LEMON SOLE
Microstomus kitt

GENERAL INFORMATION

Lemon sole is found all around Iceland, but the highest abundance and the main fishing grounds are off the west and southwest coast. Lemon sole is a demersal and shallow water species, mainly found on a sandy or gravel substrate and occurring mostly at 20-200 m depths.

Females grow larger than males; only a small proportion of males become larger than 35 cm, whereas females rarely grow larger than 40 cm. Size at sexual maturity differs between the sexes. On the main spawning grounds off the south coast, large males are rarely found and about half of the males reach maturity at the length of 13 cm, while females reach that level at 24 cm length.

THE FISHERY

The general fishing grounds for lemon sole are on the west and south coasts (Figure 1). Hardly any catch is recorded north and east of Iceland. Small changes towards north-west have been observed in the general distribution of the fishing grounds in recent years.

Spatial distribution of the Icelandic lemon sole fishery has been stable since 2000, with around 85% caught south, southwest and west of Iceland (Figure 2). Since 2000, most of the catches are taken at 41-120 m depth (Figure 3). In recent years, proportion of the catch taken at 41-81 m depths has increased whereas catch at 81-120 m has decreased. Lemon sole was primarily caught in demersal seine, and as bycatch in demersal trawls, amounting to more than 95% of the landings in most years (Figure 4, Table 1). This proportion has been relatively stable through the years with increasing proportions caught by demersal trawls which caught more than 50% in 2022. Demersal seiners operate mainly at 41-80 m depths whereas lemons sole in the trawl fishery is mostly caught at 80-120 m depth.

Between 31 and 85 trawlers and between 26 and 51 demersal seiners have reported catches of lemon sole (1000 kg or more) since 2000 (Table 1). The number of seiners has been stable since 2014 with 26-30 vessels, however the number of trawlers increased from 31 in 2014 to 53 vessels in 2022 (Table 1). The number of vessels accounting for about 95% of the total lemon sole catch decreased from about 135 in 1996 to about 50 in 2014 and has increased slightly since (Figure 5). The reduction in number of vessels in 1996-2007 occurred despite catches being higher, but in 2009-2014 the drop coincided with reduced catches.
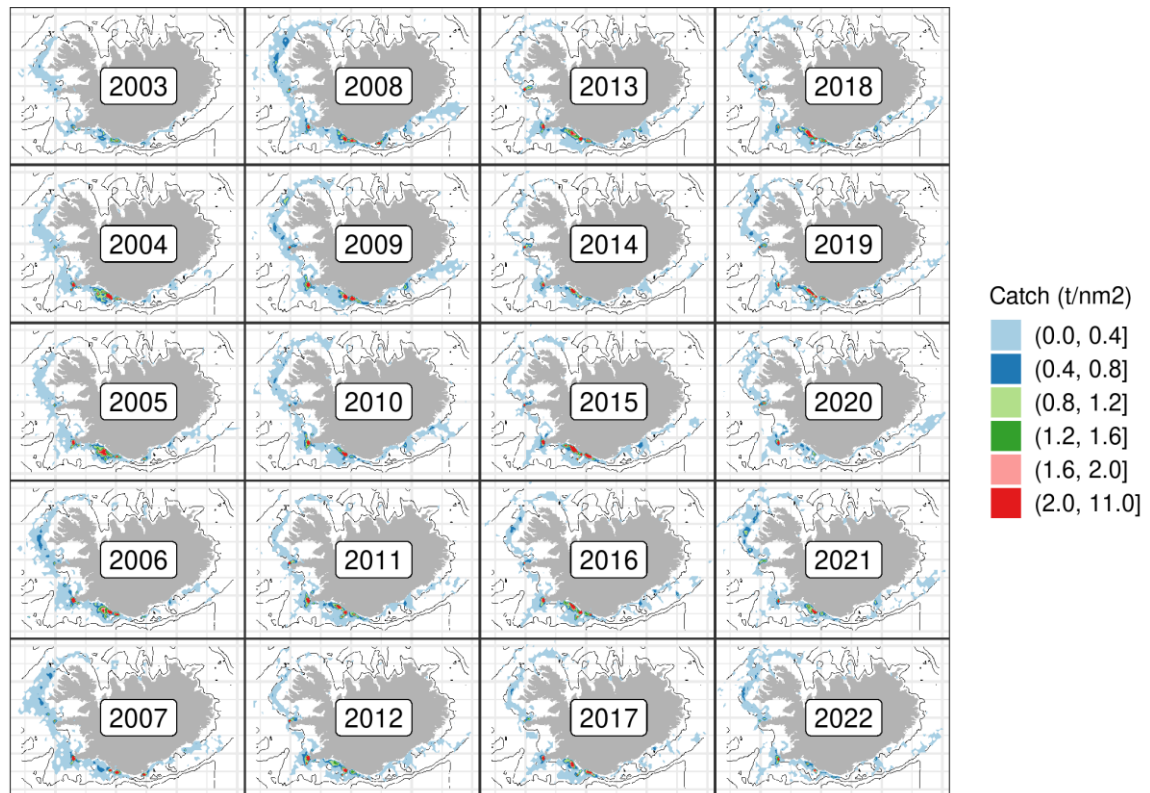
Figure 1. Lemon sole. Geographical distribution of the Icelandic fishery 2003-2022. Reported catch from logbooks.
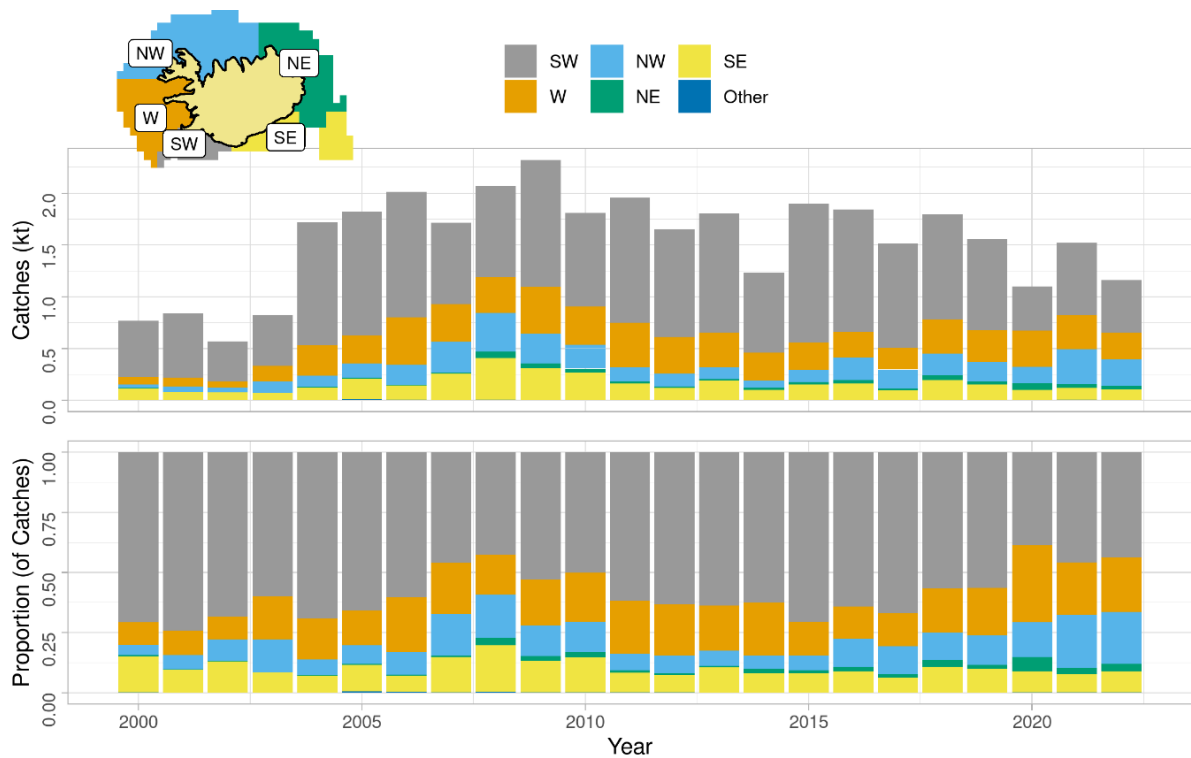

