COD

Gadus morhua

GENERAL INFORMATION

Cod is widely dispersed in Icelandic waters, with higher abundance in north-western, northern, and north-eastern part of the shelf. Cod is considered demersal with moderately wide depth distribution which can vary from depths of few meters down to 600 m, occasionally even deeper. Adult cod does not have much preference regarding bottom structure and can be found on various substrates; however, a large share of the cod juveniles prefer moderately sheltered, shallow kelp and seagrass environments. The ideal sea temperature for cod is around 4-7°C, nevertheless the temperature limits for this species are somewhat wider, and a significant proportion of the catch is taken where temperature is less than 2°C.

Cod spawns all around Iceland by smaller regional spawning components, however the main spawning areas are situated in the south, southwest and west. Spawning starts early in the spring (March-April) on the main spawning grounds in the warmer waters in the south. In the past, spawning started later on in the colder waters in the north, but in recent years spawning time in the north has advanced significantly. North- and eastward pelagic egg- and larval drift mainly occurs clockwise to the nursery grounds situated in the north and north-eastern area. The adult stock takes feeding migrations to the deeper waters in the north-west and south-east, but part stays in the shallow domains to feed. Cod is the most important exploited groundfish species in Iceland.

Due to wide spatial distribution of cod in Icelandic waters, the fishing grounds are scattered around the shelf and partially divided by gear type (Figures 1-3). Demersal trawl is the main fishing gear (Table 1, Figure 6). Main fishing grounds for demersal trawl are situated offshore in deeper relatively cold waters to the north-west, northeast, and east of the island. In recent years, the spatial distribution of demersal trawl fishery has been gradually contracting and aggregating at the previously mentioned trawl fishery hotspots (Figure 1). Longline accounts for the next largest portion of the catch in the cod fisheries and is widely distributed around the Icelandic shelf, with lowest reported catch in the south and southeast coast (Figure 2). The distribution pattern of the catches remains consistent between the years with occasional hotspots. Cod fisheries of the remaining fishing fleet, i.e. gillnets, demersal seine and jiggers, are widely distributed, but mainly take place in shallow waters (Figure 3).

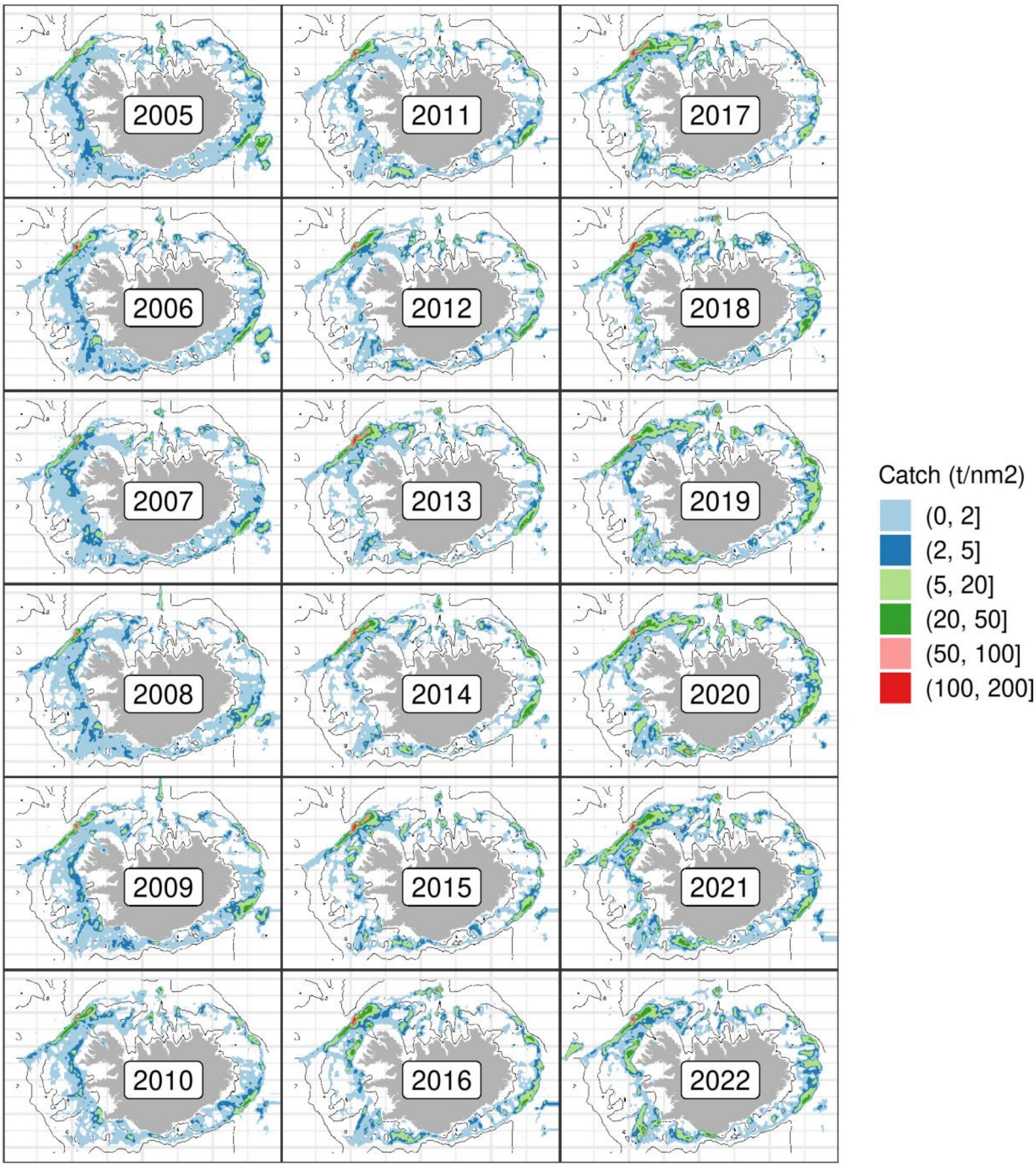

Figure 1. Icelandic cod. Geographical distribution of the Icelandic demersal trawl fishery. Reported catch from logbooks. The 100, 300, and 1000 m isobaths are shown.

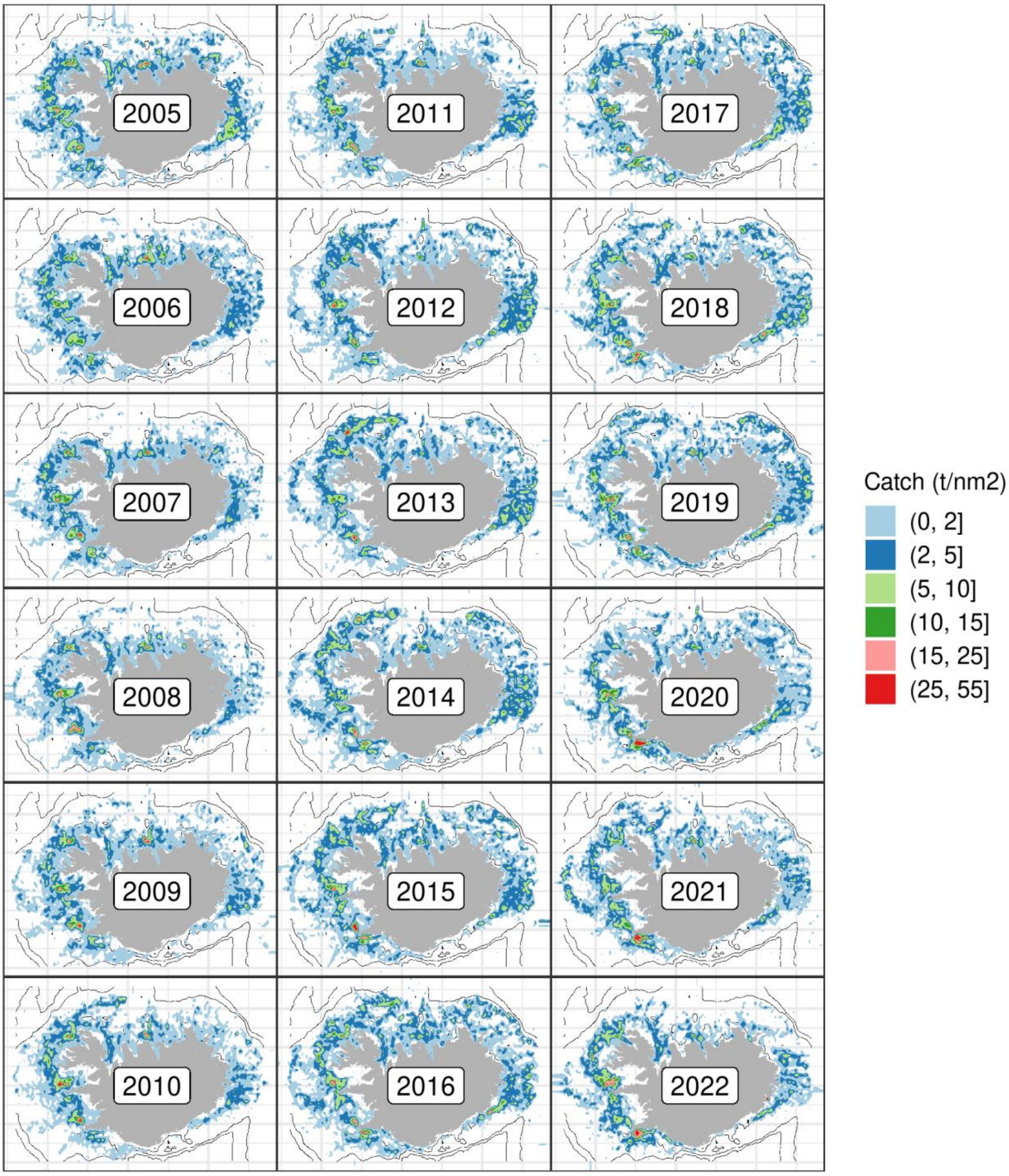

Figure 2. Icelandic cod. Geographical distribution of the Icelandic longline fisheries. Reported catch from logbooks. The 100, 300, and 1000 m isobaths are shown.

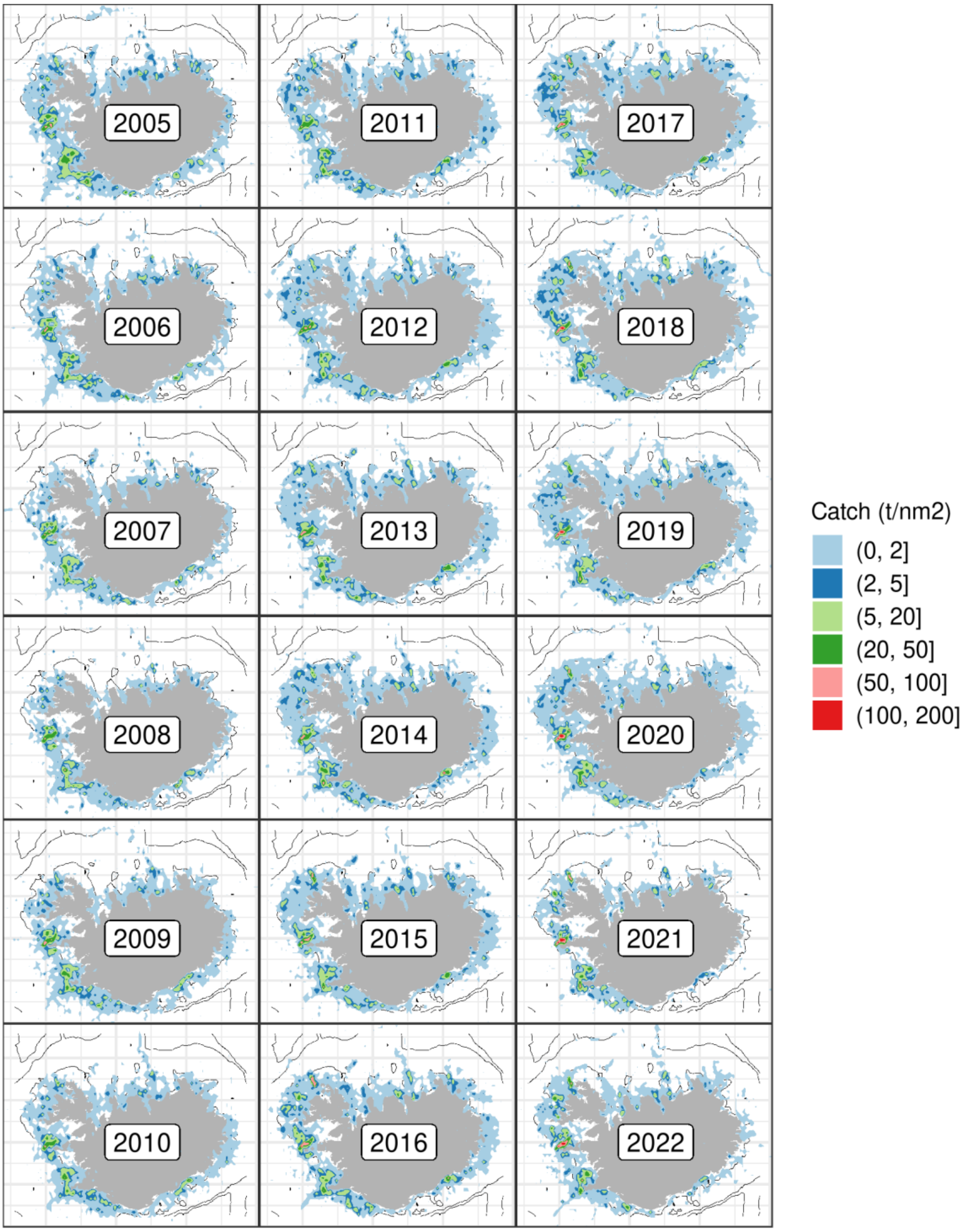

Figure 3. Icelandic cod. Geographical distribution of the Icelandic cod fisheries from gillnets, demersal seine and jiggers since 2003. Reported catch from logbooks. The 100, 300, and 1000 m isobaths are shown.

Spatial distribution of the cod fishery has been relatively stable for the past years (Figure 4). Changes in depth and spatial distribution (Figures 4 and 5) are partly caused by changes in gear composition (Figure 6). For cod, the average depth in bottom trawl is 230 m, longline 160 m, but 80 m for demersal seine and gillnets. Mixed fisheries considerations do also affect spatial distribution of the fisheries. For example, haddock TAC (Total Allowable Catch) was 50-80% of the cod TAC from 2003-2008 leading to increased fisheries in areas where haddock was abundant. For comparison, TAC for haddock has been 15-20% of the cod TAC in recent years.

The long-term pattern is that gillnets and bottom trawl were the most important gear with most of the bottom trawl catches taken in the northwest, but the gillnet catches in the south and west during spawning time. The share of gillnets has declined continuously in recent decades, while that of longlines has increased (Figure 6). Longline fisheries have the widest spatial distribution of the fleets targeting cod (Figure 2), although most of the catches come from the west and northwest. The introduction of large longliners with automatic baiting in recent decades has expanded the fishing area of longliners to deeper waters.

In some areas, especially in the northwest and southeast, cod can be found in dense schools in certain hotspots, a fact exploited by captains when they want to take a large catch of cod in a short time, e.g. just before landing. Condition and size of cod in different areas is also an issue regarding fishing areas, but all those factors are weighed against proximity to landing harbour. The main changes since 2000 in the catch proportions by region are that the proportion of the northwest region (NW) has increased from around 35% in the years 2000 to 2010 in the first decade to around 40-50% in the second decade from 2010 to 2020 (Figure 4). Over the same period, the percentage of cod catches to the west of the country (V) has decreased from around 25-30% to almost 20% and the catch to the southeast (SA) has decreased from 5-10% to below 5%. The contribution of other regions to the total catch has been fairly stable over time, the portion of the northeast region (NE) around 20 % and the southwest region (SV) around 10%.

Since 2005, there has been little change in the share of fishing gear categories in the total catch (see Figure 6). More than half of the landed catch in this season was caught with bottom trawls, followed by longlines with about 20-25%.

