9 Lemon sole in Subarea 4, divisions 3.a and 7.d (North Sea, Skagerrak, Kattegat and Eastern English Channel)

9.1 General

The assessment of North Sea lemon sole (*Microstomus kitt*) was subject to a benchmark during the winter of 2017–18 (ICES WKNSEA, 2018). In summary, the benchmark concluded the following:

- There were insufficient age samples submitted to InterCatch to allow for a full age-structured catch-based assessment. InterCatch collation was therefore conducted on the basis of length.
- Age-structured survey indices were developed using GAM estimation (Berg *et al.* 2014), for Q1 (IBTS; ages 1–5, years 2007-present) and Q3 (IBTS and BTS; ages 1–9, years 2005–present). Only ages 2–5 for the Q1 survey were used in the assessment, due to very low sample sizes for age-1 lemon sole in the Q1 IBTS survey.
- Maturity-at-age was fixed through time (based on IBTS Q1 samples), while weights-at-age were based on smoothly-varying observations from both IBTS Q1 and Q3.
- The stock assessment model used for the basis of the advice was SURBAR (Needle, 2015), including *ad hoc* adjustments for the observed low catchability of the available surveys for age 1 and 2 lemon sole.
- The advice was based on the DLS 3.2 rule, applied to relative SSB estimates provided by SURBAR.
- Stock status in relation to F_{MSY} proxies was evaluated using a suite of length-based indicators (LBIs).

These stipulations have been followed completely in this year's WGNSSK update assessment.

This is the seventh year in which the stock status for lemon sole has been evaluated by WGNSSK. Lemon sole has been defined as a category 3 species according to the ICES guidelines for data limited stocks (ICES, 2012). The assessment presented in the 2019 WGNSSK report (ICES, WGNSSK 2019) provided the basis for advice for 2020 and 2021. Subsequently, advice on lemon sole has been requested on an annual basis. The outcome of the current assessment will be used to provide new catch advice for 2022.

9.1.1 Biology and ecosystem aspects

Lemon sole is a commercially important flatfish that is found in the shelf waters of the North Atlantic from the White Sea and Iceland southwards to the Bay of Biscay. Lemon sole spawn for a lengthy period in the North Sea, starting as early as April in the north and ending as late as November in the south (Rae, 1965). In the western English Channel, lemon sole spawn in April and May (Jennings *et al.*, 1993). In the English Channel, investigations of habitat association for plaice, sole and lemon sole indicated that distribution is restricted to a few sites and that lemon soles appear to prefer sandy and gravely strata, living deeper, at higher salinities and lower temperatures than plaice or sole (Hinz *et al*., 2006). Lemon sole feed on small invertebrates, mainly polychaete worms, bivalves and crustaceans.

9.1.2 Stock ID and possible assessment areas

There is no information available on lemon sole stock identity for the greater North Sea (including the Skagerrak and eastern English Channel areas), and the assessment is assumed to cover one unit stock.

9.1.3 Management regulations

No specific management objectives are known to ICES. An EU TAC is set for EU waters of ICES Division 2.a and Subarea 4, which is a joint TAC together with witch flounder (ICES, 2013). ICES provided advice to the EU in 2018 whether several stocks (including lemon sole) should continue to be managed through TAC and quota regulations (see Annex 11 of ICES WGNSSK, 2018). This concluded that the TAC for lemon sole could be removed, or if maintained that a single-species lemon sole TAC would be more appropriate. However, the joint TAC with witch flounder continues to be the basis for management.

9.2 Fisheries data

9.2.1 Officially-reported landings

Both in the North Sea and in the Skagerrak and Kattegat, lemon sole is mainly a by-catch species in the fisheries for mixed demersal stocks and for plaice. Officially-reported landings in ICES Division 7.d, Subarea 4 and Division 3.a are shown in Figures 9.2.1 to 9.2.4, and in Tables 9.2.1 to 9.2.4. The time-series of officially-reported landings is not fully complete, and a number of countries have gaps in data provision.

9.2.2 ICES estimates of landings and discards

Investigations into the existing data for the WKNSEA data meeting (November 2017) suggested that there would be insufficient age samples to permit an age-structured catch-based assessment, so the subsequent data calls and collations have focussed on length-based data.

Commercial catch data were raised to fleet and country level using InterCatch. The benchmark meeting (ICES WKNSEA, 2018) considered whether areas should be considered separately for raising discards and length compositions, but the prevailing view was that there was no evidence of distinct stocks between areas and that therefore all areas should be treated together for raising. Initial exploration demonstrated that the final discard raising was significantly influenced by a small number of métiers with discard ratios greater than 1.5 (in other words, those métiers for which discards/landings > 1.5). Subsequently, these métiers were discounted in calculating raising factors as they were thought to be non-representative for a high-value stock such as lemon sole. Otherwise, discards for all unsampled fleets were inferred by a discard rate generated using all sampled fleets (weighted by the landings CATON), as it was not thought likely that discard rates for an (essentially) bycatch stock would vary a great deal between different métiers (apart from the extreme and unrepresentative examples discussed above).

Length-distribution allocations were conducted in the same way (weighted by mean numbers at length), with the only distinction being made between landings and discards. Length samples are reasonably well-spread across the main countries catching lemon sole, and length-based allocations are likely to be sufficiently representative.

Both BMS (Below Minimum Size) landings and logbook-recorded discards were included with discards for length-allocation purposes as the length distributions are likely to be similar. For

both 2019 and 2020, there were no submissions for logbook-recorded discards (0 tonnes). Only Scotland provided submissions of BMS landings for 2019 (a total of 0.224 tonnes for area 4), whilst only England submitted data for 2020 (a total of 0.216 tonnes for area 4).

Revised Swedish data for 2019 were provided in 2021. Therefore, the InterCatch estimation for 2019 was recalculated to include these new data, which led to a minor change (0.13%). The updated 2019 data were used for subsequent analysis.

InterCatch summary plots are given in Figures 9.2.5 to 9.2.8. The resultant estimates for landings and discards for 2002-2020, along with official landings for 1968–2020, are given in Table 9.2.5 and Figure 9.2.9. We note that the official landings for 2012 did not include estimates for the UK, which is why they are considerably lower than the new InterCatch estimates. It can also be seen that the 2013 discard estimate is very high – the problem appears to originate in the discard estimates provided by the Netherlands, which unfortunately have not yet been corrected. The abundances at length in the Dutch submissions are an order of magnitude higher than for any other year or country, for fish less than 210 mm. This gives rise to the high discard estimate in 2013. The issue was avoided in the F_{msy} proxy analysis (see Section 9.6) by removing the 2013 data, but this issue has not yet been addressed for the yield analysis.

In the North Sea, eastern English Channel and Skagerrak, lemon sole are manged using a combined TAC with witch flounder (see Section 27). The ICES estimates of landings for lemon sole and witch are compared with the joint TAC in Figure 9.2.10, which shows that the joint TAC is underutilised for most years since 2006. However, as in recent years, ICES recommends that a joint TAC for lemon sole and witch is unlikely to be effective in controlling mortality on either species.

9.3 Survey data series

9.3.1 Stock distributions

Figure 9.3.1 displays the distribution of the abundance of lemon sole in the greater North Sea obtained from IBTS Q1 (2021) and IBTS Q3 data (2020: the years used are is given as examples, as distributions do not change noticeably from year to year). The highest concentrations of lemon sole occur in the central to northern areas of the North Sea.

9.3.2 Maturity and weights-at-age

Following the Stock Annex, maturities were assumed to be fixed through time and set to the following values by age:

Age	Prop. Mature
1	0.00
2	0.72
3 and older	1.00

Weights-at-age were also estimated following the Stock Annex procedure. The mean weights at each age and year were calculated from data in the SMALK dataset of the IBTS Q1 and Q3 series (ICES DATRAS 2019). For each age, the time-series of available weights were plotted together, positioned so that Q1 weights were at y+0.25 and Q3 weights at y+0.75 (additional mean points were added at the start of each time-series to enable extrapolation). A loess smoother (span = 1) was then fitted through all points for each age, so that the final estimate was (effectively) a smoothed average of consecutive weight estimates. The fitted values are summarised in Figure 9.3.2 and Table 9.3.1. These are slightly different for several ages from the values estimated by the 2019 WG, due to small changes in several of the weight entries in the SMALK dataset. The reasons for these are unknown, but are likely to be due to updated weight-length keys used within DATRAS. We also note that estimates for 2021 are included here: these are not currently used in the stock assessment which concludes in 2020, but they are included for completeness.

Natural mortality (M) estimates for lemon sole are not available. For current advisory purposes, however, estimates of M are not required, as the assessment is survey-based and hence estimates total mortality Z.

9.3.3 Relative abundance indices

The GAM estimation approach (Berg *et* al 2014) was used by WGNSSK to generate updated Q1 (IBTS) and Q3 (IBTS and BTS) survey series for lemon sole. The new series are summarised in Table 9.3.2 and Figures 9.3.3 (bivariate scatterplots), 9.3.4 (catch curves), 9.3.5 (time series by age and cohort), and 9.3.6 (inter-series comparisons). The first three summaries indicate that the ability of the survey indices (particularly Q1) to track year-class strength is very limited. For example, in Figure 9.3.3, most of the pairwise comparisons do not show significant correlations (and some comparisons are negative). Figure 9.3.6 shows that the comparisons between the survey series are rather more consistent.

Not shown here is a significantly negative correlation between age 1 and age 2 for the Q1 (IBTS) index – this suggests that the Q1 (IBTS) age 1 index will give an incorrect impression of subsequent year-class strength, which is likely to be due to very small samples sizes at that age. The Stock Annex for this assessment calls for the full age range (1-5) to be used from the Q1 (IBTS) series. Following the presentation of the exploratory survey analyses at the 2018 meeting, WGNSSK concluded that the age-1 data from the Q1 (IBTS) survey should not be used to indicate stock trends. Therefore, the Q1 (IBTS) survey index was limited to ages 2-5 for assessment purposes at the 2019 meeting, and this has been continued in 2021.

9.4 SURBAR stock assessment

The SURBAR assessment was conducted according to the run-time settings specified in the Stock Annex, namely:

- The age- and year-effect smoother λ was set to 3.
- Mean mortality Z was calculated over ages 3-5.
- The reference age a_r for age-effect estimates was set to 3.
- GAM-estimated survey indices from both Q1 (IBTS) and Q3 (IBTS & BTS) were used.
- Catchability for ages was set as $q_1 = 0.1, q_2 = 0.5$ and $q = 1.0$ for all older ages. This correction is intended to reduce the impact on the analysis of the observed pronounced "hooks" at the top of the survey catch curves for this stock (see Figure 9.3.4). A proposal for a systematic method of determining catchability corrections to straighten catch curves prior to SURBAR assessment was presented at the WGNSSK 2020 meeting. While promising, this method remains in development and will be revisited in a future WGNSSK meeting.
- No downweighting of ages in the SURBAR SSQ estimation was used.

The SURBAR stock summary is given in Table 9.4.1, and the corresponding output plots are given in Figures 9.4.1 to 9.4.4. The stock summary (Figure 9.4.1) shows that mean Z_{3-5} has remained relatively constant since 2009, although values are very low and the confidence intervals overlap $Z = 0$ for most years. The catch curves for the surveys (Figure 9.3.4) are domed and very shallow, and remain shallow even when the catchability revision is applied, so SURBAR indicates very low mean Z_{3-5}. Both SSB and TSB are estimated with more certainty than mean Z_{3-5}, and both show steady declines since 2016. Finally, recruitment at age 1 has fluctuated without trend for much of the time series, with indications of an increase in 2019 (although the uncertainty about that estimate is large).

Log survey residuals (Figures 9.4.2) show that the Q3 index fits the SURBAR model better than the Q1 index, with lower residuals (in general) and less trends through time. Consequently, the assessment is driven more directly by the Q3 index – this is to be expected given the problems with the Q1 index highlighted in Section 9.3.3 above. There are three outliers in the Q3 index (age 1 in 2013 and 2015, age 2 in 2013), but sensitivity runs reducing the SSQ estimation weighting on these points suggested that their influence on likely advice was not significant (ICES WKNSEA, 2018). The parameter estimates are summarised in Figure 9.4.3.

The retrospective analysis in Figure 9.4.4 shows little retrospective bias or noise for SSB or TSB. Mohn's rho is high for both mean Z_{3-5} and (especially) recruitment. The final mean Z_{3-5} estimate in each year's assessment is based on a three-year average of preceding years, and is likely to be updated the following year (hence the retrospective noise). Following the removal of age-1 data from the Q1 (IBTS) index, recruitment is initially estimated by the Q3 (IBTS & BTS) index alone. With additional years of data, recruiting year-class strength is successively updated for each cohort, and this helps to explain the recruitment retrospective revisions. It is correct to remove Q1 (IBTS) age-1 data in this case (see Section 9.3.3), but the retrospective noise generated means that the higher recruitment estimate in 2020 should be considered to be uncertain.

Finally, the run presented here assumes a lambda smoother of 3.0. A low lambda setting ($\lambda = 1.0$) results in large interannual variations in all outputs, driven by survey noise and the difficulty in following cohorts. Increasing the lambda smoother leads to less variation, as expected, and the outputs for $\lambda = 3.0$ and $\lambda = 5.0$ are very similar, increasing confidence that the setting $\lambda = 3.0$ is probably reasonable (increasing lambda further doesn't lead to much change). Further methodological work on systematically defining the appropriate lambda smoother for a given assessment is underway, and will be presented at a future WGNSSK meeting.

9.5 Application of advice rule

North Sea lemon sole are currently managed according to the following advice, given in June 2020:

ICES advises that when the precautionary approach is applied, catches in 2021 should be no more than 3742 tonnes.

Management of lemon sole and and witch under a combined species TAC prevents effective control of the single-species explotation rates and could lead to the overexploitation of either species. ICES advises that management should be implemented at the species level in the entire stock distribution area (Subarea 4 and divisions 3.a. and 7.d).

Following the release of the 2019 advice, ICES has been requested to issue annual advice for North Sea lemon sole.

The application of the DLS 3.2 rule, based on the most recent advised catch (for 2021), is given in Figure 9.5.1. The change ratio of the abundance index was -17.65%, which implies that catches for 2022 should be **3081 tonnes**. As lemon sole are under the EU Landing Obligation, there is no corresponding advice for landings.

As the suggested change in catch is less than ±20%, there is no requirement to apply an uncertainty cap. Similarly, no precautionary buffer was required for the advice for 2022 with the last application being in 2019.

9.6 Length-based F_{MSY} proxy estimation

Length-based indicators (LBIs) for F_{msy} proxies were estimated for North Sea lemon sole, following the standard approach outlined by WKLIFE (ICES WKLIFE VI, 2017) and WKPROXY (ICES WKPROXY, 2017), and stipulated in the relevant Stock Annex by the 2018 benchmark meeting (ICES WKNSEA, 2018). Data were taken from the length samples submitted to InterCatch for 2002–2020.

The original InterCatch length distributions are given in Figure 9.6.1, from which erroneous length submissions for fish less than 200 mm in 2013 can clearly be seen. These seem to arise from Dutch discard samples, which could not be corrected prior to the WGNSSK meeting (see also Section 9.2.2). To address this without correcting the input data, the 2013 data were removed from the analysis (this has no impact on the final conclusions). Figure 9.6.2 shows the result of this, along with the removal of all fish less than 100 mm (to prevent the misspecification of length at first capture). Finally, the widths of the length bins were doubled to produce smoother distributions for LBI analysis (Figure 9.6.3).

