ICELANDIC SLOPE BEAKED REDFISH *Sebastes mentella*

GENERAL INFORMATION

Icelandic slope beaked redfish (*Sebastes mentella*) is a redfish species which is similar in appearance to golden redfish (*Sebastes norvegicus*). There are some characteristic features that distinguish those two species apart, and the depth is one of them, with Icelandic slope beaked redfish inhabiting deeper waters (>400 m). Around Iceland the species is mainly found in the warmer waters in the western, southern, and south-eastern parts of continental slope. Beaked redfish is a slow growing, long-lived and late-maturing species.

Icelandic slope beaked redfish on the continental shelf and slope of Iceland (the Icelandic waters ecoregion, which is defined to be within the Icelandic 200 NM EEZ and includes ICES Division 5.a and part of ICES Subarea 14), is treated as separate biological stock and management unit. Only the fishable stock is found in Icelandic waters, that is, fish mainly larger than 30 cm. The East Greenland shelf is most likely a common nursery area for the Icelandic slope stock.

SCIENTIFIC DATA

Information on abundance and biological parameters of Icelandic slope beaked redfish is available from the Icelandic autumn survey (IS-SMH) 2000-2019. The survey was not conducted in 2011. The autumn survey covers the most important distribution area of the Icelandic slope beaked redfish fishery.

The survey biomass index has fluctuated during 2000-2019 (Table 1 and Figure 1). The index was highest in 2001 but declined with fluctuating trend to the next lowest value in the time series in 2013. The survey biomass index showed an increasing trend 2014-2018 but decreased by 30% in 2019 compared to 2018. The abundance index has on the other hand been relatively stable at low levels since 2007 (Figure 1). The biomass index of fish 45 cm and larger increased from the lowest value in 2007 to the highest one in the time series in 2017 and 2018 but decreased by 34% in 2019 (Figure 1). The abundance index of fish 30 cm and smaller (recruits) has since 2007 been at very low level (Figure 1).

Table 1. Icelandic slope beaked redfish. Total biomass index of Icelandic slope *S. mentella* in the Icelandic Autumn Groundfish survey 2000-2018. No survey was conducted in 2011.

Tafla 1. Djúpkarfi. Stofnvísitala úr stofnmælingu botnfiska að hausti frá 2000 ásamt staðalfráviki. Engin stofnmæling var árið 2011.

Year	Biomass	Upper 95th percentile	Lower 95th percentile	CV
2000	134 407	172 605	96 209	0.145
2001	161 733	219 426	104 040	0.182
2002	95 059	121 143	68 975	0.140
2003	63 188	78 917	47 459	0.127
2004	96 465	128796	64 134	0.171
2005	109 196	162 702	55 690	0.250
2006	123 059	163 097	83 021	0.166
2007	82 070	111 507	52 633	0.183
2008	80 011	102 123	57 899	0.141
2009	93 653	125 592	61 714	0.174
2010	77 852	101 351	54 353	0.154
2011				
2012	74 604	95 806	53 402	0.145
2013	70 055	91 475	48 635	0.156
2014	103 051	141 629	64 473	0.191
2015	107 423	144 059	70 787	0.174
2016	80 855	100 348	61 362	0.123
2017	125 611	167 957	83 265	0.172
2018	122 292	172 388	72 196	0.209
2019	85 157	108 858	61 456	0.142

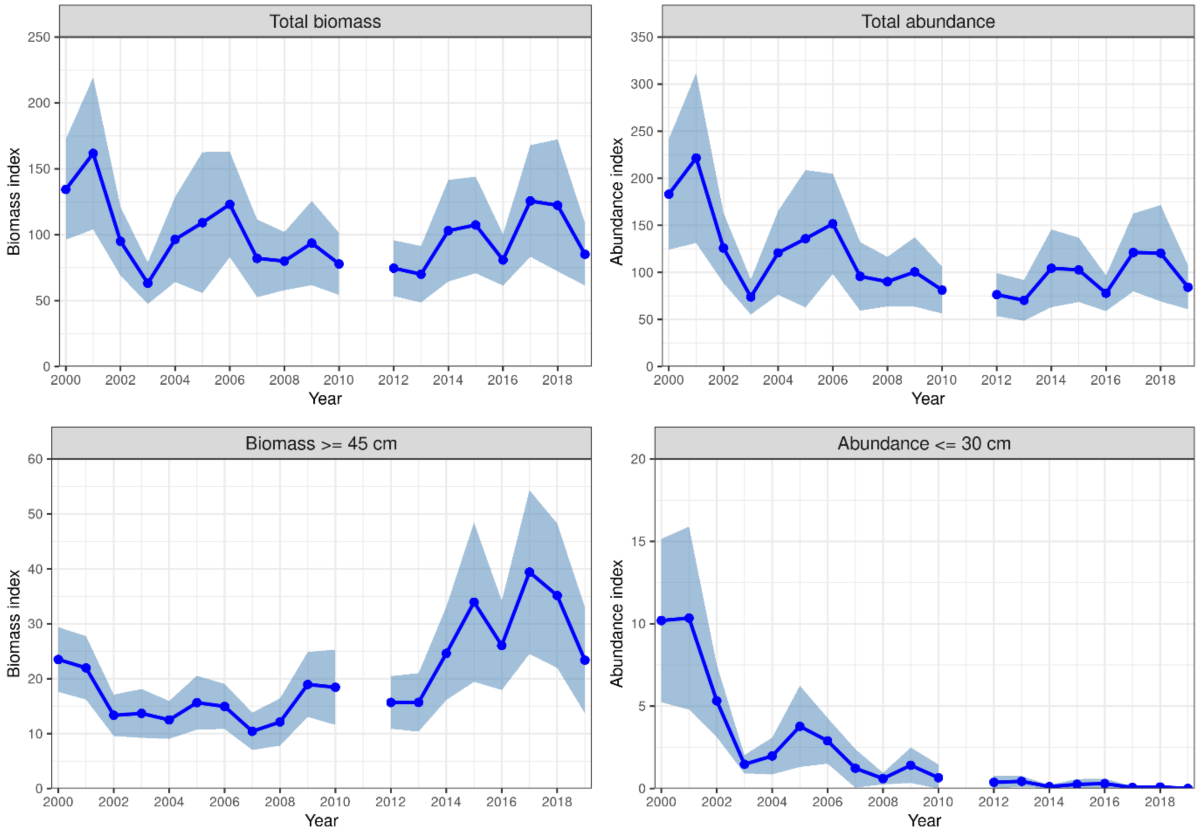

Figure 1. Icelandic slope beaked redfish. Survey indices in the autumn survey in ICES Division 5.a 2000-2019. The survey was not conducted in 2011. The figure shows the total biomass index, total abundance index, biomass index of fish 45 cm and larger and abundance index of fish 30 cm and smaller.

Mynd 1. Djúpkarfi. Heildarlífmassavísitala djúpkarfa (efri til vinstri), heildarfjöldavísitala (efri til hægri), lífmassavísitala stærri einstaklinga (>45 cm, neðri til vinstri) og nýliðunarvísitölu (<=30 cm, neðri til hægri) úr stofnmælingu botnfiska að hausti (SMH) frá 2000, ásamt staðalfráviki. Engin stofnmæling var árið 2011.

Icelandic slope beaked redfish from Icelandic autumn survey is caught along the south-east to the west slope of the Icelandic continental shelf at depths between 400-800 m (Figure 2), but is most abundant south-west along the Reykjanes ridge and west of Iceland (Figure 3).

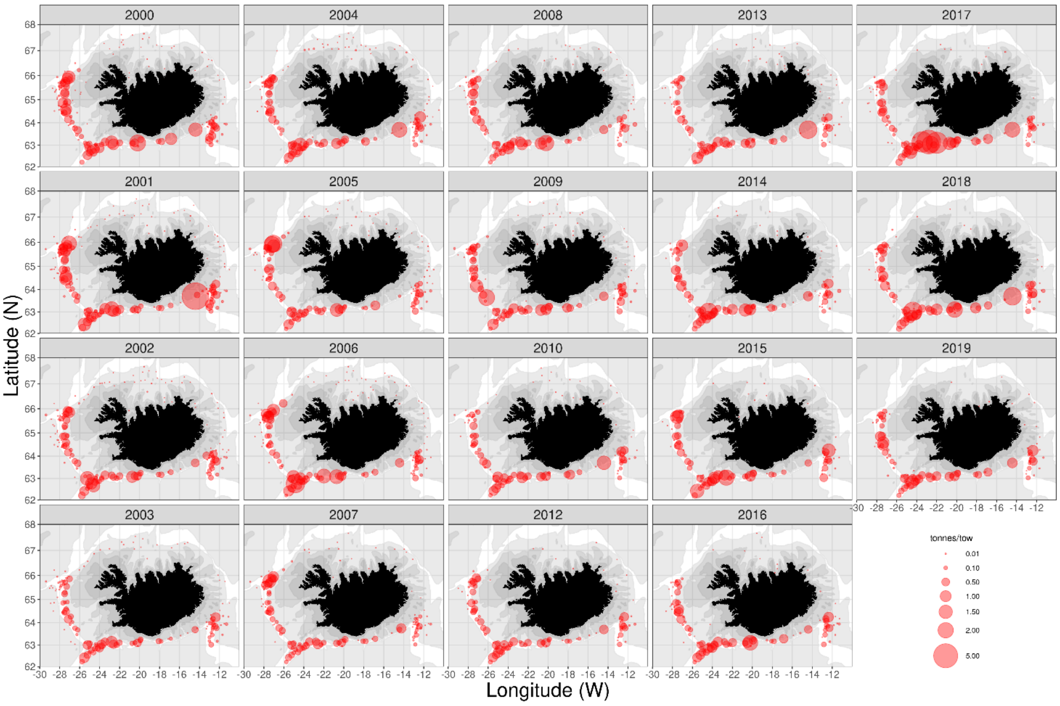

Figure 2. Icelandic slope beaked redfish. Spatial distribution of Icelandic slope *Sebastes mentella* in Icelandic autumn survey in 2000-2019. The survey was not conducted in 2011.

Mynd 2. Djúpkarfi. Útbreiðsla í stofnmælingu botnfiska að hausti árin 2000-2019. Engin stofnmæling var árið 2011.

