

SPOTTED WOLFFISH

Anarhichas minor

GENERAL INFORMATION

Spotted wolffish has been exploited for many years in Icelandic waters. It is an elongate fish characterised by dark spots on its skin and sharp, protruding teeth. In catches, the common length range of spotted wolffish is 60-90 cm, although the largest individual caught in Icelandic waters was 144 cm. Spotted wolffish is mainly found in the northern parts of the continental shelf of Iceland. They reside on sandy or muddy substrate at depths ranging from 100-400 m. In Icelandic waters, female spotted wolffish mature at an average length of 83 cm and age of 9 years. Prior to maturity, mean annual growth is approximately 6.5 cm.

THE FISHERY

From 1982-1995, the catch of spotted wolffish was fairly stable, averaging just over 900 tonnes each year, the majority of which was caught by bottom trawlers. From 1995, catches gradually increased to a historical high of 3640 tonnes in 2006. This increase was mostly due to increased catch on longlines. Since 2006, the annual catch has generally declined between years and was 1193 tonnes in 2021, a similar value to the catch in 1997 (Figure 4). The main fishing grounds for spotted wolffish are located northwest of Iceland (Figure 1). Prior to 2000, most of the catches were taken in the NE area. However, the proportion of catches in the NW area has been gradually increasing since 2000. In 2021, catches in the NE and NW areas accounted for 79% of all catches (Figures 1 and 2).

Approximately 6% of the catch of spotted wolffish is caught at depths less than 100 m, and ~20-30% is caught from 100-200 m (Figure 3). From 2000-2004, approximately 50% of the spotted wolffish catch was caught at depths between 200 and 300 m, decreasing to approximately 40% in the following years. The catch taken at more than 300 m has been relatively stable (20-25%) since 2000 (Figure 3).

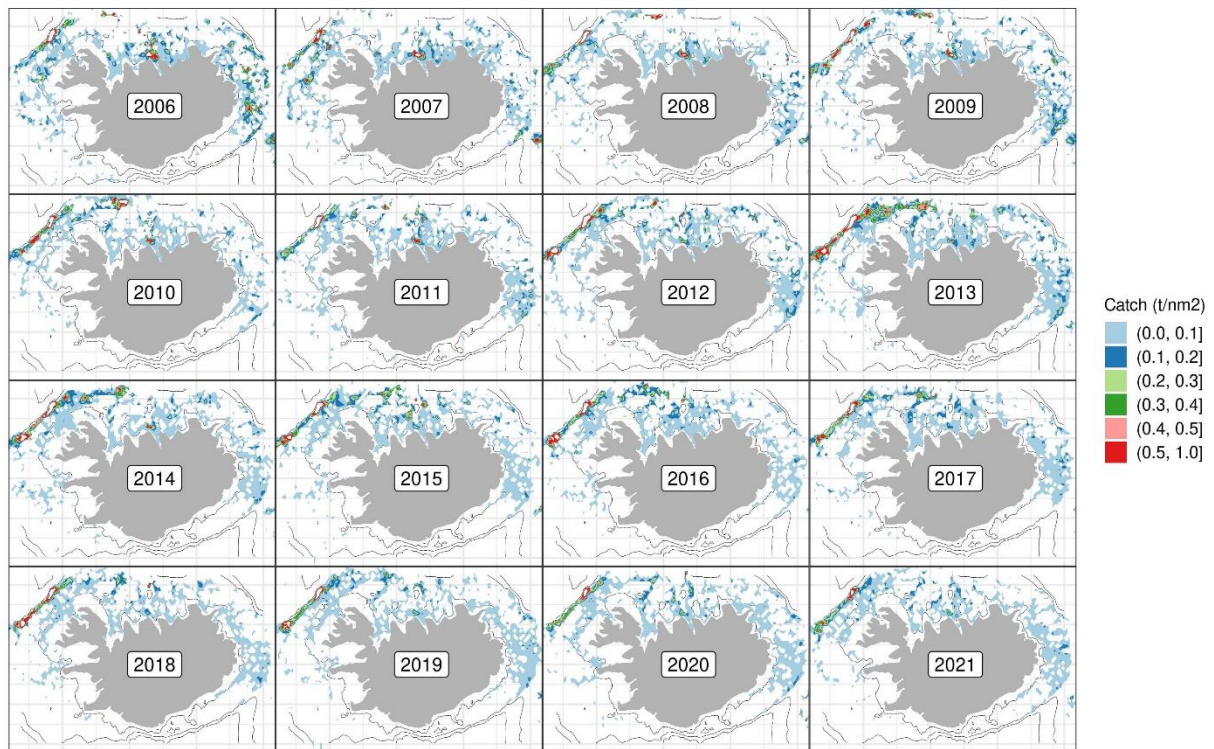


Figure 1: Spotted wolffish. Geographic distribution of the Icelandic fishery since 2006 (logbooks records).

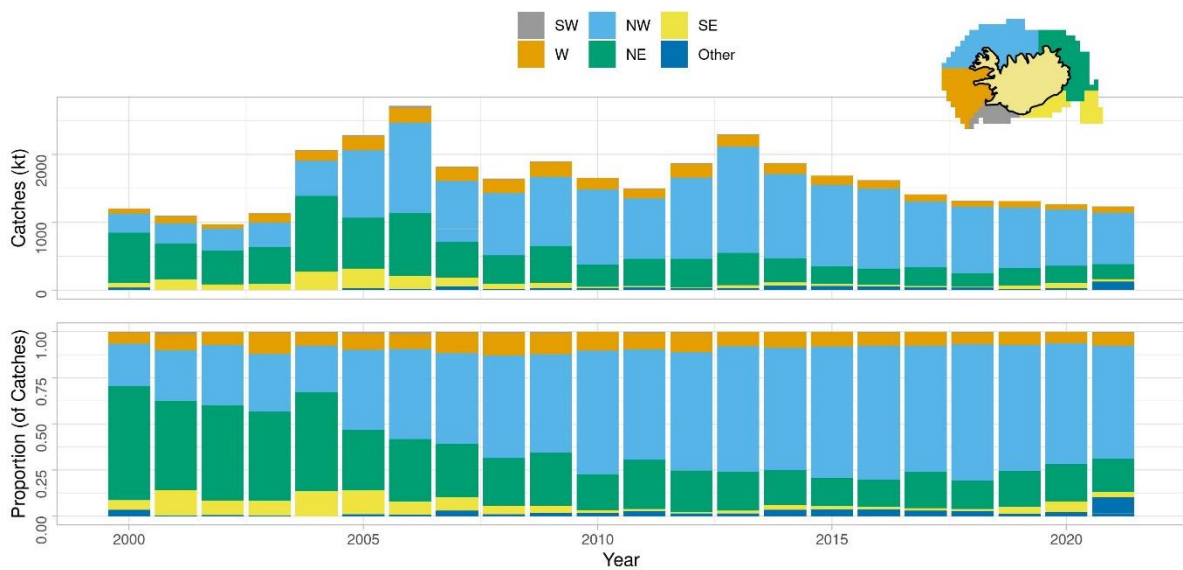


Figure 2: Spotted wolffish. Annual spatial distribution of catches according to logbooks. All gears combined.