Previous LBI runs carried out at WGNSSK in 2017 (ICES WGNSSK, 2017) and WKNSEA in 2018 (ICES WKNSEA 2018) used an assumption that $L_{50\%mat}$ was 150 mm, and L_∞ was 670 mm. These values were taken from the FishBase dataset (Froese and Pauly 2018), but may not be relevant to the current stock analysis as they are derived from historical records. Figure 9.6.4 shows a logit maturity ogive fitted to maturity data from the Q1 (IBTS) and Q3 (IBTS & BTS) survey records, using a binomial GLM with a logit link. This analysis indicates that a suitable estimate of $L_{50\%mat}$ would be 130 mm, which is the equivalent estimate produced by WGNSSK in 2020.

Figure 9.6.5 shows an estimated L_∞ value of 282 mm, derived from all available survey data (the corresponding value from WGNSSK 2020 was 283 mm). WGNSSK was concerned that the survey-derived value of 282 mm was likely to be too low, given the possibility (although uncertain) that survey catchability for older fish may be poor. Two alternative estimates of L_∞ were hence considered – the longest fish observed in the commercial fishery landings data (685 mm), and a trimmed alternative based on the 99%ile of the commercial catch length distribution (385 mm, collated over all available years). The estimates are summarised in Figure 9.6.6. Given L_{max}, WGNSSK proposed that L_∞ should be derived from the following equation (García-Carreras *et al* 2016):

$$\log_{10} L_\infty = 0.068260 + 0.969112 \log_{10} L_{max}$$

The resultant estimates are then:

Basis	L_{max}	L_∞
Trimmed L_{max}	385 mm	375 mm
Observed L_{max}	685 mm	642 mm
Survey data	-	282 mm

WGNSSK conclude that L_∞ should be set to 375 mm (as for last year), as the estimate of 642 mm does not seem to be representative of the bulk of the stock, and the survey-based estimate may be biased low by reduced catchability for older lemon sole in the surveys.

This estimate of L_∞ , along with the new estimate of $L_{50\%mat}$ were then used in an LBI estimation run which is summarised in Figures 9.6.7 and 9.6.8, and Table 9.6.1. The key points are:

- Length at first catch (L_c) is below L_{mat} for the full time-series, which indicates many immature individuals in the catches.
- The ratio of the mean length of the upper 5th percentile of catches to L_∞ is around 1.0 throughout the time series, which would suggest a reasonable number of large (and hence old) fish in the population.
- The L_{mean}/L_{opt} ratio is greater than 1.0 for most of the time series, which suggests that the exploitation is targeting the most productive length classes.
- $L_{mean}/L_{F=M}$ is greater than 1.0 for all years in the time-series, which indicates that this stock is being fished at a rate less than (or around) F_{MSY}.

The LBI results suggest that immature fish are well protected, and that the catch length distribution is not truncated at larger sizes: under optimal and sustainable exploitation the mean length in the catch is expected to be higher than the value observed, and this is the case here. The fact that the ratio of $L_{mean}/L_{F=M}$ is greater than 1.0 throughout the time-series would suggest that F_{MSY} is **not** being exceeded for this stock.

9.7 Conclusions and further work

Although the SURBAR estimates for SSB are uncertain, the median values indicate a declining trend since 2016 which is reflected in the reduced advice for 2022. The estimate also suggests that the 2019 and 2020 recruitment may be larger than recent years, although retrospective noise problems indicates that this should be treated as being very uncertain.

The estimation of status relative to F_{msy} proxies indicates that fishing is occurring at or below F_{msy}, which was also the conclusion in the WGNSSK meetings in 2017–2020.

These conclusions are based on stock dynamics indicated by a survey-based assessment, and the inability (in many cases) of the available surveys to track year-class strength is a weak point of the advice. An important issue for the development of new advice in 2022 would be to reconsider the survey series used – further work may indicate an alternative method of collating the survey data that could be more appropriate for lemon sole.

9.8 Issues list

9.8.1 Data and assessment

The current survey indices used for North Sea lemon sole are not able to track cohort strength on a consistent basis, and they exhibit generally poor catchability characteristics which limit the reliability of the advice based thereon. It would be very beneficial to be able to include commercial catch data in the assessment in order to improve reliability and reduce variability. Unfortunately, age data are lacking from commercial catch data, so a (spatial) length-based assessment using both catch and survey data should be explored (for example, Stock Synthesis 3).

Natural mortality is assumed to be time-invariant in the current assessment. The potential of using key MSVPA runs to provide time-varying natural mortality estimates for North Sea lemon sole should be explored.

9.8.2 Forecast

Lemon sole advice is currently based on the DLS 3.2 approach. If a length-based assessment can be generated, then there may be a requirement (and opportunity) to develop a forecast methodology, and this will need to be addressed when appropriate.

9.9 References

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Table 9.2.1. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. Official lemon sole landings by area (tonnes).

Official landings									
Year	**3.a**	**4**	**7.d**	**Total**	**Year**	**3.a**	**4**	**7.d**	**Total**
1950	307	3754	208	4269					
1951	248	4710	314	5272	1986	639	5047	251	5937
1952	243	4922	298	5463	1987	669	5516	310	6495
1953	132	5440	386	5958	1988	642	5898	258	6798
1954	128	3972	534	4634	1989	693	5967	364	7024
1955	102	3836	141	4079	1990	872	6190	423	7485
1956	96	3395	103	3594	1991	734	6618	428	7780
1957	78	3419	102	3599	1992	952	6126	364	7442
1958	94	3104	82	3280	1993	1156	5839	422	7417
1959	130	3647	82	3859	1994	803	5262	695	6760
1960	153	4035	66	4254	1995	714	4712	877	6303
1961	161	4900	108	5169	1996	635	4737	1151	6523
1962	93	4630	101	4824	1997	768	4727	563	6058
1963	99	3791	66	3956	1998	868	6466	346	7680
1964	134	4121	77	4332	1999	844	6316	140	7300
1965	164	4949	105	5218	2000	803	5980	388	7171
1966	159	5415	201	5775	2001	584	5389	483	6456
1967	191	6188	331	6710	2002	522	3827	474	4823
1968	185	6270	337	6792	2003	543	3688	491	4722
1969	215	4470	315	5000	2004	607	3543	424	4574
1970	169	3434	256	3859	2005	674	3444	350	4468
1971	173	3967	357	4497	2006	417	3627	246	4290
1972	168	3672	475	4315	2007	432	3892	164	4488
1973	214	4568	451	5233	2008	276	3466	234	3976
1974	183	4227	351	4761	2009	262	2693	442	3397
1975	317	5029	33	5379	2010	350	2625	223	3198
1976	361	4830	42	5233	2011	251	3365	403	4019
1977	627	5661	37	6325	2012	482	2119	358	2959
1978	705	6108	141	6954	2013	289	2981	491	3761
1979	833	6428	260	7521	2014	315	3017	356	3688
1980	722	6424	152	7298	2015	269	2871	253	3393
1981	793	5933	290	7016	2016	299	3266	240	3805
1982	735	7168	584	8487	2017	343	2822	158	3323
1983	759	8257	491	9507	2018	280	2635	99	3014
1984	595	6930	586	8111	2019	329	2805	104	3238
1985	793	6435	347	7575	2020	340	2219	95	2655

Table 9.2.2. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. Official lemon sole landings in area 7.d by country.

Year	BEL	DNK	FRA	NED	UK	Other	Total	Year	BEL	DNK	FRA	NED	UK	Other	Total
1950	10	0	174	0	24	0	208								
1951	5	0	262	0	47	0	314	1986	77	0	133	0	41	0	251
1952	10	0	188	0	100	0	298	1987	81	0	185	0	44	0	310
1953	7	0	196	0	183	0	386	1988	74	0	155	0	29	0	258
1954	9	0	361	0	164	0	534	1989	68	0	252	0	44	0	364
1955	9	0	0	0	132	0	141	1990	68	0	272	0	83	0	423
1956	4	0	0	0	99	0	103	1991	83	0	272	0	73	0	428
1957	7	0	0	0	95	0	102	1992	66	0	176	0	122	0	364
1958	1	0	0	0	81	0	82	1993	36	0	311	0	75	0	422
1959	2	0	0	0	80	0	82	1994	97	0	505	0	93	0	695
1960	4	0	0	0	62	0	66	1995	138	0	584	0	155	0	877
1961	1	0	0	0	106	1	108	1996	213	0	720	0	218	0	1151
1962	2	0	0	0	99	0	101	1997	143	0	305	0	115	0	563
1963	3	0	0	0	63	0	66	1998	53	0	198	0	95	0	346
1964	5	0	0	0	72	0	77	1999	50	0	0	0	90	0	140
1965	16	0	0	0	89	0	105	2000	62	0	200	0	126	0	388
1966	7	0	0	0	194	0	201	2001	104	0	191	0	188	0	483
1967	6	0	0	0	325	0	331	2002	101	0	256	0	117	0	474
1968	8	0	0	0	329	0	337	2003	128	0	251	0	112	0	491
1969	12	0	0	0	303	0	315	2004	120	0	198	1	105	0	424
1970	16	0	0	0	240	0	256	2005	90	0	187	2	71	0	350
1971	22	0	0	0	335	0	357	2006	98	0	100	0	48	0	246
1972	18	0	0	0	457	0	475	2007	70	0	72	1	21	0	164
1973	25	0	0	0	426	0	451	2008	140	0	46	3	45	0	234
1974	16	0	0	1	334	0	351	2009	149	0	176	9	108	0	442
1975	19	0	0	0	14	0	33	2010	101	0	85	5	32	0	223
1976	24	0	0	0	18	0	42	2011	153	0	178	15	57	0	403
1977	21	1	0	0	15	0	37	2012	171	0	167	20	0	0	358
1978	45	2	63	0	31	0	141	2013	176	0	179	26	110	0	491
1979	60	0	165	0	35	0	260	2014	162	0	108	14	72	0	356
1980	33	0	109	0	10	0	152	2015	123	0	84	5	41	0	253
1981	66	0	212	0	12	0	290	2016	115	0	69	9	47	0	240
1982	96	0	406	1	81	0	584	2017	87	0	34	8	29	0	158
1983	108	0	298	0	85	0	491	2018	57	0	21	5	15	0	99
1984	110	0	367	0	109	0	586	2019	49	0	27	6	23	0	104
1985	117	0	164	0	66	0	347	2020	46	0	25	6	18	0	95

Table 9.2.3. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. Official lemon sole landings in ICES subarea 4 by country.

Year	BEL	DNK	FRA	GER	NED	NOR	UK	Other	Total	Year	BEL	DNK	FRA	GER	NED	NOR	UK	Other	Total
1950	112	435	139	31	156	0	2855	26	3754										
1951	115	845	90	21	167	0	3430	42	4710	1986	511	577	103	16	0	0	3839	1	5047
1952	98	391	227	26	168	0	3953	59	4922	1987	448	742	174	14	0	0	4137	1	5516
1953	73	409	189	18	132	0	4590	29	5440	1988	539	639	184	14	301	0	4220	1	5898
1954	2	272	177	24	112	0	3368	17	3972	1989	441	828	176	40	397	0	4083	2	5967
1955	49	311	0	15	78	0	3374	9	3836	1990	491	1007	208	49	0	0	4431	4	6190
1956	48	222	0	19	58	0	3034	14	3395	1991	544	1099	250	41	0	12	4666	6	6618
1957	39	249	0	24	64	0	3032	11	3419	1992	577	1149	177	30	0	13	4175	5	6126
1958	30	171	0	13	43	0	2835	12	3104	1993	525	966	240	37	0	9	4059	3	5839
1959	85	242	0	40	43	0	3226	11	3647	1994	436	597	436	27	0	11	3754	1	5262
1960	155	577	0	46	67	0	3178	12	4035	1995	588	585	412	70	0	9	3046	2	4712
1961	286	488	0	79	102	0	3934	11	4900	1996	592	547	534	67	0	18	2976	3	4737
1962	175	501	0	54	106	0	3794	0	4630	1997	504	499	224	76	0	29	3391	4	4727
1963	365	222	0	36	71	0	3097	0	3791	1998	815	796	197	149	838	23	3643	5	6466
1964	484	358	0	62	75	0	3142	0	4121	1999	662	1015	0	62	681	24	3866	6	6316
1965	562	385	0	91	93	0	3818	0	4949	2000	711	1277	184	72	492	17	3222	5	5980
1966	594	548	0	98	65	0	4110	0	5415	2001	694	1281	191	77	451	22	2666	7	5389
1967	601	791	0	136	61	0	4599	0	6188	2002	604	971	190	116	402	17	1521	6	3827
1968	422	775	0	96	34	0	4943	0	6270	2003	517	1008	239	136	369	16	1399	4	3688
1969	292	639	0	80	36	0	3423	0	4470	2004	667	1113	120	81	355	12	1192	3	3543
1970	241	307	0	52	58	0	2776	0	3434	2005	595	1057	102	85	402	13	1188	2	3444
1971	348	514	0	54	122	0	2929	0	3967	2006	552	968	57	183	412	13	1440	2	3627
1972	423	530	0	59	130	0	2530	0	3672	2007	542	1136	65	143	367	23	1610	6	3892
1973	566	478	0	73	217	16	3218	0	4568	2008	527	925	47	120	434	26	1383	4	3466
1974	486	447	0	59	269	0	2966	0	4227	2009	389	898	88	64	294	31	927	2	2693
1975	748	521	0	83	299	0	3367	11	5029	2010	375	821	32	102	323	35	935	2	2625
1976	493	506	0	68	308	0	3443	12	4830	2011	387	999	56	96	641	27	1157	2	3365
1977	618	321	0	71	262	0	4387	2	5661	2012	406	999	34	61	587	30	0	2	2119
1978	760	517	28	54	231	0	4518	0	6108	2013	527	649	27	67	479	16	1214	2	2981
1979	674	876	136	41	390	0	4308	3	6428	2014	648	626	27	63	425	23	1202	3	3017
1980	484	599	102	49	303	0	4885	2	6424	2015	425	794	16	82	423	12	1116	3	2871
1981	555	605	237	39	412	0	4084	1	5933	2016	448	1054	15	82	443	23	1196	5	3266
1982	879	670	419	52	759	0	4386	3	7168	2017	345	1032	0	42	356	14	1028	4	2822
1983	1122	735	402	28	1009	0	4957	4	8257	2018	370	815	9	52	347	14	1025	3	2635
1984	1144	567	344	22	0	0	4850	3	6930	2019	467	671	8	46	473	13	1122	4	2805
1985	989	555	157	26	0	0	4703	5	6435	2020	376	497	9	32	385	5	910	6	2219

Table 9.2.4. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. Official landings in area 3.a by country.