Figure 2. Lemon sole. Spatial distribution of the Icelandic fishery by fishing area since 2000 according to logbooks. All gears combined.
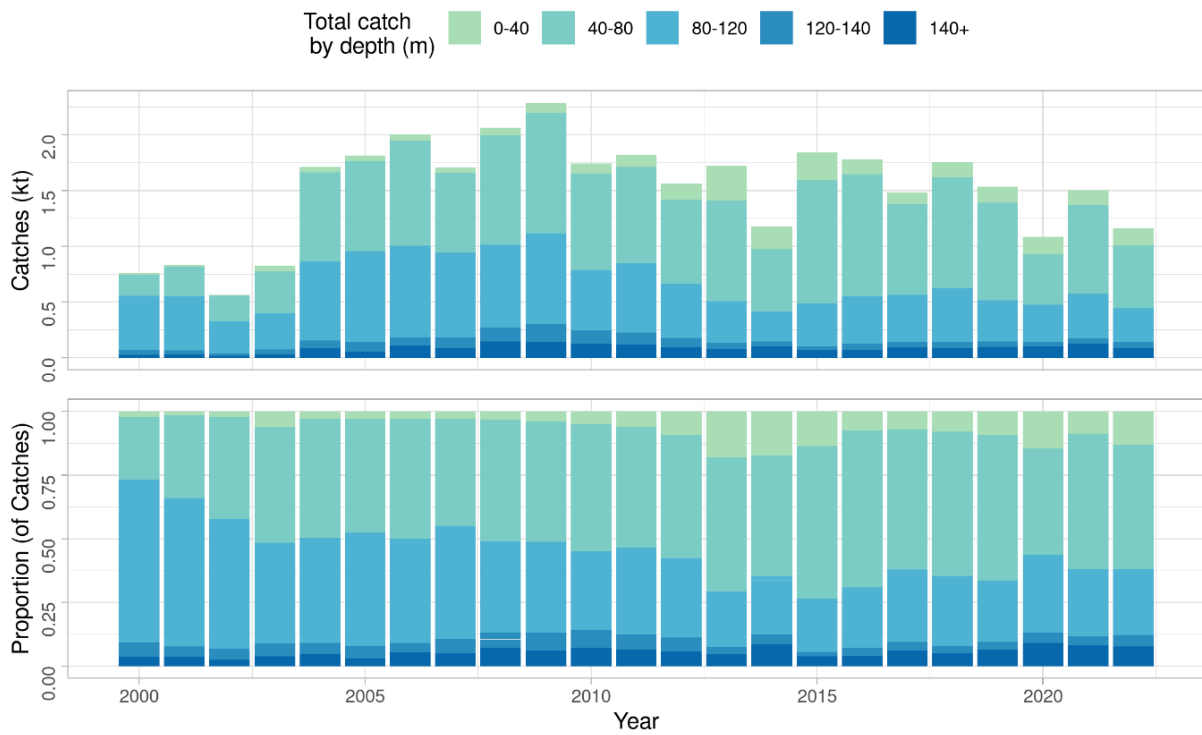
Figure 3. Lemon sole. Depth distribution of catches according to logbooks.
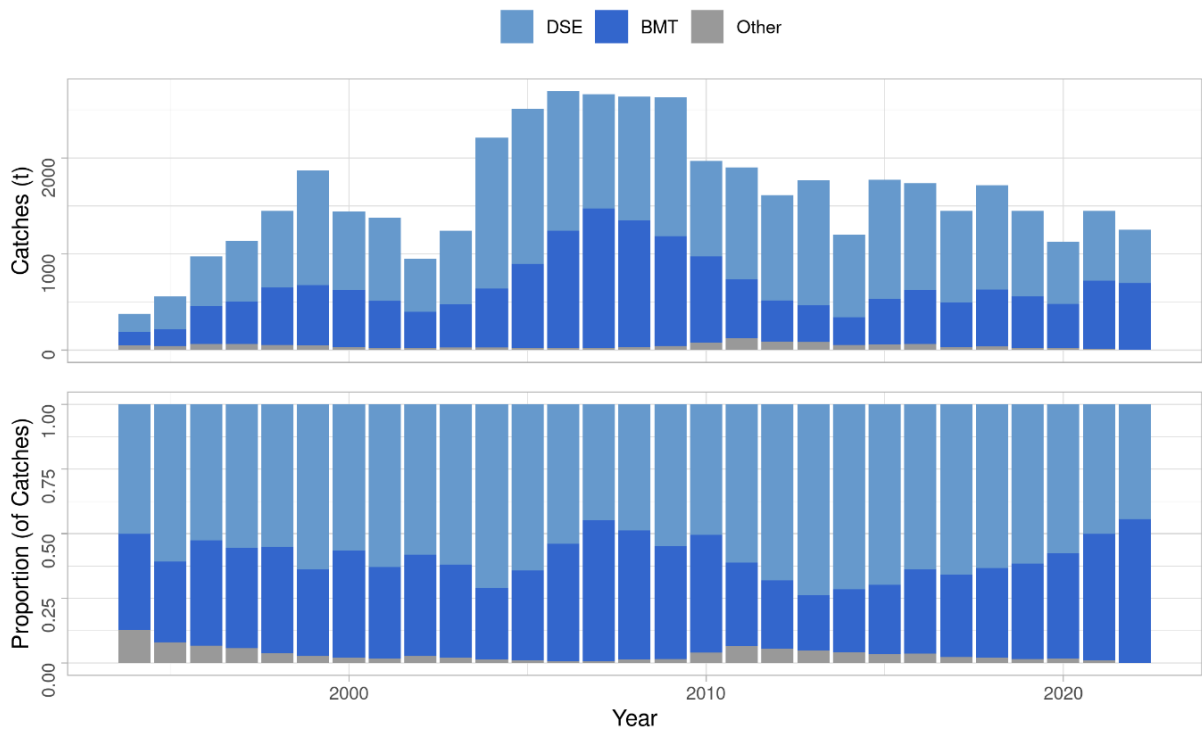

Figure 4. Lemon sole. Total catch (landings) by fishing gear since 1994, according to statistics from the Directorate of Fisheries.

Table 1. Lemon sole. Number of Icelandic vessels landing catch of 1000 kg or more of lemon sole, and all landed catch divided by gear type.

| YEAR	NUMBER OF VESSELS			CATCHES (TONNES)			
	Trawlers	Seiners	Other	Demersal trawl	Demersal	Other	Sum
2000	85	50	7	591	815	32	1438
2001	70	46	4	483	861	27	1371
2002	60	37	10	370	552	28	950
2003	66	46	5	446	782	18	1246
2004	65	56	9	608	1565	36	2209
2005	66	50	11	868	1608	29	2505
2006	71	49	10	1220	1446	22	2688
2007	74	44	11	1450	1194	18	2662
2008	69	41	9	1318	1282	34	2634
2009	66	47	11	1143	1437	49	2629
2010	59	39	15	894	995	81	1970
2011	42	38	13	611	1164	124	1899
2012	38	39	12	435	1099	79	1614
2013	38	35	14	378	1304	82	1765
2014	31	30	13	290	860	52	1202
2015	38	28	12	473	1237	62	1772
2016	45	28	11	565	1112	61	1738
2017	41	29	8	464	953	33	1450
2018	47	29	7	592	1085	38	1715
2019	45	28	7	534	893	23	1449
2020	50	28	6	457	646	21	1121
2021	51	26	1	703	722	15	1438
2022	53	26	0	695	555	0	1250
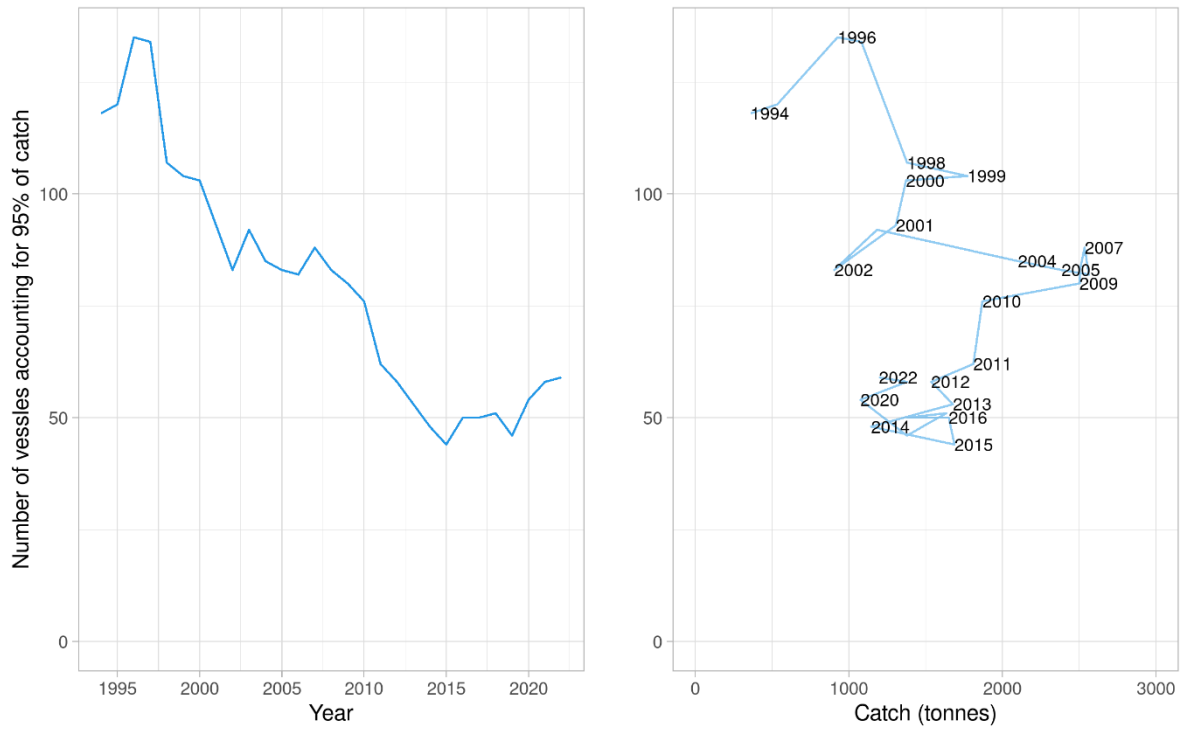
Figure 5. Lemon sole. Number of vessels (all gear types) accounting for 95% of the total catch annually since 1994. Left: Plotted against year. Right: Plotted against total catch. Data from the Directorate of Fisheries.

CATCH PER UNIT EFFORT (CPUE) AND EFFORT.

CPUE estimates of lemon sole 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-standardized CPUE in demersal seine (kg/set) is calculated as the total weight in sets in which lemon sole was >10% of the catch, and where lemon sole is part of the catch. In 2000-2012, lemon sole CPUE, where lemon sole was >10% of the catch was around 200 kg/set, but in 2013-2022 it has fluctuated between 250-370 kg/set (Figure 6). CPUE of lemon sole (>10% of the catch) in demersal trawl gradually increased from around 50 kg/hour in 2000-2002 to a peak of approximately 120 kg/hour in 2015-2017. In the last three years, CPUE has decreased and was around 80 kg/hour in 2022.
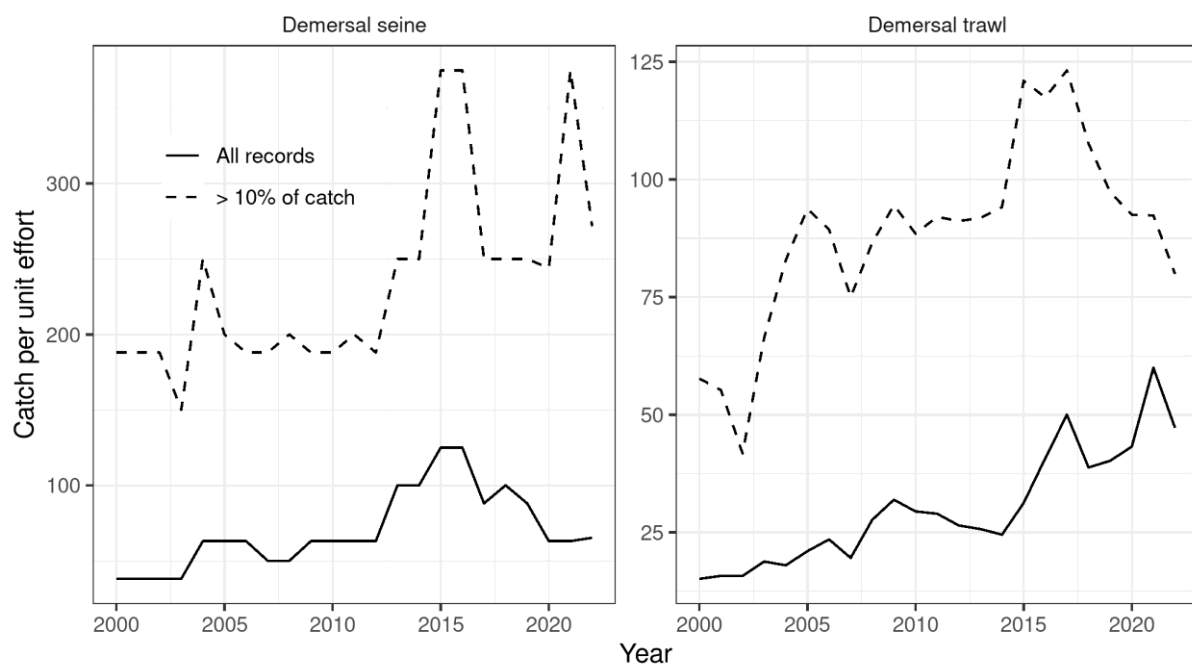

Figure 6. Lemon sole. Unstandardized CPUE for demersal trawl (kg/hour, left) and demersal seine (kg/set, right).

