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 765 tonnes in 2022, similar to 1995. Reduced catches in 2022 may be due the fact that in December 2020 fishermen were granted a permission to release spotted wolffish, possibly leading to significant releases in 2022.

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 gradually increased in 2000-2016, therefrom it has decreased a little. In 2022, catches in the NE and NW areas accounted for 82% of all catches (Figures 1 and 2).

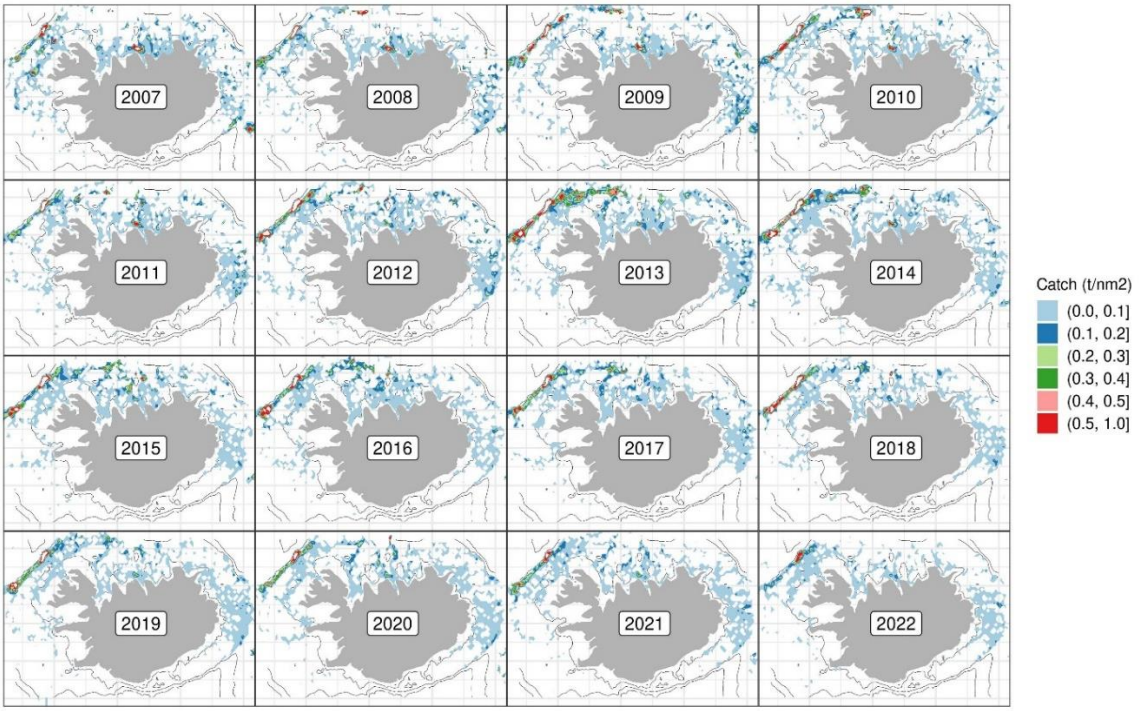

Figure 1: Spotted wolffish. Geographic distribution of the Icelandic fishery since 2006 (logbooks records).

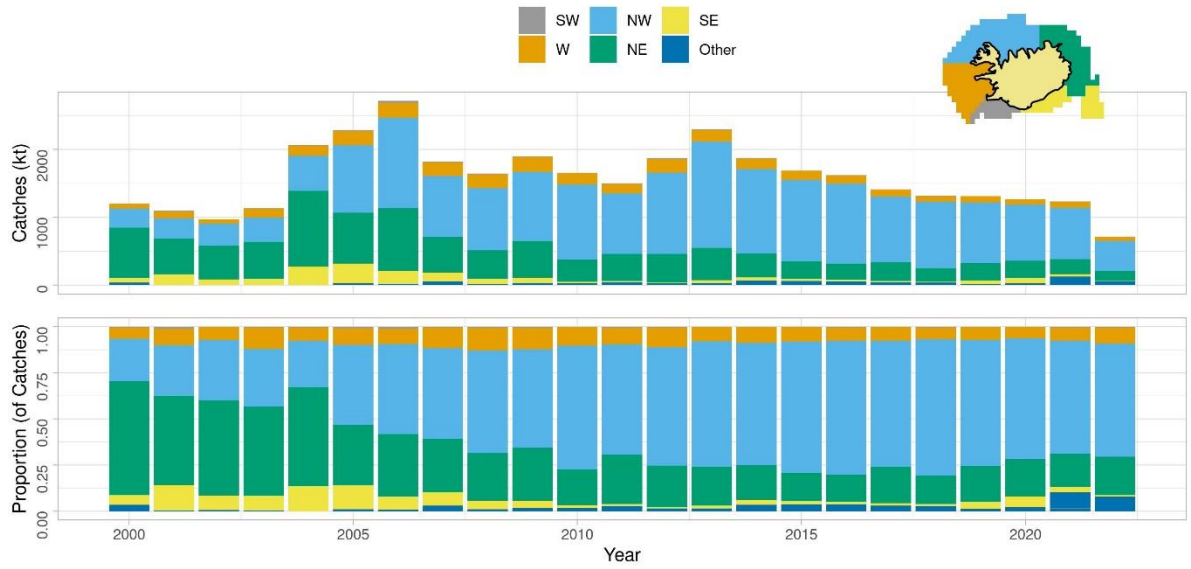

Figure 2: Spotted wolffish. Annual spatial distribution of catches according to logbooks. All gears combined.

Approximately 7% of the catch of spotted wolffish is caught at depths less than 100 m, and about 25-35% 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, since then it has been 35-45%. The catch taken at more than 300 m has been relatively stable (20-25%) since 2000 (Figure 3).

Around 98% of landed spotted wolffish is caught on longline and in demersal trawl. From 2000-2003, demersal trawls caught more 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).

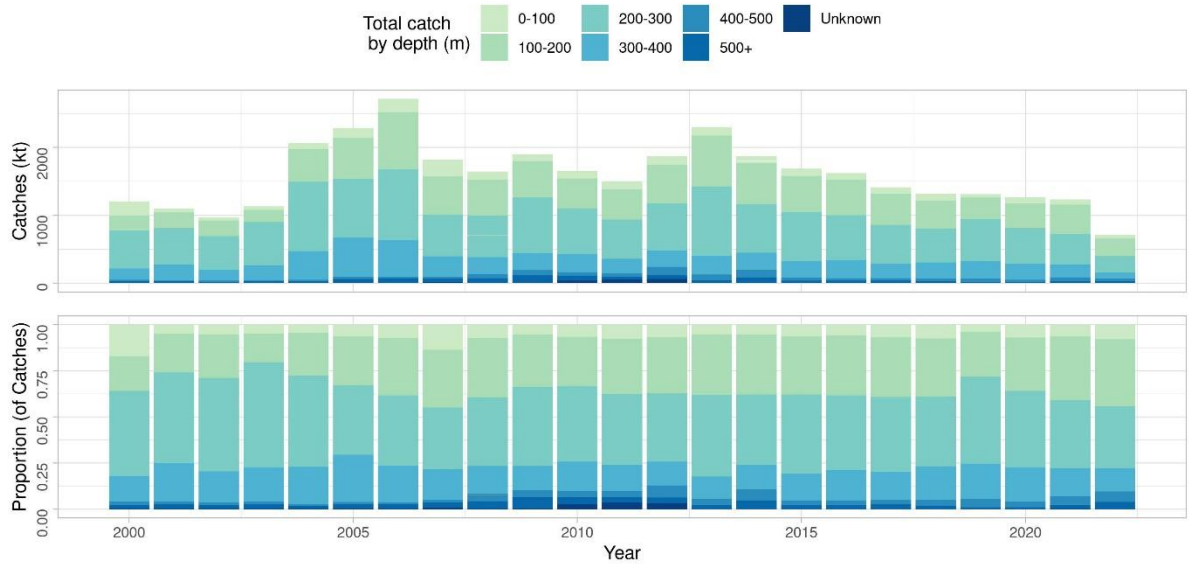

Figure 3: Spotted wolffish. Depth distribution of catches according to logbooks. All gears combined.

