15 Atlantic wolffish (*Anarcichas lupus*) in Division 5.a (Icelandic grounds)

15.1 Atlantic wolffish in 5a

15.1.1 Fishery

The main fishing grounds for Atlantic wolffish are in the west and northwest part of the Icelandic shelf. From 2010, the proportion of the catch has been increasing in northwest of Iceland compared to west of Iceland. Catches at the main spawning ground (Látragrunn) west of Iceland have been decreasing since 2008 (Figures 15.1.1 and Figure 15.1.2). About 80% of the catch of Atlantic wolffish is caught at depths less than 120 m. Proportion of the catch taken at depth range 0-60 m decreased from 2003 to 2007, but since then it has been increasing. At the depth range 61-120 m the proportion of the catch has been rather stable since 2000. At depths from 121 to 180 m, which includes the main spawning ground (Látragrunn), it the proportion of the catch increased in 2003-2008 but since then it has been decreasing (Figure 15.1.3).

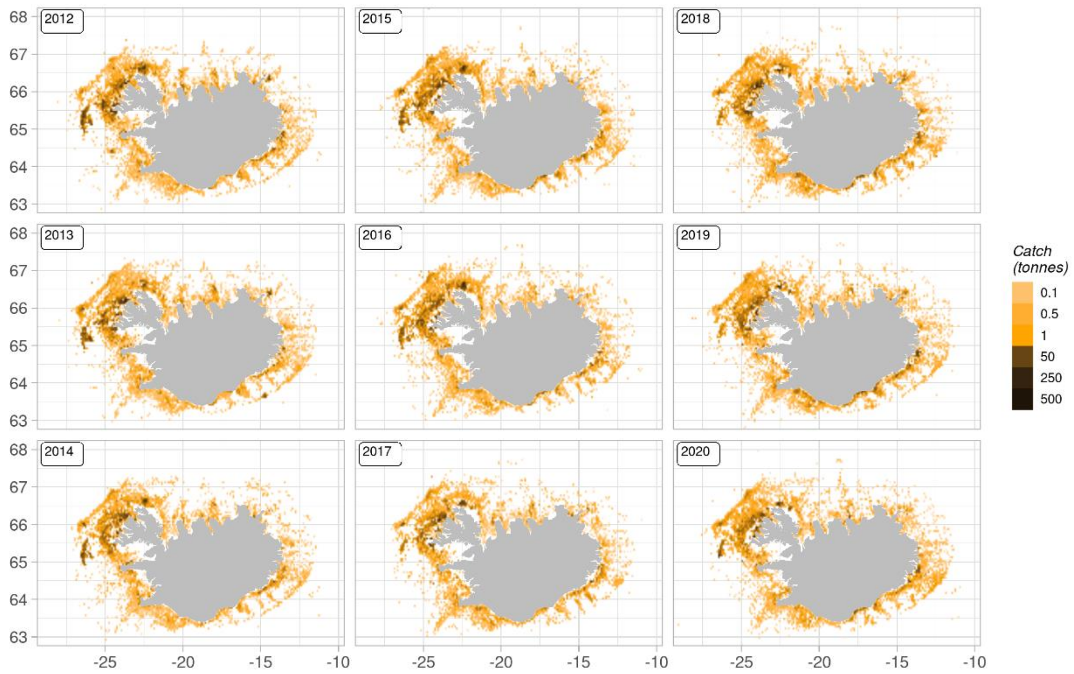

Figure 15.1.1 Atlantic wolffish in 5.a. Geographical distribution of the Icelandic fishery since 2012 as reported in logbooks. All gear types combined.

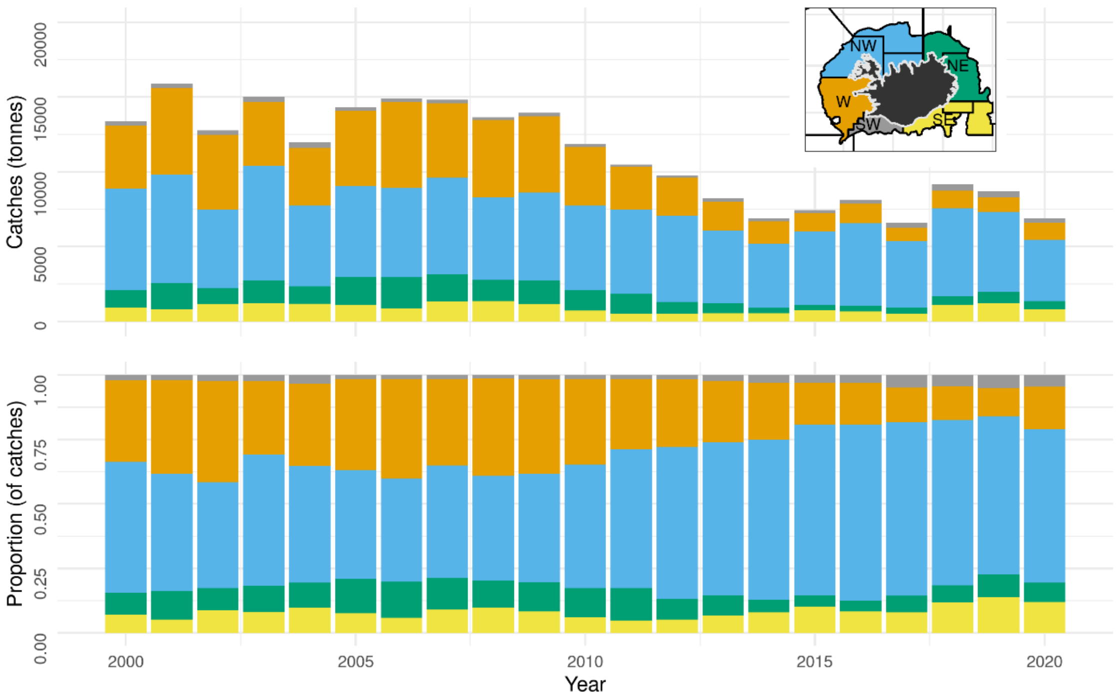

Figure 15.1.2: Atlantic wolffish in 5a. Spatial distribution of the Icelandic fishery by fishing area since 2000 according to logbooks. All gears combined.

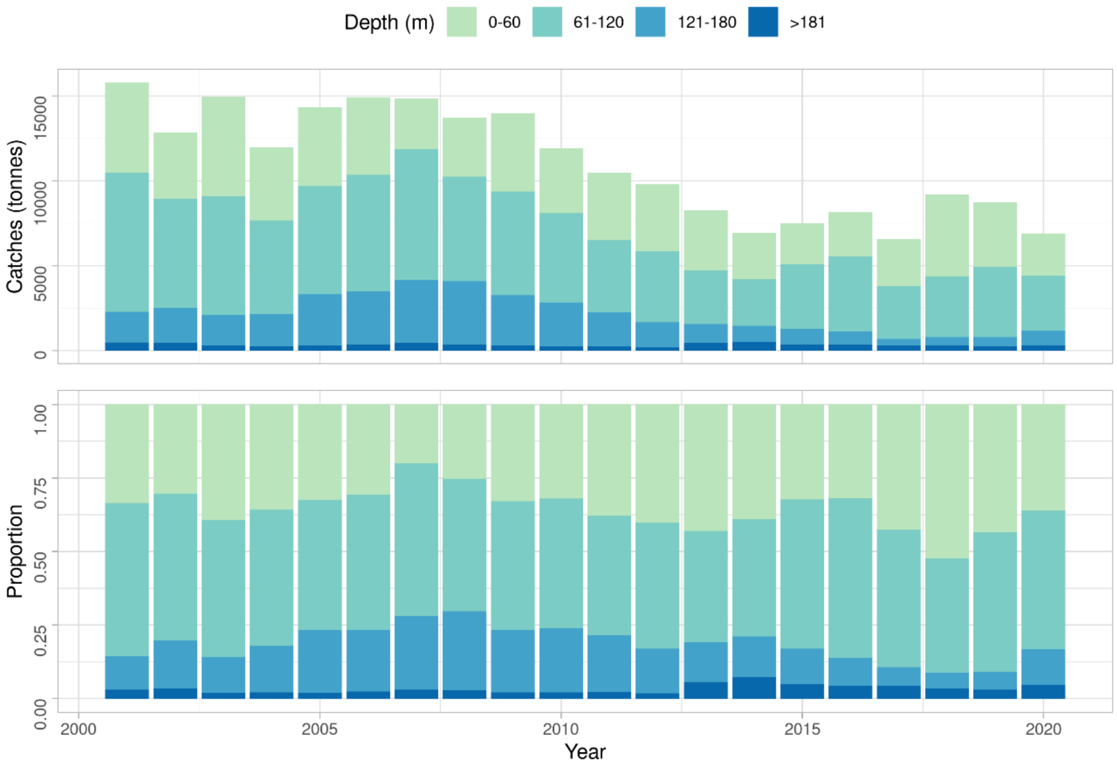

Figure 15.1.3. Atlantic wolffish in 5.a. Depth distribution of demersal trawl, longline and demersal seine catches according to logbooks.