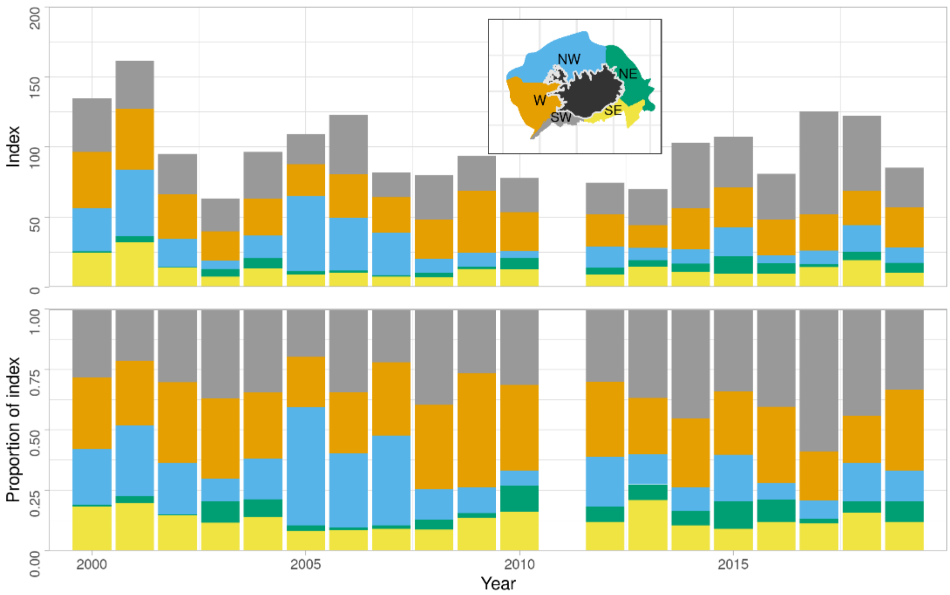

Figure 3. Icelandic slope beaked redfish. Spatial distribution of the total biomass index from the Icelandic autumn survey 2000-2019. The survey was not conducted in 2011.

Mynd 3. Djúpkarfi. Dreifing lífmassavísitölu í stofnmælingu botnfiska að hausti frá árinu 2000-2019. Engin stofnmæling var árið 2011.

The length of the Icelandic slope beaked redfish caught in the autumn survey is between 25 and 55 cm. Since 2000, the mode of the length distribution has shifted to the right, that is, from 34-38 cm in 2000 to about 42-43 cm in 2019 (Figure 4). Much less of fish smaller than 35 cm was observed in the surveys after 2010 compared to previous years.

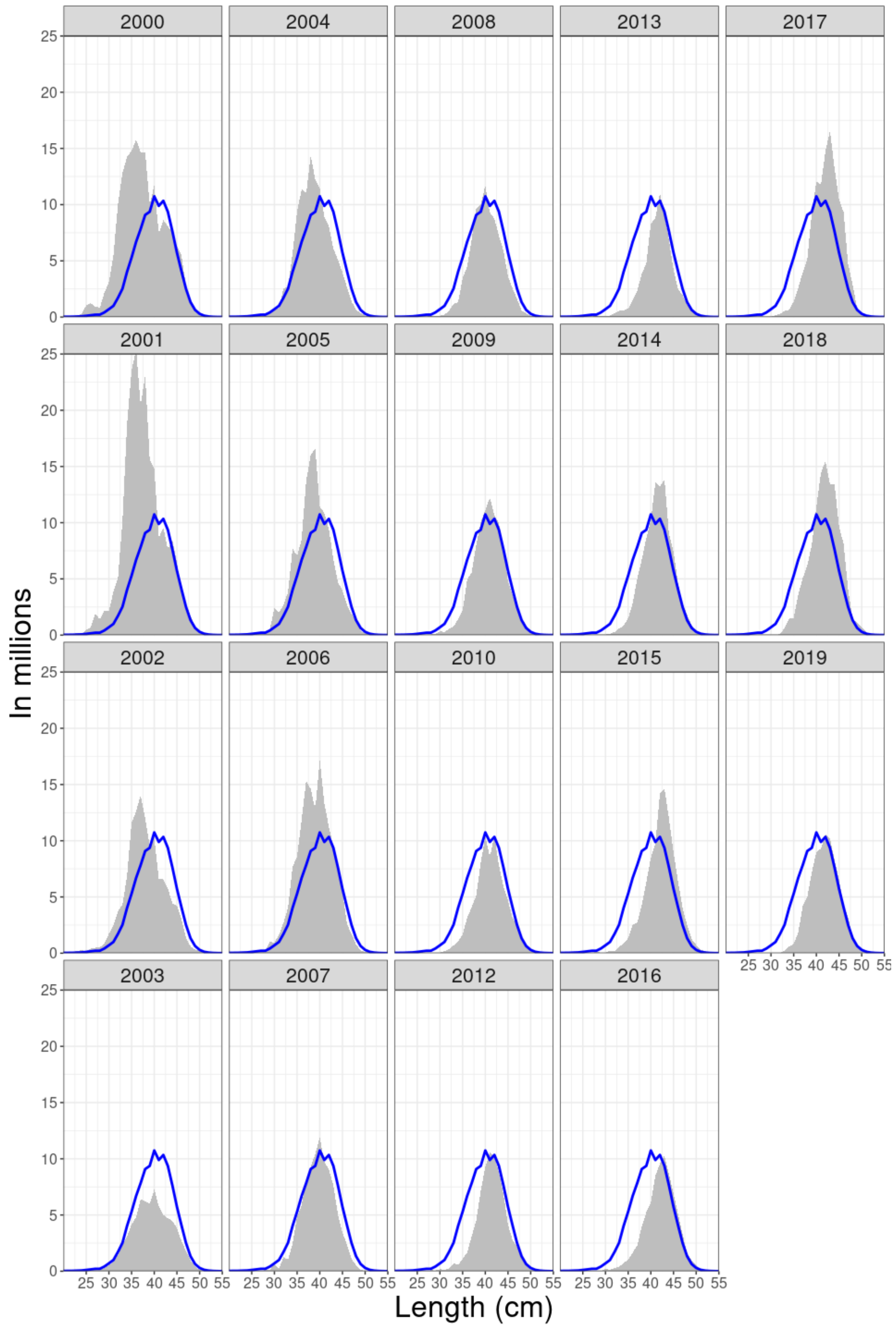

Figure 4. Icelandic slope beaked redfish. Length disaggregated abundance indices in the autumn Survey 2000-2019. No survey was conducted in 2011. The blue line is the mean of 2000-2019.

Mynd 4. Djúpkarfi. Lengdarskiptar vísitölur úr stofnmælingu botnfiska að hausti 2000-2019 ásamt meðaltali allra ára (blá lína). Engin stofnmæling var árið 2011.

Age reading from the autumn survey (2000, 2006, 2009, 2010, 2017 and 2018) shows that the stock consists of many yearclasses and the age ranges from 5 to over 50 years (Figure 5). The 1985 and 1990 yearclasses were large and were in the 2017 and 2018 surveys still relatively strong. There is an indication in the 2017 and 2018 surveys that the 2002-2005 yearclasses are relatively strong. These yearclasses can also be seen in the 2010 survey as 5-8 years old fish. Fish younger than 10 years old were not observed in otolith samples from the 2018 survey.

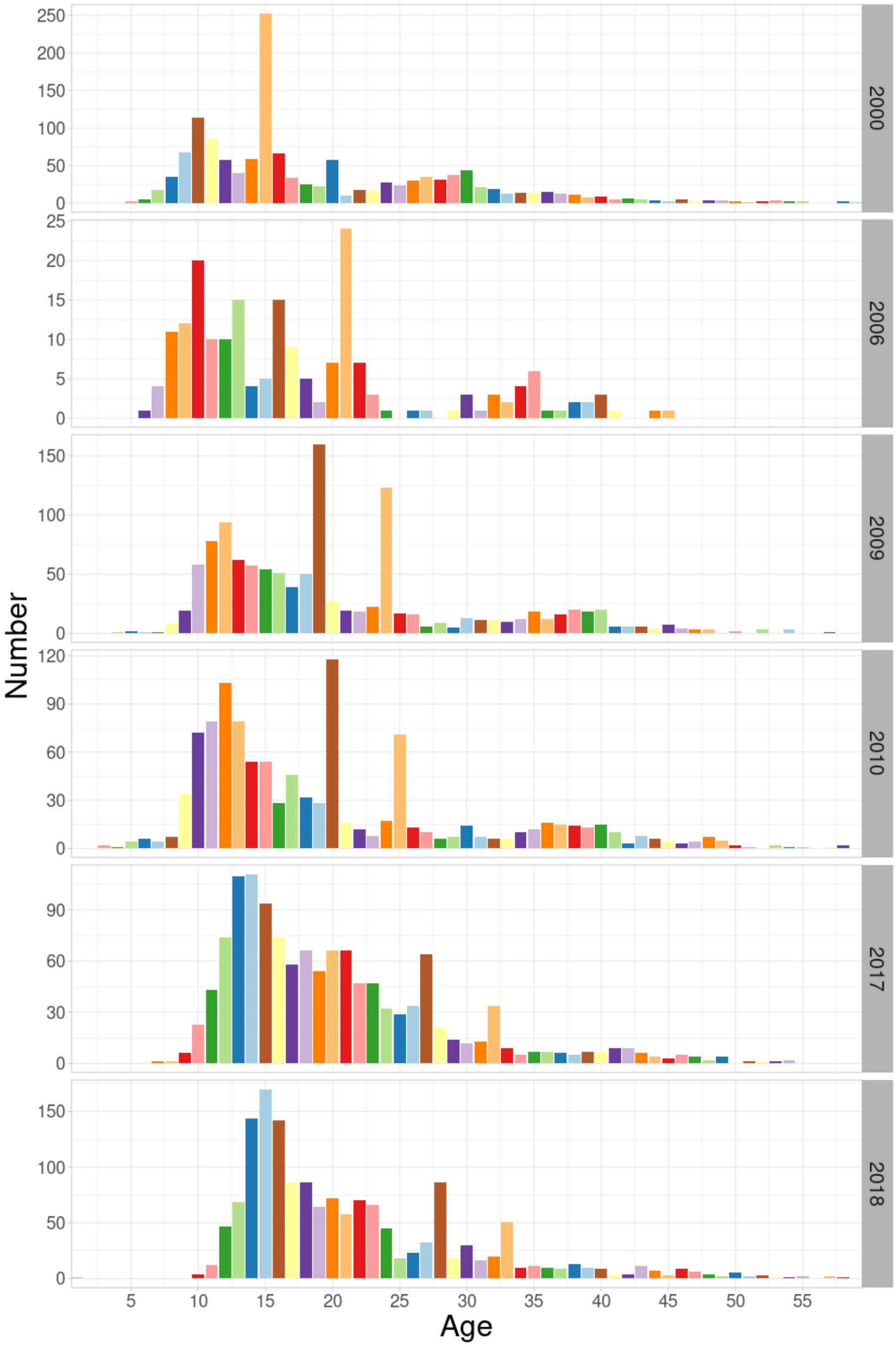

Figure 5. Icelandic slope beaked redfish. Age distribution from the autumn survey in 2000 (n = 1405), 2006 (n = 199), 2009 (n = 1206), 2010 (n = 1101), 2017 (n = 1299) and 2018 (n = 1568). The age class 60 are the combined age-classes of 60 years and older.

