LEMON SOLE – ÞYKKVALÚRA
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. No changes 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, except for 2020 registered catch. Lemon sole is primarily caught in demersal seine, and as bycatch in demersal and *Nephrops* 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 demersal seine taking more than half of the catches. Demersal seiners operate mainly at 41-80 m depths whereas lemons sole in the trawl fishery is caught at 80-120 m depth.

Between 31 and 85 trawlers and between 28 and 50 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 28-30 vessels, however the number of trawlers increased from 31 in 2014 to 50 vessels in 2020 (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 fluctuated around that number 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.

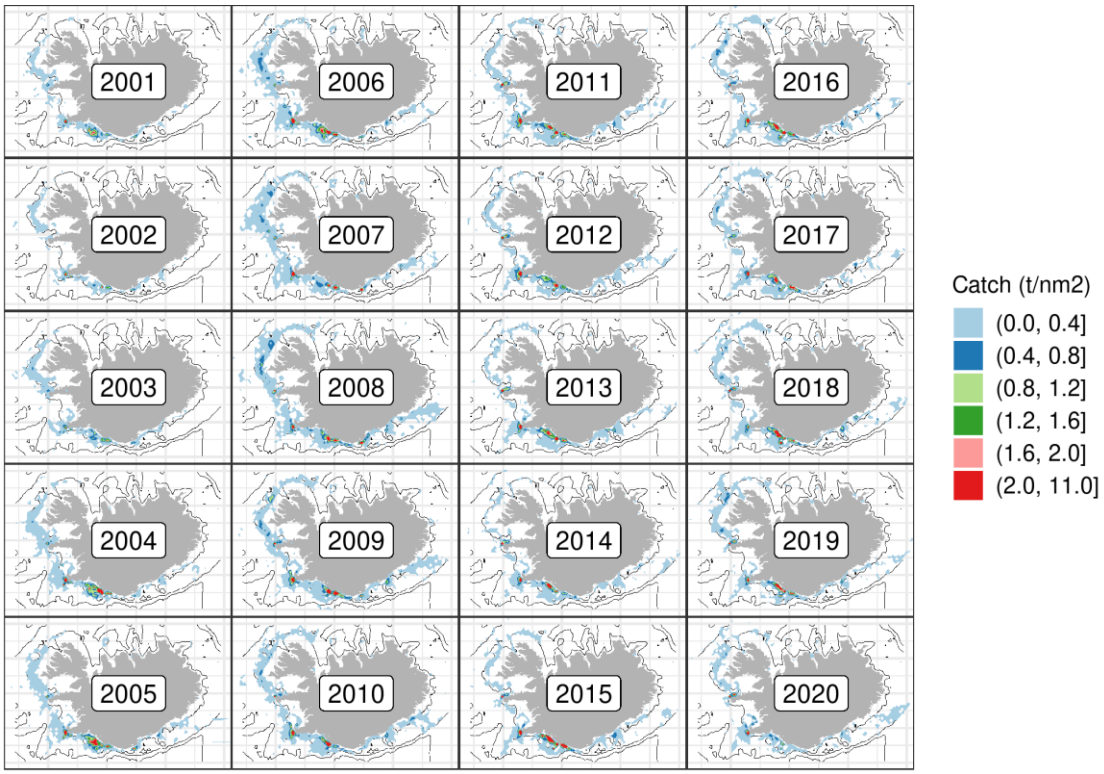

Figure 1. Lemon sole. Geographical distribution of the Icelandic fishery 2001-2020. Reported catch from logbooks.

Mynd 1. Þykkvalúra. Útbreiðsla veiða á Íslandsmiðum 2001-2020 samkvæmt afladagbókum.

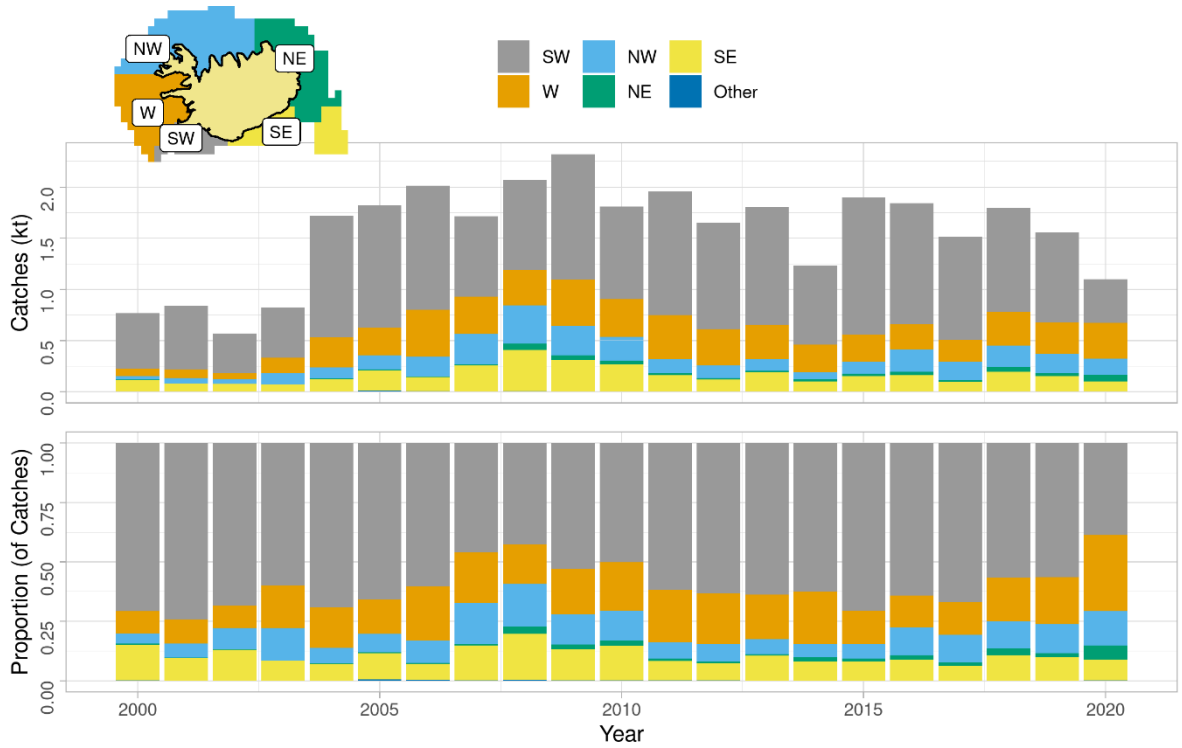

Figure 2. Lemon sole. Spatial distribution of the Icelandic fishery by fishing area since 2000 according to logbooks. All gears combined.

Mynd 2. Þykkvalúra. Útbreiðsla veiða á íslensku veiðisvæði frá árinu 2000 samkvæmt afladagbókum. Öll veiðarfæri samanlagt.

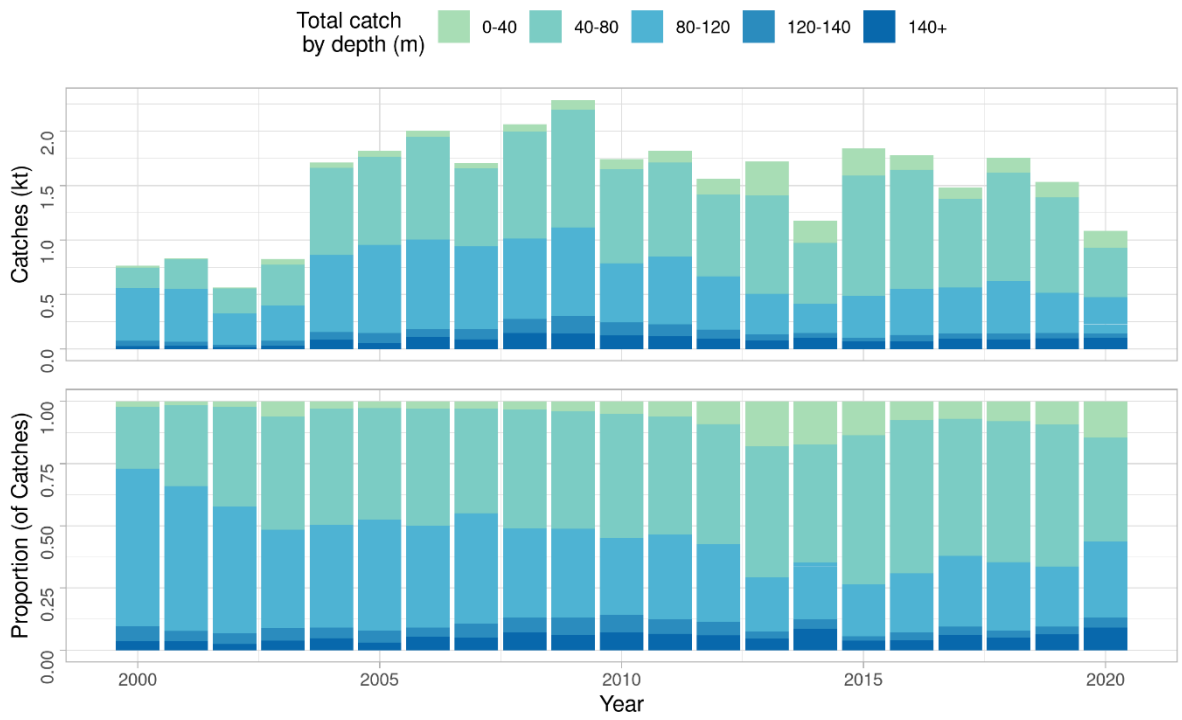

Figure 3. Lemon sole. Depth distribution of catches according to logbooks.

Mynd 3. Þykkvalúra. Afli samkvæmt afladagbókum, skipt eftir dýpi.

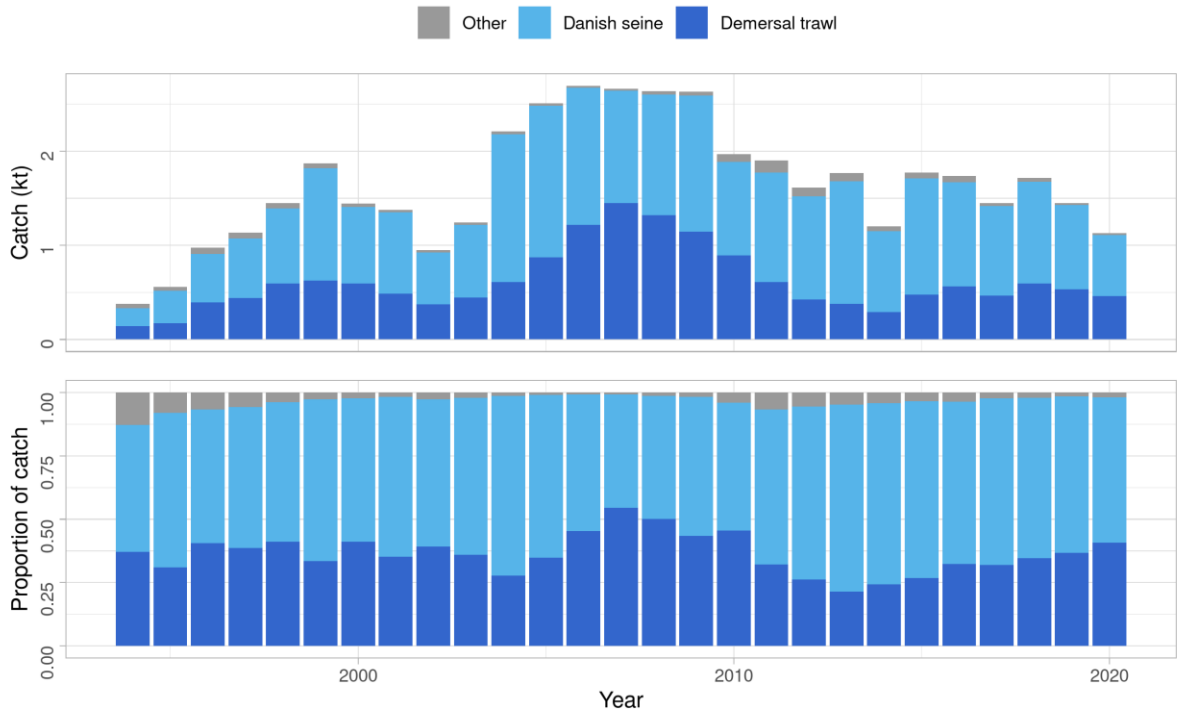

Figure 4. Lemon sole. Total catch (landings) by fishing gear since 1994, according to statistics from the Directorate of Fisheries.