AGE DISTRIBUTION OF LANDED LEMON SOLE

Sampling of biological data from main gears (demersal seine and bottom trawl) in commercial catches is considered good in general. The sampling covers spatial distribution of catchers to satisfactory extent. The sampling coverage by gear is shown in figure 7. Otoliths have been collected from commercial catches since 1999. Annually since 2010, 14-36 samples have been collected from demersal seine and 8-34 samples from demersal trawl, or a total of 345-925 and 200-840 otoliths, respectively (Table 2, Figure 7). About 90% of the otoliths are age read annually after 2010.

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

Tafla 2. Þykkvalúra. Fjöldi sýna og aldursgreindra fiska úr lönduðum afla.

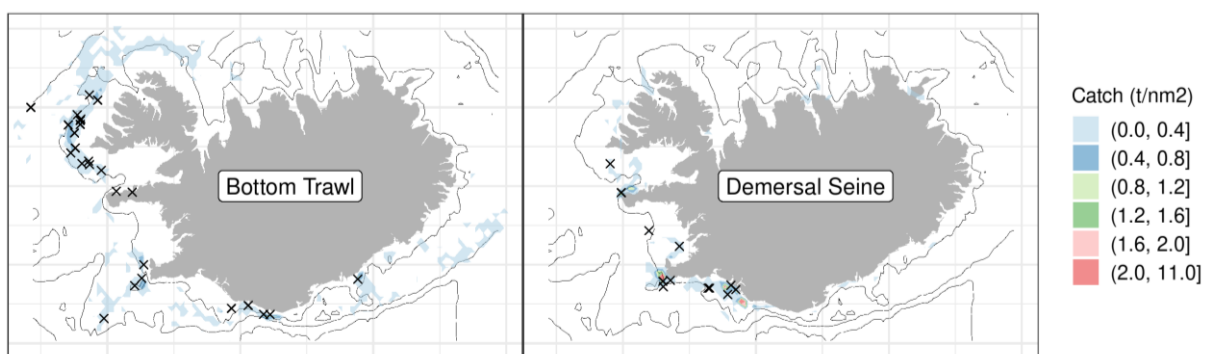| Year	Demersal seine		Demersal trawl	
	Samples	Otoliths	Samples	Otoliths
2010	23	575	21	506
2011	36	875	12	300
2012	37	925	14	361
2013	36	899	8	200
2014	20	500	8	200
2015	28	700	17	420
2016	27	675	17	425
2017	22	475	19	550
2018	22	545	11	275
2019	19	470	17	425
2020	14	345	14	350
2021	14	350	36	890
2022	13	262	30	605

Figure 7. Lemon sole. Fishing grounds for demersal seine and trawl in 2022 as reported in logbooks and positions of samples taken from landings (x).

Age composition of landed catch consists mainly of 6-9 year old lemon sole (Figure 8). In most recent years, however the proportion of younger age groups is decreasing and presence of 10 year old and older fish is noticeable.
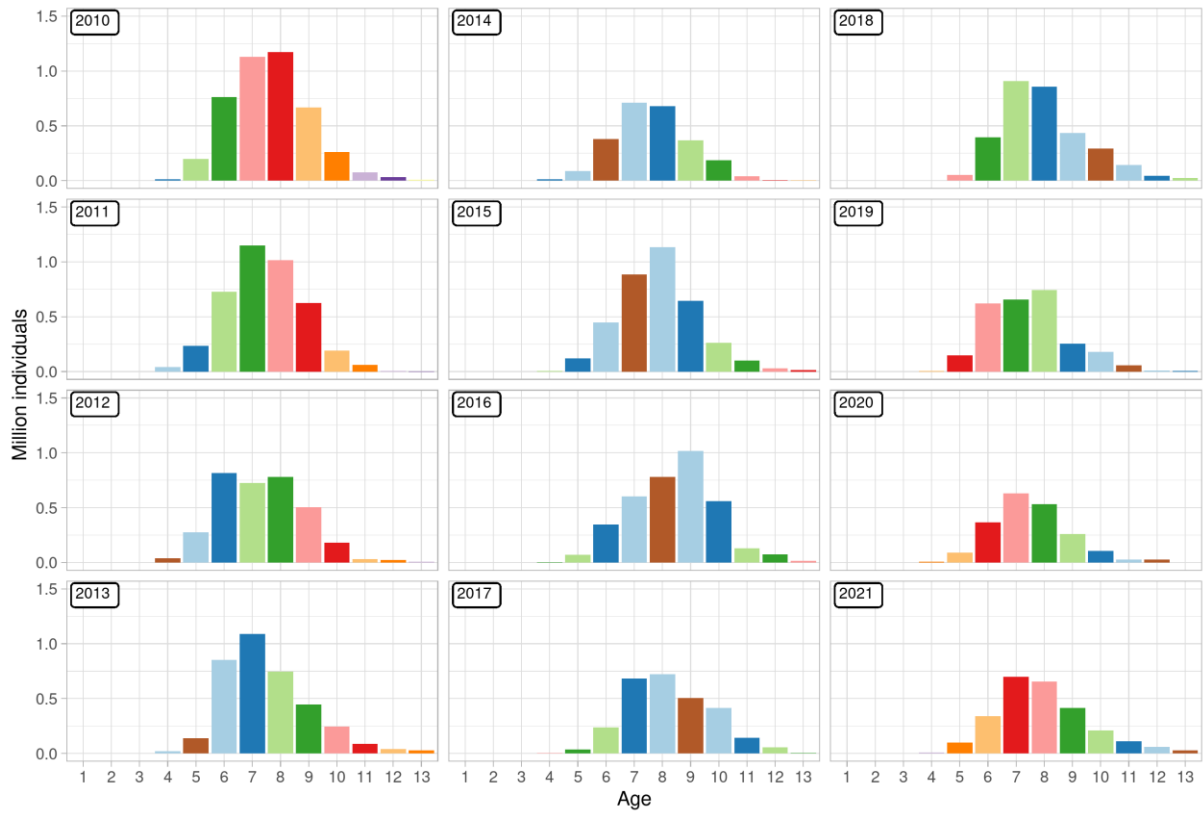

Figure 8. Lemon sole. Estimated age distribution of landed catch based on landings and otoliths collected from landed catch.

LENGTH DISTRIBUTION OF LANDED LEMON SOLE

Relative length distribution of landed lemon sole has been quite stable, with a slight shift towards larger fish since 2017 (Figure 9).
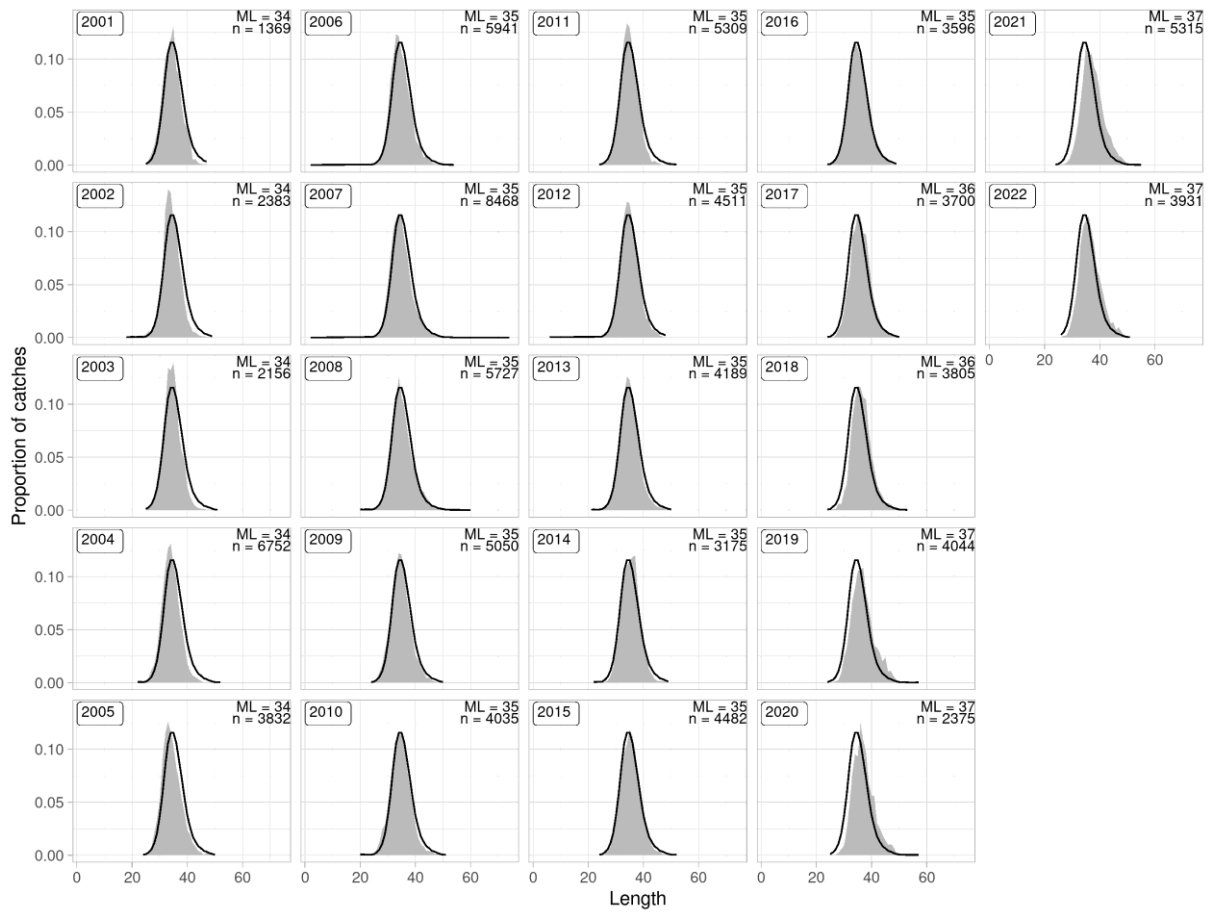

Figure 9. Lemon sole. Relative length distribution from landed catch. The dotted line represents the mean length distribution for all years.