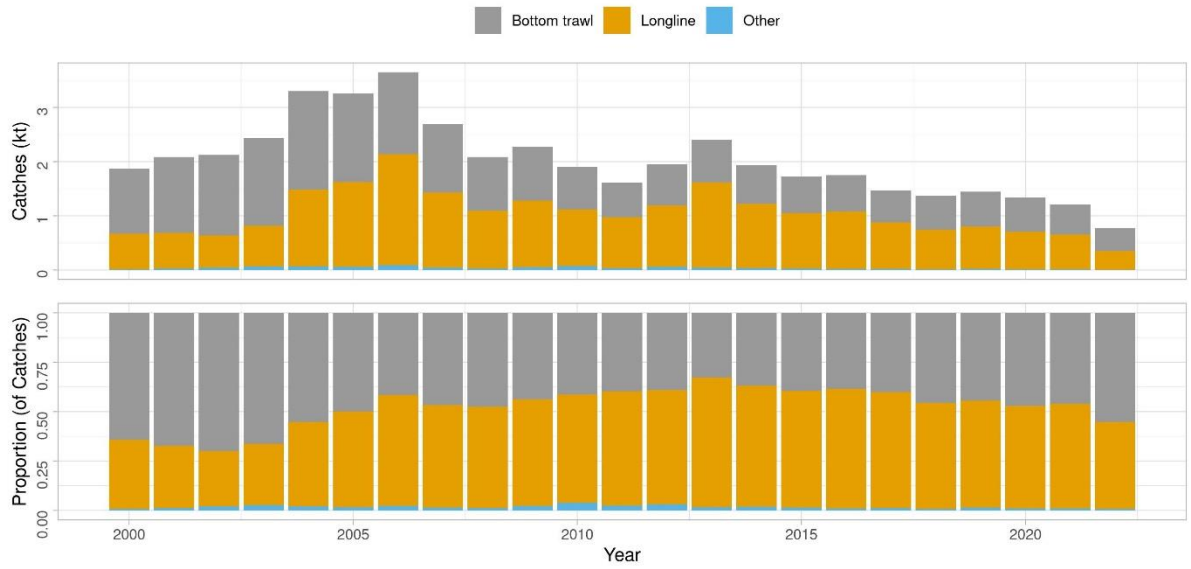

Figure 4: Spotted wolffish. Total catch (landings) by fishing gear, according to statistics from the Directorate of Fisheries.

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	1185	12	1851
2001	32	66	2	654	1401	26	2081
2002	36	69	3	591	1488	30	2109
2003	52	69	4	757	1614	26	2397
2004	72	72	9	1412	1816	47	3275
2005	99	67	6	1573	1624	38	3235
2006	127	66	3	2052	1511	73	3636
2007	115	71	5	1391	1255	38	2685
2008	84	61	2	1073	990	24	2088
2009	84	62	2	1226	998	51	2275
2010	76	58	1	1045	786	71	1903
2011	79	57	2	934	642	38	1614
2012	79	61	1	1129	761	59	1950
2013	90	61	0	1575	788	39	2402
2014	84	55	0	1166	712	36	1915
2015	79	53	0	1008	683	24	1716
2016	69	51	0	1031	676	18	1725
2017	59	54	1	818	589	18	1424
2018	62	50	1	718	625	10	1353
2019	47	50	3	729	640	20	1389
2020	56	52	1	658	630	14	1302
2021	45	49	1	625	559	13	1196
2022	40	43	2	333	425	6	765

In 2000-2006, the number of longliners reporting catches of ≥1000 kg/year of spotted wolffish increased from 24 to 128 (Table 1). At the same time catches on longline increased from 654 to 2052 tonnes. Since then, the number of longliners has decreased and in 2008-2021 they were on the average 60 each year. In 2022 they were only 40 and the catch was similar as it was in 1997. The number of trawlers has varied from 50-80 between 2000 and 2021 with no observable trend, but in 2022 they decreased and were only 43. However, catches in demersal trawl since 2008 have dropped to about 50% of the catches from 2000-2007 and in 2022 the catch was lower than before 1982 (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.

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).

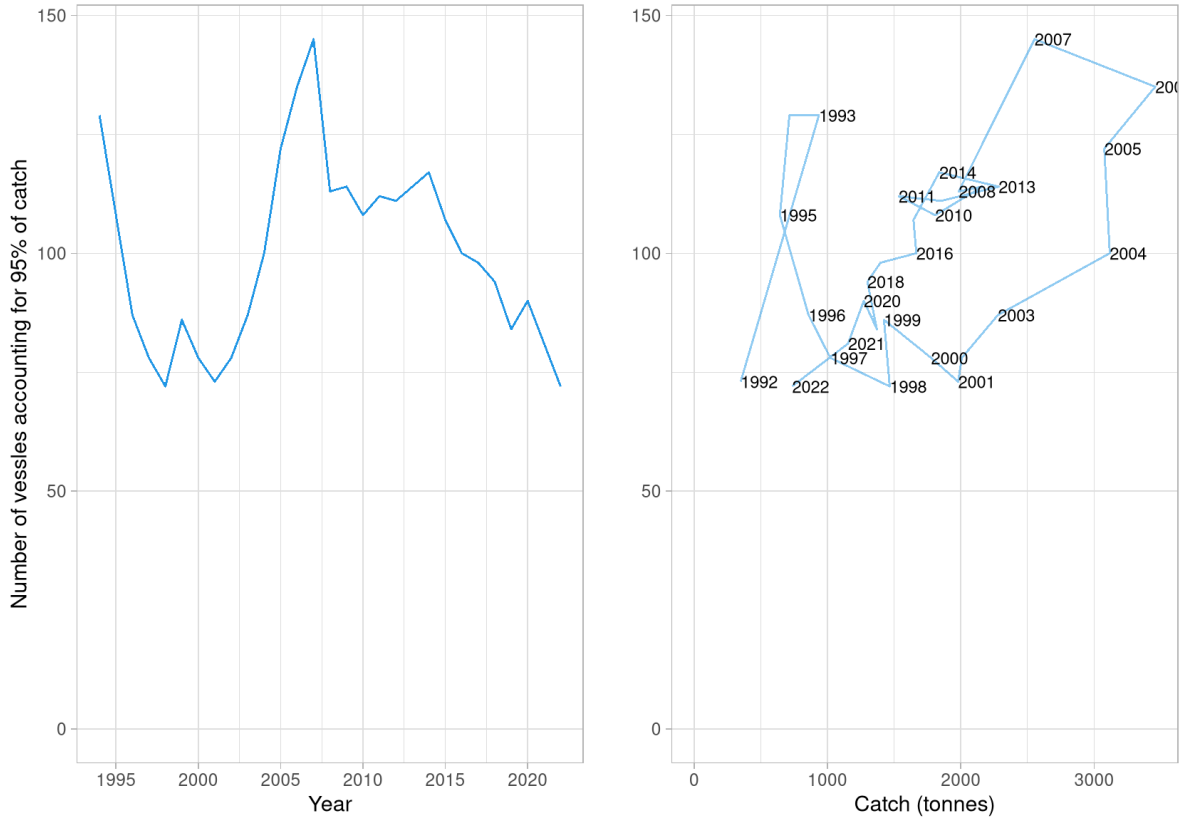

Figure 5. Spotted wolffish. Number of vessels (all gear types) accounting for 95% of the total catch annually since 1994. Left: Plotted against year. Right: Plotted against total catch. Data from the Directorate of Fisheries.

