BLUE LING - BLÁLANGA

Molva dypterygia

GENERAL INFORMATION

Blue ling is most common in south, west and northwest of Iceland along the Icelandic continental shelf, in deeper areas than most of the other gadoids. It is smaller than the common ling, reaching an average length of ~80 cm and a maximum of 152 cm according to the Icelandic autumn groundfish survey 1996-2019. Sexual maturity is reached at 75-90 cm, males mature smaller/younger than females.

THE FISHERY

The change in geographical distribution of the Icelandic blue ling fisheries from 2001 to 2020 (Figures 1-2), indicates an expansion of the fishery of blue ling to north-western waters. This increase may partly be the result of increased availability of blue ling in the north-western area.

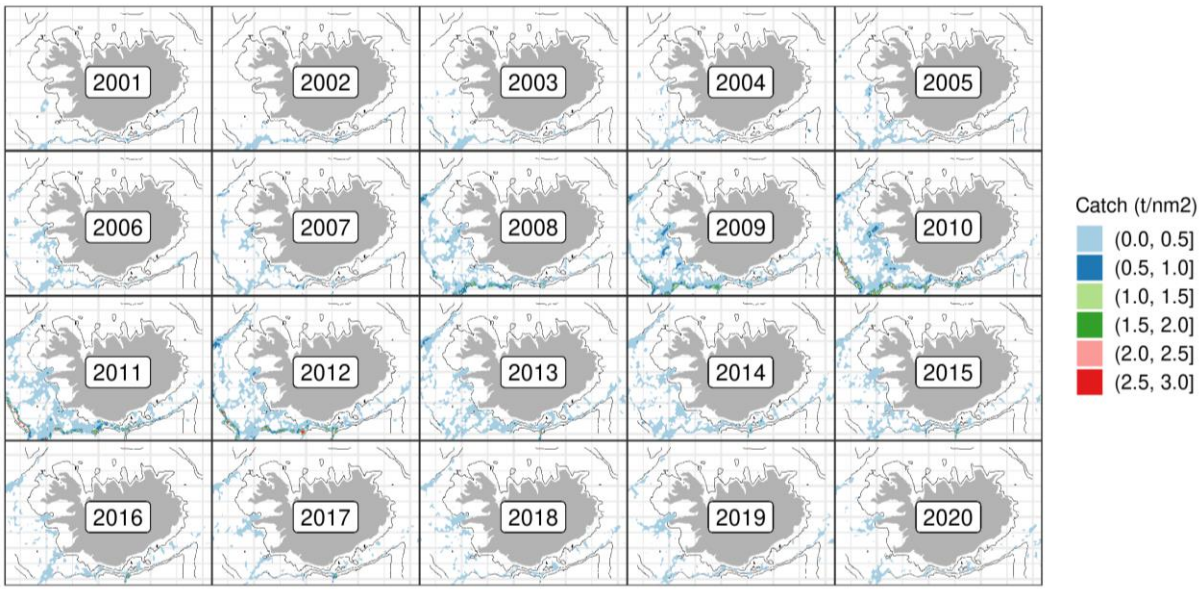

Figure 1. Blue ling. Geographic distribution of the Icelandic fishery since 2001 as reported in logbooks.

Before 2008, the majority of blue ling catches were by trawlers, as bycatch in fisheries targeting Greenland halibut, redfish, cod and other demersal species (Table 1). Most of the catches by trawlers are taken in waters shallower than 700 m and by longliners until 2008 mostly at depths shallower than 600 m.

After 2007 there was a substantial change in the fishery for blue ling (Table 1 and Figure 4). The proportion of catches taken by longliners increased from 7–20% in 2001–2007 to around 70% in 2011 as longliners started targeting blue ling. The trend has reversed and in 2015–2019 the proportion of longline catches decreased to 20–30%. At the same time longliners started fishing in deeper waters than before 2008 and until 2013 the bulk of the longline catches were taken at depths greater than 500 m. In recent years, the depth distribution resembles the distribution observed before 2008, or at depths less than 400 m (Figure 3).

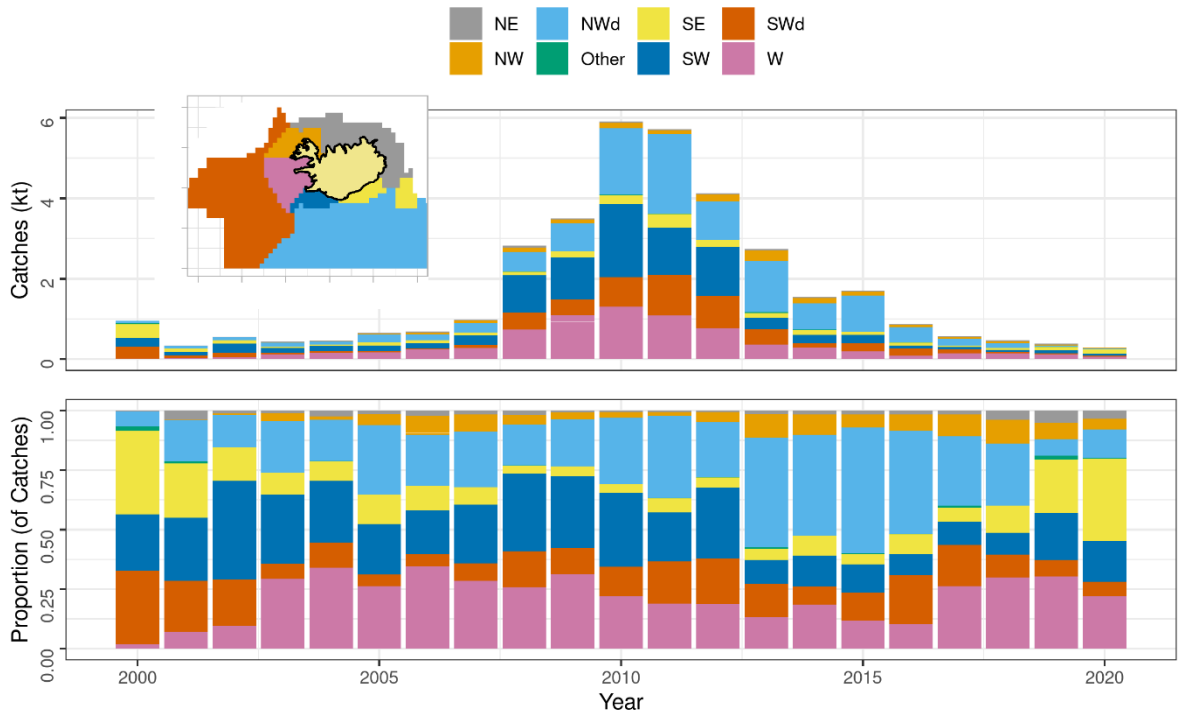

Figure 2. Blue ling. Spatial distribution of reported catches in tonnes (upper) and as annual proportions (lower). The inserted map shows the area division.

The preliminary total landings in 2020 were 349 t of which the Icelandic fleet caught 343 t (Table 4). Catches of blue ling increased by more than 370% between 2006 and 2010, the main part of this increases can be attributed to increased targeting of blue ling by the longline fleet. Since then, catches decreased compared to 2010 or by around 5900 tonnes (Table 1).

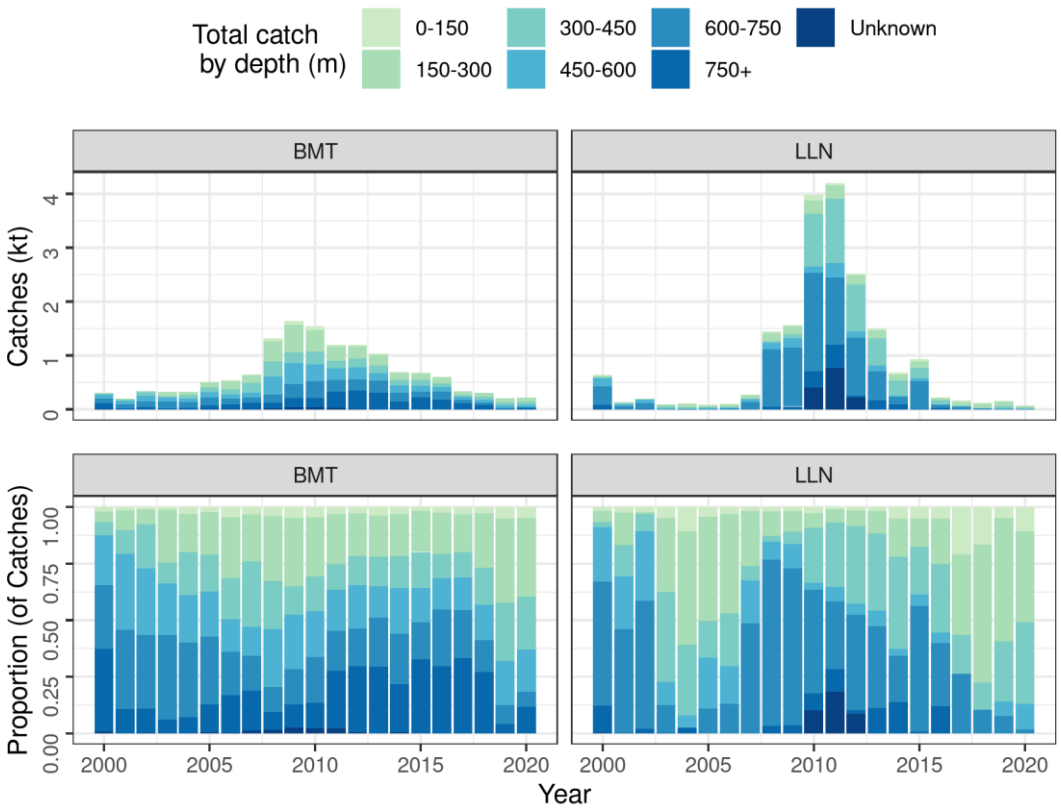

Figure 3. Blue ling. Depth distribution and proportion of longlines (LLN) and trawls (BMT) catches according to logbook entries.