15.1.2 Landings trend

More than 97% of the Atlantic wolffish catch is taken by longliners (50-65%), demersal trawlers (20-30%) and demersal seiners (about 10%) (Figure 15.1.4). These proportions have been relatively stable through the years. However, in 2004-2008 longline and demersal trawl catches were similar (40-50%) and in the last three years catches by demersal seiners hasve been increasing and are now greater than in demersal trawlers (Figure 15.1.4). Since 2001, the number of longliners and trawlers reporting Atlantic wolffish catches of 10 tonnes/year or more has decreased. In the longline fleet, the number of vessels has dropped from 198 in 2001, down to 67 in 2018. The number of trawlers has also decreased significantly from 76 in 2000 to 40 in the last year (Table 1).

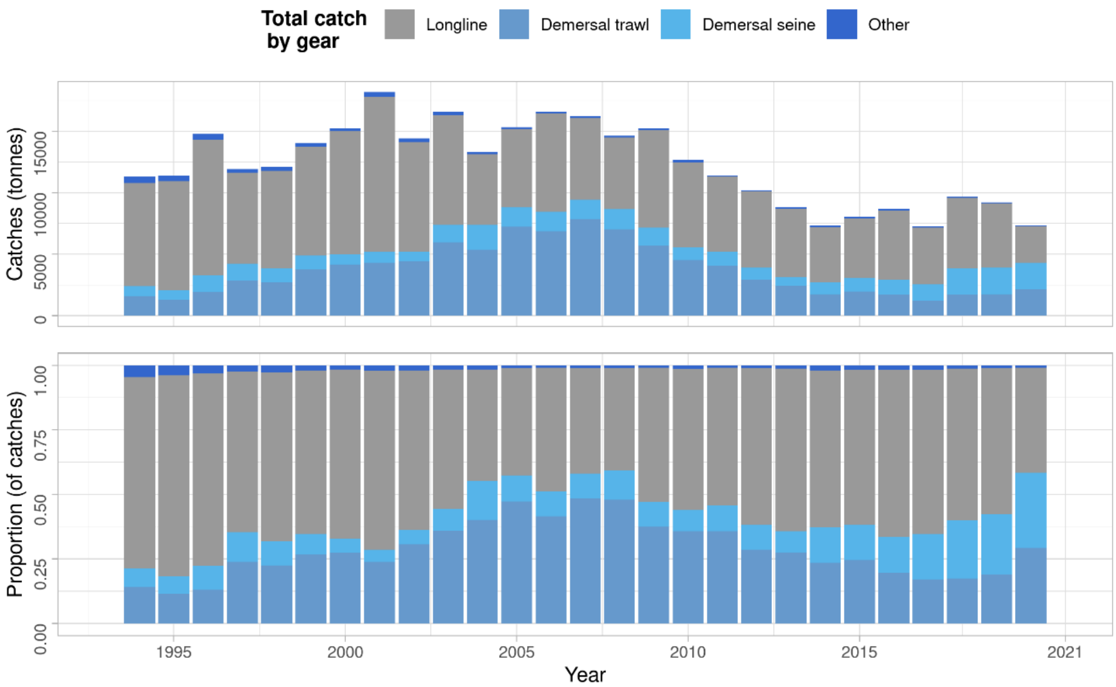

Figure 15.1.4. Atlantic wolffish in 5.a. Total catch (landings) by fishing gear since 1994, according to statistics from the Directorate of Fisheries.

In 1994 and 1995, more than 500 vessels accounted for 95% of the annual catch of Atlantic wolffish in Icelandic waters, but this number had dropped to 200 vessels in 2008 despite higher catches. Since 2010 the number of vessels accounting for 95% of the annual catch has remained relatively constant (about 150-200 vessels), despite catch reductions (Figure 15.1.5).

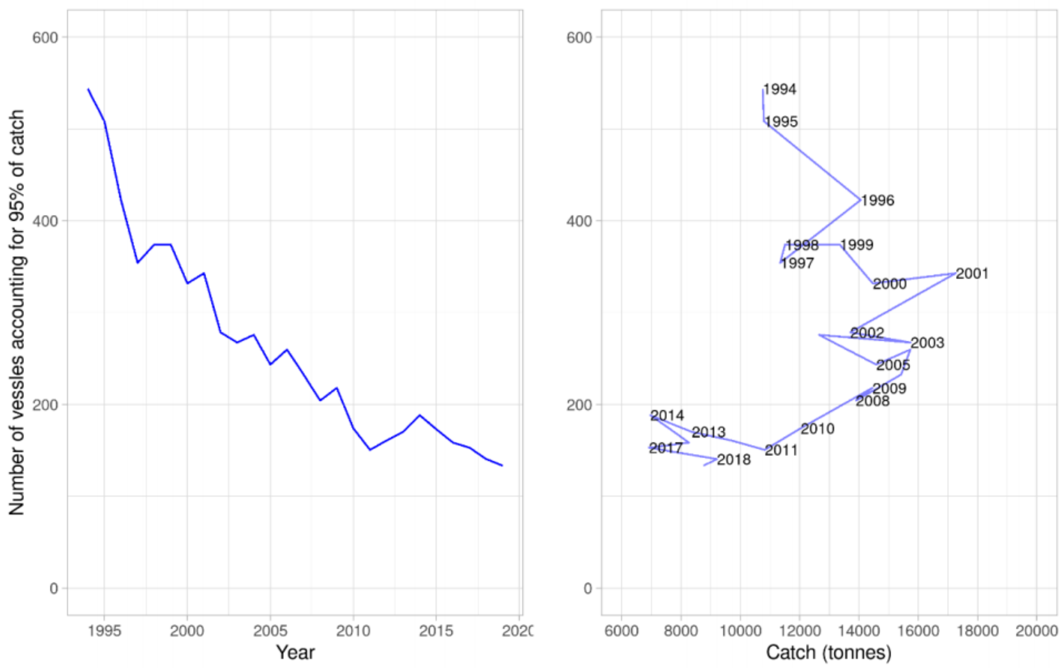

Figure 15.1.5. Atlantic wolffish in 5.a. Number of vessels (all gear types) accounting for 95% of the total catch annually since 1994. Left: Plotted against year. Right: Plotted against total catch. Data from the Directorate of Fisheries.

15.1.3 Data available

The commercial catch samples taken are normally representative of the landings with most number of samples taken in areas of high catch intensity (Figure 15.1.7).

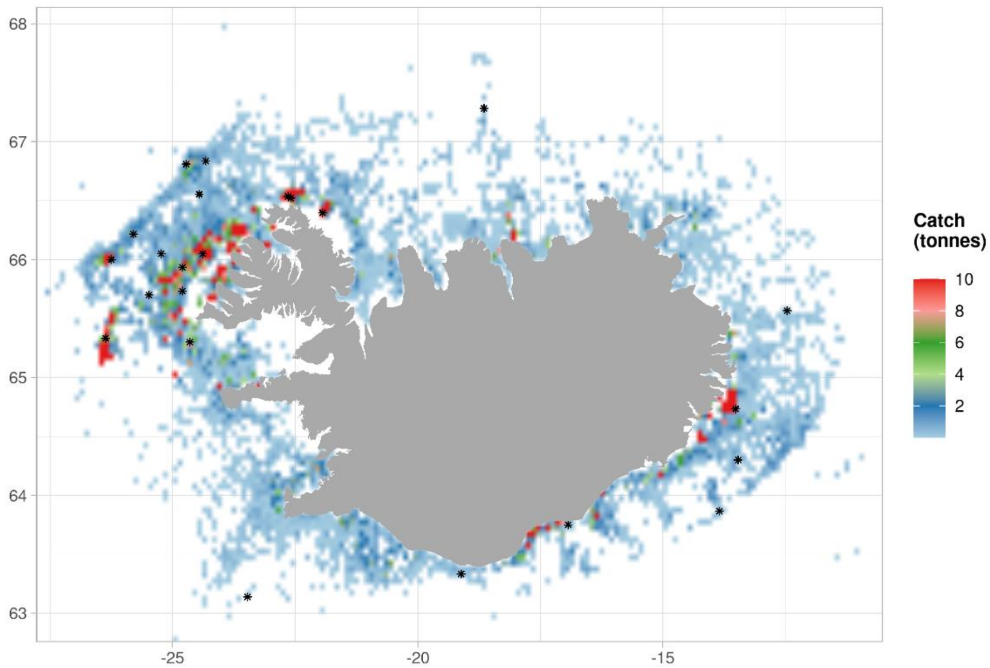

Figure 15.1.7. Atlantic wolffish in 5.a. Fishing grounds in 2020 as reported in logbooks and positions of samples taken from landings (asterisks).

