COD – ÞORSKUR
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 has not much of preference regarding bottom structure and can be found on various substrates, however 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 of the island. Spawning starts early in the spring (March-April) on main spawning grounds in the warmer waters in the south. Spawning used to start 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.

THE FISHERY

Due to wide spatial distribution of cod in Icelandic waters, the fishing grounds are scattered around the shelf and partially divided by gear type (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 is the second most important gear type 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). All cod fishing grounds are illustrated accordingly to registrations in mandatory logbooks for the years 2001-2019.

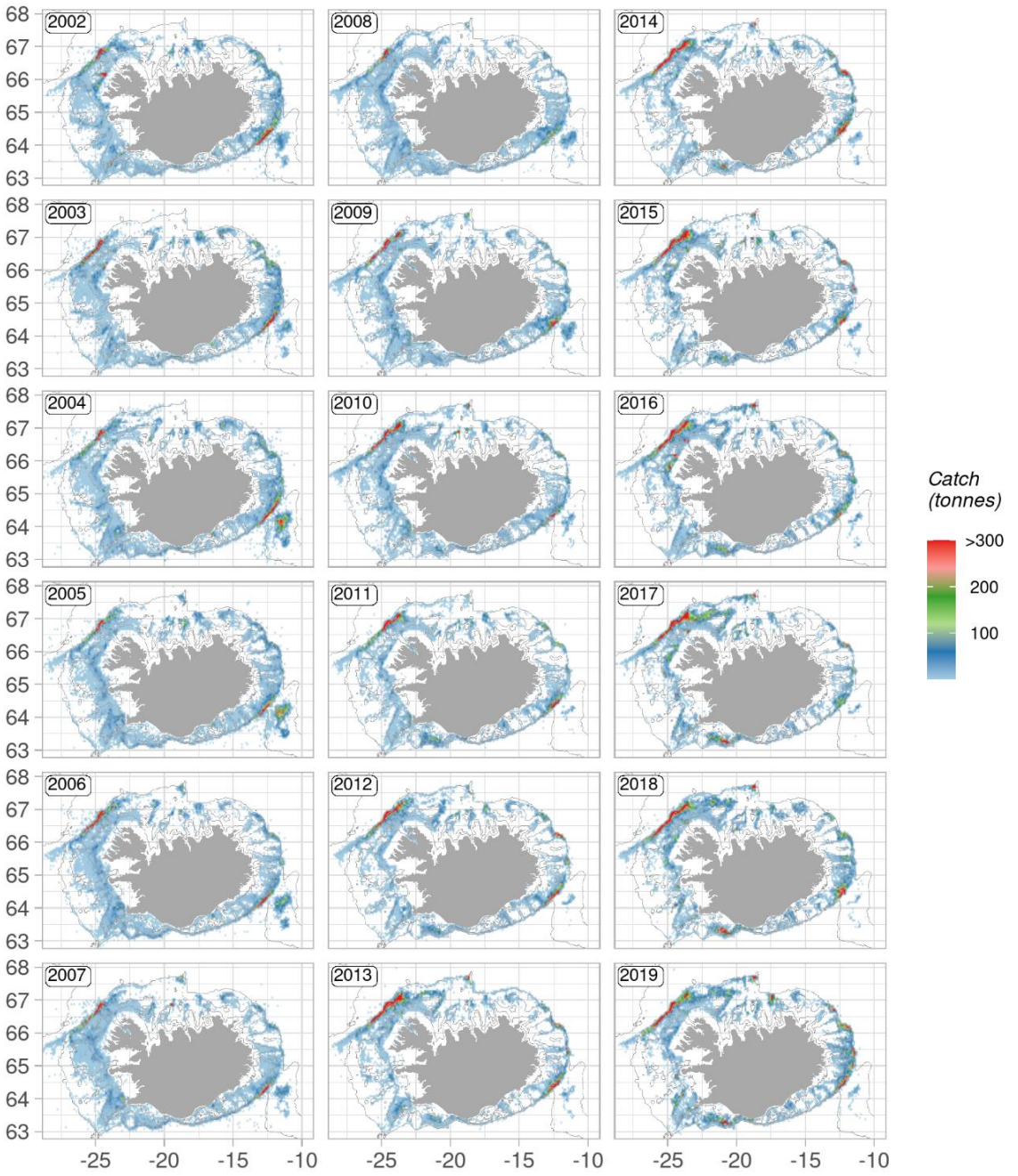

Figure 1. Cod. Geographical distribution of the Icelandic demersal trawl fishery since 2002. Reported catch from logbooks. The 100, 200, and 500 m isobaths are shown.

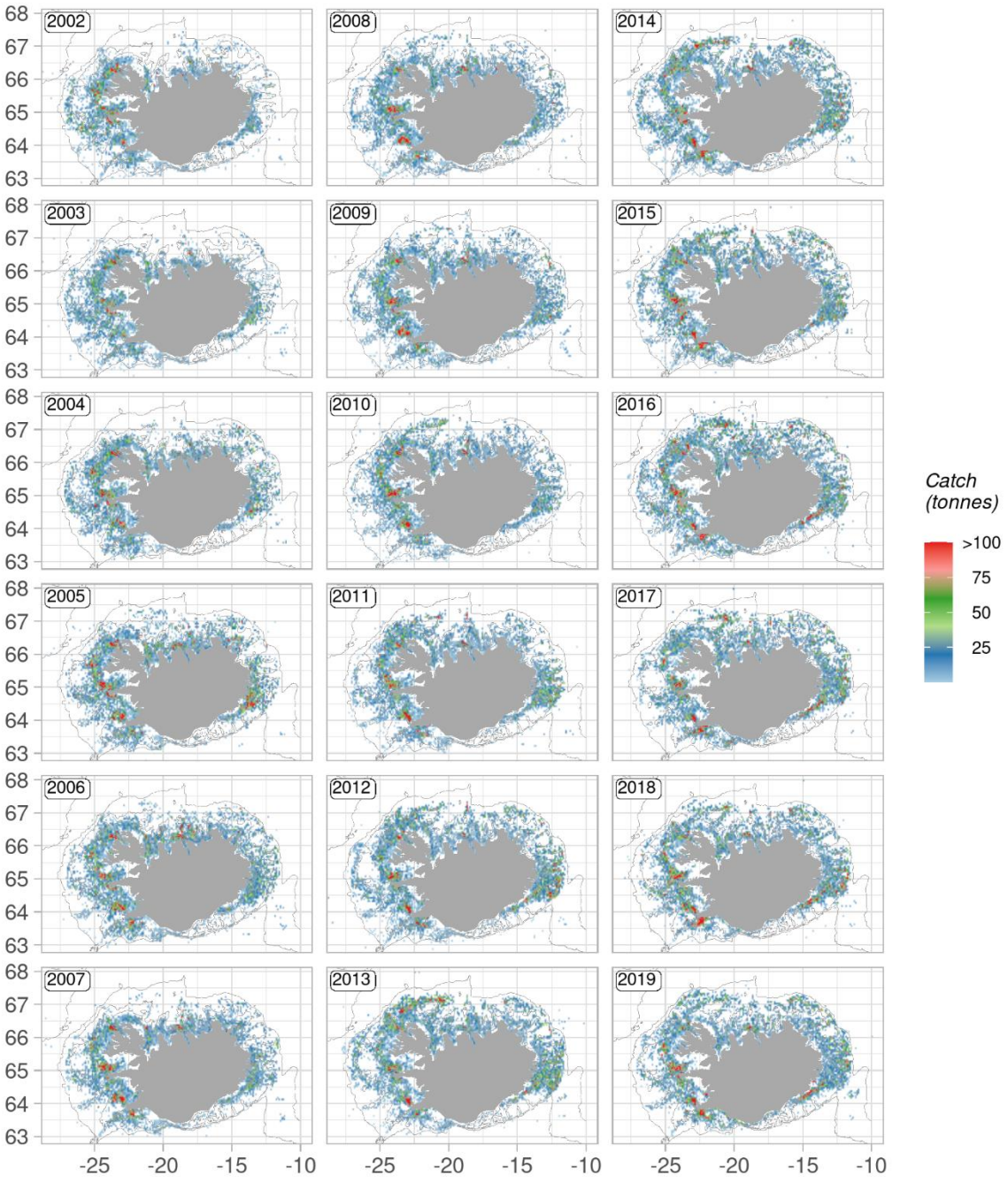

Figure 2. Cod. Geographical distribution of the Icelandic longline fisheries since 2002. Reported catch from logbooks. The 100, 200, and 500 m isobaths are shown.

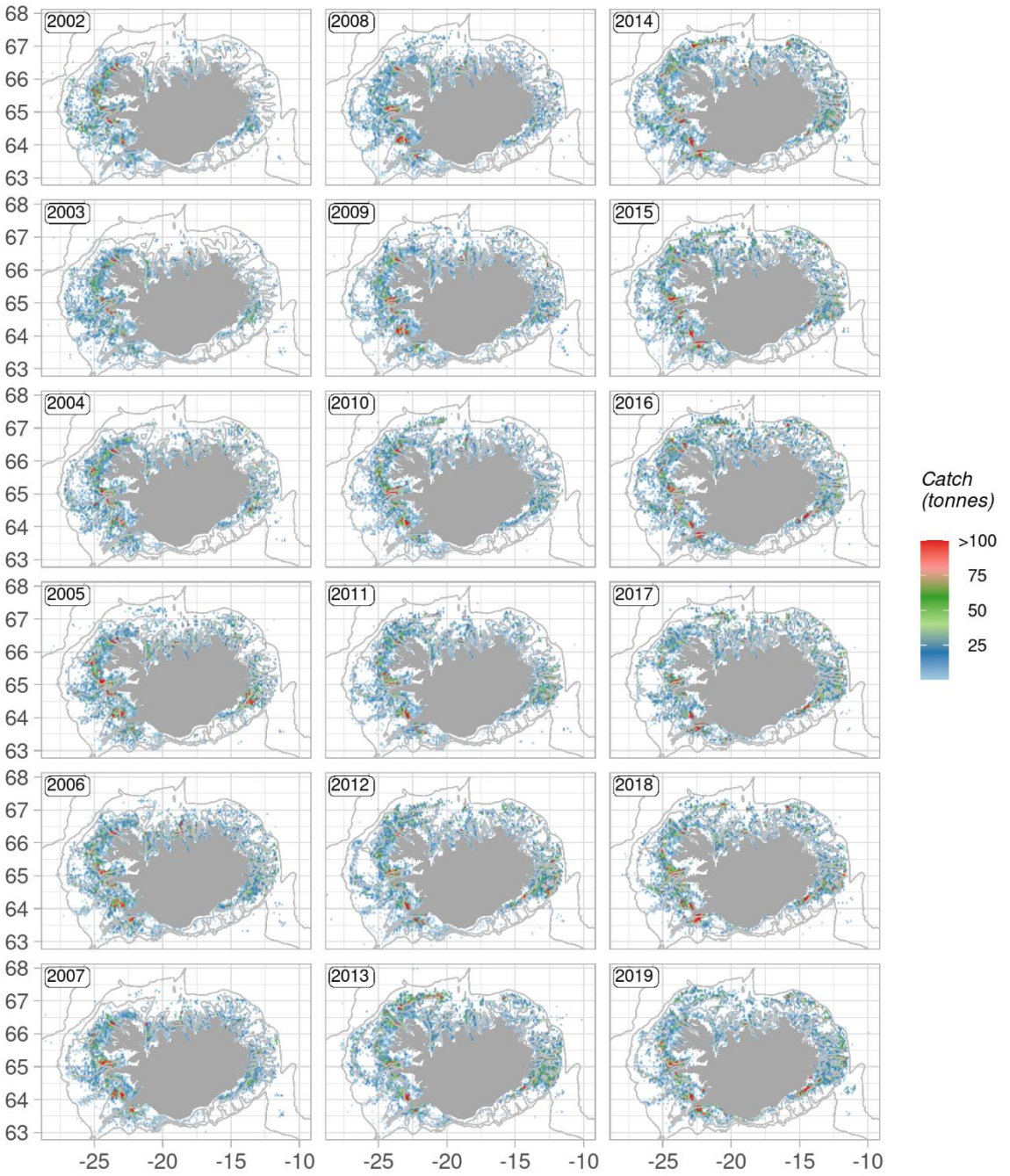

Figure 3. Geographical distribution of the Icelandic cod fisheries from gillnets, demersal seine and jiggers since 2002. Reported catch from logbooks. The 100, 200, and 500 m isobaths are shown.

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 15-18% 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. 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 catch large amount of cod in short time, e.g. just before landing. Condition and size of cod in different areas is also an issue regarding fishing areas, but all those factors have to be weighed against proximity to landing harbour.