SURVEY DATA

The Icelandic groundfish survey (spring survey, IS-SMB), which has been conducted annually in March 1985-2023, covers the most important distribution area of the lemon sole. The Icelandic autumn groundfish survey (autumn survey, IS-SMH) was commenced in 1996. The autumn survey was not conducted in 2011. The spring survey is considered to measure changes in abundance/biomass better than the autumn survey. It may not, however, adequately cover the main recruitment grounds for lemon sole as the main nursery areas are thought to be in shallow water in habitats not covered by the survey. In addition to these two surveys, a designated flatfish survey with beam trawl, conducted annually in July/August since 2016, with the objective to cover the recruitment grounds of lemon sole and other flatfish species.

Figure 10 shows trends in various biomass indices and a recruitment index based on abundance of lemon sole ≤20 cm. Survey length-disaggregated abundance indices are shown in Figures 11-12, and abundance and changes in spatial distribution in Figures 13-15.

Total biomass index and the biomass index for lemon sole larger than 30 cm (harvestable part of the stock) has decreased with fluctuation from the peak in 2006. This year, the biomass index is at similar level as in the early 2000s before the highest peak (Figure 10). The index for lemon sole larger than 39 cm increased significantly from 2000 to 2004 and has since then fluctuated around that level, with year 2021 being the highest value recorded. The index of juvenile abundance (≤20 cm) in the spring survey has decreased after peak in 2011, but increased again in 2021 and it is at similar level this year. The result from the autumn survey shows similar trend to those observed from the spring survey, except for the juvenile abundance index that shows a different pattern than the spring survey.
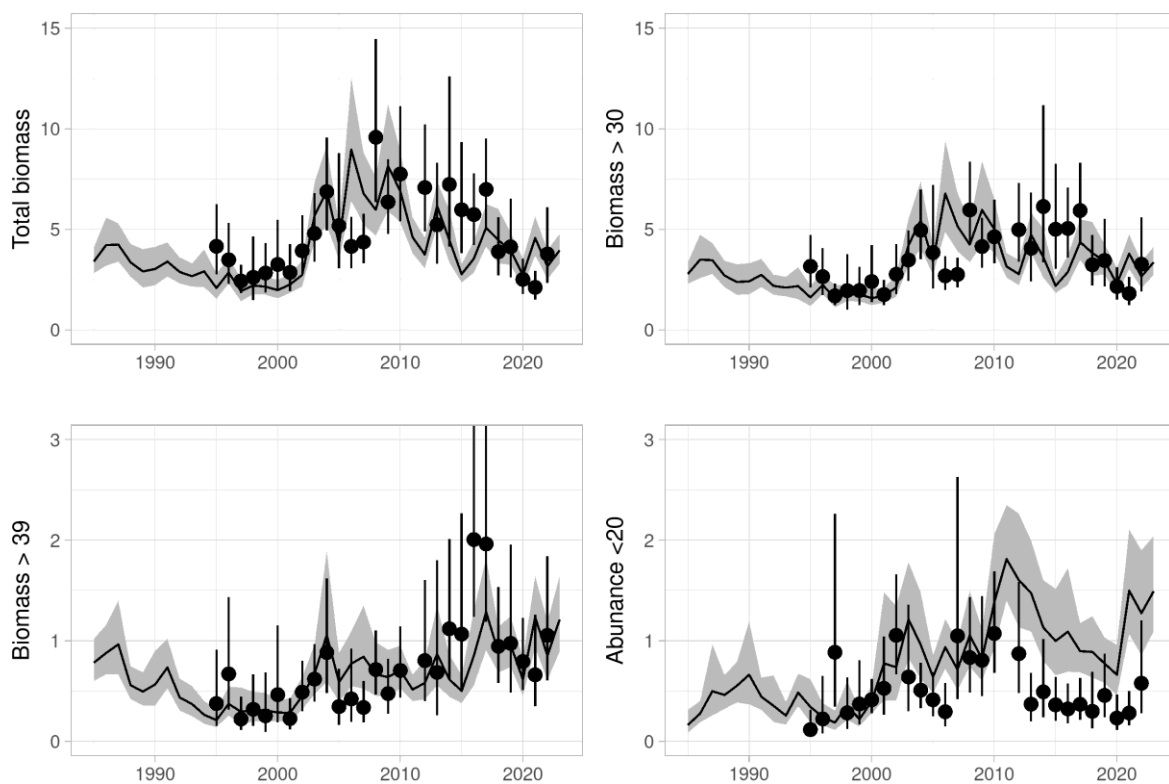

Figure 10. Lemon sole. Total biomass indices (upper left) and harvestable biomass indices (≥30 cm, upper, right), biomass indices of larger individuals (≥39 cm, lower left) and juvenile abundance indices (≤20 cm, lower right) from the spring survey (blue) from 1985 and autumn survey (red) from 1996, along 95% CI.

Similar to the commercial catch, the size distribution in the spring survey has been stable, with little variation over time (Figure 11). This year, as in 2022, a significant recruitment pulse was observed in length data from the spring survey. Length data from the autumn survey tells a similar story (Figure 12).
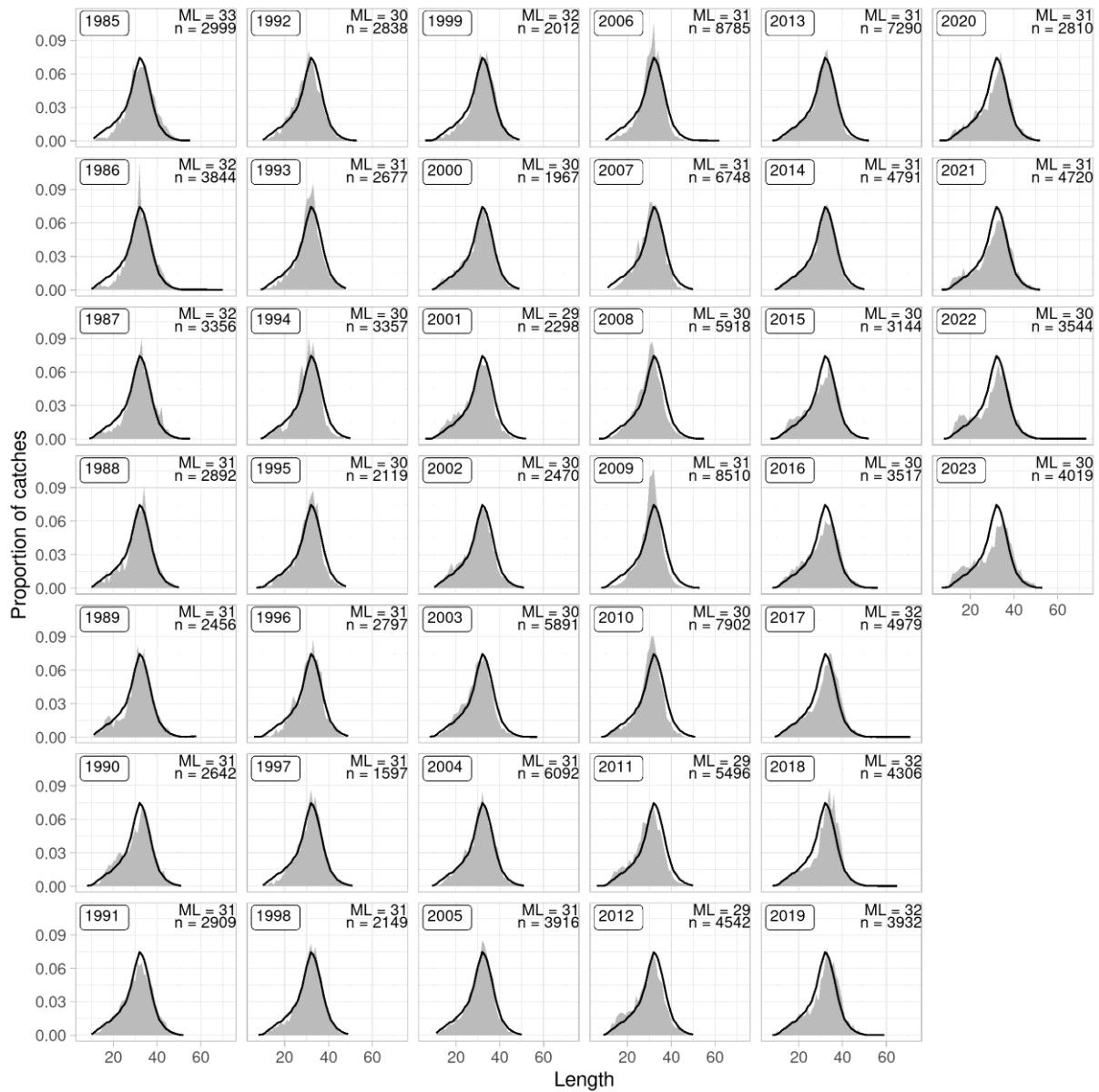