Mynd 4. Þykkvalúra. Landaður afli eftir veiðarfærum frá árinu 1994, samkvæmt aflaskráningarkerfi Fiskistofu.

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.

Tafla 1. Þykkvalúra. Fjöldi íslenskra skipa sem landað hafa 1000 kg af þykkvalúru og allur landaður afli eftir veiðarfærum.

YEAR	NUMBER OF VESSELS			CATCHES (TONNES)			
	Trawlers	*Seiners*	*Other*	*Demersal trawl*	*Demersal seine*	*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	460	648	21	1129

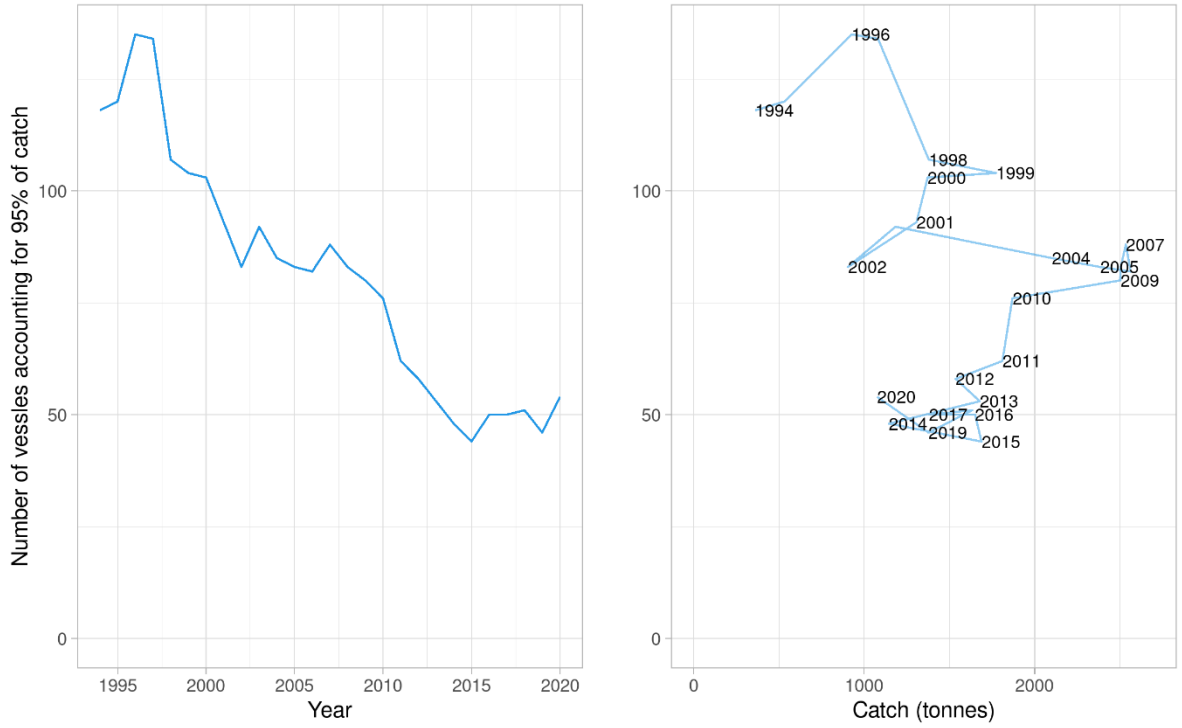

Figure 5. Lemon sole. Number of vessels (all gear types) accounting for 95% of the total catch annually since 1994. Left: Plotted against year. Right: Plotted against total catch. Data from the Directorate of Fisheries.

Mynd 5. Þykkvalúra. Fjöldi skipa og báta (öll veiðarfæri) sem veiddu 95% heildaraflans hvert ár frá 1994. Vinstri: Sýnt eftir árum. Hægri: Sýnt í samanburði við heildarafla. Gögn frá aflaskráningarkerfi Fiskistofu.

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 more than 10% of the catch. In 2000-2015, lemon sole CPUE gradually increased from 200 to around 600 kg/set, but has since then decreased and was about 350 kg/set in 2020 (Figure 6). CPUE of lemon sole in demersal trawl gradually increased from 2002-2017 to a peak in approximately 200 kg/hour. In the last three years the CPUE decreased to 110 kg/hour in 2020.

Total fishing effort for lemon sole by demersal seine is estimated as the number of sets where lemon sole was more than 10% of the total catch. The fishing effort was relatively low in 2002 but increased rapidly and peeked in 2004. Since then, effort gradually decreased and was in 2020 at the same level as in 2002. This is both due to the fact that fewer seiners are fishing and catch per unit effort is higher. For demersal trawl, fishing effort during these years was highest in 2006-2011. Since the peak in 2009, demersal trawl effort has declined sharply to a low in 2014 and has remained fluctuating since (Figure 6).

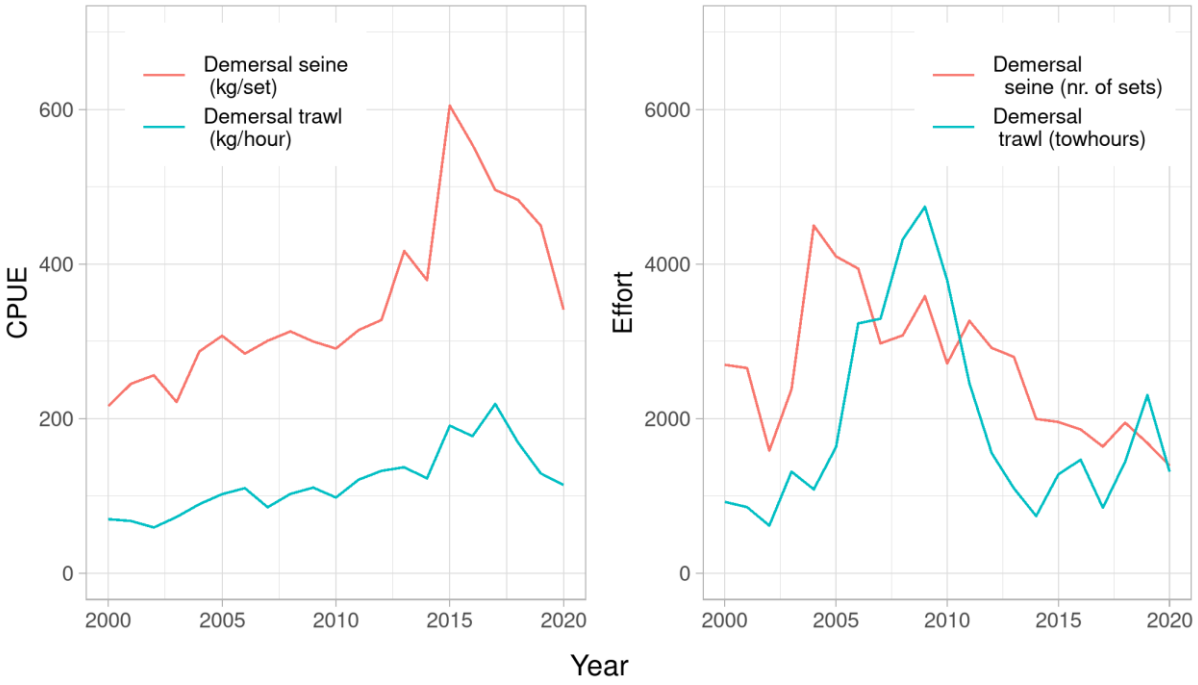

Figure 6. Lemon sole. Raw CPUE (left) and fishing effort (right) from demersal seine (kg/set or nr. of sets) (in red) and demersal trawl (kg/hour or towhours) (in blue).

Mynd 6. Þykkvalúra. Afli á sóknareiningu (vinstri) og sókn (hægri) með dragnót (kg í kasti eða fjöldi kasta) (rautt) og botnvörpu (kg/klst eða togtímar) (blátt).

AGE DISTRIBUTION OF LANDED LEMON SOLE

Otoliths have been collected from commercial catches since 1999. Annually 11-38 samples have been collected from demersal seine and 3-21 samples from demersal trawl, or a total of 275-1100 and 100-500 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	16	400
2020	14	345	15	350

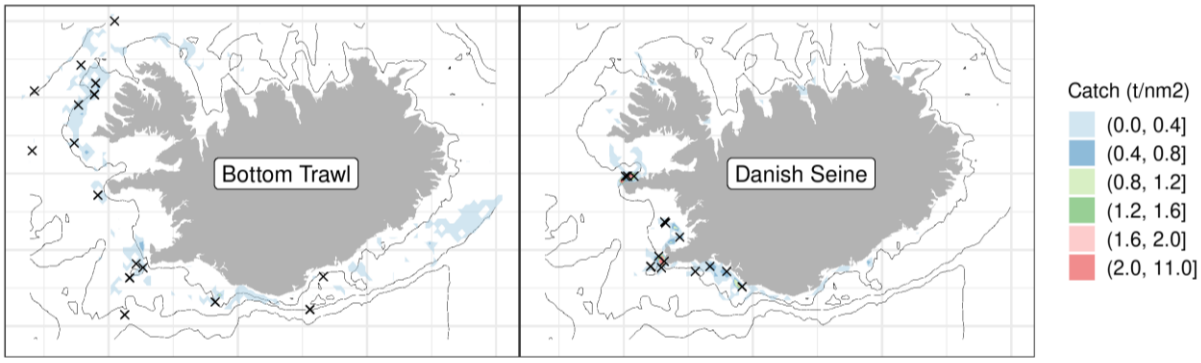

Figure 7. Lemon sole. Fishing grounds for demersal seine and trawl in 2020 as reported in logbooks and positions of samples taken from landings (asterisks).

Mynd 7. Þykkvalúra. Veiðisvæði dragnótar og botnvörpu við Ísland árið 2020 samkvæmt afladagbókum og staðsetningar sýna úr lönduðum afla (kross).

In 2010-2014, the catches consisted mainly of 6-9 years old lemon sole, or about 70% of landings in numbers (Figure 8). Age of landed fish increased in 2016-2017 to 7-10 year old lemon sole, however the similar 6-9 age group pattern was again observed in 2019-2020.