15.1.3.1 Landings and discards

Landings by Icelandic vessels are given by the Icelandic Directorate of Fisheries. Landings of Norwegian and Faroese vessels are given by the Icelandic Coast Guard. Discarding is banned by law in the Icelandic demersal fishery, as well as in Norway. Measures in the Icelandic management system such as converting quota share from one species to another are used by the Icelandic fleet to a large extent, and this is thought to discourage discards in mixed fisheries.

15.1.3.2 Length composition

The length distribution of landed Atlantic wolffish has been relatively stable since 2004 (Figure 15.7.8). The average length in the commercial catch increased from about 65 cm in 2003 to about 70 cm in 2011 where from it has been similar.

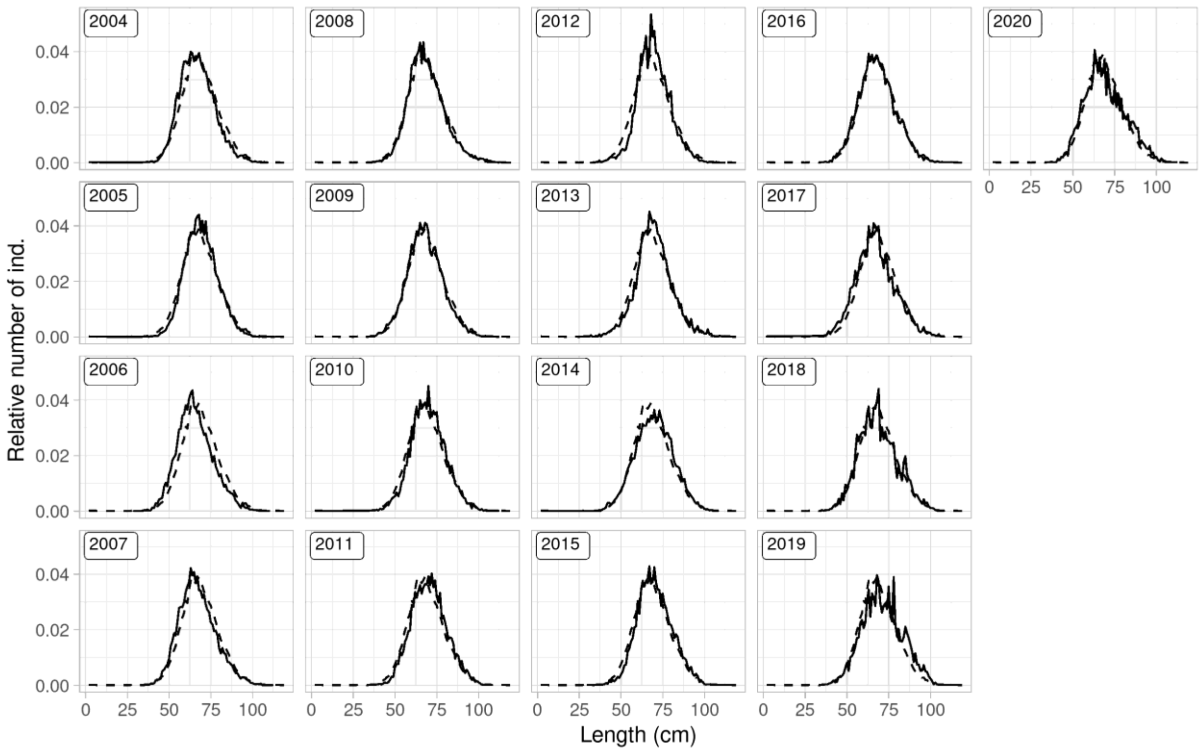

Figure 15.7.8. Atlantic wolffish in 5.a. Relative length distribution of fish sampled from landed catch. The dotted line represents the mean length distribution for all years.

Since 2004, the length frequency distribution in the spring survey has been bimodal because of a relatively greater decrease in number of fish at 40-60 cm (Figure 15.7.9). The mean length of Atlantic wolffish has been about 39 cm on average . It was, however, lowest in 1994-2004, about 37 cm, but in these years the recruitment index was high. Due to decreasing recruitment beginning 2004 (Figure 15.7.9), the mean length increased and was on the average about 41 cm in 2007-2019 (Figure 15.7.9). Mean length in the autumn survey oscillated from 34-40 cm in 1996-2019, with no clear trend (Figure 15.7.10).

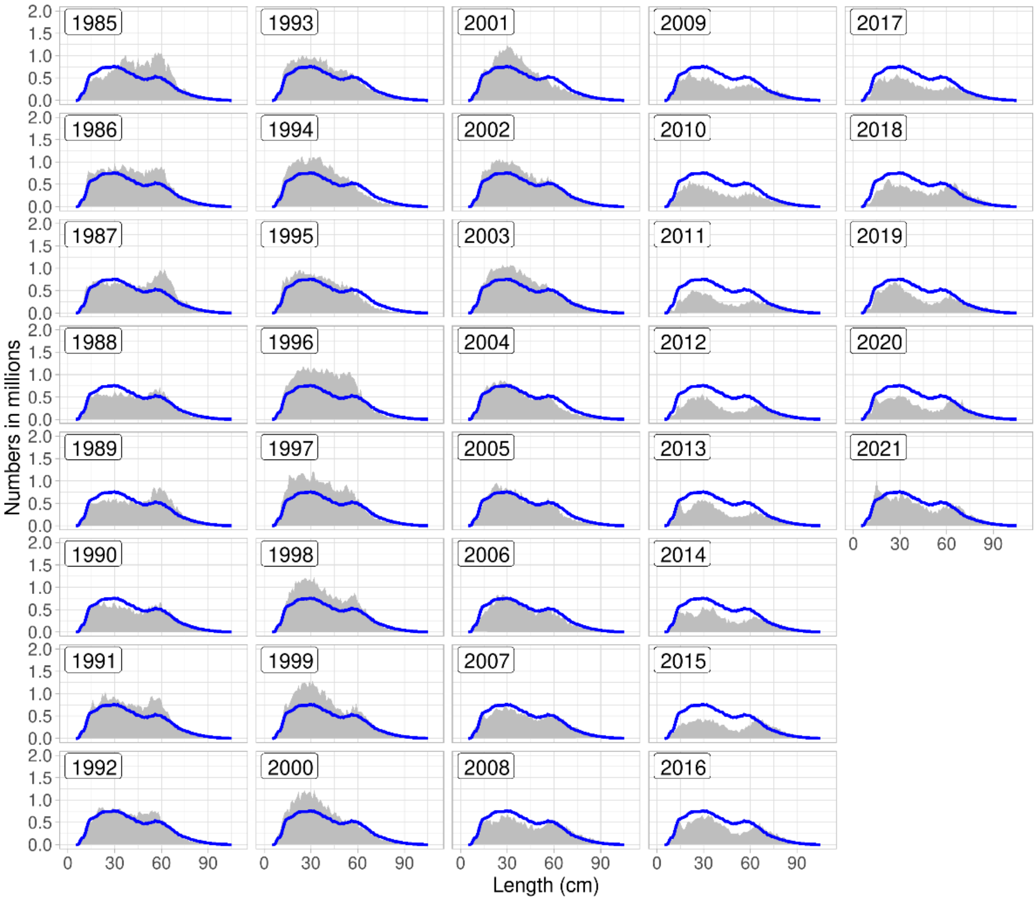

Figure 15.7.9. Atlantic wolffish in 5.a. Length-disaggregated abundance indices from the spring survey. The blue line shows the mean for all years.

