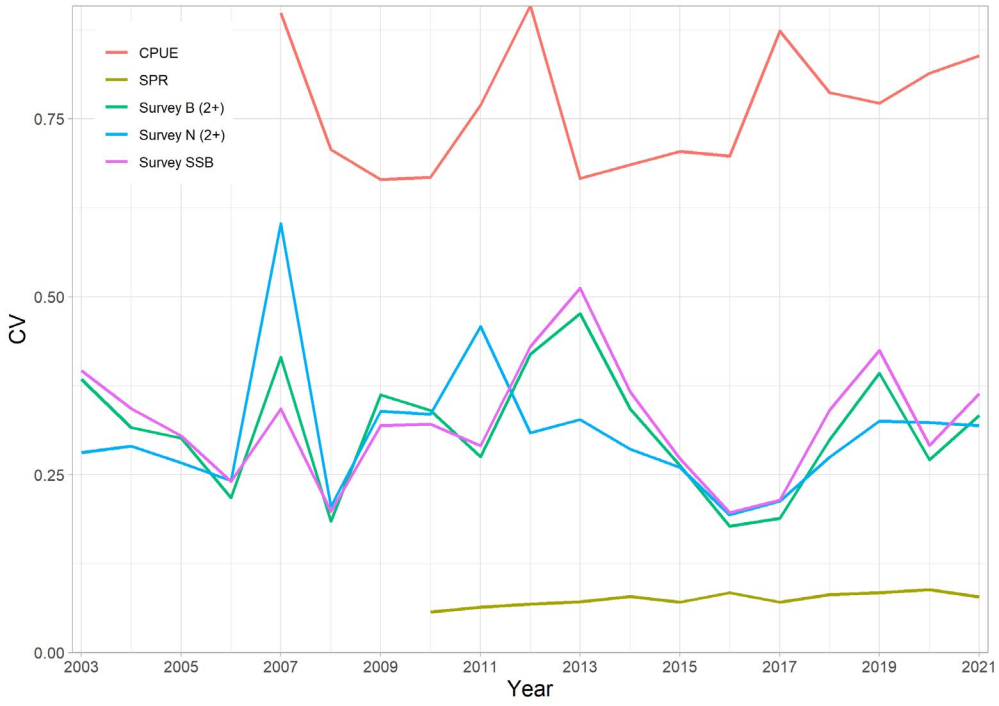

Figure 2.3.17. Coefficient of variation (CV) from the coastal survey trawl swept-area indices, reference fleet CPUE index, and SPR. Three alternative indices are calculated from the coastal survey: total age-2+ biomass (Survey B 2+), numbers age-2+ (Survey N 2+), and spawning-stock biomass (Survey SSB).

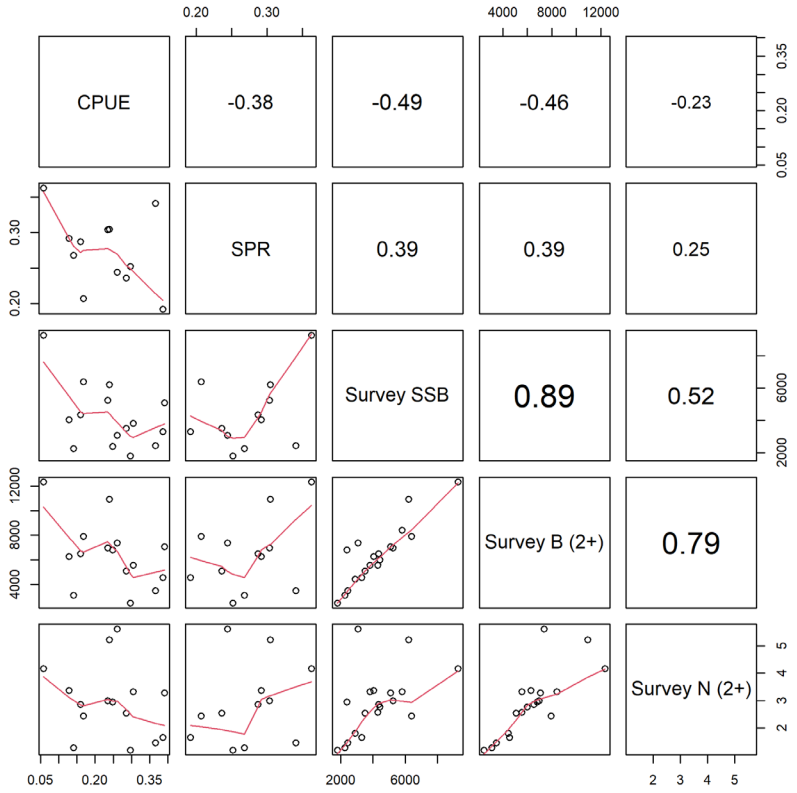

Figure 2.3.18. Correlation between the coastal survey trawl swept-area indices, reference fleet CPUE index, and SPR. Three alternative indices are calculated from the coastal survey: total age-2+ biomass (Survey B 2+), numbers age-2+ (Survey N 2+), and spawning-stock biomass (Survey SSB).