Year	BEL	DNK	GER	NED	SWE	Other	Total	Year	BEL	DNK	GER	NED	SWE	Other	Total
1950	0	100	1	0	206	0	307								
1951	0	74	1	0	173	0	248	1986	7	576	0	0	56	0	639
1952	0	64	0	0	179	0	243	1987	24	577	0	0	68	0	669
1953	0	35	0	0	97	0	132	1988	11	569	0	6	56	0	642
1954	0	33	0	0	95	0	128	1989	8	610	0	0	75	0	693
1955	0	29	0	0	73	0	102	1990	16	782	0	0	74	0	872
1956	0	33	0	0	63	0	96	1991	11	640	0	0	83	0	734
1957	0	27	0	0	51	0	78	1992	22	793	0	0	120	17	952
1958	0	38	0	0	56	0	94	1993	14	980	4	0	141	17	1156
1959	0	71	0	0	59	0	130	1994	10	648	2	0	127	16	803
1960	0	95	1	0	57	0	153	1995	27	576	2	0	91	18	714
1961	0	90	0	0	71	0	161	1996	0	513	1	0	97	24	635
1962	0	92	1	0	0	0	93	1997	0	628	2	0	115	23	768
1963	0	99	0	0	0	0	99	1998	0	743	3	0	100	22	868
1964	0	133	1	0	0	0	134	1999	0	731	3	0	88	22	844
1965	0	163	1	0	0	0	164	2000	0	722	1	0	65	15	803
1966	0	159	0	0	0	0	159	2001	0	511	1	0	53	19	584
1967	0	189	1	0	0	1	191	2002	0	457	4	0	41	20	522
1968	0	184	0	0	0	1	185	2003	0	451	6	30	35	21	543
1969	0	215	0	0	0	0	215	2004	0	472	5	82	29	19	607
1970	0	169	0	0	0	0	169	2005	0	468	5	147	38	16	674
1971	0	173	0	0	0	0	173	2006	0	321	8	40	32	16	417
1972	0	168	0	0	0	0	168	2007	0	374	5	16	18	19	432
1973	0	214	0	0	0	0	214	2008	0	239	7	3	15	12	276
1974	0	183	0	0	0	0	183	2009	0	233	4	1	15	9	262
1975	0	263	1	1	52	0	317	2010	0	286	3	35	19	7	350
1976	10	294	1	19	37	0	361	2011	0	223	0	0	12	16	251
1977	9	528	2	37	51	0	627	2012	0	446	3	0	15	18	482
1978	4	628	2	12	59	0	705	2013	0	259	3	5	10	12	289
1979	7	704	1	10	111	0	833	2014	0	276	7	12	14	6	315
1980	12	622	0	0	87	1	722	2015	0	250	4	0	9	6	269
1981	1	710	0	3	75	4	793	2016	0	265	5	16	7	6	299
1982	2	647	0	9	77	0	735	2017	0	314	5	11	6	7	343
1983	3	636	0	10	110	0	759	2018	0	252	5	14	6	2	280
1984	6	525	0	0	64	0	595	2019	0	293	1	29	5	1	329
1985	0	729	0	0	64	0	793	2020	0	288	3	44	4	1	340

Table 9.2.5. Lemon sole in areas 4, 7.d and 3.a. ICES estimates of landings and discards for areas 3.a, 4 and 7.d.

Year	Official landings	ICES Landings	ICES Discards	ICES Total Catch	Discard rate
1968	6792				
1969	5000				
1970	3859				
1971	4497				
1972	4315				
1973	5233				
1974	4761				
1975	5379				
1976	5233				
1977	6325				
1978	6954				
1979	7521				
1980	7298				
1981	7016				
1982	8487				
1983	9507				
1984	8111				
1985	7575				
1986	5937				
1987	6495				
1988	6798				
1989	7024				
1990	7485				
1991	7780				
1992	7442				
1993	7417				
1994	6760				
1995	6303				
1996	6523				
1997	6058				
1998	7680				
1999	7300				
2000	7171				
2001	6456				
2002	4823	4011	511	4522	11.30%
2003	4722	4575	1036	5611	18.46%
2004	4574	4394	635	5028	12.62%
2005	4468	4429	527	4955	10.63%
2006	4290	4294	1,515	5809	26.08%

Year	Official landings	ICES Landings	ICES Discards	ICES Total Catch	Discard rate
2007	4488	4468	451	4919	9.18%
2008	3976	4153	898	5051	17.77%
2009	3397	3405	996	4401	22.64%
2010	3198	3234	673	3907	17.21%
2011	4019	4030	1024	5055	20.27%
2012	2959	4099	2461	6560	37.52%
2013	3761	3725	5938	9663	61.45%
2014	3688	3645	1690	5335	31.68%
2015	3393	3480	1636	5116	31.97%
2016	3805	3834	1167	5000	23.33%
2017	3323	3315	651	3966	16.41%
2018	3014	3046	331	3376	9.79%
2019	3238	3273	605	3878	15.60%
2020	2655	2653	391	3044	12.86%

Table 9.3.1. Lemon sole in areas 4, 7.d and 3.a. Estimates of mean weight-at-age.

Year	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9
2005	0.0877	0.0741	0.1173	0.2215	0.3001	0.3449	0.3803	0.2155	0.2633
2006	0.0777	0.0747	0.1211	0.2242	0.3051	0.3378	0.3693	0.2348	0.261
2007	0.0684	0.0748	0.1238	0.2253	0.3077	0.3318	0.3603	0.2551	0.2622
2008	0.0599	0.074	0.1251	0.2249	0.3081	0.3268	0.3533	0.2753	0.266
2009	0.0521	0.0727	0.1254	0.223	0.3064	0.3225	0.3479	0.2955	0.2727
2010	0.0448	0.0709	0.1246	0.2195	0.3021	0.3186	0.3434	0.3148	0.2819
2011	0.0382	0.0685	0.1226	0.2141	0.2959	0.3156	0.3411	0.3363	0.2953
2012	0.0321	0.0654	0.1194	0.2074	0.2868	0.3139	0.3422	0.3552	0.3078
2013	0.0274	0.0614	0.1147	0.1986	0.2743	0.3133	0.3451	0.3747	0.3266
2014	0.0251	0.0579	0.1104	0.1875	0.2645	0.3153	0.3541	0.394	0.3456
2015	0.0225	0.0543	0.1058	0.1787	0.2546	0.3191	0.3643	0.4079	0.3526
2016	0.0199	0.0515	0.1014	0.1696	0.2455	0.3185	0.367	0.4115	0.3518
2017	0.0177	0.0488	0.0967	0.1625	0.2366	0.3168	0.3649	0.4074	0.3454
2018	0.0157	0.0467	0.0923	0.1558	0.2283	0.3134	0.36	0.3976	0.3337
2019	0.014	0.0448	0.0879	0.1503	0.2207	0.3088	0.3527	0.3816	0.3168
2020	0.0125	0.0433	0.0836	0.1456	0.2137	0.3036	0.3433	0.3595	0.2939
2021	0.0113	0.04212	0.0795	0.1422	0.2077	0.2974	0.3314	0.3316	0.2646

Table 9.3.2. Lemon sole in areas 4, 7.d and 3.a. GAM-estimated survey indices for Q1 (upper: NS IBTS) and Q3 (lower: NS IBTS + BTS). Data used in the assessment is highlight in bold.

NS Lemon Sole: IBTS Q1; Last group is NOT a plus-group. Calculations made on 22/04/2021 at 09:59:00.					
2007	2021				
1	1	0.09164804	0.09164804		
2	5				
1	128.5955	525.4095	443.1093	950.053	
1	350.917	489.5737	257.0786	259.3079	
1	343.1154	253.4795	273.229	112.7514	
1	442.4642	677.1069	915.4798	229.6984	
1	554.6513	1018.0489	602.9027	537.4863	
1	1774.6929	1993.7594	675.3875	312.951	
1	555.9307	777.763	917.0621	372.1282	
1	658.3365	1294.4395	924.0509	205.1571	
1	384.4856	1700.2849	1133.4635	349.2428	
1	906.9785	1650.6593	981.9899	403.2208	
1	636.2537	1010.4937	1063.7176	394.3887	
1	444.8309	740.4127	313.5275	302.0084	
1	692.7892	1523.3923	828.0682	255.4757	
1	762.1216	1315.4097	711.3283	275.6707	
1	378.4485	820.7201	1196.25	185.3992	

NS Lemon Sole: BTS & IBTS Q3; Last group is NOT a plus-group. Calculations made on 22/04/2021 at 09:59:00										
2005		2020								
1	1	0.6213935		0.6213935						
1	10									
1	203.3971	1596.5504	1750.8707	1619.6242	844.4385	1247.1648	508.7407	346.2973	531.9478	527.3128
1	129.284	1025.5664	1781.1944	1455.247	1475.3374	799.905	1209.4689	422.4152	200.4711	950.2557
1	722.1517	1613.0016	2124.6291	1750.107	1476.1872	1525.62	662.9034	826.7673	367.3843	768.4939
1	258.3927	2126.9125	2216.3341	1653.0906	1632.9107	745.6956	1093.3353	430.7593	400.3247	689.6695
1	592.0146	1518.9025	2534.4519	1558.6956	1034.2903	1040.9899	322.7608	682.8938	86.1345	774.8048
1	531.3581	1282.3393	2002.5613	1692.6984	2013.5499	1458.2887	1376.6898	556.3658	591.8736	629.1284
1	185.6848	2977.9689	3444.635	1988.176	2400.8841	1877.7232	865.4003	1278.9611	360.8428	1332.0103
1	454.0838	2328.0943	3215.4712	2495.2206	1743.8305	1329.4933	991.5343	717.0816	943.9445	1219.2577
1	12.3323	352.2942	2010.2667	3360.7555	2190.1292	2116.2592	1857.8176	1243.156	472.8761	1843.2137
1	438.1932	995.9492	2462.0234	3251.9733	3094.6666	2051.2798	1040.2114	899.9692	457.6814	1428.4659
1	43.2154	2219.1183	3660.37	3449.5804	2978.7394	1638.6165	927.0533	851.0846	627.6804	1068.3748
1	287.3964	1829.7776	3101.3691	2286.2135	2700.5277	2348.7785	1451.616	726.0363	727.042	1290.8178
1	51.7892	1162.7871	2486.8561	2381.3963	2583.0924	2195.0933	1470.5847	1052.4571	617.0264	837.2548
1	127.0669	1512.963	2158.3877	2053.9065	2326.9947	1865.6064	1463.4391	978.0559	538.6722	773.4331
1	315.6598	1438.0069	2589.4112	1863.1726	1434.458	1597.9202	1586.6928	1137.2113	700.3659	1256.2965
1	629.5958	1545.0032	2371.9828	2320.6581	1570.4525	1458.3711	1302.1879	992.1502	1070.5919	1771.0653

Table 9.4.1. Lemon sole in areas 4, 7.d and 3.a. SURBAR stock summary. Mortality Z is given as the mean total mortality over ages 3-5, while SSB and recruitment at age 1 are mean-standardised relative indices. Each estimate is given with lower and upper bounds of a 90% confidence interval.

Year	z.low	z	z.high	ssb.low	ssb	ssb.high	rec.low	rec	rec.high
2005	-0.109	0.183	0.49	0.671	0.84	1.176	0.49	0.69	0.96
2006	-0.052	0.20	0.43	0.721	0.891	1.187	0.52	0.71	0.98
2007	0.169	0.41	0.64	0.76	0.911	1.188	0.67	0.96	1.34
2008	0.131	0.38	0.61	0.631	0.761	0.98	0.55	0.76	1.04
2009	-0.25	-0.023	0.195	0.529	0.64	0.82	0.66	0.88	1.18
2010	-0.23	0.0020	0.22	0.735	0.869	1.098	0.87	1.17	1.59
2011	-0.096	0.143	0.38	0.915	1.093	1.412	0.87	1.18	1.55
2012	0.024	0.26	0.50	0.983	1.191	1.545	0.78	1.1	1.49
2013	0.021	0.25	0.47	0.938	1.129	1.44	0.63	0.83	1.13
2014	-0.072	0.157	0.38	0.916	1.09	1.384	0.79	1.07	1.43
2015	-0.154	0.069	0.28	0.957	1.144	1.481	0.51	0.69	0.92
2016	-0.060	0.170	0.39	1.027	1.257	1.624	0.59	0.82	1.15
2017	0.0170	0.25	0.48	0.998	1.213	1.593	0.55	0.8	1.14
2018	-0.063	0.156	0.37	0.866	1.042	1.369	0.6	0.91	1.35
2019	-0.167	0.121	0.37	0.825	0.975	1.262	0.71	1.17	2
2020	0.058	0.174	0.29	0.753	0.953	1.333	1	2.26	5.6

Table 9.4.1. Lemon sole in areas 4, 7.d and 3.a. Output from LBI analyses. Green shows indicators that are met or exceeded, while red shows indicators that are not met.

	Conservation				Optimising yield	MSY
	L_c/L_{mat}	L_{25}/L_{mat}	$L_{max5\%}/L_{inf}$	P_{mega}	L_{mean}/L_{opt}	$L_{mean}/F_{F=M}$
Year	>1	>1	>0.8	>30%	~1(>0.9)	≥1
2002	0.692	1.808	1.001	0.588	1.107	1.716
2003	1.154	1.731	0.997	0.481	1.074	1.302
2004	1.769	1.885	1.001	0.609	1.202	1.128
2005	1.923	1.885	0.910	0.383	1.126	1.001
2006	0.846	1.885	0.962	0.555	1.106	1.569
2007	0.846	1.885	0.975	0.501	1.085	1.539
2008	1.462	1.731	0.996	0.477	1.105	1.170
2009	0.538	1.731	0.994	0.479	1.064	1.819
2010	0.692	1.808	1.005	0.518	1.112	1.724
2011	0.231	1.346	0.959	0.285	0.919	1.976
2012	0.538	1.500	0.948	0.267	0.939	1.606
2013	NA	NA	NA	NA	NA	NA
2014	0.538	1.500	0.988	0.325	0.962	1.645
2015	0.231	1.577	0.995	0.284	0.963	2.070
2016	0.692	1.577	1.005	0.449	1.038	1.609
2017	0.538	1.577	1.023	0.499	1.041	1.779
2018	2.077	1.962	1.076	0.698	1.291	1.090
2019	0.538	1.500	1.024	0.433	1.032	1.764
2020	1.154	1.654	1.034	0.518	1.081	1.310

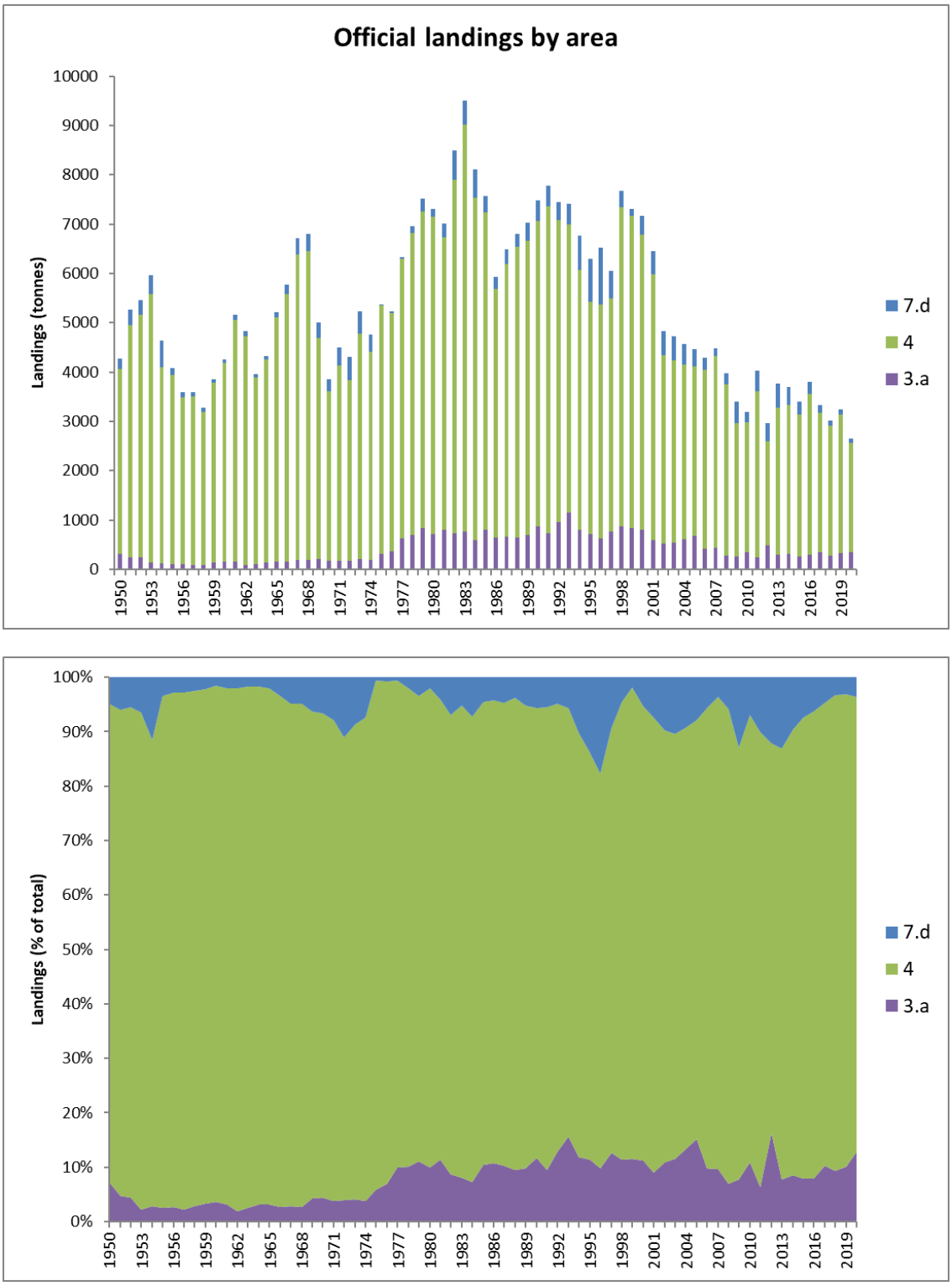

Figure 9.2.1. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. Officially-reported landings of lemon sole by area in the greater North Sea. Upper plot: landings in tonnes. Lower plot: landings by area as a percentage of the full area.