Mynd 5. Djúpkarfi. Aldursgreindir einstaklingar úr stofnmælingu botnfiska að hausti árin 2000 (n = 1405), 2006 (n = 199), 2009 (n = 1206), 2010 (n = 1101), 2017 (n = 1299) og 2018 (n = 1568). 60 ára er samansettur úr fiski 60 ára og eldri.

INFORMATION FROM THE FISHING INDUSTRY

LANDINGS

Total annual landings of Icelandic slope beaked redfish from the Icelandic Waters ecoregion 1950–2019 are presented in Tables 2 and 5 and Figure 6.

During the 1950-1977 period, before the extension of the Icelandic EEZ to 200 nm, Icelandic slope beaked redfish was mainly fished by West-Germany (Table 4). The catches peaked in 1953 to about 87 000 t but gradually decreased to about 23 000 t in 1977. After the extension of the Icelandic EEZ in 1978 the fishery has almost exclusively been conducted by Icelandic vessels. Annual landings gradually decreased from 57 000 t in 1994 to 17 000 t in 2001. Landings in 2001-2010 fluctuated between 17 000 and 20 500 t except in 2003 and 2008 when annual landings were 28 500 and 24 000 t, respectively. Annual landings in 2011-2019 were between 8300 and 12 000 t. The total catch in 2019 was 8716 t, about 1300 t less than in 2018.

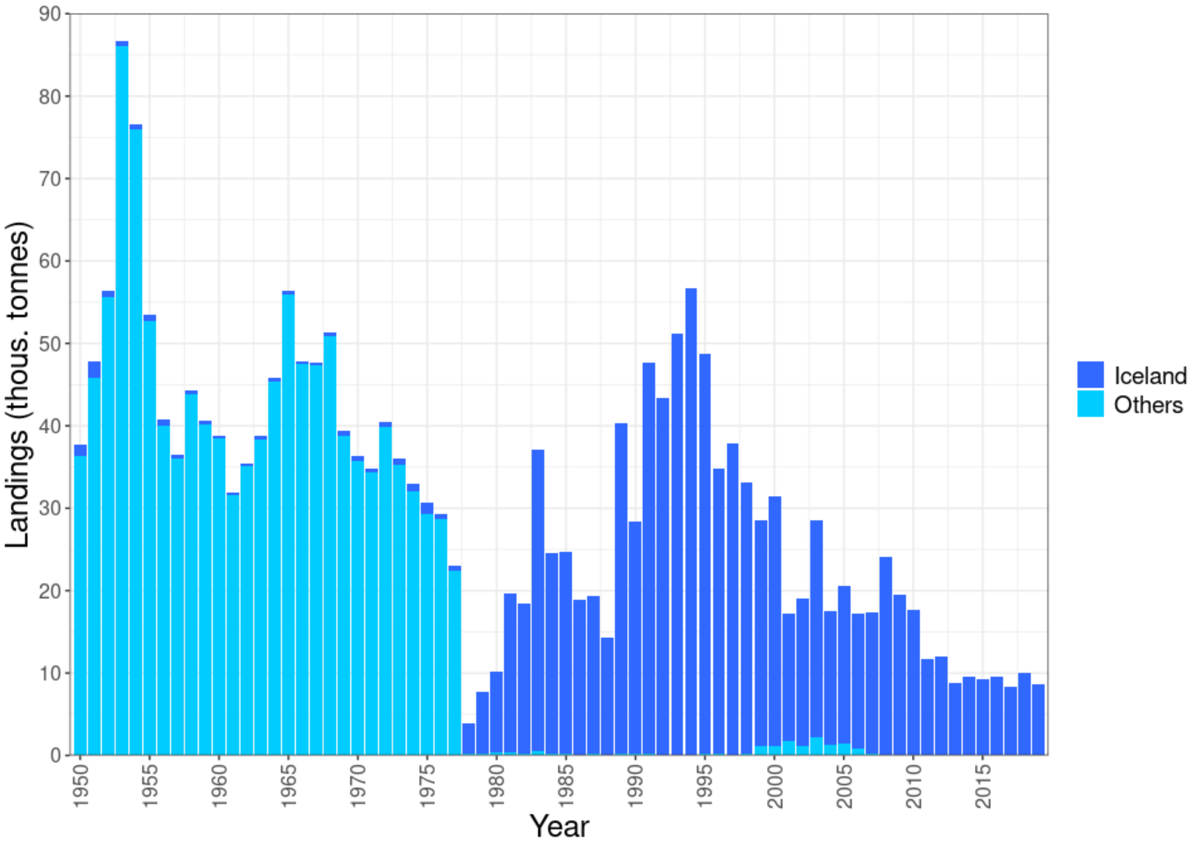

Figure 6. Icelandic slope beaked redfish. Nominal landings (in tonnes) from Icelandic waters (ICES Division 5.a and Sub-area 14) 1950-2019.

Mynd 6. Djúpkarfi. Landaður afli (í tonnum) á Íslandsmiðum 1950-2019.

Table 2. Icelandic slope beaked redfish. Nominal landings (in tonnes) 1950-2019 from Icelandic waters.

Tafla 2. Djúpkarfi. Landaður afli (í tonnum) á Íslandsmiðum 1950-2019.

Year	Iceland	Others	Total
1950	1 458	36 269	37 727
1951	1 944	45 825	47 769
1952	885	55 554	56 439
1953	658	86 011	86 669
1954	577	75 972	76 459
1955	654	52 784	53 438
1956	674	40 047	40 721
1957	558	35 993	36 551
1958	409	43 820	44 229
1959	398	40 175	40 573
1960	407	38 428	38 836
1961	307	31 534	31 841
1962	264	35 122	35 386
1963	456	38 338	38 794
1964	362	45 414	45 776
1965	473	55 930	56 403
1966	332	47 491	47 823
1967	357	47 313	47 670
1968	494	50 892	51 386
1969	486	38 358	39 345
1970	500	35 800	36 300
1971	495	34 376	34 871
1972	593	39 874	40 468
1973	794	35 251	36 045
1974	806	32 103	32 909
1975	1 404	29 301	30 705
1976	715	28 632	29 346
1977	590	22 427	23 018
1978	3 693	209	3 902
1979	7 448	246	7 694
1980	9 849	348	10 197
1981	19 242	447	19 689
1982	18 279	213	18 492
1983	36 585	530	37 115
1984	24 271	222	24 493
1985	24 580	188	24 768
1986	18 750	148	18 898
1987	19 132	161	19 293
1988	14 177	113	14 290

Year	Iceland	Others	Total
1989	40 013	256	40 269
1990	28 214	215	28 429
1991	47 378	273	47 651
1992	43 414	0	43 414
1993	51 221	0	51 221
1994	56 674	46	56 720
1995	48 479	229	48 708
1996	34 508	233	34 741
1997	37 876	0	37 876
1998	32 841	284	33 125
1999	27 475	1 115	28 590
2000	30 185	1 208	31 393
2001	15 415	1 815	17 230
2002	17 870	1 175	19 045
2003	26 295	2 183	28 478
2004	16 226	1 338	17 564
2005	19 109	1 454	20 563
2006	16 339	869	17 208
2007	17 091	282	17 373
2008	24 123	0	24 123
2009	19 430	0	19 430
2010	17 642	0	17 642
2011	11 738	0	11 738
2012	11 965	0	11 965
2013	8 761	0	8 761
2014	9 500	0	9 500
2015	9 311	0	9 311
2016	9 536	0	9 536
2017	8 371	0	8 371
2018	9 995	0	9 995
2019[1)]	8 716	0	8 716

1) Provisional

FISHERIES AND FLEETS

The fishery for Icelandic slope beaked redfish in Icelandic waters is a directed bottom trawl fishery along the shelf and slope southwest and west of Iceland at depths between 500 and 800 m (Figure 7). In recent years between 14 and 24 trawlers have participated in the fishery catching 92- 97% of the total Icelandic beaked redfish catch. The main trend in the spatial distribution of the Icelandic slope beaked redfish catches according to logbook entries is the decreased proportion caught in the southeast fishing area (Figure 7). This area has historically been an important fishing area for Icelandic slope beaked redfish.

In 1991-2000, 10-44% of the Icelandic slope redfish catches were taken by pelagic trawls (Table 3). Since 2001, no pelagic fishery occurred or was negligible except in 2003 and 2007. The pelagic fishery was mainly in the same areas as the bottom trawl fishery (Figure 8).