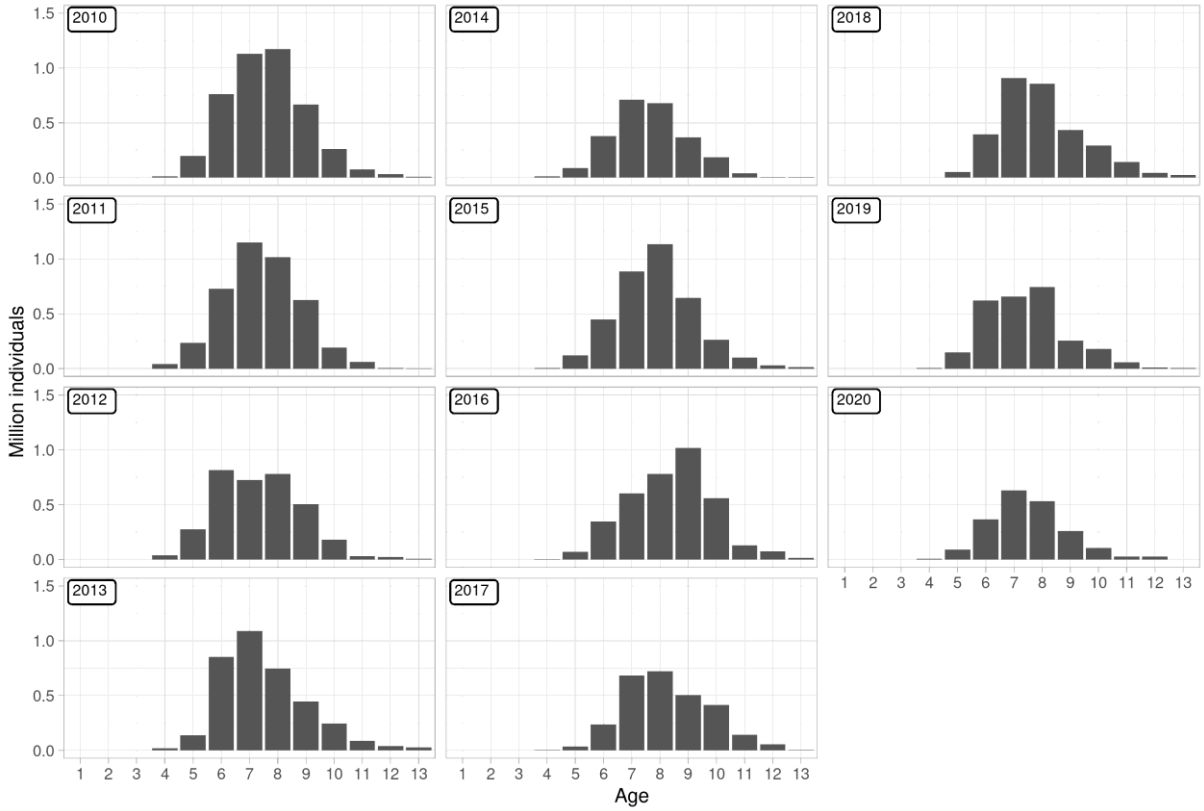

Figure 8. Lemon sole. Estimated age distribution of landed catch based on landings and otoliths collected from landed catch.

Mynd 8. Þykkvalúra. Áætluð aldursdreifing landaðs afla byggð á aldursgreiningum á fiskum úr afla.

LENGTH DISTRIBUTION OF LANDED LEMON SOLE

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

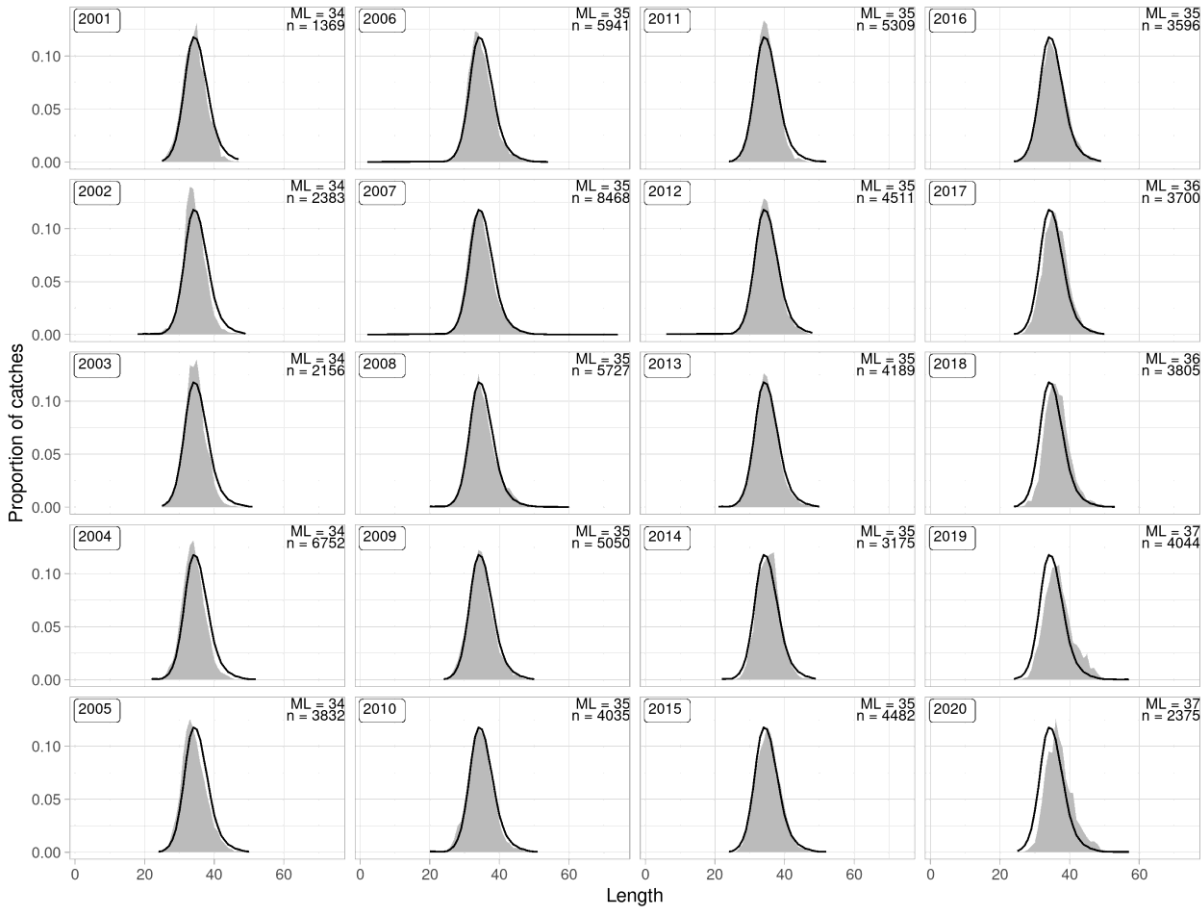

Figure 9. Lemon sole. Length distribution from landed catch. The dotted line represents the mean length distribution for all years.

Mynd 9. Þykkvalúra. Lengdardreifing aflasýna frá árinu 2001 með meðal lengdardreifingu fyrir öll árin (punktalína).

SURVEY DATA

The Icelandic spring groundfish survey (hereafter spring survey, IS-SMB), which has been conducted annually in March 1985-2000, covers the most important distribution area of the lemon sole. In addition, the Icelandic autumn groundfish survey (hereafter 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 spring 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. The plan is to incorporate this survey in the stock assessment for lemon sole in the future.

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 mid-2000s before the highest peak (Figure 10). The index for lemon sole larger than 39 cm increased significantly from 2000 to 2003 and has since then fluctuated around that level, with 2021 being the highest value recorded. The index of juvenile abundance (≤20 cm) in the spring survey has decreased after it peaked in 2011, but increased considerably in 2021. 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. 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.

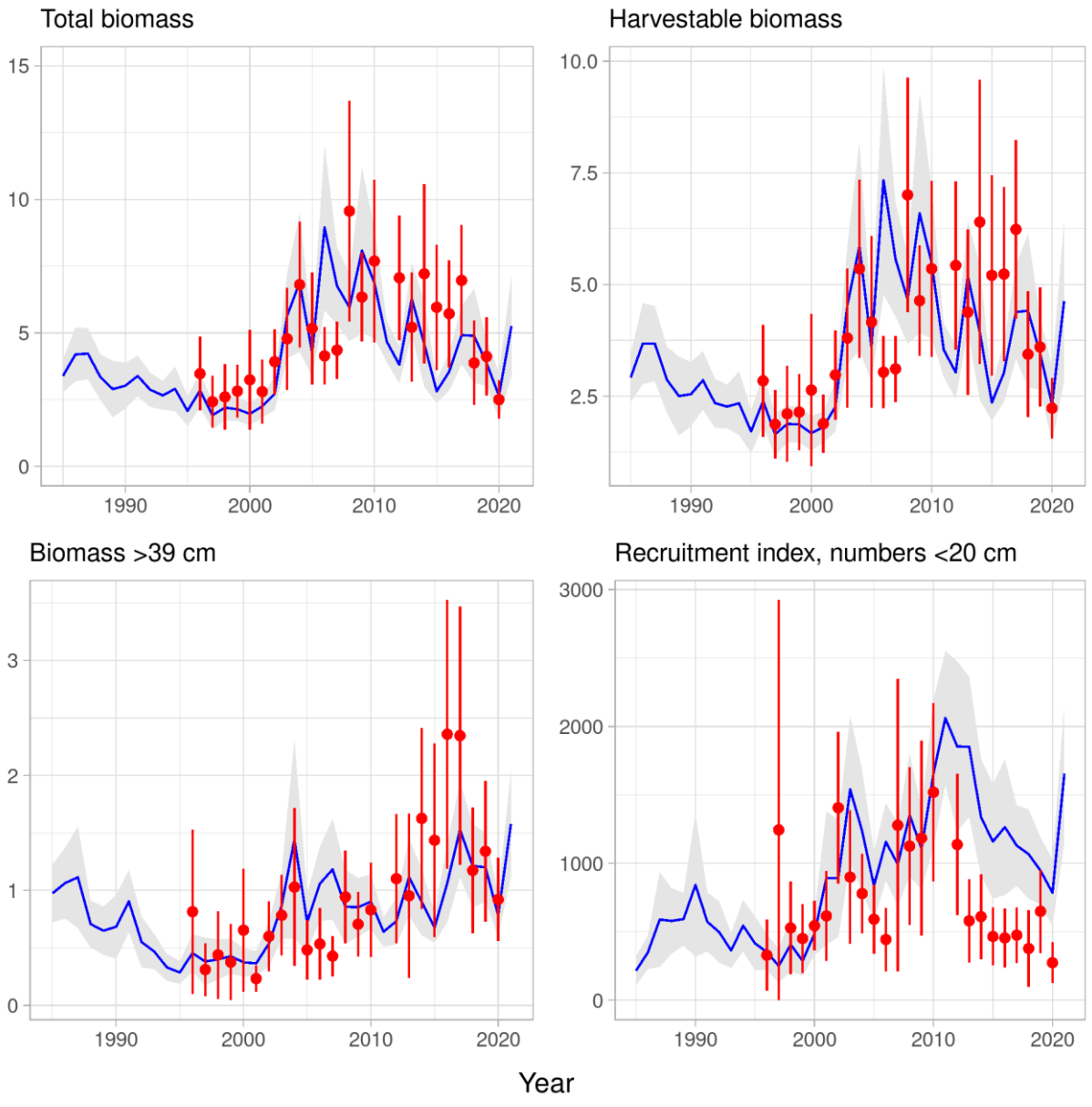

Figure 10. Lemon sole. Total biomass indices (upper left) and harvestable biomass indices (≥30 cm, upper, right), biomass indices of larger individuals (≥39 cm, lower left) and juvenile abundance indices (≤20 cm, lower right) from the spring survey (blue) from 1985 and autumn survey (red) from 1996,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

Mynd 10. Þykkvalúra. Stofnvísitala (efri til vinstri), vísitala veiðistofns (≥30 cm, efri til hægri) og vísitala stærri einstaklinga (≥39 cm, neðri til vinstri) og nýliðunarvísitala (≤20 cm, neðri til hægri), úr stofnmælingu botnfiska að vori (blátt) frá árinu 1985 og hausti (rautt) frá árinu 1996, ásamt 95% öryggismörkum.

Similar to the commercial catch, the size distribution in the spring survey has been stable, with little variation over time (Figure 11). Data from the autumn survey tells a similar story (Figure 12).