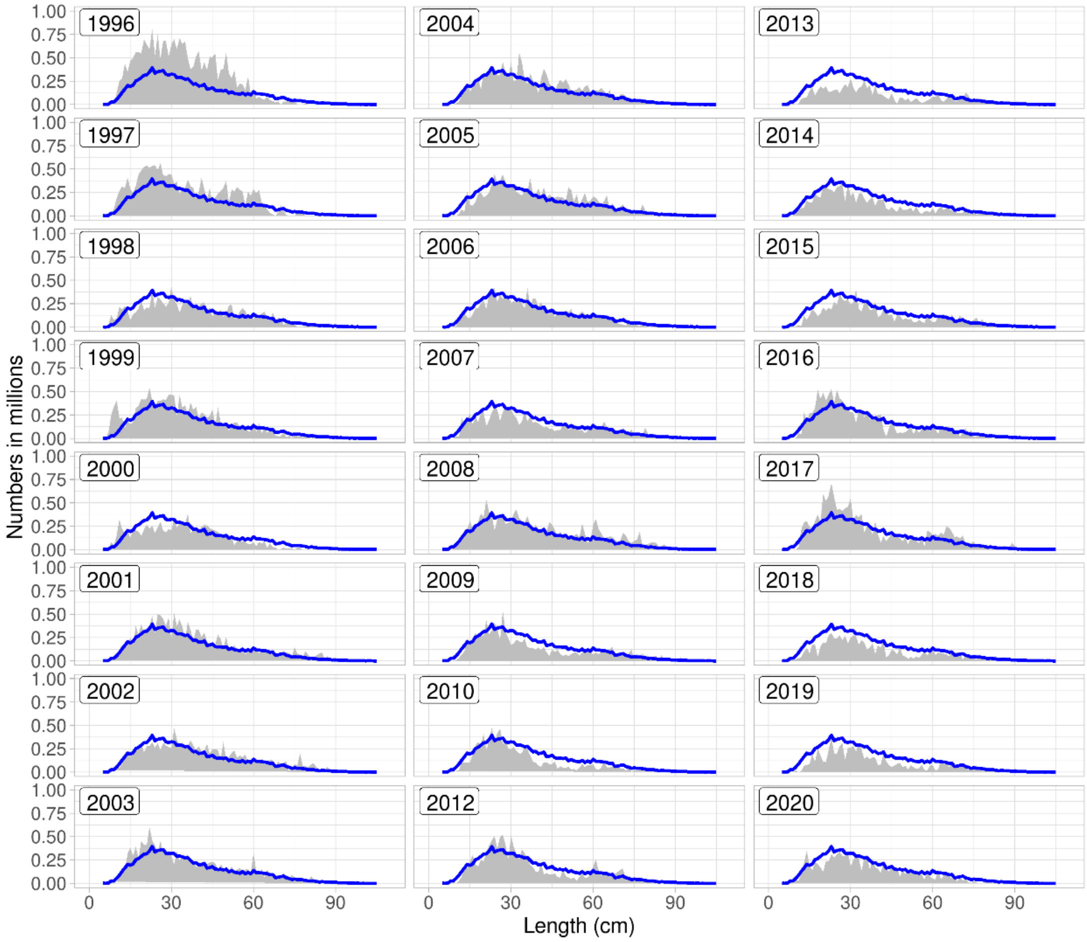

Figure 15.7.10. Atlantic wolffish in 5.a. Length-disaggregated abundance indices from the autumn survey. The blue line shows the mean for all years.

15.1.3.3 Age composition

Age composition data are available from surveys. Commercial age data are available from earlier periods (1978). In samples from commercial landings, the mean age of Atlantic wolffish was around 10.7 years in 1999. Since then, mean age in samples from commercial catches has generally been increasing to around 12 years in recent years.

15.1.3.4 Weight-at-age

Weight-at-age data in Icelandic waters are available from 1996.

15.1.3.5 Maturity and natural mortality

Females have the most reliable maturity designations; a maturation scale for males is unavailable. Therefore, maturity analysis is based on females caught during the autumn survey and in commercial catches from June – December. From these data, maturation occurs close to 60 cm and around age 10 but is highly variable and difficult to measure. No information is available on natural mortality. For assessment and advisory purposes, the natural mortality is set to 0.10 for all age groups.

15.1.3.6 Catch, effort and survey data

CPUE estimates of Atlantic wolffish in Icelandic waters are not considered representative of stock abundance, as changes in fleet composition, technical improvements and differences in gear setup among other things have not been accounted for when estimating CPUE. Non-standardised estimates of CPUE in longline (kg/1000 hooks), and demersal trawl (kg/hour), are calculated as the total weight in sets or tows in which Atlantic wolffish was more than 10% of the catch, according to logbooks. Effort of demersal trawl was defined as the number hours towed, and for longline number of hooks, in both cases where Atlantic wolffish was more than 10% of the catch. CPUE in longline vessels has been similar among years prior to 2018, around 100-150 kg/1000 hooks. CPUE of demersal trawl increased from about 230 to 400 kg/h in 2000-2005, but since 2006 it has fluctuated at around 250-300 kg/h (Figure 15.7.11). Both indices have shown a sharp decrease over the past three years. Fishing effort in longline increased from 66 million hooks in 2000 to 97 million hooks in 2001. Since then it has been generally decreasing and was around 22 million hooks in 2018. In demersal trawl, fishing effort increased from about 14 thousand tow-hours in 2004 to 23 thousand tow-hours in 2008, followed by a sharp decrease to 4.8 thousand tow-hours in 2014. Since then it has been at a similar level, but with a notable decrease in 2019 (Figure 15.7.11).

Figure 15.7.11. Atlantic wolffish in 5.a. Non-standardised estimates of CPUE (left) from demersal trawl (kg/h) and long-line (kg/1000 hooks). Fishing effort (right) for longline (10000 hooks) for demersal trawl (tow-hours).

The Icelandic spring groundfish survey (hereafter spring survey, IGFS), which has been conducted annually in March since 1985, covers the most important distribution area of Atlantic wolffish in Icelandic waters. In addition, the Icelandic autumn groundfish survey (hereafter autumn survey, IAGS) was started in 1996 and expanded in 2000. However, a full autumn survey was not conducted in 2011 due to a labour strike. Because the spring survey covers the main distribution area, it is considered adequate to measure changes in abundance/biomass of Atlantic wolffish better than the autumn survey.

Total biomass and harvestable biomass indices decreased from 1985-1995. In 1996, the biomass index increased to 1998, then decreased to a historical low level in 2010-2012, but since then it has been increasing (Figure 15.7.12). The harvestable biomass has generally been increasing from 1995 with considerable oscillators. The recruitment index was high in the years 1992-2003, since 1999 it has been decreasing, which coincides with increasing effort and catch of trawlers at the main spawning ground west of Iceland (Látragrunn) during the spawning and incubation time. The recruitment index reached a historical low level in 2011, but since then it has been rather stable or increased slightly. This coincides with that the closed spawning/incubation area on Látragrunn was enlarged from 500 km² (from 2002) to 1000 km² in October 2010.

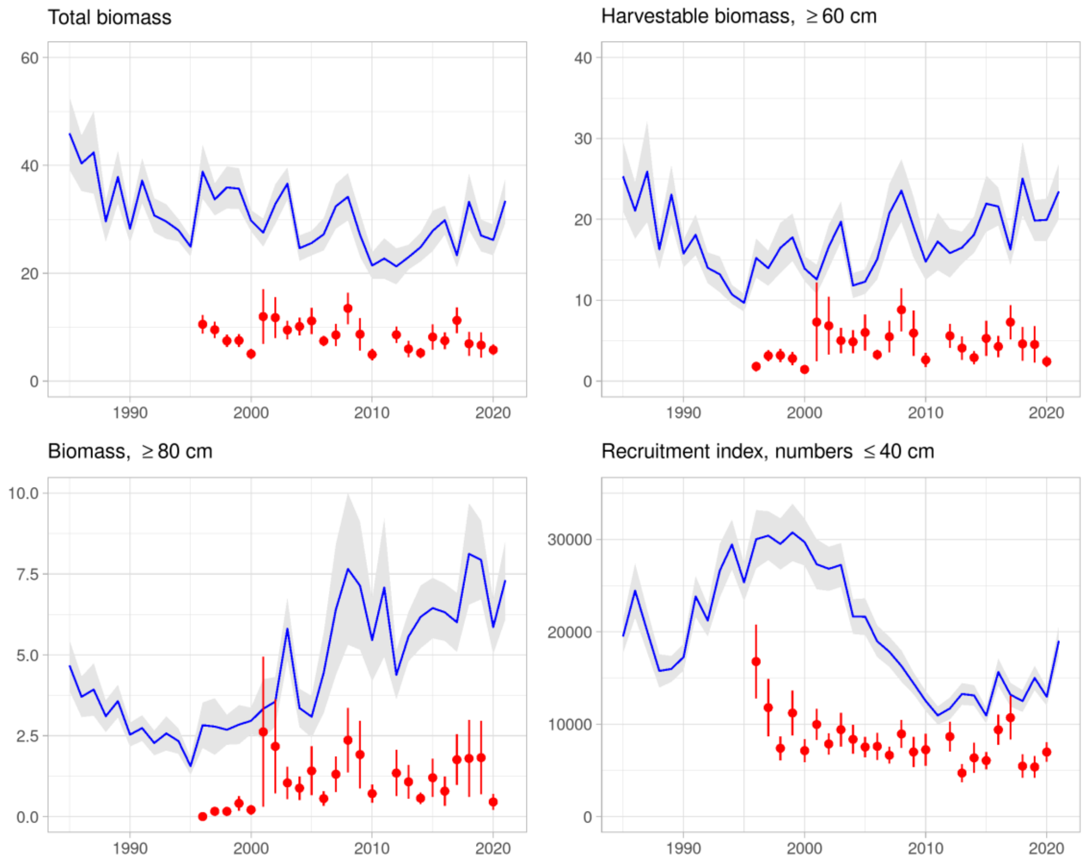

Figure 15.7.12. Atlantic wolffish. Total biomass indices (upper left) and harvestable biomass indices (≥60 cm, upper right), large fish biomass indices (≥80 cm, lower left) and juvenile abundance indices (≤40 cm, lower right), from the spring survey (blue) and the autumn survey (red), along with the standard deviation.