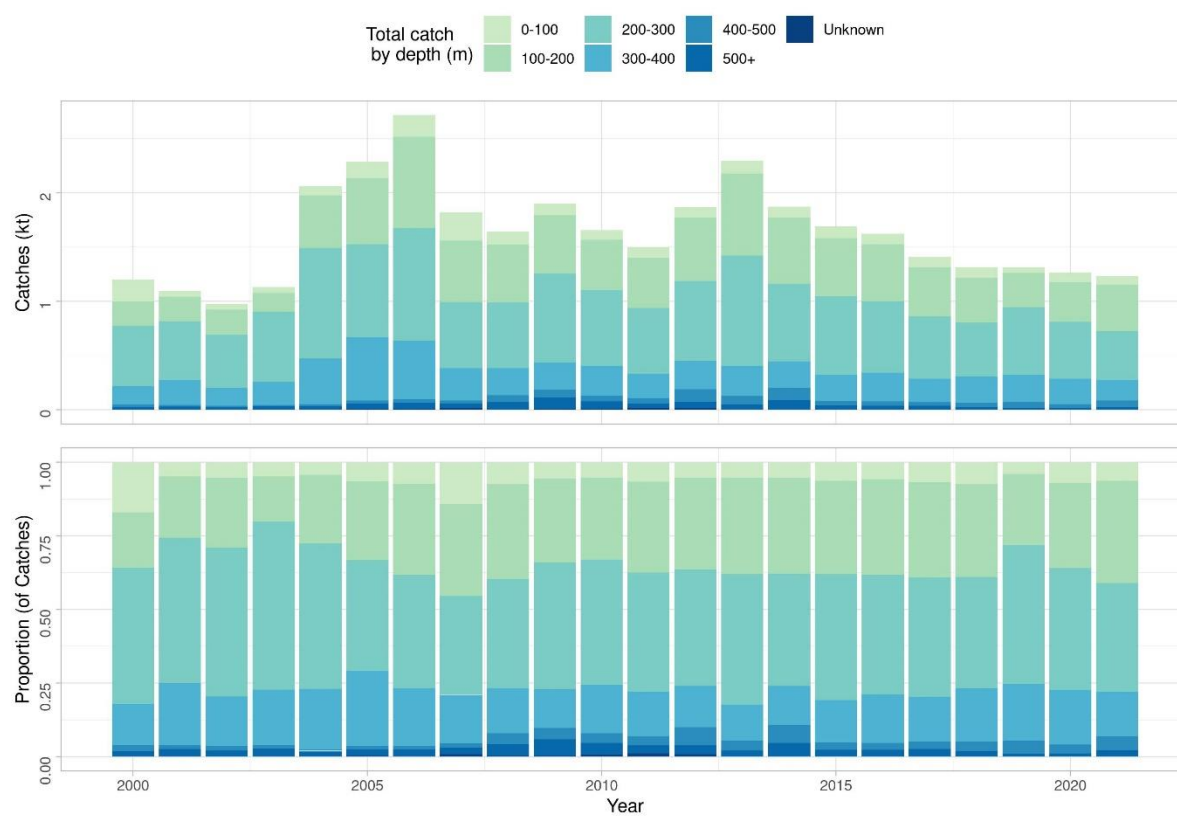


Figure 3: Spotted wolffish. Depth distribution of catches according to logbooks. All gears combined.

Around 98% of landed spotted wolffish is caught on longline and in demersal trawl. From 2000-2003, demersal trawls caught greater than 60% of the total catch. Following this period, the proportion of catch by longline increased, peaking at approximately 66% in 2013. Subsequently, the proportion of catch by longline has decreased to levels that are similar to the proportion caught in demersal trawl. Since 2018, both gear types have caught approximately 50% of the total catch (Figure 4).

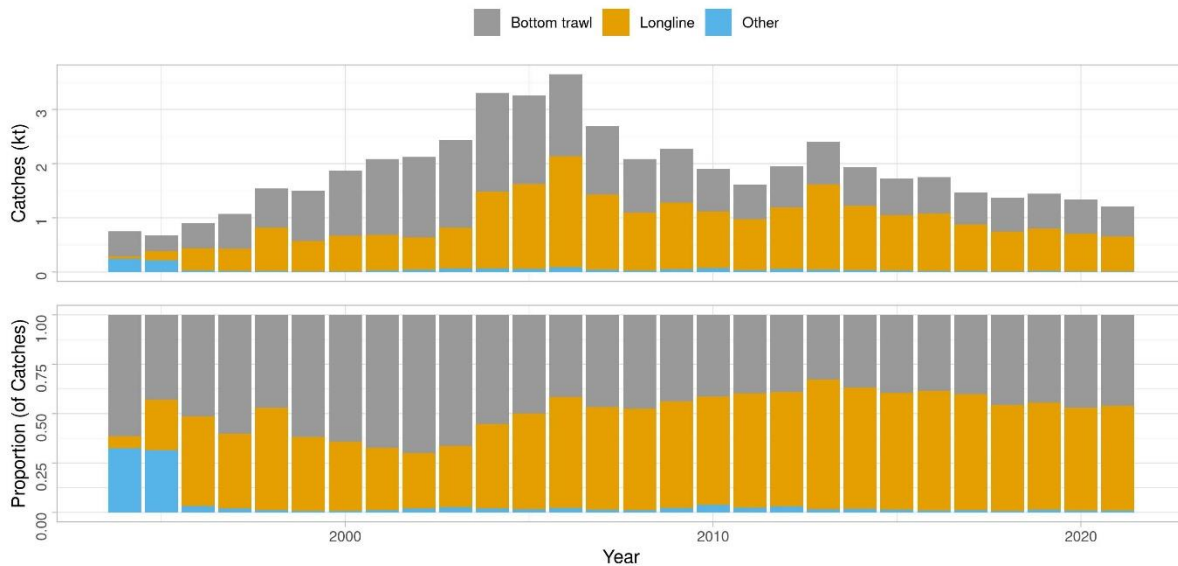


Figure 4: Spotted wolffish. Total catch (landings) by fishing gear, according to statistics from the Directorate of Fisheries.

In 2000-2006, the number of longliners reporting catches of 1000 kg/year or more of spotted wolffish increased from 27 to 127 (Table 1). At the same time catches on longline increased from 654 to 2052 tonnes. Since then, the number of longliners reporting spotted wolffish catches has decreased to around 50 vessels in the last few years, whilst annual longline catches have ranged from 600-1500 tonnes since 2008, and are currently at similar levels to the catches in 2000-2003. The number of trawlers has varied from 50-80 between 2000 and 2021 with no observable trend. However, catches in demersal trawl since 2008 have dropped to about 50% of the catches from 2000-2007 (Table 1).

In 1996, longliners caught greater than 400 tonnes of spotted wolffish. This signified the increased targeting of spotted wolffish by longliners because prior to 1996 the annual catch was usually less than 100 tonnes. This increased effort could be related to the fact that in the fishing year 1996/97, the closely related species, Atlantic wolffish, was included in ITQ system for the first time.