In 2019, half of the cod catch was taken in bottom trawl, almost one third on longlines, 7% by gillnets, 5% by jiggers, and 5.5% by demersal seine. Around 57% of the last years catch was taken in the western and northwestern area, 12% in the SW and 31% in the southern area (NE and SE). Cod was caught in deeper waters in 2019 compared with previous years.

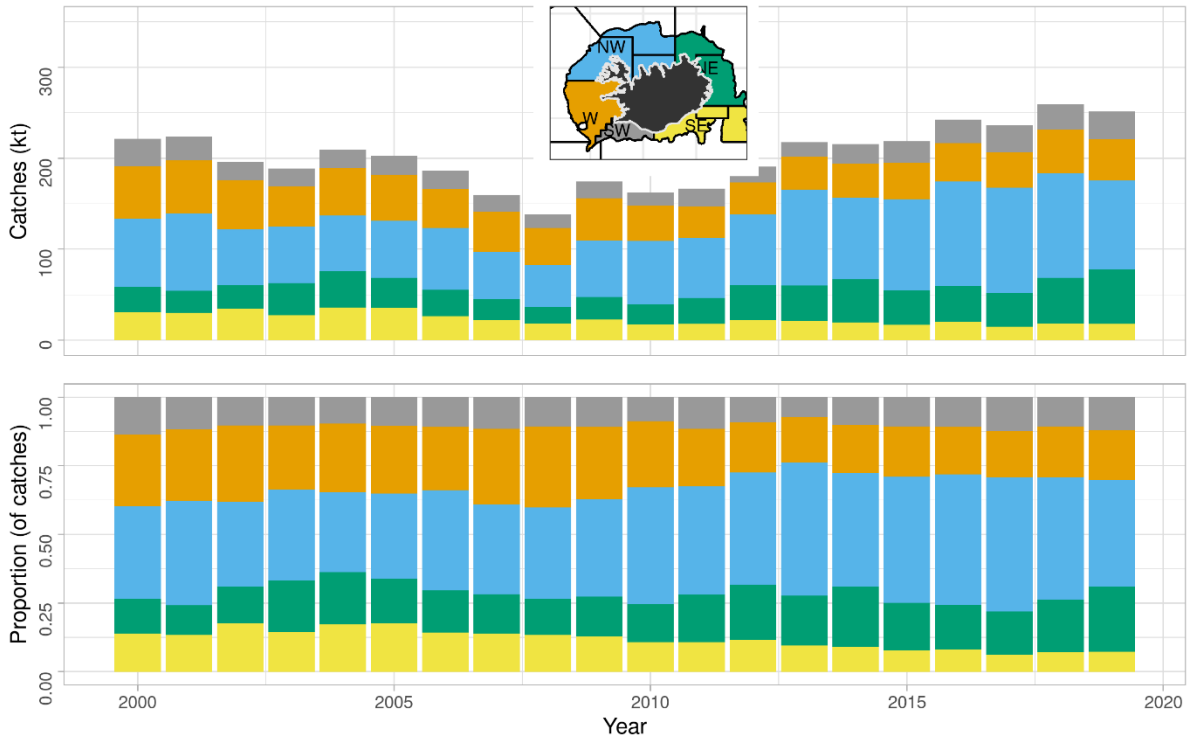

Figure 4. Cod. Spatial distribution of the Icelandic fishery by fishing area since 2000 according to logbooks. All gears combined.

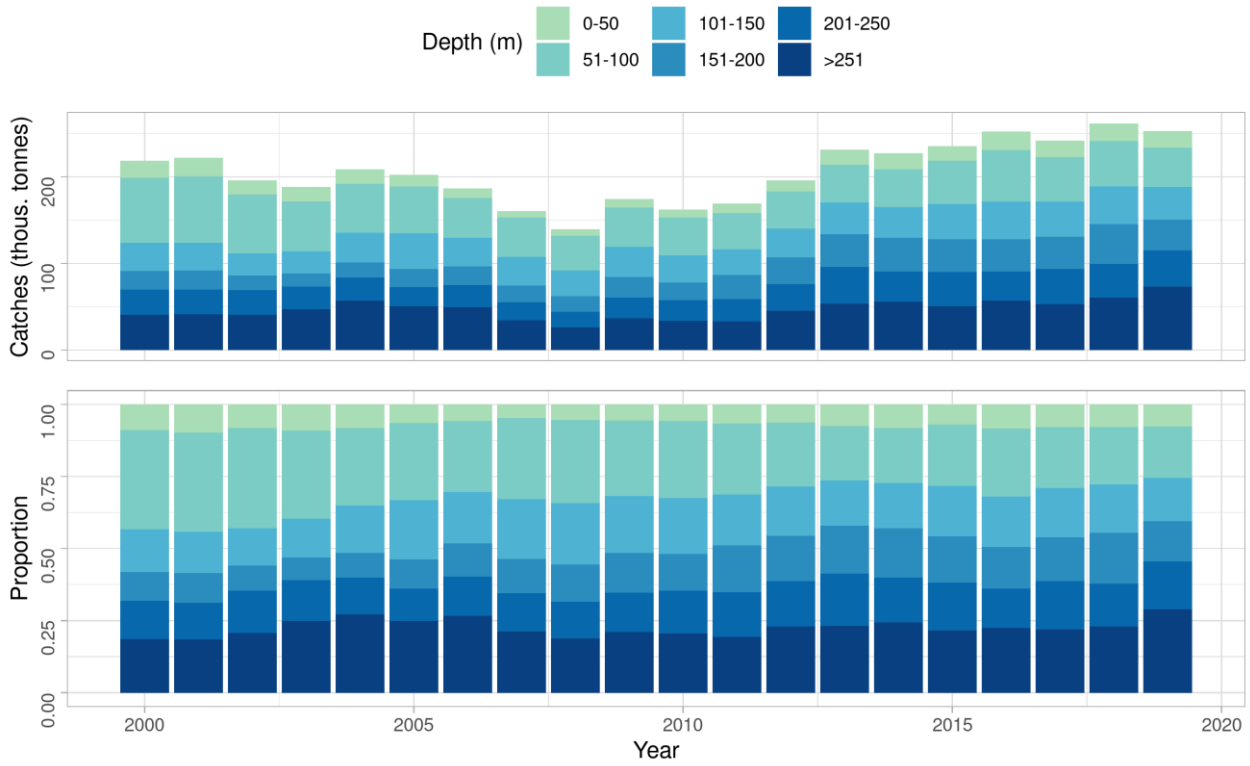

Figure 5. Cod. Depth distribution of catches since 2000 according to logbooks.

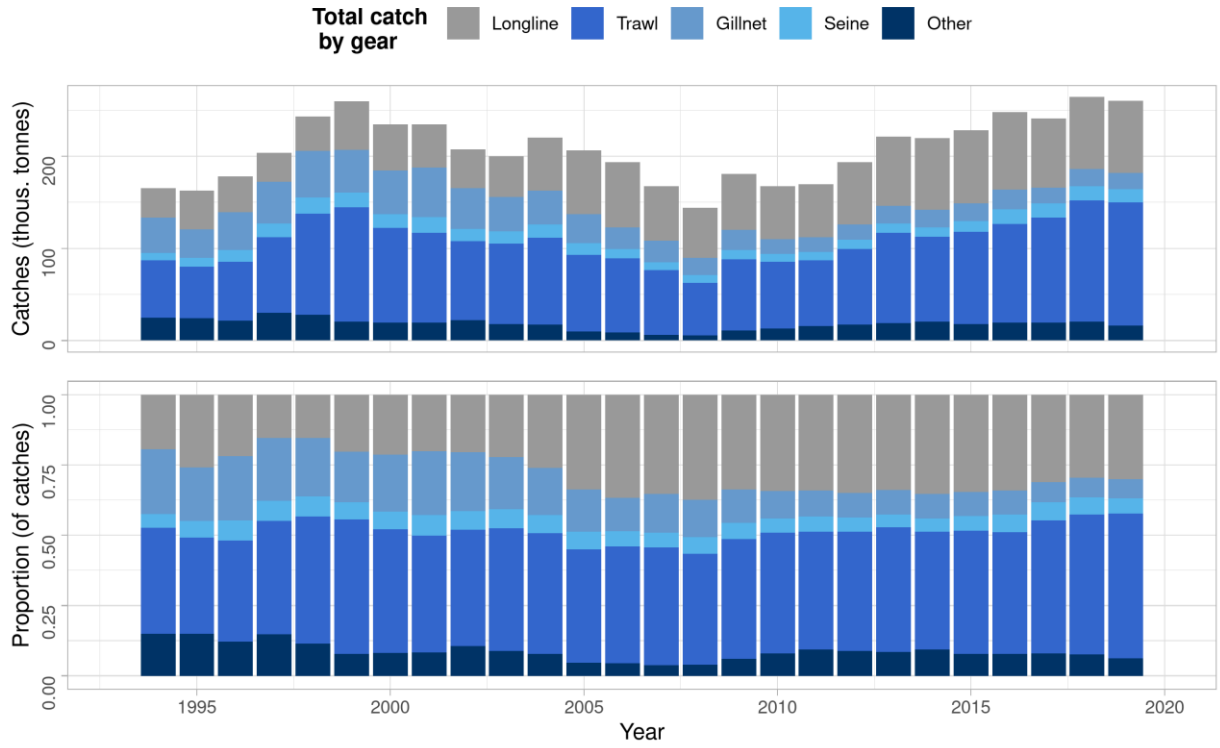

Figure 6. Cod. Total catch (landings) by fishing gear since 1994, according to statistics from the Directorate of Fisheries.

Since 1994, the number of vessels reporting catches 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 and last year's total catch was 260 thousand tonnes (Table 1).

Table 1. Cod Number of Icelandic vessels landing catch of 10 tonnes or more of cod, and all landed catch divided by gear type.

	NUMBER OF VESSELS					CATCHES (THOUS. TONNES)					
YEAR	*Long-liners*	*Gill-netters*	*Trawlers*	*Seiners*	*Other*	*Line*	*Gillnet*	*Trawl*	*Seine*	*Other*	***Sum***
1994	430	240	143	83	642	32	38	62	8	25	**165**
1995	427	193	140	93	653	42	31	55	10	24	**163**
1996	424	217	132	106	634	39	41	64	13	21	**178**
1997	345	200	130	108	714	31	46	81	14	30	**203**
1998	371	244	136	106	687	37	51	108	18	28	**242**
1999	400	241	137	96	602	53	47	123	16	20	**259**
2000	381	258	119	86	568	50	48	102	15	19	**234**
2001	375	325	109	87	546	47	54	97	17	19	**234**
2002	333	284	97	85	537	42	44	86	25	11	**208**
2003	341	237	99	81	482	45	37	87	13	18	**200**
2004	343	231	99	83	488	57	37	94	14	18	**220**
2005	350	187	97	77	321	69	32	83	13	9	**206**
2006	317	138	89	72	258	71	23	80	10	9	**193**
2007	273	116	89	63	185	59	23	70	9	6	**167**
2008	237	89	79	59	169	54	19	57	8	6	**144**
2009	221	90	80	63	333	61	22	77	10	11	**181**
2010	209	80	72	52	388	57	17	72	8	13	**167**
2011	202	77	70	49	565	58	16	71	9	16	**170**
2012	208	76	74	50	592	68	17	82	10	17	**194**
2013	215	78	75	50	616	45	20	98	10	19	**222**
2014	218	71	67	43	645	78	19	92	10	20	**220**
2015	204	76	64	45	599	79	19	100	12	18	**228**
2016	191	70	65	44	625	84	21	107	16	19	**248**
2017	176	63	65	44	613	57	17	114	15	37	**241**
2018	146	64	65	42	571	78	19	132	16	39	**264**
2019	139	53	61	39	553	78	18	134	14	16	**260**

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 400-600, but at the same time annual catches have increased by 80 thousand tonnes (Figure 7).