When the spring survey is conducted, Atlantic wolffish are on their feeding grounds which are commonly in relatively shallow waters. In the spring survey, the highest abundance has always been measured in the NW area (Figure 15.7.13).

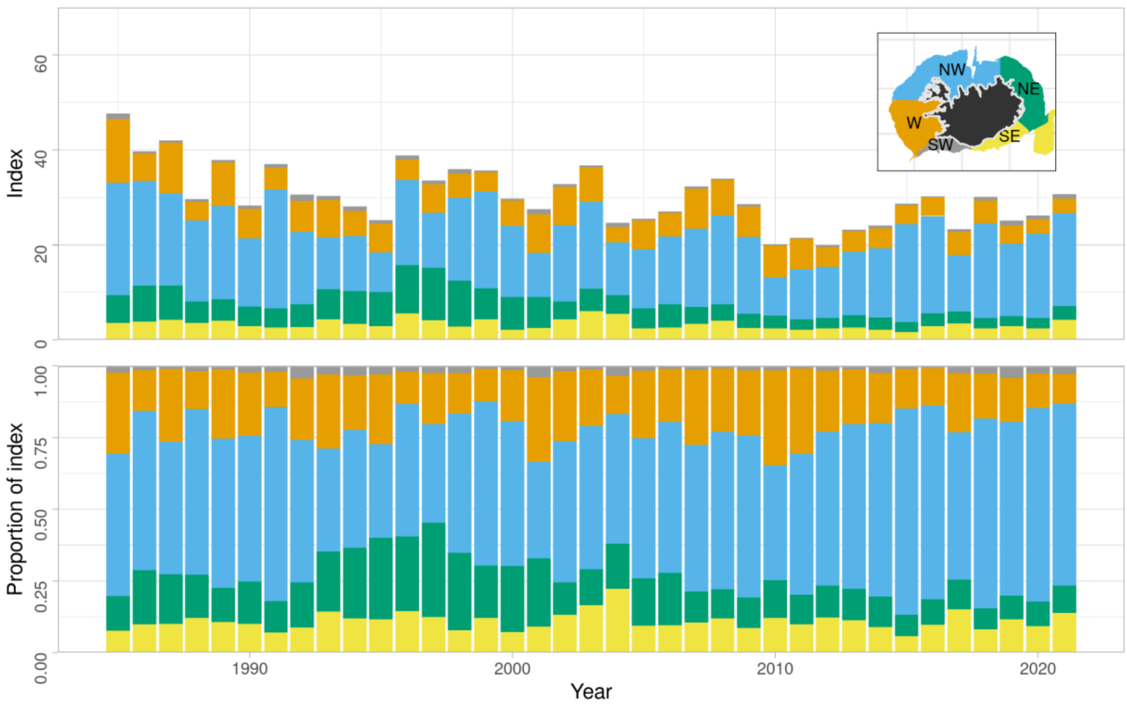

Figure 15.7.13. Atlantic wolffish in 5.a. Spatial distribution of biomass index from the spring survey.

15.1.4 Data analysis

Analytical assessment on wolffish in Icelandic waters using GADGET

Since 2001 the Gadget model (**G**lobally applicable **A**rea **D**isaggregated **G**eneral **E**cosystem **T**oolbox, see www.hafro.is/gadget) has been used for the assessment of Atlantic wolffish in Icelandic waters.

15.1.4.1 Data used by the assessment and model settings

In 2001-2010 natural mortality (M) was set at 0.15 and the advice based on F0.1 but since 2011 natural mortality has been set as M=0.10 and advice based on F_{MSY} (F_{max}). Weights of different likelihood components were estimated in the2011 assessment and again in the 2013 and 2015 assessments. The weights in the final run have been kept unchanged since 2013.

The parameters estimated in the model are:

- Initial numbers at age
- Recruitment at age 1 every year
- Size of recruits
- Selection pattern of the commercial fleet and survey.

Data used in the estimation are:

- Length distributions from survey and catches.
- Length-disaggregated abundance indices from survey in 6 groups. 5-13 cm, 14-19 cm, 29-29 cm, 30-55 cm, 56-74 cm, and 75-109 cm.
- Age data from survey and catches used as age-length keys.

Selection pattern of the fisheries and the survey are size based. According to the selection pattern, estimated by the model, the L50 of the commercial fleet is 62.9 cm that corresponds to approximately 13 years old fish. In the model the growth and selection pattern are fixed for all the simulation period. Still the size at age can changed as the fisheries are modelled to target the largest fish of each cohort leading to lower mean length at age of the survivors and some change in selection by age if fishing mortality varies much. Therefore, harvestable biomass is defined according to a selectivity pattern applied to the estimated biomass. To calculate harvestable biomass, the estimated biomass in each length group is multiplied by probabilities generated by a constant a logistic curve ($S(L) = 1/(1+\exp(-0.200*(L-62.9)))$, where L represents length in cm) that roughly represents the estimated selection pattern.

15.1.4.2 Diagnostics

Observed and predicted proportions by fleets

Overall, the fit of the predicted proportional length distributions is close to the observed distributions (Figures 15.1.14 and 15.1.15). The bimodality observed in the spring survey (Figure 15.1.14) is not observed in commercial catches because the commercial selectivity curve excludes most of the smaller fish in the left mode (Figure 15.1.15). In addition, preliminary analyses suggest that the cause of the bimodality in length distributions is spatial variation in growth, with Atlantic wolffish from the southwest attaining larger sizes at age than in the northeast of Iceland. Atlantic wolffish from the west and northwest, where most fishing occurs, also tend to attain larger sizes at age than in the northeast. Alternatively, or in addition, it is possible that this size range may have a higher catchability than others. Because the bimodality does not appear to represent cohort structure and spatial variation in growth is not included in the model, the model is not able to fit this bimodality in more extreme cases.

The survey age distributions fit well toward the end of the time series; however, the beginning of the time series shows that the first decade of the age distribution data do not fit well (Figure 15.1.16). This is likely to be due to either a change in growth or ageing. However, as the model fits well to more recent data, these minor misfits are unlikely to affect model results and projections. In general, the commercial catch age distributions are well-fitted by the model (Figure 15.1.17).