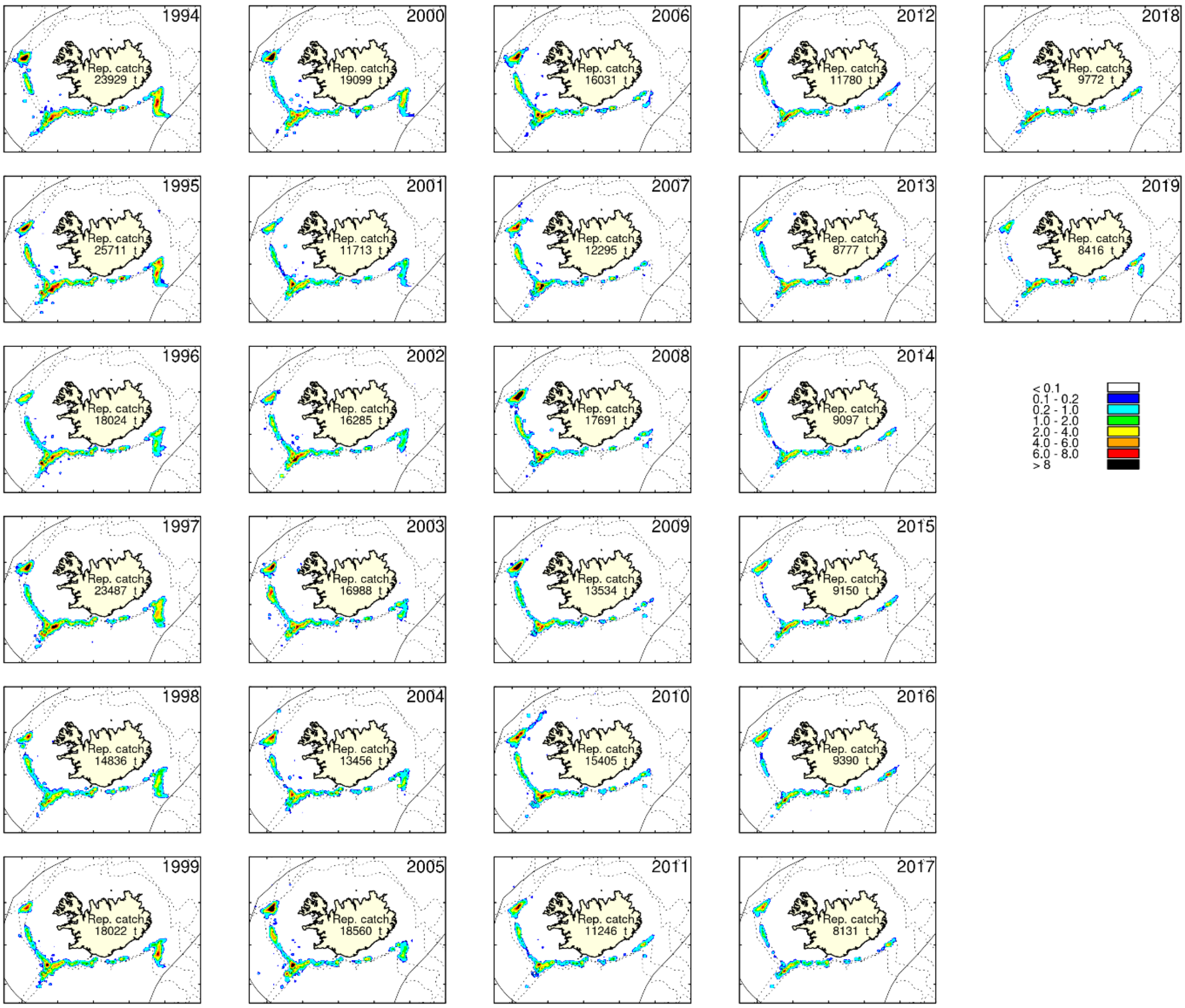

Figure 7. Icelandic slope beaked redfish. Geographical location of the bottom trawl catches in Icelandic waters (ICES Division 5.a and Subarea 14) 1994-2019 as reported in logbooks of the Icelandic fleet. The black line indicates part of the management unit for the deep-pelagic redfish stock. The dotted line represents the 500 and 1000 m isobaths.

Mynd 7. Djúpkarfi. Útbreiðsla botnvörpuveiða á Íslandsmiðum 1994-2019 samkvæmt afladagbókum. Svartar línur sýna stjórnunareiningu neðri stofns úthafskarfa, en punktalínur eru 500 og 1000 m dýptarlínur.

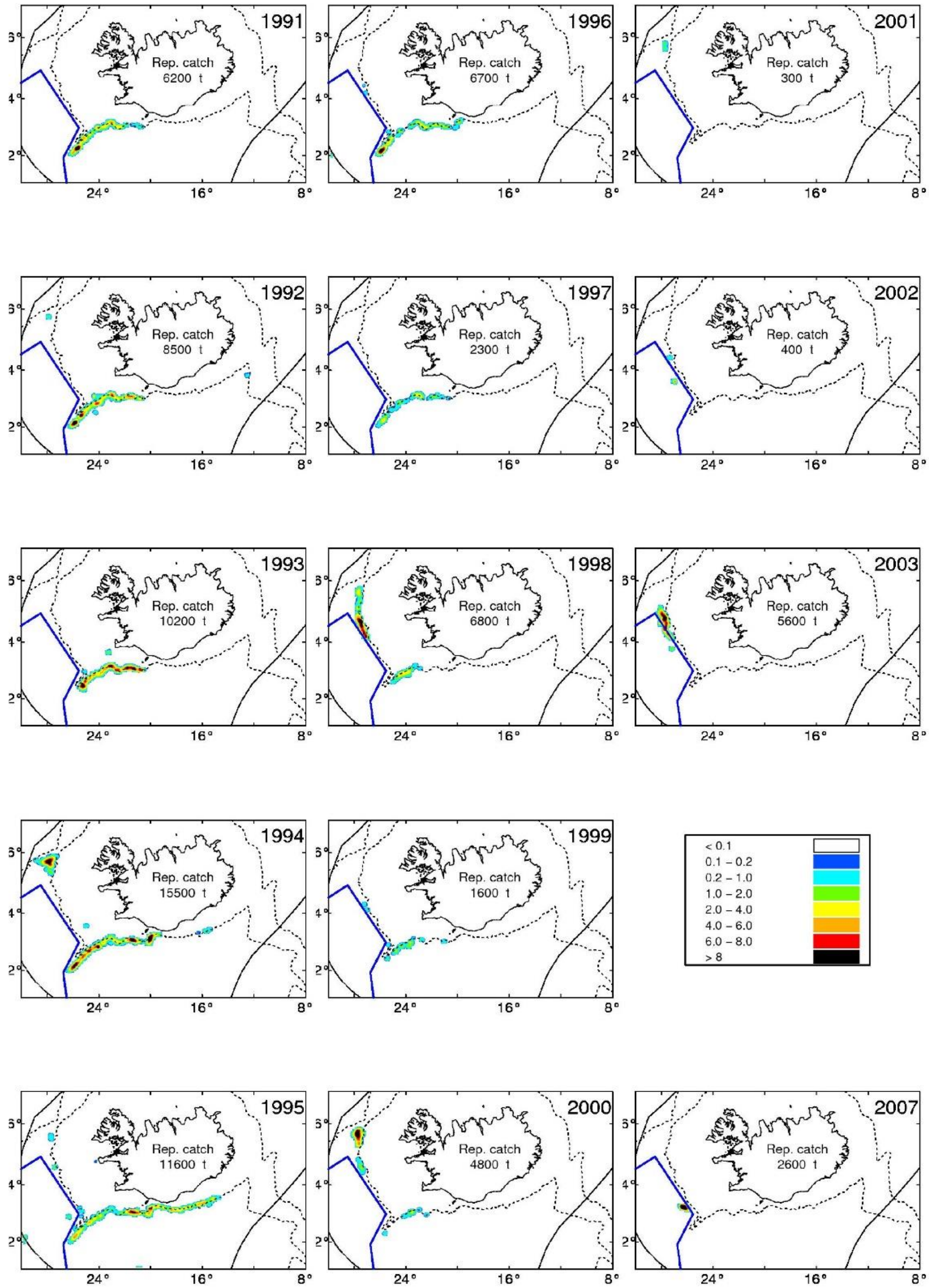

Figure 8. Icelandic slope beaked redfish. Geographical location of the pelagic trawl catches in Icelandic waters (ICES Division 5.a and Subarea 14) 1991-2003 and 2007 as reported in logbooks of the Icelandic fleet. The blue line indicates part of the proposed management unit for the deep-pelagic redfish stock. The dotted line represents the 500 m isobaths.

Mynd 8. Djúpkarfi. Útbreiðsla íslenskra flotvörpuveiða 1991-2003 og 2007 samkvæmt afladagbókum. Blá lína sýnir tillögu að stjórnunareiningu fyrir neðri stofn úthafskarfa. Sýnd einnig 500 m dýptarlína (punktalína).

Table 3. Icelandic slope beaked redfish. Proportion of the landings of Icelandic slope *S. mentella* taken in ICES Division 5.a by pelagic and bottom trawls since 1991.

Tafla 3. Djúpkarfi. Skipting landaðs afla við Ísland eftir veiðarfærum (flotvörpu og botnvörpu frá 1991).

Year	Pelagic trawl	Bottom trawl
1991	22%	78%
1992	27%	73%
1993	32%	68%
1994	44%	56%
1995	36%	64%
1996	31%	69%
1997	11%	89%
1998	37%	63%
1999	10%	90%
2000	24%	76%
2001	3%	97%
2002	3%	97%
2003	28%	72%
2004	0%	100%
2005	0%	100%
2006	0%	100%
2007	17%	83%
2008-2019	0%	100%

SAMPLING FROM THE COMMERCIAL FISHERY

Table 4 shows biological sampling from the catch of Icelandic slope beaked redfish in the Icelandic Waters ecoregion 2000-2019. Number of samples and the number of length measurements have decreased since 2012. The reason is reduced sampling effort of onboard observers from the Directorate of Fisheries. Otoliths from the commercial catch have been collected, but no systematic age reading is done.

Although sampling from the commercial catches has decreased, it is considered sufficient and covers the spatial distribution of catches. The sampling coverage 2019 is shown in Figure 9.

Table 4. Icelandic slope beaked redfish. Number of samples and number of fish length measured from the commercial catches 2000-2019

Tafla 4. Djúpkarfi. Fjöldi sýna og fjöldi mældra fiska úr afla 2000-2019.