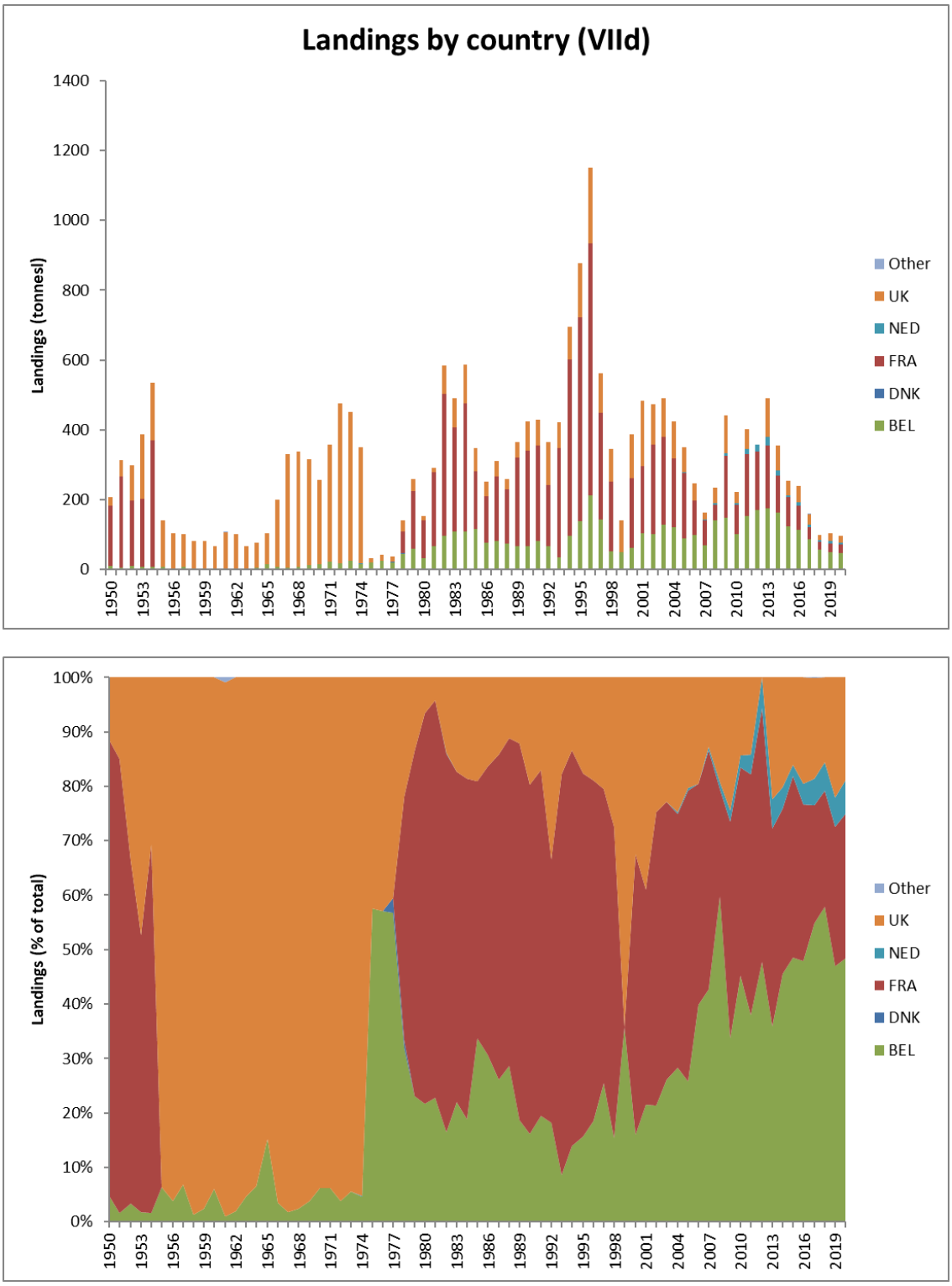

Figure 9.2.2. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. Official landings of lemon sole in area 7.d by country. Upper plot: landings in tonnes. Lower plot: landings by country as a percentage of the total area 7.d landings.

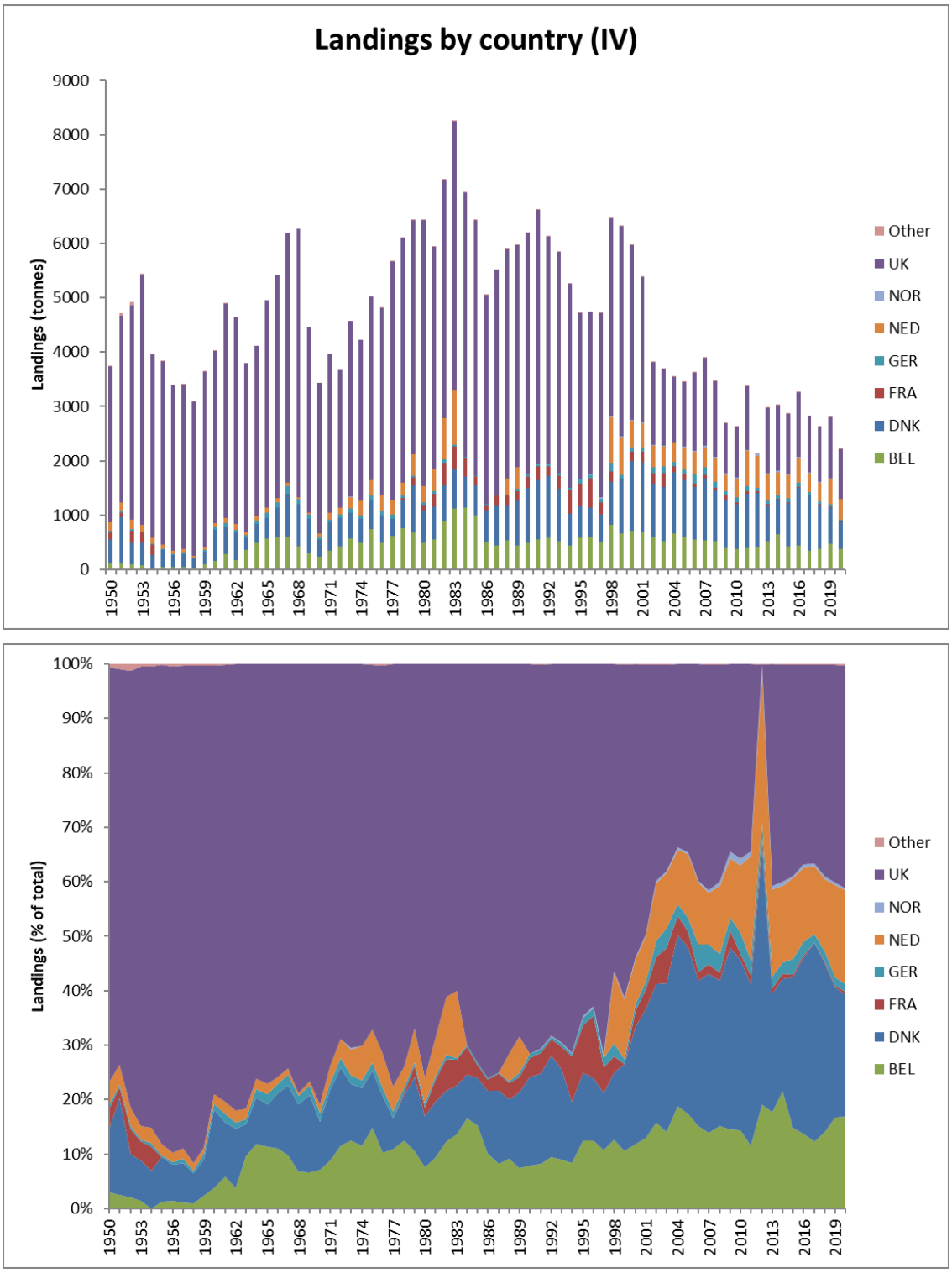

Figure 9.2.3. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. Official landings of lemon sole in area 4 by country. Upper plot: landings in tonnes. Lower plot: landings by country as a percentage of the total area 4 landings.

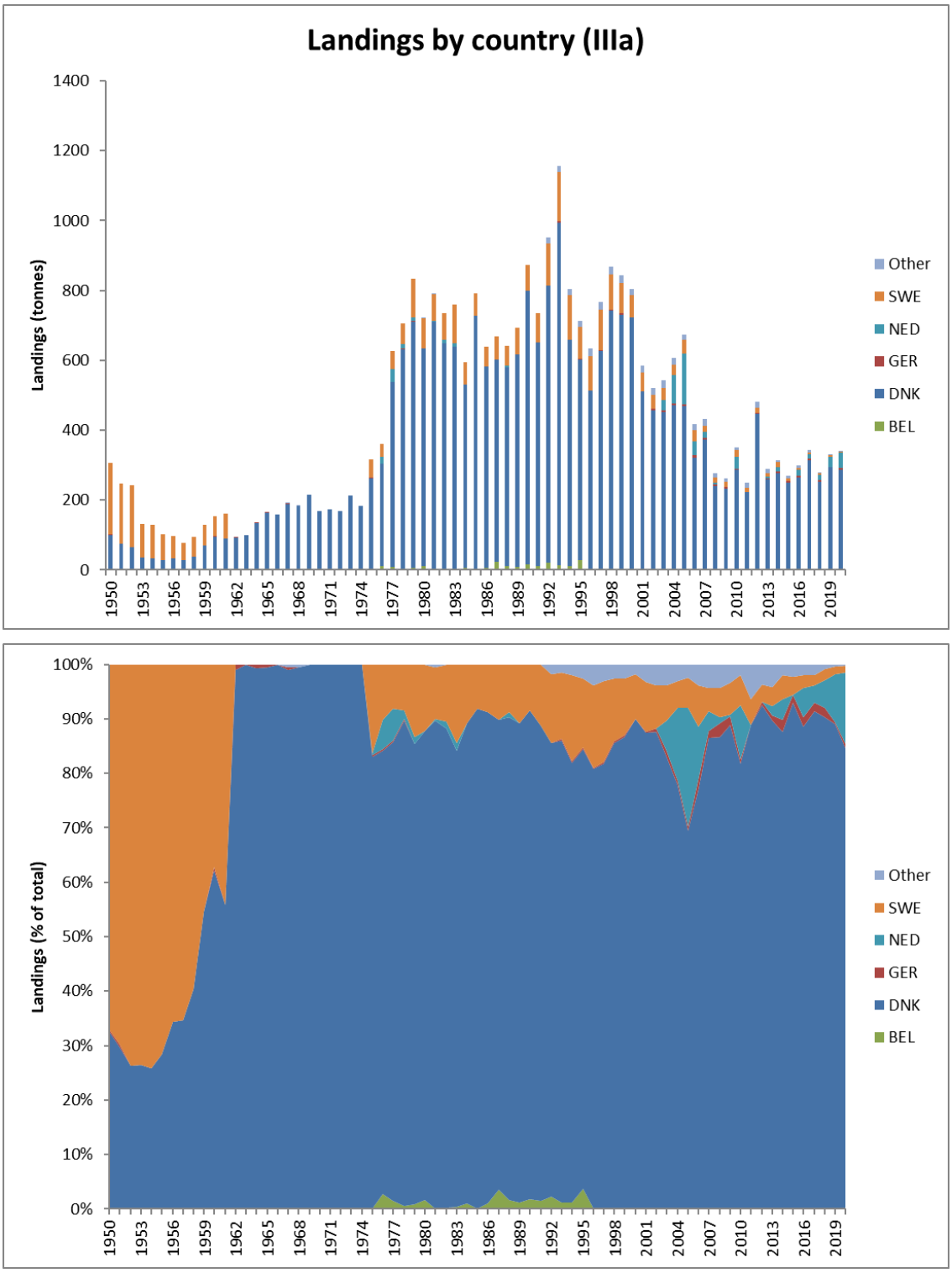

Figure 9.2.4. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. Official landings of lemon sole in area 3.a by country. Upper plot: landings in tonnes. Lower plot: landings by country as a percentage of the total area 3.a landings.

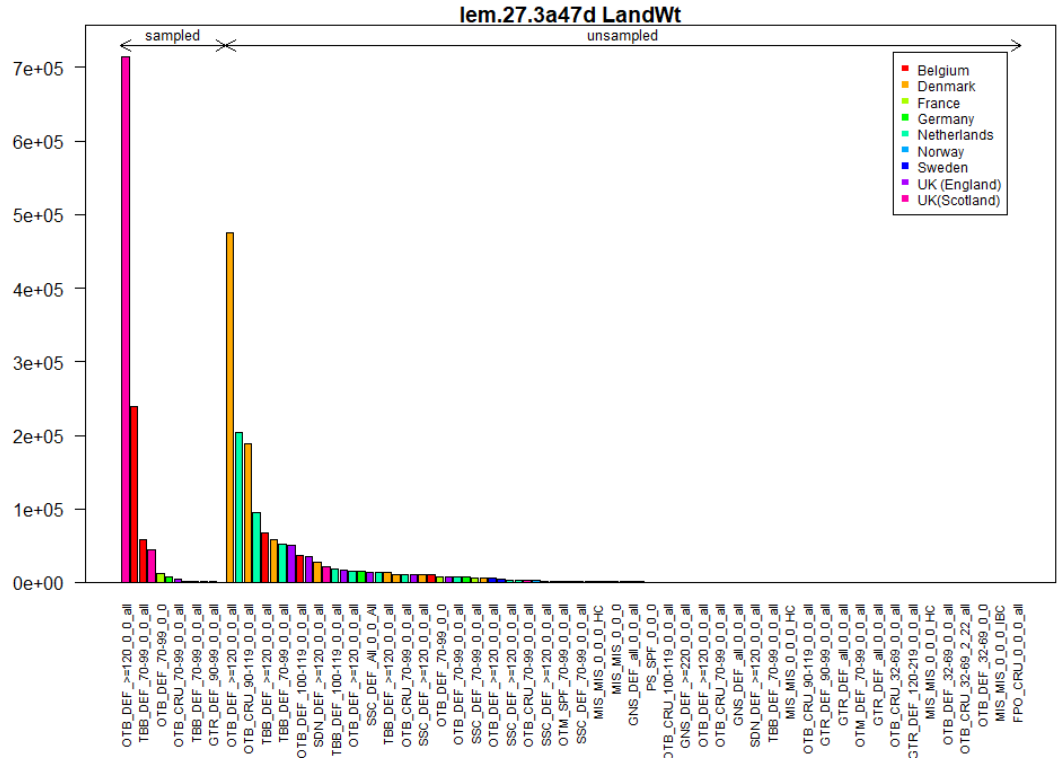

Figure 9.2.5. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. InterCatch summary plots. Sampled and unsampled fleets for landings yield estimation (tonnes).