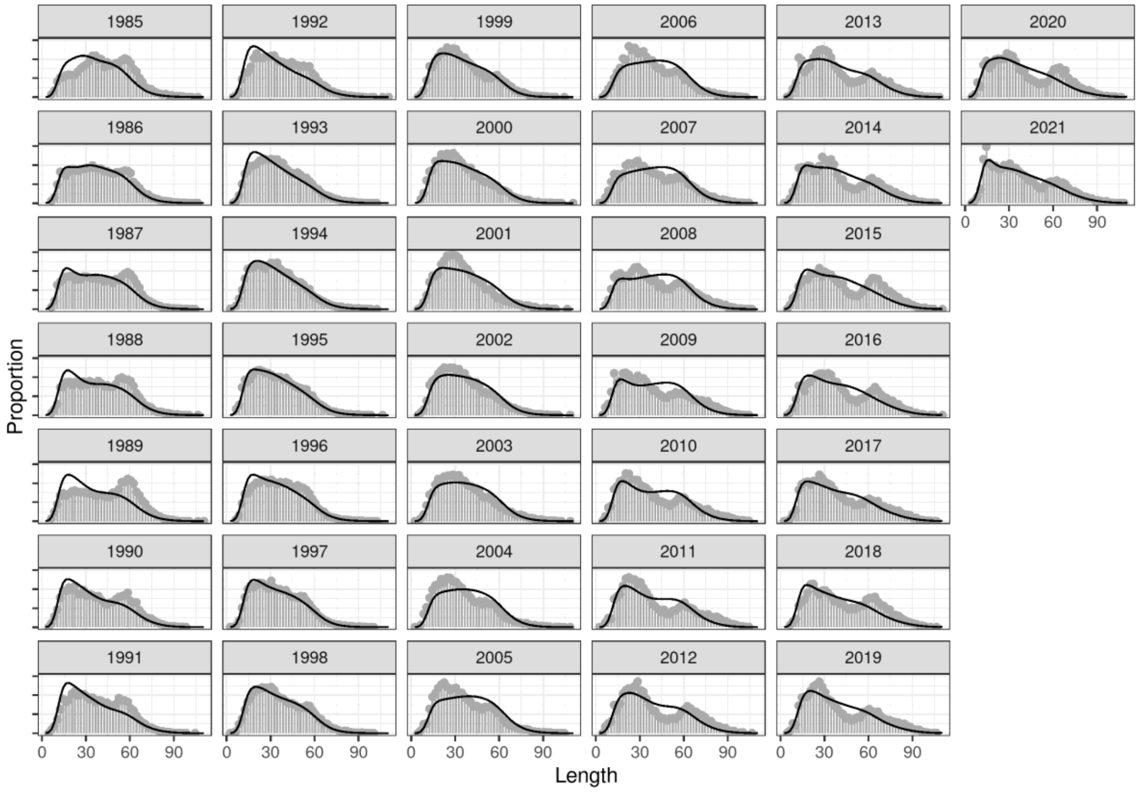

Figure 15.1.14 Atlantic wolffish in 5.a. Fitted proportions-at-length from the Gadget model (black lines) compared to observed proportions in the spring survey (grey lines and points).

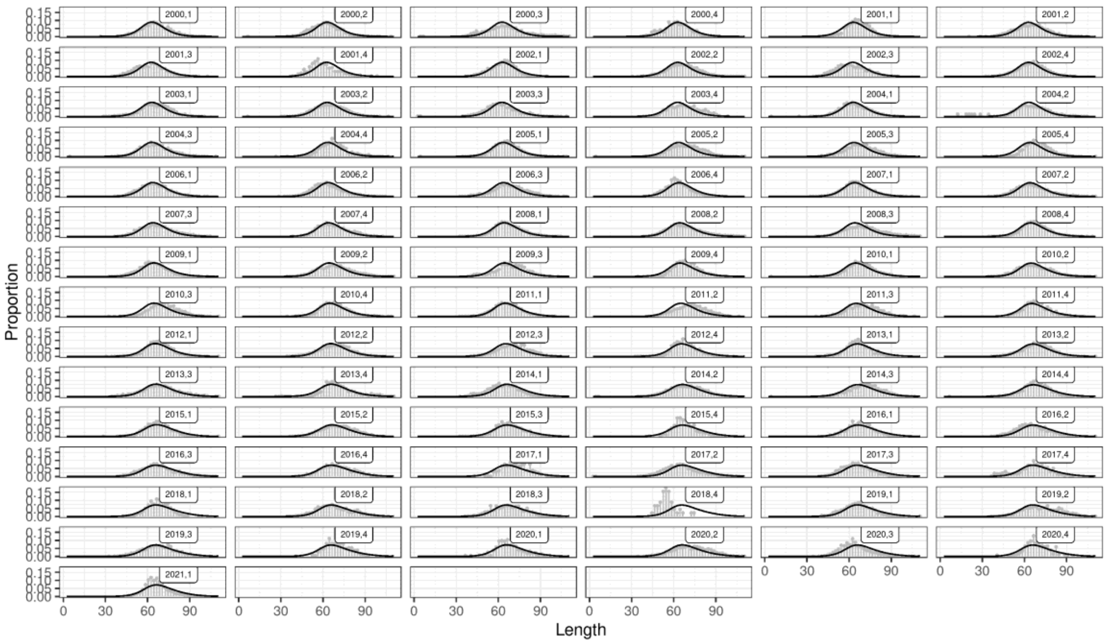

Figure 15.1.15. Atlantic wolffish in 5.a. Atlantic wolffish in 5.a. Fitted proportions-at-length from the Gadget model (black lines) compared to observed proportions from commercial catches (grey lines and points).

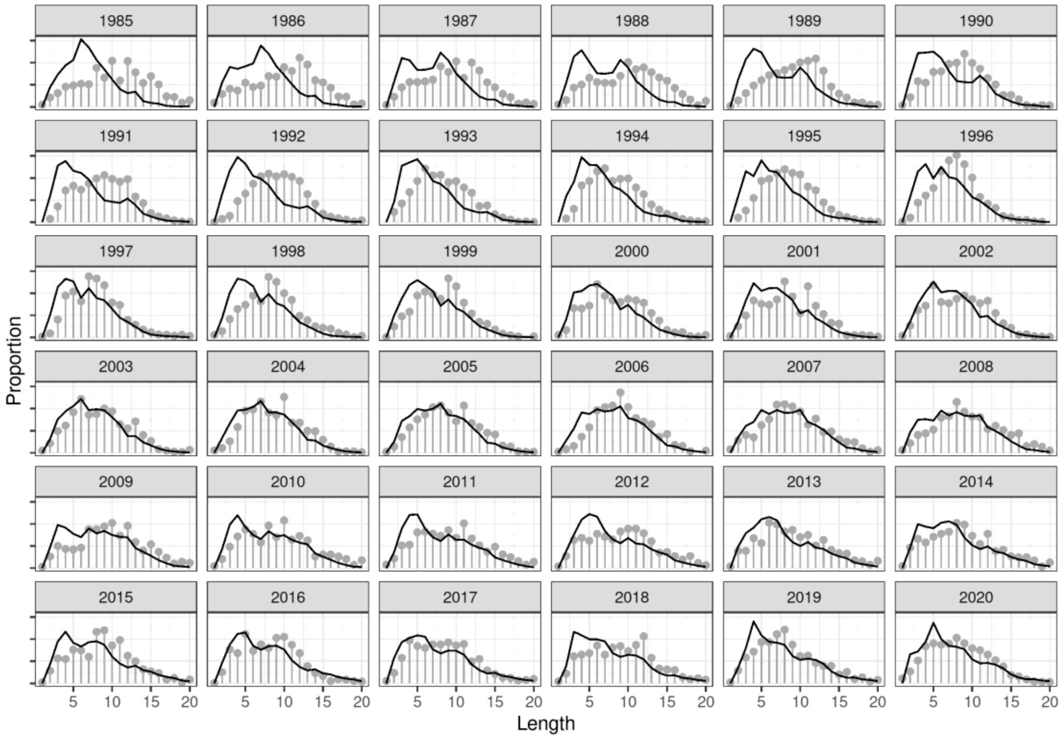

Figure 15.1.16. Atlantic wolffish in 5.a. Fitted proportions-at-age from the Gadget model (black lines) compared to observed proportions in the spring survey catches (grey lines and points).

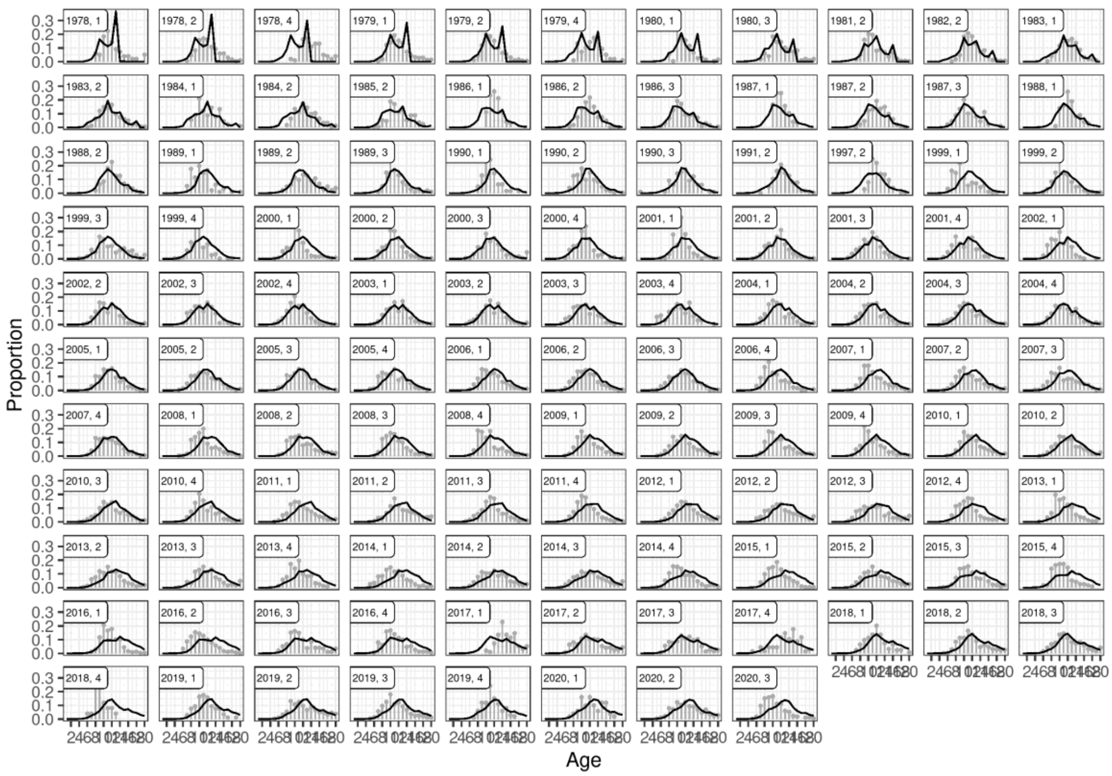

Figure 15.1.17. Atlantic wolffish in 5.a. Fitted proportions-at-age from the Gadget model (black lines) compared to observed proportions in commercial catches (grey lines and points).