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. In both cases, data was either constrained so that spotted wolffish accounted for more than 10% of the catch, or that spotted wolffish was part of the catch according to logbook records. Here, CPUE is calculated for each fishing trip and the median CPUE of all fishing trips in each year is presented (Figure 6).

Estimates of CPUE from demersal trawl were catch was ≥10% of the total catch was lowest in 2001 (83 kg/h) Since then it generally increased and was highest in 2014 (134 kg/h), since 2019 it has been decreasing (Figure 6). Where the catch was >0, CPUE increased from 2000 to its highest level in 2004 (74 kg/h). Therefrom it decreased to 2007 (36 kg/h) and has since oscillated between 33-57 kg/h with no clear trend, but in 2022 it was lowest (23 kg/h). The estimated longline CPUE where catch was ≥10% oscillated between 30-57 kg/ 1000 hooks in 2000-2022 , with no clear trend (Figure 6). . Where the catch was >0, CPUE decreased gradually from 2000 to 2018 but has similiar since then.

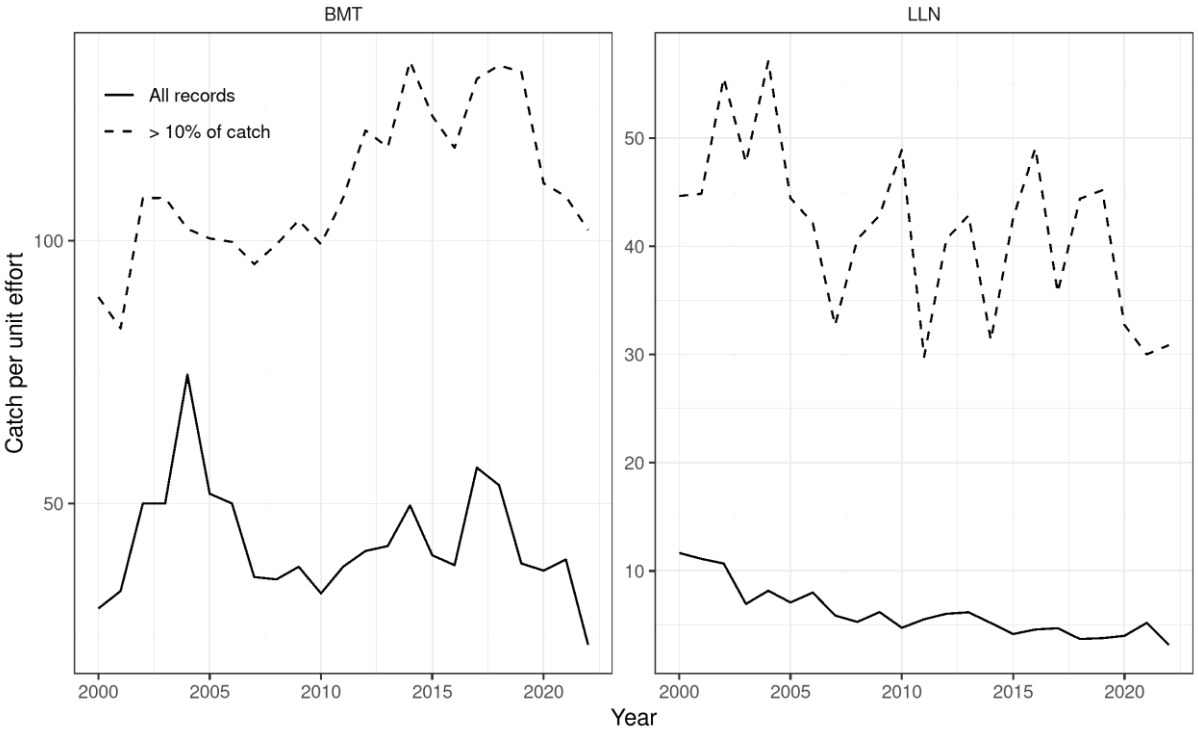

Figure 6: Spotted wolffish. Non-standardised estimates of CPUE (left) from demersal trawl (kg/h) and longline (kg/1000 hooks).

SAMPLING AND AGE DISTRIBUTION OF LANDED SPOTTED WOLFFISH

Between 300 and 1900 otoliths have been sampled annually for age reading by the MFRI. The number of samples collected from longline and demersal trawl ranged from 3-45 and 4-30 respectively (Table 2, Figure 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
2022	3	60	10	263

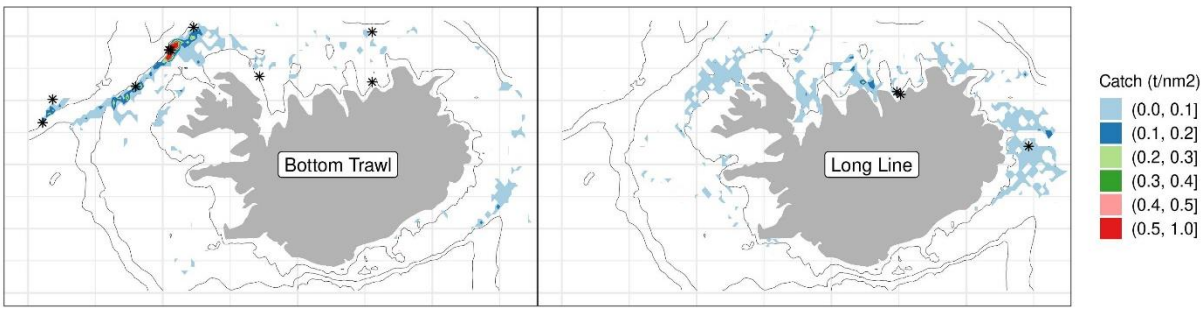

Figure 7: Spotted wolffish. Fishing grounds in 2022 as reported in logbooks and positions of samples taken from landings (asterisks).

LENGTH DISTRIBUTION OF LANDED SPOTTED WOLFFISH

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 it 67 cm in 2022 (Figure 8). Some of the samples collected in 2022 were from catch in Dohrnbank, but samples have not been collected from that area before. The spotted wolffish in these samples was unusually small, which partly explains the low mean length in samples in 2022 as compared to other years.