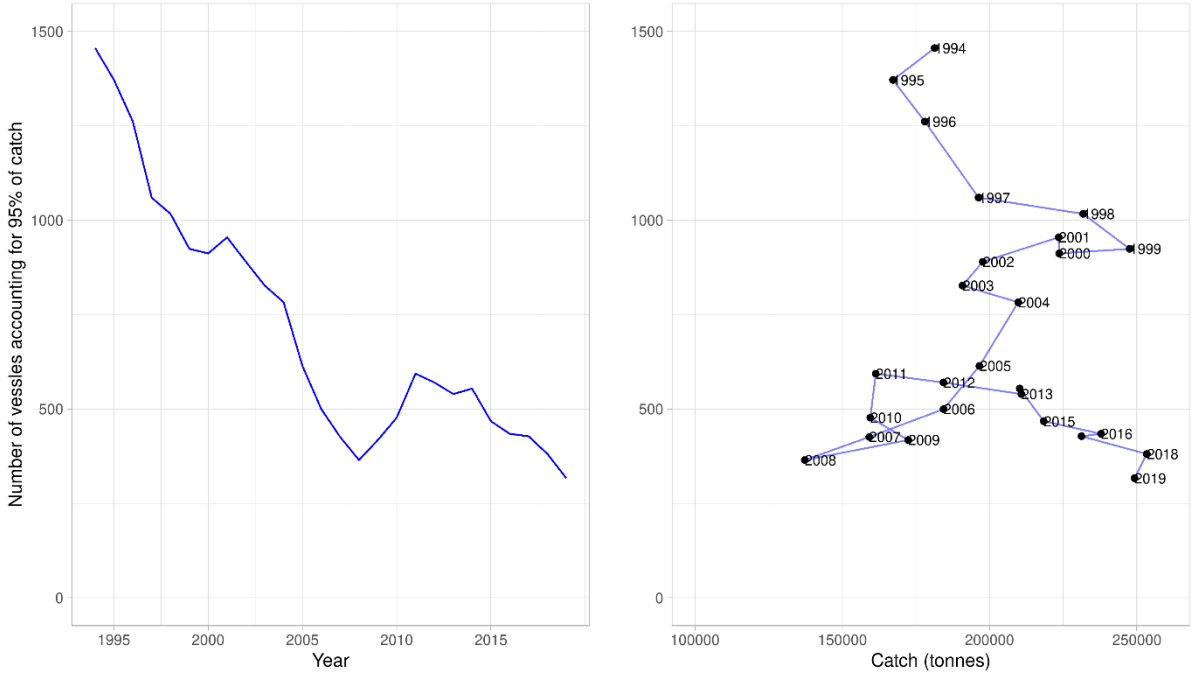

Figure 7. Cod. Number of vessels (all gear types) accounting for 95% of the total catch annually since 1994. Left: Plotted against year. Right: Plotted against total catch. Data from the Directorate of Fisheries.

CATCH PER UNIT EFFORT (CPUE) AND EFFORT.

CPUE estimates of cod in Icelandic waters are not considered representative of stock abundance as changes in fleet composition and technical improvements among other things have not been accounted for when estimating CPUE.

Non-standardized estimates of CPUE of demersal trawl (kg/hour) in hauls where cod is more than 10% of the catch, increased considerably since the lowest CPUE in 2008 with 500 kg/hour to the highest with approximately 1300 kg/hour in 2017 (Figure 8, left). In the last two years, the CPUE has declined slightly and was 1250 kg/hour in 2019.

CPUE in longline (kg/1000 hooks), is calculated as the total weight in sets in which cod was more than 10% of the catch. According to logbooks, cod CPUE remained quite stable since 2000 with slightly under 250 kg of cod on average per 1000 hooks. However, since 2012 CPUE has increased slightly and was just above 260 kg/1000 hooks last year.

Total fishing effort (number of towing hours where cod was more than 10% of the total catch) for cod in demersal trawl has gradually decreased since 2000 and has fluctuated around 100 thous. tow-hours (Figure 8). Fishing effort in longline increased rapidly between 2003 and 2006 from approximately 120 million hooks in 2003 to 350 million hooks in 2006. Since then the effort has decreased and was around 260 million hooks in 2019 (Figure 7).

Figure 8. Cod. Non-standardised estimates of CPUE (left) from demersal trawl (kg/h) and longline (kg/1000 hooks). Fishing effort (right) for demersal trawl (tow-hours) and longline (1000 hooks).

AGE DISTRIBUTION OF LANDED COD

Table 2 shows the number of otoliths samples and number of age reading in 2010-2019 divided by gear type and Figure 9 shows the location of otoliths sampling in 2019.

Table 2. Cod. Number of samples and aged otoliths from landed catch.

	DEMERSAL TRAWL		LONGLINE		GILLNET		DEMERSAL SEINE	
YEAR	*Samples*	*Otoliths*	*Samples*	*Otoliths*	*Samples*	*Otoliths*	*Samples*	*Otoliths*
2010	89	4395	58	2881	16	799	7	350
2011	84	4200	46	2294	14	700	10	500
2012	88	4400	56	2800	21	1031	10	582
2013	71	3550	59	2947	21	1050	7	329
2014	87	2667	58	1725	29	850	20	525
2015	112	3192	52	1453	35	875	28	700
2016	110	2915	60	1544	40	1000	41	1025
2017	84	2106	46	1119	26	644	39	975
2018	92	2369	39	945	16	400	30	750
2019	113	3671	50	1614	12	312	27	825

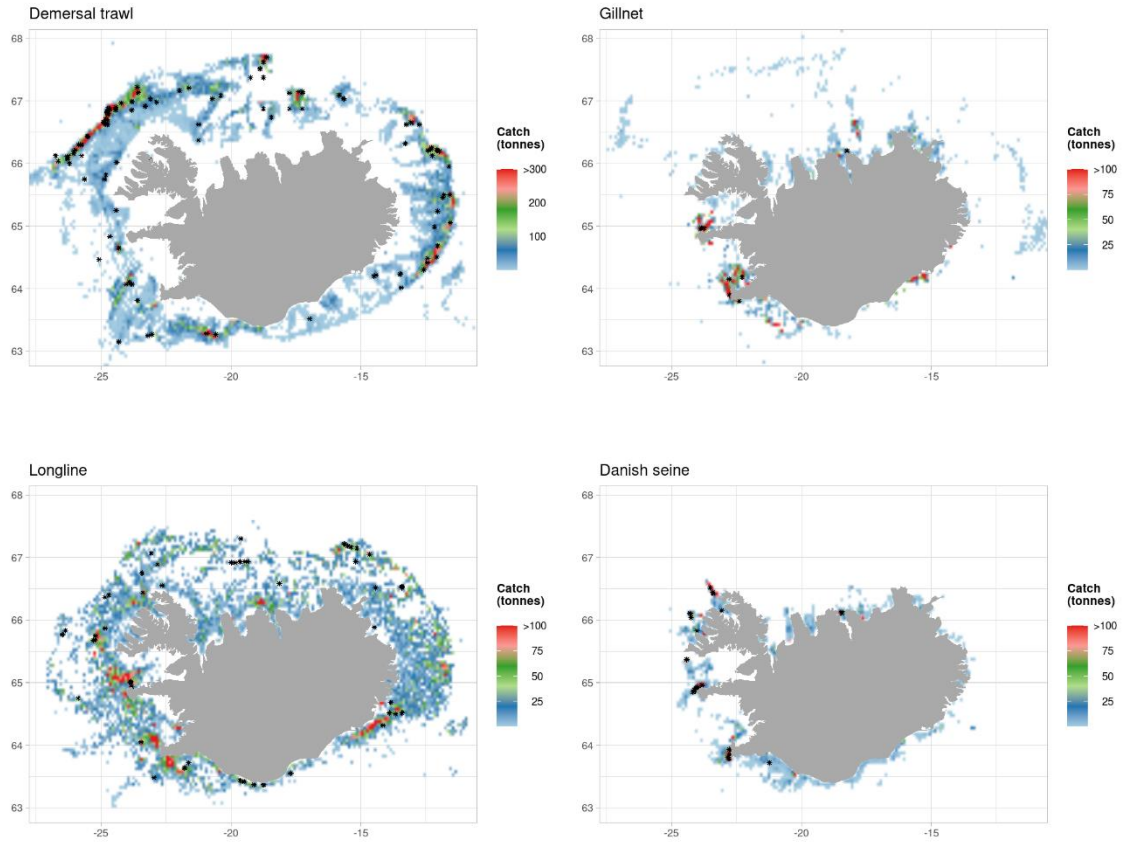

Figure 9. Cod. Fishing grounds in 2019 as reported in logbooks and positions of samples taken from landings divided by gear (asterisks).

The age composition of the catch has shifted from younger to older fish in the last few decades (Figure 10), likely as a result of decreasing fishing pressure. E.g. ages 8 years and older were approximately 31% of the landings (in weight) in 2010 while in 2018 it was 41%. A marked jump in 2019 is observed in the samples, with landings of age 10 years and older going from 13% in 2018 to 24% in 2019. It is unclear if this reflects the true catch composition in 2019 or because of some unknown bias in the samples taken from the catches.

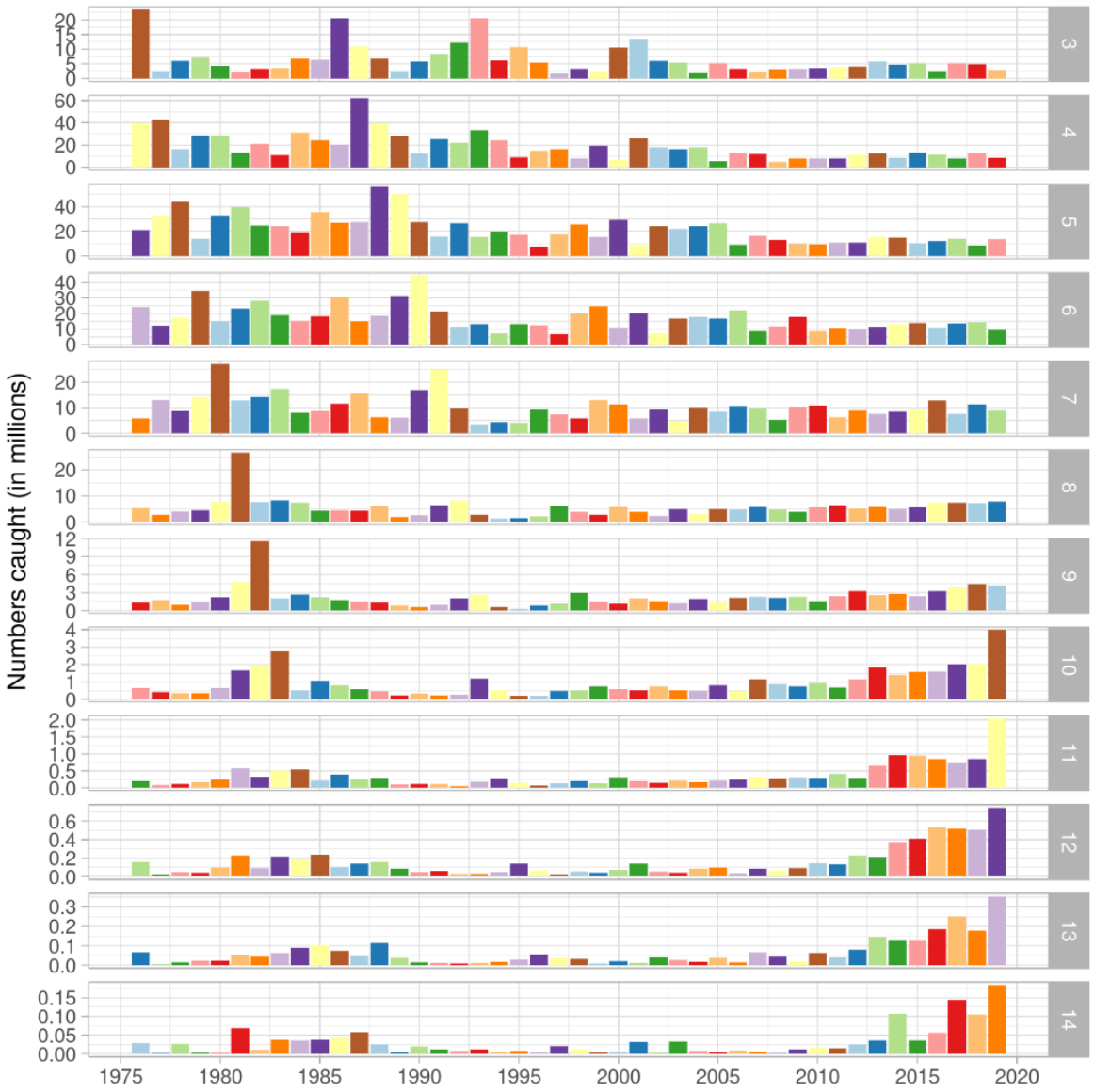

Figure 10. Cod. Estimated age distribution of landed catch based on landings and otoliths collected from landed catch (note different scales on the y-axes).

The mean weight age in the catch (Figure 11) declined from 2001 to 2007, reaching then a historical low in many age groups. The weight at age have been increasing in recent years and are in 2019 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 2020 is based on the relationship between spring survey and catch weights in 2019 and the survey weights at age from the 2020 spring survey. For ages older than age 10, the values from 2019 is used.