Table 1. Spotted wolffish. Number of Icelandic vessels reporting catch of 1000 kg/year or more, and all landed catch divided by gear type according to statistics from the Directorate of Fisheries.

| YEAR | NUMBER OF VESSELS | | | CATCHES (TONNES) | | | |
|------|-------------------|----------|-------|------------------|-------|-------|-------|
| | Longline | Trawlers | Other | Longline | Trawl | Other | Sum |
| 2000 | 27 | 74 | 3 | 654 | 1 185 | 12 | 1 851 |
| 2001 | 32 | 66 | 2 | 654 | 1 401 | 26 | 2 081 |
| 2002 | 36 | 69 | 3 | 591 | 1 488 | 30 | 2 109 |
| 2003 | 52 | 69 | 4 | 757 | 1 614 | 26 | 2 397 |
| 2004 | 72 | 72 | 9 | 1 412 | 1 816 | 47 | 3 275 |
| 2005 | 99 | 67 | 6 | 1 573 | 1 624 | 38 | 3 235 |
| 2006 | 127 | 66 | 3 | 2 052 | 1 511 | 73 | 3 636 |
| 2007 | 115 | 71 | 5 | 1 391 | 1 255 | 38 | 2 685 |
| 2008 | 84 | 61 | 2 | 1 073 | 990 | 24 | 2 088 |
| 2009 | 84 | 62 | 2 | 1 226 | 998 | 51 | 2 275 |
| 2010 | 76 | 58 | 1 | 1 045 | 786 | 71 | 1 903 |
| 2011 | 79 | 57 | 2 | 934 | 642 | 38 | 1 614 |
| 2012 | 79 | 61 | 1 | 1 129 | 761 | 59 | 1 950 |
| 2013 | 90 | 61 | 0 | 1 575 | 788 | 39 | 2 402 |
| 2014 | 84 | 55 | 0 | 1 166 | 712 | 36 | 1 915 |
| 2015 | 79 | 53 | 0 | 1 008 | 683 | 24 | 1 716 |
| 2016 | 69 | 51 | 0 | 1 031 | 676 | 18 | 1 725 |
| 2017 | 59 | 54 | 1 | 818 | 589 | 18 | 1 424 |
| 2018 | 62 | 50 | 1 | 718 | 625 | 10 | 1 353 |
| 2019 | 47 | 50 | 3 | 729 | 640 | 20 | 1 389 |
| 2020 | 56 | 52 | 1 | 658 | 630 | 14 | 1 302 |
| 2021 | 45 | 49 | 1 | 625 | 559 | 13 | 1 196 |

The number of vessels accounting for 95% of the annual catch of spotted wolffish ranges from 75-150 (Figure 5). Despite an increase in catches from 1996-2003, the number of vessels remained relatively stable during this period. However, from 2004-2006, the number of vessels increased when annual catches exceeded 3000 tonnes. Since 2007, a drop in the number of vessels accounting for 95% of the catches has coincided with catch reductions (Figure 5).

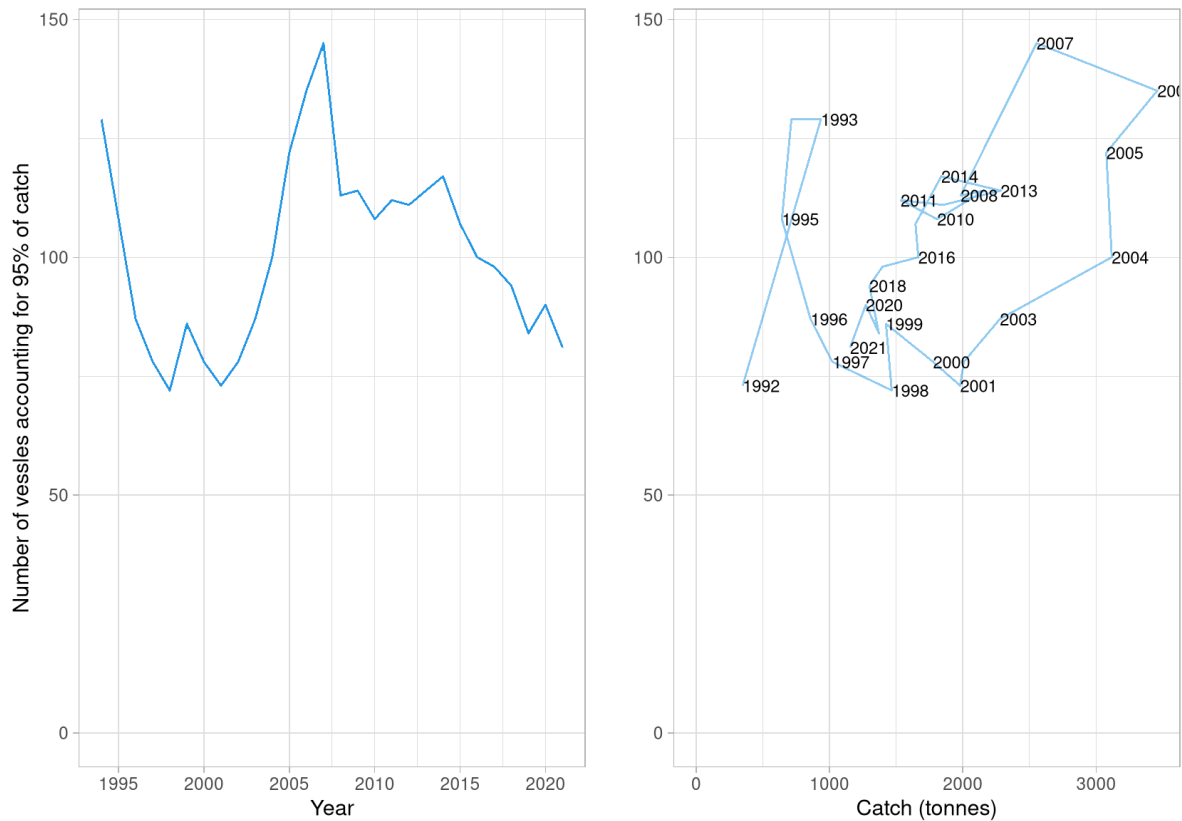


Figure 5. Spotted wolffish. Number of vessels (all gear types) accounting for 95% of the total catch annually since 1994. Left: Plotted against year. Right: Plotted against total catch. Data from the Directorate of Fisheries.

CATCH PER UNIT EFFORT (CPUE) AND EFFORT.

When catch per unit effort (CPUE) is estimated, changes in fleet composition, technical improvements, and differences in gear setup have not been considered. Therefore, CPUE estimates of spotted wolffish in Icelandic waters are not considered to be representative of stock abundance.

CPUE of longline (kg/1000 hooks) and demersal trawl (kg/tow-hour) were calculated as the total weight in sets or tows that spotted wolffish accounted for more than 10% of the catch, according to logbook records. Similarly, effort of demersal trawl was the number of tow-hours and effort of longline was the number of hooks. In both cases, data was constrained so that spotted wolffish accounted for more than 10% of the catch. Catch in sets and tows as a proportion of the total catch in Iceland has been decreasing from 2000 (about 30%) to 2021 (about 11%).