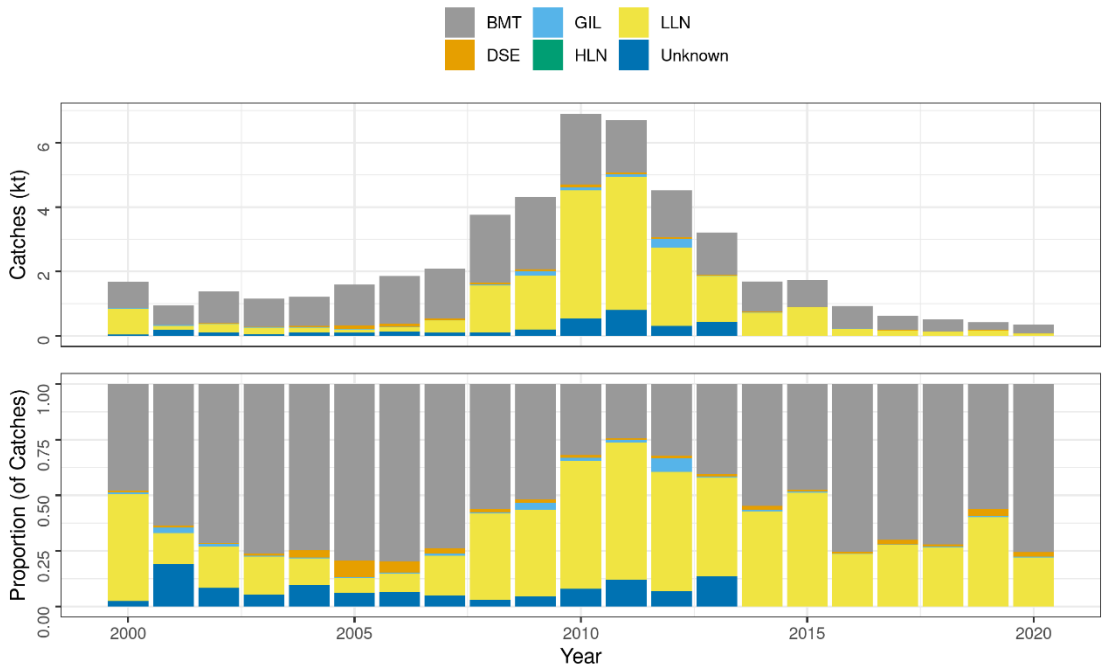

Figure 4. Blue ling. Total catch (landings) and proportion by fishing gear since 2000, according to statistics from the Directorate of Fisheries.

Table 1. Blue ling. Catches by gear type, number of boats participating in the blue ling fishery (with catch over 1000 kg).

YEAR	LONGLINE	TRAWL	OTHER GEAR	TOTAL LANDINGS	LONGLINERS	TRAWLERS
	(tonnes)	(tonnes)	(tonnes)	(tonnes)	NO BOATS	NO BOATS
2000	804	797	25	1626	14	**11**
2001	129	576	51	756	10	**7**
2002	255	980	22	1257	7	**9**
2003	197	879	22	1098	5	**10**
2004	145	891	44	1080	6	**11**
2005	102	1260	143	1505	6	**20**
2006	151	1461	121	1733	10	**17**
2007	373	1537	81	1991	9	**23**
2008	1453	2111	88	3652	14	**29**
2009	1678	2245	208	4131	19	**29**
2010	3977	2184	213	6374	26	**29**
2011	4138	1618	144	5900	21	**23**
2012	2425	1306	476	4207	21	**20**
2013	1421	1293	53	2767	16	**22**
2014	622	911	54	1588	14	**14**
2015	868	841	25	1734	18	**13**
2016	213	681	30	925	11	**9**
2017	169	436	14	619	12	**5**
2018	134	372	7	513	9	**7**
2019	160	238	16	425	13	**4**
2020	70	264	9	343	6	**6**

CATCH, EFFORT AND SURVEY DATA

Effort and nominal CPUE data from the Icelandic trawl and longline fleet are given in Figure 5. Due to changes in the fishery (expansion into new areas, fleet behaviour, etc.) and technical innovations CPUE is not considered a reliable index of biomass abundance of blue ling and therefore no attempt has been made to standardize the series. However, looking at fluctuations in CPUE and effort may be informative regarding the development of the fishery. CPUE from longlines was high from 2008 to 2013 but has decreased markedly since. CPUE from trawls has been gradually decreasing in the period. Effort from longlines peaked in 2009 but has since then decreased sharply. Effort from trawls peaked in 2011 but has remained relatively stable since.

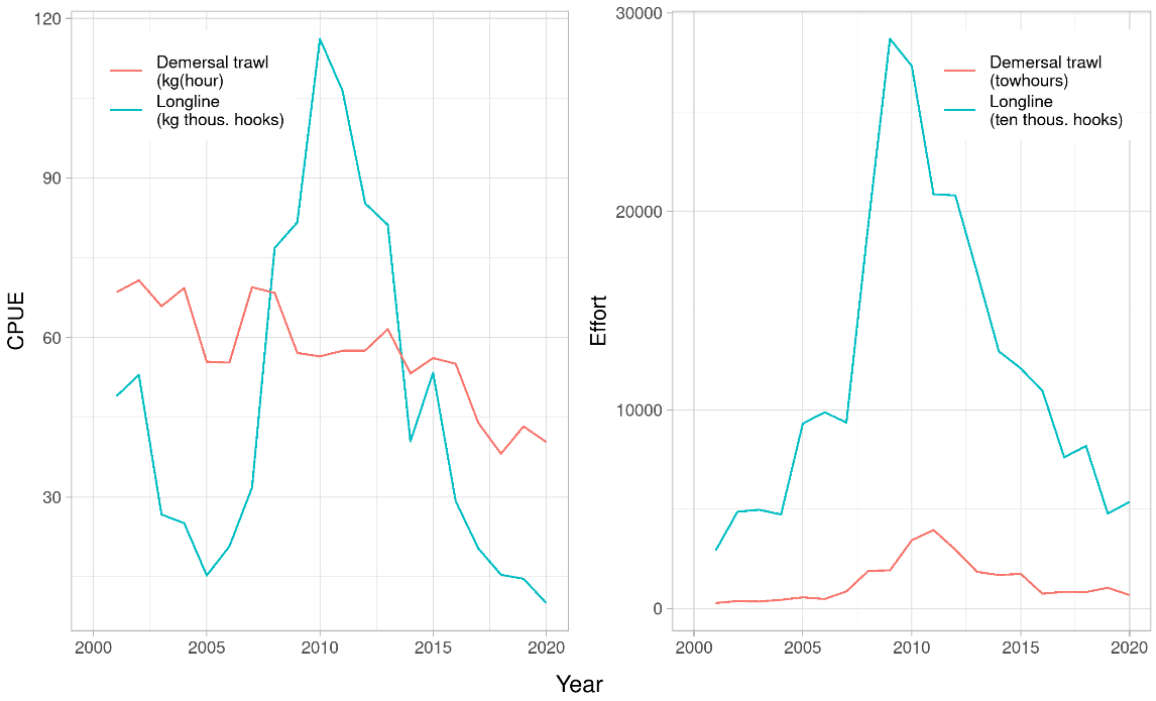

Figure 5. Blue ling. Non-standardised estimates of CPUE (left) and fishing effort (right) from longlines and trawls based on logbook data where blue ling was recorded in catches.

LANDINGS AND DISCARDS

Landing data are given in Tables 1 and 3. Discarding is banned in the Icelandic fishery. There is no available information on discarding of blue ling. Being a relatively valuable species and not being subjected to TAC constraints before 2013/2014 fishing year nor minimum landing size there should be little incentive to discard blue ling.

SAMPLING FROM COMMERCIAL CATCHES

In general sampling is considered adequate from commercial catches from the main gears (longlines and trawls). The sampling does seem to cover the spatial distribution of catches for longlines and trawls. Similarly, sampling does seem to follow the temporal distribution of catches (WGDEEP 2012).

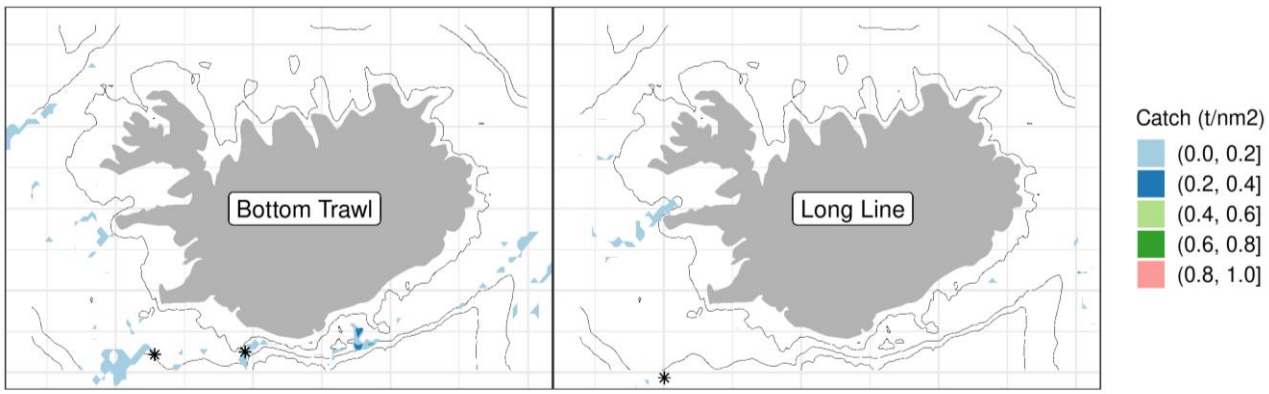

Figure 6. Blue ling. Spatial distribution of length samples (black dots) from commercial catches in Icelandic waters in 2020

Table 2. Blue ling. Number of available length measurements from Icelandic commercial catches.