Year	Samples	Measurements
2000	202	42253
2001	103	19737
2002	179	32864
2003	168	29318
2004	140	22309
2005	207	34233
2006	256	40261
2007	142	22689
2008	200	33880
2009	184	30606
2010	168	28463
2011	138	21239
2012	68	11118
2013	64	9468
2014	93	15380
2015	58	9089
2016	92	13715
2017	57	10453
2018	26	4787
2019	41	7676

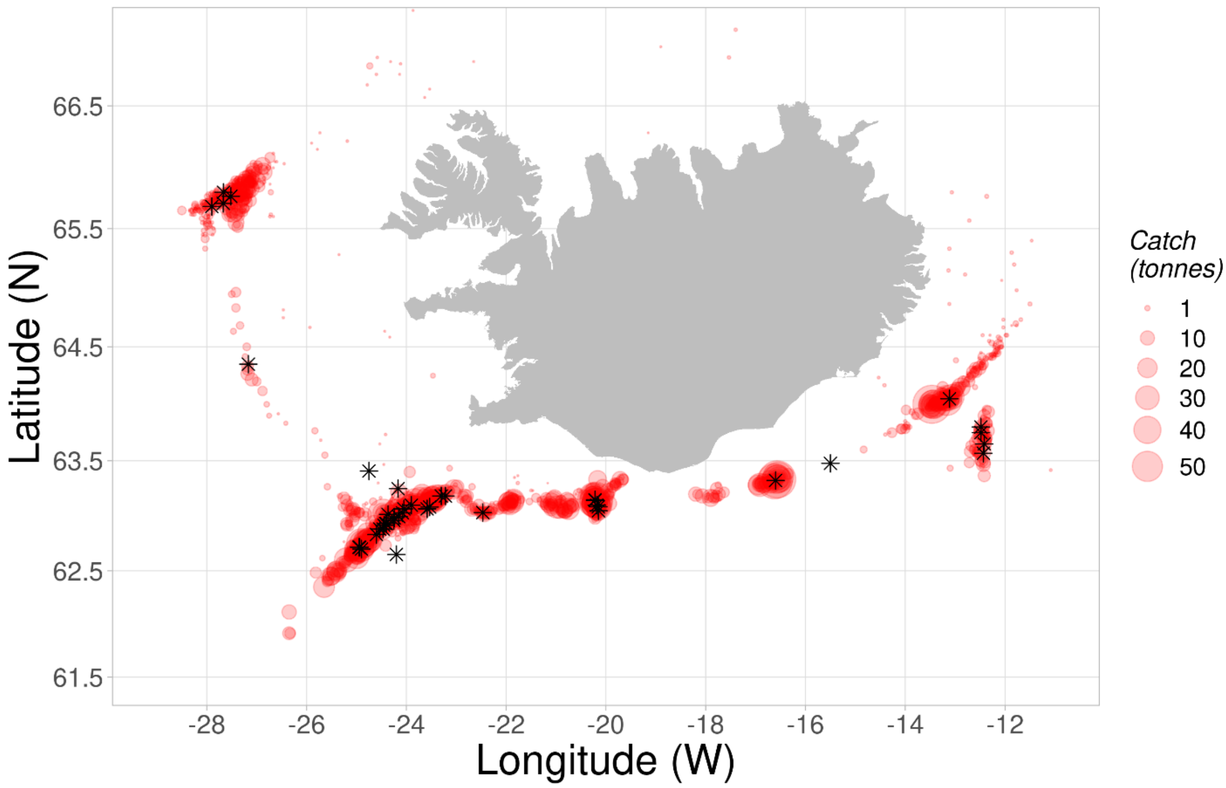

Figure 9. Icelandic slope beaked redfish. Demersal trawl fishing grounds in 2019 as reported in logbooks (red) and positions of samples taken from landings (asterisks).

Mynd 9. Djúpkarfi. Veiðisvæði við Ísland árið 2019 samkvæmt afladagbókum (rautt) og staðsetningar sýna úr lönduðum afla (stjörnur).

LENGTH DISTRIBUTION FROM THE COMMERCIAL CATCH

Length distributions of Icelandic slope beaked redfish from the bottom trawl fishery show an increase in the number of small fish in the catch in 1994 compared to previous years (Figure 10). The peak of about 32 cm in 1994 can be followed by approximately 1 cm annual increase in 1996—2002. The length distribution in 2004—2019 peaked around 39—42 cm. The length distribution of Icelandic slope beaked redfish from the pelagic fishery, where available, showed that in most years the fish was on average bigger than taken in the bottom trawl fishery (Figure 10).

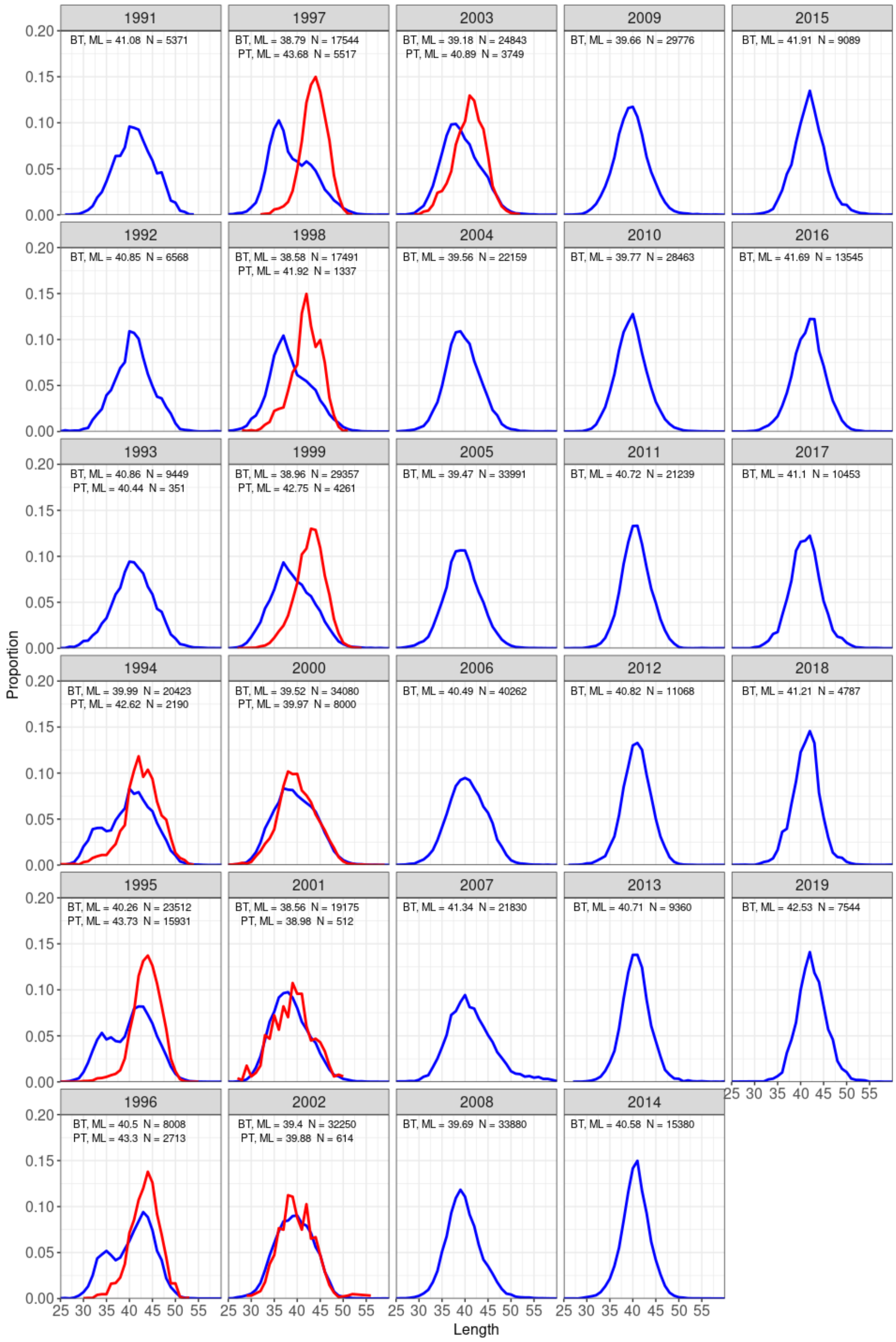

Figure 10. Icelandic slope beaked redfish. Length distributions from the Icelandic commercial landings taken with bottom trawl (blue line) and pelagic trawl (red line) in Icelandic waters (ICES Division 5.a and Subarea 14) 1991-2019.

Mynd 10. Djúpkarfi. Lengdardreifing úr afla botnvörpu (bláar línur) og flotvörpu (rauðar línur) 1991-2019.

CATCH PER UNIT EFFORT

Trends in non-standardized CPUE (kg/hour) and effort (thousand hours fished) are shown in Figure 11. CPUE of tows where more than 50% and 80% of the catch was Icelandic slope beaked redfish gradually decreased from 1978 to a record low in 1994. Since then CPUE has been steadily increasing and was in 2019 at the highest level observed in the time series. From 1991 to 1994, when CPUE decreased, the fishing effort increased drastically. Since then, effort has decreased and is now at a similar level as in 1980.

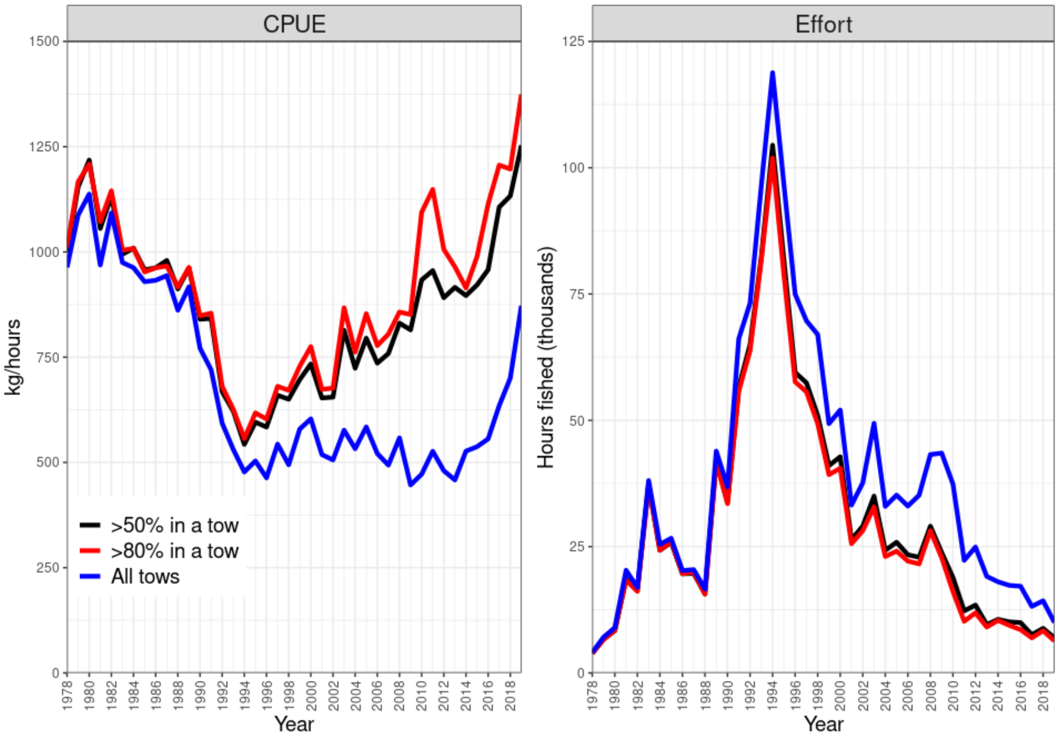

Figure 11. Icelandic slope beaked redfish. CPUE and effort from Icelandic trawlers 1978–2019 where golden redfish catch composed at least 50% of the total catch in each haul (black line), 80% of the total catch (red line) and in all tows where golden redfish was caught (blue line)..