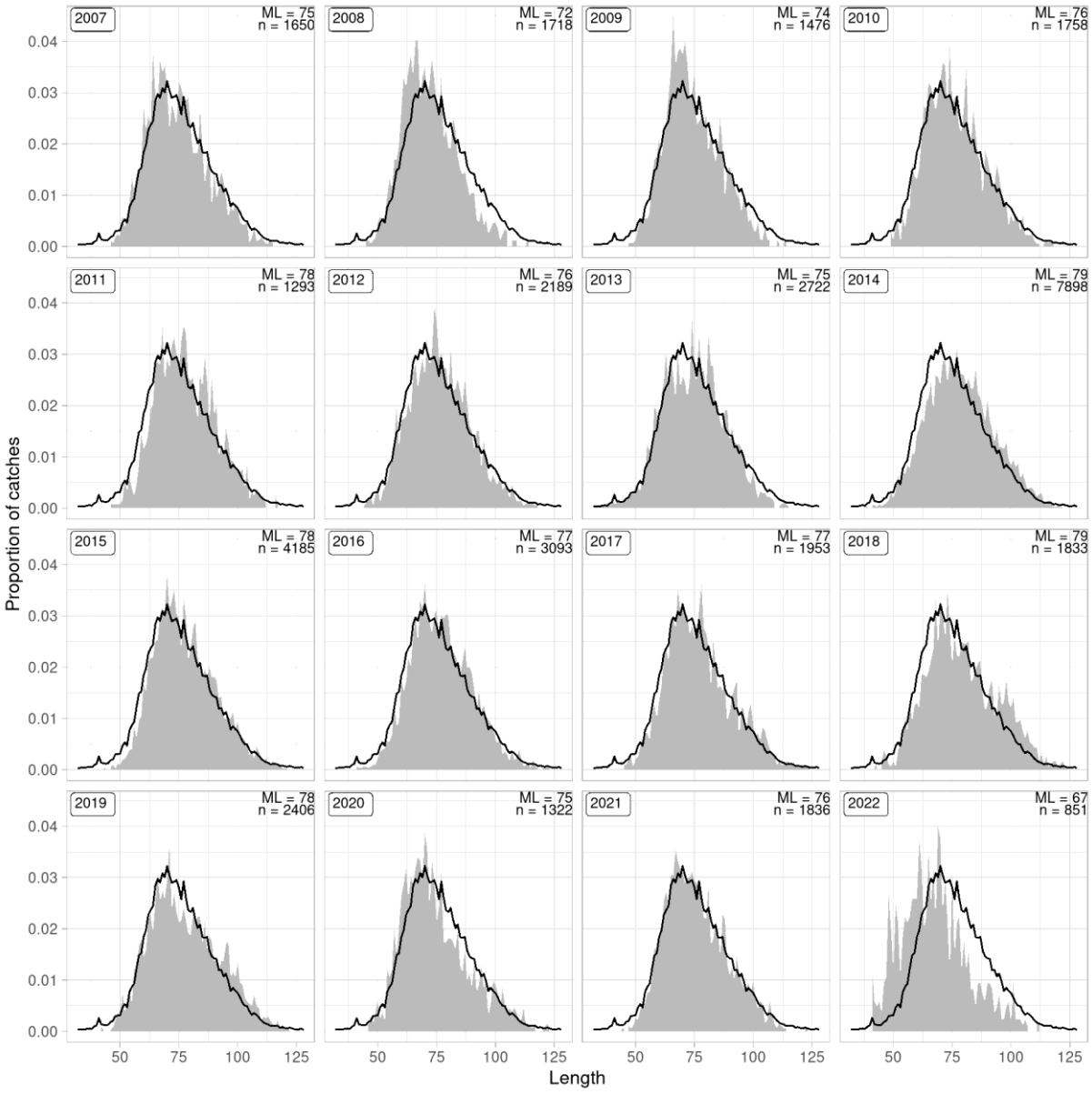

Figure 8: Spotted wolffish. Length distribution of spotted wolffish sampled from landed catch. The black line shows the mean length distribution for all years combined.

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 and were at a historic low in 2020. An upward revision was observed in 2021 and the indices have been at a similar level since then (Figure 9).

The recruitment index was high in the years 1992-2000, after which it decreased gradually to a historic low in 2012. Thereafter, the recruitment index from the spring survey has been low, although it has been slightly higher in 2021-2023 as compared to 2012-2020 (Figure 9).

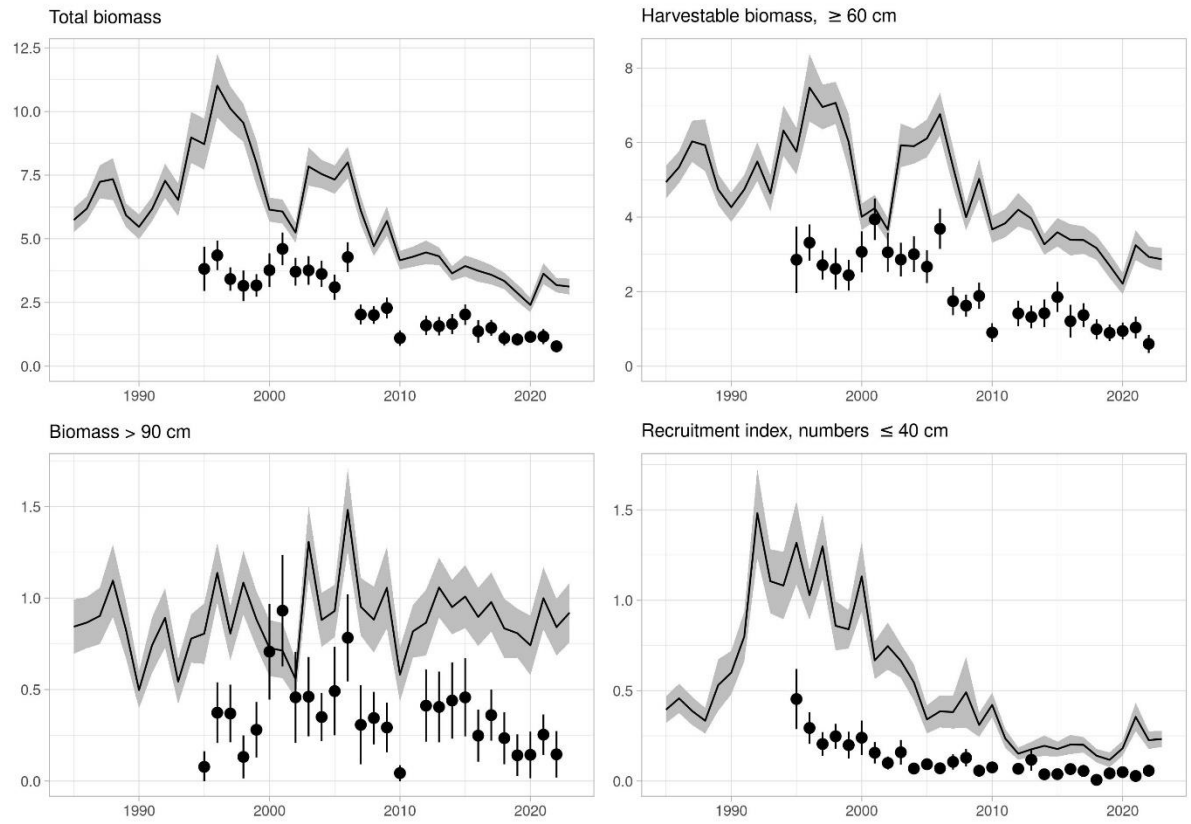

Figure 9: Spotted wolffish. Total biomass indices (upper left), harvestable biomass indices (upper right), large fish biomass indices (lower left) and juvenile abundance indices (lower right) from the spring survey (line) from 1985 and the autumn survey (points) from 1996. The shaded area and point intervals 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 2022 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, but in 2022 the proportion in the NV area was lower compared to recent years and higher in NA-area (Figures 10 and 11).