YEAR	LONGLINE		TRAWLS	
	Samples	Measured	Samples	Measured
2005	1	94	12	1164
2006	0	0	9	824
2007	2	238	12	1461
2008	14	1960	13	1685
2009	15	1940	23	2894
2010	38	5191	29	3161
2011	44	6513	12	1364
2012	27	3829	11	1135
2013	15	1564	6	757
2014	11	1222	5	411
2015	0	0	4	394
2016	0	0	3	309
2017	0	0	0	0
2018	1	120	2	240
2019	**1**	**120**	**1**	114
2020	1	120	2	126

LENGTH COMPOSITIONS

Only one samples was collected from longline and two samples from bottom trawl in 2020 (from commercial catches) and does therefore not cover the spatial distribution of catches (Table 2, Figure 6). Length distributions from the Icelandic trawl and longline catches for the period 2005–2020 are shown in Figure 7. Due to a mistake, no length measures were called for from commercial catches in 2017. Mean length from trawls increased from 86 cm in 2012 to 91 cm in 2020. On average mean length from longlines is higher than from trawls.

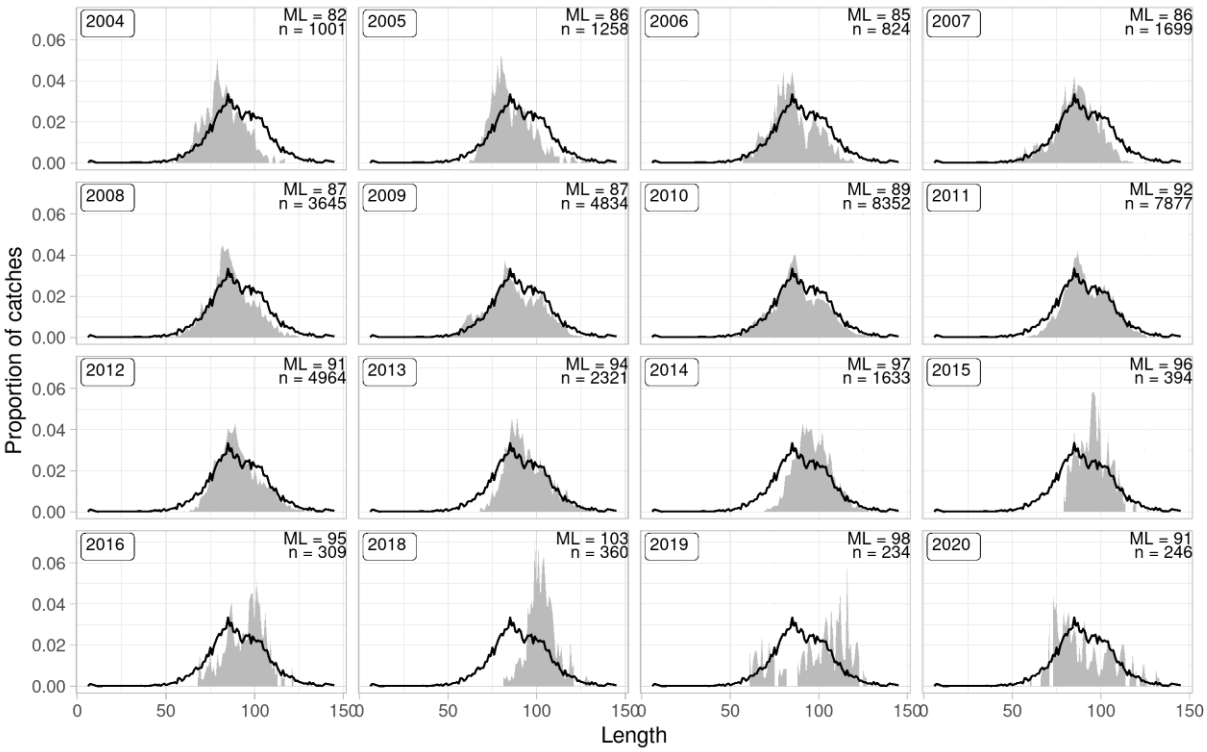

Figure 7. Blue ling. Length distribution of blue ling from trawls and longlines (grey area) of the Icelandic fleet since 2004-2020. Black line is the mean length distribution of the period. No data available in 2017.

ICELANDIC SURVEY DATA

Time-series stratified abundance and biomass indices from the spring and autumn trawl surveys are shown in Figure 8 and length distributions from the autumn survey and its spatial distribution in Figures 9 and 10. Due to industrial action in 2011 the autumn survey was cancelled after about one week of survey time. Therefore, no estimates are presented for 2011.

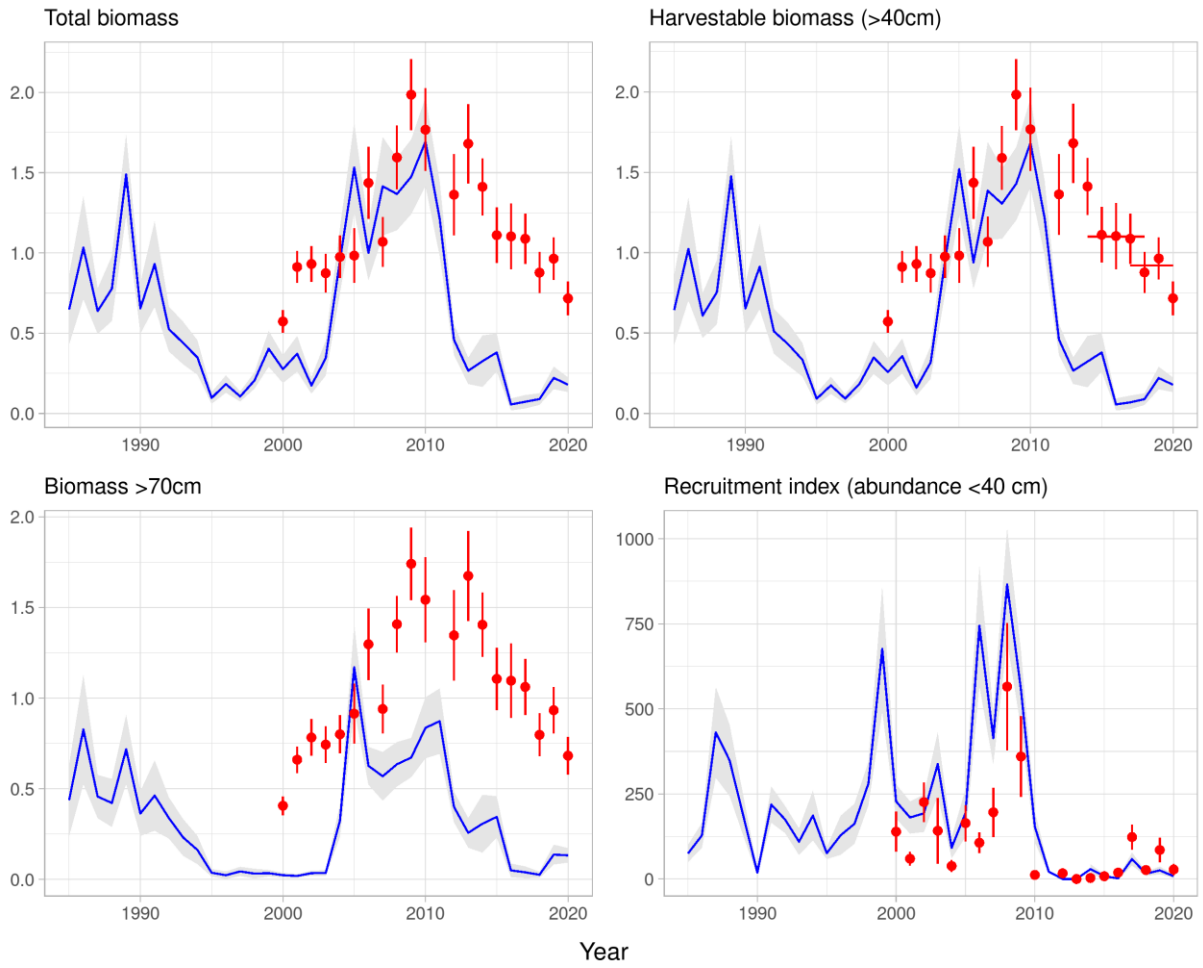

Figure 8. Blue ling. Abundance indices for blue ling in the Icelandic autumn survey since 2000 (red points and vertical lines) and the spring survey since 1985 (faded line and shaded area). Total biomass index (top-left), biomass of 40 cm and larger (top-right), biomass of 70 cm and larger (bottom-left) and abundance index of <40 cm (bottom-right). The shaded area and the vertical bar show +/- standard error of the estimate.

Figure 9. Blue ling. Abundance and location of blue ling in spring survey (SMB) in 2021 and autumn survey (SMH) in 2020.