The estimated longline CPUE has no clear trend; it was highest in 2003 (94 kg/1000 hooks) and lowest in 2021 (39 kg/1000 hooks). Estimates of CPUE from demersal trawl fluctuated between 93 and 150 kg/h from 2000-2010, also with no clear trend. From 2011 (111 kg/h) to 2020 (119 kg/h), CPUE has generally increased with the highest value of 156 kg/h occurring in 2017 (Figure 6).

Longline effort increased from 6 million hooks in 2000 to around 11 million hooks in 2006, but since then it has been decreasing and was around 1.9 million hooks in 2021. Fishing effort of demersal trawl was in the range of 1500-2350 tow-hours in 2000-2006. Since 2006 the effort has been decreasing and was around 550 tow-hours in 2021 (Figure 6).

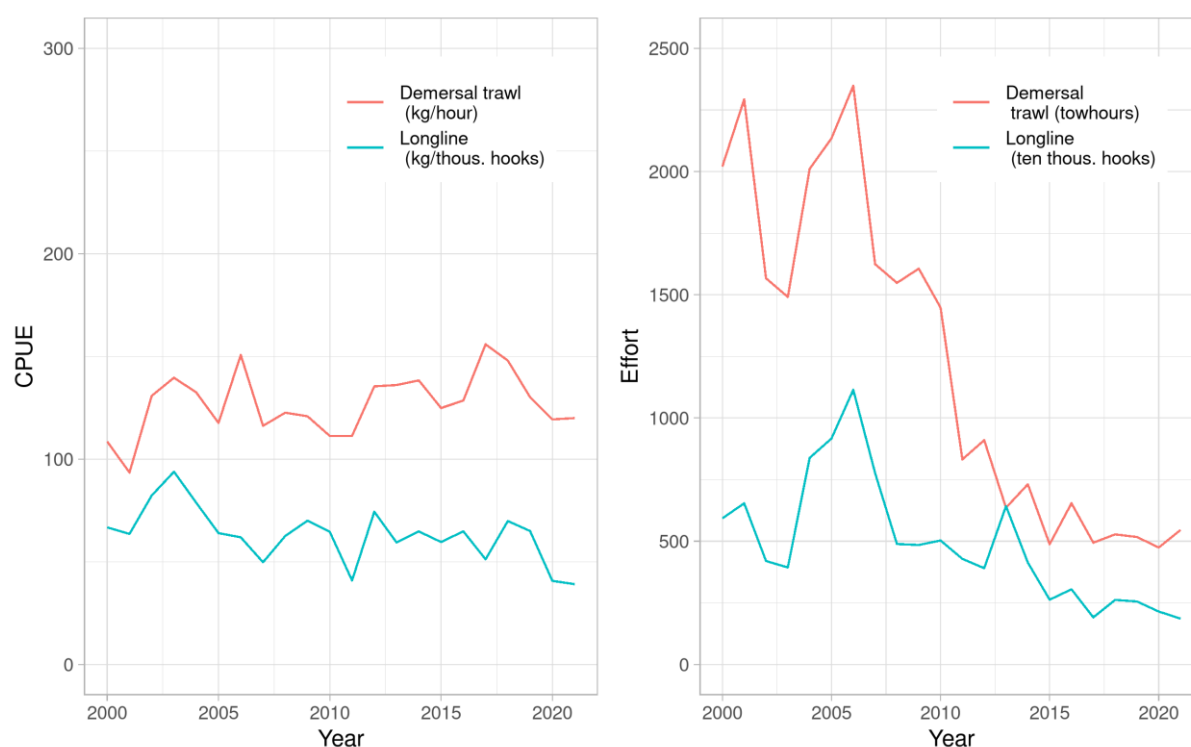


Figure 6: Spotted wolffish. Non-standardised estimates of CPUE (left) from demersal trawl (kg/h, red) and longline (kg/1000 hooks, blue). Fishing effort (right) for demersal trawl (tow hours, red) and longline (10000 hooks, blue).

SAMPLING AND AGE DISTRIBUTION OF LANDED SPOTTED WOLFFISH

Between 400 and 1900 otoliths have been sampled annually for age reading by the MFRI. The number of samples collected from longliners and demersal trawl ranged from 4-45 and 4-30 respectively (Table 2, **Error! Reference source not found.**7). Samples were not taken from other gear types because they represent a small proportion (~2%) of the total catch.

In samples from commercial catches in 2015 about 400 specimens were aged. The estimated age range was 5-16 years, whilst ages 8 and 9 were most common, accounting for approximately 40% of the readings. Age has not been determined for spotted wolffish landed since 2016, but recently age determination began for spotted wolffish from the spring groundfish survey.

Table 2. Spotted wolffish. Number of samples and otoliths sampled from landed catch.

| Year | Longline | | Demersal trawl | |
|------|----------|----------|----------------|----------|
| | Samples | Otoliths | Samples | Otoliths |
| 2007 | 7 | 334 | 5 | 230 |
| 2008 | 9 | 391 | 8 | 352 |
| 2009 | 4 | 200 | 7 | 350 |
| 2010 | 7 | 295 | 8 | 355 |
| 2011 | 7 | 329 | 5 | 246 |
| 2012 | 9 | 432 | 10 | 451 |
| 2013 | 16 | 788 | 4 | 200 |
| 2014 | 45 | 1101 | 30 | 800 |
| 2015 | 19 | 475 | 20 | 500 |
| 2016 | 14 | 350 | 12 | 300 |
| 2017 | 8 | 200 | 9 | 225 |
| 2018 | 8 | 200 | 9 | 225 |
| 2019 | 12 | 300 | 12 | 300 |
| 2020 | 4 | 100 | 12 | 300 |
| 2021 | 18 | 336 | 11 | 270 |

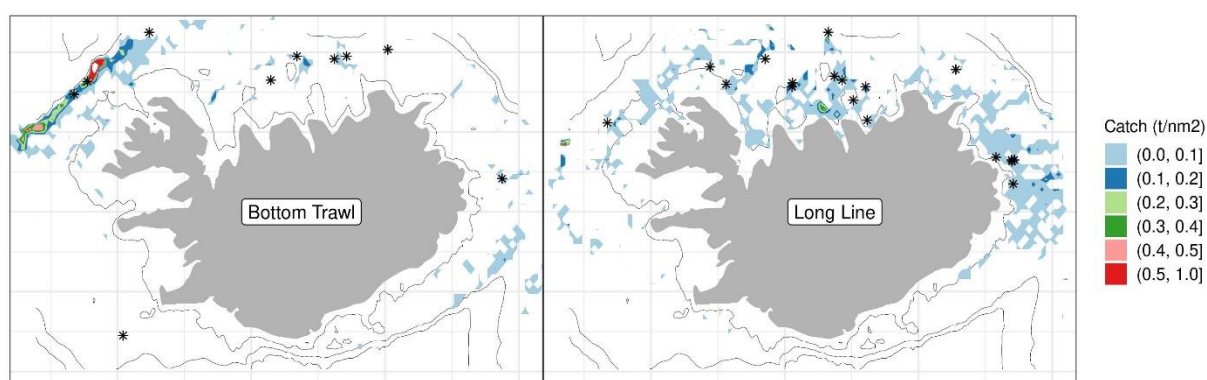


Figure 7: Spotted wolffish. Fishing grounds in 2021 as reported in logbooks and positions of samples taken from landings (asterisks).