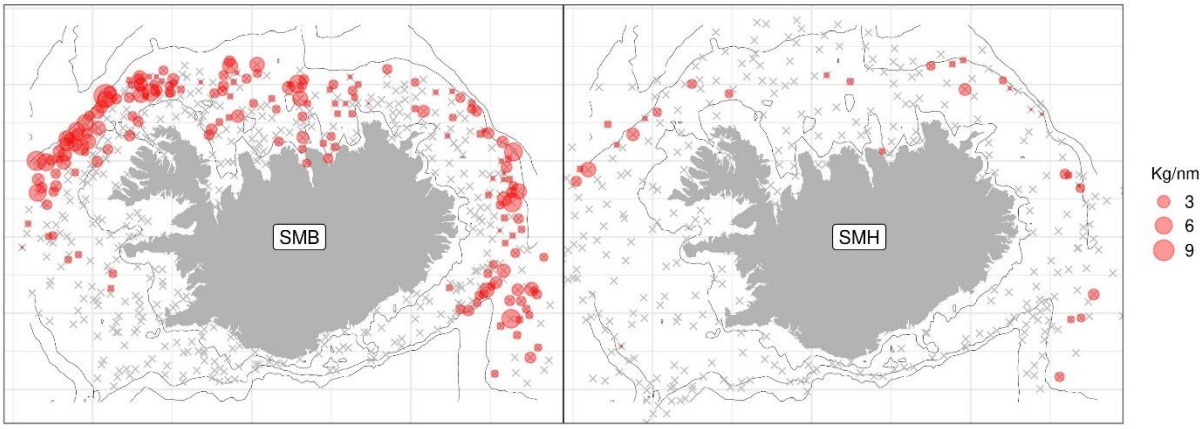

Figure 10: Spotted wolffish. Spatial distribution and abundance in the spring survey (SMB) and autumn survey (SMH) in 2021.

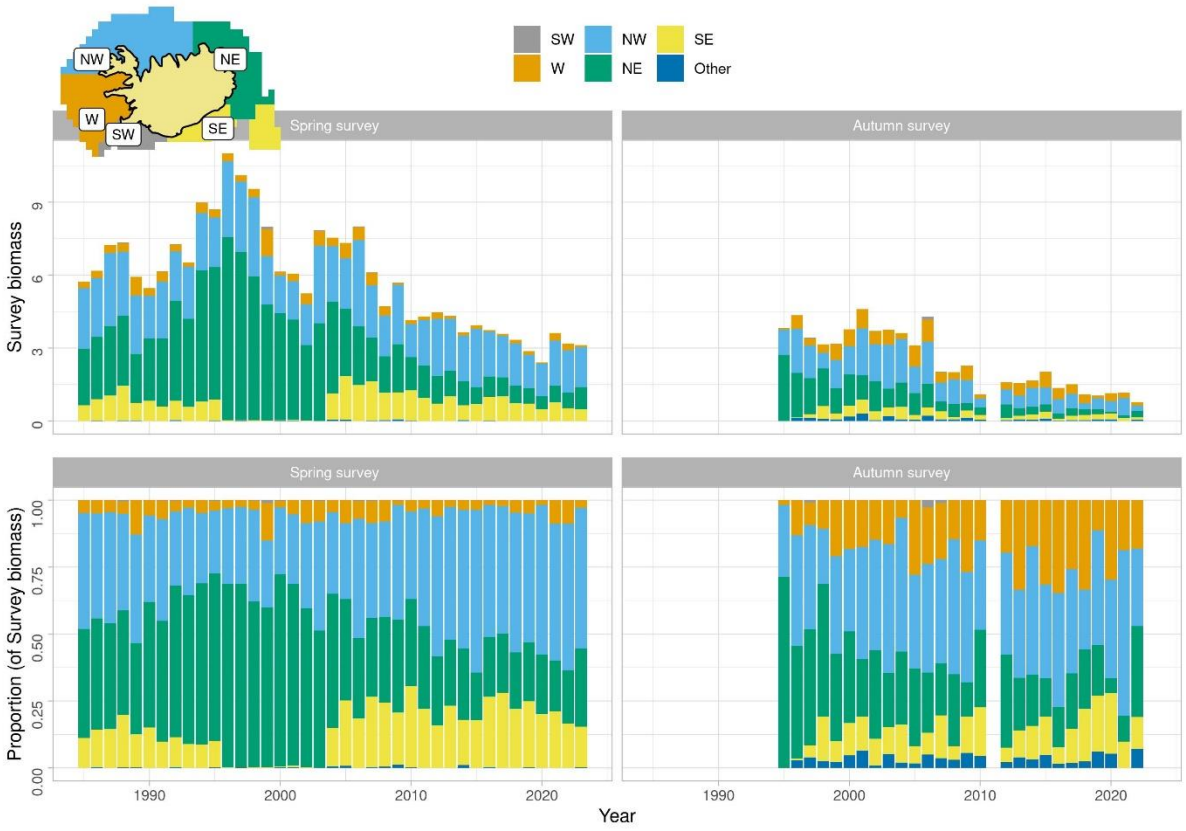

Figure 11: Spotted wolffish. Spatial distribution of the index from the spring survey and autumn survey. Note that the Iceland-Faroe ridge was not sampled in 1996-2003.

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. Since then, the number of observed fish increased to between 480 and 550 individuals.