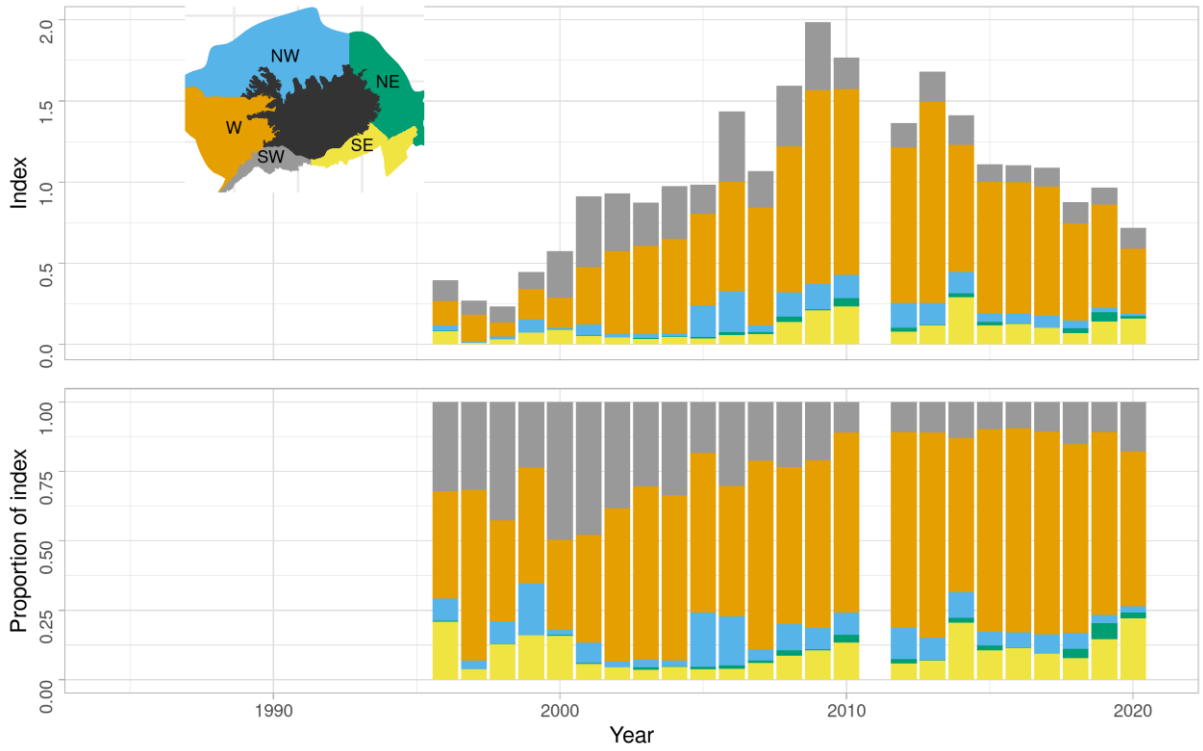

Figure 10. Blue ling. Spatial distribution of biomass index from the Icelandic autumn survey 1996-2020.

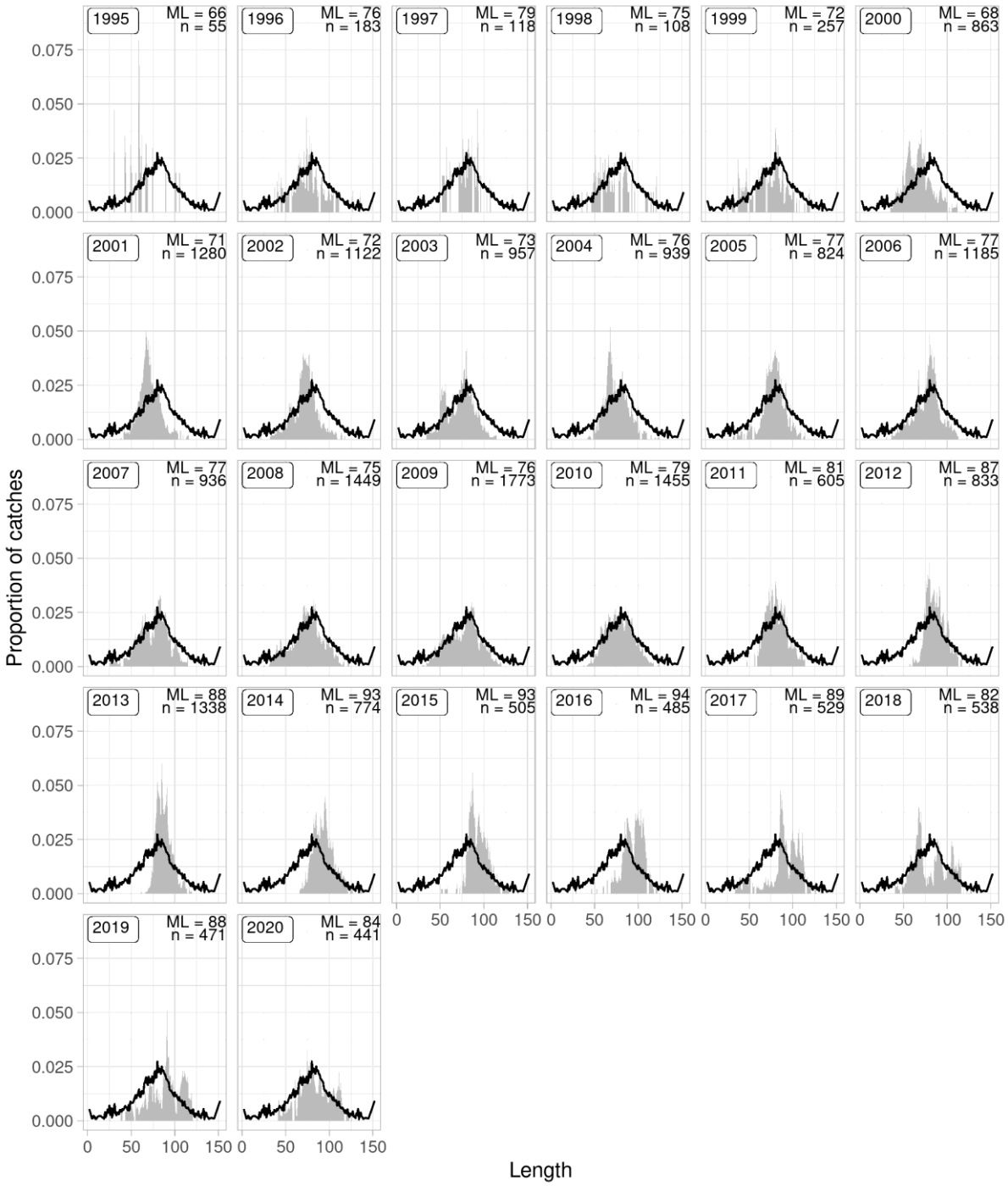

Figure 11. Blue ling. Length distributions from the Icelandic autumn survey since 1995. Black line is the average by length over the displayed period.

DATA ANALYSES

AGE COMPOSITIONS

No new data were available. Existing data are not presented due to the difficulties in the ageing of this species.

WEIGHT-AT-AGE

No new data were available. Existing data are not presented because of difficulty in ageing.

MATURITY AND NATURAL MORTALITY

Length at 50% maturity is estimated at roughly 77 cm and the range for 10–90% maturity is 65–90 cm.

No information is available on natural mortality (M).

LANDINGS AND SAMPLING

Catches from the Icelandic longline fleet increased rapidly from 2007–2010 resulting in a rapid expansion of the fishing area and change in the selectivity of the fishery although there are now strong indications since 2012 that this may have reversed (Table 1).

In 2005 longliners caught 102 tonnes of blue ling when trawlers caught 1260 tonnes or 84% of the total catches (1505 tonnes). In 2011 trawlers caught 1618 tonnes, out of 5900 tonnes or 27%, but longliners 4138 tonnes or 70%. Since then, the proportion taken by longliners has decreased and in 2020 longliners caught 20.5% of the catches, trawls 77% and other gear 2.5%.

As longliners take on average larger blue ling this will have resulted in an overall change in the selection pattern in 2006–2015. Total catches by the Icelandic fleet decreased between 2010 and 2013 and this decrease is mainly the result of decrease in trawls in 2011 but in longlines in 2012 and 2013. The expansion of the longline fleet to deeper waters (Figure 3) may be the result of decreased catch rates in shallower areas.

CPUE AND EFFORT

As stated above, cpue indices from commercial catches are not considered a reliable index of stock abundance. Therefore, the rapid increase in cpue from longlines should not be viewed as an increase in stock biomass but rather as the result of increased interest by the longline fleet and its expansion into deeper waters (Figure 7). In 2011 to 2012 there was a slight decrease in cpue from longline but the cpue increased again in 2013 to its highest value in the time-series. Cpue from trawling has remained at low levels while effort increased until about 2009 after which it has decreased (Figure 5).

SURVEYS

The spring survey covers only the shallower part of the depth distributional range of blue ling and shows high interannual variance (Figure 9). It is thus unknown to what extent the spring indices reflect actual changes in total blue ling biomass, given that it does not cover the depths were largest abundance of blue ling occur. It is however not driven by isolated large catches at a few survey stations.

The shorter autumn survey, which goes to greater depths and is therefore more likely to reflect the true biomass dynamics, does indicate that there was an increase in blue ling biomass 2007-2009 (Figure 8). Since 2010 the biomass index has decreased to similar levels as observed in 2002–2005. A large increase of more than 200% in the recruitment index was observed in 2008 but in the 2010 it had decreased again

to its lowest observed value and has not increased again for nine years, with the exception of 2017, when an increase was observed (Figures 9 and 10). As a result, mean length measured in the autumn survey has been higher after 2009 than it was before. Due to industrial action, only part of the autumn survey was conducted in 2011.

F_{PROXY}

Relative fishing mortality (F_{proxy} = Yield/Survey biomass index) derived from the autumn survey (+39 cm) and the combined catches from Iceland and Greenland, indicates that fishing mortality may have increased by more than 150% between 2006–2010 (Figure 12 and Table 6). Since then, there are indications that it has decreased by similar percentage between 2012 and 2014, to the same levels as observed in 2002 and 2009 but has decreased even further in 2015-2017.

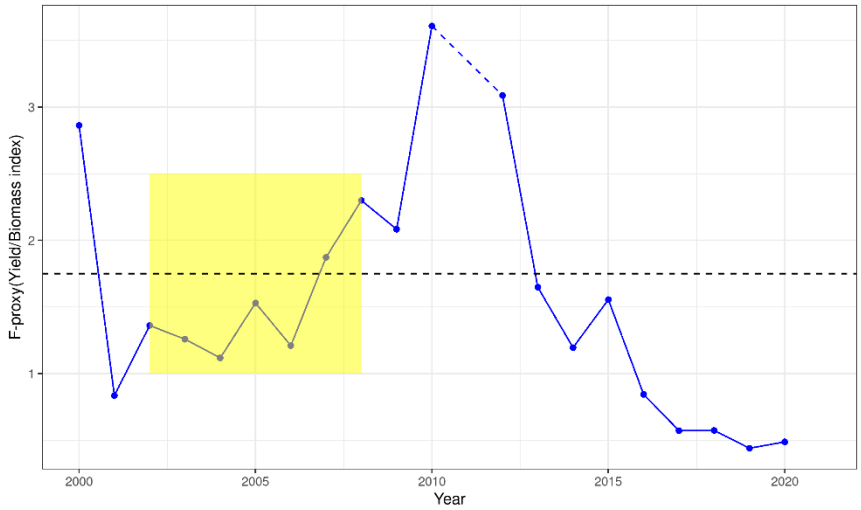

Figure 12. Blue ling. Changes in relative fishing mortality (Yield/Survey biomass >39 cm).