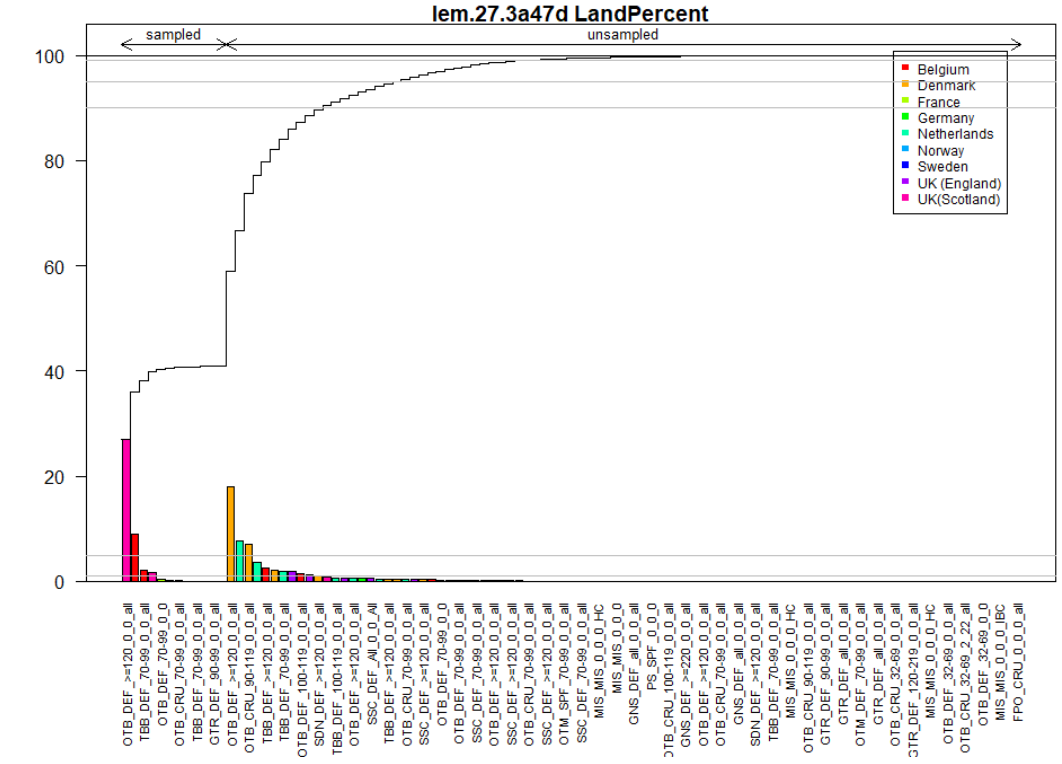

Figure 9.2.6. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. InterCatch summary plots. Sampled and unsampled fleets for landings yield estimation (cumulative contribution).

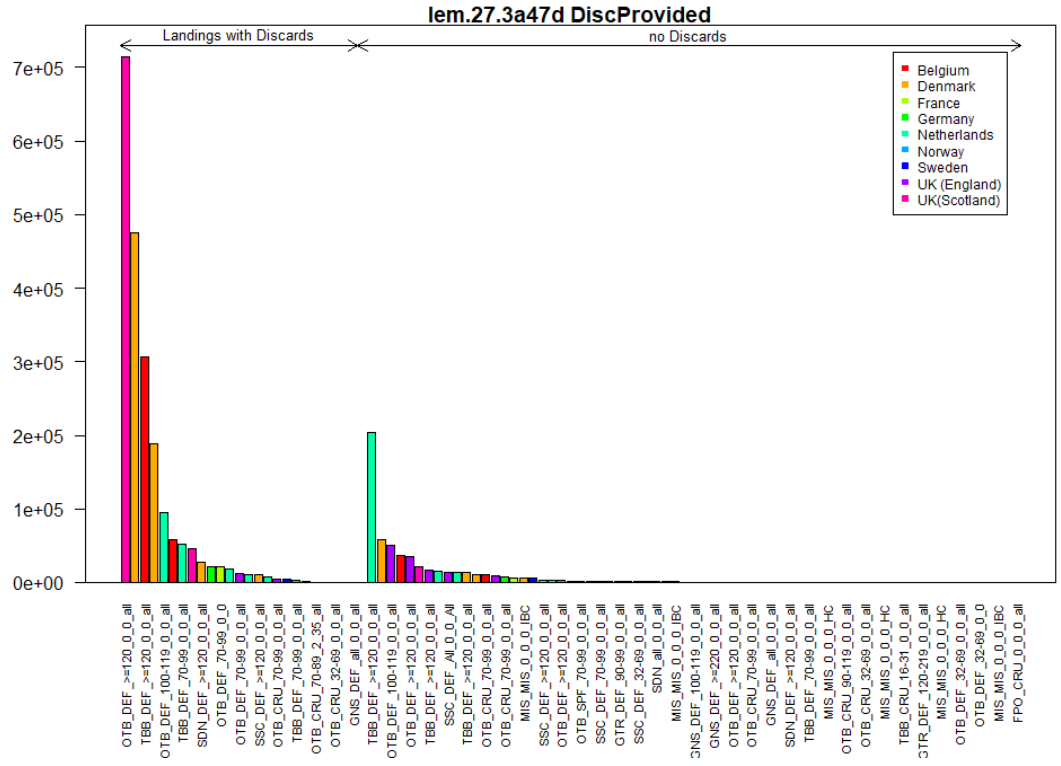

Figure 9.2.7. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. InterCatch summary plots. Fleets provided with and without discard estimates.

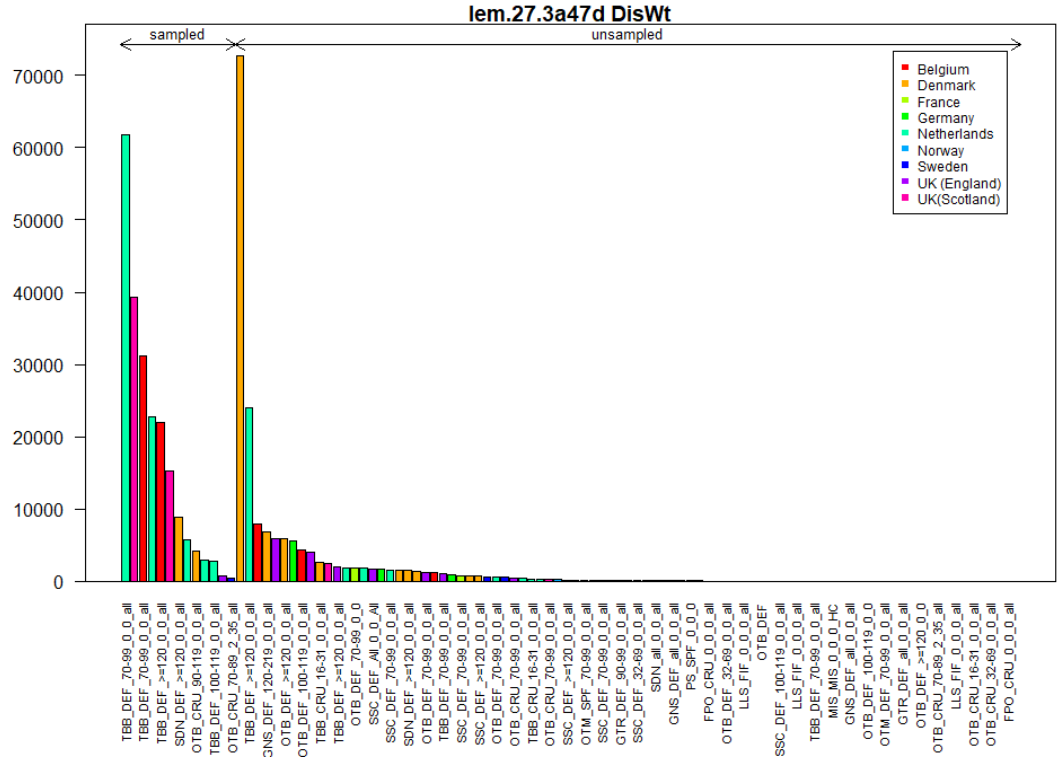

Figure 9.2.8. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. InterCatch summary plots. Sampled and unsampled fleets for discard yield estimation.

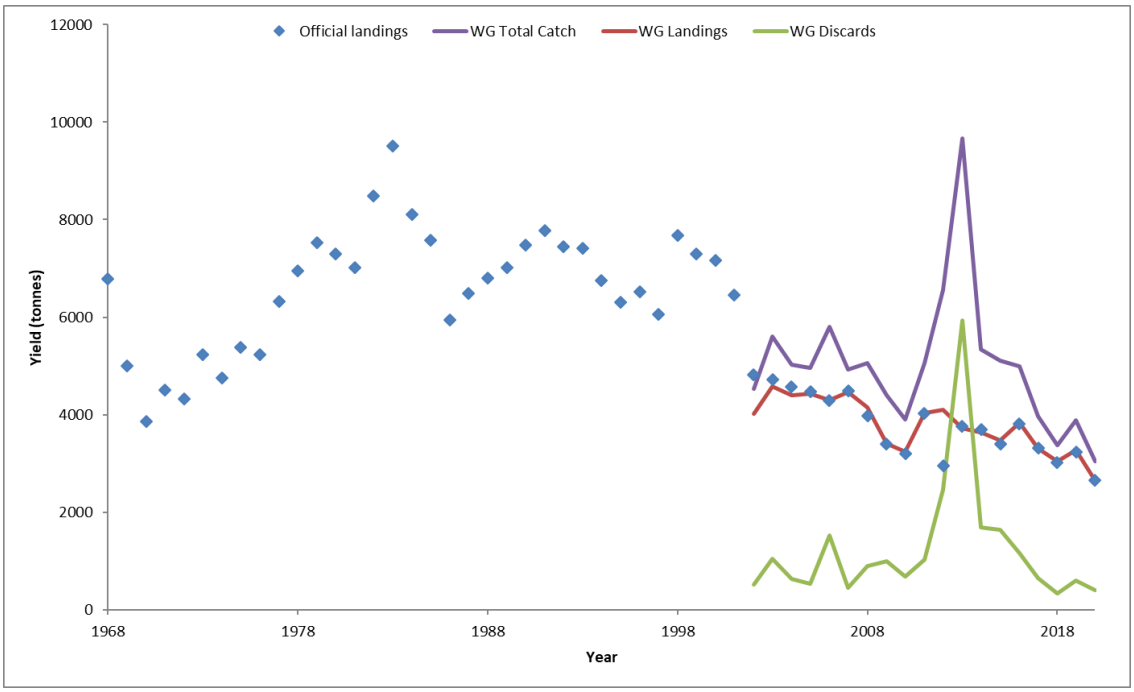

Figure 9.2.9. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. Time-series of official landings (dots) along with ICES WG estimates of total catch (purple line), landings (red line) and discards (green line).

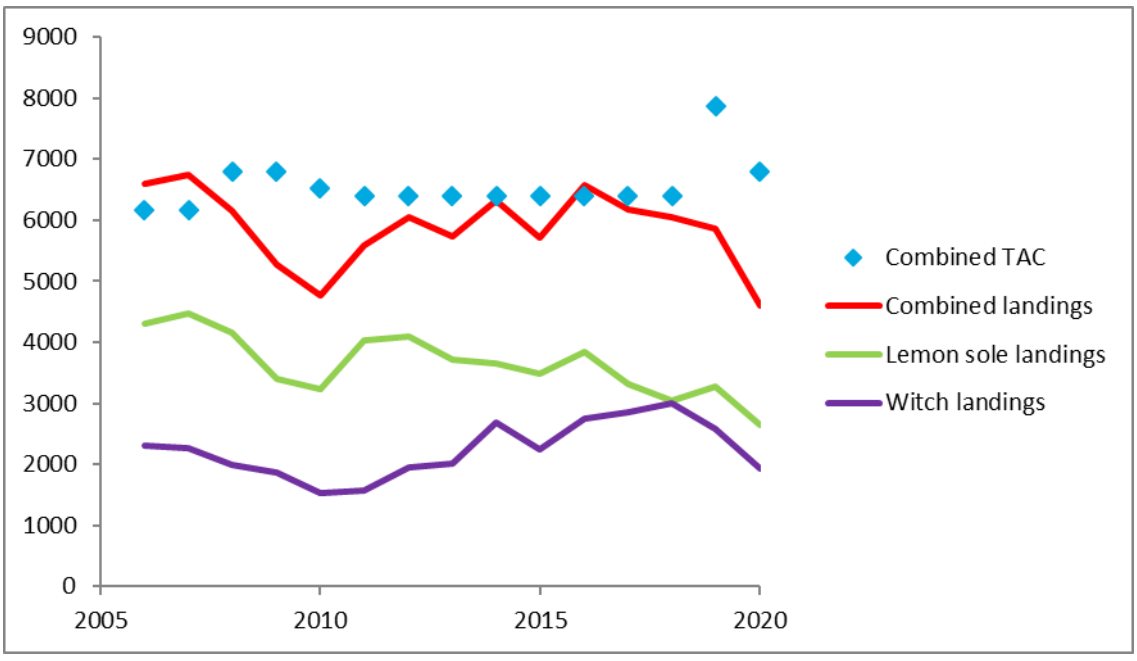

Figure 9.2.10. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. Time-series of ICES WG estimates of landings for lemon sole (green line), witch (purple line) and combined (red line), along with the joint lemon sole-witch TAC (dots).

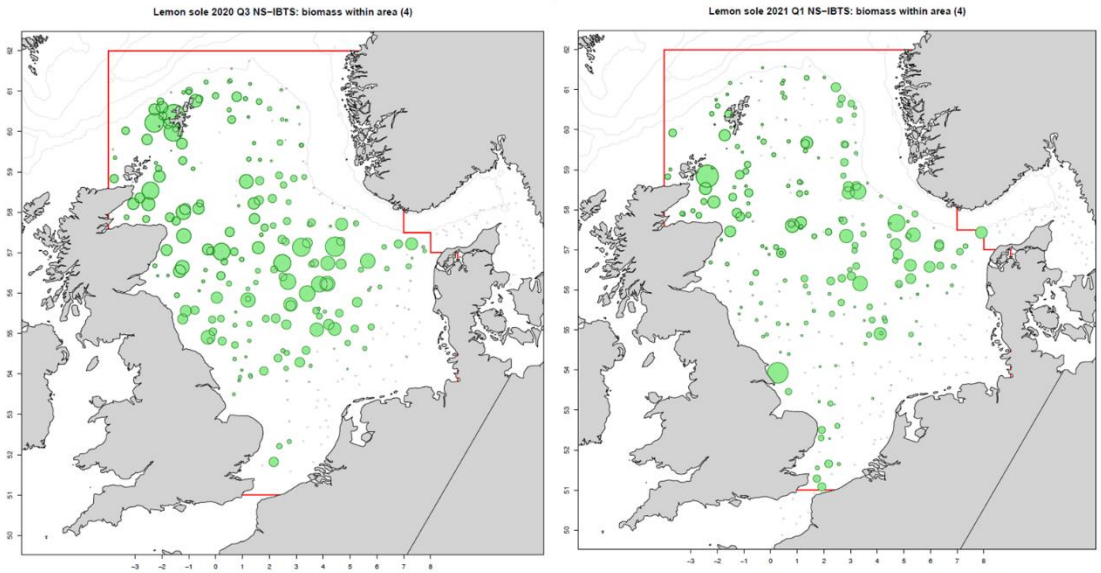

Figure 9.3.1. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. Distribution of lemon sole in the North Sea derived from IBTS Q3 2020 (left) and IBTS Q1 2021 (right). The sizes of the circles are proportional to the square root of the estimated weight of lemon sole caught in each haul.