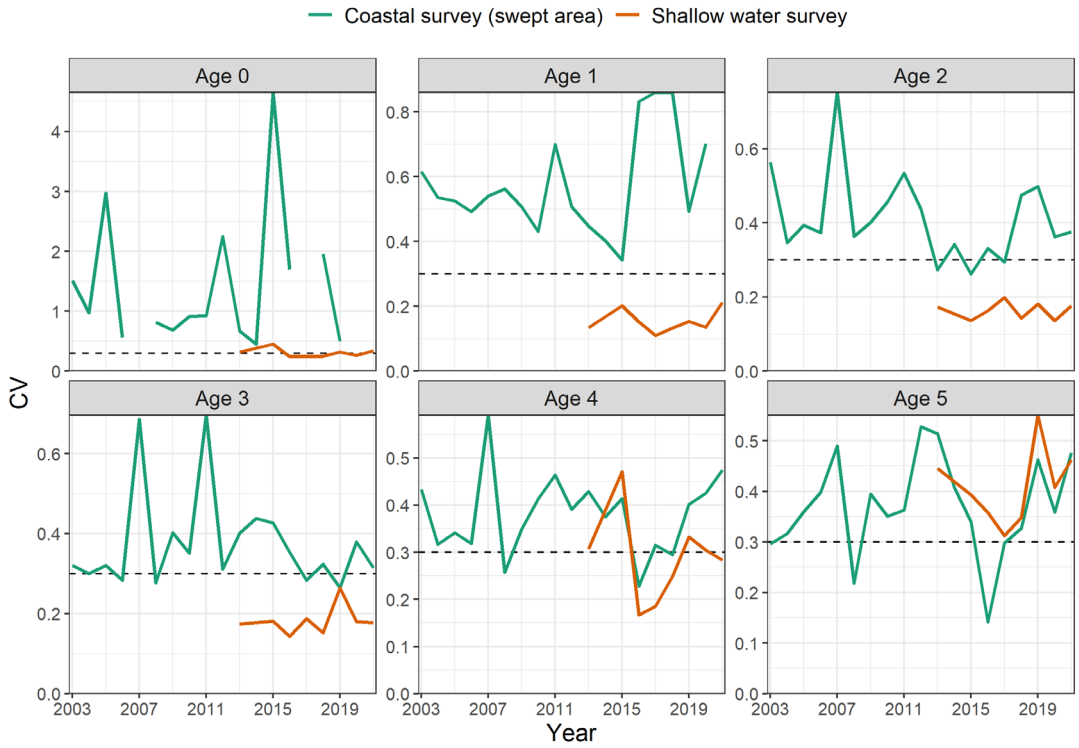

Figure 2.3.19. Coefficient of variation (CV) for additional survey indices-at-age, by year. Green: coastal survey swept-area (trawl). Orange: shallow water (garn ruse) survey. Dashed horizontal line indicates CV = 0.3, a commonly used upper threshold for considering indices to be informative on stock trends. See WD 13 for more details.