Mynd 11. Djúpkarfi. Afli á sóknareiningu (vinstri) og sókn (hægri) í botnvörpu frá íslenskum skipum 1978-2019 þar sem gullkarfi var að minsta kosti 50% af heildarafla í hverju togi (svört lína, 80% af heildarafla í hverju togi (rauð lína) og þar sem gullkarfi kom fyrir í hverju togi (blá lína).

DISCARD

Although no direct measurements are available on discards, it is believed that there are no significant discards of Icelandic slope *S. mentella* in the Icelandic redfish fishery.

STOCK ASSESSMENT METHODS

No analytical assessment was conducted on this stock.

REFERENCE POINTS

There are no biological reference points for the species. Previous reference points established were based upon commercial CPUE indices, but they are now considered to be unreliable indicators of stock size.

STATE OF THE STOCK

The North-Western Working Group concludes that the state of the stock is at a low level. With the information at hand, current exploitation rates cannot be evaluated for the Icelandic slope beaked redfish in Division 5.a.

The fishable biomass index from the Icelandic autumn survey has fluctuated during 2000-2019 period. The biomass index for 2004-2013 decreased to similar level as in 2003 when it was at lowest level. In 2014-2018 the index gradually increased but decreased in 2019.

CPUE indices show a reduction from highs in the late 1980s, but there is an indication that the stock has started a slow recovery since the middle of 1990s, when CPUE was close to 50% of the maximum. The CPUE index gradually increased from 1995–2019 the highest level in the time series. It is, however, not known to what extent CPUE series reflect change in stock status of Icelandic slope beaked redfish. The nature of the redfish fishery is targeting schools of fish using advancing technology. The effect of technological advances is to increase CPUE but is unlikely to reflect biomass increase.

In 2000-2008, good recruitment was observed in the German survey on the East Greenland shelf (growth of about 2cm/yr) which is assumed to contribute to both the Icelandic slope and pelagic stock at unknown shares. The German survey and the Greenland shrimp and fish shallow water survey both show no new recruits and no juveniles (<18 cm) are present. This suggests that the fishery in coming years will be based on the same cohorts.

MANAGEMENT CONSIDERATIONS

Beaked redfish is a slow growing, late maturing deep-sea species and is therefore considered vulnerable to overexploitation and advice must be conservative.

BASIS FOR ADVICE

Icelandic slope beaked redfish is considered a data limited stock (DLS) and follows the ICES framework for such (Category 3.2; ICES 2012). Below is the description of the formulation of the advice.

Based on the North Western Working Group recommendation, the stock is treated as a stock with survey data, but no proxies for MSY $B_{trigger}$ or F values are known. The IS-SMH survey index was used as an indicator of stock development. The advice is based on a comparison of the two latest index values with the three preceding values, combined with the latest catch advice This means that the catch advice is based on the survey adjusted status quo catch equation:

$$C_{y+1} = C_{y-1}\left(\frac{\sum_{i=y-x}^{y-1} I_i/x}{\sum_{i=y-z}^{y-x-1} I_i/(z-x)}\right)$$

where I is the survey index, x is the number of years in the survey average, z > x, and C_{y-1} is the advice last year. In this case, x = 2, which is the average of the two latest index values, and z = 5 the total number of survey values.

REGULATIONS AND THEIR EFFECTS

The species is managed under the Icelandic ITQ system, without direct management. Until the 2010/11 fishing year, Icelandic authorities gave a joint quota for golden redfish (*S. norvegicus*) and Icelandic slope beaked redfish. The separation of quotas was implemented in the fishing year that started September 1, 2010.

Figure 12 shows the net transfers of Icelandic slope beaked redfish in the Icelandic ITQ-system. Quota transfers from other species to Icelandic slope beaked redfish have been minimal or within 5%. However, net transfers from Icelandic slope beaked redfish to other species has increased since the 2015/216 fishing year and 20% of the beaked redfish quota was transferred to other species in the 2018/2019 fishing year (Figure 12, upper). Those net transfers were most likely due to fleet not finishing the given quota and possibly moving the quota to golden redfish. Net transfers of unused Icelandic slope beaked redfish quota from one fishing year to the next have usually been within 5% (Figure 12, lower).

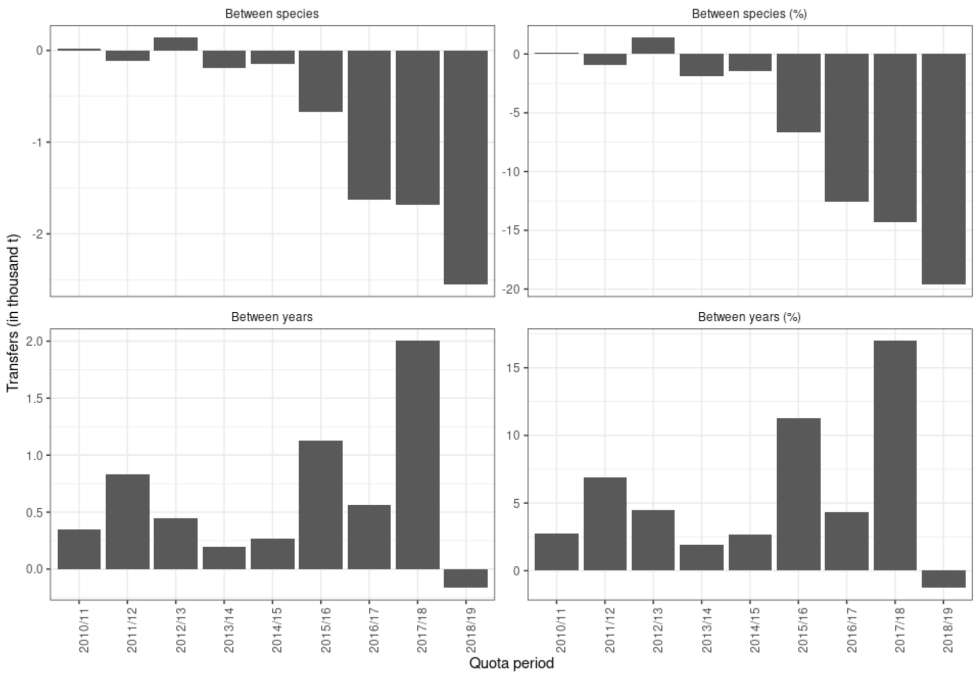

Figure 12. Icelandic slope beaked redfish. Net transfers of quota to and from Icelandic slope beaked redfish in the Icelandic ITQ system by quota year. Between species (upper): Positive values indicate a transfer of other species to Icelandic slope beaked redfish, but negative values indicate a transfer of Icelandic slope beaked redfish quota to other species. Between years (lower): Transfer of quota from given quota year to the next quota year (may include unused quota).

Mynd 12. Djúpkarfi. Nettó tilfærsla á kvóta eftir fiskveiðiárum. Tilfærsla milli tegunda (efri myndir): Jákvæð gildi tákna tilfærslu á kvóta annarra tegunda yfir á djúpkarfa en neikvæð gildi tilfærslu djúpkarfakvóta á aðrar tegundir. Tilfærsla milli ára (neðri myndir): Tilfærsla kvóta frá viðkomandi fiskveiðiári yfir á næsta fiskveiðiár (gæti innihaldið ónotaðar aflaheimildir).

DATA ANALYSIS – EXPLORATORY ASSESSMENT

EXPLORATORY ANALYTICAL ASSESSMENT USING GADGET

No analytical assessment is conducted on this stock. In this chapter, preliminary run and analysis of a Gadget model is presented. The purpose is to explore assessment methods as a potential category 1 assessment (ICES, 2012). Current assessment (based on survey trends) is not considered to capture true state of the stock. Currently, golden redfish and deep pelagic beaked redfish in the Irminger Sea and adjacent waters are assessed with Gadget models.

In this document, only model settings and the results are presented.

DATA USED AND MODEL SETTINGS

Beaked redfish is a long-lived species and the maximum age is set at 50 years as a plus group. Simulation begin in 1970, but the fishery started in 1950. No biological data are available prior to 1970. The immature stock matures at age 20 at the latest. Recruitment to the immature stock component occurs at age 3. The length range in the model ranged between 10 and 55 cm (with no mature individual <18 cm). An overview of the data sets and model parameters used in the model study is shown in Table 5.

Table 5: Icelandic slope beaked redfish. 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 obtained from the Marine and Freshwater Research Institute, Iceland.

Tafla 5. Djúpkarfi.

Component name	Qarters	Year range	N	Delta 1	Type
aldist.aut	4	2000-2019		1 cm	Age- length distribution
aldist.comm	All quarters	1998-2018		1 cm	Age- length distribution
ldist.aut	4	2000-2019		1 cm	Length distribution
ldist.comm	All quarters	1976-2019		1 cm	Length-distribution
matp.aut	4	2000-2019		?	Ratio of immature:mature by length group
si.10-20.aut	4	2000-2019		10-20 cm	Survey indices
si.20-25.aut	4	2000-2019		20-25 cm	Survey indices
si.25-30.aut	4	2000-2019		25-30 cm	Survey indices
si.30-35.aut	4	2000-2019		30-35 cm	Survey indices
si.35-40.aut	4	2000-2019		35-40 cm	Survey indices
si.40-45.aut	4	2000-2019		40-45 cm	Survey indices
si.45-55.aut	4	2000-2019		45-55 cm	Survey indices

Below is a brief description of the data used in the model and model settings is given.

Model settings:

- The simulation period is from 1970 to 2024 using data until the end of 2019 for estimation.
- Four time-steps (3-month period) are used each year.