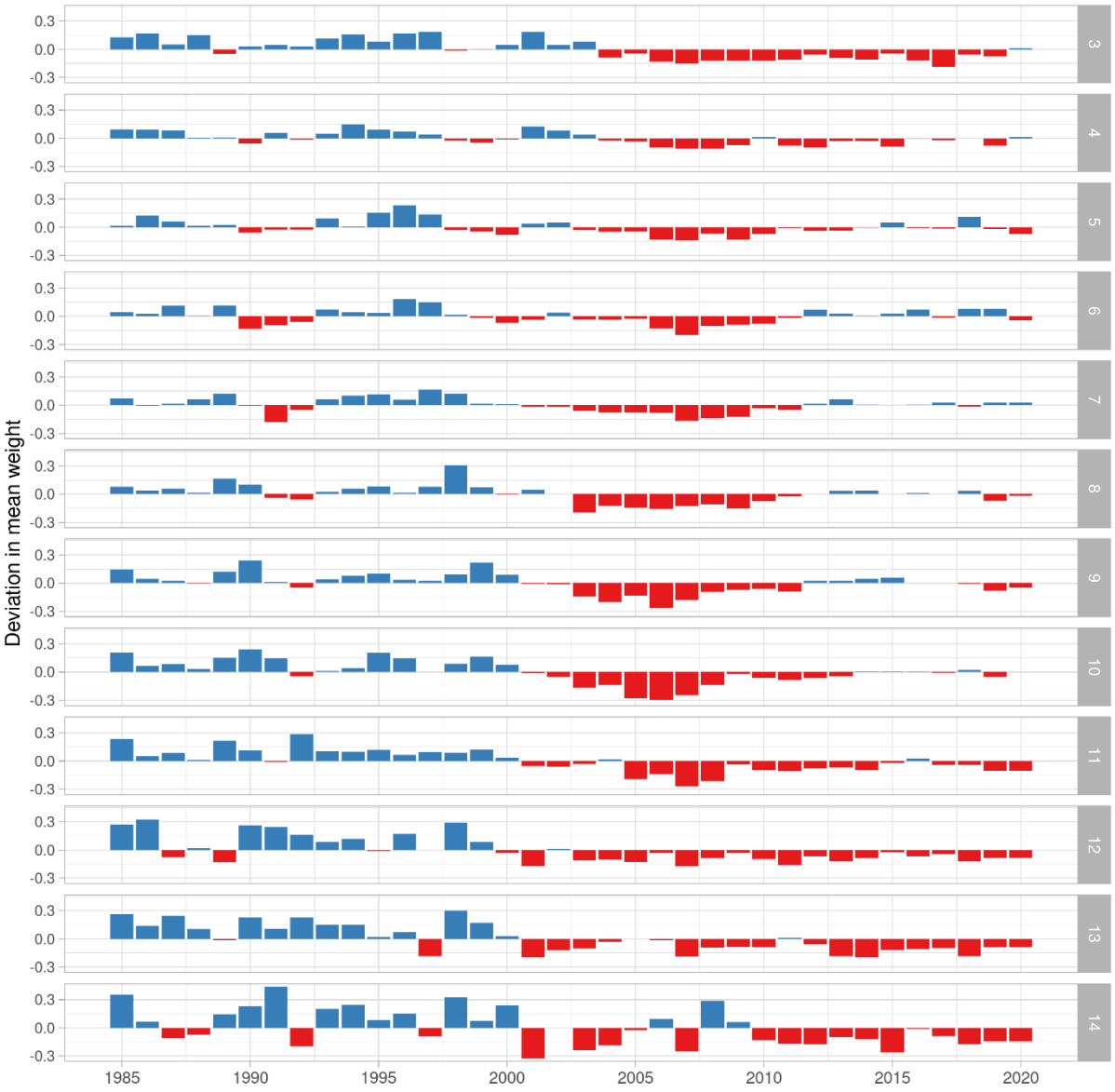

Figure 11. Cod. Deviation in weight at age (numbers of each panel indicate age classes) in the catches (blue: weight above the average 1985-2019, red: weight below average).

LENGTH DISTRIBUTION OF LANDED COD

The length distribution of landed catch has shifted towards larger cod in the last ten years (Figures 12-13). This change is observed for all the main gear, except jiggers (Figure 14).

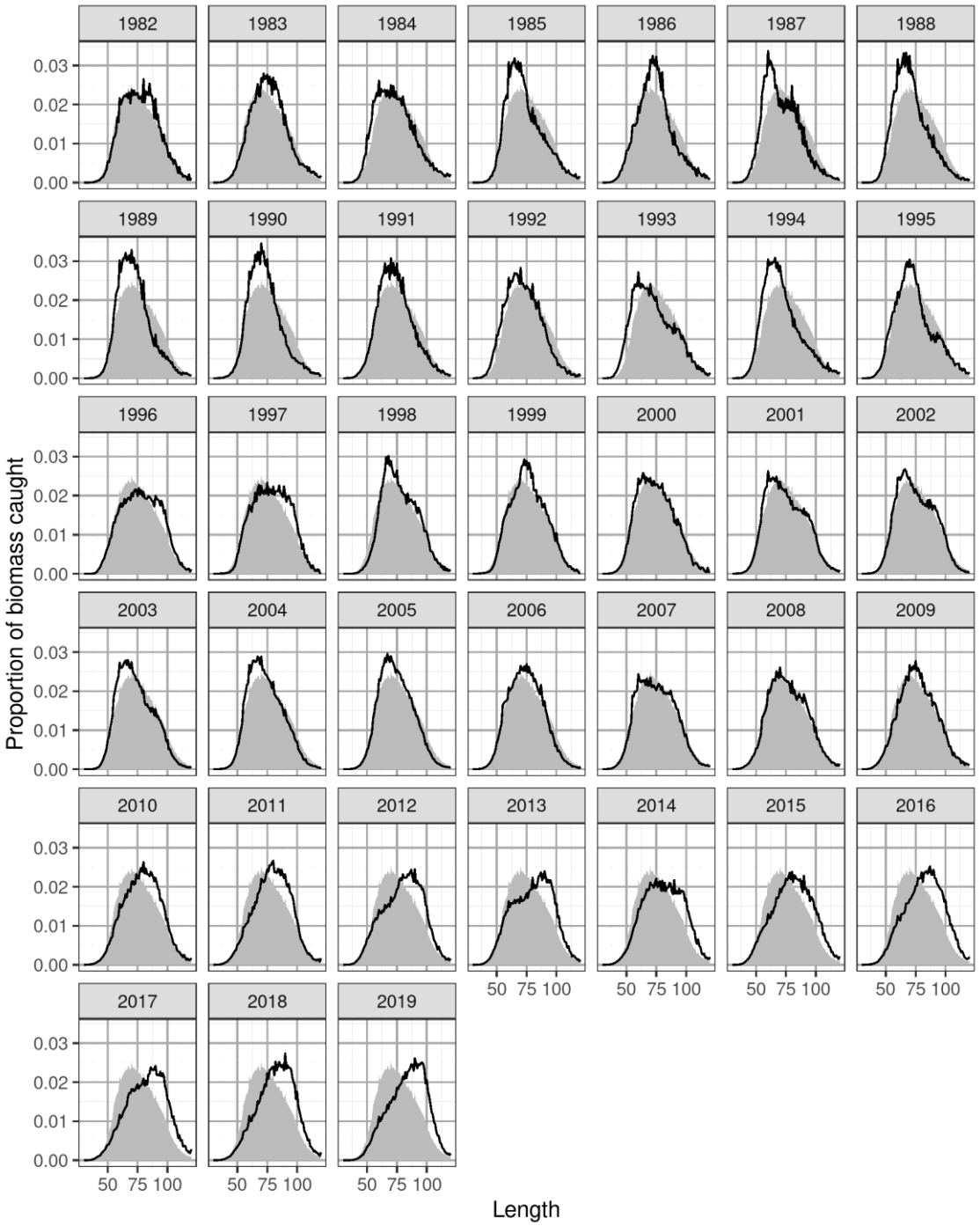

Figure 12. Cod. Length distribution from landed catch. The grey area represents the mean length distribution for all years.

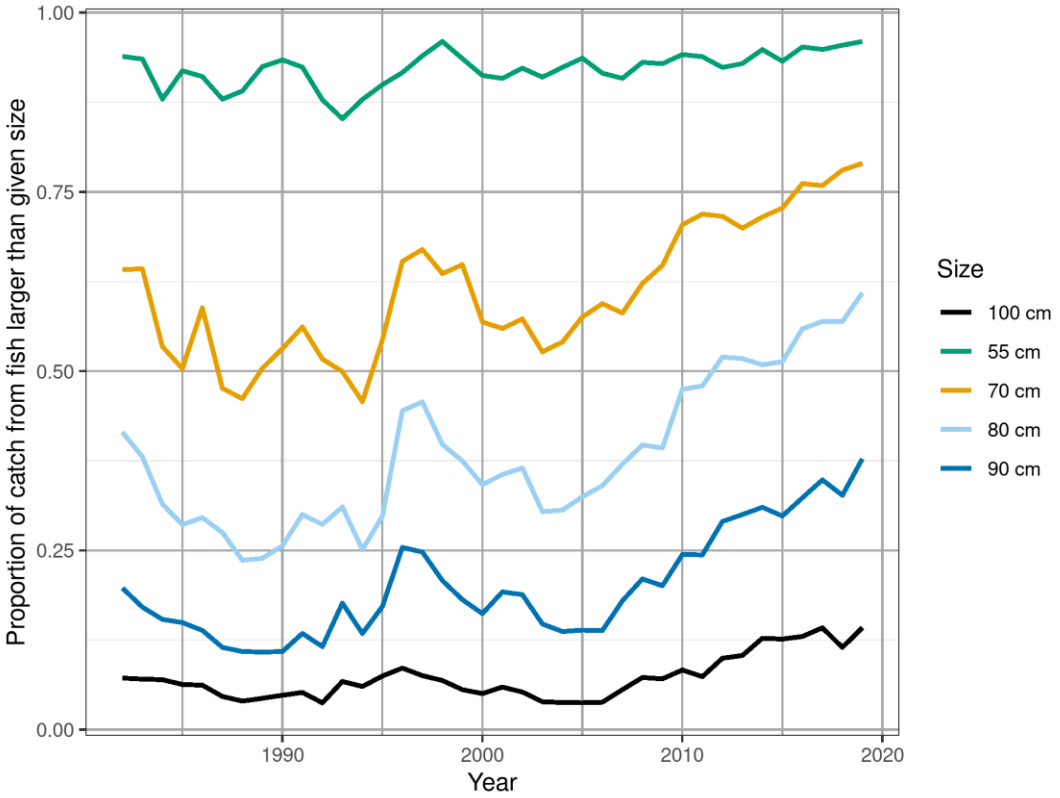

Figure 13. Cod. Proportion of the commercial catch (by weight) from fish larger than a given size (cm).

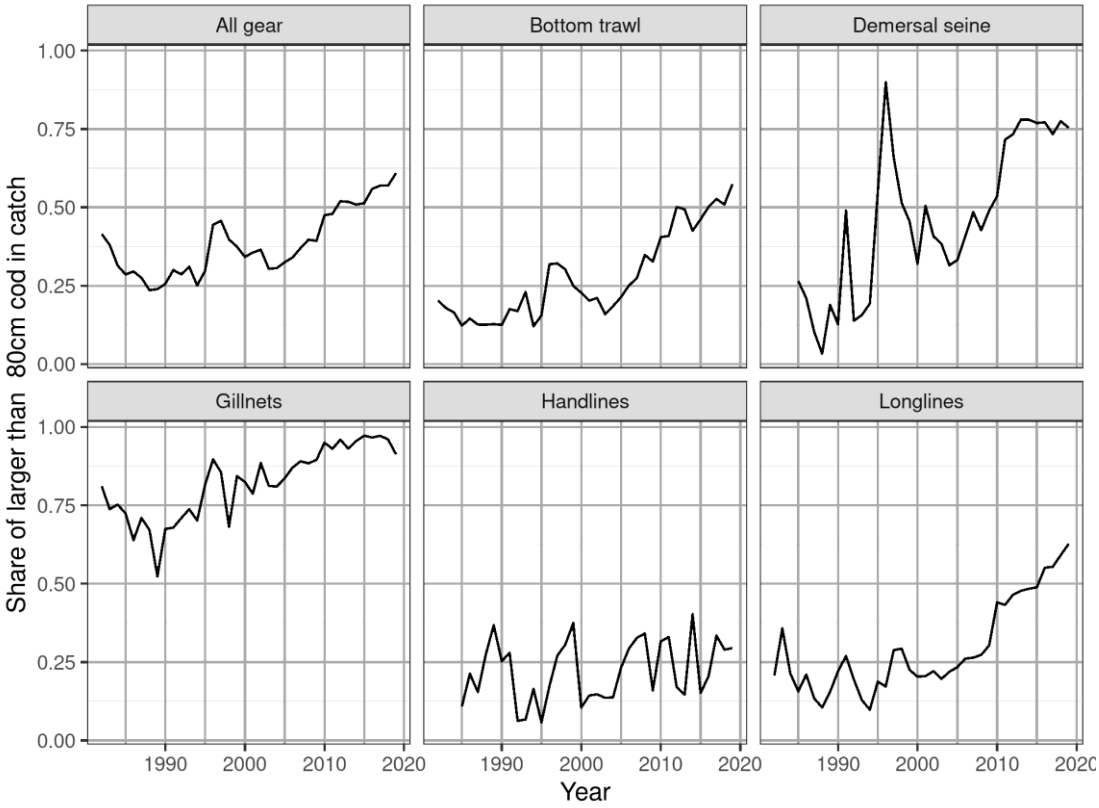

Figure 14. Cod. Proportion of fish larger than 80 cm in the catches (by weight) taken by different gear types.