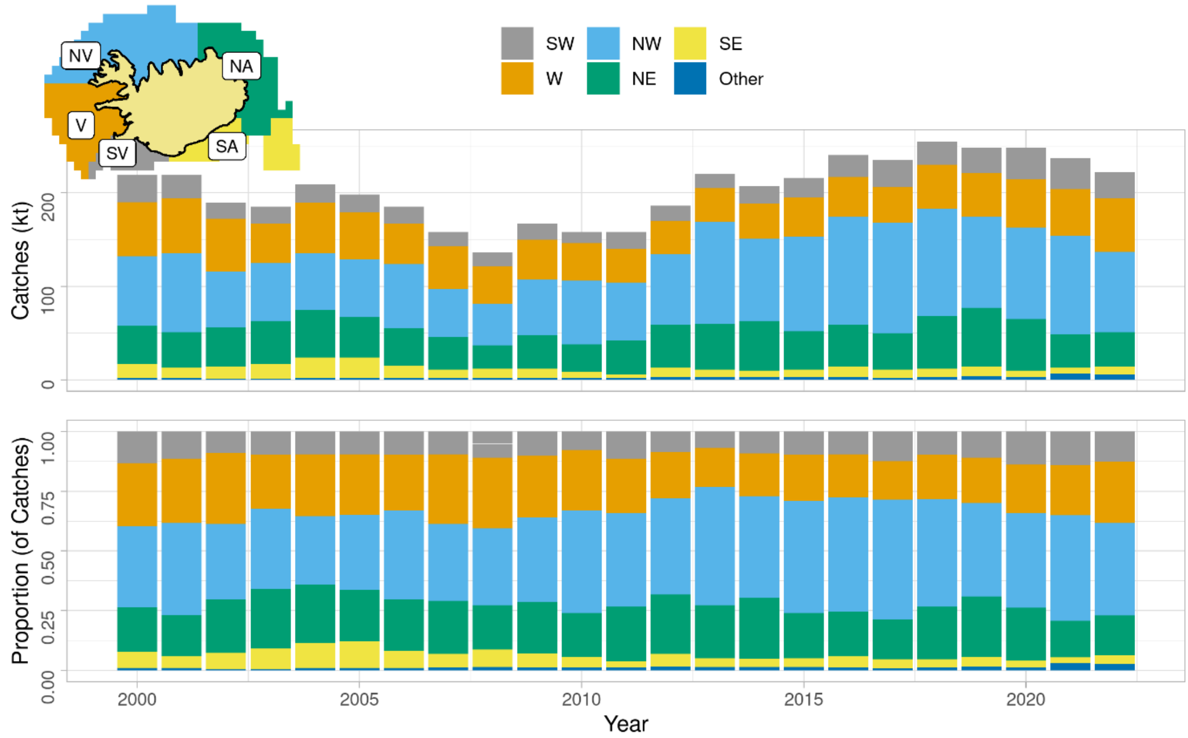

Figure 4. Icelandic cod. Spatial distribution of the Icelandic fishery by fishing area since 2000 according to logbooks. All gears combined.

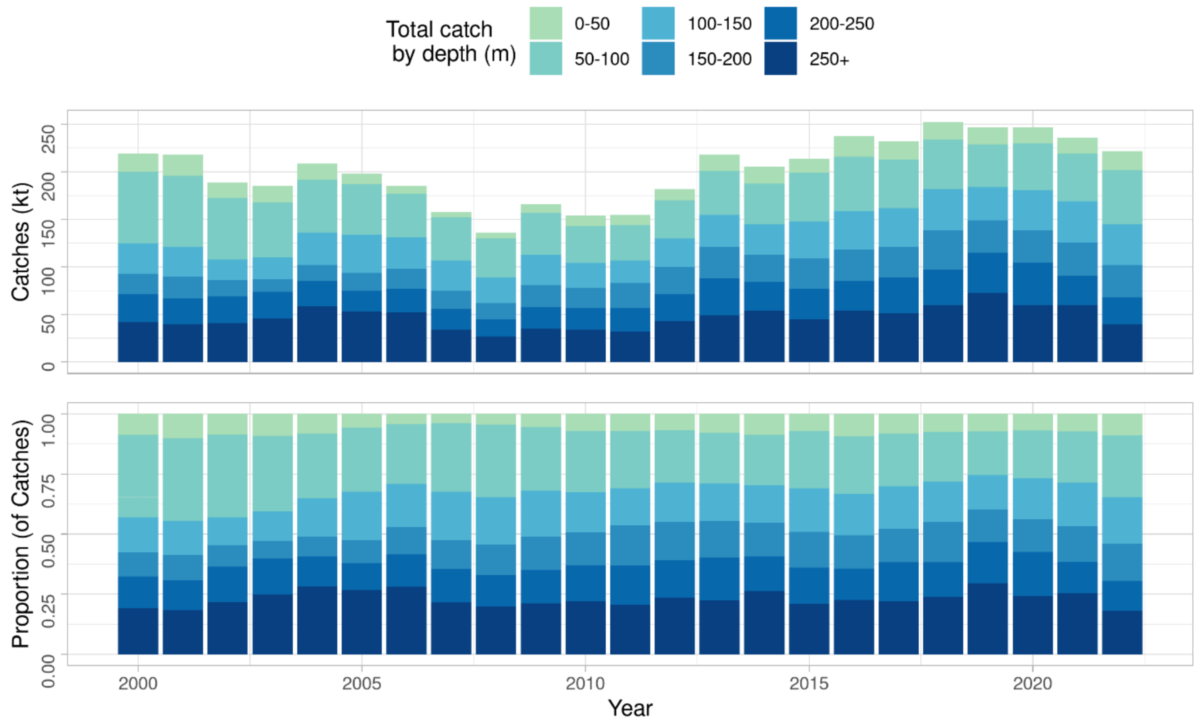

Figure 5. Icelandic cod. Depth distribution of catches since 2000 according to logbooks.

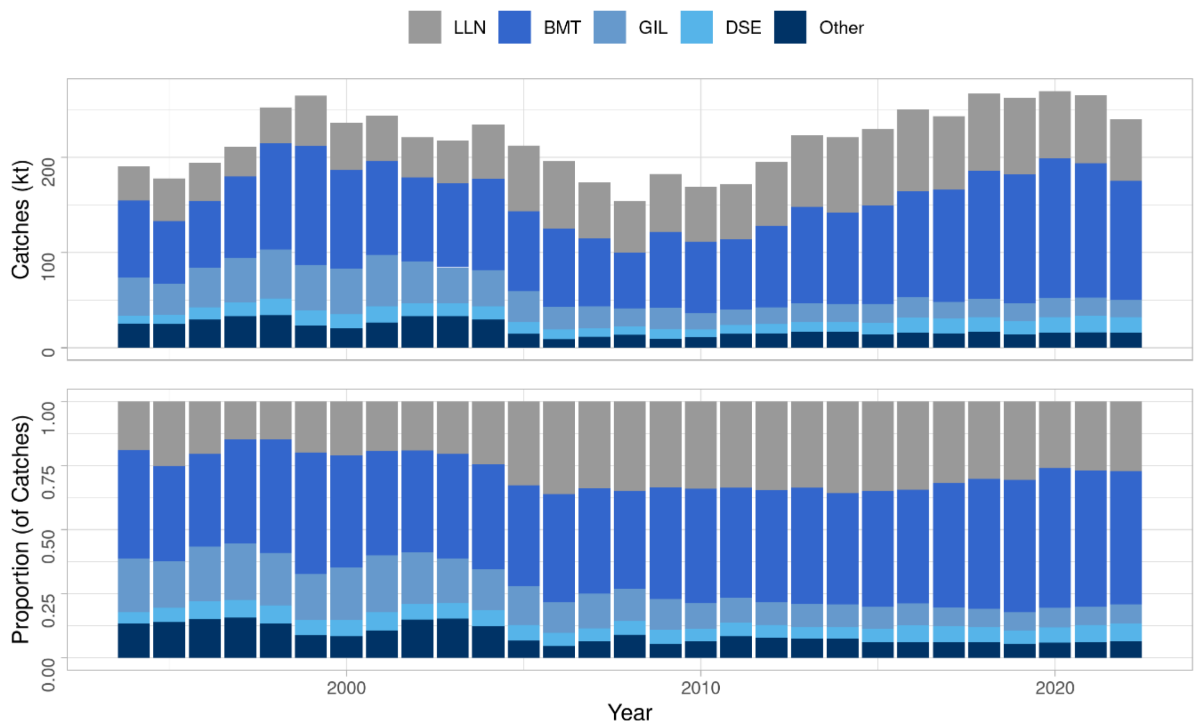

Figure 6. Icelandic cod. Total catch (landings) by fishing gear since 1994, according to statistics from the Directorate of Fisheries.

Cod catch increased from under 200 thousand tons to around 250 thousand tons between 1994 and 1999 (Figure 6). During the next 10 years, the catch decreased fairly steadily and reached a minimum in 2008, just around 150 thousand tons. The catch increased again steadily and in the last four years has been over 250 thousand tons. Bottom trawlers have historically been the most important fishing gear and their portion of the total catch has rarely been below 40%. This portion has grown somewhat in recent years from almost 45% in 2010-2016 to almost 55% in the last two years (Figure 6). Until 2003, the portion of catch by longlines was around 20%, but it was around 35% between 2005 and 2016. Along with the increased bottom trawling in recent years, the portion of longlines has at the same time decreased from around 35% to just over 25%. The portion of catch by gillnets was around 20% until 2001 but has since decreased and is now around 7% of the total catch. The portion of demersal seines contributing to the catch has remained fairly stable over the period and was around 5-7.5 % of the total catch. During the period, the share of other fishing gear (shrimp and lobster traps) has gone from around 10-15% to around 5%.

In 2022, more than half of the cod catch was taken in bottom trawl (52%), around 27% on long-lines, 8% by gillnets, 6% by jiggers, and 7% by demersal seine. The largest proportion of the catch in recent years was taken in the western and northwestern area, followed by the northeast and southwest areas. Cod was caught at similar depth as in previous years, but perhaps slightly shallower (Figure 6).

Since 1994, the number of vessels reported as having landed over 10 tonnes of cod in total annually, has decreased. This decline is noticeable in all the fleets, as the number of vessels has dropped by more than half since 1994 (Table 1). However, total catches have been increasing steadily in the past few years (Table 1).

Table 1. Icelandic cod. Number of Icelandic vessels landing catch of 10 tonnes or more of cod in the calendar year, divided by gear type. Landings data from the Directorate of Fisheries. Catch sums are for the vessels included, less than the total including all vessels for the calendar year.

	NUMBER OF VESSELS					CATCHES (THOUS. TONNES)					
YEAR	*Long-liners*	*Gill-netters*	*Trawlers*	*Seiners*	*Other*	*Line*	*Gillnet*	*Trawl*	*Seine*	*Other*	***Sum***
1994	517	265	258	88	672	35	40	80	8	23	186
1995	495	228	193	93	673	44	32	66	10	21	173
1996	454	245	182	107	634	39	41	70	13	20	183
1997	345	223	163	110	641	31	46	86	15	26	204
1998	373	262	161	106	627	37	51	112	18	23	241
1999	401	250	156	96	559	52	47	125	16	17	257
2000	382	265	130	86	539	50	48	103	15	17	233
2001	376	333	131	87	505	47	54	99	17	16	233
2002	333	291	121	85	496	42	44	88	14	18	206
2003	342	249	117	81	445	44	37	88	13	15	197
2004	343	242	117	83	454	57	37	96	14	14	218
2005	350	193	117	77	281	69	32	84	13	7	205
2006	317	146	107	72	211	71	24	82	10	5	192
2007	273	119	102	64	152	58	23	71	9	3	164
2008	237	93	96	59	140	53	19	59	8	3	142
2009	221	94	92	63	302	61	22	80	10	6	179
2010	209	83	90	52	344	57	17	76	8	6	164
2011	202	89	87	50	521	57	16	74	9	10	166
2012	208	81	91	52	552	67	17	85	10	11	190
2013	217	79	89	51	584	75	20	101	10	13	219
2014	231	81	82	45	606	79	19	96	10	14	218
2015	218	78	73	46	573	80	19	103	12	12	226
2016	204	74	69	45	603	86	21	111	16	14	248
2017	189	71	67	46	585	77	17	118	15	14	241
2018	160	77	66	42	543	80	19	135	16	15	265
2019	150	67	62	39	522	80	18	136	14	12	260
2020	125	71	64	37	582	70	20	147	16	15	268
2021	126	62	63	34	567	72	19	141	18	15	265
2022	110	57	62	42	605	65	18	125	16	14	238

The number of vessels accounting for 95% of the annual catch of cod in Icelandic waters reduced from almost 1500 to about 900 vessels in 1994-1999 (Figure 7). This reduction occurred despite annual catch increasing by almost 100 thousand tonnes. In 1999-2008, the number of vessels accounting for 95% of the cod catch reduced with reduced total catches to about 400 vessels. Since 2009 the number of vessels has remained relatively constant between 250 and 500, although the most recent years are marked by having the lowest numbers of vessels. At the same time, annual catches have increased substantially (Figure 7).

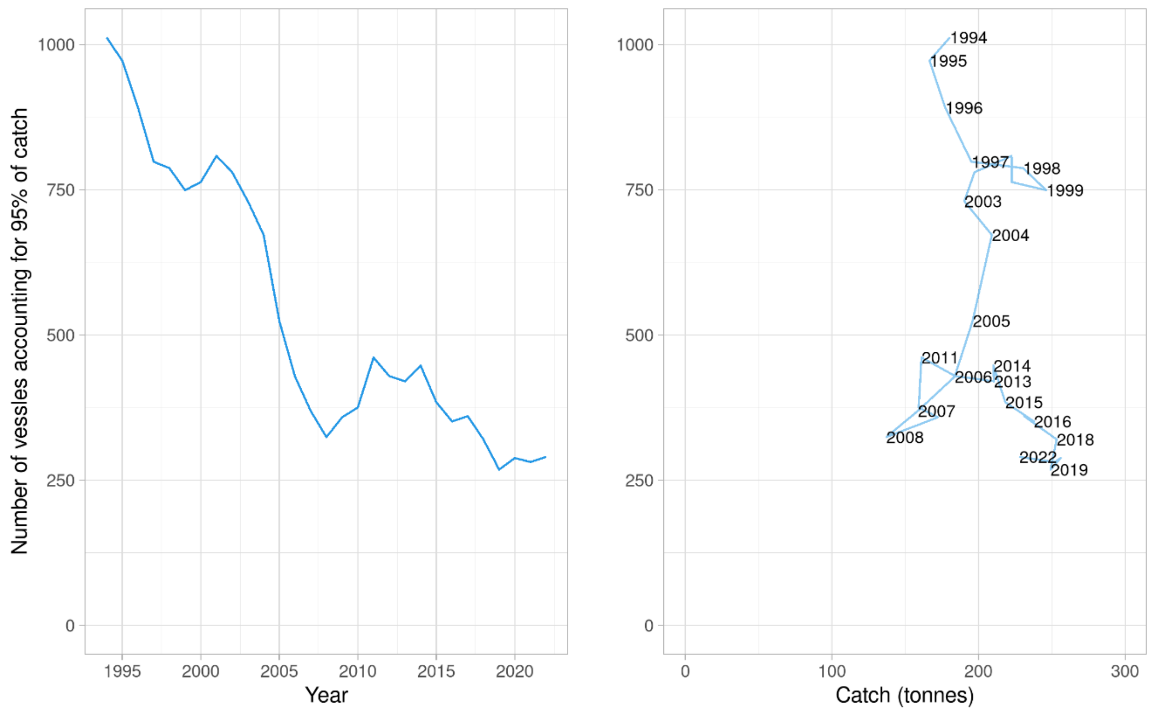

Figure 7. Icelandic cod. Number of vessels (all gear types) accounting for 95% of the total catch annually since 1994. Left: Plotted against year. Right: Plotted against total catch. Data from the Directorate of Fisheries.