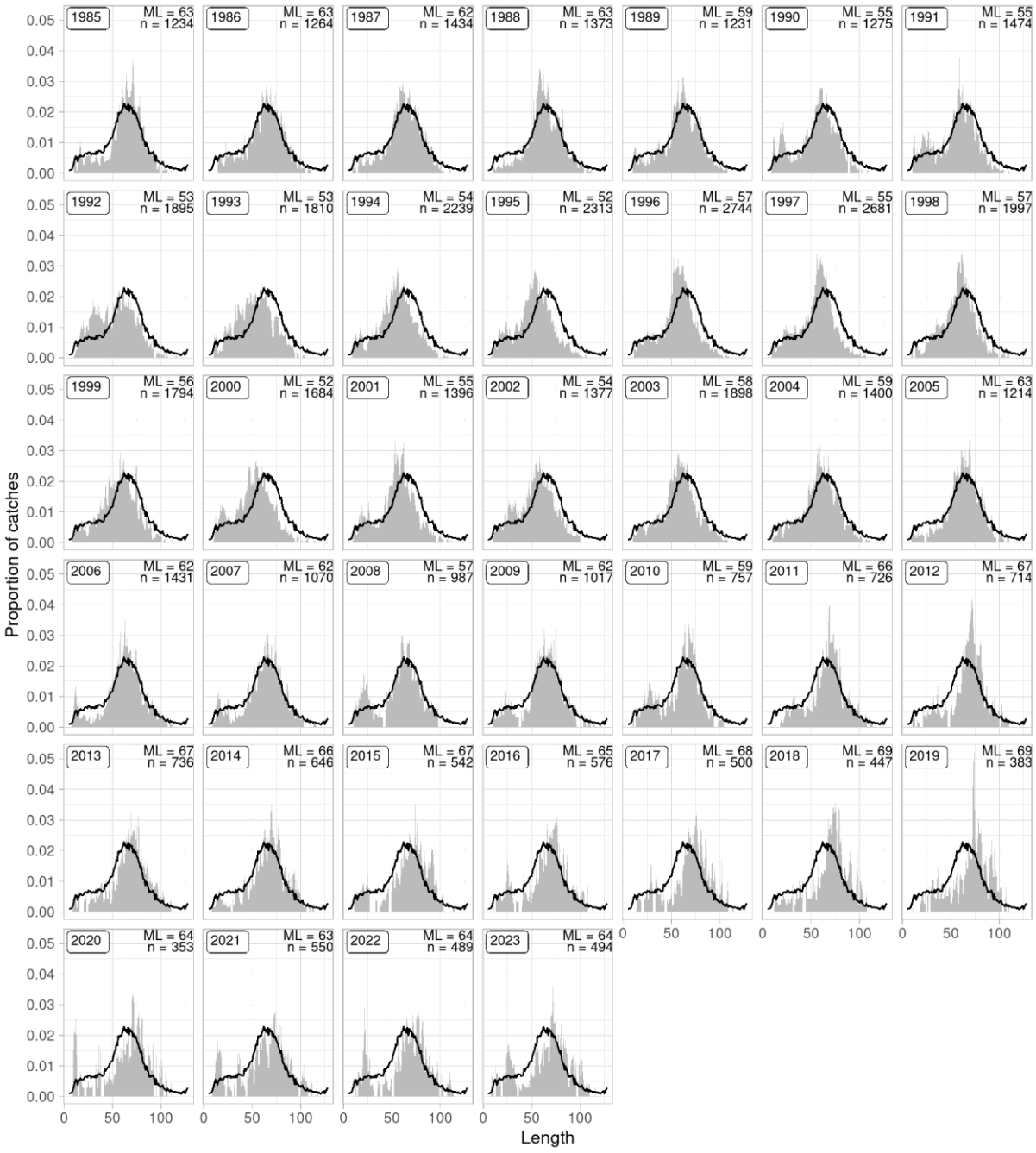

Figure 12: Spotted wolffish. Length abundance indices from the spring survey. The black line shows the mean across all years.

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 2022, 53 fish were caught in the survey, which is the lowest number hitherto.

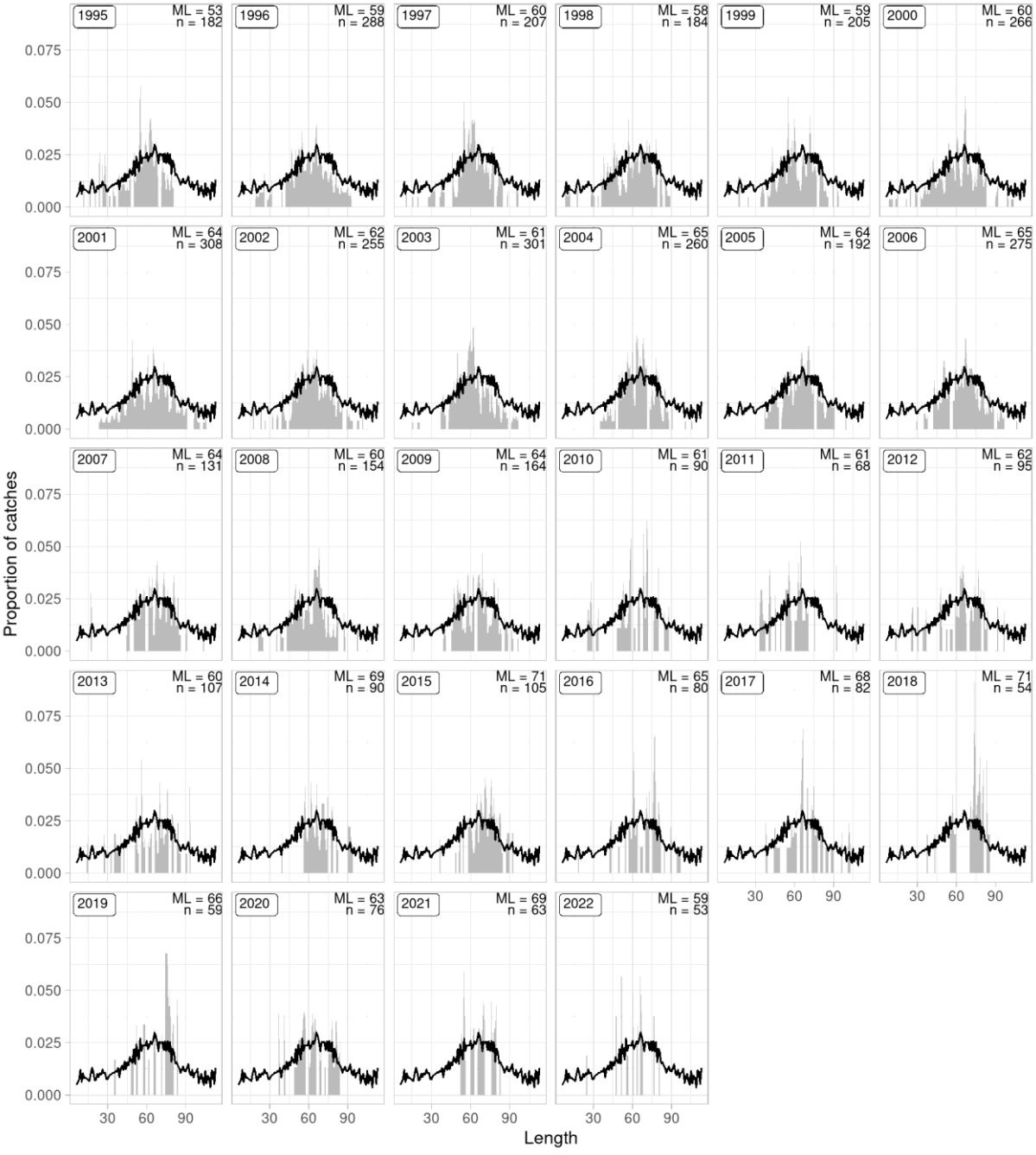

Figure 13: Spotted wolffish. Length distribution from the autumn survey. The black line shows the mean across all years.

In 2020, age determination for spotted wolffish from IS-SMB was initialised. Currently, individuals from 2015-2022 have been aged, a total of 1436 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.

STOCK ASSESSMENT

COMMENTS ON THE ASSESSMENT AND ADVICE

The assessment is based on the ICES rfb-rule for data limited stocks (ICES 2021).

The assessment method for spotted wolffish changed in 2023. Following ICES guidelines for data-limited stocks (ICES 2021), the ICES *rfb*-rule was utilized for the assessment. This method incorporates life-history traits, exploitation characteristics, and other relevant parameters for data-limited stocks into an empirical assessment rule (ICES 2021). The *rfb*-rule has the following form:

$$A_{y+1} = A_y r f b m$$

where A_{y+1} is the advised catch, A_y is the current advice (issued in the previous year), The parameter r corresponds to the rate of change in the biomass index (the ICES "2 over 3" rule), f is a proxy for the exploitation level (mean catch length divided by an MSY reference length), and b is a biomass safeguard (reducing the catch when the biomass index drops below a trigger value).

The parameter r is calculated by dividing the mean of the last two survey index (I) values by the mean of the three preceding survey index values:

$$r = \frac{\sum_{i=y-2}^{y-1}(I_i/2)}{\sum_{i=y-5}^{y-3}(I_i/3)}$$

The length-ratio component f is calculated as follows:

$$f = \frac{\overline{L}_{y-1}}{L_{F=M}}$$

where $\overline{L}_{y-1}$ is the mean length in the observed catch that is above the length at first capture (L_c). The length at first capture is defined as the length at 50% of modal abundance (Figure X). The target reference length ($L_{F=M}$) is the expected mean length when fishing at MSY and is calculated via:

$$L_{F=M} = 0.75L_c + 0.25L_\infty$$

where L_c is the length at first capture (see above) and L_∞ is von Bertalanffy growth parameter.