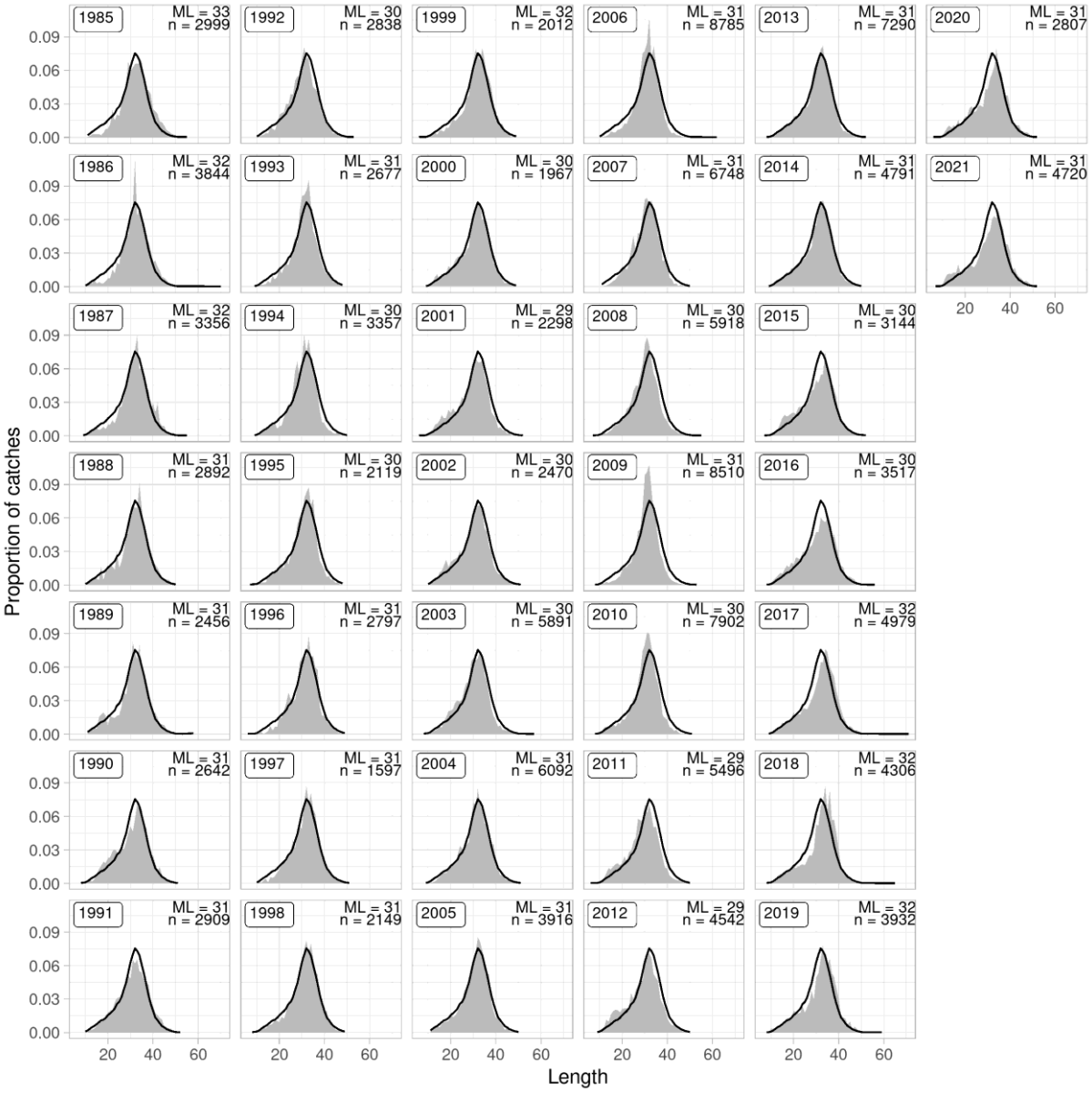

Figure 11. Lemon sole. Length-disaggregated abundance indices from the spring survey. The black line shows the mean for all years.

Mynd 11. Þykkvalúra. Lengdarskiptar vísitölur úr stofnmælingu botnfiska að vori ásamt meðaltali allra ára (svört lína).

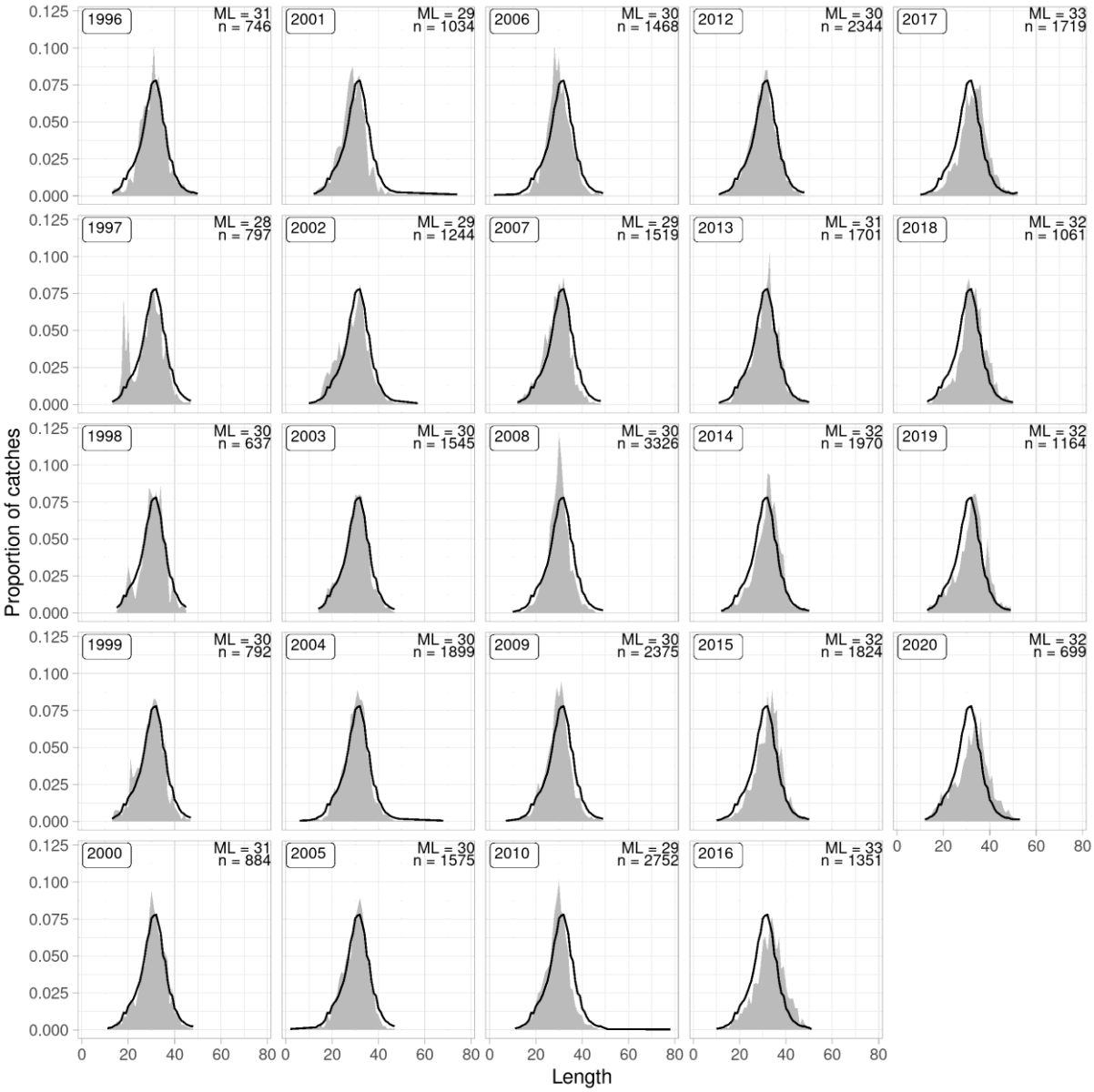

Figure 12. Lemon sole. Length-disaggregated abundance indices from the autumn survey. The black line shows the mean for all years.

Mynd 12. Þykkvalúra. Lengdarskiptar vísitölur úr stofnmælingu botnfiska að hausti ásamt meðaltali allra ára (svört lína).

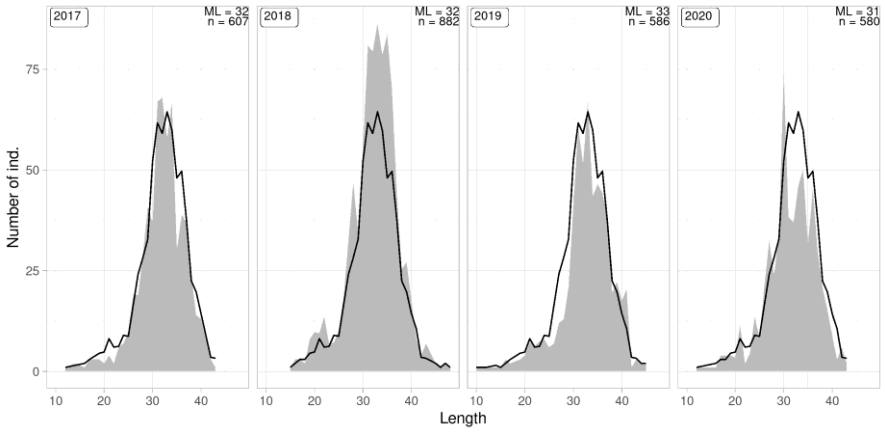

Figure 13. Lemon sole. Length distribution from the beam trawl survey (BTS). The black line shows the mean for all years.

Mynd 13. Þykkvalúra. Lengdardreifing í grunnslóðaralli ásamt meðaltali allra ára (svört lína).

Lemon sole was mostly caught on the main fishing grounds in the southwest and west part of Iceland in the spring survey in 2021, 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, although in years with exceptionally high biomass estimates (i.e. 2006 and 2009) the increase was mostly in the SW area.

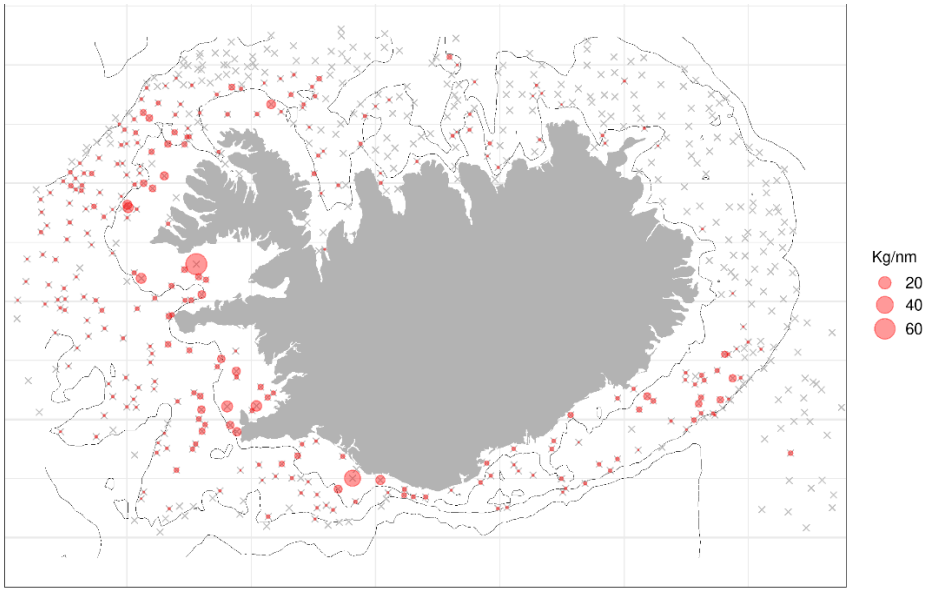

Figure 14. Lemon sole. Spatial distribution in the spring survey in 2021.

Mynd 14. Þykkvalúra. Útbreiðsla í stofnmælingu botnfiska að vori 2021.