LANDINGS TRENDS

Landings of cod in Icelandic waters has been historically high since industrial fishing began, although a productivity shift in the 1980s has led to relatively less recruitment and lower sustainable yield in the following decades. Landings were around 350 000 to 450 000 tonnes prior to World War II and during the 1960s but have ranged closer to 150 000 to 250 000 both as a result of the productivity shift and management action. Sharp reductions in foreign catches are visible during World War II and the 1970s, when the Icelandic EEZ was expanded to 200 nautical miles. Landings in 2022 amounted to 242 192. Foreign landings account for a small portion of this, attributable to bilateral agreements allowing Norwegian and Faroese vessels to land a small amount of cod and other demersal species (Figure 8).

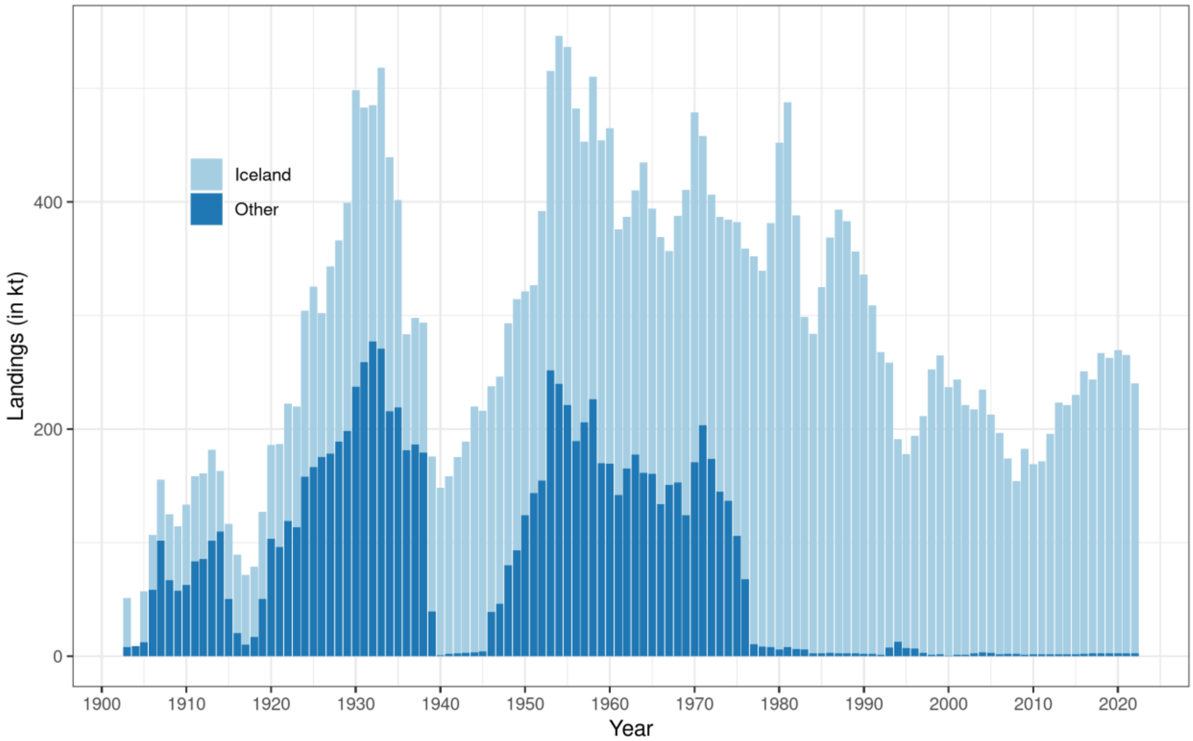

Figure 8. Icelandic cod. Landings. Data from the Directorate of Fisheries.

DATA AVAILABLE

In general, sampling is considered good from commercial catches from the main gears (demersal seines, longlines, gillnets and trawls). The sampling does seem to cover the spatial and seasonal distribution of catches (see Figures 9 and 10). In 2020, sampling effort was reduced substantially, on-board sampling in particular, due to the COVID-19 pandemic. Although this reduction in sampling continued through 2022, sampling operations are expected to return to normal in coming years and current samples are still considered to be sufficiently representative of the fishing operations. Thus, it is not considered to substantially affect the assessment of the stock.

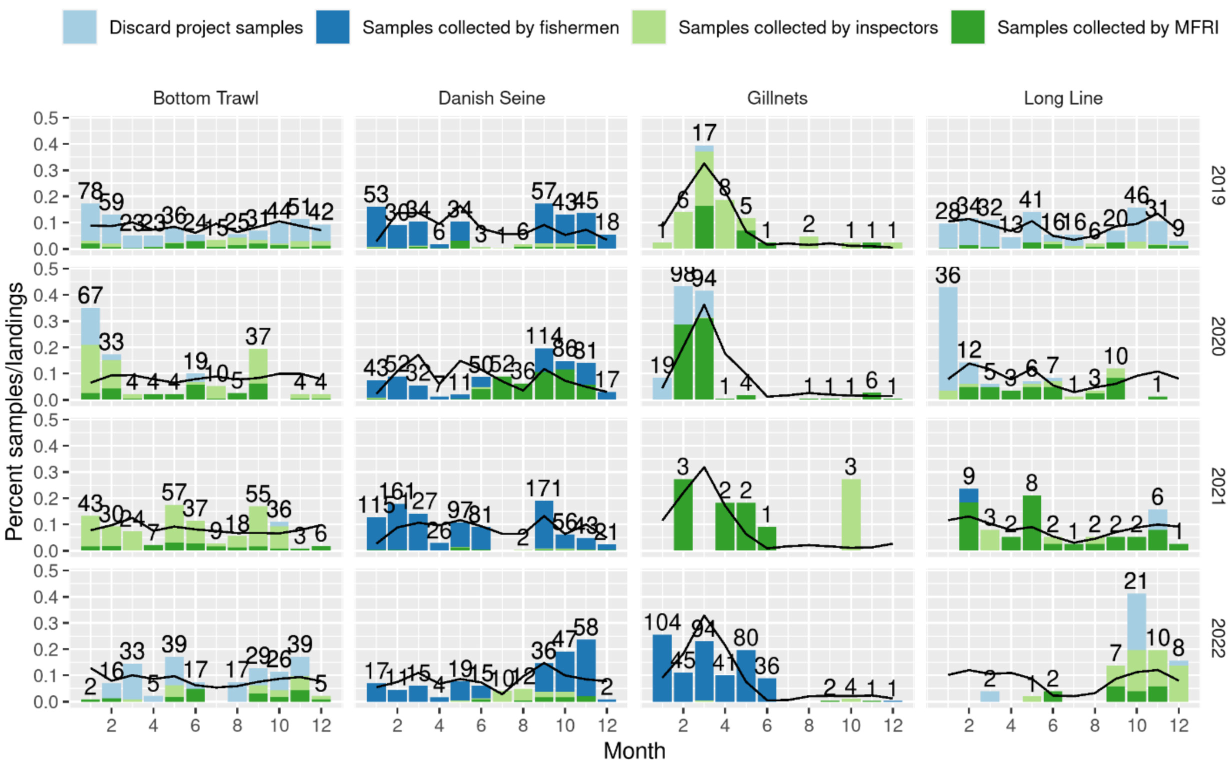

Figure 9. Icelandic cod. Ratio of samples by month (blue bars) compared with landings by month (solid black line) split by year and main gear types. Numbers above the bars indicate the number of samples by year, month, and gear.

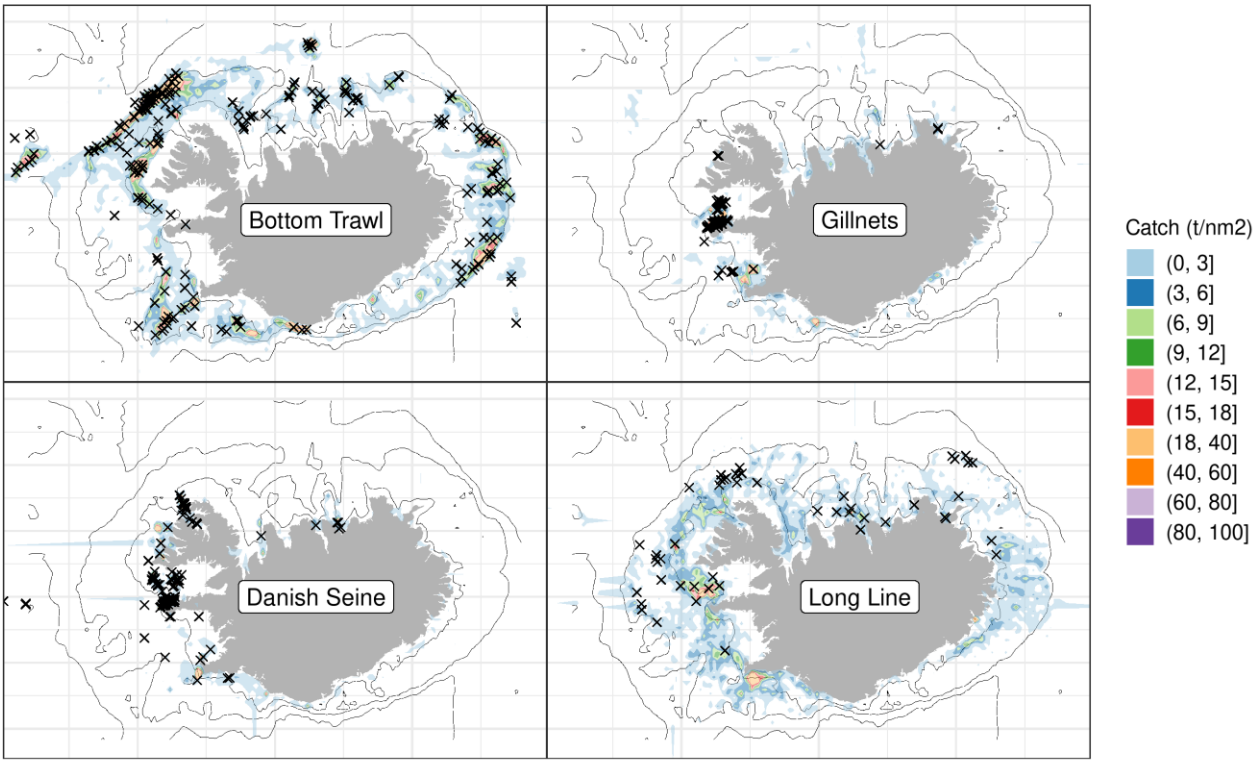

Figure 10. Icelandic cod. Fishing grounds as reported in logbooks and positions of samples taken from landings divided by gear (x).

AGE DISTRIBUTION OF LANDED COD

Table 2 shows the number of otoliths samples and number of age readings divided by gear type and Figure 10 shows the location of otoliths sampling.

Table 2. Icelandic cod. Number of samples, number of length measurements, and number of aged otoliths from landed catch.

	DEMERSAL TRAWL			LONGLINE			GILLNET			DEMERSAL SEINE VESSELS		
	Samples	*Lengths*	*Otoliths*	*Samples*	*Lengths*	*Otoliths*	*Samples*	*Lengths*	*Otoliths*	*Samples*	*Lengths*	*Otoliths*
2010	806	77979	5880	757	11241	1121	849	26467	1505	986	81958	3516
2011	596	64643	5403	921	7443	1417	652	29408	1197	765	56099	2779
2012	604	54037	5757	748	8928	1334	646	22778	1557	1124	98415	3895
2013	661	73855	6194	694	2840	1041	765	4272	1790	630	83238	3302
2014	531	46615	5104	262	5340	747	453	27415	1162	691	96774	2096
2015	554	65641	4937	1018	6858	1686	767	6565	1632	1037	84003	2128
2016	493	57116	5015	1031	7182	2006	797	26568	1674	1060	97164	2183
2017	518	67512	3818	1270	8287	2189	311	7413	908	368	77691	1119
2018	264	48111	2369	1368	6545	2073	1004	16636	1290	395	74874	945
2019	451	81165	2828	330	4970	966	43	5754	300	292	56710	1237
2020	191	35494	1847	581	3915	1397	226	12606	437	84	13242	775
2021	325	53645	2171	900	6468	2304	11	1133	200	38	4333	750
2022	228	38180	1264	246	5540	524	408	1755	834	51	11228	342

The age composition of the catch has shifted from younger to older fish in the last few decades (Figure 11), likely as a result of decreasing fishing pressure.

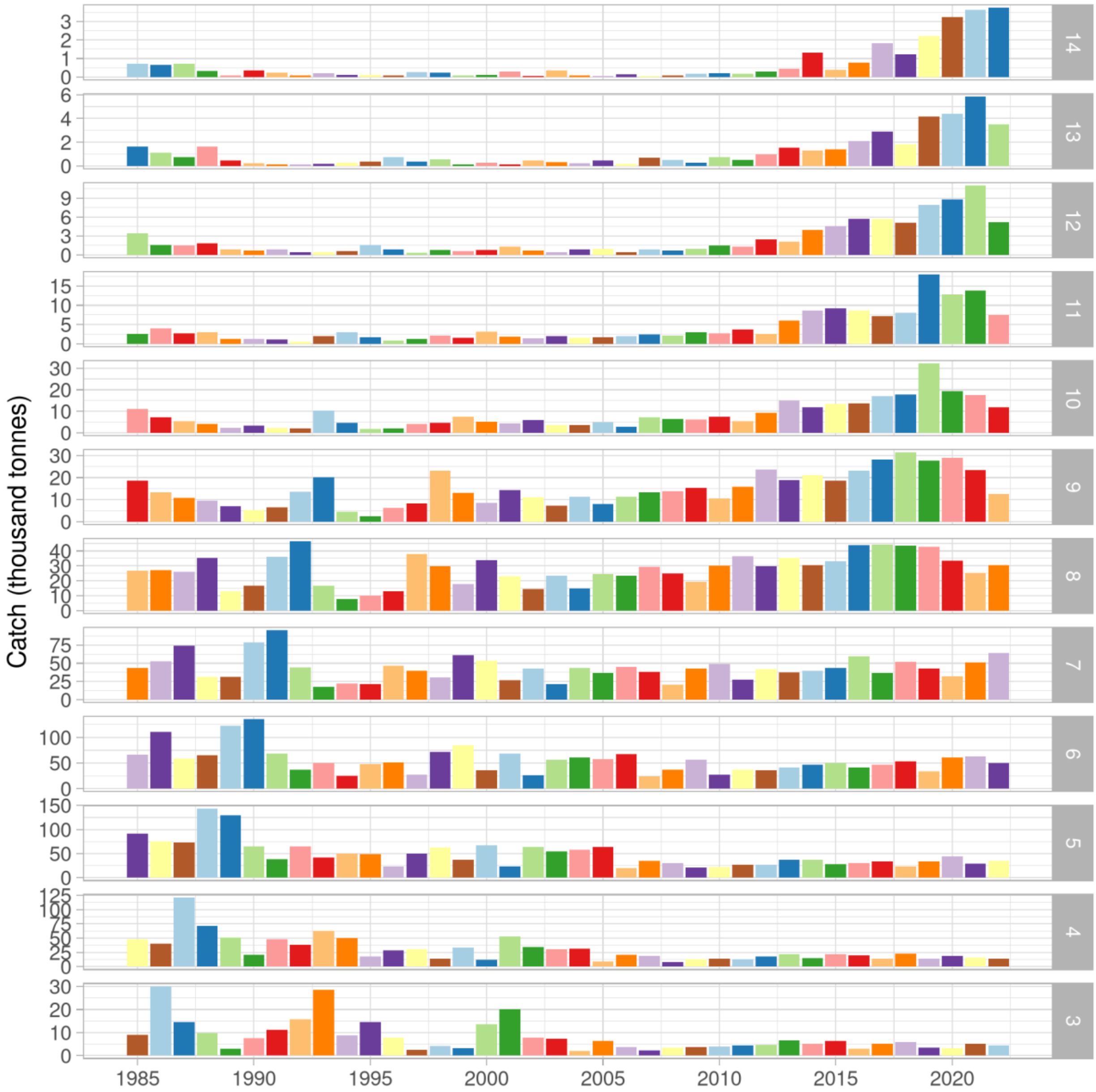

Figure 11. Icelandic cod. Estimated age distribution of landed catch based on landings and otoliths collected from landed catch (note different scales on the y-axes).