The biomass safeguard b is used to reduce catch advice when the index falls below a threshold denoted by $I_{trigger}$:

$$b = \min\left\{1, \frac{I_y}{I_{trigger}}\right\}$$

where $I_{trigger}$ = $1.4I_{loss}$, and I_{loss} is the lowest observed index value (see Figure X). Note that b cannot exceed a value of 1.

The multiplier m is based on stock growth. The von Bertalanffy growth parameter K for spotted wolffish is less than 0.2, therefore m = 0.95 (ICES 2021).

ANALYSIS ON THE ASSESSMENT AND ADVICE

The assessment is based on the rfb-rule for ICES category 3 data-limited stocks and is applied to spotted wolffish for the first time this year for the forthcoming fishing year 2023/24. The Icelandic spring trawl survey (IS-SMB) was used as the index for the stock development. The advice follows the equation outlined above (A_{y+1} = $A_y$rfbm), and with parameter values inserted, A_{y+1} = 334 * 1.06 * 0.95 * 0.93. The advice for the fishing year 2023/2024 is 296 t, which is an 11% reduction from the previous year (334 t).

Although there is a positive trend in the biomass index, the index value in 2023 remains below the reference point $I_{trigger}$ which leads to a reduction in the advice.

Table 3. Spotted wolffish. Comparison between the *rfb*-rule and the f-proxy rule.

	rfb-rule		Old f-proxy rule
Previous advice	334	**Previous advice**	334
Index A	3153	**Index 2023**	3123
Index B	2968	**Target Fproxy**	0.131
Ratio (A/B)	1.06	**Initial advice**	409
Length ratio	0.95		
Biomass safeguard	0.93		
Multiplier	0.95		
Initial advice	296		
Stability clause applied	-		
Precautionary buffer*	-	**Precautionary buffer**	Yes
Final advice	296	**Final advice**	327
Advice change	-11	**Advice change**	-3%

***Last applied in 2022.**

THE APPLICATION OF RFB-RULE

- r is calculated as the average of last two years values, divided by average of three preceding years values which results in r = 1.06 (Figure 14, Table 3)

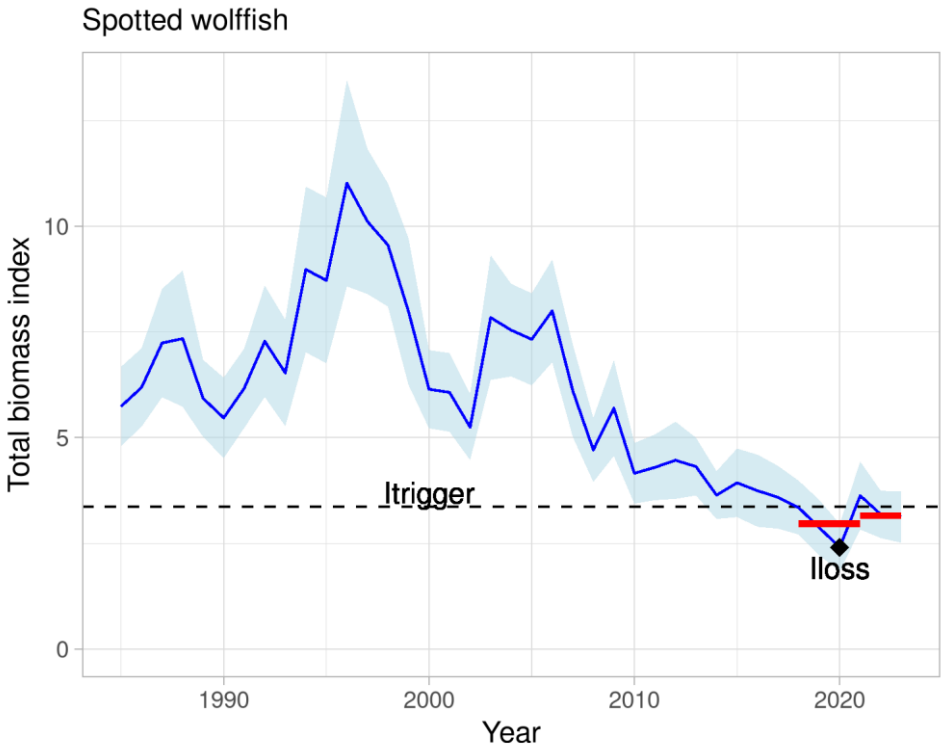

Figure 14. Spotted wolffish. Total biomass index. The red lines show the average of last two years values and the three preceding years used to calculate *r*. The dashed horizontal line shows $I_{trigger}$. The black point shows I_{loss}.

- f is the length-ratio component. The mean length from catches in 2022 that are above L_c was 74.7 cm and the target reference length was 79 cm (Figure 15 and Figure 16). This resulted in a value of f = 0.95.

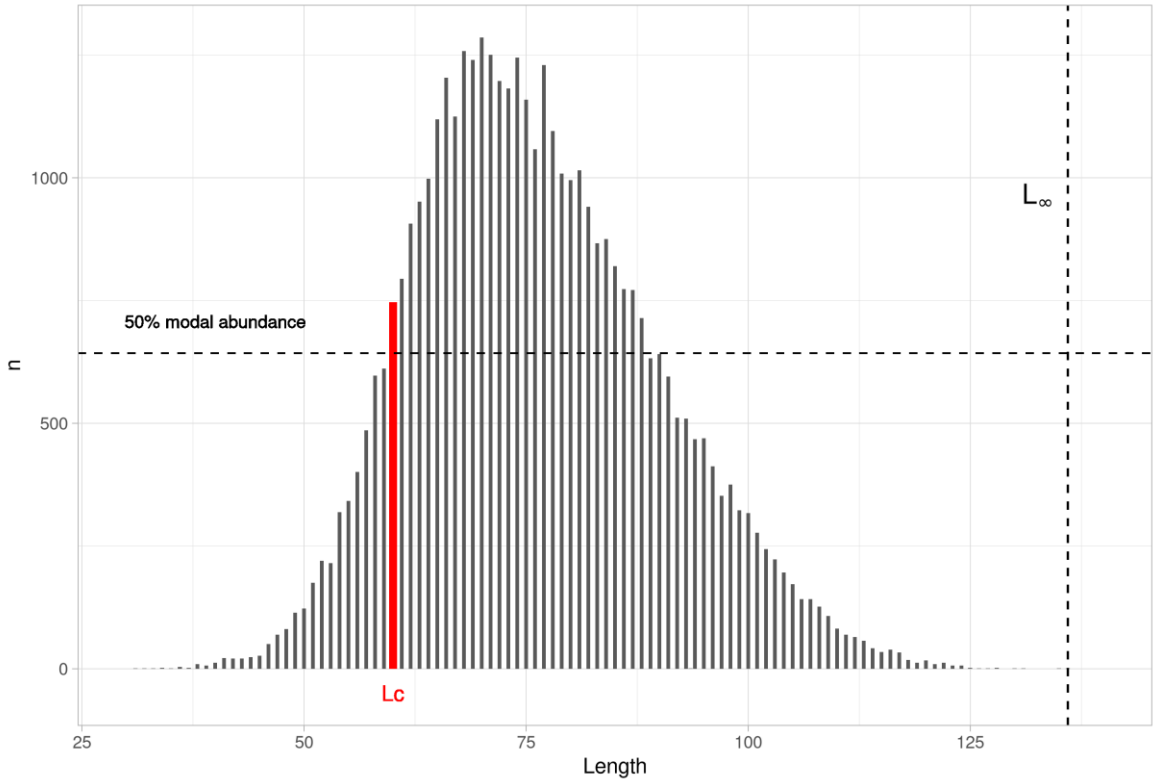

Figure 15. Spotted wolffish. Length frequency distribution from catches. Red line is the length at first capture. The horizontal dash line is 50% of the modal abundance. The vertical dashed line shows L_∞.