LENGTH DISTRIBUTION OF LANDED SPOTTED WOLFFISH

The mean length of spotted wolffish sampled from commercial catches has generally been increasing from 2008 (72 cm) to 2018 (79 cm), since then it has decreased and was 76 cm in 2021 (Figure 8).

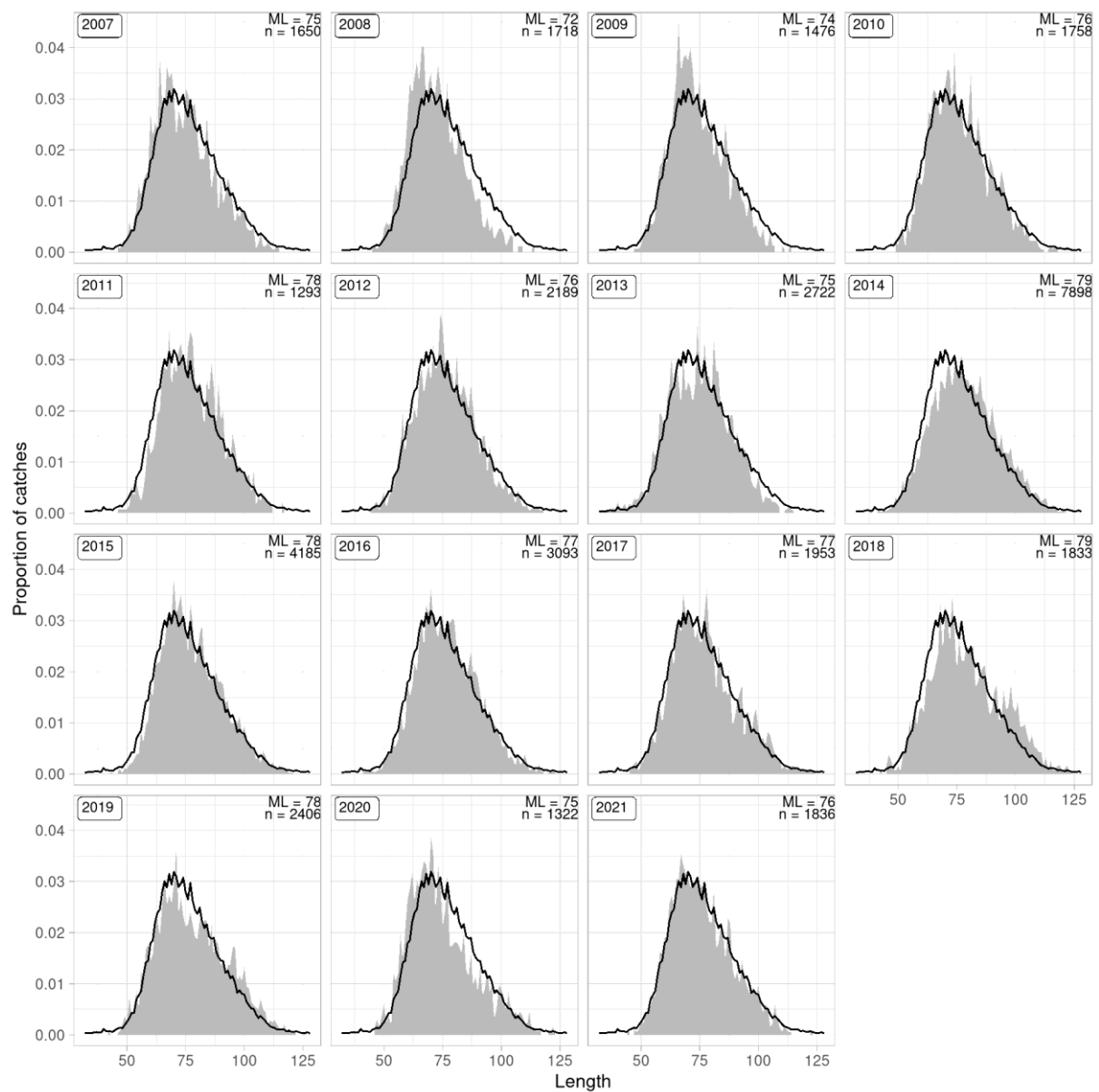


Figure 8: Spotted wolffish. Length distribution of spotted wolffish sampled from landed catch. The black line shows the mean length distribution for all years combined.

SURVEY DATA

The Icelandic spring groundfish survey (hereafter 'spring survey', IS-SMB), which has been conducted annually in March since 1985, covers the most important areas in terms of the distribution of the spotted wolffish fishery. In addition, the Icelandic autumn groundfish survey (hereafter 'autumn survey', IS-SMH) was commenced in 1996 and expanded in 2000. However, a full autumn survey was not conducted in 2011 due to a labour dispute. For spotted wolffish, the spring survey is considered to measure changes in abundance/biomass better than the autumn survey, although from 1996-2003 the Iceland-Faroe ridge was not sampled in the spring survey.

Indices of total biomass and harvestable biomass have been decreasing since 1996, except in the years 2003-2006 (note that in 2004, stations at the Iceland-Faroe ridge were reintroduced in IS-SMB). In 2020, the indices were at a historic low; however, an upward revision was observed in 2021 and a small decline from this revision was observed in the most recent survey (Figure 9).

The recruitment index was high in the years 1992-2000. Since then, it decreased in almost every year to a historic low in 2012. Thereafter, the recruitment index from the spring survey remained stable until 2021 when it increased to a level similar to the 2011 value. Similar to the other biomass indices, the value in 2022 showed a decline from the 2021 level (Figure 9).