LENGTH DISTRIBUTION OF LANDED COD

The length distribution of landed catch has shifted towards larger cod in the last ten years (Figures 12-13).

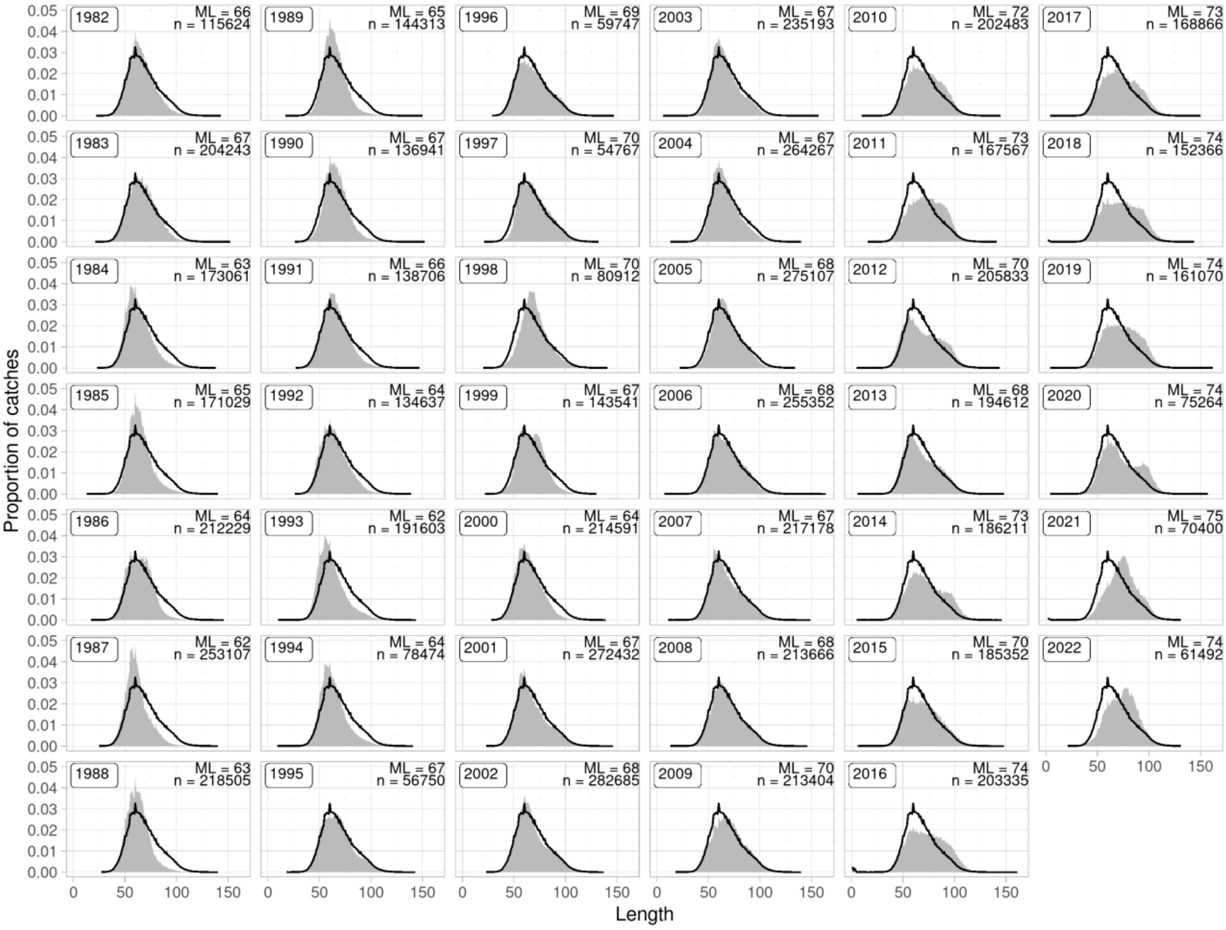

Figure 12. Icelandic cod. Length distribution from landed catch. The black line represents the mean length distribution for all years.

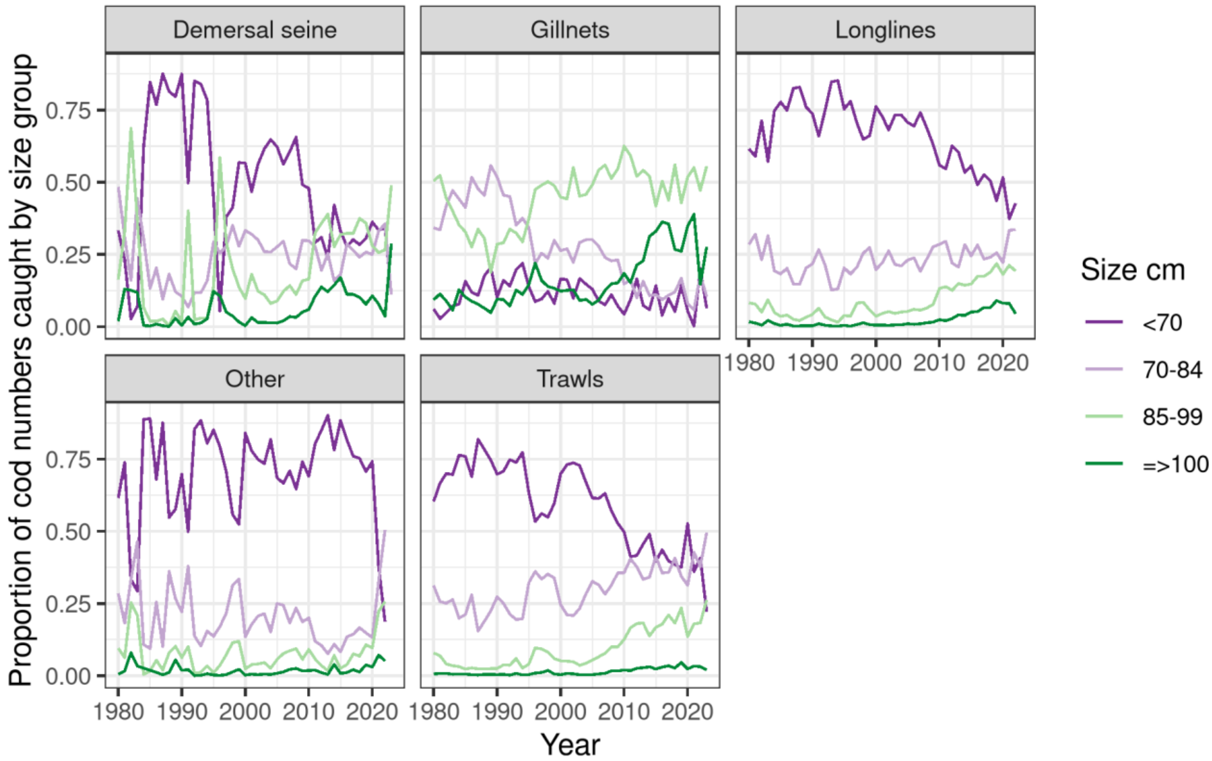

Figure 13. Icelandic cod. Proportion of the commercial catch (by numbers) from fish of a given size (cm).

WEIGHT AT AGE IN THE CATCH

The mean weight age in the catch (Figure 14) declined from 2001 to 2007, reaching then a historical low in many age groups. The weight at age has been increasing in recent years and are currently around the average weights observed over the period from 1985 in age groups 3 to 10, while around 10% below average in older age groups. The catch weight at age 3-10 in the final year (assessment year) is based on the relationship between spring survey and catch weights in in the previous year for ages 3-9, and for older ages, the values from the previous year are used (see short-term projections).

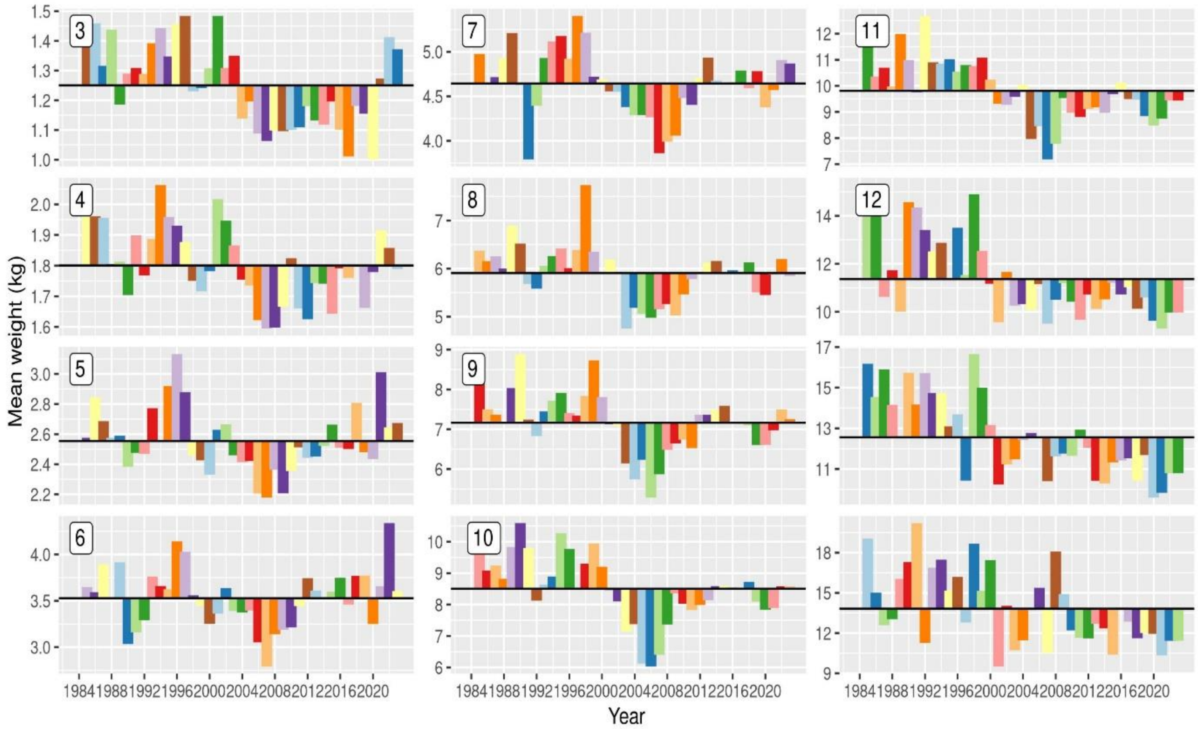

Figure 14. Icelandic cod. Weight at age (numbers in panel indicate age classes) in the catches expressed as deviations from the mean (blue: weight above the average, red: weight below average). Weight at age in the assessment year are based on predictions using the spring survey weights. Note that values that are equal to the mean are not visible in this type of plot.

NATURAL MORTALITY

Information on natural mortality is limited.

SURVEY DATA

The Icelandic spring groundfish survey (hereafter spring survey) has been conducted annually in March since 1985. In addition, the Icelandic autumn groundfish survey (hereafter autumn survey) was commenced in 1996. However, a full autumn survey was not conducted in 2011.

Figure 15 shows both a recruitment index based on abundance of cod smaller than 55 cm, and trends in various biomass indices. Survey abundance by tow and changes in spatial distribution in Figures 16-17 (spring survey) and Figures 18-19 (autumn survey).

The total biomass index in the spring survey has been high but fluctuating and with a slight decline over the last decade according to the spring survey index. The total spring (SMB) and fall survey (SMH) measurements decreased significantly from the highest value observed in 2017 to the 2020 measurement and have since increased again slightly (Figure 15). While the 2021 and 2022 spring survey measurement were on par with that observed in 2018 and 2019 the fall survey measurement in 2021 continued to decline, it being the lowest observed since 2004. The 2020 survey indices were substantially below expectations for size classes that constitute the bulk of the fishable biomass, a trend which continued in 2021 in autumn survey indices but not spring survey indices. In general, the two surveys have shown similar trends through time (Figure 15) but the contrast through the increase and decline since the late 2000s is greater in the fall survey. The discrepancy between the last two pairs of the spring (2021 and 2022) vs the fall biomass measurements (2020 and 2021) are the highest observed in the time series. A greater decline is therefore observed in the autumn survey biomass index (Figure 15).

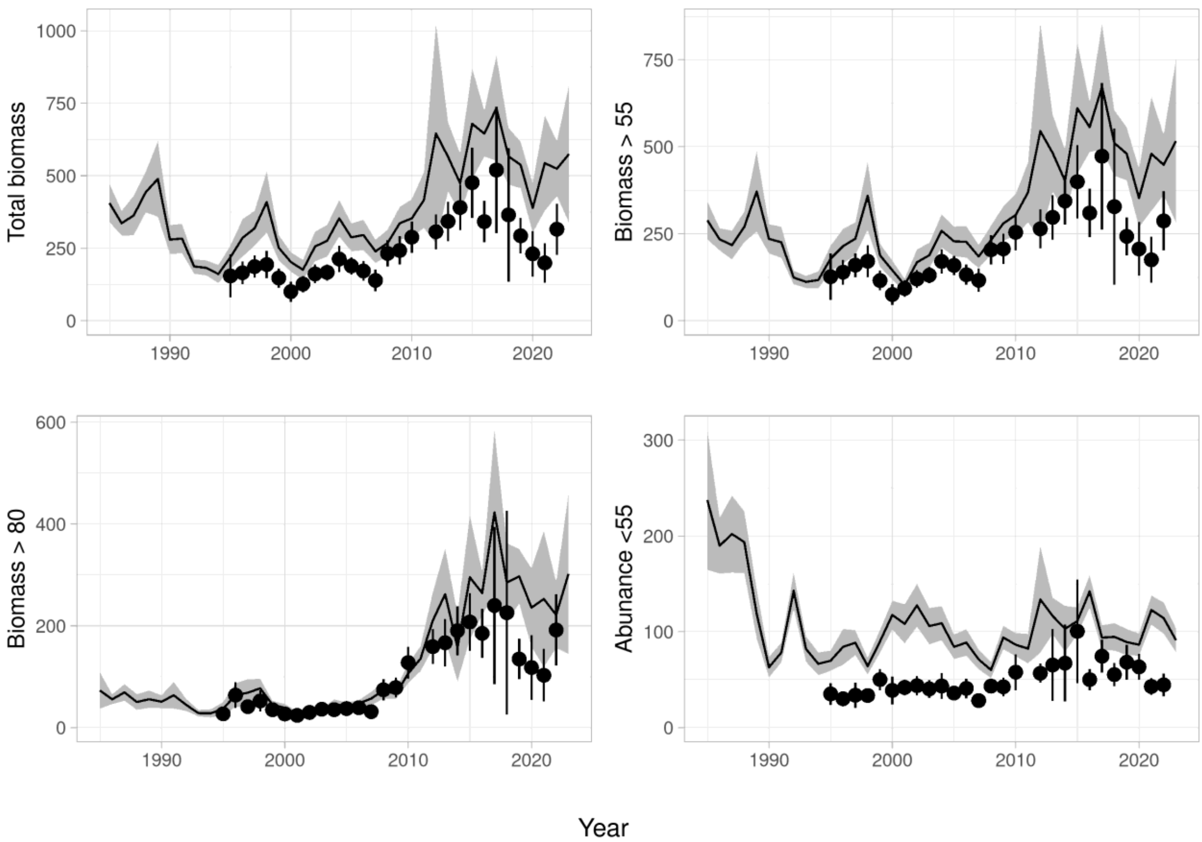

Figure 15. Icelandic cod. Total biomass indices (upper left) and harvestable biomass indices (≥55 cm) (upper, right), biomass indices of larger ind. (≥80 cm) (lower left) and juvenile abundance indices (≤55 cm) (lower right) from the spring survey (line) from 1985 and autumn survey (black dots) from 1996, along with 95% CI.