Figure 11. Lemon sole. Relative length-disaggregated abundance indices from the spring survey. The black line shows the mean for all years.
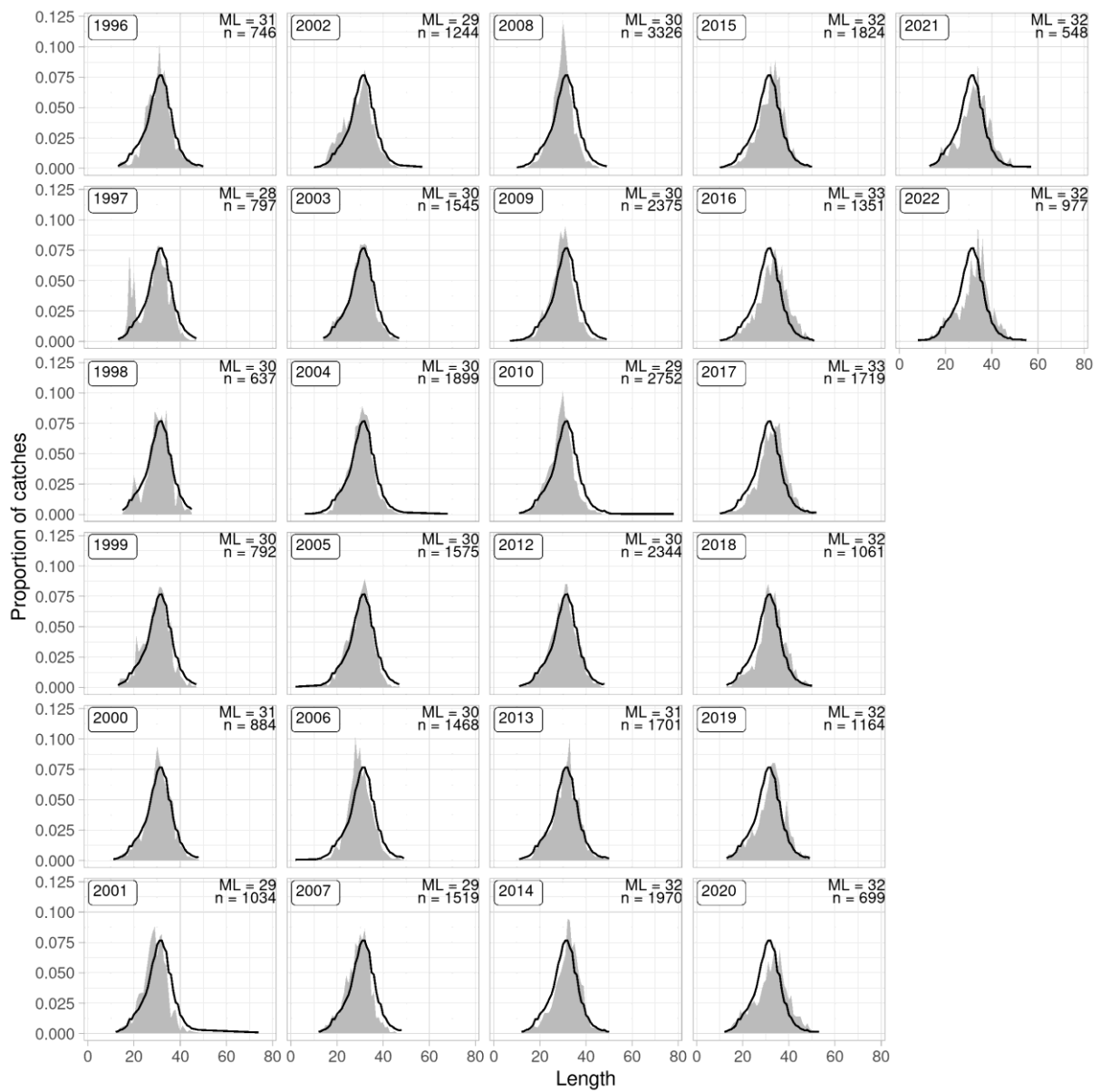
Figure 12. Lemon sole. Relative length-disaggregated abundance indices from the autumn survey. The black line shows the mean for all years.

In Figure 13, the length distribution from the beam trawl survey is shown. As the beam trawl survey was designed to target recruitment grounds, juveniles down to 10 cm can be registered.
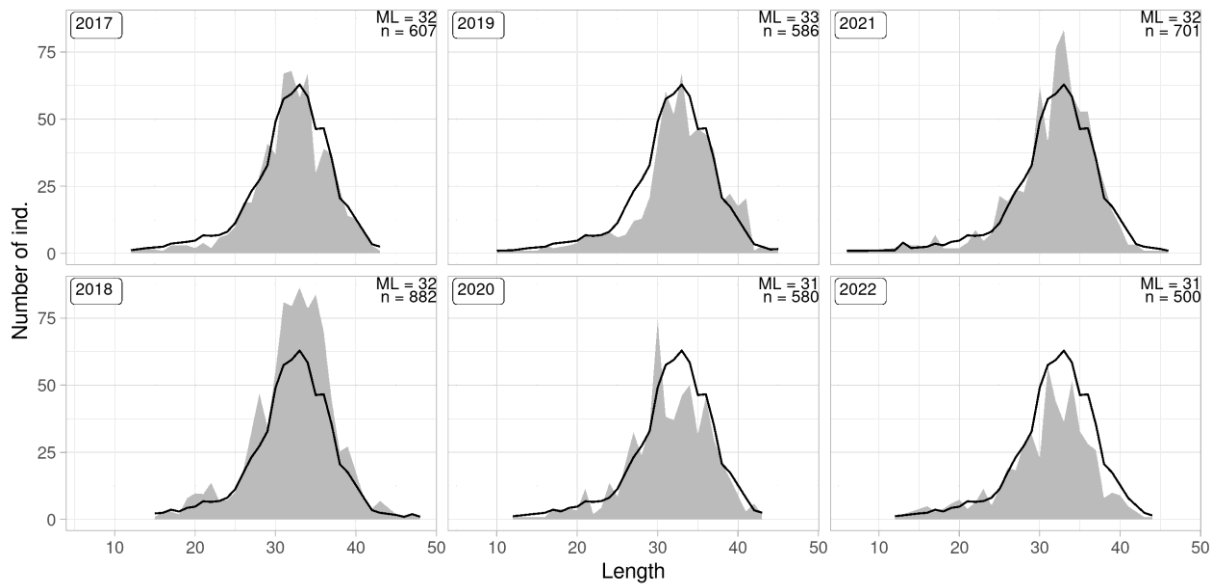

Figure 13. Lemon sole. Length distribution from the beam trawl survey (BTS). The black line shows the mean for all years.

Lemon sole was mostly caught on the main fishing grounds in the southwest and west part of Iceland in the spring survey in 2022, with considerable amount also caught deep of the southeast coast (Figure 14). The coldest waters off the northeast and east coast are almost devoid of lemon sole. Spatial distribution of lemon sole in the spring survey has been relatively stable since the survey was established in 1985 (Figure 15). The increase in estimated biomass after 2002 occurred more or less evenly in all areas. Spatial distribution of lemon sole in autumn survey in 2021 is very similar as in this year's spring survey (Figure 16). Most lemon sole in recent autumn surveys have been caught in the west and northwest of the country (Figure 17).
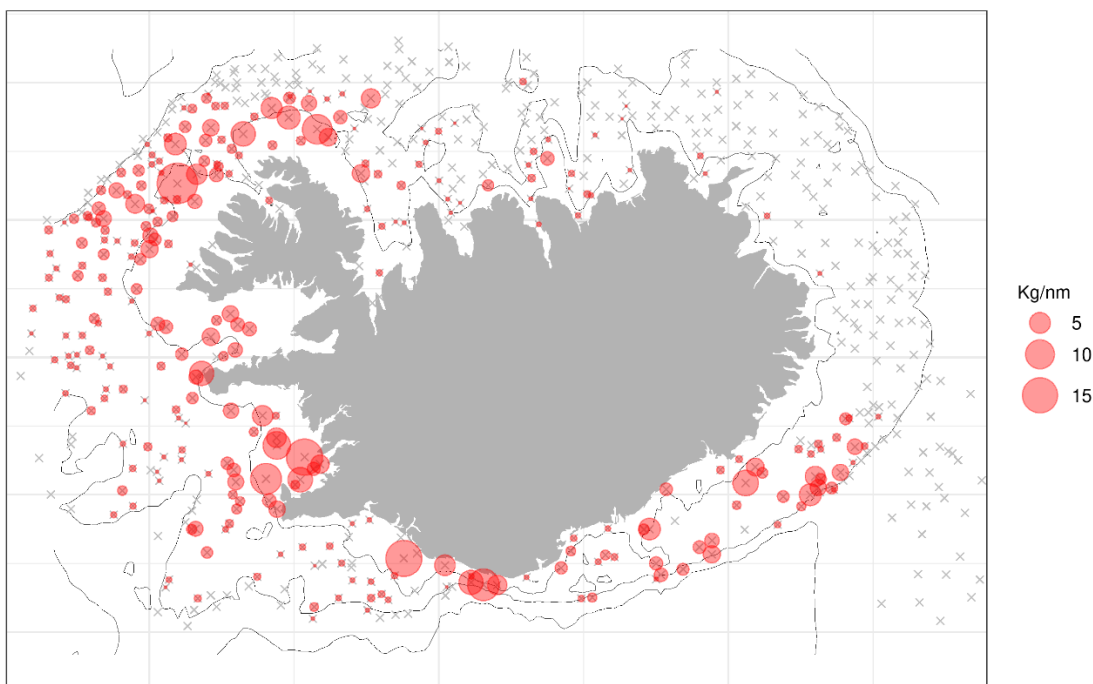