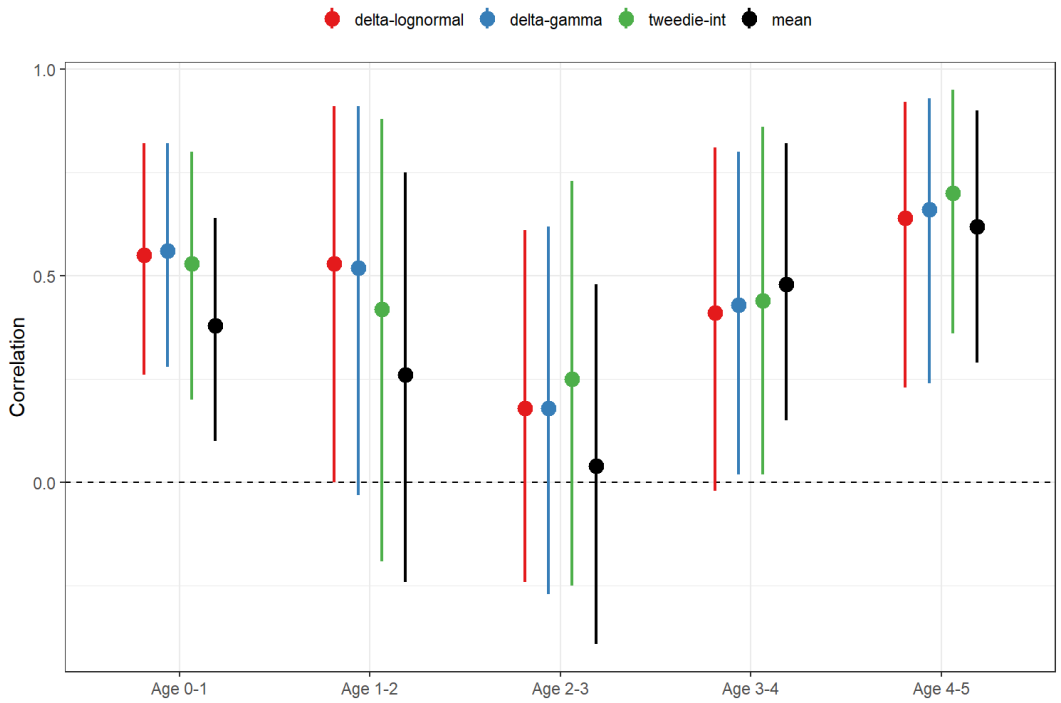

Figure 2.3.20. Correlation between the shallow water survey index-at-age in the previous age/year to the next, i.e. consistency, or the ability to track cohorts. Error bars indicate bootstrapped 95% confidence intervals. The delta-lognormal model was selected. See WD 13 for more details.

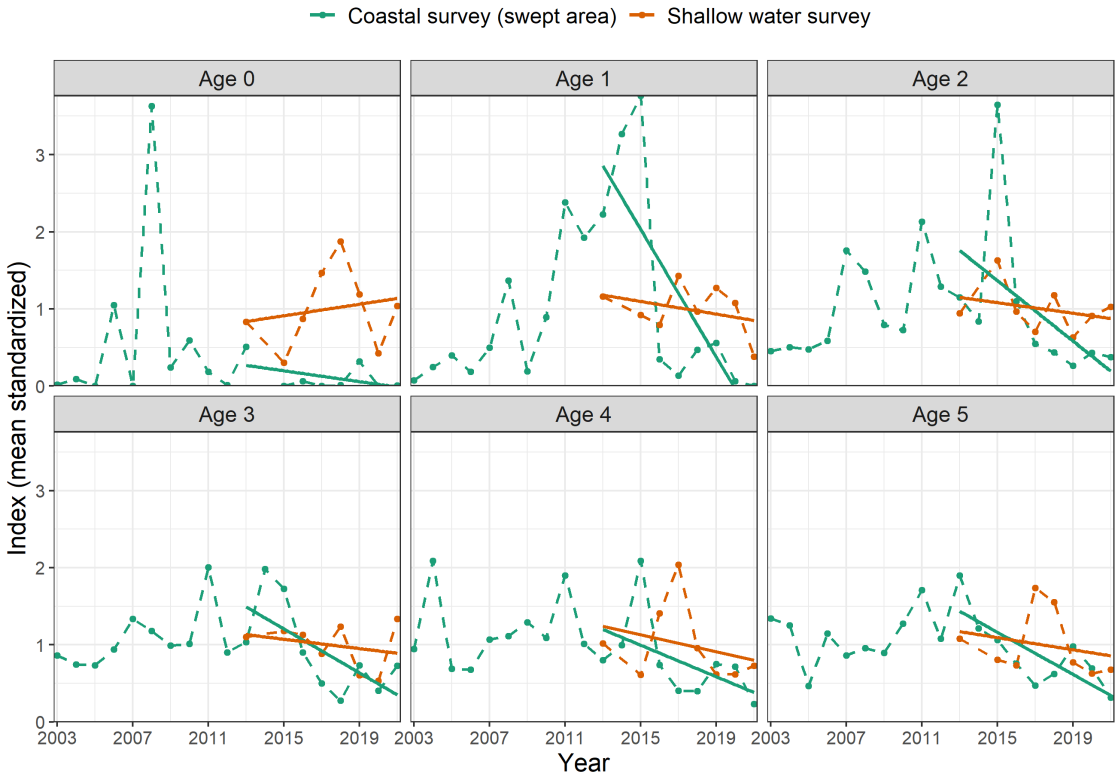

Figure 2.3.21. Southern Norwegian coastal cod indices-at-age from two available surveys, standardized to their means (horizontal dashed lines). Green: coastal survey swept-area (trawl). Orange: shallow water (garn ruse) survey. Lines are linear model fits from 2013–2021. See WD 13 for more details.

Section contents