- The ages used were 3 to 50 years, where the oldest age is treated as a plus group (fish 50 years and older).
- Modelled length ranged between 10-60 cm.
- The length increments in the survey were 10-20 cm, 21-25 cm, 26-30 cm … 41-45 cm and 46-55 cm. The survey vas not conducted in 2011.
- One commercial fleet (bottom trawl). Survey catch distribution data are modelled as a separate fleet.
- Recruitment was set at age 3.

List of parameters in the Gadget model:

- Natural mortality, M_a, fixed at 0.05 for all ages. The value chosen was based on settings in other redfish stocks.
- Length-based Von Bertalanffy growth function, k, L_∞, informed by age–length frequencies.
- Parameter β of the beta-binomial distribution controlling the spread of the length distribution.
- Logistic fleet selection, b_f, $l_{50,f}$; one set for each of the fleets (Autumn survey or Commercial).
- Initial abundance at ages 3-50 in 1970 by η_{sa} and $a \in (3, 50^+)$. 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.
- Initial guess of the logistic maturity ogive, λ, l_{50}, was estimated from survey data.
- Length at recruitment, l_0, σ_0: mean length (at age 3) and std. deviation in length at recruitment.
- Number of recruits by year, R_y, and $y \in (1970, 2019)$.
- Length-weight relationship μ_s, ω_s, were fixed based on the means of log-linear regression of survey data.
- Scalars, R_c, $I_{c,s}$, F_0 : recruitment 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

Survey indices can be variable for Icelandic slope beaked redfish due to its tendency to be influenced by a few very large hauls. The index data used as input here are the total raw numbers of fish caught (within length slices) in the entire autumn survey. Although they are expected to represent the entire stock, they are also expected to be highly variable because no treatment or data pre-processing has been performed to reduce this variability. This variability is reflected in the model's fit to the survey index data (Figure 15). In general, the model appears to follow the stock trends historically except for the 25-30 cm and 30-35 cm length groups. In these length groups model underestimates the first three years. Furthermore, the terminal estimate is not seen to deviate substantially from the observed value for most length groups, except for the largest one, 45-55 cm, with model overestimating the abundance.

Model fits to the age-length distribution data from the autumn survey show that the fit is not particularly good for the oldest ages (30+) where the model underestimates these ages (Figure 16). Furthermore, the model overestimates certain age classes which can be followed through years, first in 2009 as 12-19 years old fish and then again in 2017 and 2018 as 20-28 year old fish.

The main portions of the length distributions appear to have a reasonable fit (Figure 17). In some years, the overall fit to the predicted proportional length distributions in the survey is smaller to the observed for fish with the greatest density within the fished population (ca. 40-45 cm fish).

Length distributions from the commercial catch does usually show good fit (Figure 19). The fit between predicted and observed age distributions is much worse and could be related to few age readings in each time step (Figures 18).

Bubble plots generally show the same trends in fits to the length data of the commercial and survey data with an underestimation of the smallest fish (roughly <20 cm), good estimation of the sizes contributing most to the exploitable fishery (roughly 30-50 cm), and an underestimation of the largest fish (roughly >50 cm (Figures 19 and 20). Because inter-age and inter-length correlations are not included in Gadget, some blocks of similar residuals can be seen, and are more pronounced in the length bubble plot because of its finer resolution.

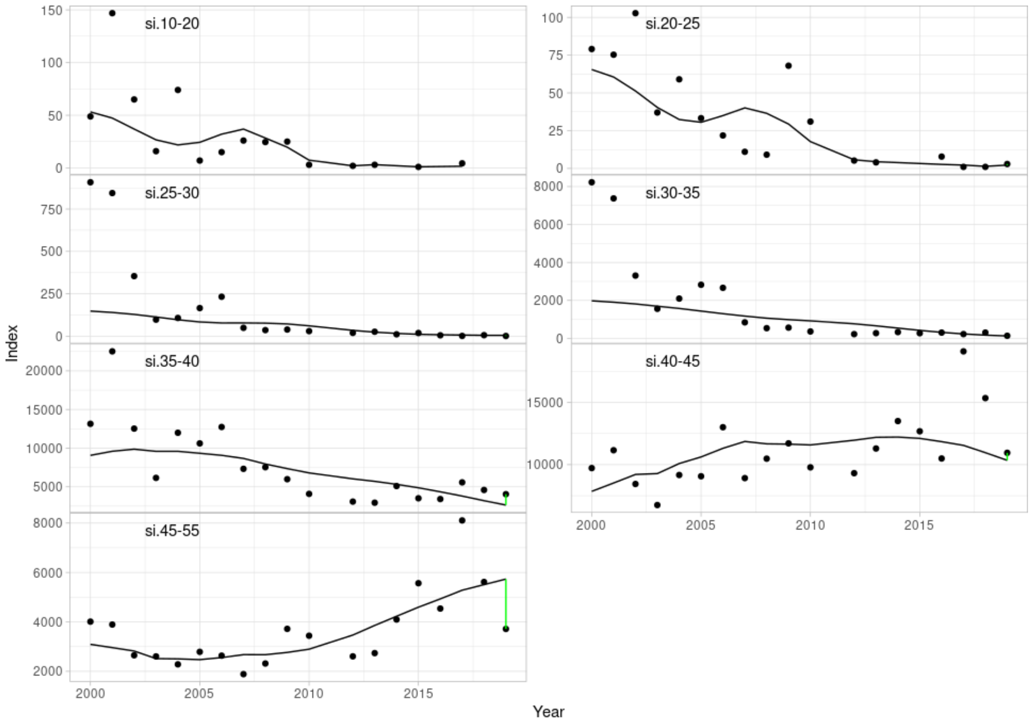

Figure 15. Icelandic slope beaked redfish. Autumn survey index number fits (lines) to data (points). The green line indicates the difference between model and data values in the last year.

Mynd 15. Djúpkarfi. Lífmassavísitala úr Gadget líkani (svartar línur) eftir stærðarflokkum borin saman við fenginn fjölda djúpkarfa í haustralli (punktar). Grænar línur sýna muninn á samsvörun gagna og líkans við lok tímabilsins.

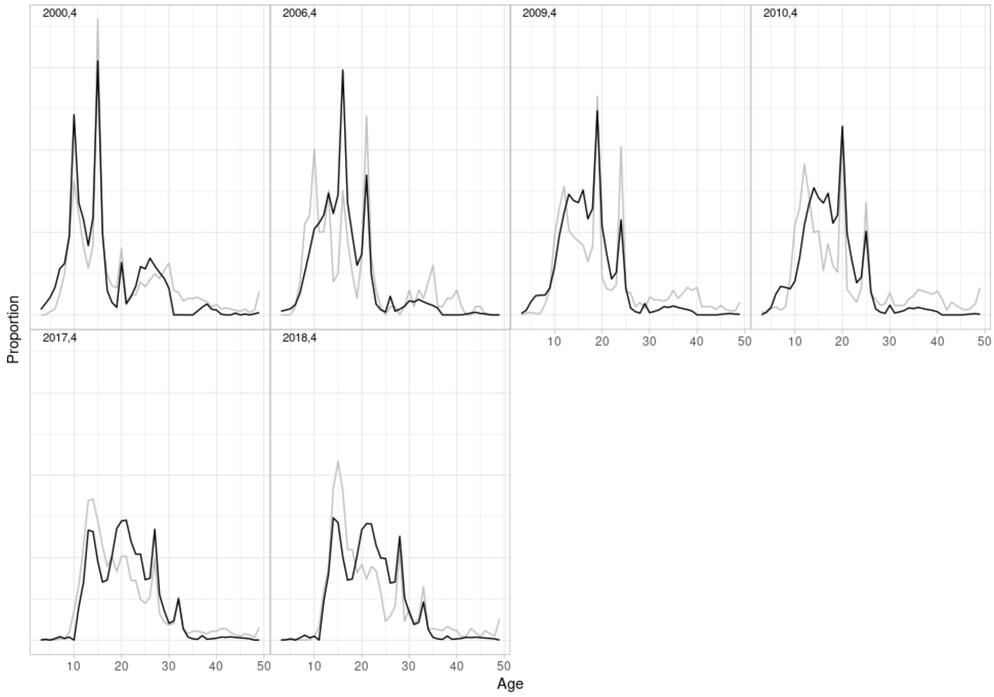

Figure 16. Icelandic slope beaked redfish. Comparison of autumn survey age distribution fits between model fits (black) and data (grey). Labels indicate the year and step of data sampled and model comparison.

Mynd 16. Djúpkarfi. Hlutföll eftir aldri úr Gadget líkani (svartar línur) samanborið við fengin hlutföll úr IS-SMH (gráar línur).

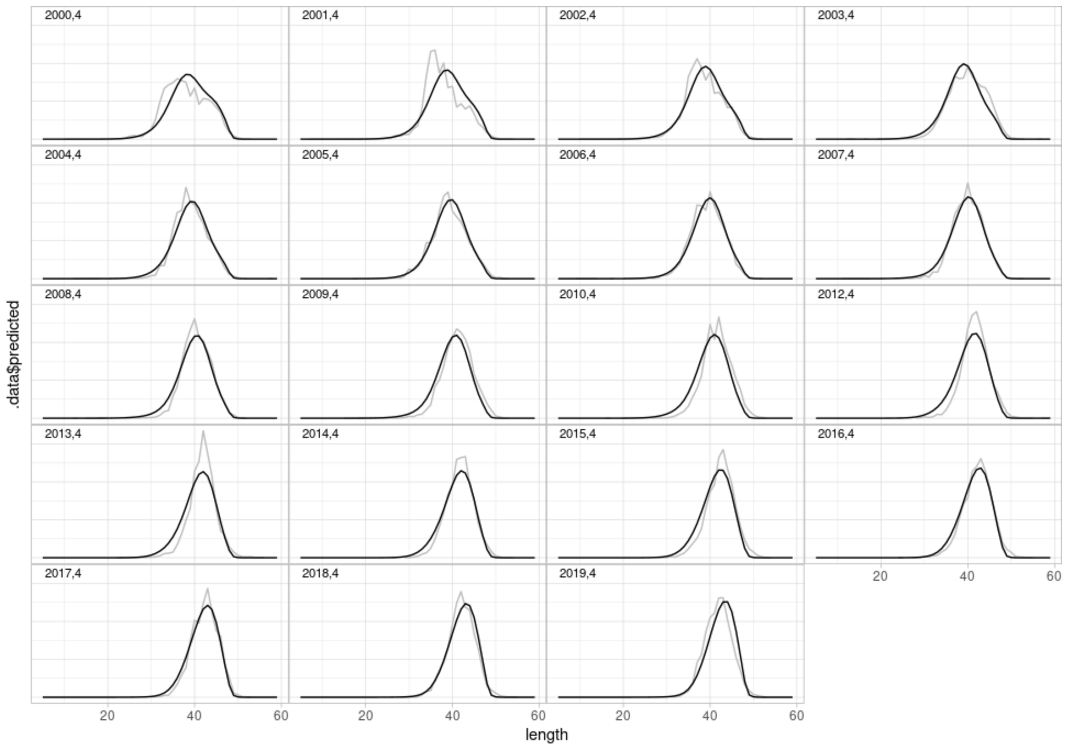

Figure 17. Icelandic slope beaked redfish. Comparison of autumn survey length distribution fits between model fits (black) and data (grey). Labels indicate the year and step of data sampled and model comparison.