ANALYTICAL ASSESSMENT

EXPLORATORY STOCK ASSESSMENT ON BLUE LING USING GADGET

An exploratory stock assessment of blue ling using the Gadget model was presented at WGDEEP 2012. Updated results of the model were presented at WGDEEP 2021.

COMMENTS ON THE ASSESSMENT AND ADVICE

The assessment presented above is based on the ICES DLS approach for category 3 stocks. The Icelandic autumn trawl survey (IS-SMH) was used as the index for the stock development. The advice is based on the ratio of the mean of the last two index values (index A) and the mean of the three preceding values (index B) multiplied by the last years advice. The index/ratio is estimated to have decreased by less than 20% and thus the uncertainty cap was not applied. The stock status relative to candidate reference points is unknown and the precautionary buffer was applied. The result is advice for 2021/2022 set at 334 t ((9840.6/1022.9)*406), which is a 8% decrease from last year's advice.

The basis for the advice 2012-2019 was the following: The ICES framework for category 3.3 stocks was applied (ICES, 2012). The Icelandic autumn trawl survey was used together with the catch to calculate a harvest rate index. Based on this an F_{proxy} has been chosen from a reference period, 2002–2009, when the fishing pressure was relatively constant and the SSB increased steadily, which implies that the harvest was considered sustainable.

The advice was based first on a comparison of the latest index value (index A) with the preceding value (index B), combined with the F_{proxy} target (catch/survey biomass). When the index was estimated to have changed by more than 20% the uncertainty cap was applied.

However, following the close of the WGDEEP working group meeting in 2019 and during the preparation of the draft advice for 2020, there were discussions about the appropriateness of using the F_{proxy} in deriving the advice. It was concluded that the recruitment estimates of recent years were much lower than those observed during the period used for the calculation of the F_{proxy} and that the F_{proxy} is likely no longer appropriate. Consequently, the ICES framework for category 3 stocks using survey trends was applied instead.

MANAGEMENT

Before the 2013/2014 fishing year the Icelandic fishery was not regulated by a national TAC or ITQs. The only restrictions on the Icelandic fleet regarding the blue ling fishery were the introduction of closed areas in 2003 to protect known spawning locations of blue ling, which are in effect. As of the 2013/2014 fishing year, blue ling is regulated by the ITQ system (regulation 662/2013) used for many other Icelandic stocks such as cod, haddock, tusk and ling. The TAC for the 2018/2019 fishing year was set at 1520 based on the recommendations of MFRI using the same advisory procedure as for ICES category 3 stocks.

The difference between national TAC and landed catch in Icelandic waters can be attributed to species transformation which for blue ling is only from blue ling to other species and not *vice versa* as for other species in the ITQ system (Figure 13).

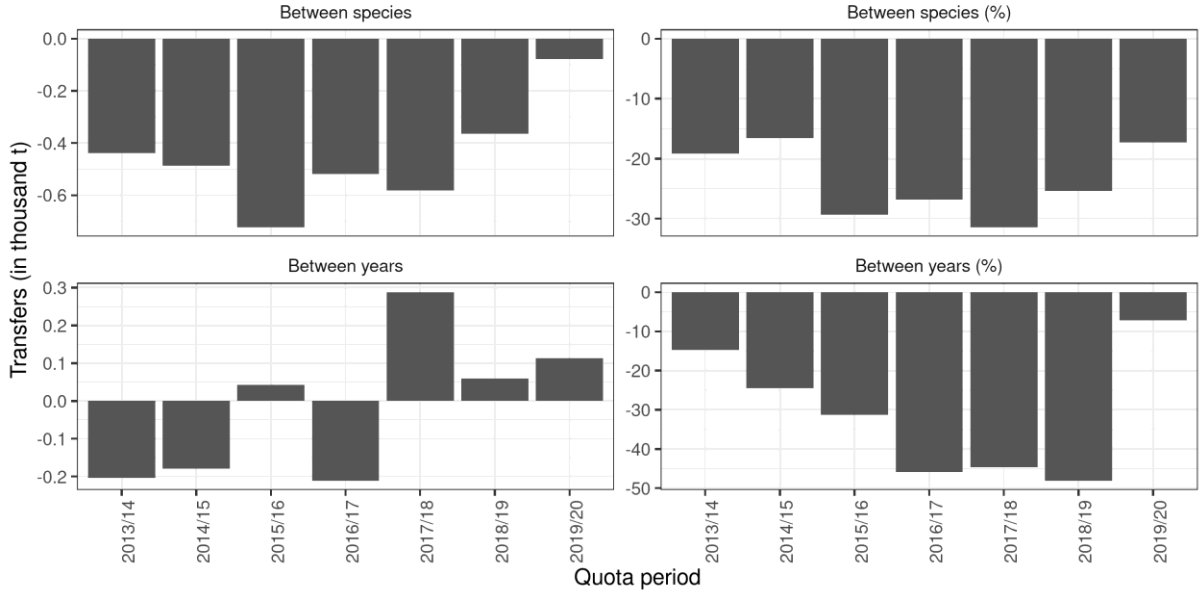

Figure 13. Blue ling. Net transfer of quota, from blue ling to other species, in the Icelandic ITQ system by fishing year.

Table 3. Blue ling. Advised TAC, national TAC and total landings since the quota year 2013/2014.

FISHING YEAR	ADVICE	NATIONAL TAC	ICELAND	OTHERS	LANDINGS
2013/2014	2400	2400	1655	6	1661
2014/2015	3100	3100	1900	105	2005
2015/2016	2550	2550	1097	10	1007
2016/2017	2032	2032	636	3	639
2017/2018	1956	1956	549	4	**553**
2018/2019	1520	1520	464	7	**471**
2019/2020	483	**483**	371	5	**376**
2020/2021	406	406			

MANAGEMENT CONSIDERATIONS

Landings have decreased considerably in the last year and as blue ling is now part of the ITQ system such a rapid increase in landings as observed between 2006 and 2011 is unlikely. Blue ling is caught in mixed fisheries by the trawler fleet, mainly targeting redfish and Greenland halibut. After the inclusion of blue ling in the ITQ system the longliners have shifted from a directed fishery to a more mixed fishery for the species. Because of the restrictions of the TAC the implications of low blue ling TAC for the trawlers can be considerable, although the species is a low percentage in their catches.

Recruitment index from the autumn survey indicates very little recruitment to the stock since 2010, resulting in a truncated length distribution from both the survey and commercial catches.

Closure of known spawning areas should be maintained and expanded where appropriate.

CONCLUSIONS

The biomass index is approaching its lowest values and only large blue ling are being caught, which is most likely because there has been no recruitment coming into the stock for nearly a decade.

The findings presented here support the general view of WGDEEP that advice should be more precautionary for as long as there is no recruitment.

Table 4. Blue ling: Landings from Icelandic fishing grounds.

YEAR	FAROE	GERMANY	ICELAND	NORWAY	UK	TOTAL
1975	69	1418	434	366	89	**2376**
1976	29	1222	624	135	28	**2038**
1977	39	1253	700	317	0	**2309**
1978	38	0	1237	156	0	**1431**
1979	85	0	2019	98	0	**2202**
1980	183	0	8133	83	0	**8399**
1981	220	0	7952	229	0	**8401**
1982	224	0	5945	64	0	**6233**
1983	1195	0	5117	402	0	**6714**
1984	353	0	3122	31	0	**3506**
1985	59	0	1407	7	0	**1473**
1986	69	0	1774	8	0	**1851**
1987	75	0	1693	8	0	**1776**
1988	271	0	1093	7	0	**1371**
1989	403	0	2124	5	0	**2532**
1990	1029	0	1992	0	0	**3021**
1991	241	0	1582	0	0	**1823**
1992	321	0	2584	0	0	**2905**
1993	40	0	2193	0	0	**2233**
1994	89	1	1542	0	0	**1632**
1995	113	3	1519	0	0	**1635**
1996	36	3	1284	0	0	**1323**
1997	25	0	1319	0	0	**1344**
1998	59	9	1086	0	0	**1154**
1999	31	8	1525	8	11	**1583**
2000	0	7	1605	25	8	**1645**
2001	95	12	752	49	23	**931**
2002	28	4	1256	74	10	**1372**
2003	16	16	1098	6	24	**1160**
2004	38	9	1083	49	20	**1199**
2005	24	25	1497	20	26	**1592**
2006	63	22	1734	27	9	**1855**
2007	78	0	1999	4	10	**2091**
2008	88	0	3653	21	0	**3763**
2009	178	0	4132	5	0	**4315**
2010	515	0	6377	13	0	**6905**
2011	797	0	5903	2	0	**6702**
2012	312	0	4207	2	0	**4521**
2013	435	0	2769	2	0	**3204**
2014	71	0	1588	30	0	**1689**
2015	10	0	1734	4	0	**1748**
2016	6	0	925	0	0	**931**
2017	4	0	619	0	0	**623**
2018	28	0	513	0	0	**541**
2019	28	0	415	4	0	**447**
2020[1)]	**6**	**0**	**343**	**0.1**	**0**	**349**

[1)] **Provisional figures.**

Table 5. Blue ling. Landing in Greenlandic fishing grounds. Source: STATLANT database.