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 length-disaggregated abundance indices are shown in Figures 16-17, abundance and changes in spatial distribution in Figures 18-21.

The total biomass index in the spring survey has decreased by approximately 46% in the last four years (Figure 15). A decline is also observed in the autumn survey biomass index in the last three years although the measurements between years are within the statistical confidence estimates.

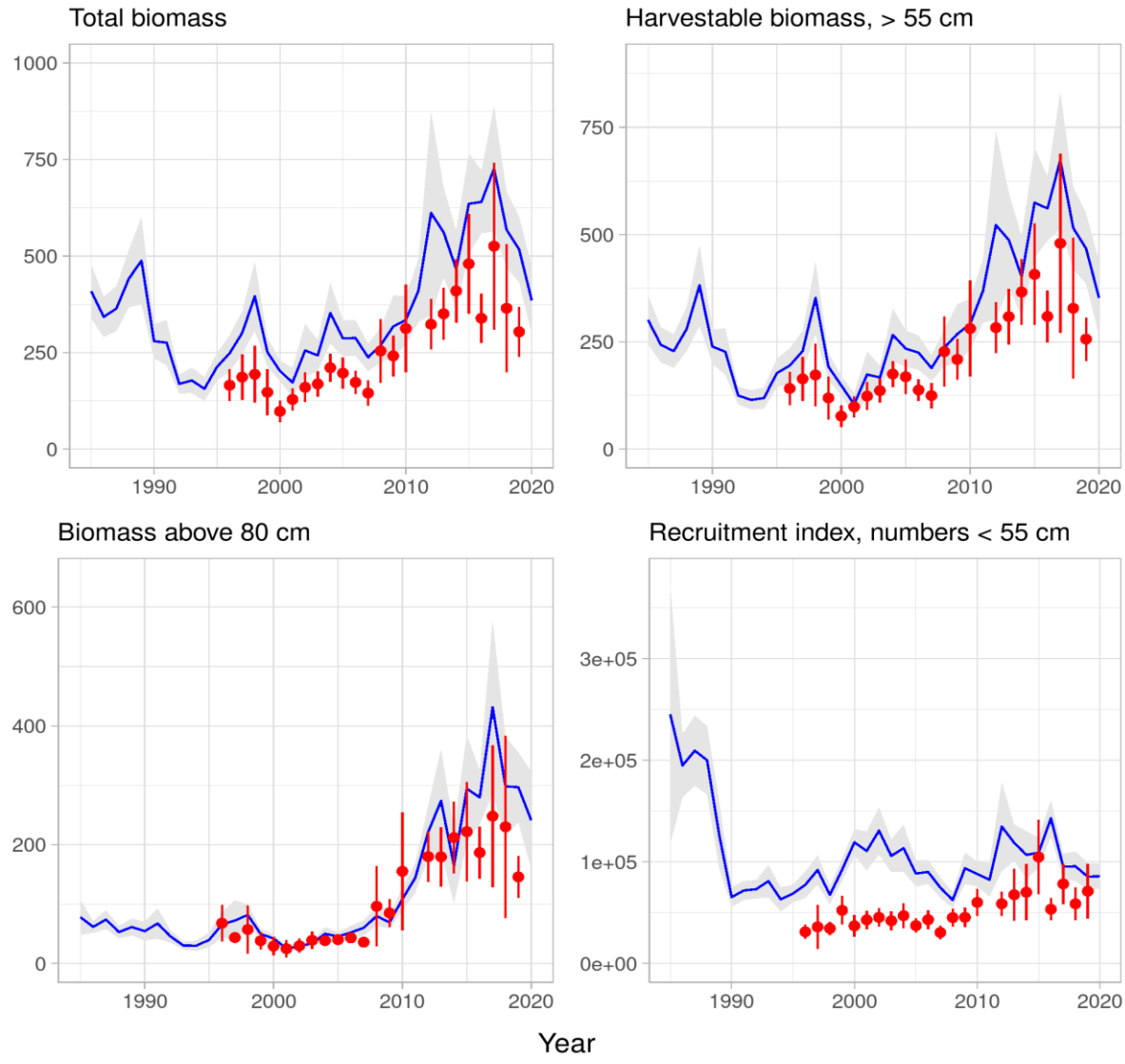

Figure 15. Cod. Total biomass indices (upper left) and harvestable biomass indices (≥55 cm) (upper, right), biomass indices of larger ind. (≥80 cm) (lower left) and juvenile abundance indices (≤55 cm) (lower right) from the spring survey (blue) from 1985 and autumn survey (red) from 1996, along with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

Cod in the spring survey in 2020 was caught all around Iceland, with catch hotspots in offshore waters in the north and east, and in shallow waters in the south (Figure 16). The catch on continental slope to the west was similar to the previous year. Spatial distribution of the total biomass index of the catch in the spring survey, shows that the NW and NE areas are dominating in the all 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 area. In 2020 there was decrease in almost all areas except for SE.

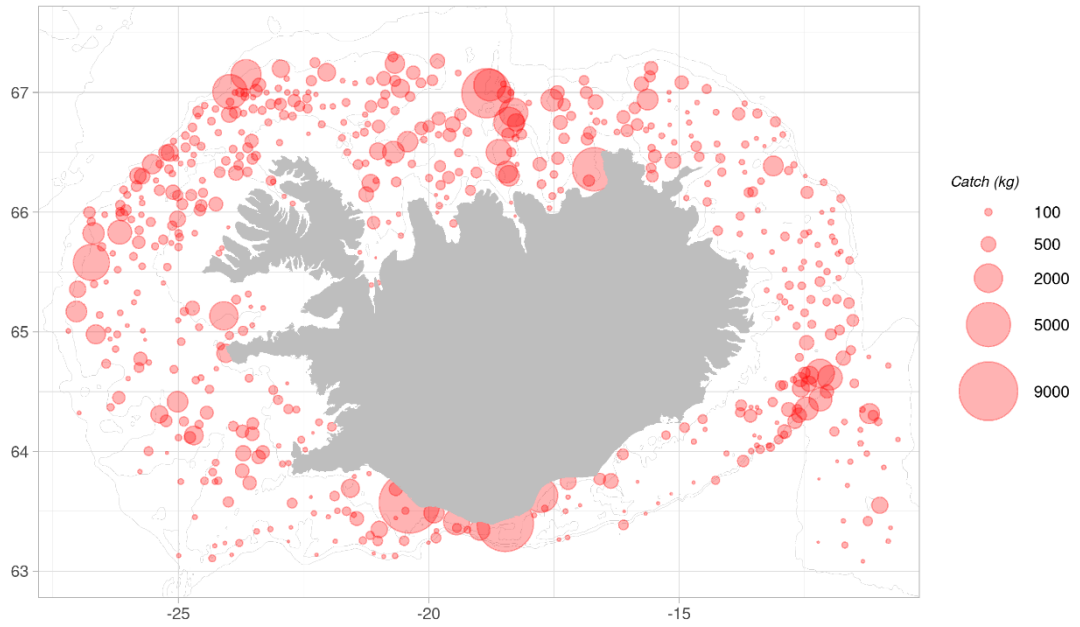

Figure 16. Cod. Spatial distribution in the spring survey 2020. The 100, 300 and 500 m isobaths are shown.

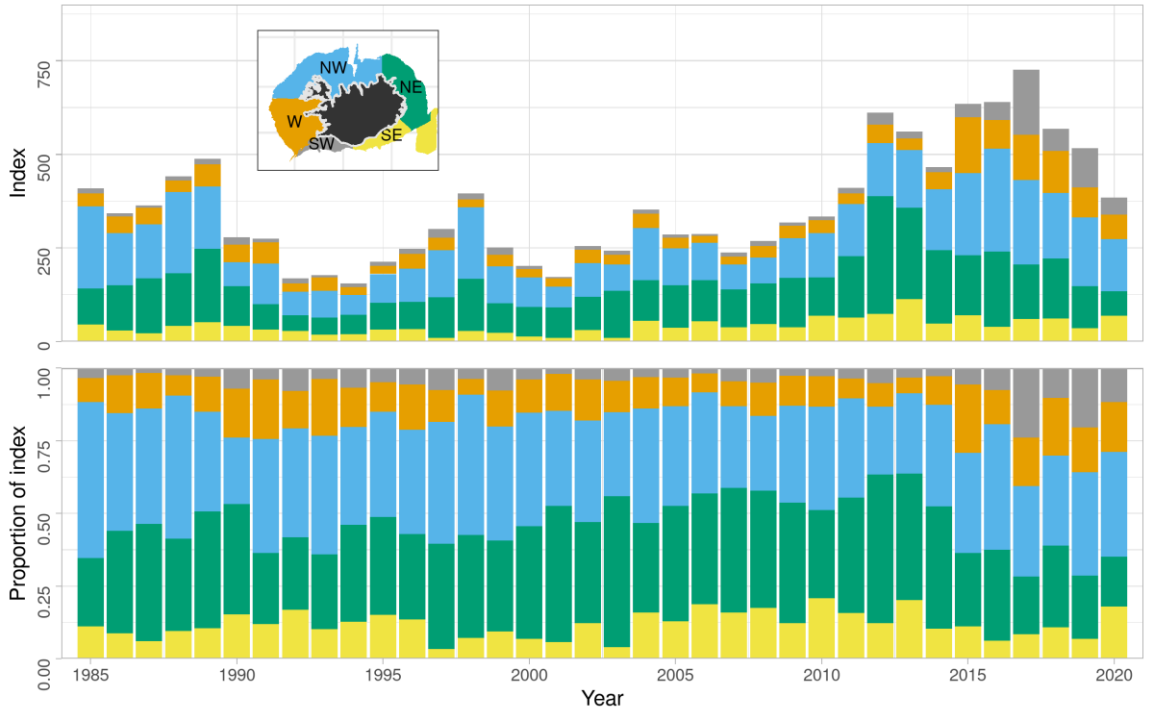

Figure 17. Cod. Spatial distribution of biomass index in the spring survey.

Spatial distribution of cod in autumn survey in 2019 was somewhat similar as in previous years, however the main hotspots were found in the north of Iceland (Figure 18). The majority of cod in the autumn survey has been caught on the traditional fishing grounds in the northwest and northeast. There has been an increase in the abundance of cod on both the NW and NE areas in the past decade (Figure 19).

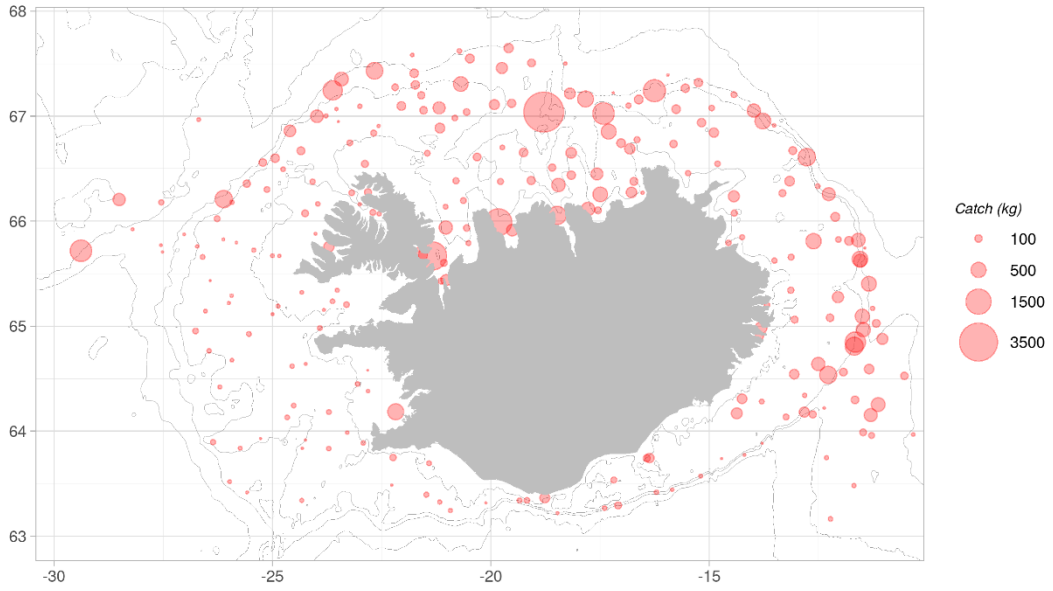

Figure 18. Cod. Spatial distribution of cod in the autumn survey 2019. The 100, 300 and 500 m isobaths are shown.