Cod in the spring survey in 2023 was caught all around Iceland, with hotspots in offshore waters in the north and southwest, and in shallow waters in the south (Figure 16). Spatial distribution of the total biomass index in the spring survey shows that the NW and NE areas are dominating in most years (Figure 17). However, some temporal changes have been occurring in recent years with the catch in the NE area decreasing and increasing in the W and SE area. In 2023 there was an increase in almost all areas except for the northern areas.

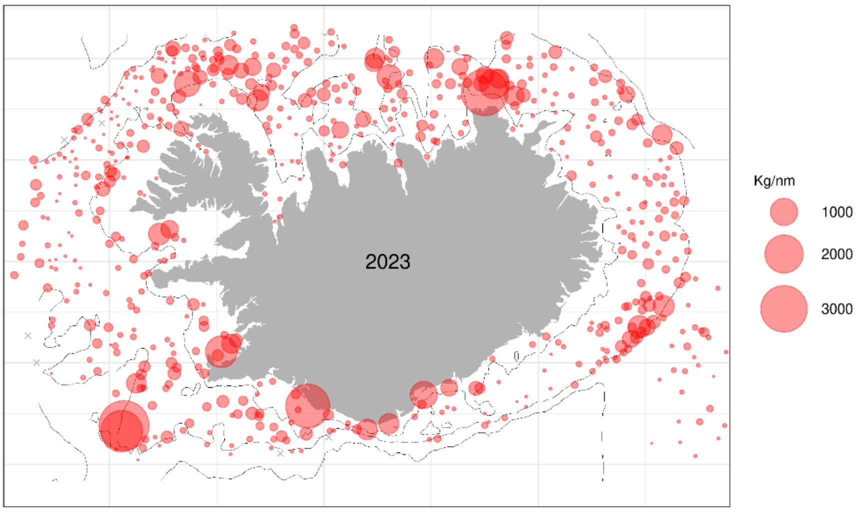

Figure 16. Icelandic cod. Spatial distribution in the spring survey. The 100, 500 and 1000 m isobaths are shown.

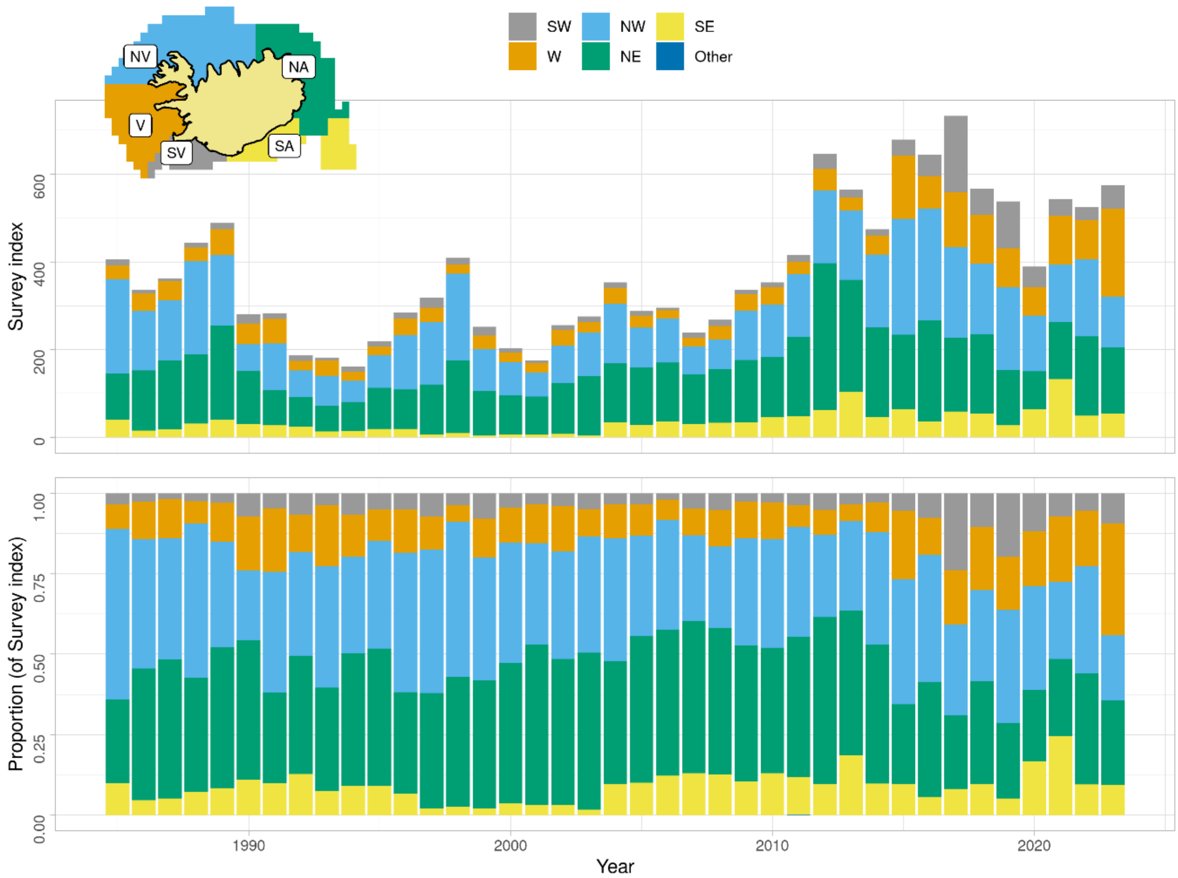

Figure 17. Icelandic cod. Spatial distribution of biomass index in the spring survey.

Spatial distribution of cod in autumn survey in 2023 was similar as in previous years (Figure 18). Most cod in the autumn survey have been caught on the traditional fishing grounds in the northwest and northeast (Figure 19).

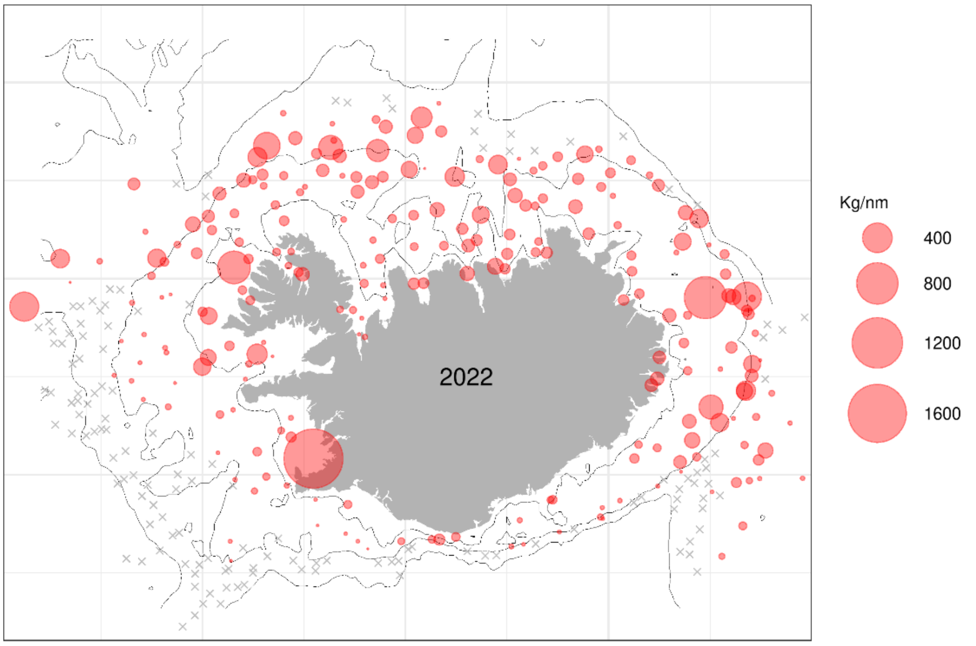

Figure 18. Cod. Spatial distribution of cod in the autumn survey. The 100, 300 and 1000 m isobaths are shown.

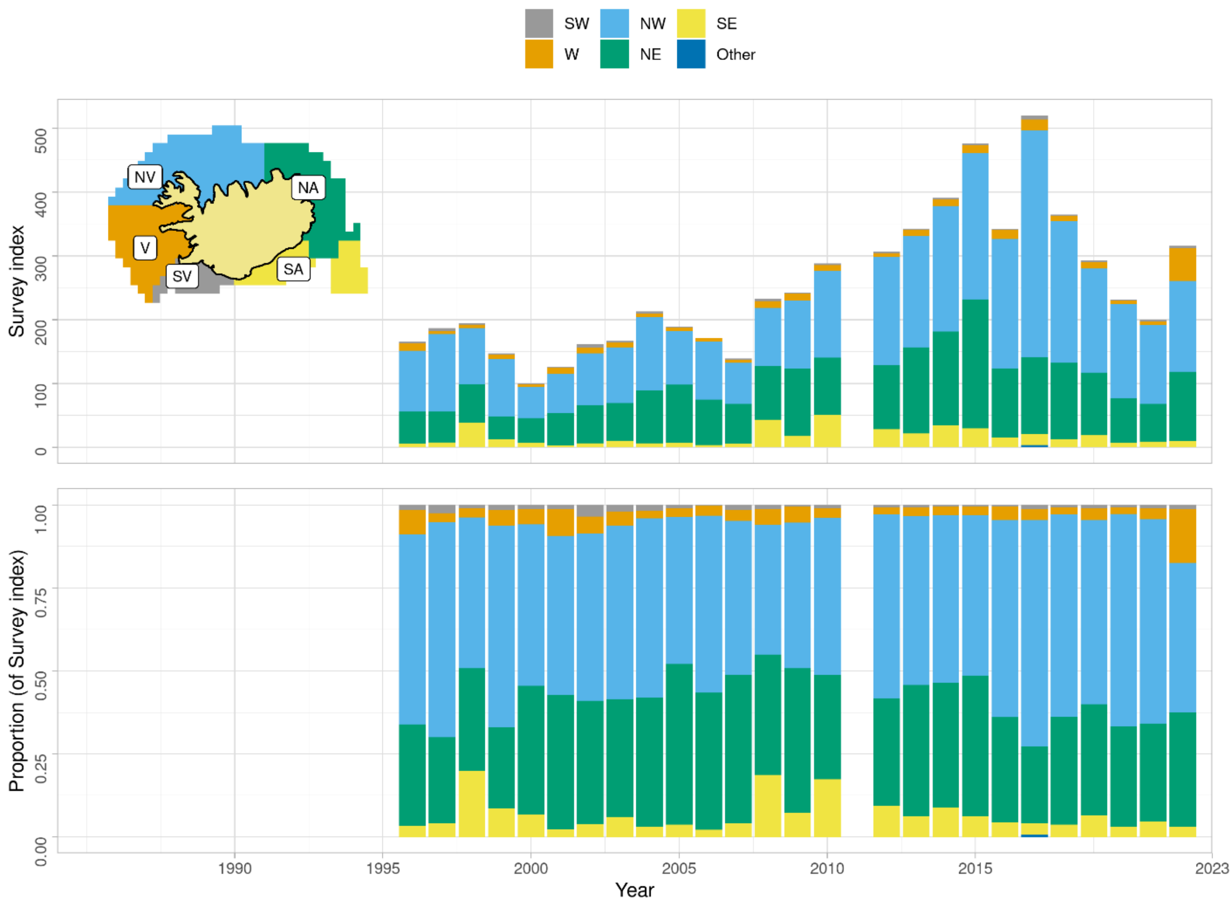

Figure 19. Icelandic cod. Spatial distribution of biomass index in the autumn survey.

Length distributions from both surveys illustrate quite clearly age-groups division in the youngest age groups (Figures 20-21). Thereafter the division is not quite as clear, due to variability in individual growth and maturity, but some multimodal length distribution can be seen.

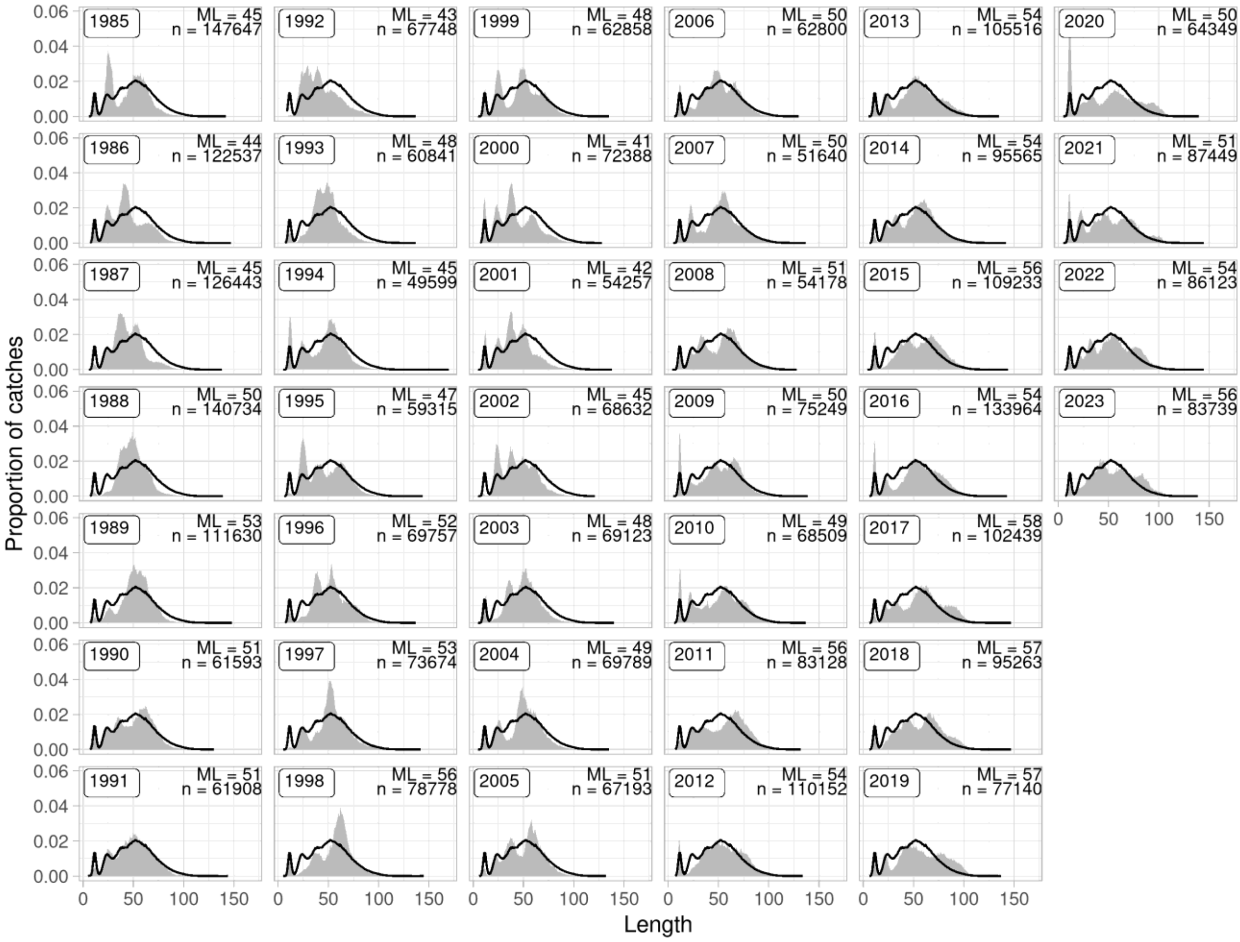

Figure 20. Icelandic cod. Length-disaggregated abundance indices from the spring survey. The black line shows the mean for all years.