YEAR	FAROE	GERMANY	GREENLAND	ICELAND	NORWAY	RUSSIA	SPAIN	UK	DENMARK	TOTAL
1983	0	621	0	0	0	0	0	0	0	**621**
1984	0	537	0	0	0	0	0	0	0	**537**
1985	0	315	0	0	0	0	0	0	0	**315**
1986	214	149	0	0	0	0	0	0	0	**363**
1987	0	199	0	0	0	0	0	0	0	**199**
1988	21	218	3	0	0	0	0	0	0	**242**
1989	13	58	0	0	0	0	0	0	0	**71**
1990	0	64	5	0	0	0	0	10	0	**79**
1991	0	105	5	0	0	0	0	45	0	**155**
1992	0	27	2	0	50	0	0	32	0	**111**
1993	0	16	0	3124	103	0	0	22	0	**3265**
1994	1	15	0	300	11	0	0	57	0	**384**
1995	0	5	0	117	0	0	0	19	0	**141**
1996	0	12	0	0	0	0	0	2	0	**14**
1997	1	1	0	0	0	0	0	2	0	**4**
1998	48	1	0	0	1	0	0	6	0	**56**
1999	0	0	0	0	1	0	66	7	0	**74**
2000	0	1	2	4	0	0	889	2	0	**898**
2001	1	0	1	11	61	0	1631	6	0	**1711**
2002	0	0	0	11	1	0	0	0	0	**12**
2003	0	0	3	0	36	0	670	5	0	**714**
2004	0	0	7	0	1	0	0	7	0	**15**
2005	2	0	6	0	1	0	176	8	0	**193**
2006	0	0	6	0	3	1	0	0	0	**10**
2007	19	0	1	0	1	0	0	0	0	**21**
2008	1	0	5	0	2	0	381	0	1	**390**
2009	1	0	5	0	3	0	111	4	0	**124**
2010	1	0	8	0	9	0	34	0	3	**55**
2011	0	0	8	0	2	0	0	1	6	**17**
2012	0	0	13	367	9	0	0	0	3	**392**
2013	0	0	16	0	0	0	0	3	9	**28**
2014	0	0	14	0	3	0	0	0	0	**17**
2015	0	0	66	0	1	0	0	0	5	**72**
2016	0	0	9	0	0	0	0	0	7	**16**
2017	0	0	3,7	0	4	0	0	0	3	**19**
2018	0	0	34	0	12	0	0	0	5	**51**
2019	0	7	20	0	36	0	0	0	0	**62**
2020[1)]	**0**	**7**	**18**	**0**	**2**	**0**	**0**	**0**	**0**	**27**

[1)] Provisional figures.

Table 6. Blue ling. Catches along with survey biomass index (larger than 40 cm) from the Icelandic Autumn survey and the calculated F_{proxy} ((Catches in Iceland and Greenland)/Index).

YEAR	ICELAND	GREENLAND	INDEX	F_{PROXY}
2000	1645	898	574.5	4.43
2001	931	1711	950.2	2.78
2002	1372	12	988.3	1.40
2003	1160	714	930.1	2.01
2004	1199	15	1039.7	1.17
2005	1592	193	1051.4	1.70
2006	1855	10	1492.9	1.25
2007	2091	21	1128.1	1.87
2008	3758	390	1645.2	2.52
2009	4233	124	2073.8	2.10
2010	6905	55	1836.8	3.79
2011	6702	17	*No survey*	
2012	4521	392	1411.5	3.48
2013	3082	28	1762.3	1.76
2014	1588	17	1455.8	1.10
2015	1734	72	1161.1	1.56
2016	925	16	1118.0	0.84
2017	623	19	1086.0	0.59
2018	541	51	884.0	0.67
2019	424	62	964	0.50
2020	349	27	716	0.52

EXPLORATORY ASSESSMENT MODEL USING GADGET

An exploratory Gadget model (**G**lobally applicable **A**rea **D**isaggregated **G**eneral **E**cosystem **T**oolbox, see www.hafro.is/gadget) was developed for blue ling in Icelandic waters.

DATA USED AND MODEL SETTINGS

The size-structured model contains two stock components: a mature and an immature stock. On an annual basis, recruits enter the immature component, and a fraction of the immature component moves to the mature component. Growth is modelled using a von Bertalanffy function. Fishing mortality results from multiple fleets, each of which has a unique selection pattern. As there is no information regarding natural mortality, values of 0.15 are applied to both components across length intervals.

The following data is used in the model:

- Length distributions from the autumn survey (2000 onwards) and commercial catches.
- Length-disaggregated abundance indices from the autumn survey. The following length groups were defined: 20-52 cm, 52-60 cm, 60-72 cm, 72-80 cm, 80-92 cm, 92-100 cm, 100-140 cm.
- Maturation data (ratio of mature to immature per length interval) from the autumn survey.

Existing age data was not included in the model due to the difficulties in the ageing of this species.

The parameters estimated in the model include:

- Initial numbers at age.
- Recruitment at age 3 each year.
- Size of recruits.
- Selection pattern of the commercial fleet and survey.
- Growth parameters.

MODEL DIAGNOSTICS

Overall fit to the predicted proportional length distributions is close to the observed distributions (Figures 14-16). The model captures the age truncation seen in the observed survey data with the median length increasing from 2010 to 2016 due to poor recruitment. A recruitment spike in 2017 led to a bimodal length distribution from 2017 to 2020. The bimodal distribution is visible in the observed survey data, though not as well defined as in the model.

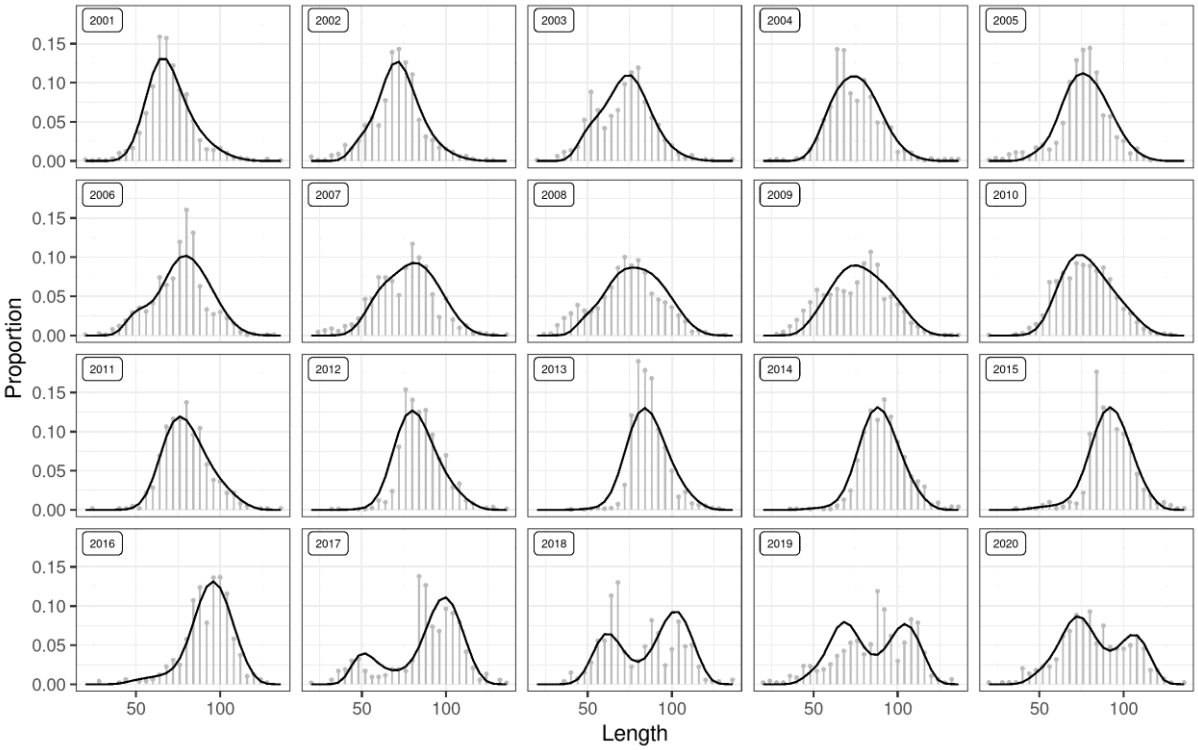

Figure 14: Blue ling. Fitted proportions-at-length from the Gadget model (black lines) compared to observed proportions in the autumn survey (vertical lines and points).