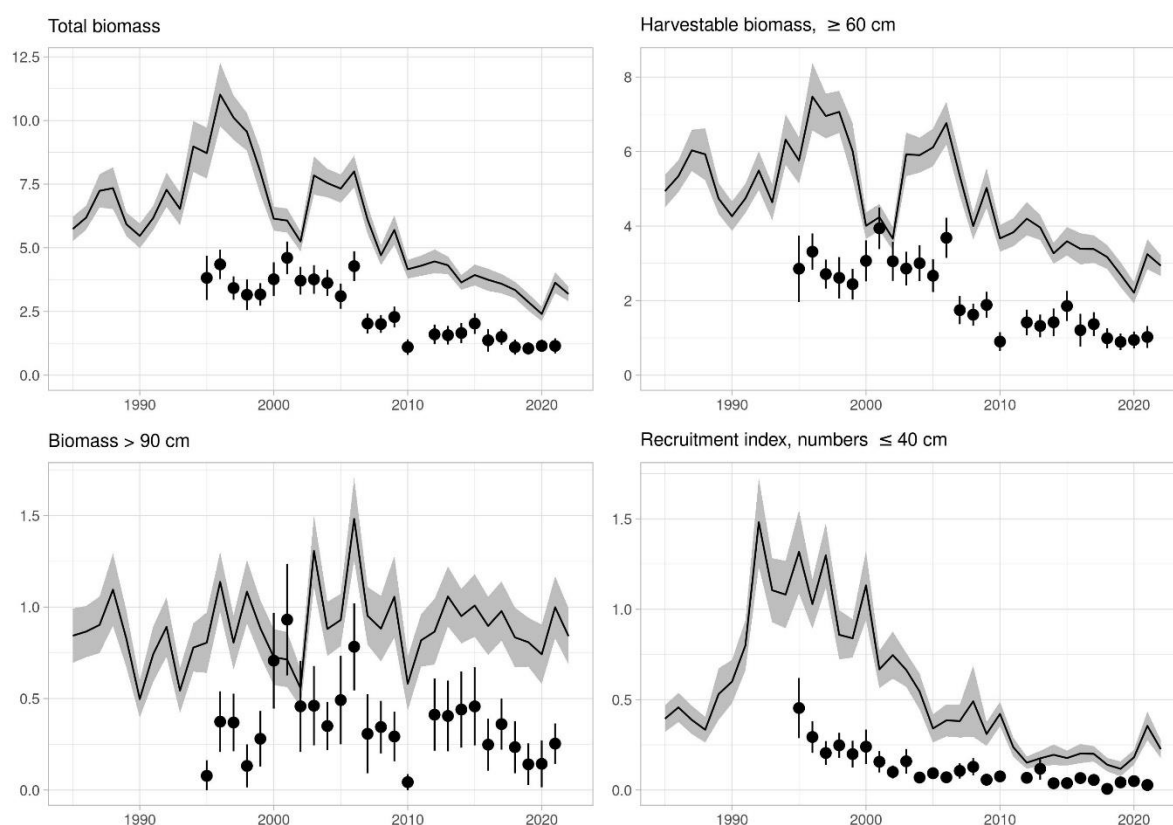


Figure 9: Spotted wolffish. Total biomass indices (upper left), harvestable biomass indices (upper right), large fish biomass indices (lower left) and juvenile abundance indices (lower right) from the spring survey (line) from 1985 and the autumn survey (points) from 1996. The shaded area and point intervals show the standard deviations.

Since 2012, spotted wolffish has mostly been caught in the slope areas northwest and north of Iceland in the spring survey (Figures 10 and 11). Biomass indices from the NW area have been relatively stable throughout the survey period. Greater changes have taken place in the NE area, where biomass increased in 1985-1996 but has decreased significantly since then (Figure 11). In 1996-2003 the Iceland-Faroe ridge

was not sampled in the spring survey, which seems to have resulted a 15-20% underestimation of the total biomass index for spotted wolffish.

Spotted wolffish spawn in late summer or autumn and the distribution of the catch is similar in the autumn and spring surveys, suggesting a spatial proximity between spawning and feeding grounds. (Figures 10 and 11). However, in 1996-2003, a lower proportion of the autumn survey biomass was measured in the NE area compared to the spring survey. In the 2021 autumn survey, the majority of spotted wolffish were caught at the slope areas northwest of Iceland, but the biomass there has been decreasing since 2006. The biomass index in the NE area has been decreasing from 1996, in accordance with the spring survey (Figures 10 and 11).

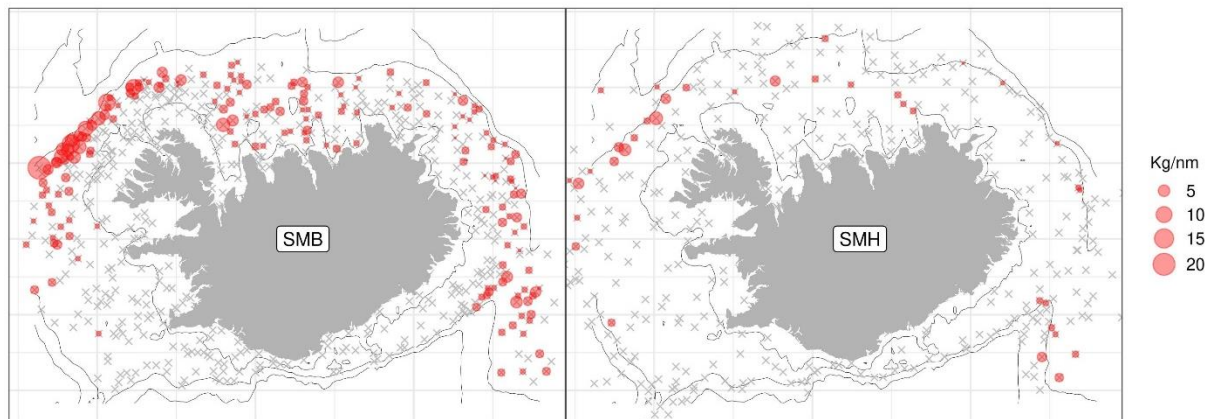


Figure 10: Spotted wolffish. Spatial distribution and abundance in the spring survey (SMB) and autumn survey (SMH) in 2021.



Figure 11: Spotted wolffish. Spatial distribution of the index from the spring survey and autumn survey. Note that the Iceland-Faroe ridge was not sampled in 1996-2003.

The mean length in spring survey decreased from 1986 (62.9 cm) to 1995 (52.1 cm) due to increased abundance of fish smaller than 60 cm (Figure 12). Thereafter, the mean length increased to 69.4 cm in 2019, due to lower abundance of fish smaller than 60 cm. The mean length has decreased since. The number of spotted wolffish caught in the spring survey increased from 1273 fish in 1990 to 2744 fish in 1997. Since then, the number has been declining and reached the lowest level of 353 fish in 2020. In 2021 and 2022, the number of observed fish increased to 550 and 489 individuals respectively.

In 2020, age determination for spotted wolffish from IS-SMB was initialised. Currently, individuals from 2015-2021 have been aged, a total of 1260 fishes. The age of spotted wolffish ranged from 1-16 years, with approximately 70% of the fish between 7 and 12 years (the weighted mean was 8.7 years old). The main purpose of the age determination is to provide data for stock assessment with the Gadget model.