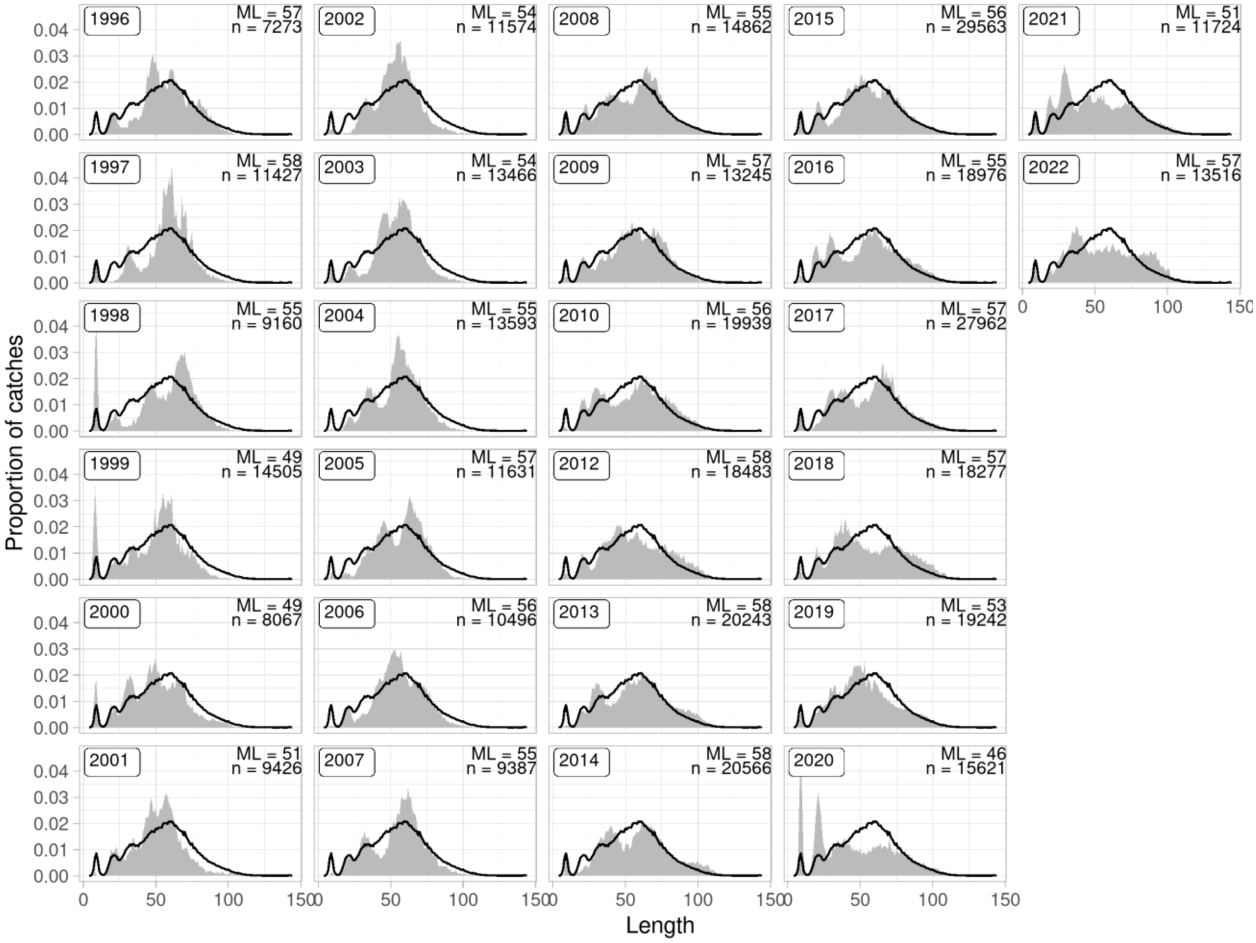

Figure 21. Icelandic cod. Length-disaggregated abundance indices from the autumn survey. The black line shows the mean for all years.

Survey age-based indices of older fish are all relatively high in recent decade despite the pattern that several of the year classes showing high indices recently were showed low - moderate indices when younger (Figure 22). The 2020 spring survey anomaly are clearly apparent, e.g. for year-classes 2014 and 2015 that are around the long term average in 2019 (then ages 4 and 5) but roughly half of that in 2020 (then ages 5 and 6).

The log ratio of spring survey indices (Figure 23) over time illustrates the anomaly in the measurements between 2019 and 2020 for some selected age groups. Although noisy, the overall pattern over time shows a decline in the log-ratio (consistent with long term reduction in mortality), but in 2020 there is an increase in the ratio, even in the younger age groups that normally are not yet fully selected into the survey.

Figure 22. Icelandic cod. Age-based abundance indices of cod in the groundfish survey in spring (SMB) and autumn (SMH). The indices are standardized within each age group and within each survey.

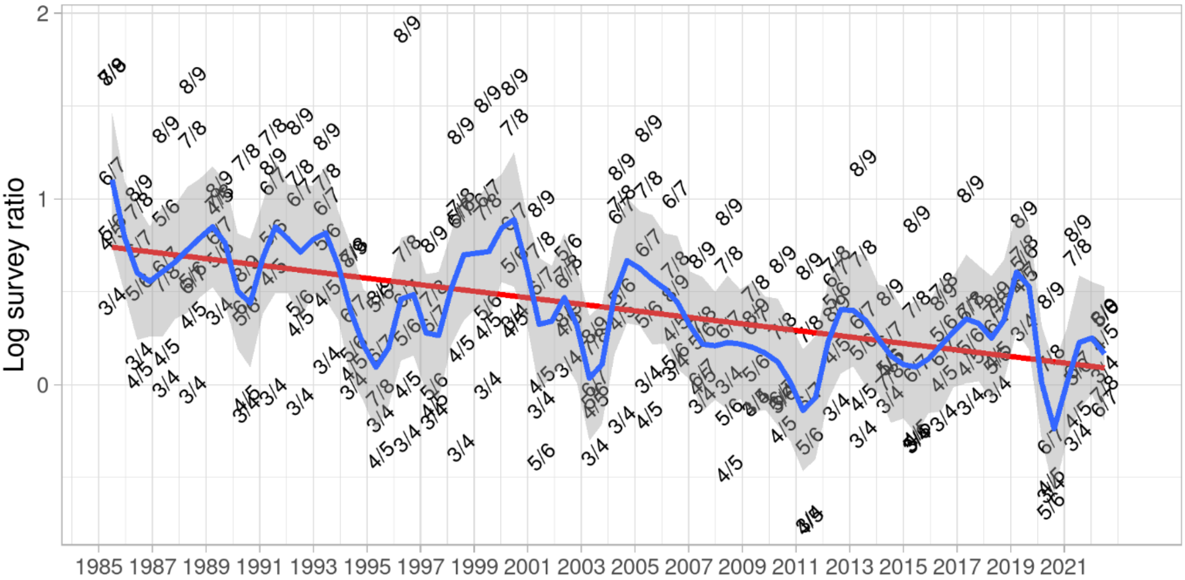

Figure 23. Icelandic cod. Log-ratio of the spring survey indices for adjacent age groups (3-9, labelled as text), with blue line showing local smoother and the red line indicating the overall trend.

Mean weights in the spring survey for all ages of cod were below average during roughly 2000 – 2010. After this period, younger ages remained older ages become mainly above average. The autumn survey shows a similar trend but only ages 3 and 4 continue to exhibit frequent below-average weights (Figure 24).

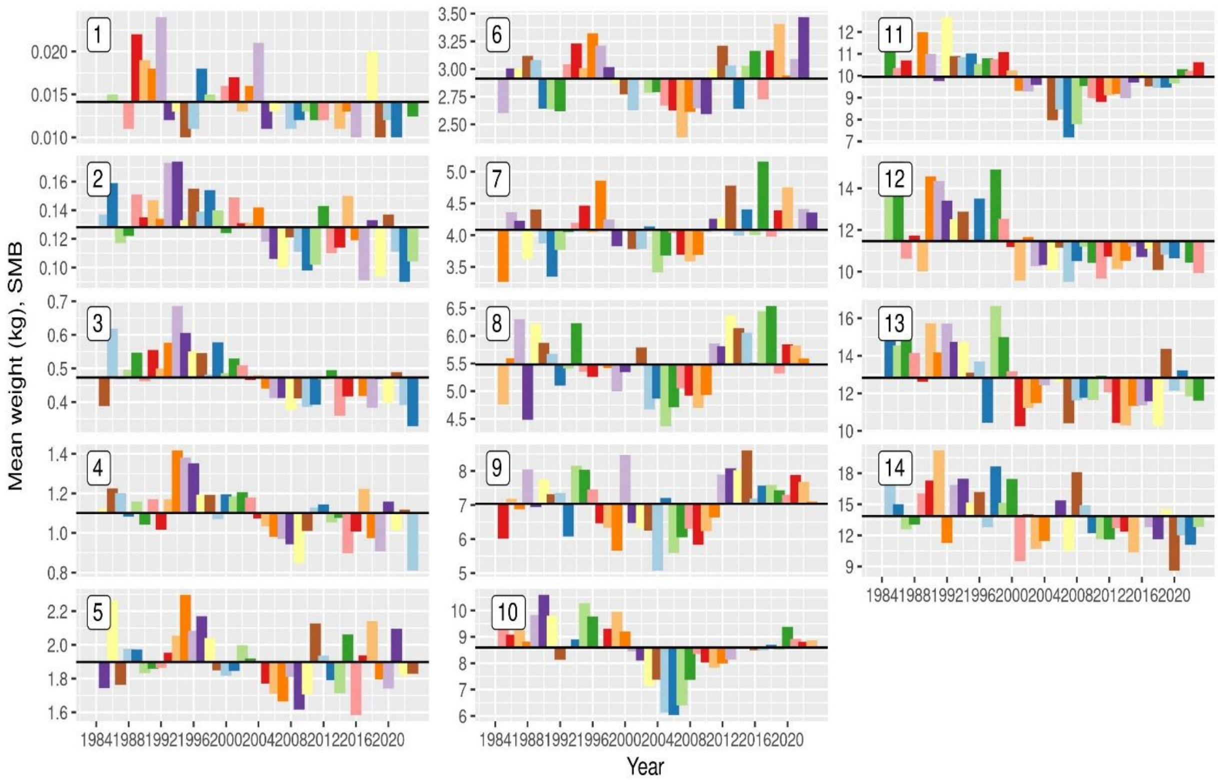

Figure 24. Icelandic cod. See below.

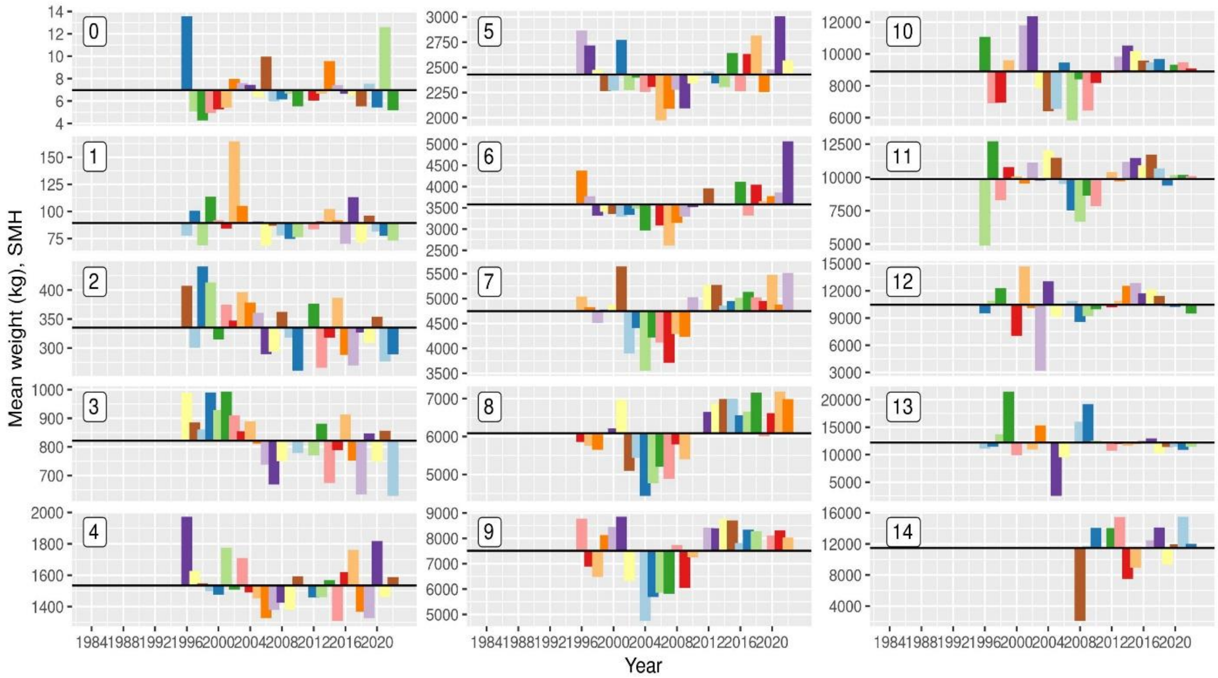

Figure 24. Icelandic cod. Weight at age (numbers in panel indicate age classes) in the spring survey (SMB) and fall survey (SMH) expressed as deviations from the mean (blue: weight above the average, red: weight below average). No fall survey was conducted in 2011. Note that values that are equal to the mean are not visible in this type of a plot. No age 14 cod were found in the autumn survey at the beginning of the time series.

DATA ANALYSIS

ANALYTICAL ASSESSMENT

The stock assessment for cod is based on a separable statistical catch-at-age model that takes into account annual effects of stock measurements. The input in the analytical age-based assessment are catch at age 1955–2021 (age 3 to 14) and ages 1 to 14 (from the 1985–2022 spring (often referred to as SMB in this report) and ages 3 to 13 from the 1996–2021 fall groundfish surveys (often referred to as SMH in this report). The same framework is used to carry the stock dynamics forward to evaluate reference points and HCR. This framework was benchmarked in 2021 and a full description of the modeling framework can be found in the ICES stock annex (ICES 2021).

Mean weight age in the catch (Figure 14) declined from 2001 to 2007, reaching then a historical low in many age groups. The weights at age have been increasing in recent years and are at or above the average in the most important age groups. The variation in the pattern of weight at age in the catches is in part a reflection of the variation in the weight in the stock as seen in the measurements from the surveys (Figure 24).

DIAGNOSTICS

Deviations of measured and estimated age-specific survey indices show large negative deviations in SMB 2020 in important age groups (ages 4 to 8), but later deviations are closer to what has been observed historically (Figure 25). In fish aged 10 years and older in SMB, however, positive deviations are unusually high in the last two years. The deviations of the model from the measured and estimated SMH indices are generally negative in the last two years, the highest in 4 to 9-year-old fish. A summary of the measured and estimated values of the residuals of the model (Figure 25) shows that the model fails to follow the decline in SMH indices in the following years 2019 to 2021 (Figure 26). Although deviations in individual years can be considerable, the discrepancy in the development of population size indices in SMB and SMH the last few years, which means that the stock assessment is now subject to greater uncertainty than in general.