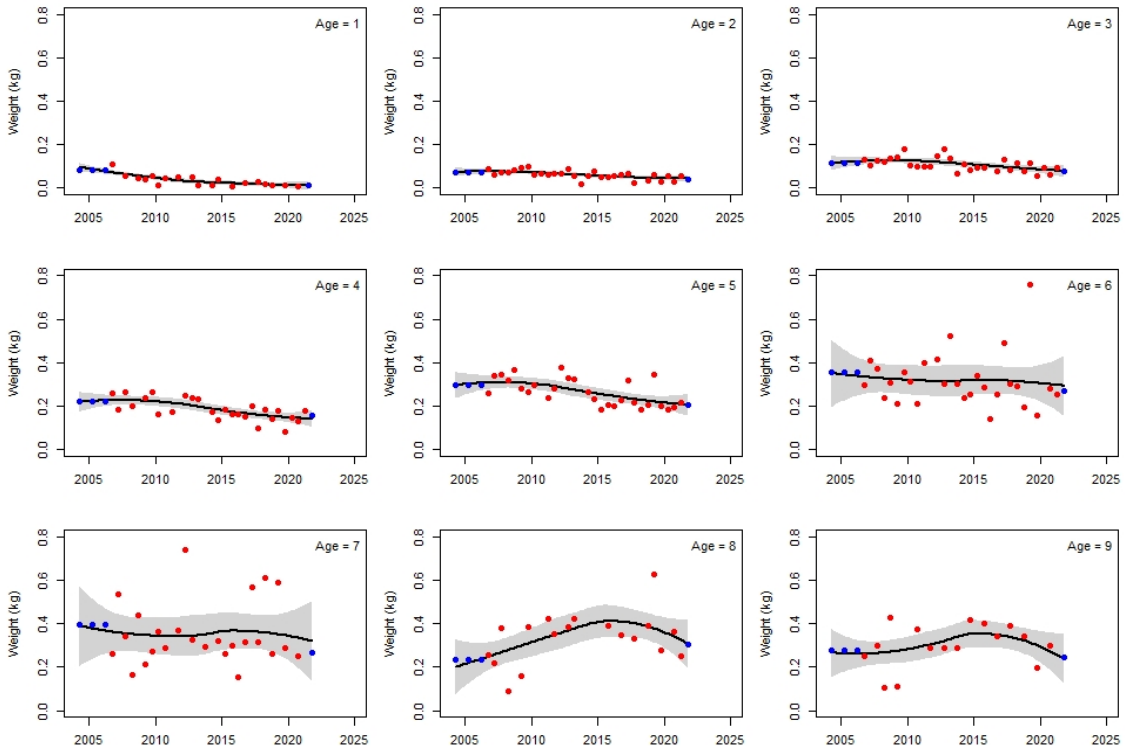

Figure 9.3.2. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. Time-series of mean weight-at-age estimates (red dots) from IBTS Q1 and Q3 surveys, summarised by a loess smoother (span = 1) for each year (the grey band gives a 95% confidence interval about the loess smoother). The blue dots show averages (of either the first or last two estimates), included to allow extrapolation to the start and end point of the survey indices.

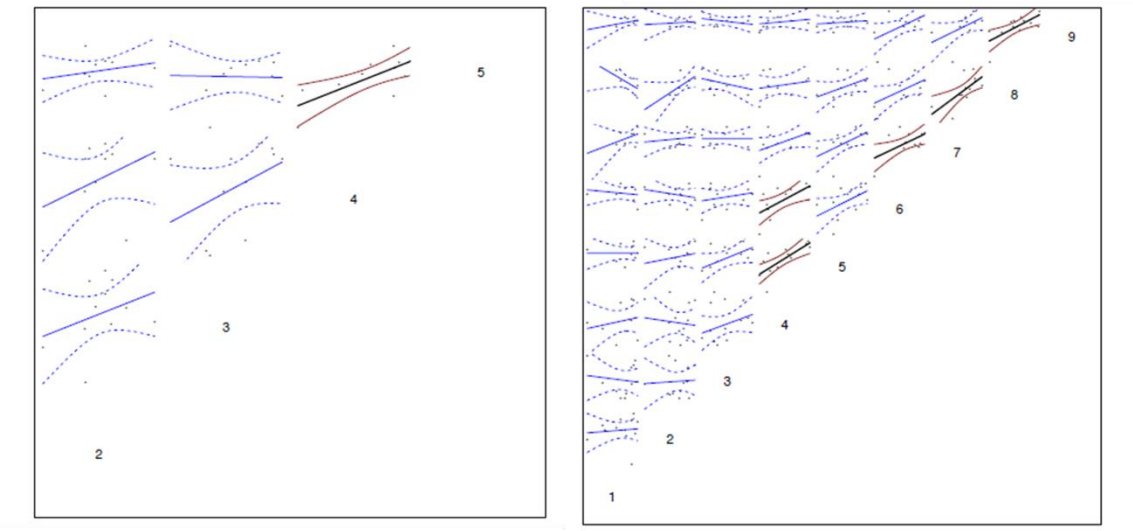

Figure 9.3.3. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. Bivariate scatterplots showing consistency in cohort-strength estimation, for Q1 (left: IBTS) and Q3 (right: IBTS and BTS).

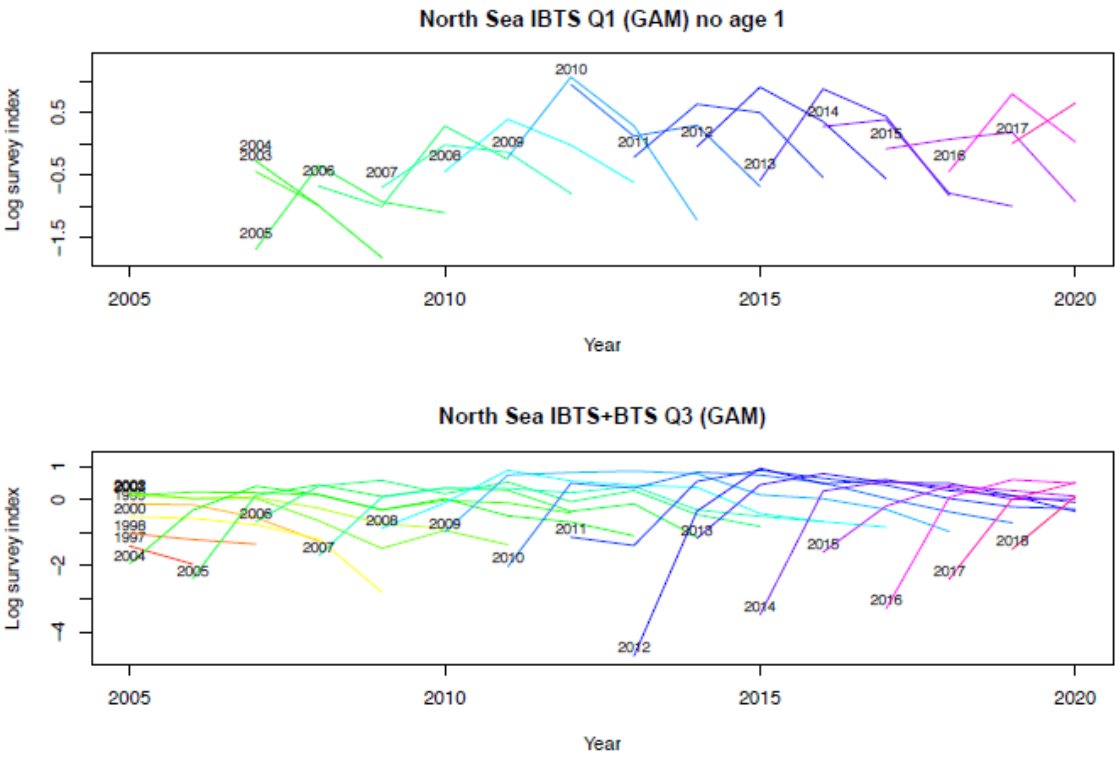

Figure 9.3.4. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. Survey catch curves, for Q1 (upper: IBTS) and Q3 (lower: IBTS and BTS).

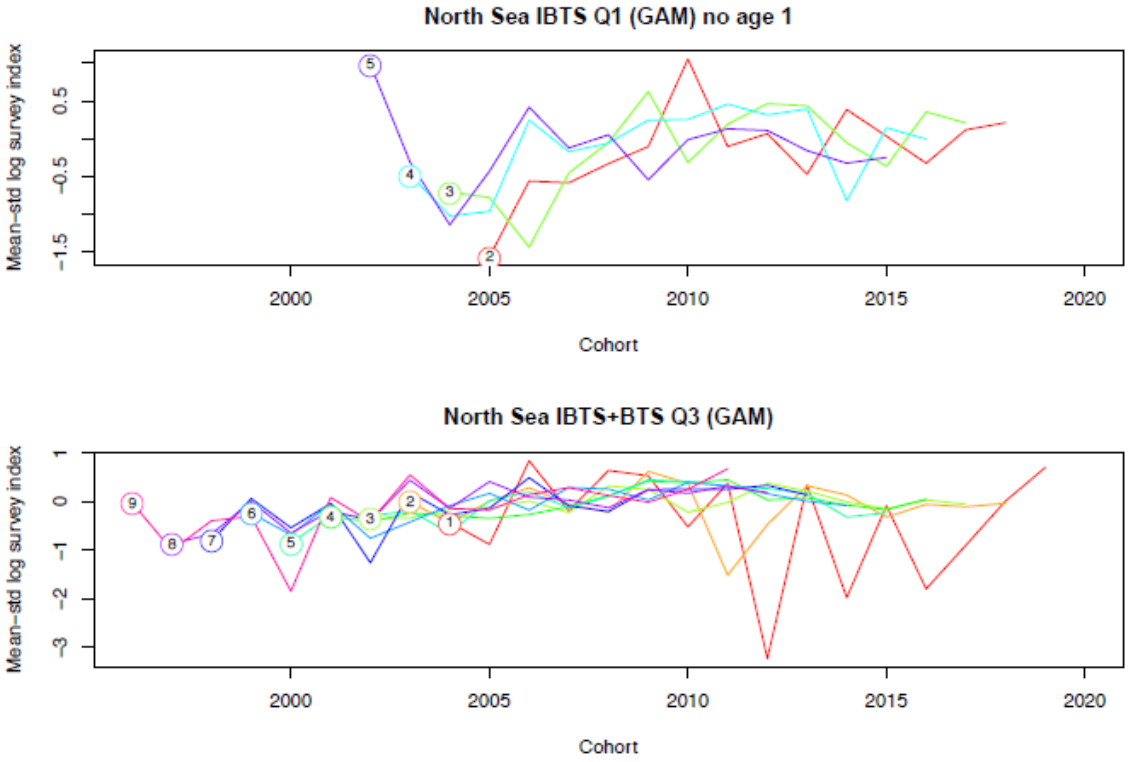

Figure 9.3.5. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. Survey indices by age, cohort and year, for Q1 (upper: IBTS) and Q3 (lower: IBTS and BTS).

Figure 9.3.6. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. Mean-standardised survey indices for Q1 (IBTS, blue lines) and Q3 (IBTS+BTS, red lines), shown as time-series for each age. Solid lines indicate data that are used in the assessment.

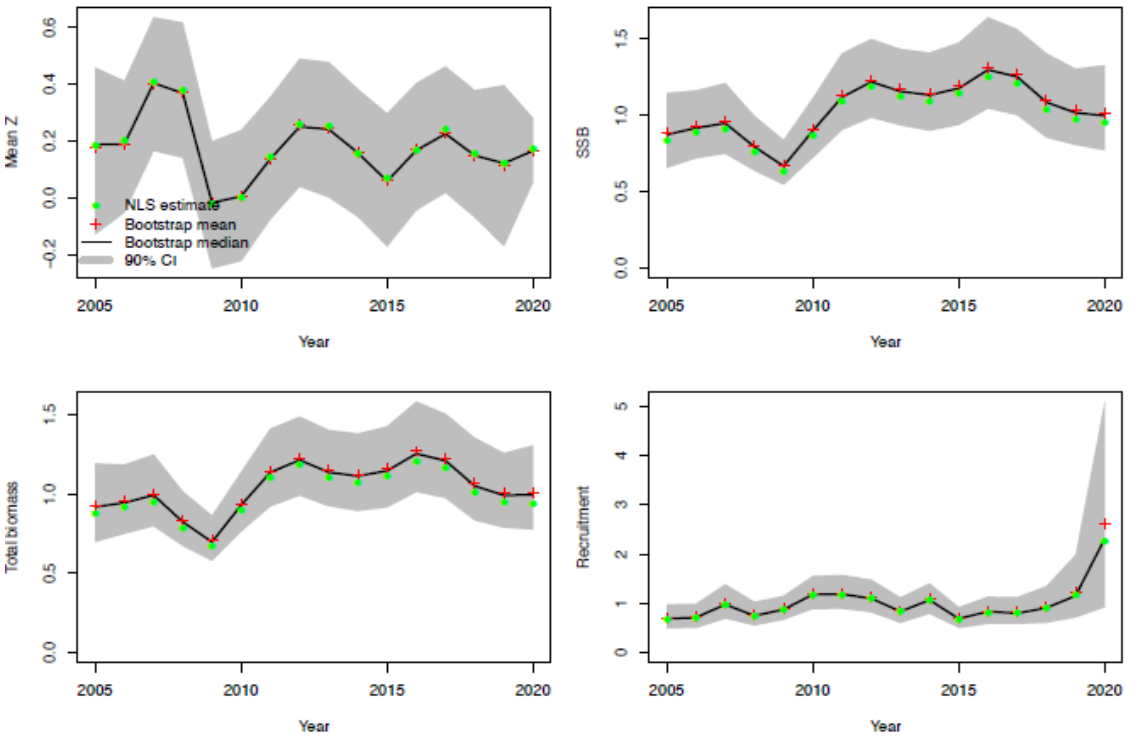

Figure 9.4.1. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. SURBAR stock summary (clockwise from upper left: mean Z(3-5), relative SSB, relative recruitment at age 1, relative total biomass). In each plot, the green dots give the nonlinear least-squares estimates, the red crosses give the uncertainty-estimation bootstrap mean, the black line gives the bootstrap median, and the grey band gives a 90% confidence interval about the median.