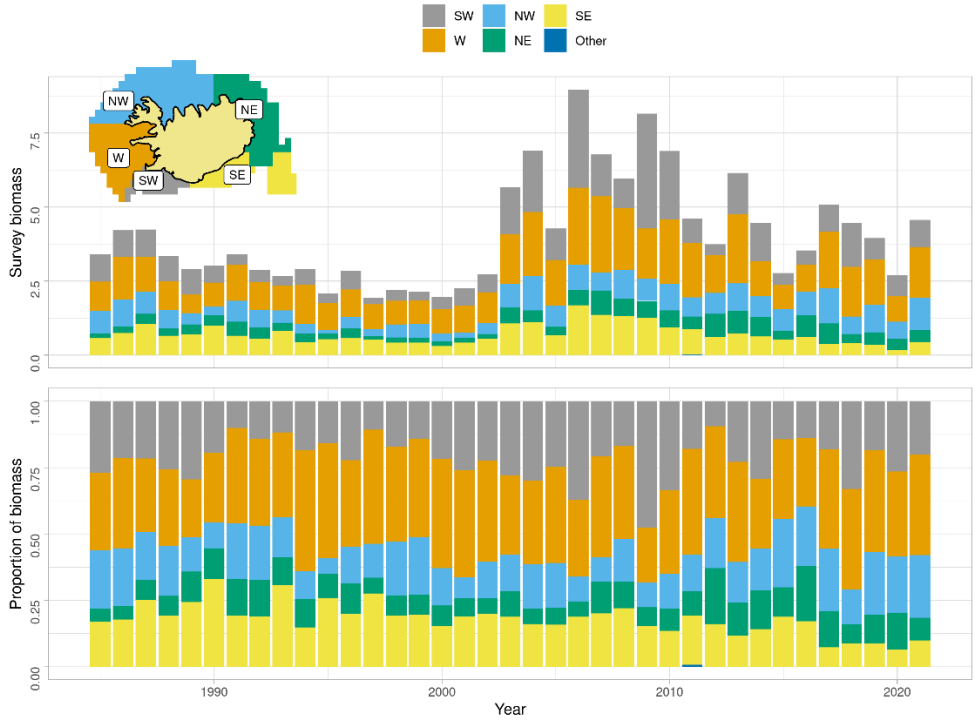

Figure 15. Lemon sole. Spatial distribution of biomass index from the spring survey.

Mynd 15. Þykkvalúra. Dreifing lífmassavísitölu í stofnmælingu botnfiska að vori.

Lemon sole catch was fairly distributed in the autumn survey in 2020, with exception of the northern part of NE area (Figure 16). The majority of lemon sole in the autumn survey in last five years has been caught mostly in the west and northwest of the country (Figure 17).

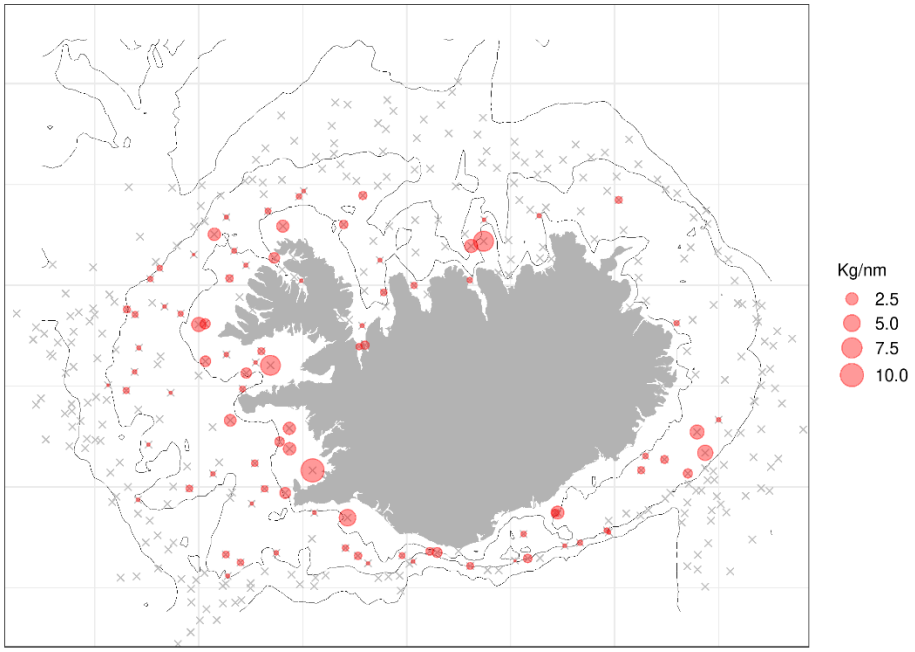

Figure 16. Lemon sole. Spatial distribution in the autumn survey in 2020.

Mynd 16. Þykkvalúra. Útbreiðsla í stofnmælingu botnfiska að hausti árið 2020.

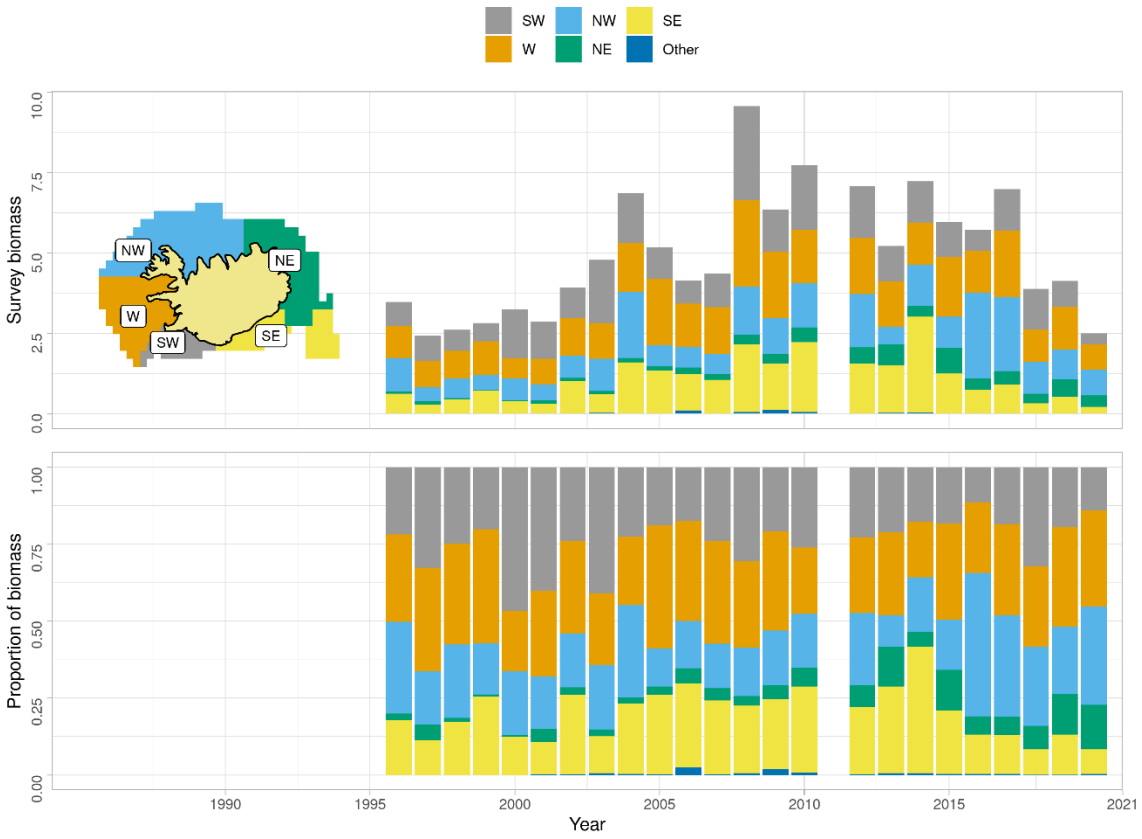

Figure 17. Lemon sole. Spatial distribution of biomass index from the autumn survey.

Mynd 17. Þykkvalúra. Dreifing lífmassavísitölu í stofnmælingu botnfiska að hausti.

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.

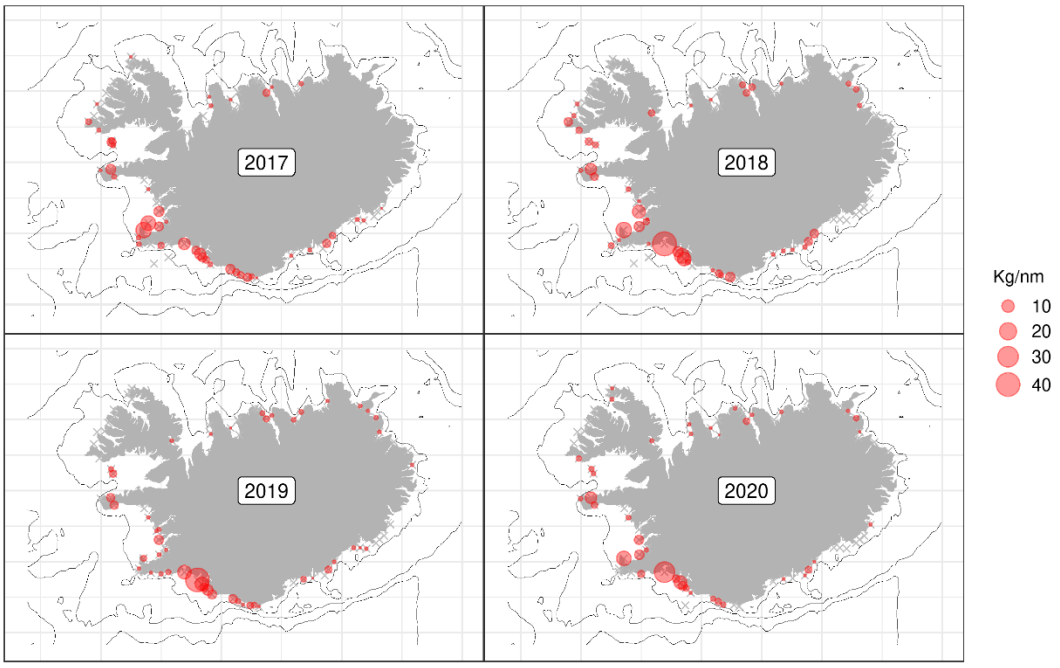

Figure 18. Lemon sole. Spatial distribution in the beam trawl survey since 2017. The NE-area was not sampled in 2017.

Mynd 18. Þykkvalúra. Útbreiðsla í grunnslóðaralli frá árinu 2017. Ekki var farið á norðaustursvæðið árið 2017.

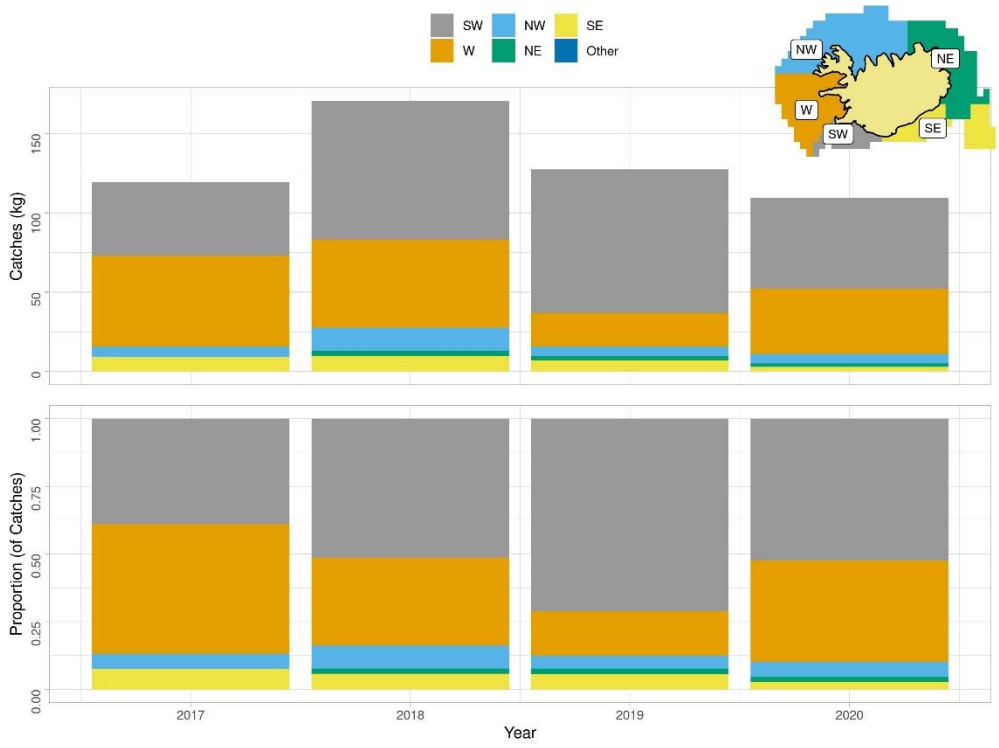

Figure 19. Lemon sole. Spatial distribution of the catch in the beam trawl survey since 2017. The NE area was not sampled in 2017.