15.1.4.3 Model fit

In Figure 15.1.18 the length-disaggregated indices are plotted against the predicted numbers in the stock as a time series. The fit between observed and predicted is good for the first four and the last length groups (– < 13.5, 13.5–19.5, 19.5–29.5, 29.5–55.5, 55.5–74.5 and > 74.5 cm). However, for the size group 55.5-74.5 cm, which is the size accounting for the largest part of the harvestable biomass, the fit between observed and predicted is low. Part of the explanation for a poor fit is that there has been a small dynamic range of the stock in this size group (12-18 million fish). However, this is also the size range where bimodality in the length distributions (see Figure 15.1.14) interferes with the model fit to spring survey proportions at length, which is more likely explained by spatial variation in growth or catchability than cohort structure. Therefore, the model settings of having the same catchability all years for this size group could also be a problem: catchability might instead vary depending on which part of the range 55.5-74.5 cm is most heavily populated. Current values (intersection of the green lines in Figure 15.1.18) shows that the model predictions are lower in the terminal year for all length groups except 5.5-13.5cm. Although the model does not fit the 55.5-74.5 cm length group, it does not appear to be biased toward overestimation in this range because the model predictions are lower than the observed values towards the end of the time series.

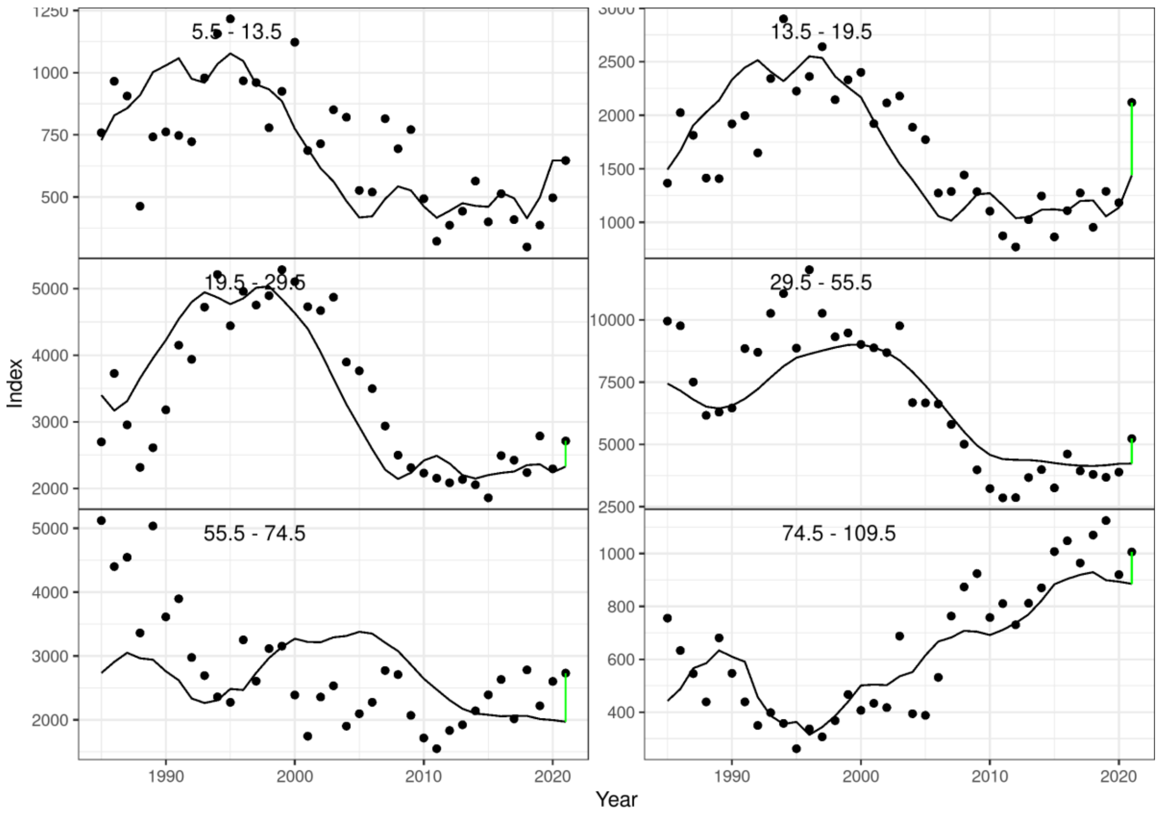

Figure 15.1.18. Atlantic wolffish. Fitted spring survey index by length group from the Gadget model (black line) and the observed biomass index in the survey (points). The green line indicates the difference between the terminal fit and the observations.

15.1.5 Model results

Model results show that Atlantic wolffish total biomass levels decreased from high levels in 2000 – 2006 to current levels. Excluding biomass values earlier than 1985, which are highly uncertain because spring survey data begin in 1985, current total biomass levels are on par with those in 2013, which represent a minimum in the more reliable post-1985 portion of the time series. This pattern contrasts with that of a higher value for harvestable biomass, which represents larger fish. This decrease in total biomass therefore indicates a smaller proportion of smaller fish contribution to total biomass and appears to be due to a halving of recruitment levels from roughly 20 million prior to 2000 to roughly 10 million after 2000. However, following a step decrease in landings and fishing mortality from high levels in 2009 to current levels, total biomass levels have been relatively stable after 2010 (Figure 15.1.19).

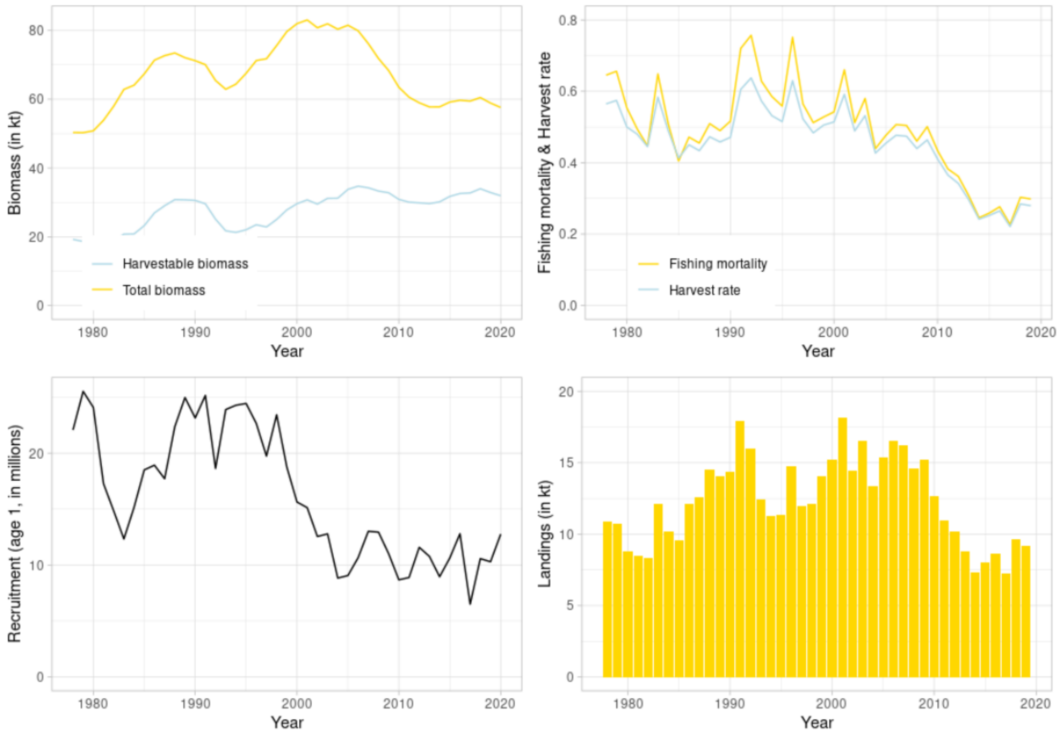

Figure 15.1.19. Atlantic wolffish in 5.a. Estimated biomass, spawning stock biomass (SSB), fishing mortality for fully selected fish and harvest rate, recruitment and total catches.