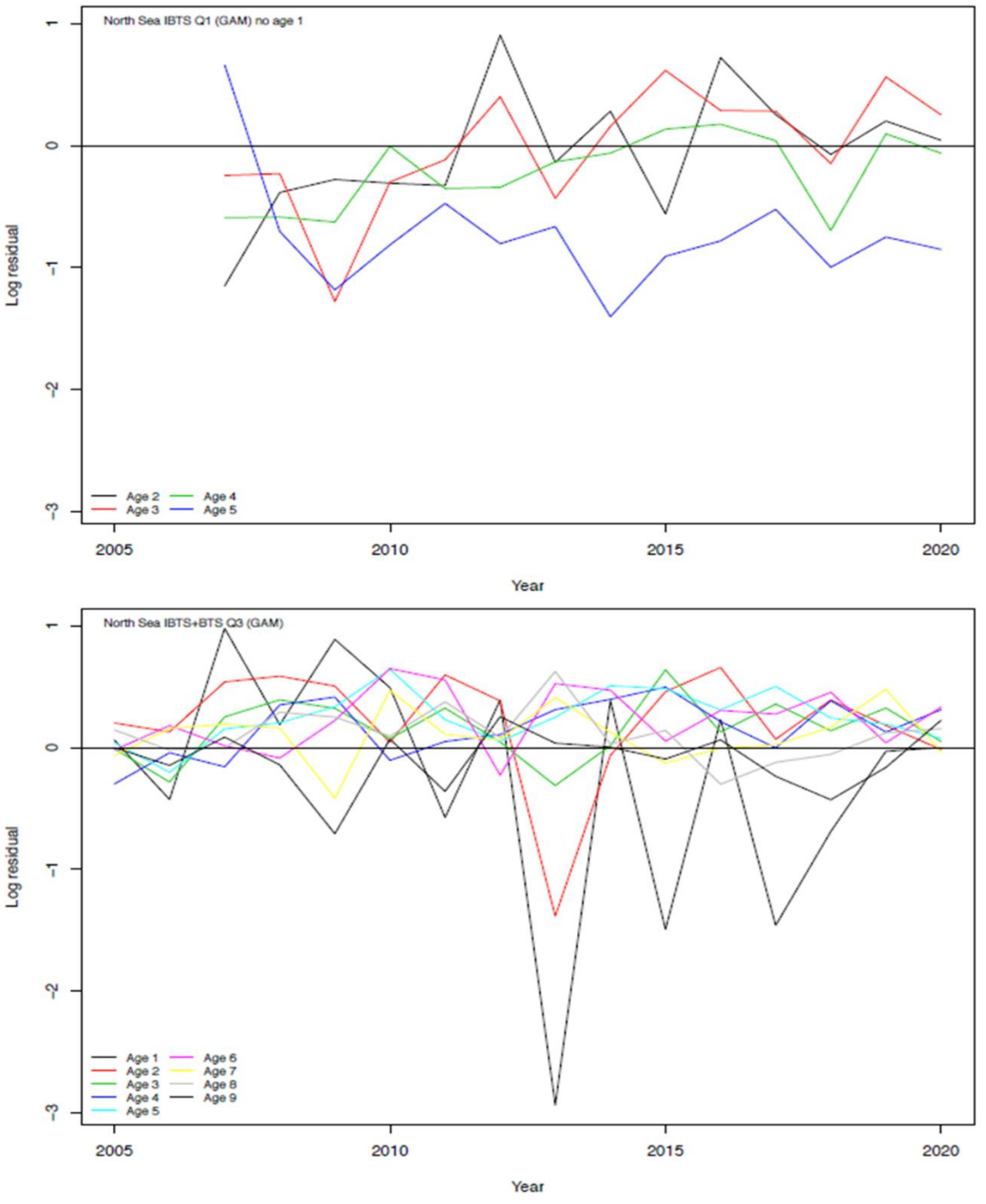

Figure 9.4.2. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. Upper: Log SURBAR residuals for Q1 (IBTS). Lower: Log SURBAR residuals for Q3 (IBTS+BTS).

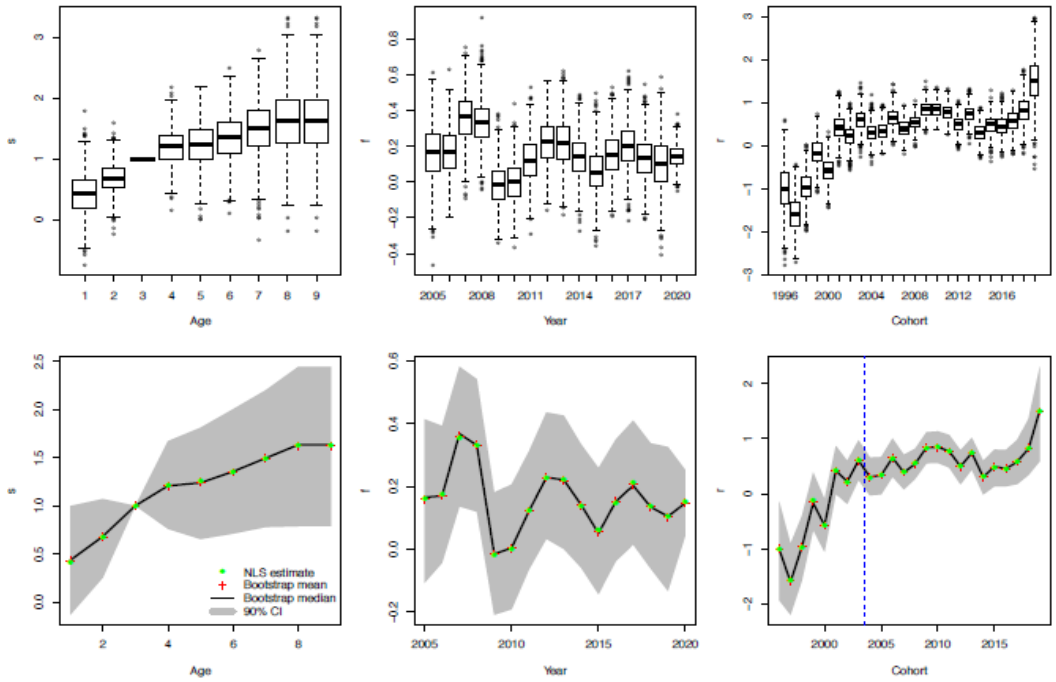

Figure 9.4.3. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. Estimated SURBAR parameters: age effects (*s*) and year effects (*f*) of total mortality, and cohort effects (*r*). Upper: box-and-whisker plots of bootstrap distributions. Lower: the green dots give the nonlinear least-squares estimates, the red crosses give the uncertainty-estimation bootstrap means, the black line gives the bootstrap median, and the grey band gives a 90% confidence interval about the median.

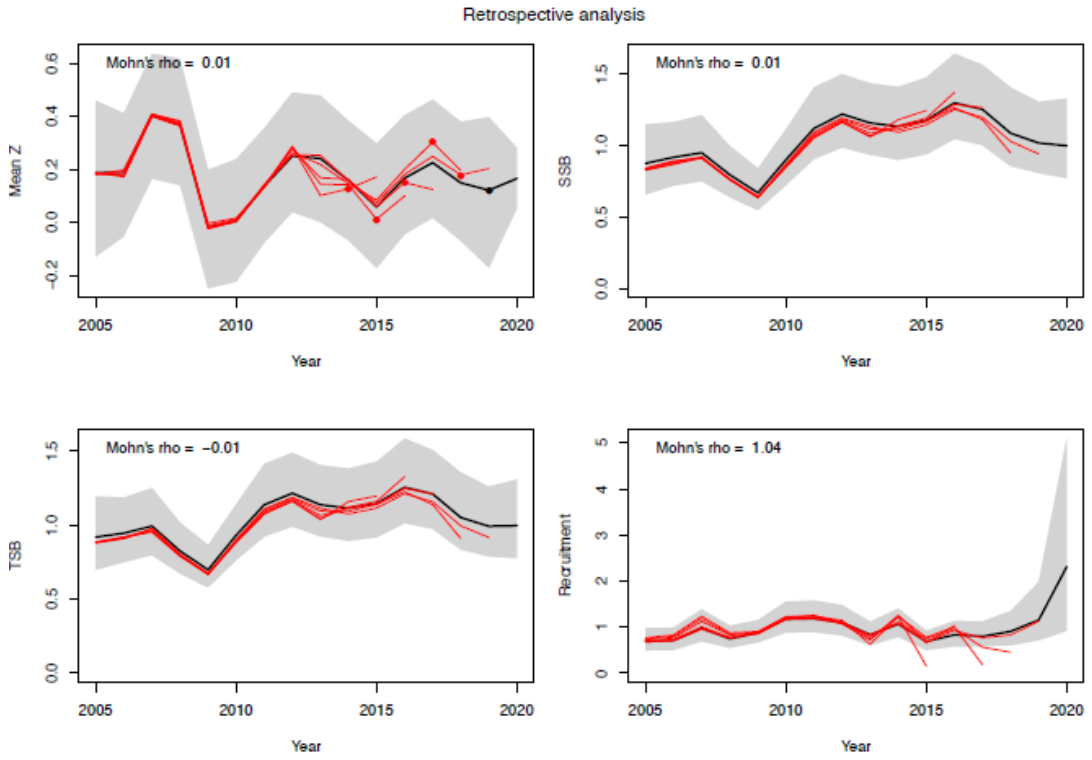

Figure 9.4.4. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. Retrospective SURBAR analysis (clockwise from upper left: mean Z(3-5), relative SSB, relative total biomass, relative recruitment at age 1). Black lines give final-year estimates (with 90% confidence interval in grey), while red lines give the results of 5 retrospective peels.

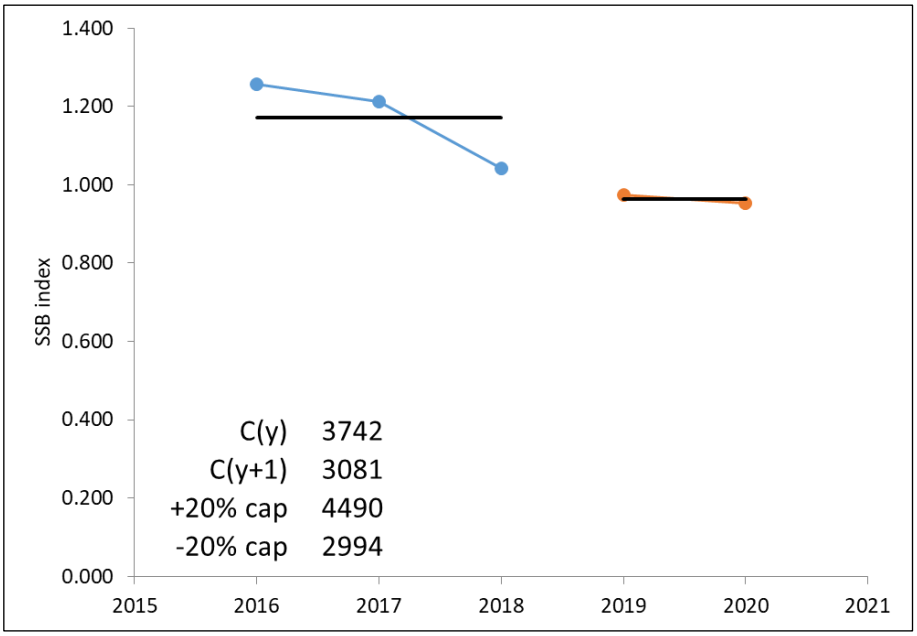

Figure 9.5.1. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. Application of the DLS 3.2 rule, using the last five years of the relative SSB estimate given in Figure 9.4.1.

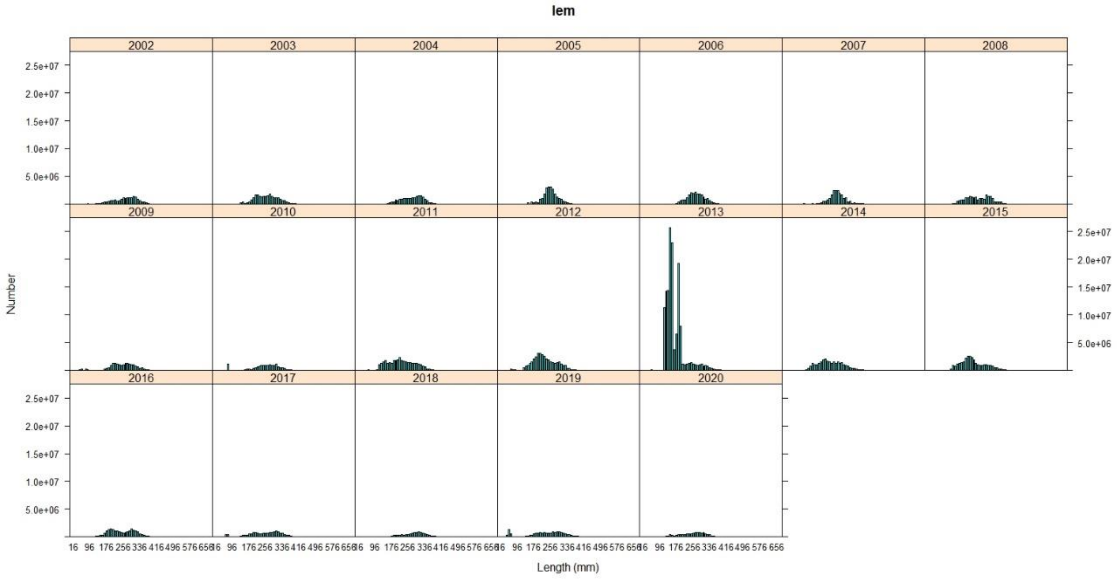

Figure 9.6.1. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. Length distributions in commercial catches (landing and discards) submitted to InterCatch, by year.

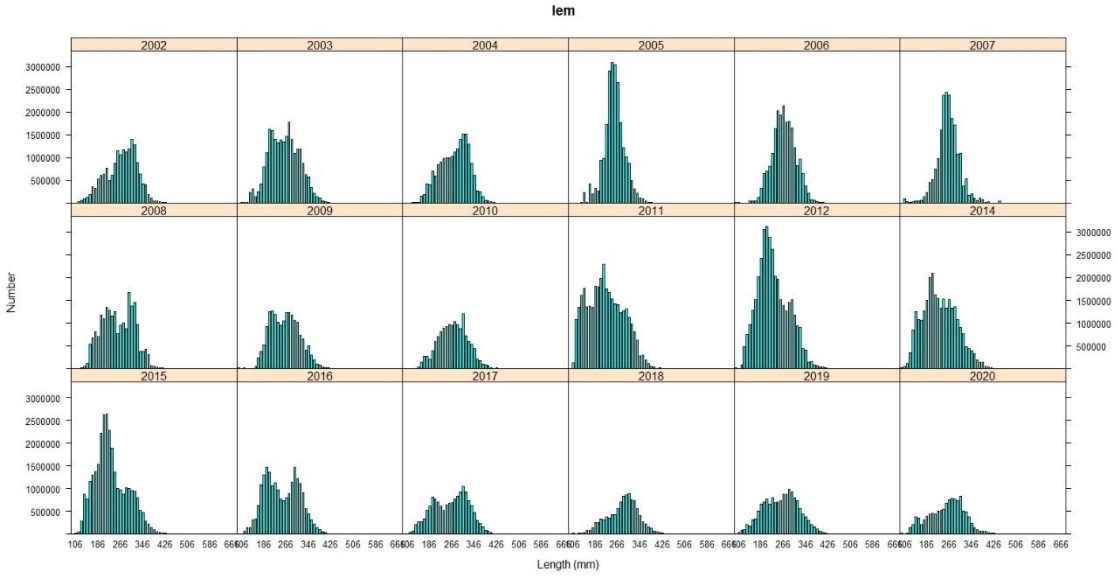

Figure 9.6.2. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. Length distributions in commercial catches (landing and discards) submitted to InterCatch, by year, with 2013 data removed due to erroneous data submissions, and all fish <100 mm removed for all years.