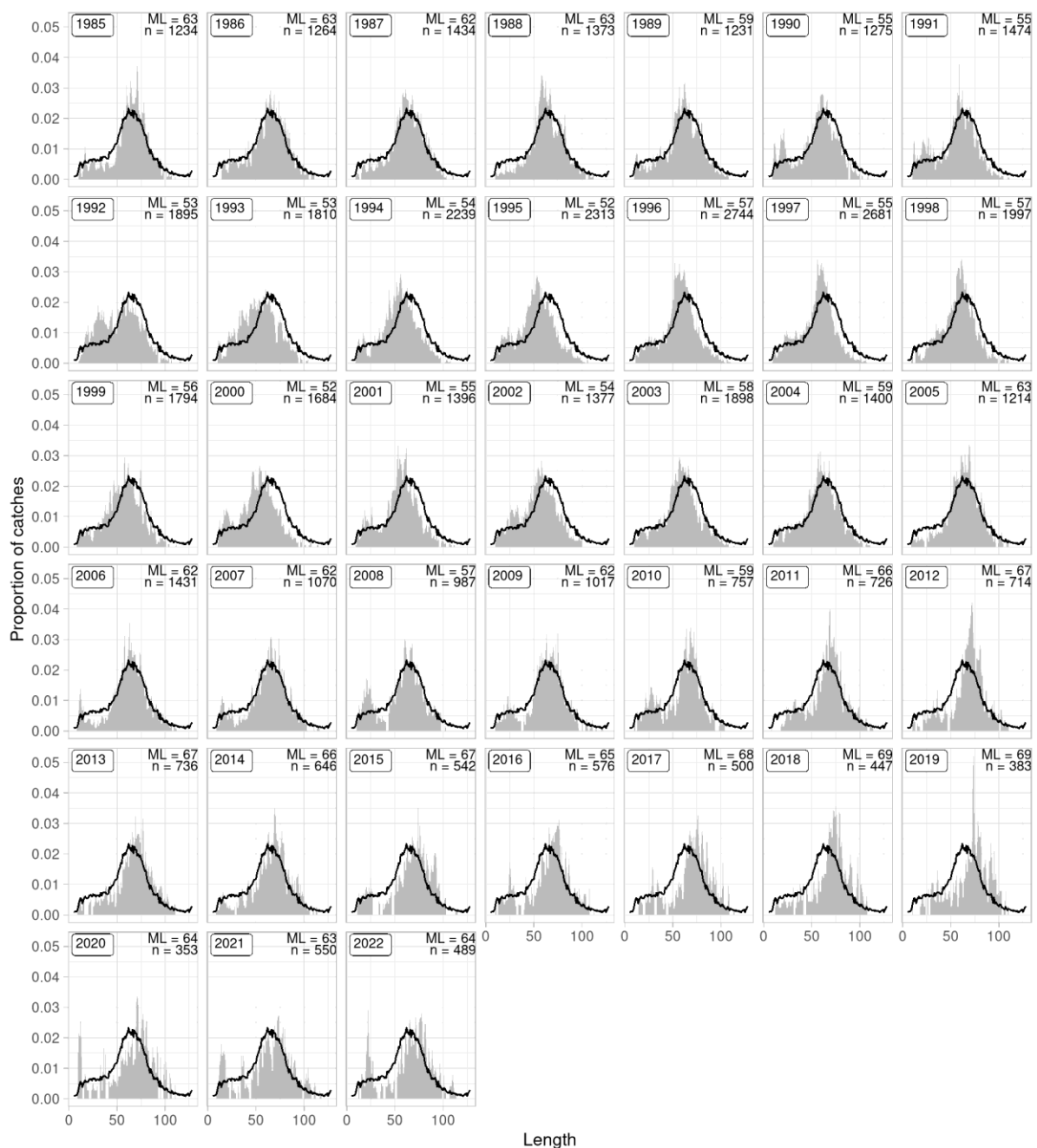


Figure 12: Spotted wolffish. Length abundance indices from the spring survey. The black line shows the mean across all years.

The mean length of spotted wolffish in the autumn survey has increased from 1996 (58.8 cm) to 2018 (70.8 cm). This is in accordance with the spring survey and the reason is decreased abundance of fish smaller than 60 cm (Figure 13). The average number of spotted wolffish caught in the autumn survey was 250 fish in the years 1996-2006. Since then, the number has been decreasing and was on average 90 fish in the years 2010-2017. In 2021, 63 fish were caught in the survey.

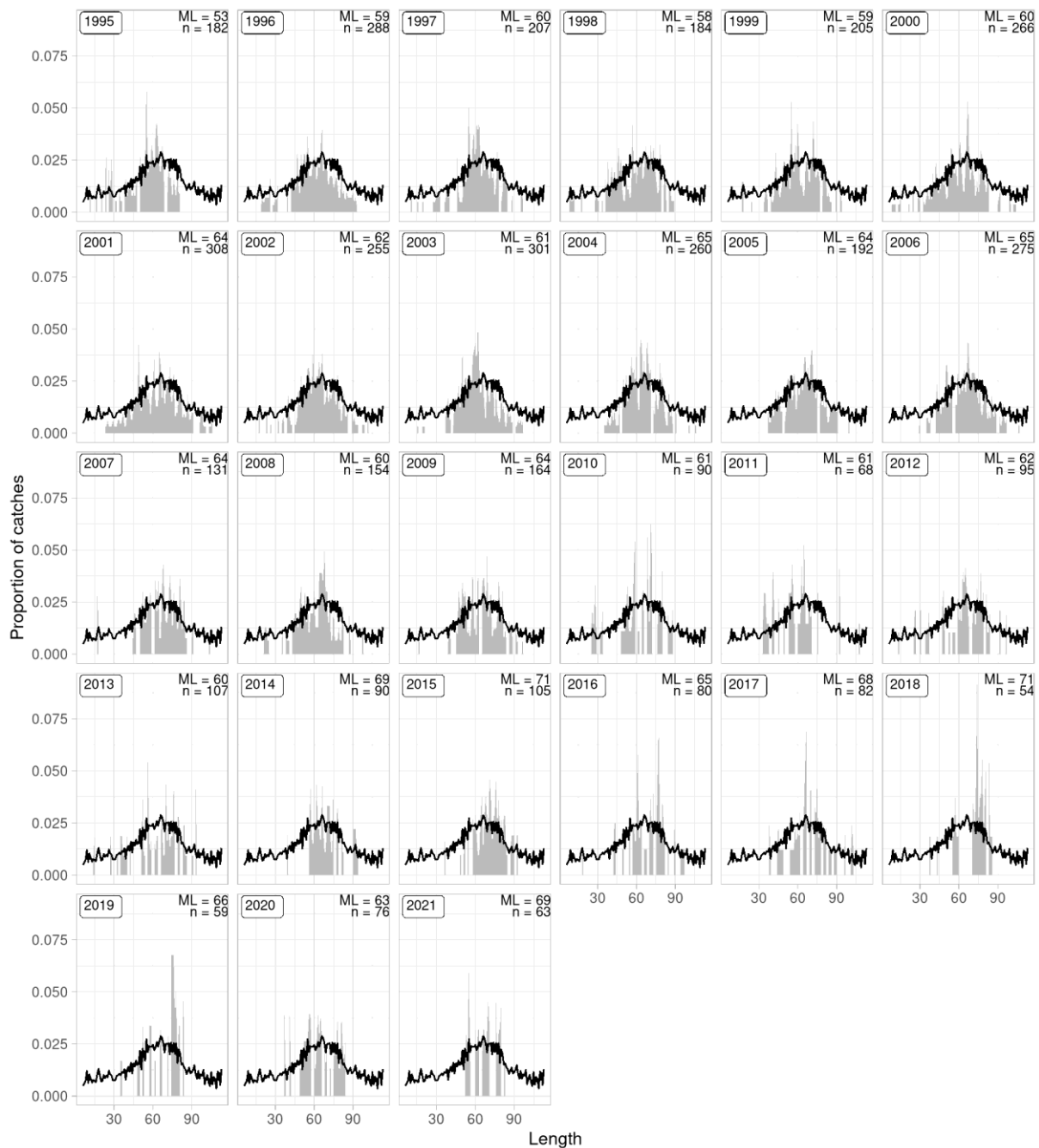


Figure 13: Spotted wolffish. Length distribution from the autumn survey. The black line shows the mean across all years.