Mynd 19. Þykkvalúra. Útbreiðsla eftir svæðum í grunnslóðaralli frá árinu 2017. Ekki var farið á NA-svæðið árið 2017.

MANAGEMENT

The Ministry of Industries and Innovation 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 3). 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 20). 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% (Figure 20).

Table 3. Lemon sole. Recommended TAC, national TAC set by the Ministry, and landings (tonnes).

Tafla 3. Þykkvalúra. Tillögur Hafrannsóknastofnunar um hámarksafla, ákvörðun stjórnvalda um aflamark og landaður afli (tonn).

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	

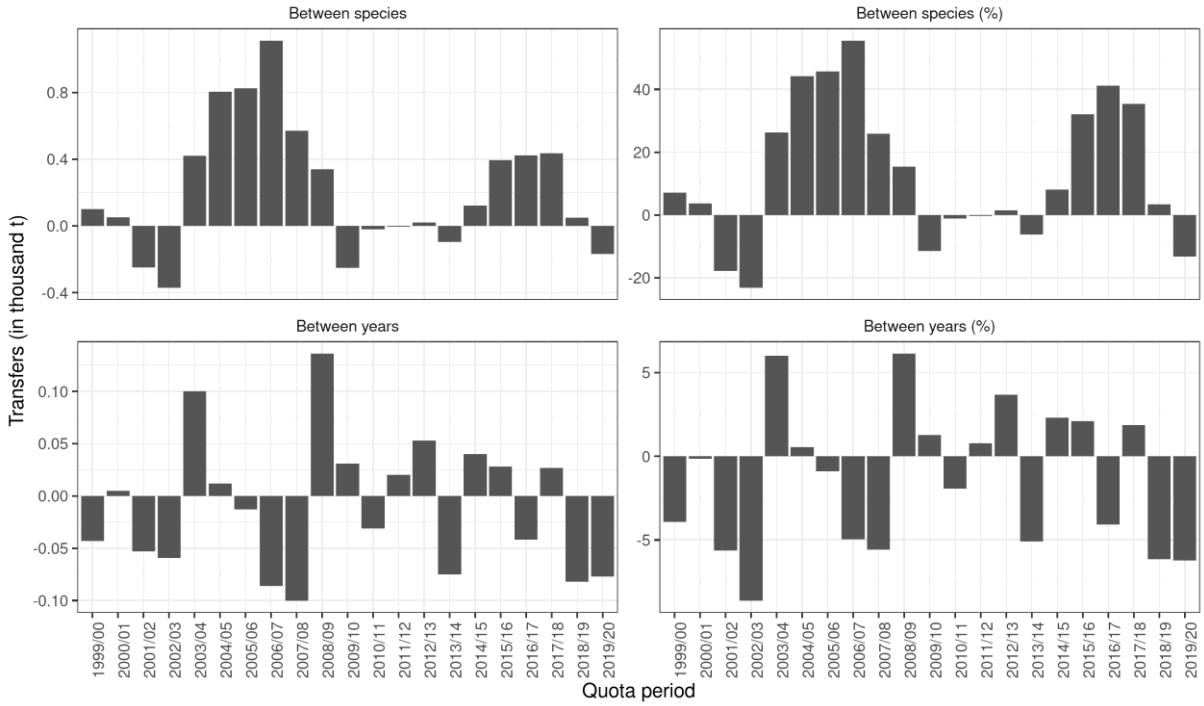

Figure 20. Lemon sole. Net transfers of quota to and from lemon sole in the Icelandic ITQ system by fishing year. Between species (upper): Positive values indicate a transfer of other species to lemon sole, but negative values indicate a transfer of lemon sole quota to other species. Between years (lower): Net transfer of quota in a given fishing year.

Mynd 20. Þykkvalúra. Nettó tilfærsla á kvóta eftir fiskveiðiárum. Tilfærsla milli tegunda (efri myndir): Jákvæð gildi tákna tilfærslu á kvóta annarra tegunda yfir á þykkvalúru en neikvæð gildi tilfærslu þykkvalúrukvóta á aðrar tegundir. Tilfærsla milli ára (neðri myndir): Nettó tilfærsla kvóta á viðkomandi fiskveiðiári.

EXPLORATORY ASSESSEMENT USING GADGET

An exploratory model for lemon sole was developed using Gadget. This work was initiated to fulfil the request from the industry to have an analytical assessment framework for this species. This is a work in progress and the preliminary results are outlined below.

DATA USE AND MODEL SETTINGS

MODEL SETTINGS

Population is defined by 2 cm length groups, from 3–70 cm and the year is divided into four quarters. The age range is 1 to 15 years, with the oldest age treated as a plus group. Recruitment happens in the first year and was set at age 1. The length-at-recruitment is estimated, and mean growth is assumed to follow the von Bertalanffy growth function estimated by the model. Weight Length relationship is obtained from spring survey data. Natural mortality was assumed to be 0.15 per year. The commercial landings are modelled as two fleets, bottom trawl and demersal seine, with selection patterns described by a logistic function and the total catch in tonnes specified for each quarter. The survey, on the other hand is modelled as one fleet with selection pattern described by logistic function.

Data used for the assessment are outlined in Table 4. Age–length data from bottom trawl (aldist.bmt), and demersal seine (aldist.dse) from 2010-2020. Age-length data from the March survey could not be used because of the difference in the age reading method. Length distribution from the Icelandic commercial catch divided into 4 quarters per year (bottom trawl from 1995-2020; demersal seine 1991-2020), and survey length distribution from 1990-2020. Maturity data (matp.igfs), proportion mature by length, from 1994; 2001-2020. Length-disaggregated survey indices (5cm increments, except the smallest 10-25cm) from the Icelandic groundfish survey in March 1990–2020.

The parameters estimated are described in List 1 below.

Table 4: Lemon sole. Overview of the likelihood data used in the model. Survey indices are calculated from the length distributions and are-disaggregated (sliced) into seven groups. Number of data-points refer to aggregated data used as inputs in the Gadget model and represent the original dataset. All data can be obtained from the Marine and Freshwater Research Institute, Iceland.

Component name	Quarters	Year range	N	Delta l	Type
aldist.bmt	All quarters	2010–2019	1167	2 cm	Age–length distributions
aldist.dse	All quarters	2010–2019	1260	2 cm	Age–length distributions
ldist.bmt	All quarters	1995–2020	871	2 cm	Length distributions
ldist.dse	All quarters	1991–2019	859	2 cm	Length distributions
ldist.igfs	2	1990–2020	700	2 cm	Length distributions
matp.igfs	2	1994–2020	736	4 cm	Ratio of immature:mature by length group
si.10-20	2	1990–2020	31	10 – 20 cm	Survey indices
si.20-25	2	1990–2020	31	20 – 25 cm	Survey indices
si.25-30	2	1990–2020	31	25 – 30 cm	Survey indices
si.30-35	2	1990–2020	31	30 – 35 cm	Survey indices
si.35-40	2	1990–2020	31	35 – 40 cm	Survey indices
si.40-45	2	1990–2020	31	40 – 45 cm	Survey indices
si.45-60	2	1990–2020	31	45 – 60 cm	Survey indices

List 1. Lemon Sole. List of parameters in the Gadget model.

- Natural mortality, M_a, fixed at 0.15. Assumption of constant natural mortality.
- Length-based Von Bertalanffy growth function, k, L_∞, informed by age–length frequencies
- Growth variation implementation as a beta-binomial distribution, β estimated while n was fixed as the maximum length group steps
- Logistic fleet selection, b_f, $l_{50,f}$; one set for each of the fleets (Spring survey or Commercial)
- Logistic maturity ogive, λ, $l_{50,y}$. λ was estimated for two time periods (1994-2007, 2008-2020), while $l_{50,y}$ was fixed at a value of 20, after which all fish are considered mature.
- Length at recruitment, l_0, σ_0: mean length (at age 1) and std. deviation in length at recruitment
- Number of recruits by year, R_y and $y \in (1990, 2018)$.
- Initial abundance at ages 1 - 15 in 1990 by η_{sa} and $a \in (1, 16^+)$. σ_a^2, i.e. variance in initial length at age a was fixed and based on length distributions obtained in the autumn survey. Initial lengths at age were defined based on the growth function.
- Survey catchability q_{lf}: estimated intercept term in a log-linear relationship with abundance. The slope term, b_g was fixed to 1 for all indices. In certain model variations, slopes were estimated for the two smallest survey index slices, but these led to overfitting of these survey indices.
- Length-weight relationship, μ_s, ω_s, fixed based on estimations made outside of the model.
- Scalars, R_c, $I_{c,s}$, F_0: recruiment scalar (multiplied against all R_y to help optimization), initial numbers at age scalars (by stock s, multiplied against all η_{sa} to help optimization) and initial fishing mortality (applied to all age groups and all years, steepens initial numbers at age distribution to reflect previous effects of fishing.)

DIAGNOSTICS

OBSERVED AND PREDICTED PROPORTIONS BY FLEET

The fit to the predicted proportional length distributions is close to the observed distribution for all fleets. The fit to age distributions does not capture the peak observed in the data, and the distribution from the model is wider than the observed distribution causing under or overestimation at the tails of the distribution (Figures 21-25).

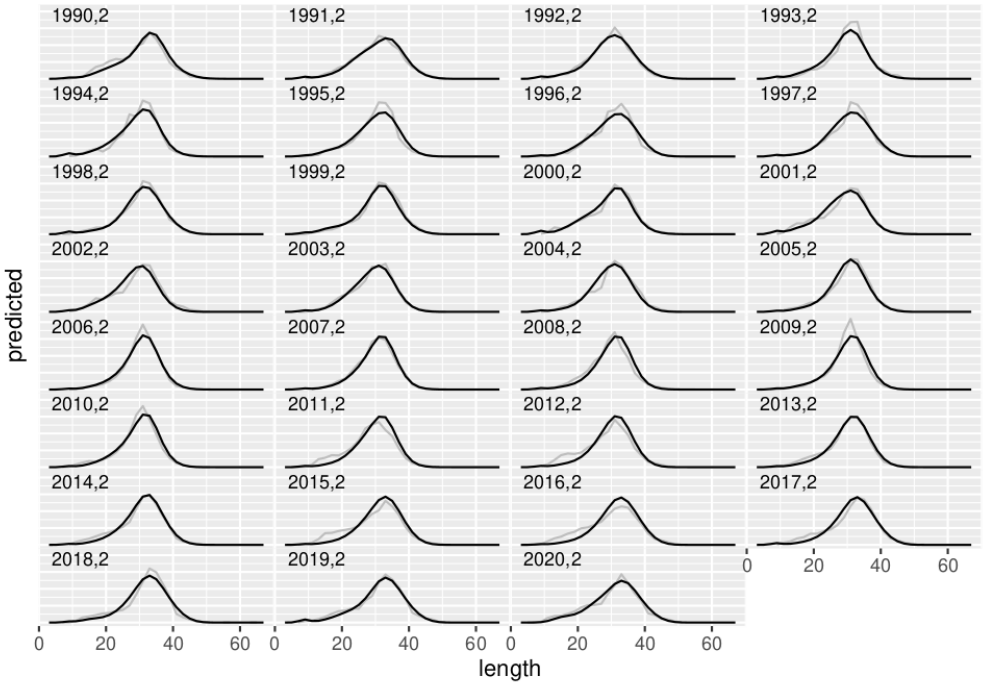

Figure 21: Lemon sole. Fitted proportions-at-length from the Gadget model (black lines) compared to observed proportions in the spring survey (grey lines).