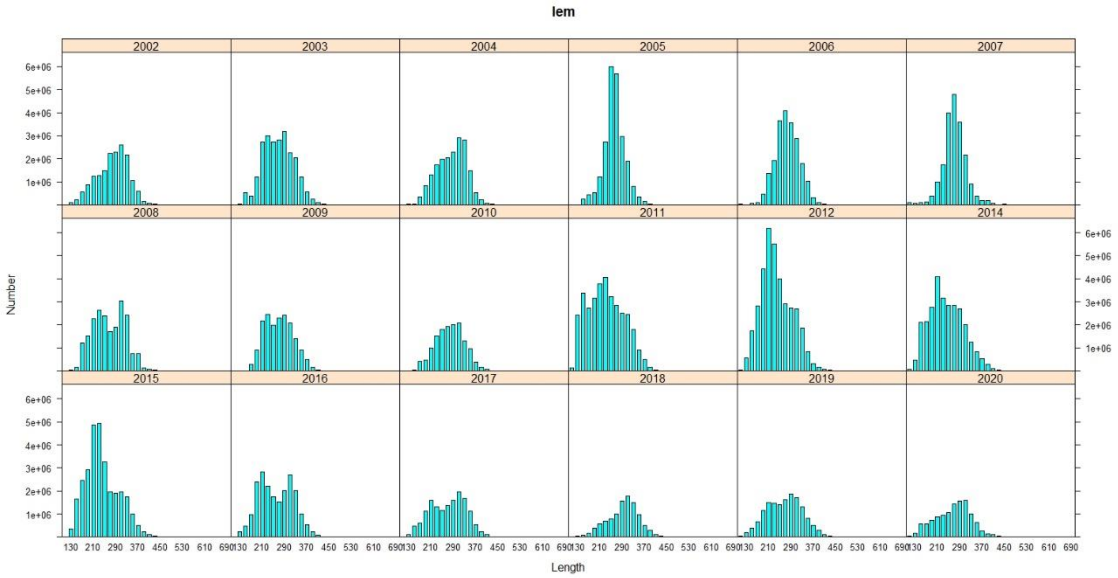

Figure 9.6.3. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. As for Figure 9.6.2, with bin widths doubled (to 20 mm).

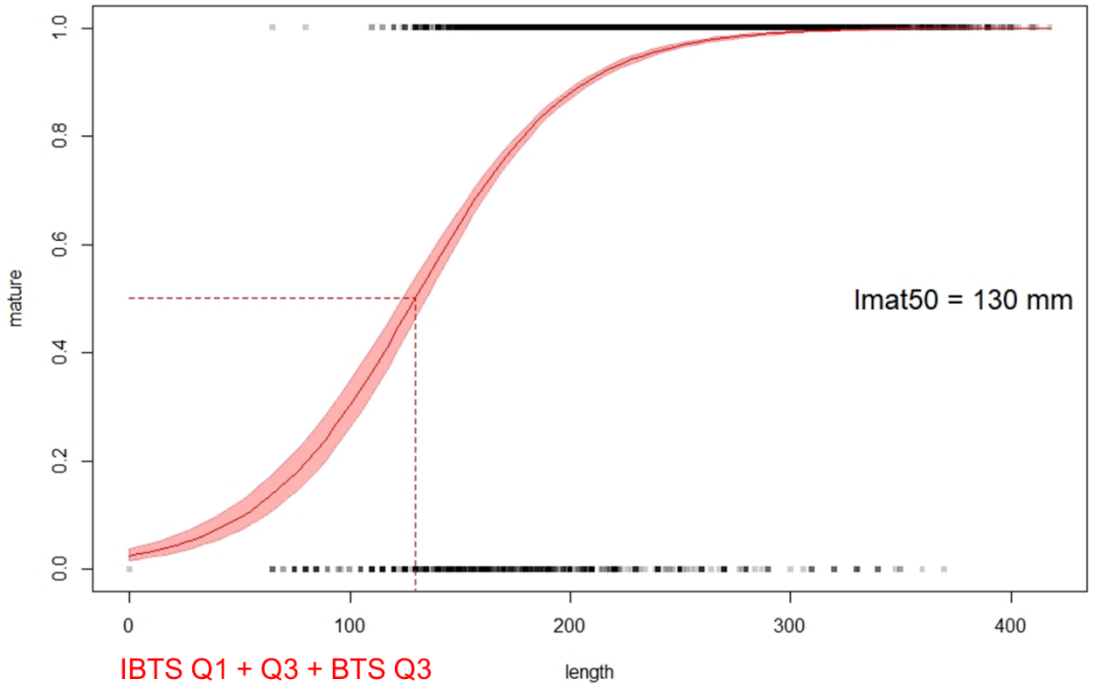

Figure 9.6.4. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. Fitted maturity-at-age estimates from Q1 (IBTS) and Q3 (IBTS & BTS) survey series, using maturity-length observations from all available years (2007-2021). Maturity indices (0 = not mature, 1 = mature) are shown as shaded dots. The solid red line gives the fitted maturity ogive with 95% confidence interval (red band), while dotted red lines highlight the length of 50% mature ($L_{50\%mat}$ = 130 mm)

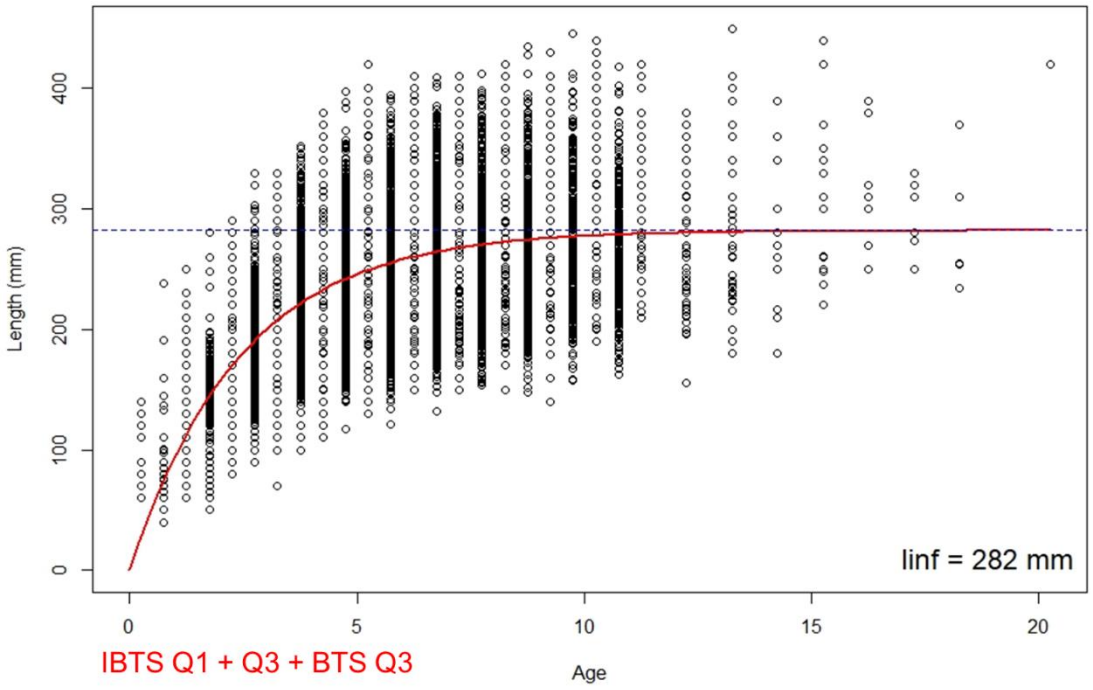

Figure 9.6.5. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. Length-at-age data from Q1 (IBTS) and Q3 (IBTS & BTS) survey series, using data from all available years (2007-2021). To account for seasons, Q1 lengths are plotted at *a* + 0.25, Q3 lengths at *a* + 0.75. The red line gives a fitted von Bertalanffy growth curve (L_∞ = 282.806 mm, K = 0.4114, t_0 = 0).

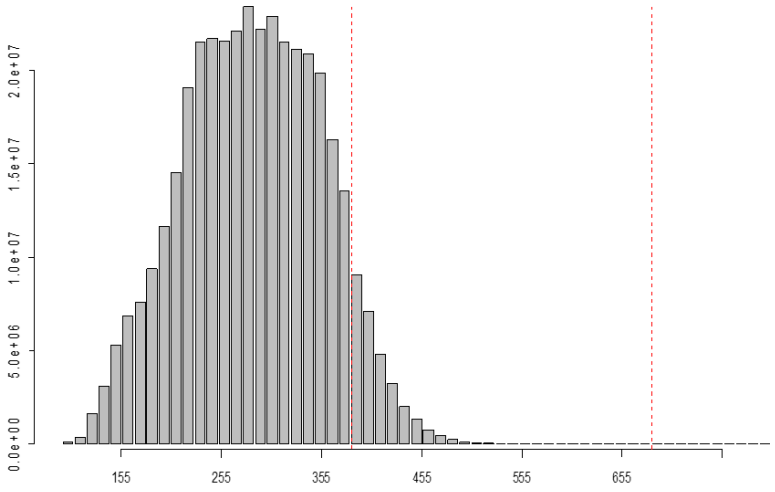

Figure 9.6.6. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. Length distribution of the commercial catch data submitted to InterCatch, collated over all available years (2002–2020). The red lines give (from left to right) the 99%ile of the distribution (385 mm) and the longest observed fish (685 mm).

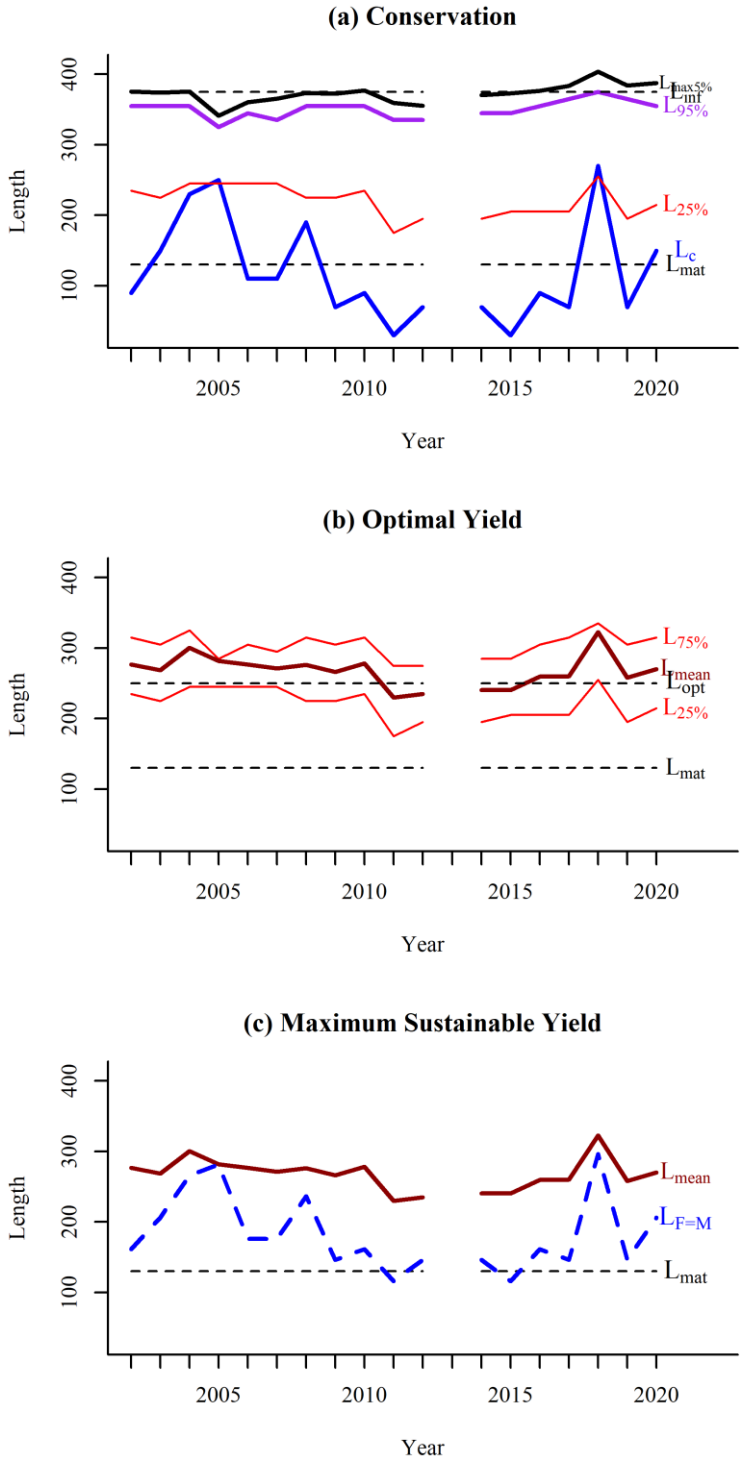

Figure 9.6.7. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. Results of LBI analysis (absolute estimates).

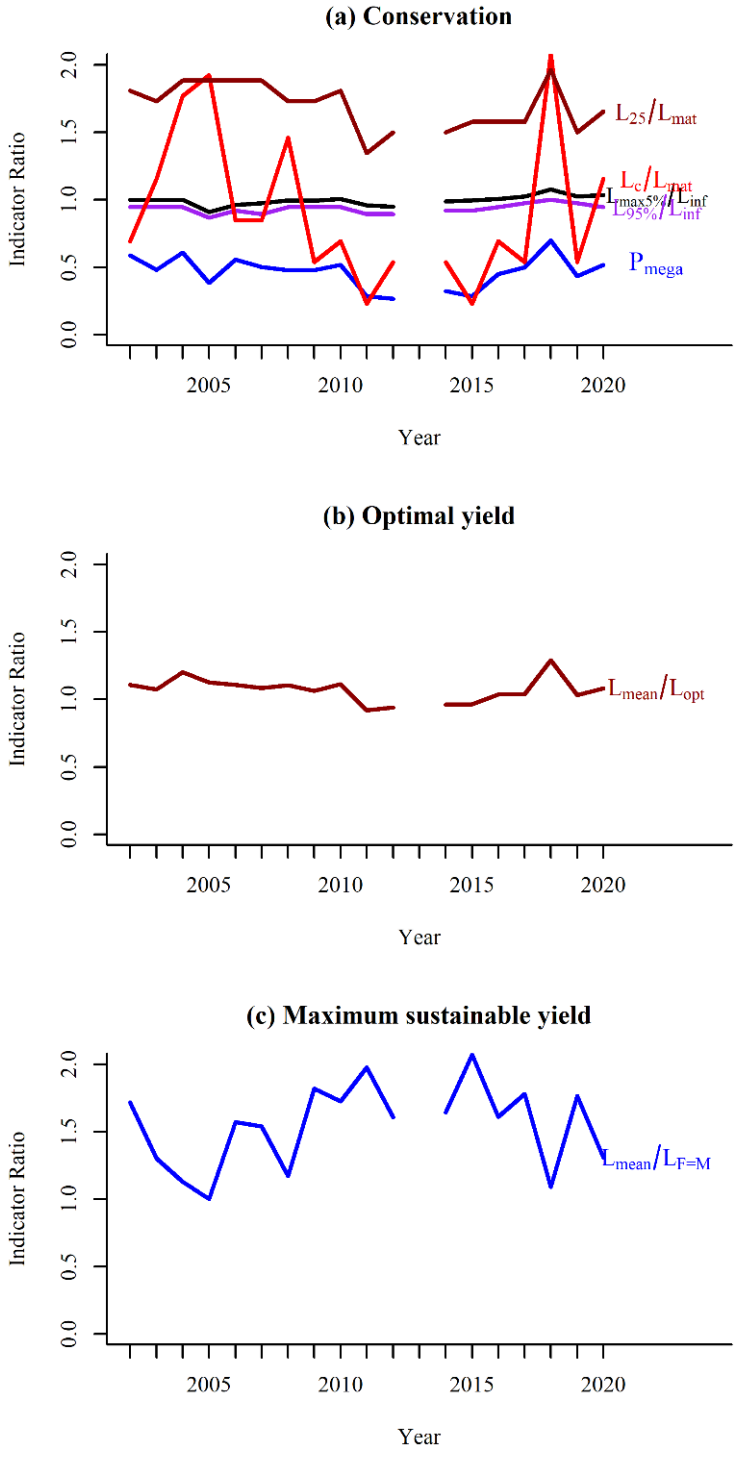

Figure 9.6.8. Lemon sole in Subarea 4, and Divisions 3.a and 7.d. Results of LBI analysis (ratio estimates).