Figure 14. Lemon sole. Spatial distribution in the spring survey in 2023.
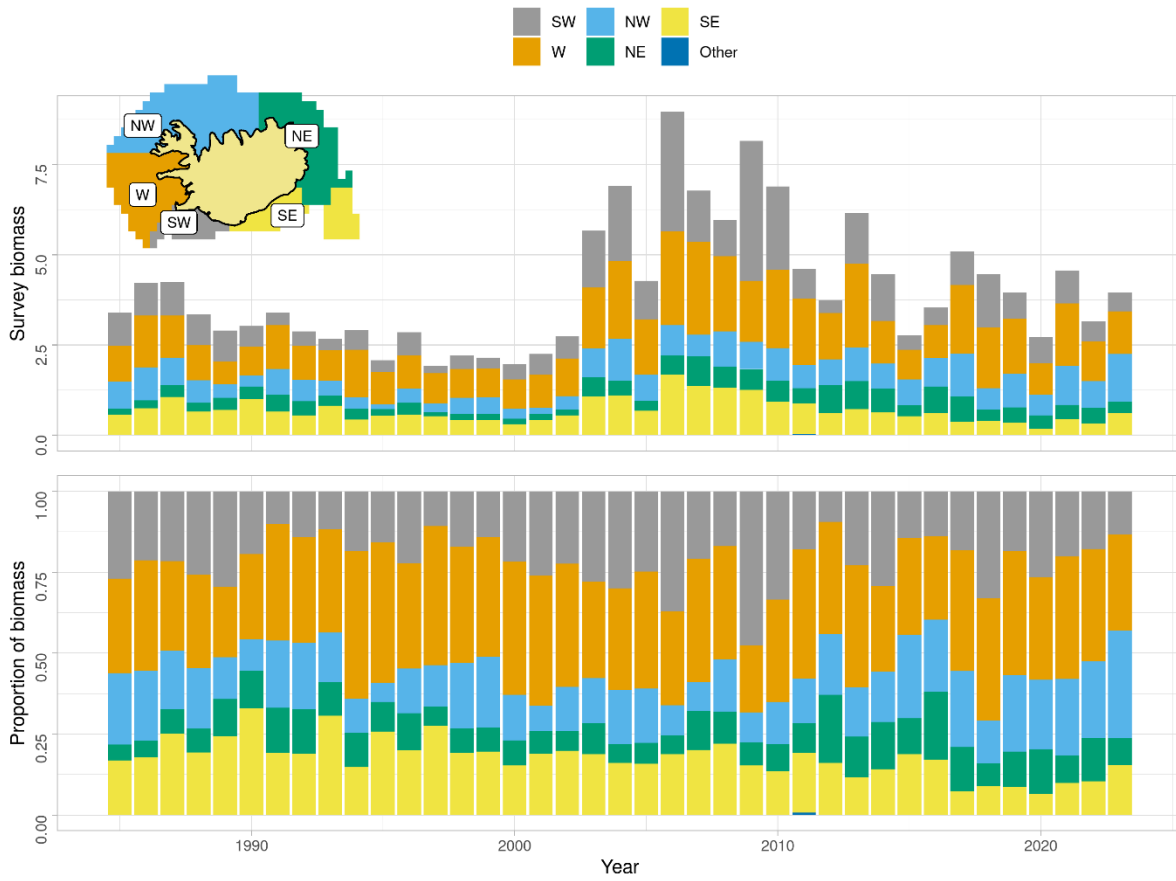
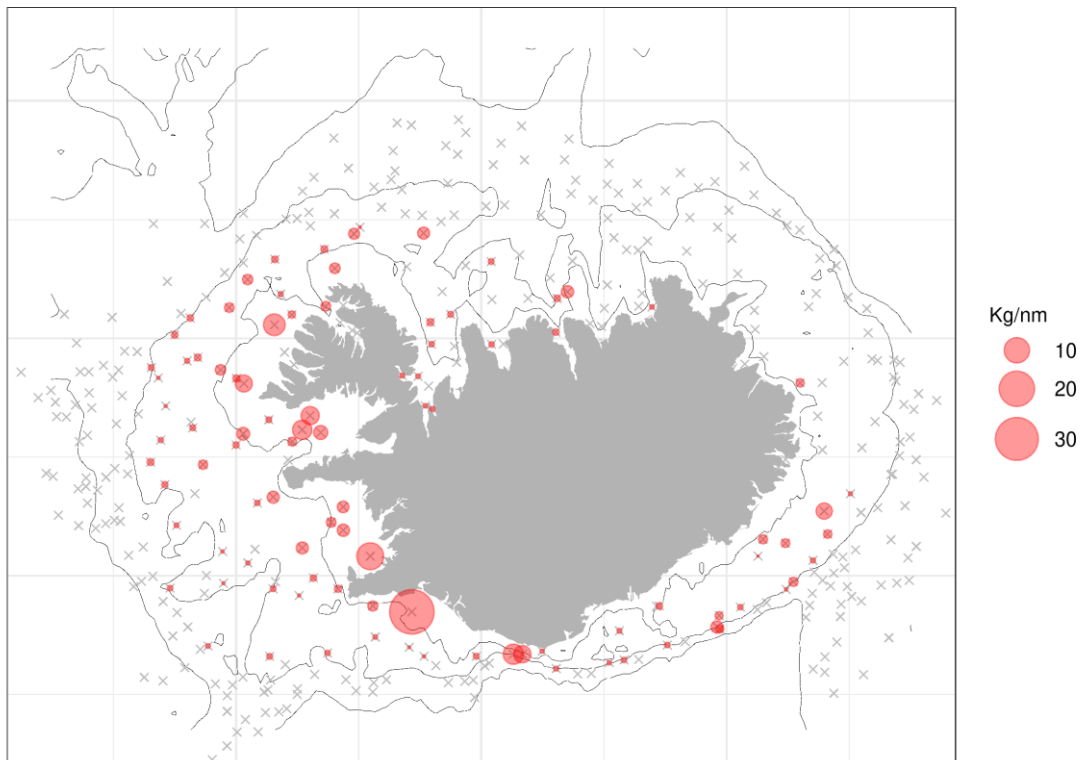**Figure 15. Lemon sole. Spatial distribution of biomass index from the spring survey.**

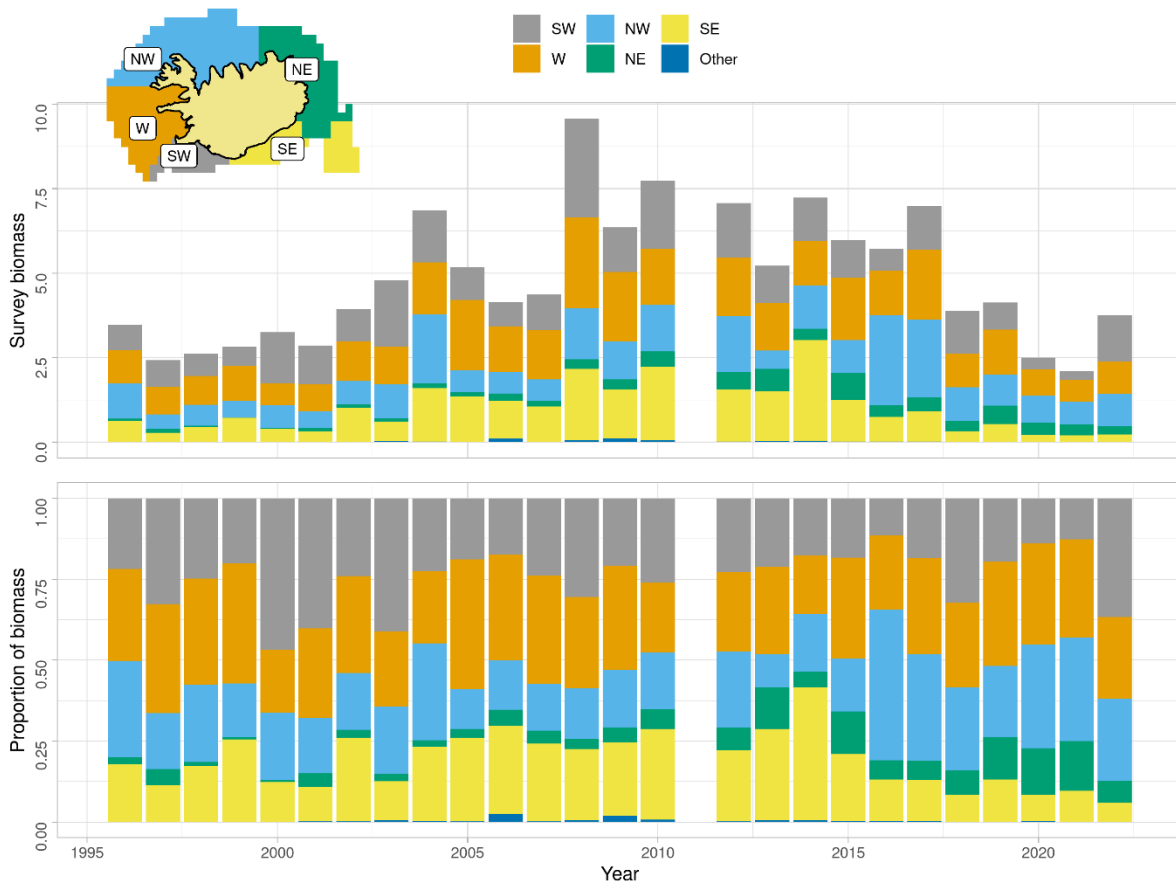**Figure 16. Lemon sole. Spatial distribution in the autumn survey in 2021.**

Figure 17. Lemon sole. Spatial distribution of biomass index from the autumn survey.