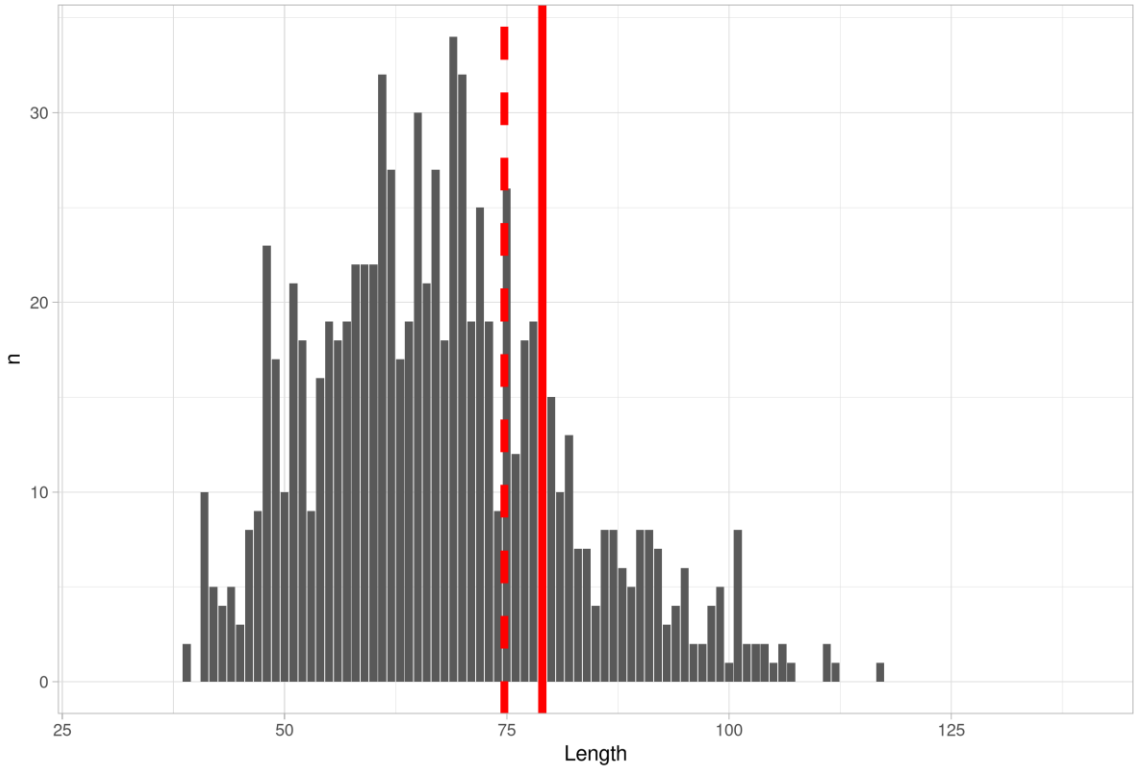

Figure 16. Spotted wolffish. Length distribution from commercial catches in 2022. The dashed red line shows the mean length above the length at first capture (see Figure 15). The solid red line shows the target reference length.

- b is the biomass safeguard and is used to reduce catch advice when index falls below the threshold $I_{trigger}$. The lowest observed index I_{loss} for spotted wolffish is 2402 and was recorded in the year 2020, therefore, $I_{trigger}$ = 1.4 * 2402 (Figure 14). The biomass index in 2023 was 3123, which is below $I_{trigger}$ leading to b = 0.93.

- m is the tuning parameter and for slow growing species (with von Bertanlaffy K < 0.2), m equals to 0.95 (Figure 17).

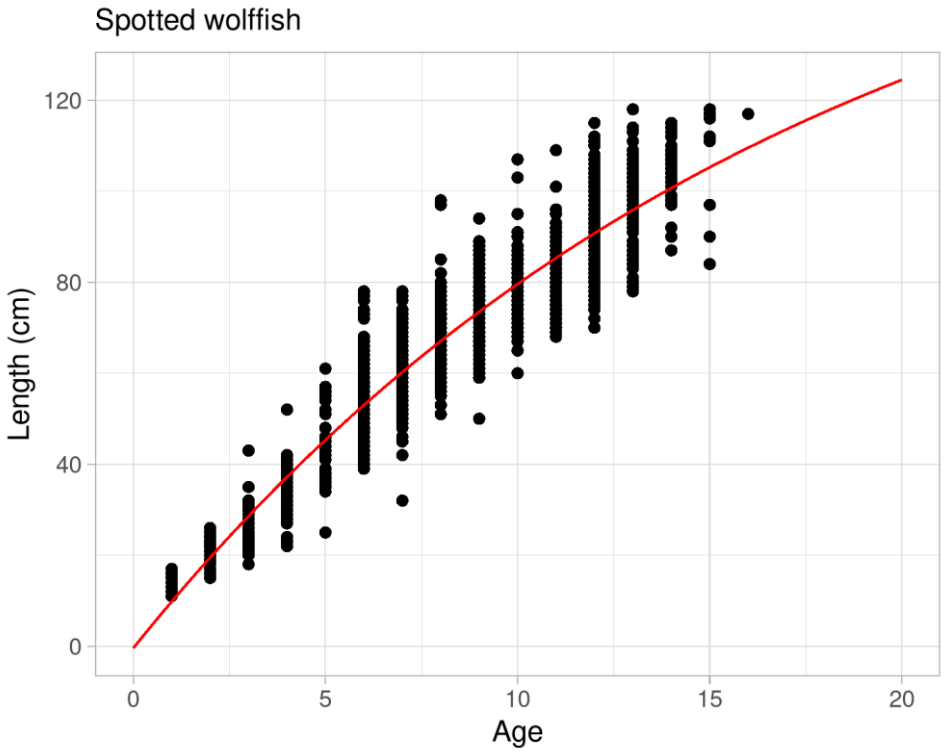

Figure 17. Spotted wolffish. The von Bertalanffy growth curve (red line) fitted to age and length data from IS-SMB. K for spotted wolffish according to available data is 0.06.

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, stock indices 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 it is mainly taken as 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. In June 2020, the MFRI proposed that fishermen were granted license to release spotted wolffish. This licence was granted by the Ministry of Industries and Innovation on 14 December 2020.

To reverse the downward trend of the stock, the MFRI recommended fishermen to release spotted wolffish that were caught beyond quota. Research has shown that the survival rate is high for post-catch released spotted wolffish. The reduction in catches in 2022 suggests that fishermen were releasing spotted wolffish; however, there are limited registrations of releases in the logbooks. A potential explanation for this is that only the amount could be recorded, but this limitation has been fixed. Registering the catch-release is important because the fraction of released fish that survive (research suggests 90%) can be estimated from these records.

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	-	1637
2015/16	900	-	1886
2016/17	1128	-	1548
2017/18	1080	-	1528
2018/19	1001	1001	1375
2019/20	375	375	1280
2020/21	314	314	1272
2021/22	377	377	895
2022/23	334	334	

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 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.

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