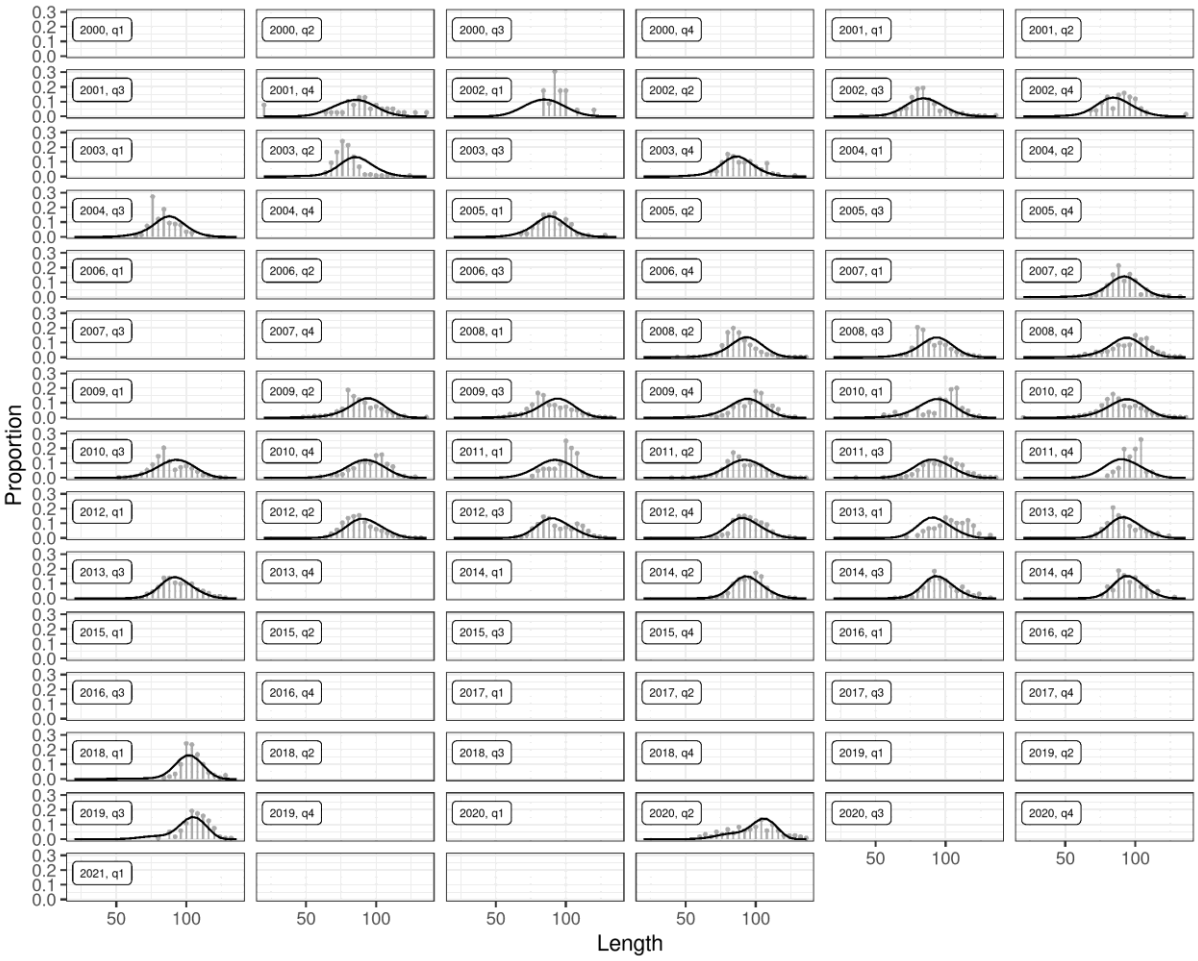

Figure 15: Blue ling. Fitted proportions-at-length from the Gadget model (black lines) compared to observed proportions from commercial catches (longline fleet).

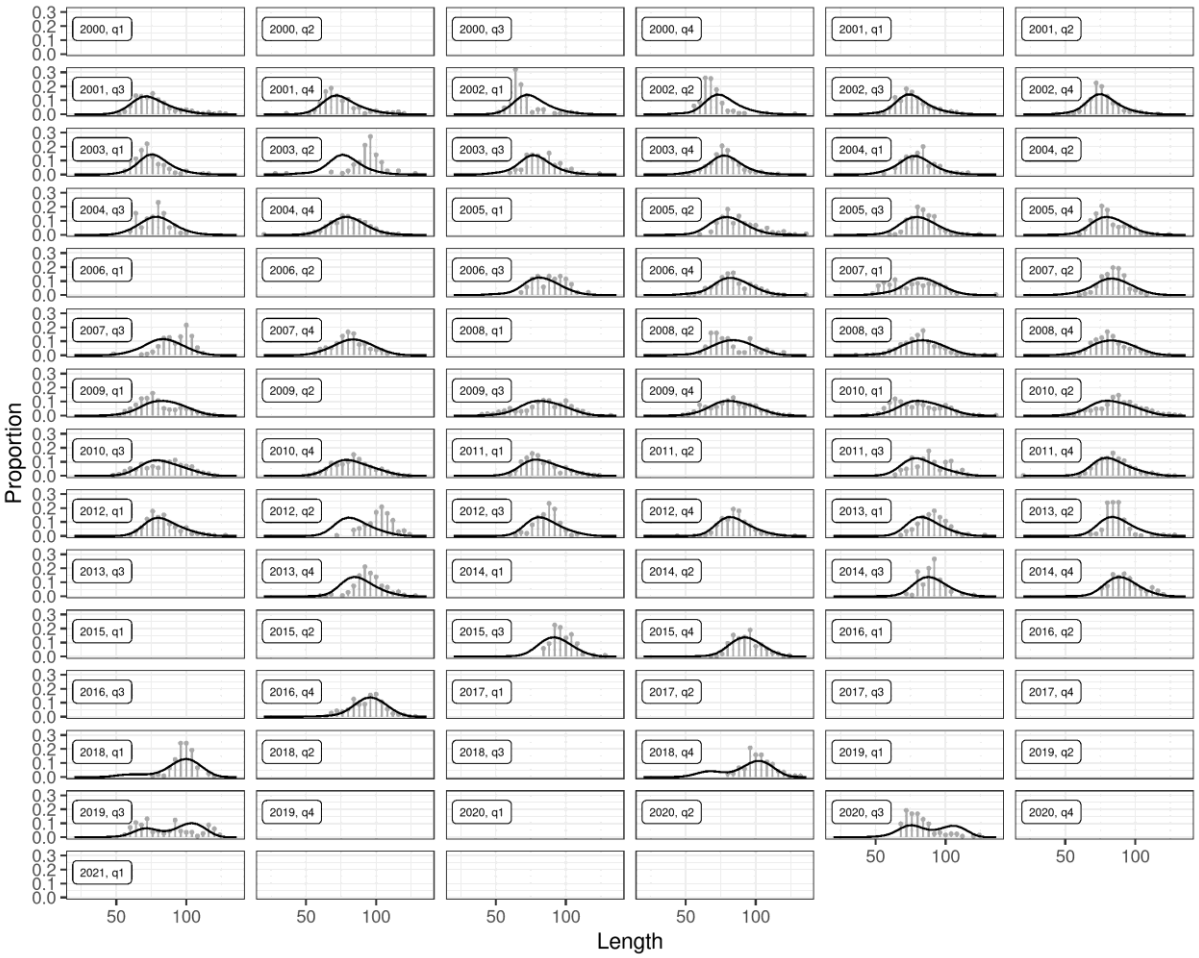

Figure 16: Blue ling. Fitted proportions-at-length from the Gadget model (black lines) compared to observed proportions from commercial catches (trawl fleet).

MODEL FIT

Figure 17 shows the overall fit to the length-disaggregated autumn survey indices. In general, the model captures the observed trends over time. The deviation between the terminal estimates and the observed values are minimal for all length groups, although slight overestimations in the 80-90 cm and 100-140 cm length groups leads to a summed prediction that is approximately 10% over the observed summed value.

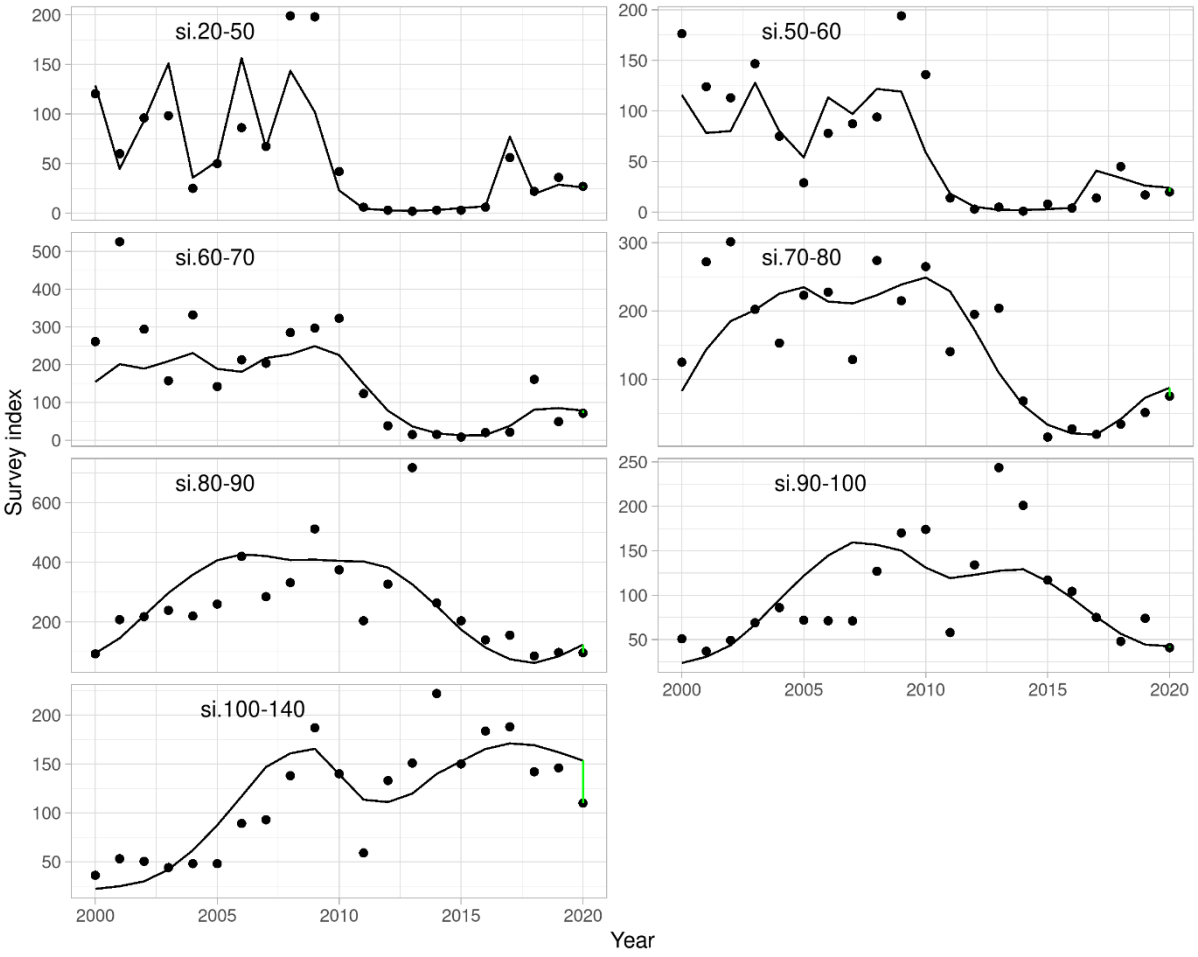

Figure 17. Blue ling. Fitted autumn survey index by length group from the Gadget model (black line) and the observed number of blue ling caught in the survey (points). The green line indicates the difference between the terminal fit and the observations.