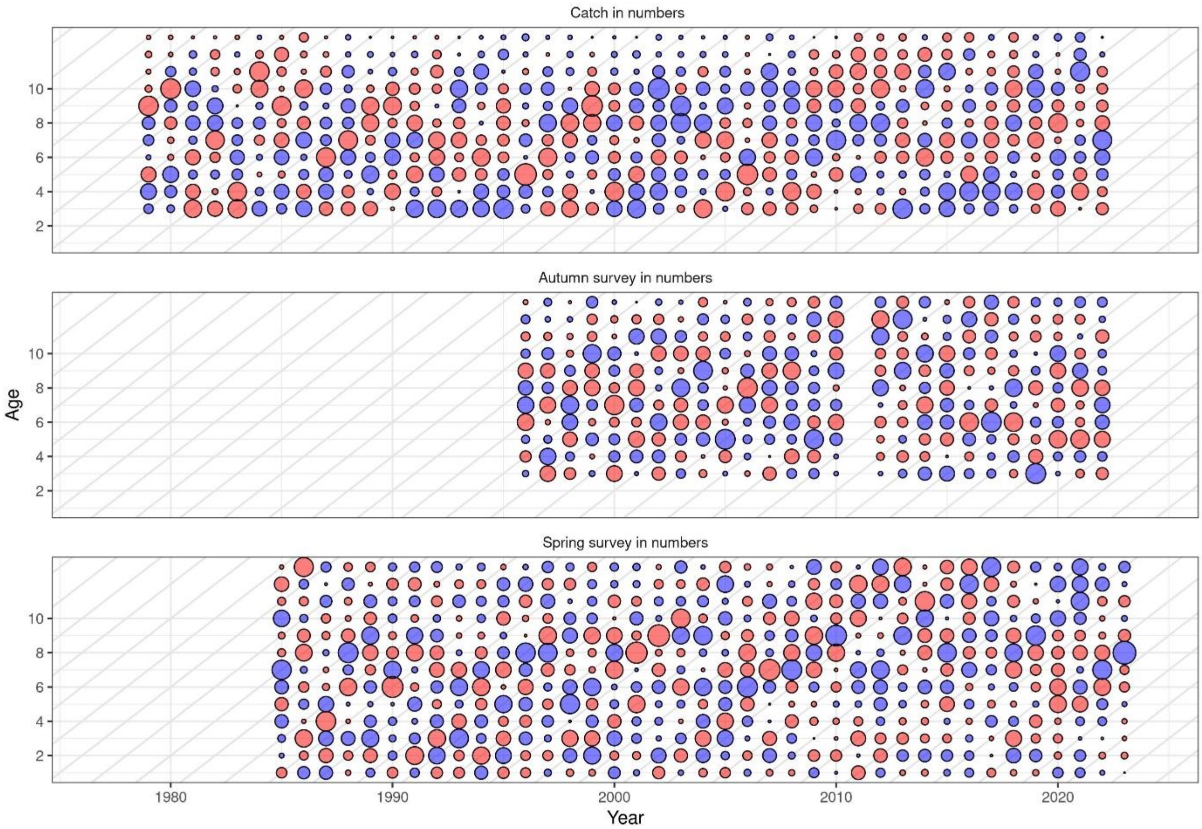

Figure 25. Icelandic cod. Catch residuals (top), spring survey residuals (SMH, middle) and fall survey residuals (SMB, bottom) by year and age (blue: measured values above the model fit, red: measured values below the model fit). Note that values that are equal to zero are not visible in this type of plot and that no survey was carried out in the fall 2011.

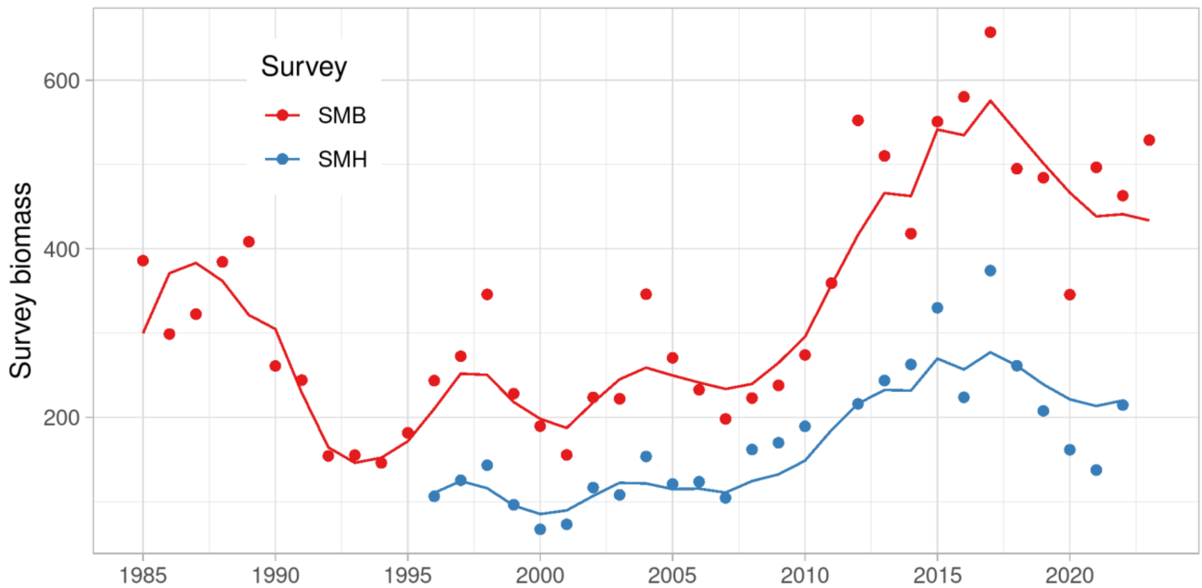

Figure 26. Icelandic cod. Observed aggregated age-based survey indices (point) and modelled indices (lines) for the spring survey (SMB) and the autumn survey (SMH).

Calculated retrospective analysis indicates that the first assessment of recruitment (at one year of age) is somewhat inaccurate, but otherwise changes are minor (Figure 27). The population estimates are fairly stable and the estimated 5-year Mohn's rho is within range (0.025 for recruitment, -0.041 for spawning stock, 0.0105 for control stock and 0.044 for fishing mortality).

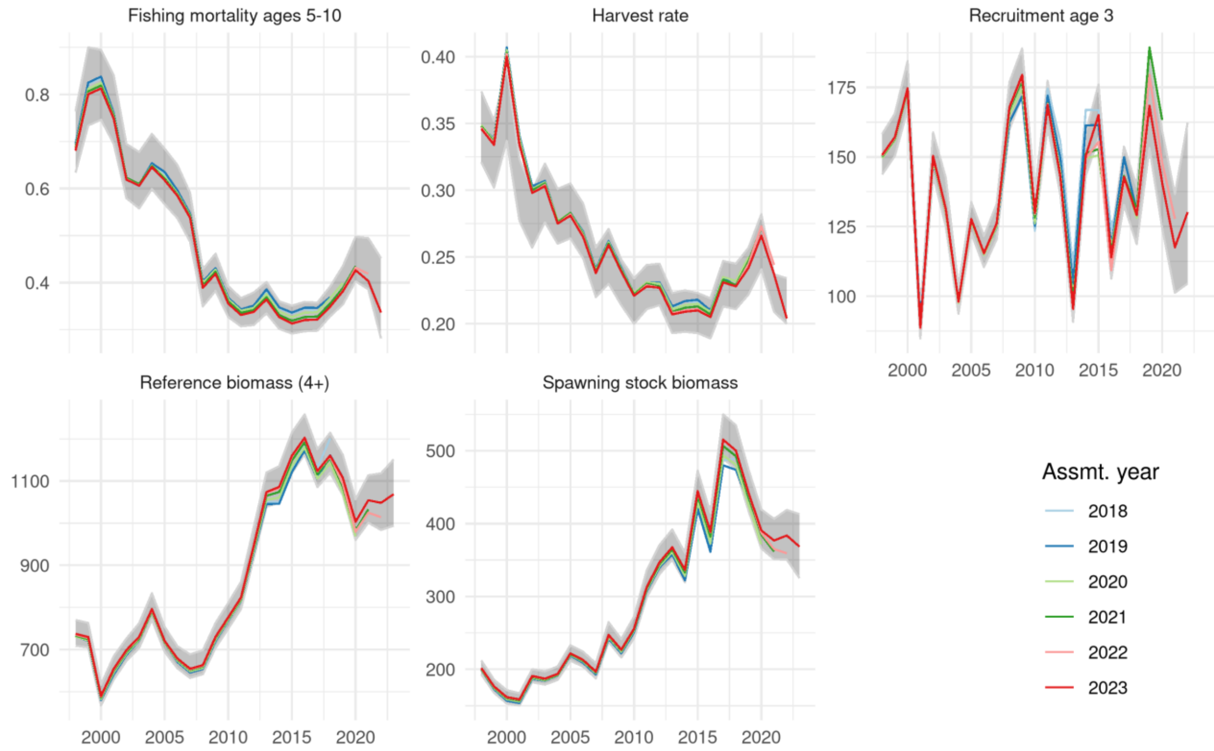

Figure 27: Icelandic cod. Analytical retrospective pattern of key metrics and the current estimates with 90% confidence intervals based on an MCMC routine (grey). The x-axis for the recruitment refers to the year class.

MODEL RESULTS

The results of this year's assessment show that the spawning stock in this assessment year is estimated to be 368.345 kt. Weight and maturity at age used in the calculation of SSB are presented in online tables. The values estimated in recent years are higher than have been observed during the last five decades. The reference biomass is estimated to be 1068.860 kt in 2023 and the fishing mortality 0.34 in 2022. Year classes since the mid-1980s are estimated to be relatively stable but with the mean around 35% lower than observed in the period 1955 to 1985.

The detailed results by age of the assessment are provided in online tables and Figure 28. The reference biomass has decreased somewhat in recent years, in part driven by incoming recruitment being somewhat lower and in part driven by increase in fishing pressure. The first estimates of the 2021 and 2022 year classes indicate that they are somewhat low, but they will not begin to enter the reference biomass until 2025.

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

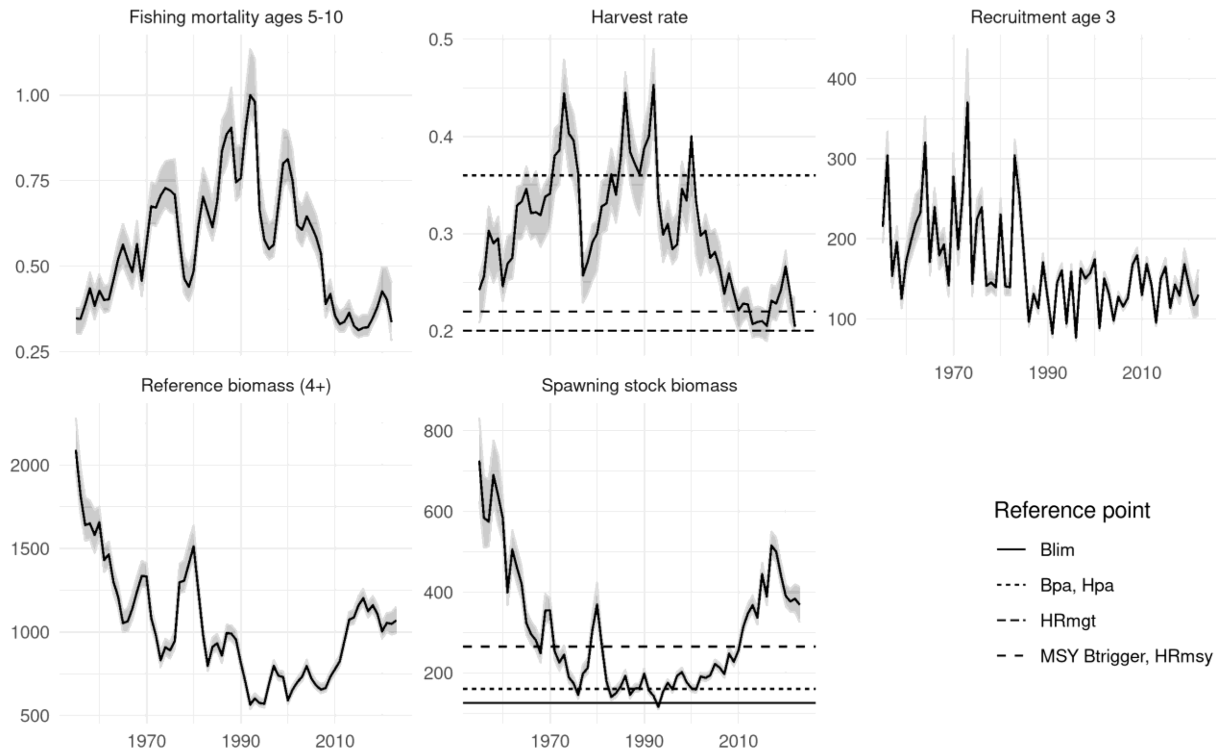

Figure 28. Icelandic cod. Stock summary plot. Catch, recruitment, fishing mortality and harvest rate, reference stock biomass (B4+) and spawning stock biomass (SSB). Grey ribbons indicate 90% confidence intervals based on an MCMC routine. The x-axis for the recruitment refers to the year class.

SHORT-TERM PROJECTIONS

Landings of Icelandic cod in 2022 are estimated to have been 242.313 kt, the bulk taken by the Icelandic fleet.

To perform short-term projections, estimates of catch for the current calendar year are needed. The estimates of landings for the current calendar year of 200 kt is based on the remainder of the quota from the current fishing year (2022/23, 209 kt) on 1. January 2023 (127 kt), the catch that is expected to be taken from 1. September to 31. December 2023 (70 kt, 1/3rd of the advised TAC of 211 kt) and the expected catch of the foreign fleet (3 kt).

Mean annual discard of cod over the period 2001-2012 is around 1% of landings in weight (Ólafur Pálsson et al 2013). More recent (unpublished) data indicate that discarding may have increased. The method used for deriving these estimates assumes that discarding only occurs as high grading.

The reference biomass (B_{4+}) upon which the TAC in the fishing year is set is derived from population numbers in the beginning of the assessment year and catch weights. The catch weights are, however, not known. In recent years, the estimates of mean weights in the catch of age groups 3–9 in the assessment years (y) have been based on a prediction from the spring survey weight measurements in that year based on a linear relationship between survey and catch weights in preceding year (y-1}. For ages 10 and older the weights from the previous year are used.

The same approach was used this year for predicting weight at age in next year's catches. I.e. the α and β were estimated from:

$$cW_{a,y-1}=\alpha+\beta*sW_{a,y-1}$$

and the catch weights for 2023 then from:

$$cW_{a,y}=\alpha+\beta*sW_{a,y}$$

Based on this, the mean weights at age in the catches in 2023 are predicted to be quite high for ages 3 and 4 (Figure 29 and Table 5), even though the weights in the spring survey in those age groups are below or at the long-term mean (Figure 14 and Table 6).

An alternative model based using all data from 1990 onwards to estimate α and β within each age group 3 to 9 (labelled 'alt') was explored:

$$cW\_a=\alpha+\beta*sW\_a$$

The catch weight in the assessment year would then be predicted using "each age" α and β and the observed stock weights in the assessment year. This alternative model gave a much more plausible estimate of catch weights in last year's assessment (2022) although the reference biomass in the terminal year (2022) was very similar (spaly B_(4+) = 977 000 t vs alternative 959 000 t). A retrospective analysis, using the current estimates of the parameters α and β, indicated that the overall predictive power of the reference biomass was better (cv of 0.035 vs 0.050, bias -0.0020 vs -0.0049) using the alternative model (Figures 30 and 31). However, it was decided that before implementation, it would be beneficial for the method to be externally reviewed either as a working document appended to next year's report, or through the next benchmark.