Figures 18 and 19, show spatial distribution of the lemon sole in the beam trawl survey, which is conducted in late August (except for in 2019 when it was conducted in late July) at very shallow depth.
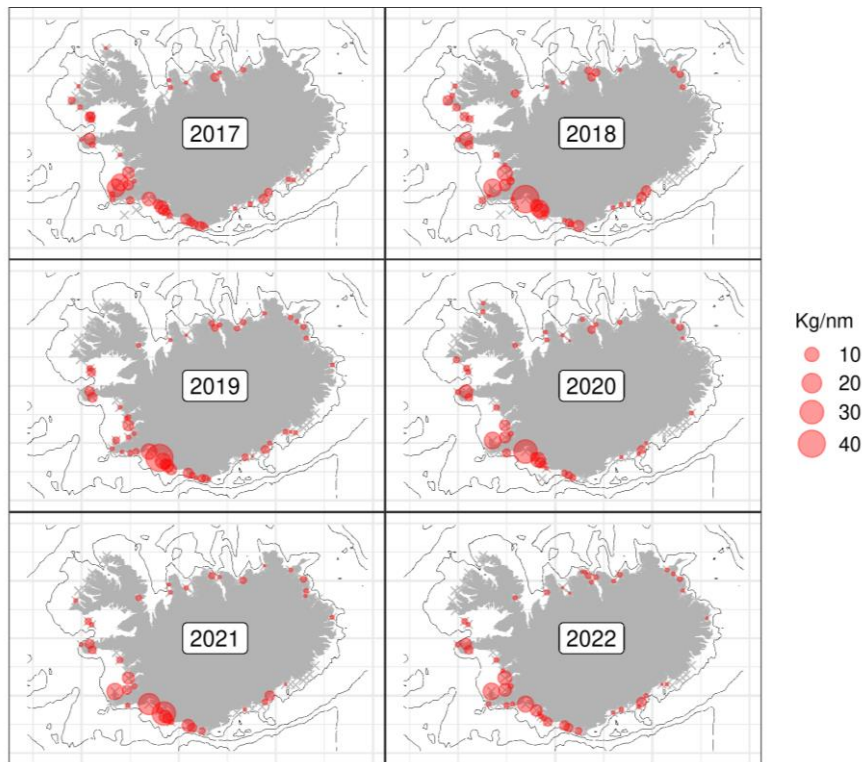
Figure 18. Lemon sole. Spatial distribution in the beam trawl survey since 2017. The NE-area was not sampled in 2017.
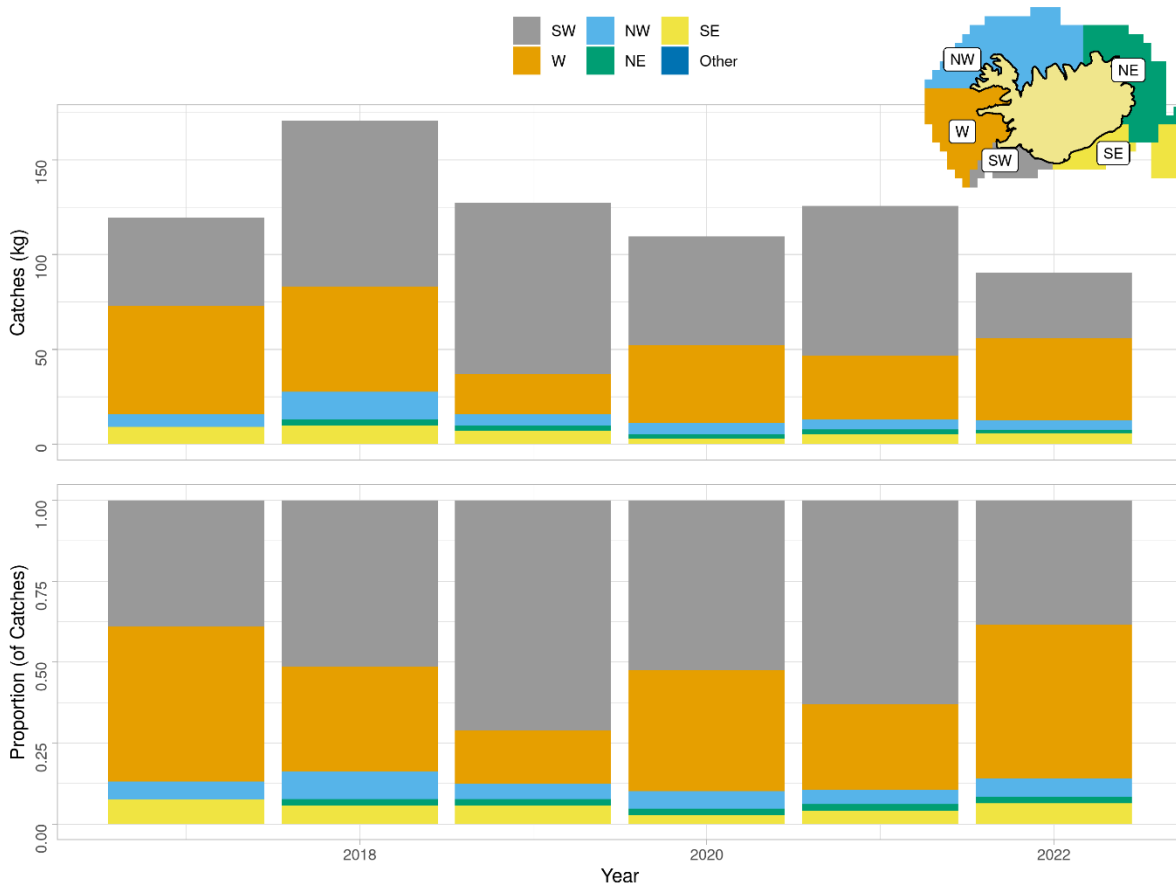

Figure 19. Lemon sole. Spatial distribution of the catch in the beam trawl survey since 2017. The NE area was not sampled in 2017.

STOCK ASSESSMENT

COMMENTS ON THE ASSESSMENT AND ADVICE

The assessment is for this stock based on ICES rfb-rule for data limited stocks for the first time in 2023, where life history traits, exploitation characteristics and other relevant parameters for data-limited stocks are considered (ICES 2021). The rfb-rule has the following form:

$$A_{y+1} = A_{y-1} \, r \, f \, b \, m$$

where A_{y+1} is the advised catch, A_{y-1} is last year's advice, r corresponds to the trend in biomass index (as in the current ICES "2 over 3" rule), f is a proxy for the exploitation (mean catch length divided by an MSY reference length) and b a biomass safeguard (reducing the catch when biomass index drops below a trigger value).

r is the ratio of the mean of the last two survey indices and the mean of the three preceding values or:

$$r = \frac{\sum_{i=y-2}^{y-1} I_1 / 2}{\sum_{i=y-3}^{y-5} I_1 / 3}$$

f is the length-ratio component where:

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

where $\overline{L}$ is is the mean catch length above $L_{F=M}$.

$L_{F=M}$ is calculated as:

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

where L_c is the length where frequency is half that of the modal value (Figure 20), and $L\infty$ is von Bertalanffy $L\infty$.

b is the biomass safeguard and is used to reduce catch advice when index falls below trigger,

$$b = min\big(1, I_y - 1/I_{trigger}\big)$$

where $I_{trigger} = i_{loss\omega}$

m is a multiplier based on stock growth. K for lemon sole is 0.2 and therefore m is 0.9.
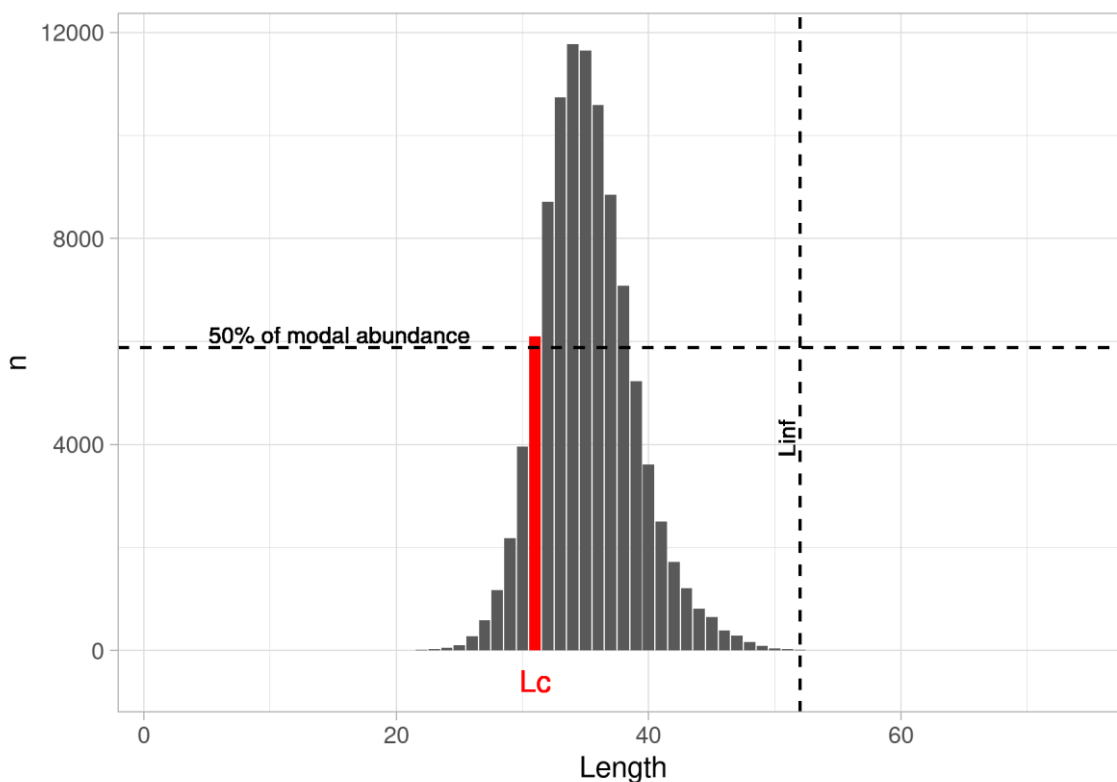
Figure 20. Lemon sole. Length frequency distribution from catches. Red line is the length at first capture.

ANALYSIS ON THE ASSESSMENT AND ADVICE

The assessment is based on the rfb-rule for ICES category 3 data-limited stocks and is applied for lemon sole for the first time this year and is applied for the next two fishing years (2023/2024 and 2024/2025). The Icelandic spring trawl survey (IS-SMB) was used as the index for the stock development. The advice is according to $A_{y+1} = A_{y-1}\ r\ f\ b\ m$ or 1137 t * 0.929 * 1.02 * 1 * 0.9 which result in advice for 2023/2024 set at 971 t (15% reduction from last year's advice) (Table 3). In 2019-2021, the advice was based on the ICES framework for data limited stocks (Category 3.2) where the ratio of the mean of the last two survey indices (Index A) to the mean of the three preceding values (Index B) is multiplied by the last year's advice. This method is no longer considered precautionary and hence, the new rule.

Table 3. Lemon sole. Comparison between the *rfb*-rule and the "2 over 3" rule.

	rfb-rule	Old 2-over-3 rule
Previous advice	1137	1137
Index A	3325	695
Index B	3471	882
Ratio (A/B)	0.929	0.788
Length ratio	1.02	-
Biomass safeguard	1	-
Multiplier	0.9	-
Initial advice	971	896
Stability clause applied	-	-20%
Precautionary buffer*	-	-
Final advice	971	910
Advice change	-15	-20

*Last applied in 2022.

APPLICATION OF THE 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=0.929 (Figure 21, Table 3)
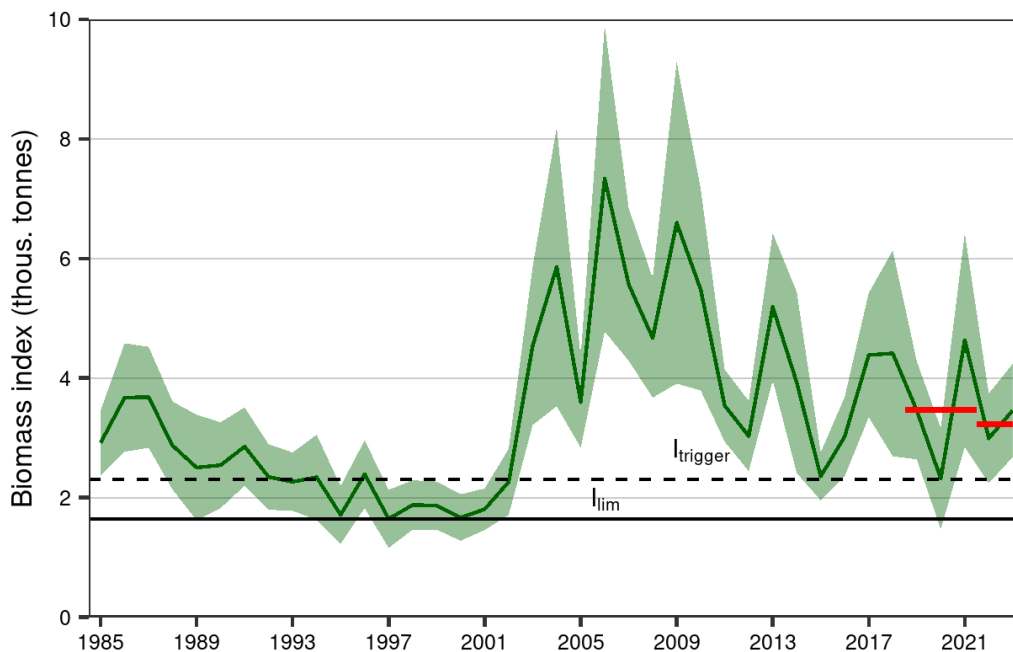

Figure 21. Lemon sole. IS-SMB biomass index since 1985. The red lines show the average of last two years values and the three preceding years used to calculate *r*.