Mynd 21. Þykkvalúra. Hlutfall eftir lengdarflokkum úr Gadget líkani (svartar línur) samanborið við hlutföll í vorralli (gráar línur).

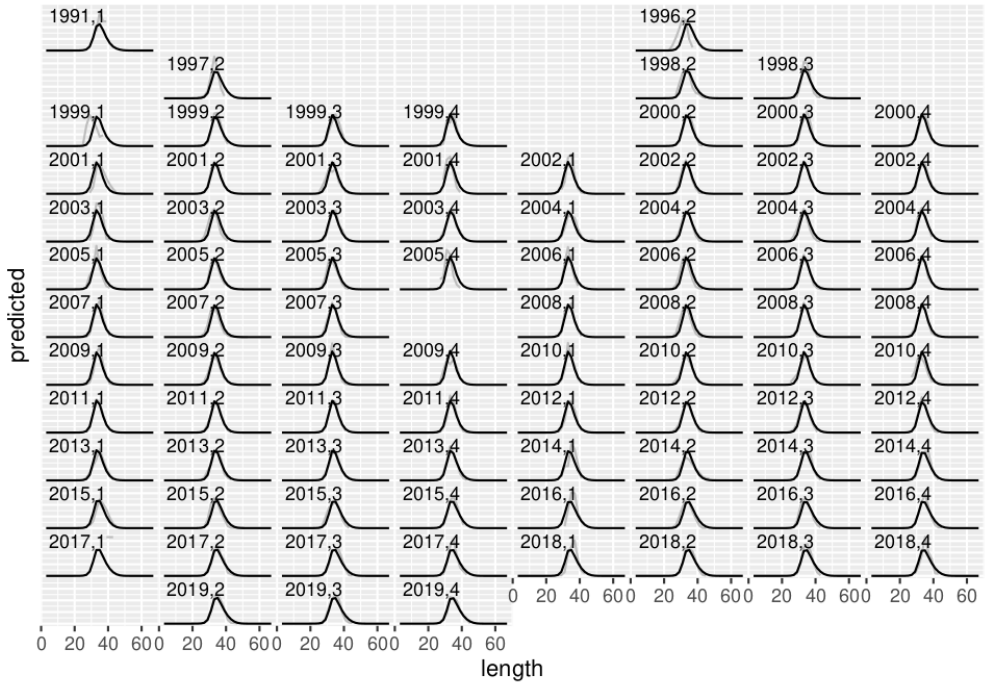

Figure 22: Lemon sole. Fitted proportions-at-length from the Gadget model (black lines) compared to observed proportions in the bottom trawl catches (grey lines).

Mynd 22. Þykkvalúra. Hlutföll eftir lengdarflokkum úr Gadget líkani (svartar línur) samanborið við hlutföll úr línuveiðum (gráar línur).

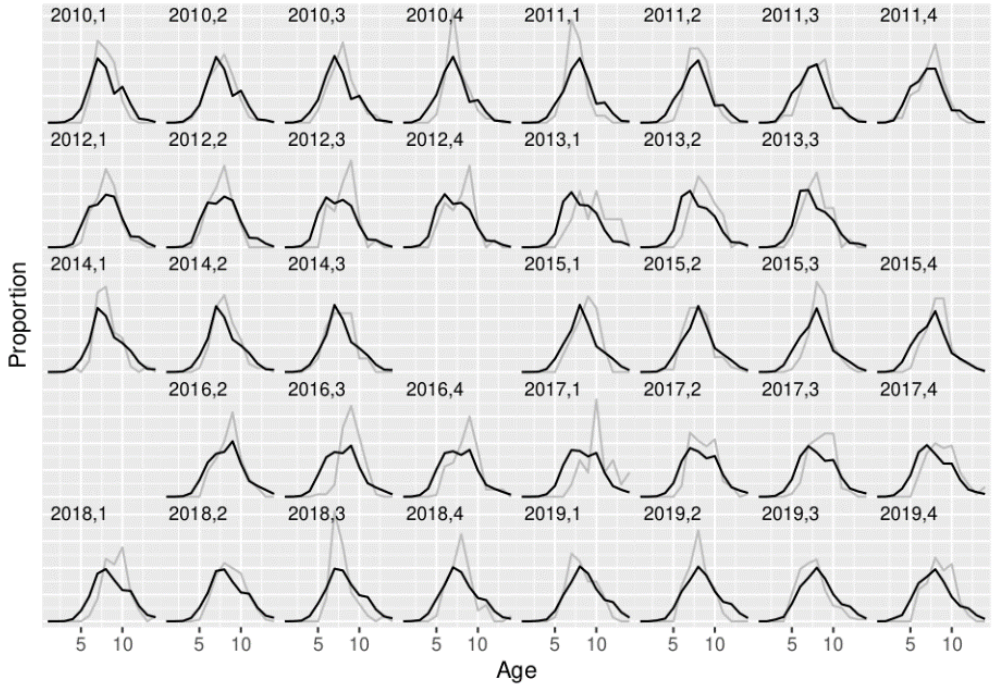

Figure 23: Lemon sole. Fitted proportions-at-age from the Gadget model (black lines) compared to observed proportions in the bottom trawl catches (grey).

Mynd 23. Þykkvalúra. Hlutfall eftir aldursflokkum úr Gadget líkani (svartar línur) samanborið við hlutföll úr botnvörpuveiðum (gráar línur).

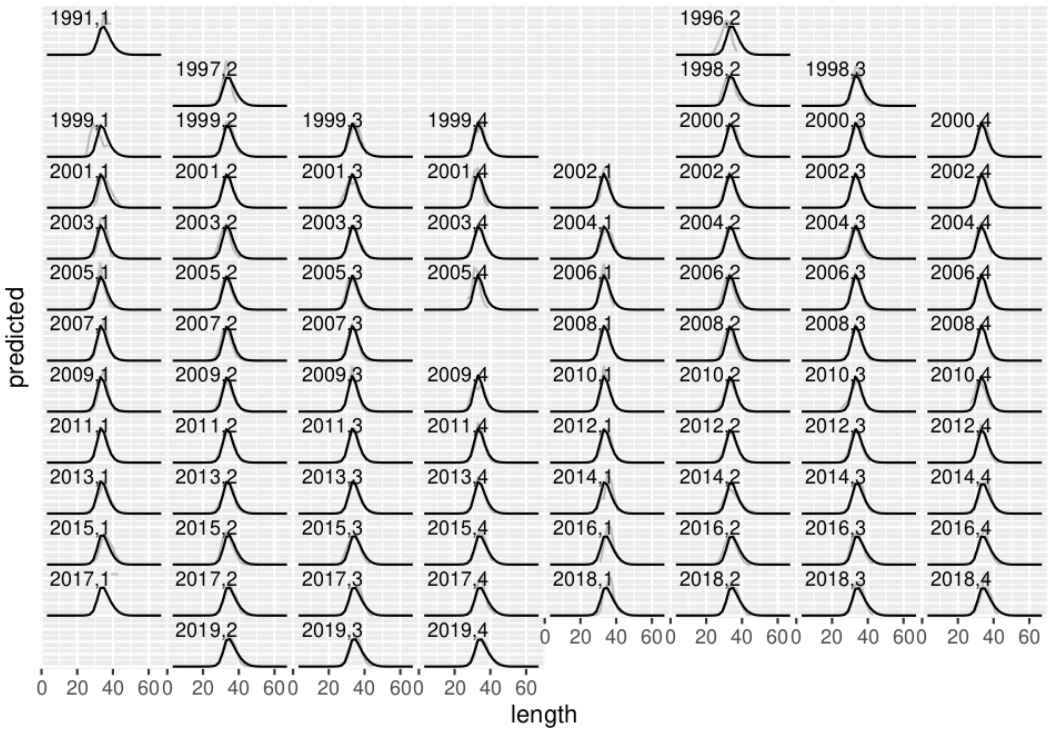

Figure 24: Lemon sole. Fitted proportions-at-length from the Gadget model (black lines) compared to observed proportions in the demersal seine catches (grey).

Mynd 24. Þykkvalúra. Hlutföll eftir lengdarflokkum úr Gadget líkani (svartar línur) samanborið við hlutföll úr dragnótaveiðum (gráar línur).

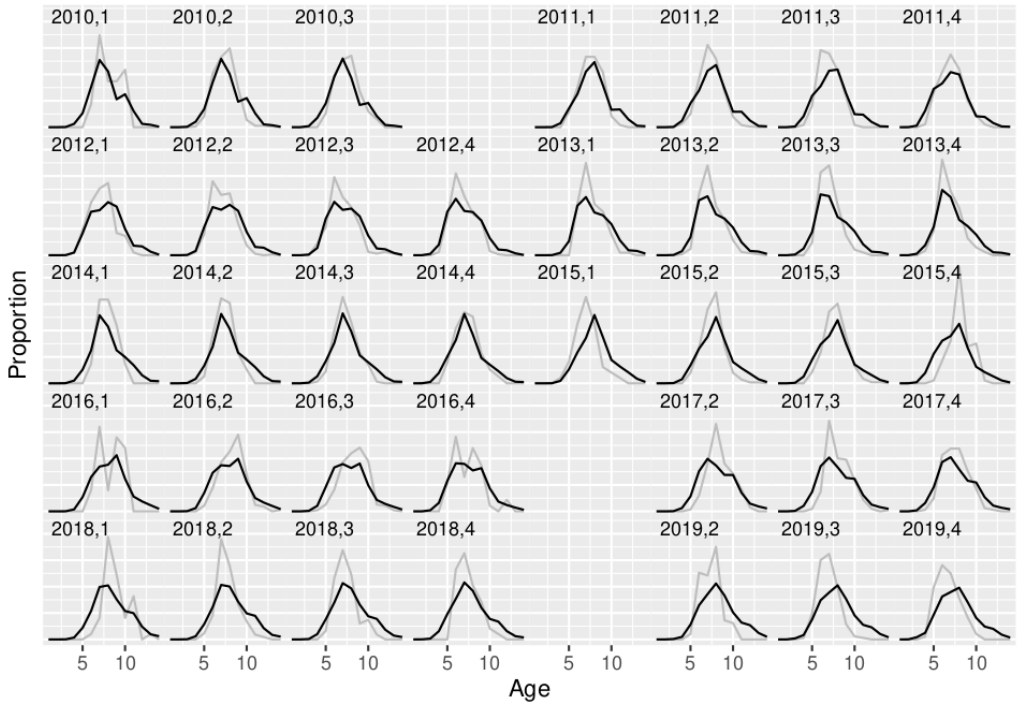

Figure 25: Lemon sole. Fitted proportions-at-age from the Gadget model (black lines) compared to observed proportions in the demersal seine catches (grey lines).

Mynd 25. Þykkvalúra. Hlutfall eftir aldursflokkum úr Gadget líkani (svartar línur) samanborið við hlutföll úr dragnótaveiðum (gráar línur).

MODEL FIT

Figure 26 shows the overall fit to the survey indices from the spring survey. In general, the model appears to follow the stock trends historically for the larger length groups. However, the terminal estimate deviates considerably from the observed value with the model overestimating the abundance in all length groups. This creates the potential for overestimation of biomass this year and downward revisions in coming years. The model fit to smaller length groups is poor where the model discounts the peak observed around 2010.