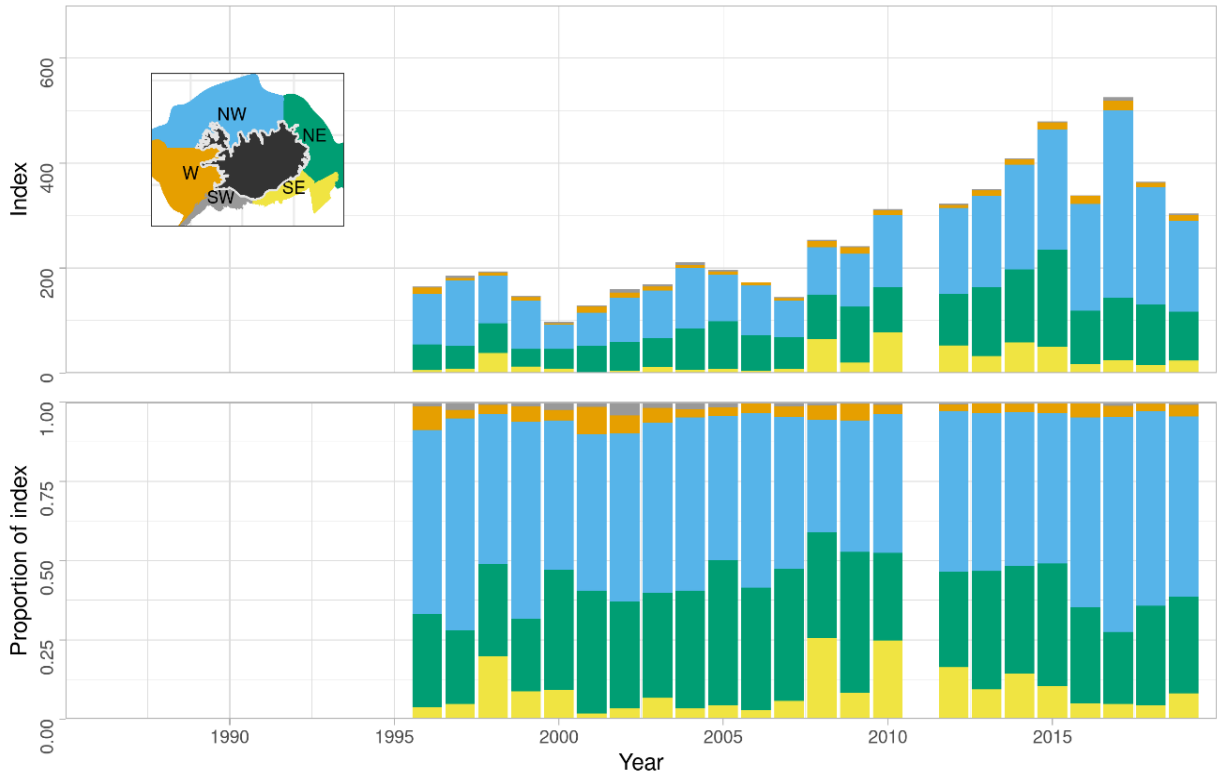

Figure 19. Cod. Spatial distribution of biomass index in the autumn survey.

Length distributions from both surveys illustrate quite clearly age groups division in the youngest age groups (Figures 16-17). Thereafter the division is not quite as clear, due to variability in individual growth and maturity, but some multimodal length distribution can be seen.

The 2020 spring survey measurement indicates that the abundance in 2020 is below average for cod 35-90 cm (Figure 16). Although abundance of the 2016 year class (approximately 50 cm mean length in year 2020) was expected to be low and although year effects in survey measurements are known, the 2020 survey measurements are substantially below expectations for size classes that constitute the bulk of the fishable biomass.

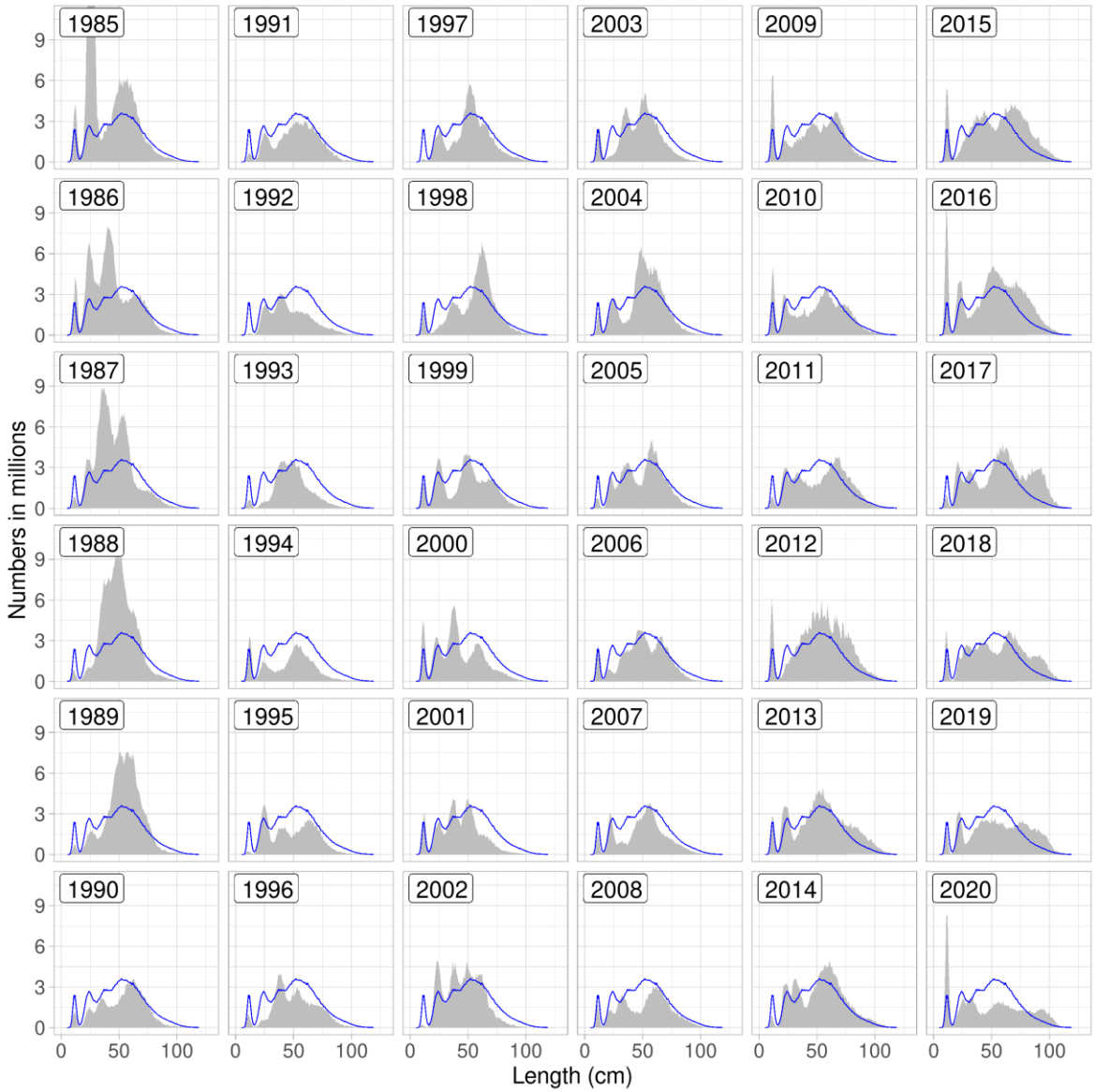

Figure 20. Cod. Length-disaggregated abundance indices from the spring survey. The blue line shows the mean for all years. Note: The spike for 2-year old fish in 1985 reached around 19 million.

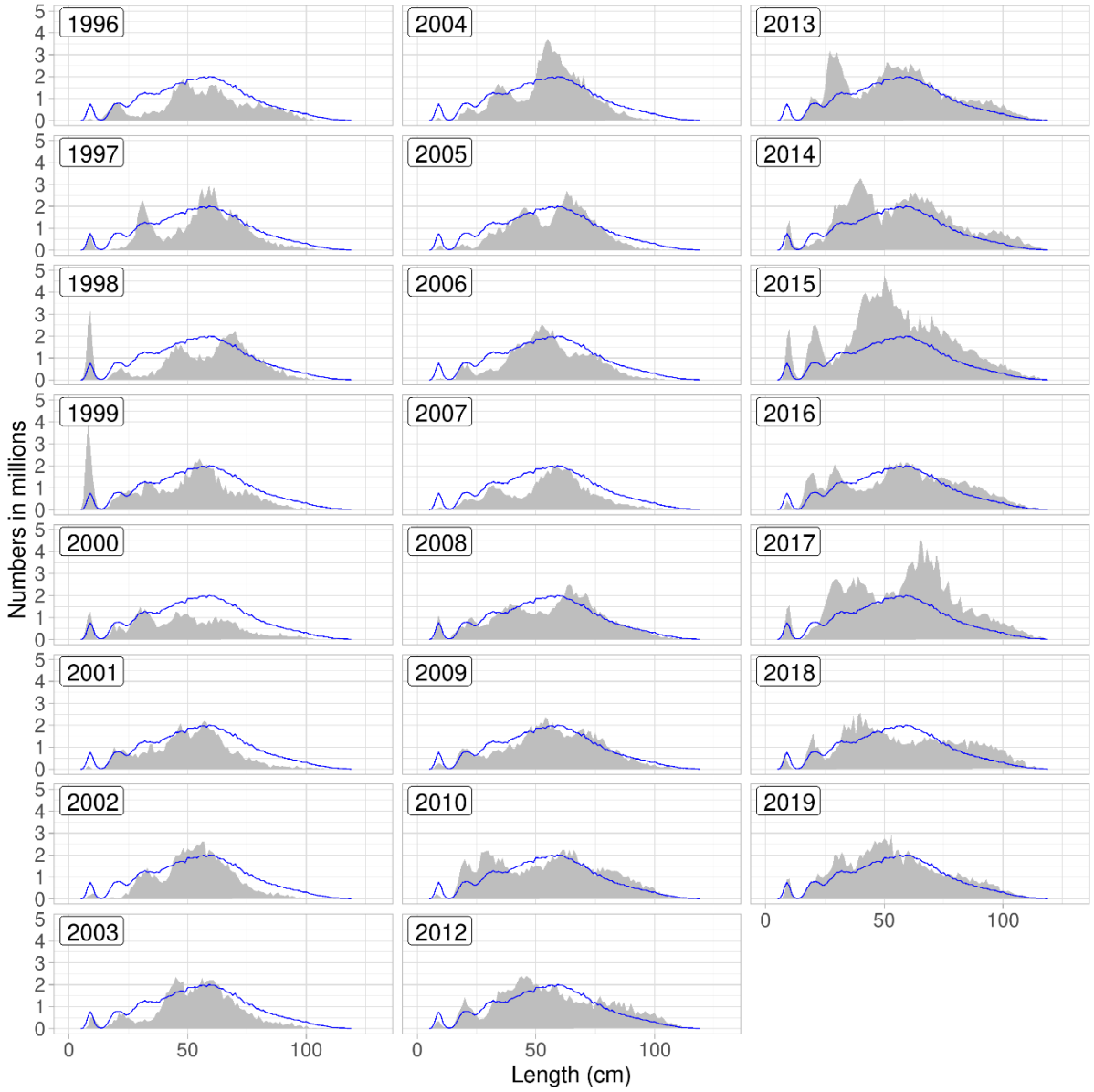

Figure 21. Cod. Length-disaggregated abundance indices from the autumn survey. The blue line shows the mean for all years.