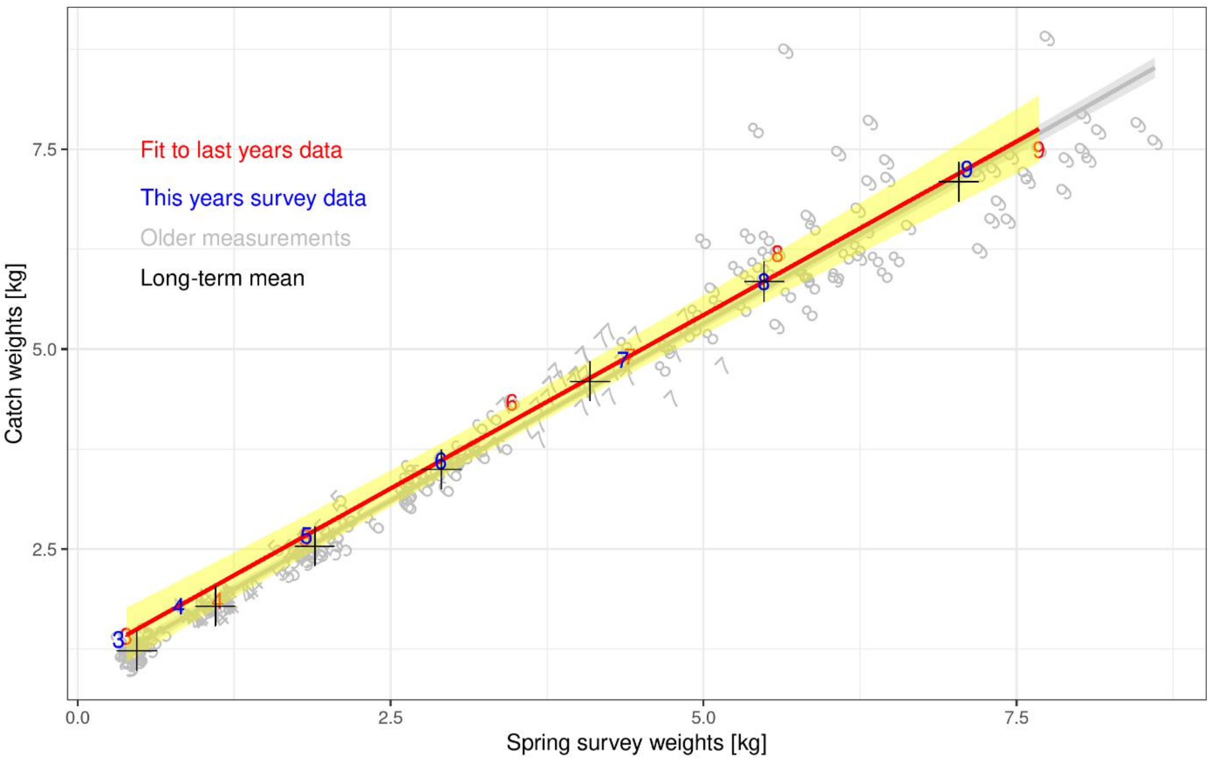

Figure 29: Icelandic cod. Prediction of catch weights age 3 to 9 in the assessment year. The 'crossed' points are the mean from 1990 to the present.

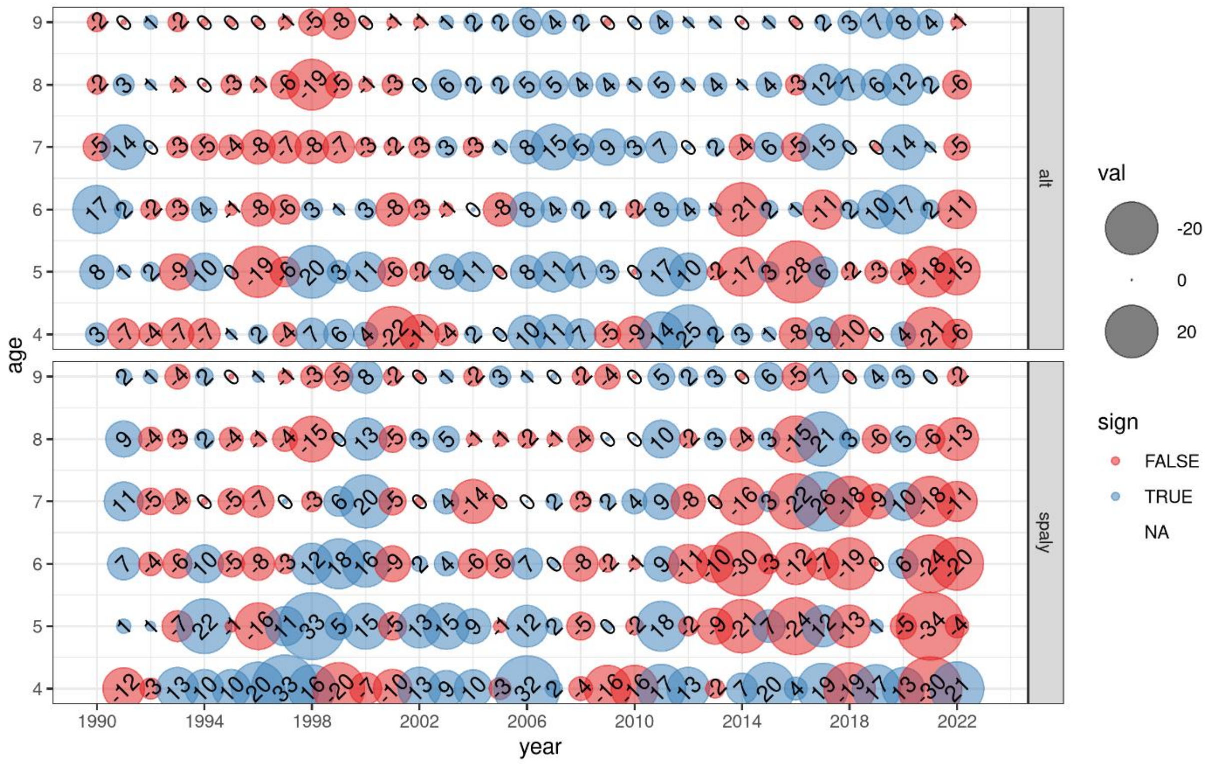

Figure 30: Icelandic cod. Residuals of the two catch prediction models, the one currently used (spaly) versus an alternative with better predictive power (alt). Numbers indicate the equivalence of biomass in thousand tonnes.

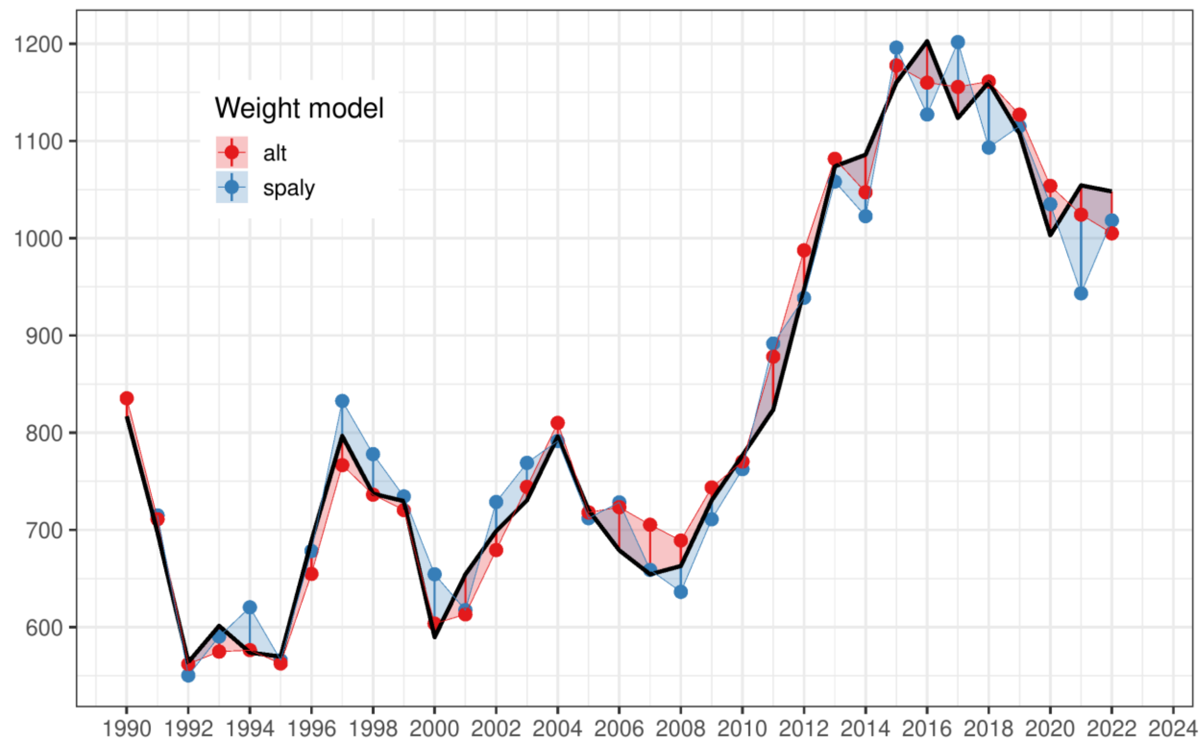

Figure 31: Icelandic cod. Comparison of the reference biomass using the two catch prediction models, the one currently used (spaly) versus an alternative with better predictive power (alt).

MANAGEMENT

The Ministry of Food, Agriculture and Fisheries is responsible for management of the Icelandic fisheries and implementation of legislation. Scientific advice on fisheries is provided by the Marine and Freshwater Research Institute and ICES. Cod was included in the ITQ system in 1984, but effort management was also implemented during the first years of the TAC system, partly to help those that thought they got unfair share of the quota. This "additional effort" management system led to catches exceeding TAC by 20-30% in the first years of the ITQ system.

In 1990 the law was changed, and effort management was eliminated except for the smallest coastal fleet that was managed by fishing days. At the same time, many limitations of the quota transfer were released and the fishing year from 1 September to 31 August was introduced. These laws took effect on 1 September 1991. In the first years, advice by MRI (Marine Research Institute) was based on reducing F (Fishing mortality) by 40%. TAC exceeded advice during those years and catch exceeded TAC.

The cod stock reduced rapidly in the early nineties due to low recruitment and high fishing mortality. The need for more strict control of fisheries was apparent and 2-3 years of work by a group of fisheries scientists lead to an adoption of HCR (Harvest Control Rule) for the fishing year 1995/96. The HCR led to significant reduction in fishing mortality.

Since the HCR was introduced, TAC has been set according to the HCR, but catch has exceeded TAC by 7.4% on average, however somewhat less or close to 5% in recent years. The main explanation for catch exceeding advice is that catch in the effort control system exceeded predictions, but the predicted catch is subtracted from the calculated TAC according to the HCR. The current effort control system for the small boats that started in 2009, includes TAC constraint so catches should not exceed TAC by large amount (1-2%).

Advice is based on an advice rule for the next fishing year (starting 1. September in the assessment year and ending on 31. August next year) in which 20% of the reference biomass of four years and older in the assessment year (B_{4+}) takes half the weight in calculation, and last year's advice takes the other half in weight (I.e., it includes a “catch stabilizer”).

$$TAC_{y/y+1} = \left(0.20 * B_{4+,y} + TAC_{y-1/y}\right)/2$$

T In addition, when the SSB in the assessment year is estimated to be above SSB_trigger (220 000) the decision rule is:

$$TAC_{y/y+1} = 0.2 * B_{4+,y} * SSB_y/220\,000$$

Quota transfers from other species to cod are not allowed and net transfers have been relatively low in recent years (Fig. 32). Net transfers of unused cod quotas from one fishing year to the next are usually below 7%.

Table 3. Icelandic cod. Advice, recommended TAC, National TAC set by the Ministry, and landings (tonnes).

FISHING YEAR	ICES ADVICE	REC. TAC	NATIONAL TAC	CATCH
1991/92	National advice	250000	265000	274000
1992/93	Reduce F by 40%	154000	205000	241000
1993/94	Reduce F by 40%	150000	165000	197000
1994/95	Reduce F by 50%	130000	155000	165000
1995/96	25% HCR	155000	155000	170000
1996/97	25% HCR	186000	186000	202000
1997/98	25% HCR	218000	218000	228000
1998/99	25% HCR	250000	250000	254000
1999/00	25% HCR	247000	250000	257000
2000/01	25% HCR	203000[1)]	220000[1)]	222000
2001/02	25% HCR	190000[1)]	190000[1)]	217000
2002/03	25% HCR	179000[1)]	179000[1)]	197000
2003/04	25% HCR	209000	209000	227000
2004/05	25% HCR	205000	205000	217000
2005/06	Reduce harvest rate	198000	198000	207000
2006/07	Reduce harvest rate	178000	193000	191000
2007/08	20% HCR	130000	130000	143000
2008/09	20% HCR	124000	160000[2)]	171000
2009/10	20% HCR	150000	155000[3)]	170000
2010/11	20% HCR	160000	160000	167000
2011/12	20% HCR	177000	177000	185000
2012/13	20% HCR	196000	195000	213000
2013/14	20% HCR	215000	214000	226000
2014/15	20% HCR	218000	216000	223000
2015/16	20% HCR	239000	239000	251000
2016/17	20% HCR	244000	244000	237644
2017/18	20% HCR	257572	257572	270217
2018/19	20% HCR	264437	264437	265385
2019/20	20% HCR	272411	272411	272385
2020/21	20% HCR	256593	256593	272137
2021/22	20% HCR	222373	222373	239925
2022/23	20% HCR	208846	208846	

1) Amended harvest control rule (HCR).
2) Initial TAC set to 130 000 according to the catch rule, raised to 160 000 in January 2009.
3) Set according to the catch rule.

Figure 32 shows the net transfers of cod quota in the Icelandic ITQ system. Quota transfers from other species to cod are not allowed, and net transfers from cod to other species have been relatively low in recent fishing years (Figure 32, upper). Net transfers of unused cod quota from one fishing year to the next have usually been in the range of 0-7%.

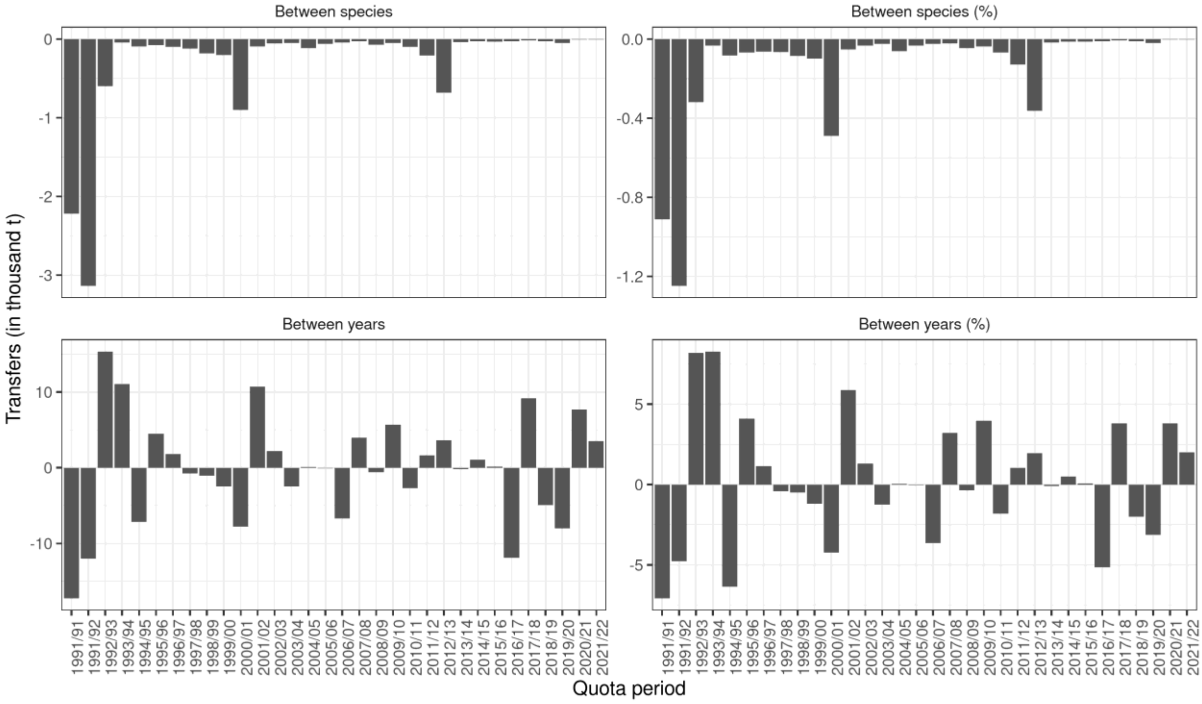

Figure 32. Icelandic cod. Net transfers of quota to and from cod in the Icelandic ITQ system by quota year. Between species (upper): Positive values indicate a transfer of other species to cod (not allowed), but negative values indicate a transfer of cod quota to other species. Between years (lower): Net transfer of quota for a given quota year.

MANAGEMENT CONSIDERATIONS

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

REFERENCES

ICES 2021. Workshop on the re-evaluation of management plan for the Icelandic cod stock (WKICE-COD). ICES Scientific Reports, 3:30. https://doi.org/10.17895/ices.pub.7987.

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