- *f* is the length-ratio component. The mean length from catches 2019, the last year that length was measured from catches, was 74.22 cm and the target reference length (*Lc*, the length where frequency is half that of the modal value * 0.75 + *L∞* * 0.25) is **52** (Figure 22).
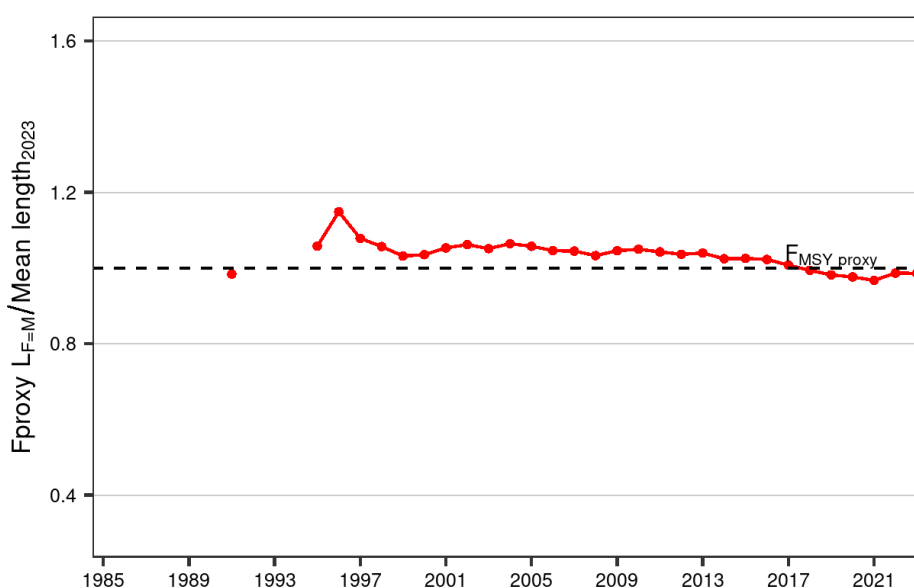

Figure 22. Lemon sole. Annual Fproxy for years for which sufficient data was available.

- b is the biomass safeguard and is used to reduce catch advice when index falls below trigger. I_{loss} for lemon sole is 1645 and was based on the lowest biomass index. $I_{trigger}$ is I_{loss} *1.4 or 2303 (Figure 21). The biomass index this year is 3459, which is above $I_{trigger}$ and hence, b is 1.

- m is the tuning parameter and for slow growing species (with von Bertalanffy 0.2< K<0.32), m equals 0.9.
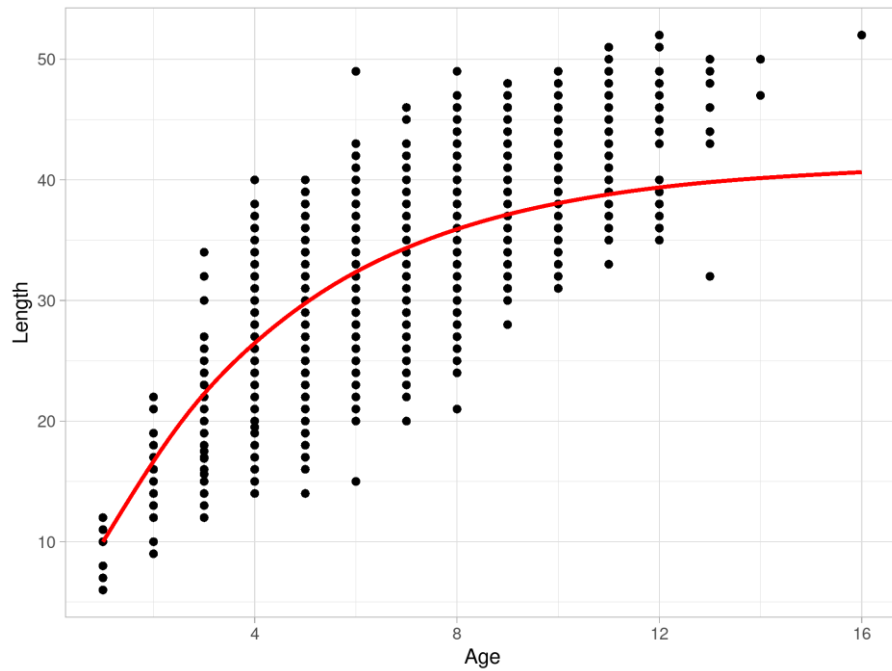

Figure 23. Lemon sole. The von Bertalanffy growth curve (red line) fitted to age and length data from the beam trawl survey and the spring survey in the last 5 years.

MANAGEMENT

The Ministry of Food, Agriculture and Fisheries is responsible for management of the Icelandic fisheries and implementation of legislation. Lemon sole was included in the ITQ system in the 1999/2000 quota year and as such subjected to TAC limitations.

Between 2005 and 2009, TAC was set higher than recommended by Marine Research Institute (MRI), but this practice stopped in the 2010/2011 quota year (Table 4). No formal management plan exists for this stock.

Figure 20 shows net transfers of lemon sole in the Icelandic ITQ-system. From 2003-2008 and 2015-2017 there was a net transfer of other species to lemon sole quota (positive values in Figure 24). In years, 2009-2014, there was little transfer from other species to lemon sole. Net transfer of lemon sole quota for a given fishing year is usually in the range of -6 to 6%, except for the fishing year 2020/2021 (Figure 24).

Table 4. Lemon sole. Recommended TAC, national TAC set by the Ministry, and landings (tonnes).

| FISHING YEAR	REC. TAC	NATIONAL TAC	CATCH
1999/00	1400	1400	1406
2000/01	1400	1400	1411
2001/02	1400	1400	1028
2002/03	1600	1600	1059
2003/04	1600	1600	2065
2004/05	1600	1600	2549
2005/06	1600	1800	2518
2006/07	1600	2000	2918
2007/08	1600	2200	2654
2008/09	1800	2200	2682
2009/10	1800	2200	1955
2010/11	1800	1800	1733
2011/12	1800	1800	1803
2012/13	1400	1400	1464
2013/14	1600	1600	1427
2014/15	1600	1600	1758
2015/16	1300	1300	1724
2016/17	1087	1087	1471
2017/18	1304	1304	1778
2018/19	1565	1565	1526
2019/20	1341	1341	1096
2020/21	1073	1073	1435
2021/22	1288	1288	1193
2022/23	1137	1137	
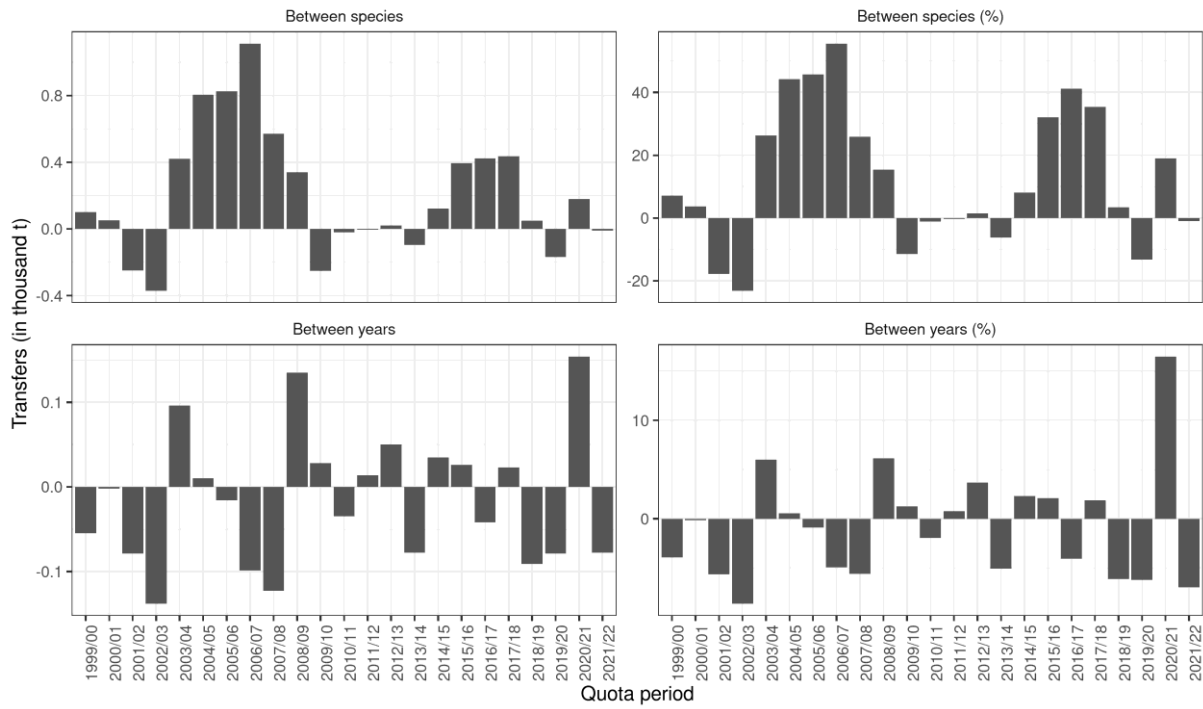
Figure 24. Lemon sole. Net transfers of quota to and from lemon sole in the Icelandic ITQ system by fishing year. Between species (upper): Positive values indicate a transfer of other species to lemon sole, but negative values indicate a transfer of lemon sole quota to other species. Between years (lower): Net transfer of quota in a given fishing year.