MANAGEMENT

The Ministry of Food, Agriculture and Fisheries is responsible for the management of Icelandic fisheries and the implementation of legislation. Spotted wolffish was included in the ITQ system in 2018. The MFRI advised catch based on F_{proxy} for the first time in the fishing year 2012/2013. For the first four fishing years, the advice was based on the average catch in the years 1985-1997 which was approximately 900 tonnes, and the stock size was rather stable during these years. When advising catch for the fishing year 2016/2017, it was decided to use 70% of the average F_{proxy} from the years 2001-2015 as the target F_{proxy} , but the biomass index from the spring survey decreased about 20% at this time. For the fishing year 2019/2020 it was decided, due to low spawning stock biomass and poor recruitment, to set target F_{proxy} on a more precautionary basis than the years before. The mean F_{proxy} for the years 1985-1998 was chosen, because fishing pressure during this period did not have any observed detrimental effects on the stock biomass (Figure 14). Catches of spotted wolffish in the fishing years 2012/2013-2015/2016 were around 100% higher than recommended by the MRI and around 40% higher in each of the next three fishing years and in last fishing year it was about 300% higher (Table 3).

The spotted wolffish stock is now at a historical low level. In 2020, the index values measured were lower than any points observed in the IS-SMB time series. The size of the spawning stock is likely to be below any candidate value of B_{lim} . Management of spotted wolffish fishing effort is difficult as most of its catch is bycatch. Therefore, the advised catch levels are expected to decline in coming years or potentially an advised landing ban of spotted wolffish. Another possibility is that fishermen release spotted wolffish beyond quota. When MFRI was advising catch of spotted wolffish for ongoing fishing year it proposed that fishermen were granted license to released spotted wolffish. This licence was granted by the Ministry of Industries and Innovation on 14 December 2021.

Table 3. Spotted wolffish. Recommended TAC, national TAC, and landings (tonnes).

| FISHING YEAR | REC. TAC | NATIONAL TAC | CATCH |
|--------------|----------|--------------|-------|
| 2012/13 | 900 | - | 2041 |
| 2013/14 | 900 | - | 2241 |
| 2014/15 | 900 | - | 1636 |
| 2015/16 | 900 | - | 1886 |
| 2016/17 | 1128 | - | 1548 |
| 2017/18 | 1080 | - | 1553 |
| 2018/19 | 1001 | 1001 | 1425 |
| 2019/20 | 375 | 375 | 1310 |
| 2020/21 | 314 | 314 | 1266 |
| 2021/22 | 334 | 334 | |

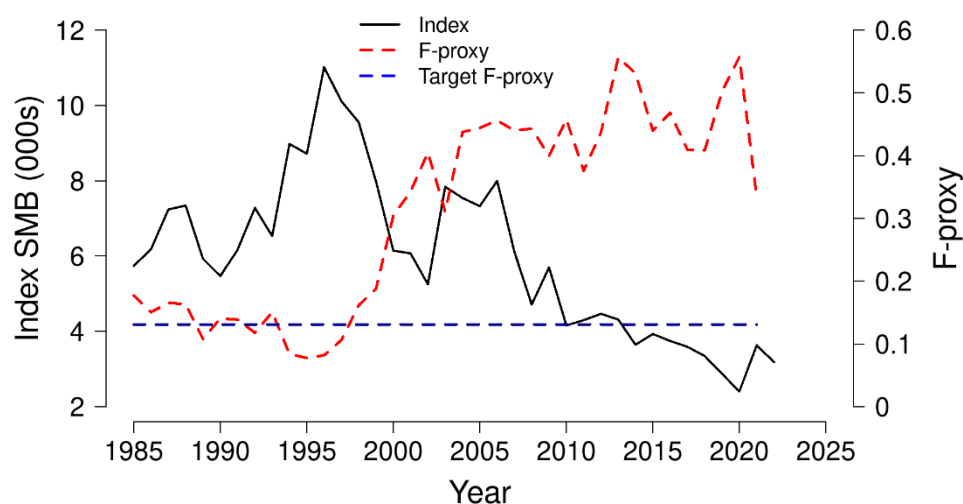


Figure 14. Spotted wolffish. F_{proxy} (catch/survey biomass). The target F_{proxy} is set as the mean of the reference period of 1985-1998.

SURVIVAL OF RELEASED SPOTTED WOLFFISH AFTER CATCH

Fish farming of spotted wolffish was carried out in Iceland from 2001-2006. Adult fish used to produce larvae were collected in conventional bottom trawl fishing and kept onboard in a container with flowing seawater. Observed mortality was negligible both on the fishing vessel and at the farming station where the fish were moved after landing. Observed mortality was also negligible for spotted wolffish sampled by handline for the fish farming.

From 2015-2017, a total of 102 spotted wolffish were tagged with conventional tags in IS-SMB and IS-SMH, and 43 individuals were tagged with DST tags. Recaptures rates were good, indicating that spotted wolffish can tolerate release after catch in bottom trawl. In the tagging experiments, it was a surprise that some of the spotted wolffish survived up to one hour on the fishing ramp. Most of these fish appeared lifeless when put into a container with flowing seawater, but after 5-10 minutes they began to swim actively in the container. In 2021 and 2022, 150 and 240 spotted wolffish were tagged with T-bar anchor tags in IS-SMB respectively. This was carried out to investigate the survival of released fish post-capture in bottom trawl.

Grant and Hiscock (2014) showed that 90% of Atlantic wolffish survived when released two hours after catch in bottom trawl, i.e., the fish could survive two hours on the fishing ramp or the conveyor belt after catch. The authors of this research assumed a similar conclusion could be applied to the related spotted wolffish. In 2020, MFRI carried out preliminary research on how long spotted wolffish can survive on the fishing ramp and conveyor belt in IS-SMH. The results indicate that spotted wolffish can survive up to two hours after catch on the fishing ramp and conveyor belt. Research have shown that spotted wolffish and Atlantic wolffish can tolerate sea with low oxygen content (Foss *et al.*, 2002), which supports the result of the two aforementioned studies.

In 2020, when MFRI recommended that fishermen can release spotted wolffish beyond quota, it was known that survival was high when released after capture in bottom trawl. However, no studies or observation had been carried out on the survival of released spotted wolffish after longline catch. Therefore, the MFRI began to investigate this in autumn 2020. Preliminary results suggest that survival of spotted wolffish is high after being released after capture in longline, it is scheduled to continue this research this year.

REFERENCES

Foss, A., Evensen, T.H., Øiestad, V., 2002. Effects of hypoxia and hyperoxia on growth and food conversion efficiency in spotted wolffish *Anarhichas minor* (Olafsen). *Aquaculture Research* 33, 437-444.

Grant, S.M., Hiscock, W., 2014. Post-capture survival of Atlantic wolffish (*Anarhichas lupus*) captured by bottom otter trawl: Can live release programs contribute to the recovery of species at risk? *Fisheries Research* 151, 169–176.