15.1.6 Management

The Ministry of Industries and Innovation is responsible for management of the Icelandic fisheries and implementation of legislation. Atlantic wolffish was included in the ITQ system in the 1996/1997 quota year and as such subjected to TAC limitations. From that time to the fishing year 2004/2005, the catch was on average 5% more than recommended by the MRI, although in some years it was lower than advised TAC. In the fishing years 2005/2006 to 2011/2012, the catch was on average around 34% above the advised TAC. The main reasons were that national TAC was set higher than the advised TAC, and quota of other species were being transferred to Atlantic wolffish quota (Table 15.1.2, Figure 15.1.6). Net transfer of Atlantic wolffish quota for each fishing year is usually less than 10%.

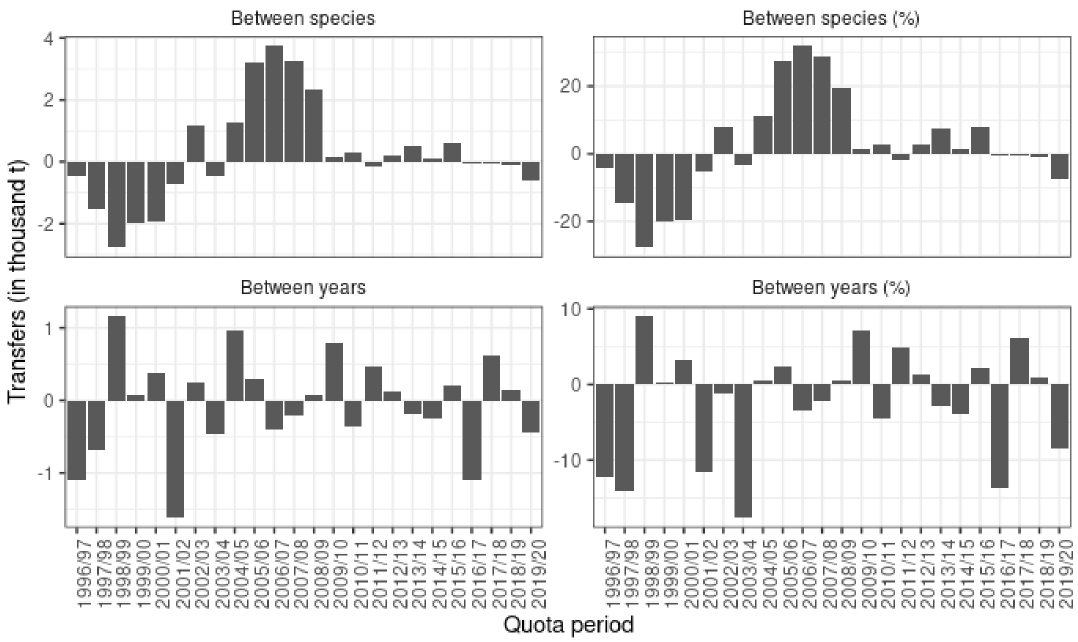

Figure 15.1.20: Atlantic Wolffish in 5.a. Net transfer of quota, from Atlantic Wolffish to other species, in the Icelandic ITQ system by fishing year.

15.1.7 Current Advisory Framework

The F used for advice is F_{max} from yield per recruit analysis of the stock (Figure 23). The model is size-based, and M = 0.1 is relatively low so F_{max} is expected to be precautionary harvesting strategy. Formal HCR evaluation is expected to take place in the winter 2022. The advice is based on F for fully recruited fish or 90 cm, which is set equal to F_{90cm} = 0.3 in the advice (blue solid line in Figure 15.1.20).

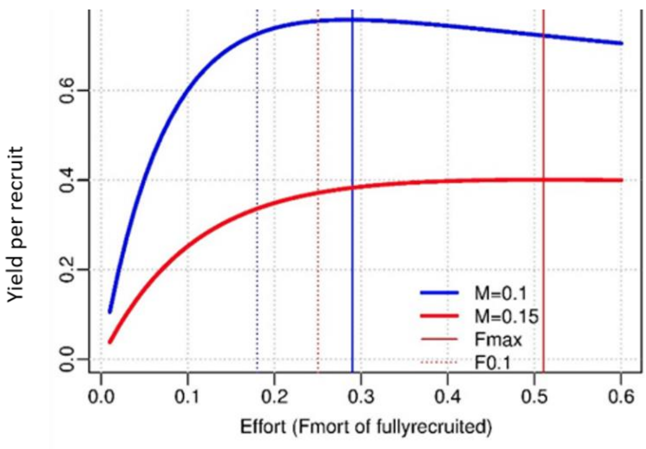

Figure 15.1.20. Atlantic wolffish. Yield per recruit as function of fishing mortality of fully recruited Atlantic wolffish.

15.1.8 Management considerations

A reduction in fishing mortality has led to harvestable biomass and SSB that seem to be stable. Atlantic wolffish is a slow-growing late-maturing species, therefore closures of known spawning areas should be maintained and expanded if needed. Similarly, closed areas fishing where there is high juvenile abundance should also be maintained and expanded if needed.

15.1.9 Ecosystem considerations

Most fishing for Atlantic wolffish occurs in the northwest and west of Iceland, where the fastest growing Atlantic wolffish are found. A likely cause for differences in growth is environmental differences between the relatively warm southwestern waters versus colder northeaster waters. However, Atlantic wolffish are also highly sedentary, especially while guarding nests during spawning and rearing season, and therefore additional metapopulation structure cannot be excluded. Therefore, it is possible that local depletion may occur in more heavily fished areas despite a stable overall biomass level.

Table 15.1.1. Atlantic wolffish in 5.a. Number of Icelandic vessels reporting catch of 10 tonnes/year or more of Atlantic wolffish, and all landed catch divided by gear type.

Number of vessels					Catch (tonnes)				
Year	Longliners	Trawls	Seiners	Other	Longline	Trawl	D. seine	Other	Sum
2000	172	76	20	1	9979	4173	834	241	15227
2001	198	76	19	4	12595	4319	862	394	18170
2002	151	65	14	3	8897	4423	800	304	14424
2003	142	63	25	1	8943	5960	1402	263	16568
2004	109	60	40	2	5746	5349	2010	216	13321
2005	96	64	34	0	6370	7247	1552	177	15346
2006	136	66	32	1	7962	6885	1569	144	16560
2007	124	65	27	1	6655	7857	1551	171	16234
2008	100	60	25	2	5810	7026	1642	152	14630
2009	124	58	34	1	7896	5709	1462	143	15210
2010	82	46	23	2	6923	4531	1033	175	12662
2011	68	36	18	0	6094	4062	1138	97	11391
2012	80	28	21	0	6209	2910	992	103	10214
2013	77	29	19	2	5537	2424	721	110	8792
2014	77	22	17	1	4463	1722	1006	138	7329
2015	68	34	18	2	4828	1926	1097	137	7988
2016	65	37	19	3	5563	1713	1201	148	8625
2017	65	26	19	1	4586	1243	1286	128	7243
2018	67	40	26	4	5657	1689	2185	125	9656

2019	66	36	22	1	5223	1748	2154	90	9215
2020					2984	2147	2147	54	7340

Table 15.1.2: Atlantic wolffish in 5.a. Advised TAC, national TAC and total landings since the quota year 2013/2014.

Fishing Year	MFRI Advice	National TAC	Landings
2013/14	7500	7500	7531
2014/15	7500	7500	7862
2015/16	8200	8200	8982
2016/17	8811	8811	7545
2017/18	8540	8540	9515
2018/19	9020	9020	9355
2019/20	8344	8344	7340
2020/21	7500	7500	7531
2021/22			

Table 15.1.3. Atlantic wolffish. Number of samples and aged otoliths from landed catch of Atlantic wolf-fish.

Year	Longline		Demersal trawl		Demersal seine	
	Samples	Otoliths	Samples	Otoliths	Samples	Otoliths
2010	29	1669	18	1040	5	285
2011	14	750	15	778	9	550
2012	26	1300	14	700	7	350
2013	25	1249	14	692	5	249
2014	30	800	26	675	28	700
2015	25	625	19	479	19	474
2016	25	625	13	325	9	225
2017	23	575	9	220	6	150
2018	22	550	9	225	17	425
2019	22	537	10	245	20	480
2020	9	223	12	294	16	386