Survey age-based indices of older fish are all relatively high in recent decade despite the indices of these year classes when younger are low or moderate in size (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 illustrate the anomaly in the measurements between 2019 and 2020 for some selected age groups. Although noisy, the overall pattern over time show a decline in the log-ratio (consistent with long term reduction in mortality), but between years 2019 and 2020 there is an increase in the ratio, even in the younger age groups that normally are not yet fully selected in to the survey.

Figure 22. 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.

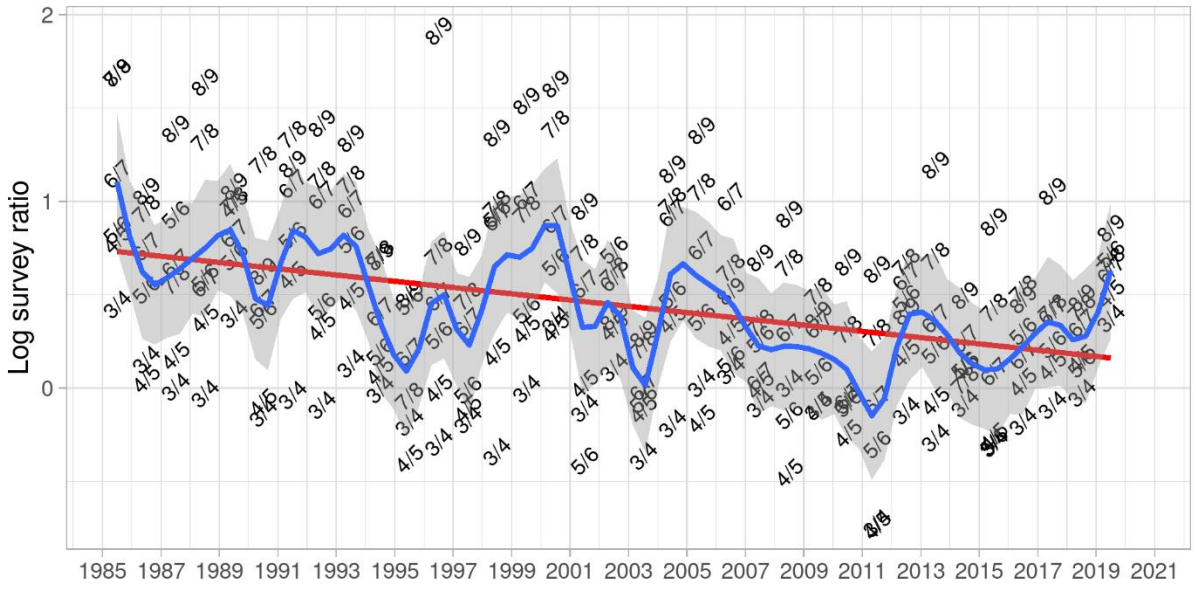

Figure 23. Cod. Log-ratio of the spring survey indices for adjacent age groups (3-9, labelled as text), with blue line showing local smoother and the red line indicating the overall trend.

STOCK ASSESSMENT

The assessment model is a statistical cohort model where fishing mortality can change gradually over time, constrained by a random walk. The input data are catch at age, and spring and autumn survey age-disaggregated indices. The model framework has been the same since 2002, with the addition of the autumn survey in 2009. The survey residuals are modelled as multivariate normal distribution to account for potential survey "year effects" - this being a feature in place since 2002. In the past the survey age groups have been age 1 to 10 in the assessment, this year the indices for age groups 11 to 14 were included.

The decision to use only ages 1 to 10 in the tuning in the past was made during the time when fishing mortality was substantially higher, resulting in indices for older aged fish being largely a reflection of noise rather than what has become a true signal. Because of this, and as landings in ages 10 years and older are above 10% in weight in recent years it was decided to base the advice on tuning ages 1 to 14.

The diagnostic this year are driven by the large negative residuals observed in the spring survey 2020 fit (Figure 24) that are larger than have been observed in previous years. Over time the residuals have been within the range of +/- 0.3, but in the year 2020 the residual for the spring survey age groups 3 to 8 range between -0.8 to -0.5. A summarized diagnostic of the observed vs. predicted survey biomass (Figure 25) illustrate the deviation between the model estimates and the point estimates, showing that the spring survey 2020 point estimate is 30% lower than the model estimate. The inertia in the assessment model in the terminal year is a result of the influence of older data, both the catches and the survey indices for each year class.

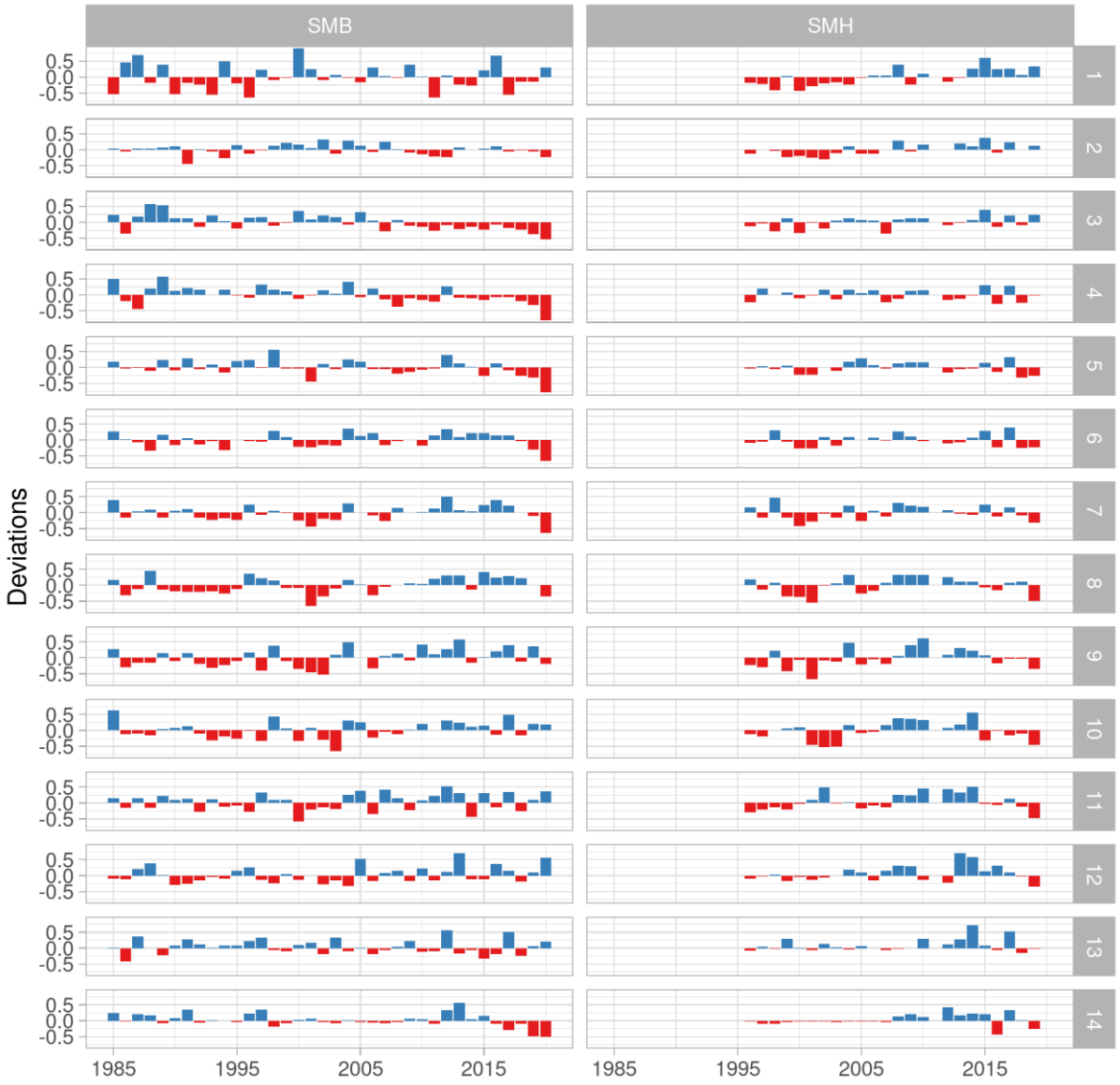

Figure 24. Cod. Residuals from the model fit to the abundance indices in SMB (left) and SMH (right) by year and age (blue: measured values above the model fit, red: measured values below the model fit). Note that values that are equal to zero are not visible in this type of a plot and that no survey was carried out in autumn 2011.

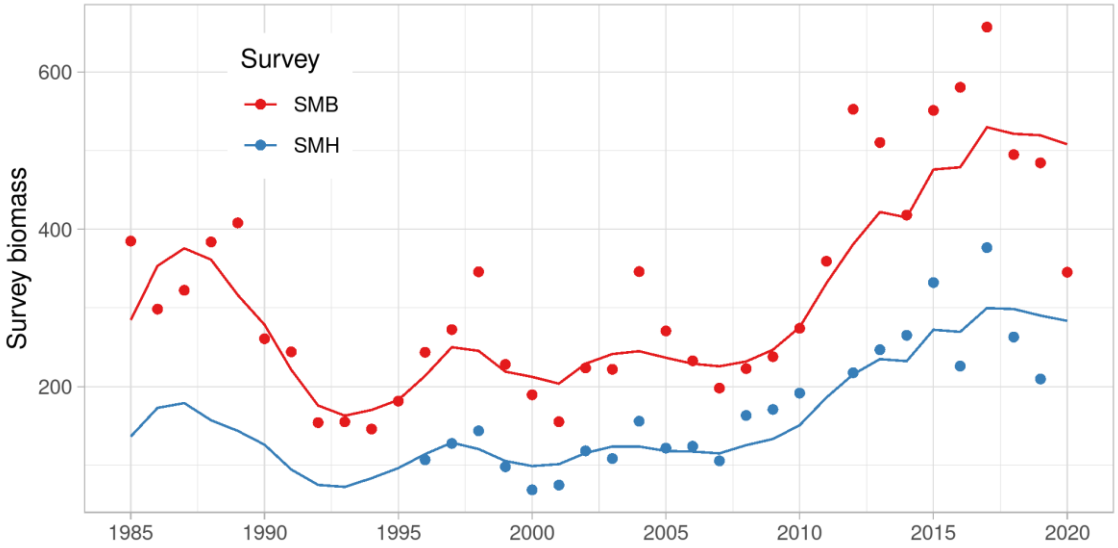

Figure 25. Cod. Observed aggregated age-based survey indices (point) and modelled indices (lines) for the spring survey (SMB) and the autumn survey (SMH).

Estimated spawning stock biomass (SSB) has increased in recent years and has not been larger in almost 60 years. Harvest rate has declined and is at its lowest value in the assessment period. Recruitment since 1988 (mean = 140) is lower than the average recruitment in the period 1955–1985 (mean = 205). The increase in SSB is therefore primarily the result of lower harvest rate. Sizes of the year classes 2014 and 2015 are near the long-term average but year class 2016 is small. The reference biomass is estimated to be 1207 663 t in 2020 and the fishing mortality 0.33 in 2019.

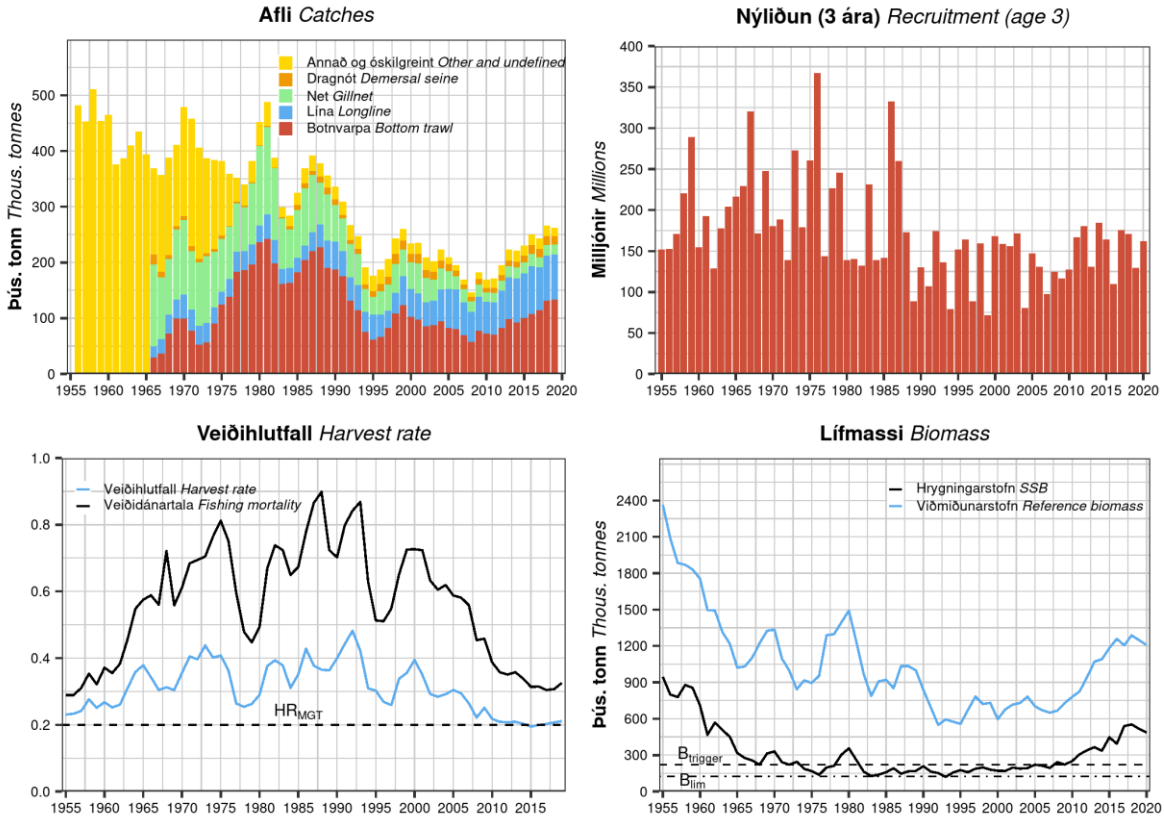

Figure 26. Cod. Stock summary plot. Catch, recruitment, fishing mortality and harvest rate, reference stock biomass (B4+) and spawning stock biomass (SSB).