RESULTS

The model results are presented in Figure 18. Total biomass and spawning stock biomass both peaked in 2010 and subsequently declined until 2017 and 2019 respectively. Slight increases in total biomass and spawning stock biomass are thereafter seen until 2020. These small increases were not seen in the abundance indices (Figure 8) and are a result of the spike in recruitment (age 3) in 2017 when the number of smaller individuals was overestimated (Figure 17). From 2000 to 2010, recruitment varies substantially between years. From 2010 to 2017, recruitment is minimal which is also seen in the recruitment index (Figure 8). The model captures the overall trend of the F-proxy (Figure 12). Fishing mortality peaked in 2011 at approximately 0.5 and has decreased to less than 0.05 in 2020, the lowest value since 2000.

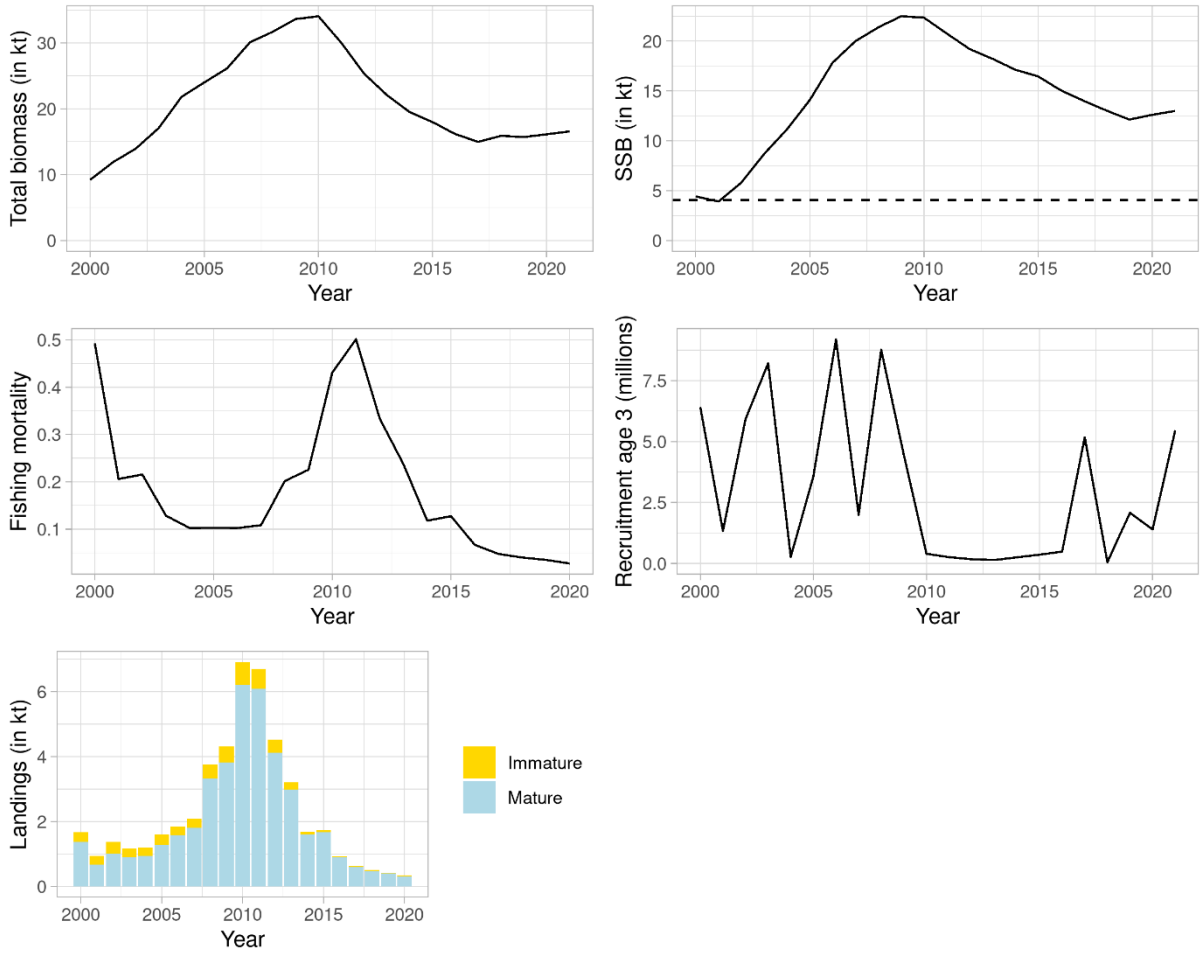

Figure 18: Blue ling. Estimated biomass, spawning stock biomass (SSB), fishing mortality, recruitment, and total catches. The dashed line in the SSB plot represents B_{pa}.

Results of the retrospective analysis are seen in Figure 19. There is an upward revision of spawning stock biomass from the 5-year peel to the 3- and 4-year peels. This is followed by a large downward revision in spawning stock biomass in subsequent years. These revisions are accompanied by downward revisions of F in the 3- and 4-year peels and upward revisions in subsequent years. Differences between the full model and the 1-year peel are negligible for spawning stock biomass, fishing mortality and recruitment. These patterns are driven by variation in the initial abundances with the 3- and 4-year peels initialising in greater numbers. Furthermore, the 3- and 4-year peels produced a retrospective pattern in recruitment that contributed to the revisions, most noticeably the substantial upward revisions of recruitment in 2007 and 2008, when the 3- and 4-year peeled models captured the 20-50 cm survey index peaks better than the full model. Further work is required to achieve greater stability in the retrospective analysis.

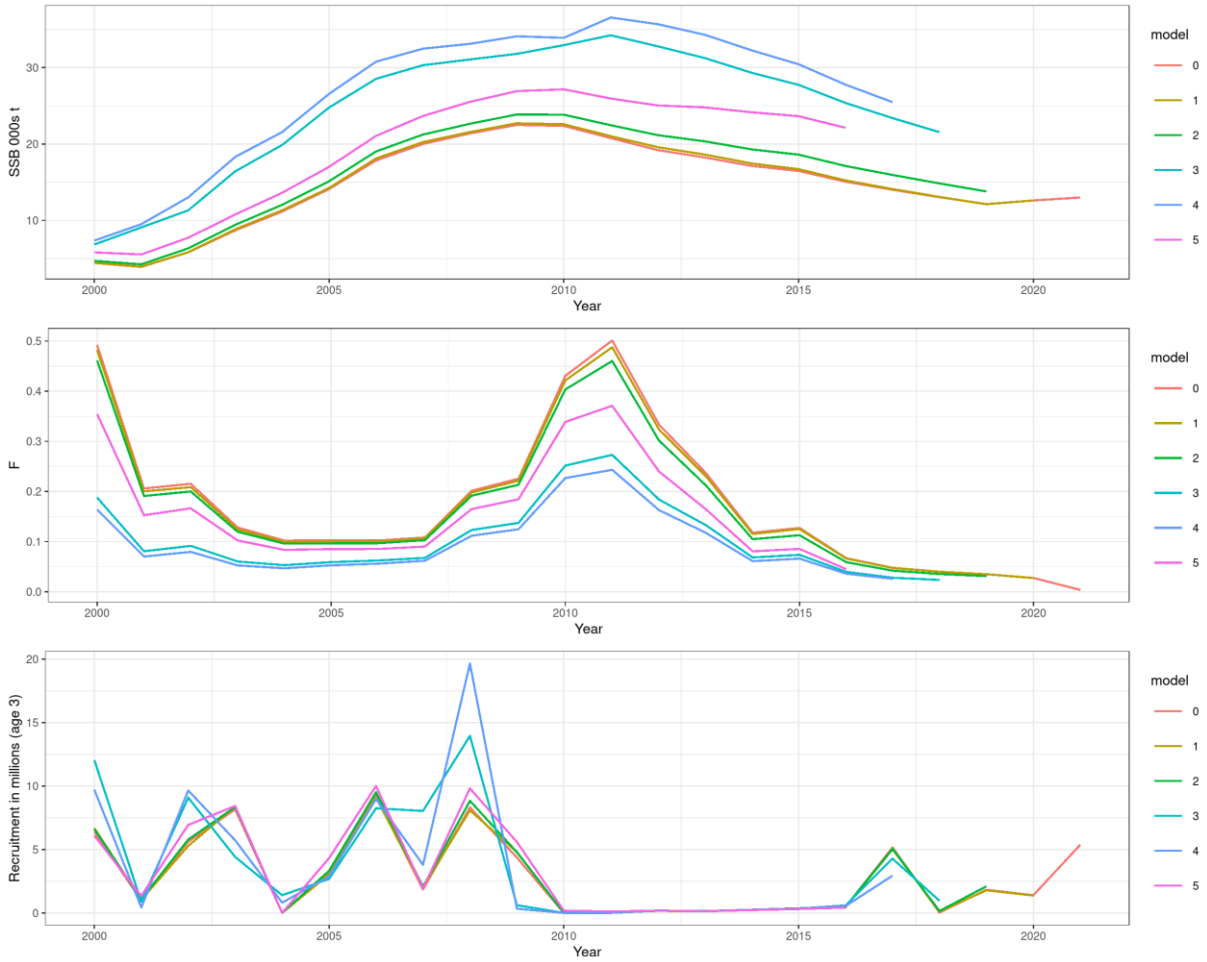

Figure 19: Blue ling. Retrospective plots illustrating stability in model estimates over a 5-year 'peel' in data. Results of spawning stock biomass, fishing mortality F, and recruitment (age 3) are shown.