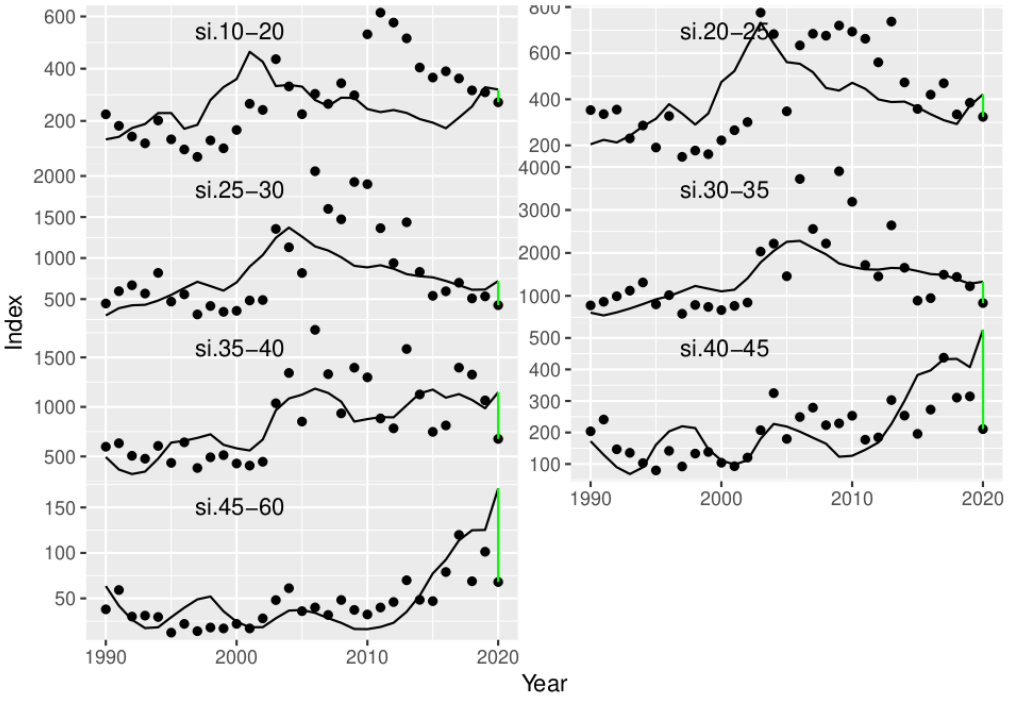

Figure 26: Lemon sole. Fitted spring survey index by length group from the Gadget model (black line) and the observed number of lemon sole caught in the survey (points). The green line indicates the difference between the terminal fit and the observations.

Mynd 26. Þykkvalúra. Lífmassavísitala úr Gadget líkani (svartar línur) eftir stærðarflokkum borin saman við fjölda þykkvalúru í vorralli (punktar). Grænar línur sýna muninn á samsvörun gagna og líkans við lok tímabilsins.

RESULTS

The results from the model are presented in Figure 27. Recruitment shows considerable variability with the highest value estimated for 2019 and the following year terminal value close to 0. The biomass and spawning stock biomass peaked around 2005. A steady decrease is seen for the next 5 years, with a stable trend observed for the rest of the time series. The bootstrap confidence bounds for the biomass estimates are considerably wide from 2010 onwards. Fishing mortality for maximal age (15) shows a downward trend from 2010 onwards.

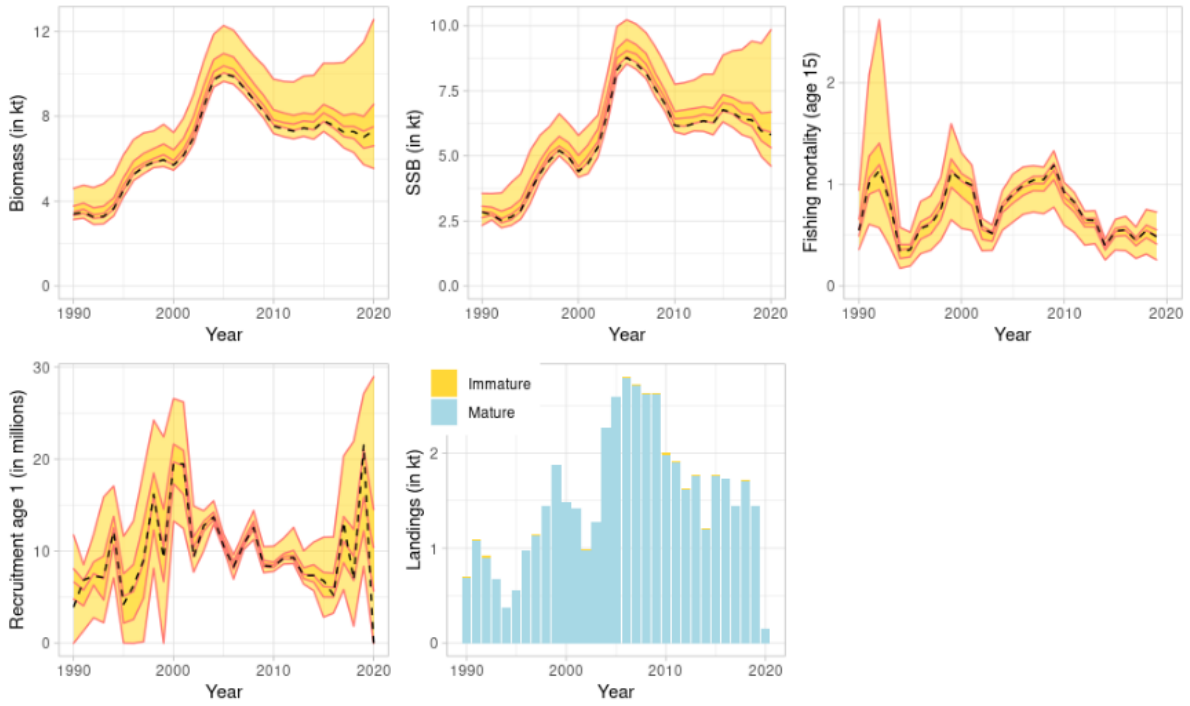

Figure 27: Lemon sole. Estimated biomass, spawning stock biomass (SSB), fishing mortality for fully selected fishes (age 15), recruitment, and total catches. The solid red lines and golden ribbons show the median, 25th-75th percentile range, and 2.5th-97.5th percentile range of the bootstrapped estimates by the model. The dashed black indicates the fit from the baseline model.

Mynd 27. Þykkvalúra. Áætlaður heildarlífmassi, lífmassi hrygningarstofns (SSB), fiskveiðidánartala 15 ára fisks, nýliðun og heildarafli. Svartar brotalínur sýna niðurstöður grunnlíkans en rauðar línu og gulir borðar gefa til kynna öryggismörk metin með endurvali.

ANALYTICAL RETROSPECTIVE ANALYSIS

The results from the analytical retrospective analysis is presented in Figure 28. The analysis indicates there was a downward revision of spawning stock biomass from the 5th to the 4th peel, with similar fluctuations observed in the subsequent peels. Consequently, upward and downward fluctuations can also be seen in F. All recruitment estimates across all peels shows a sudden drop in the terminal year. Overall, similar trends can be observed across the peels for SSB, F and recruitment, however the estimates are not very stable.

Mohn's rho was estimated to be 0.213 for SSB, -0.212 for F, and -0.192 for recruitment.

The following improvements are needed before the model could be considered for delivering advice. A better fit to survey indices for the smaller ages should help improve estimates of recruitment. These improvements will potentially stabilize the model's behaviour. Given the differences in the growth for males and females for this species, a four-stock model that considers the gender component together with maturity is also being explored.

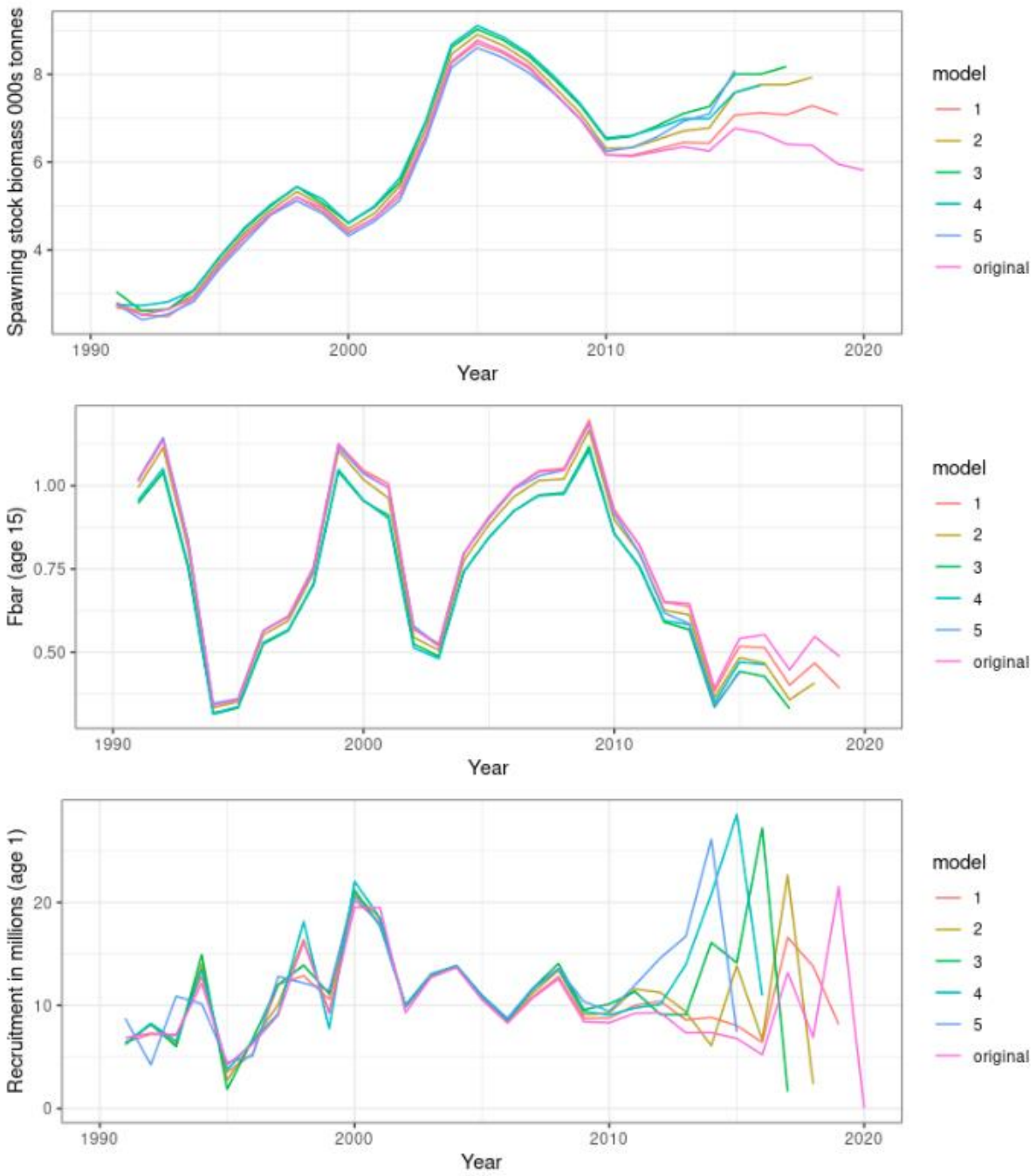

Figure 28: Lemon sole. Retrospective plots illustrating stability in model estimates over a 5-year 'peel' in data. Results of spawning stock biomass, fishing mortality F, and recruitment are shown.

Mynd 28. Þykkvalúra. Endurlitsgreining sem sýnir stöðuleika í mati líkansins fimm ár aftur í tímann. Niðurstöður eru sýndar fyrir hrygningarstofn, fiskveiðidánartölu, F og nýliðun.