Assessment based on tuning with the spring and the fall survey separately have in recent years shown that the fall survey gives a higher estimate than the spring survey (Figure 27). An assessment based on the fall survey only gave reference biomass of 1313 000 t in 2020 and fishing mortality of 0.31 in 2019. Tuning with spring survey only resulted in a reference biomass of 1061 000 t in 2020 and a fishing mortality of 0.35 in 2019.

A summarized diagnostic of the observed vs predicted survey biomass when tuning with the spring survey only (Figure 28) illustrate the deviation between the model estimates and the point estimates, showing that the spring survey 2020 point estimate is still about 20% lower than the model estimate.

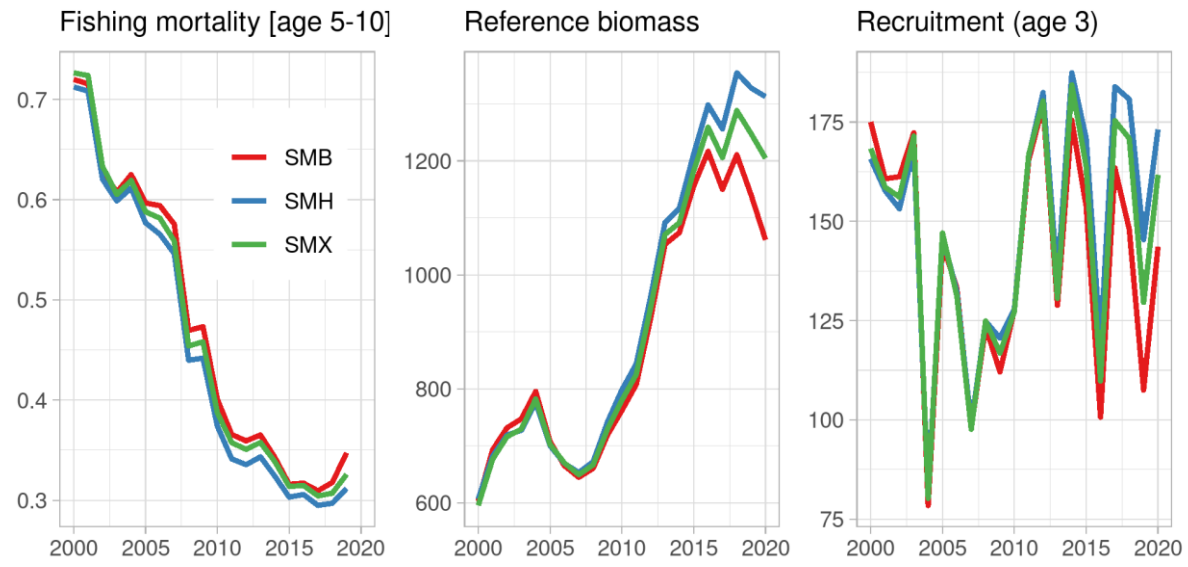

Figure 27. Cod. Comparison of assessment results using the spring survey only (SMB) and the autumn survey only (SMH) relative to the assessment based on using both surveys (SMX).

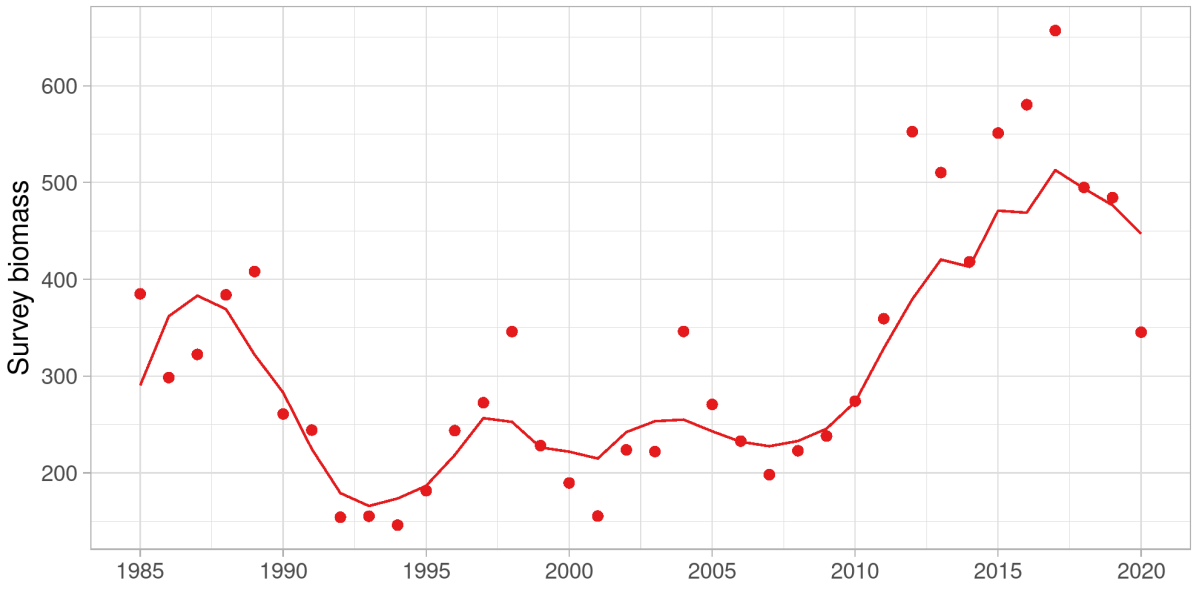

Figure 28. Cod. Observed aggregated age based survey indices (point) and modelled indices (line) for assessment based only on the spring survey (SMB).

MANAGEMENT

The Ministry of Industries and Innovation is responsible for management of the Icelandic fisheries and implementation of legislation. Cod was included in the ITQ system in 1984, but effort management was also implemented during the first years of the TAC system, partly to help those that thought they got unfair share of the quota. This "additional effort" management system led to the catches exceeding TAC by 20-30% in the first years of the ITQ system.

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

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

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

Table 6. 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	250 000	265 000	274 000
1992/93	Reduce F by 40%	154 000	205 000	241 000
1993/94	Reduce F by 40%	150 000	165 000	197 000
1994/95	Reduce F by 50%	130 000	155 000	165 000
1995/96	Apply catch rule	25% HCR	155 000	170 000
1996/97	Apply catch rule	25% HCR	186 000	202 000
1997/98	Apply catch rule	25% HCR	218 000	228 000
1998/99	Apply catch rule	25% HCR	250 000	254 000
1999/00	Apply catch rule	25% HCR	250 000	257 000
2000/01	Apply catch rule	25% HCR	220 000[1)]	223 000
2001/02	Apply catch rule	25% HCR	190 000[1)]	218 000
2002/03	Apply catch rule	25% HCR	179 000[1)]	204 000
2003/04	Apply catch rule	25% HCR	209 000	226 000
2004/05	Apply catch rule	25% HCR	205 000	214 000
2005/06	Apply catch rule	25% HCR	198 000	205 000
2006/07	Apply catch rule	25% HCR	193 000	191 000
2007/08	Apply catch rule	25% HCR	130 000	141 000
2008/09	Apply Fmax	25% HCR	160 000[2)]	169 000
2009/10	Apply Fmax	25% HCR	155 000[3)]	168 000
2010/11	Apply catch rule	20% HCR (160 000)	160 000	169 000
2011/12	Apply catch rule	20% HCR (177 000)	177 000	185 000
2012/13	Apply catch rule	20% HCR (196 000)	195 000	215 000
2013/14	Apply catch rule	20% HCR (215 000)	214 000	226 000
2014/15	Apply catch rule	20% HCR (218 000)	216 000	223 000
2015/16	Apply catch rule	20% HCR (239 000)	239 000	251 000
2016/17	Management plan	20% HCR (244 000)	244 000	237 644
2017/18	Management plan	20% HCR (257 572)	255 172	270 217
2018/19	Management plan	20% HCR (264 437)	262 000	265918
2019/20	Management plan	20% HCR (272 411)	270011	

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 30 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 30, upper). Net transfers of unused cod quota from one fishing year to the next have usually been in the range of 0-7%.

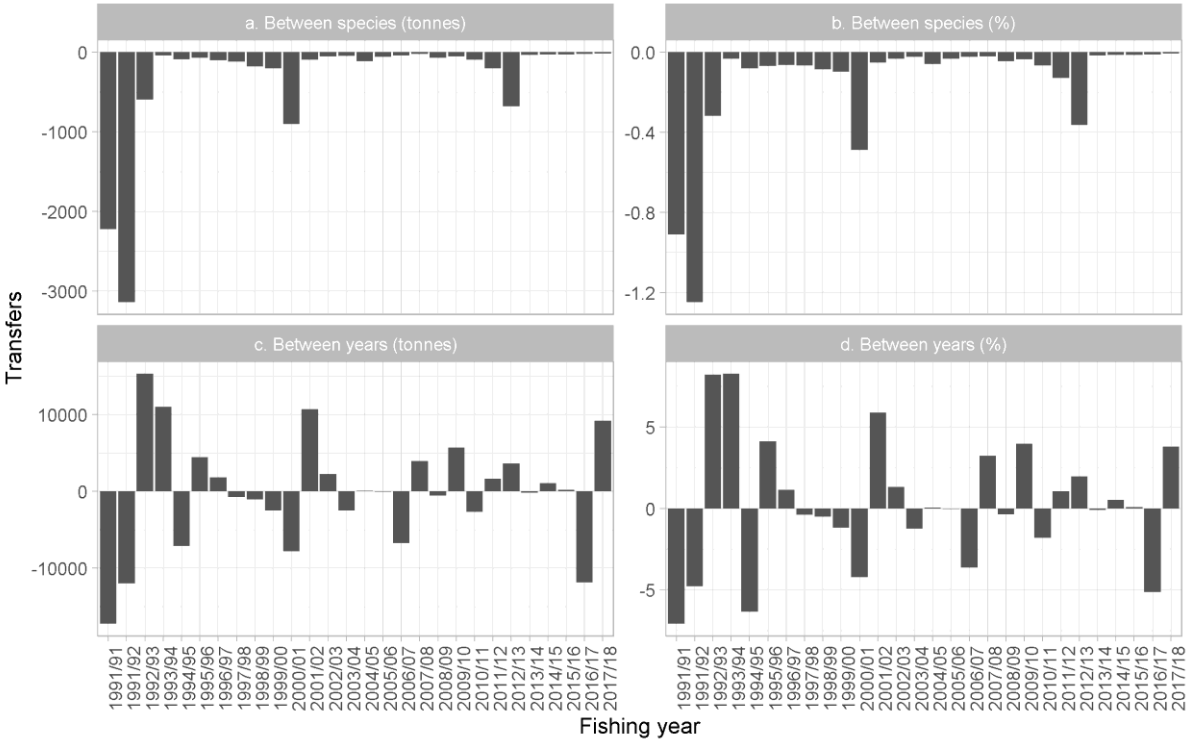

Figure 30. Cod. Net transfers of quota to and from cod in the Icelandic ITQ system by quota year. Between species (upper): Positive values indicate a transfer of other species to cod (not allowed), but negative values indicate a transfer of cod quota to other species. Between years (lower): Net transfer of quota for a given quota year.