Mynd 17. Djúpkarfi. Hlutföll eftir lengdarflokkum úr Gadget líkani (svartar línur) samanborið við fengin hlutföll úr IS-SMH (gráar línur).

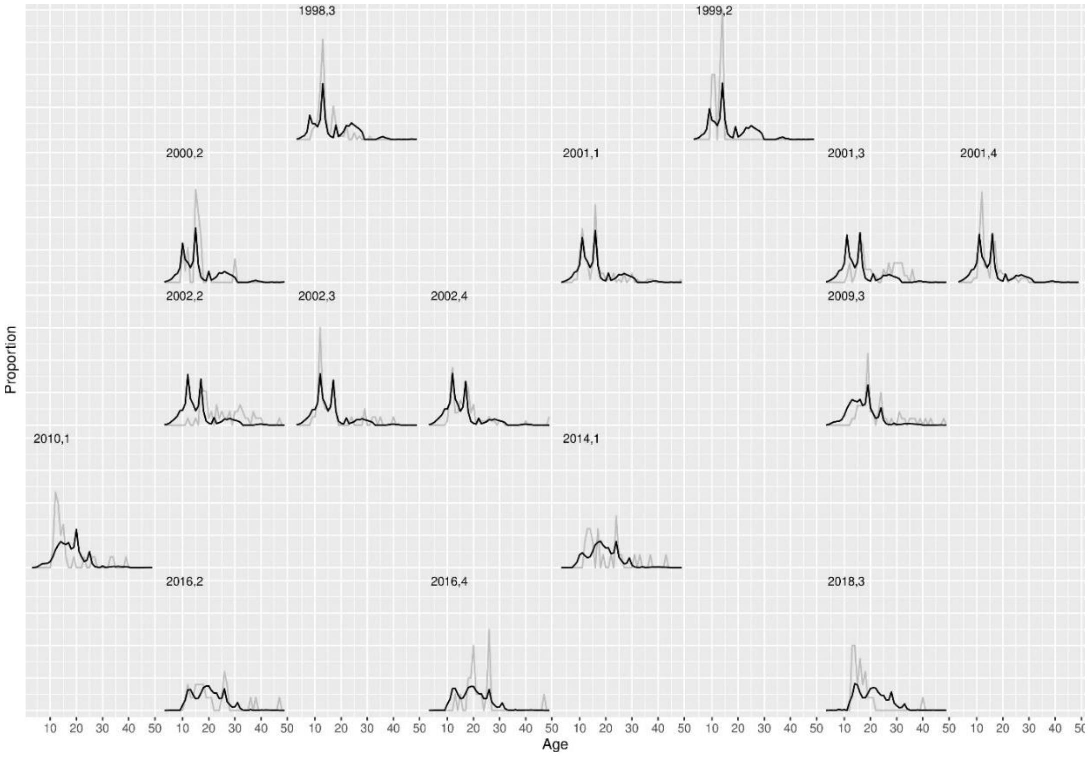

Figure 18. Icelandic slope beaked redfish. Comparison of commercial sample age-length distribution fits between model fits (black) and data (grey). Labels indicate the year and step of data sampled and model comparison.

Mynd 18. Djúpkarfi. Hlutföll eftir aldri úr Gadget líkani (svartar línur) samanborið við fengin hlutföll úr afla (gráar línur).

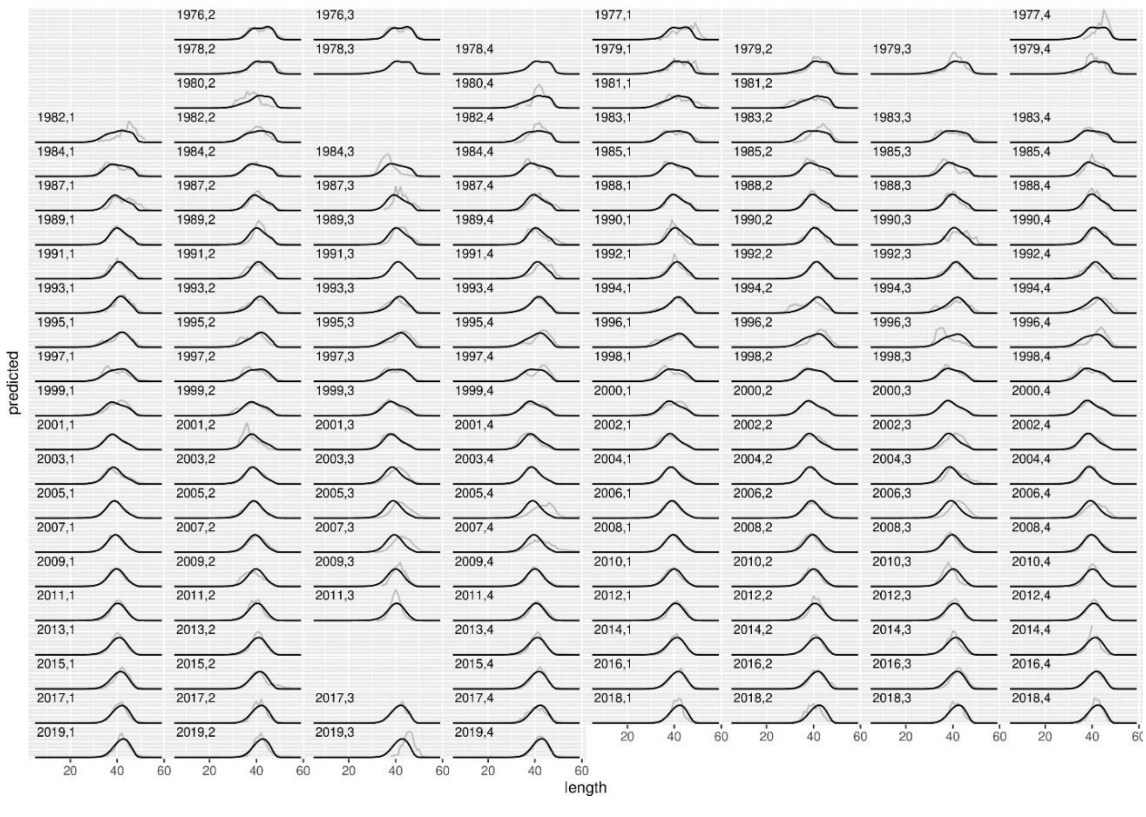

Figure 19. Icelandic slope beaked redfish. Comparison of commercial sample length distribution fits between model fits (black) and data (grey). Labels indicate the year and step of data sampled and model comparison.

Mynd 19. Djúpkarfi. Hlutföll eftir lengd úr Gadget líkani (svartar línur) samanborið við fengin hlutföll úr IS-SMH (gráar línur).

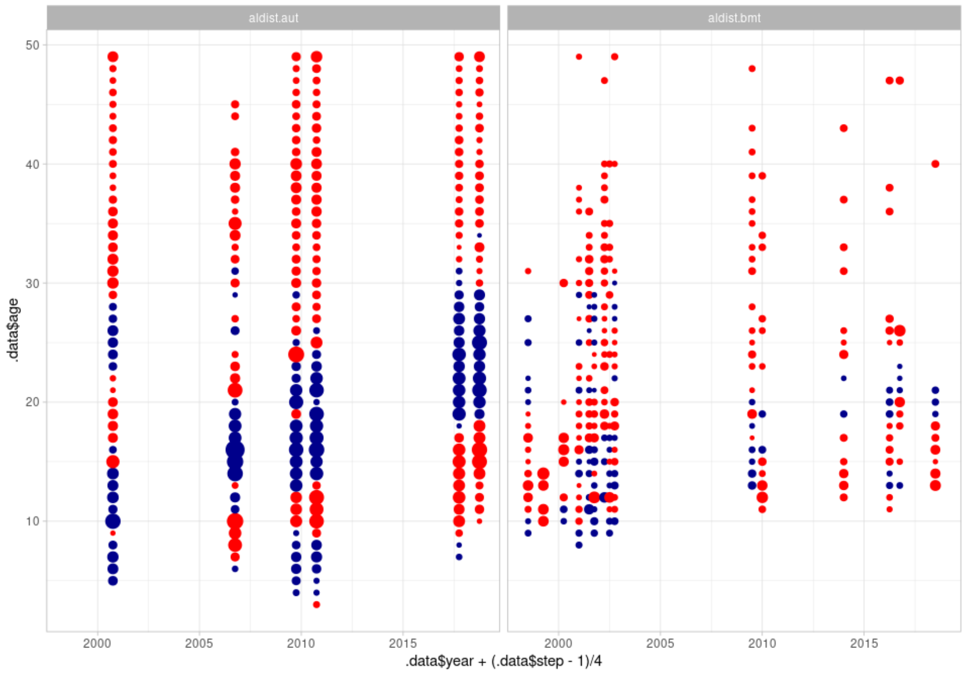

Figure 19. Icelandic slope beaked redfish. Bubble plots illustrating age-length distribution residuals between model predictions and data. Red bubbles indicate positive residuals (underestimation); blue bubbles indicate negative residuals (overestimation).

Mynd 19. Djúpkarfi. Aðhvarfsfrávik milli spágildi líkansins og vísitölum úr SMH eftir aldri (vinstri) og úr afla (hringir). Bláir hringir tákna neikvæð aðhvarfsfrávik (niðurstöður mælinga eru stærri en spágildi, þ.e. ofmat).

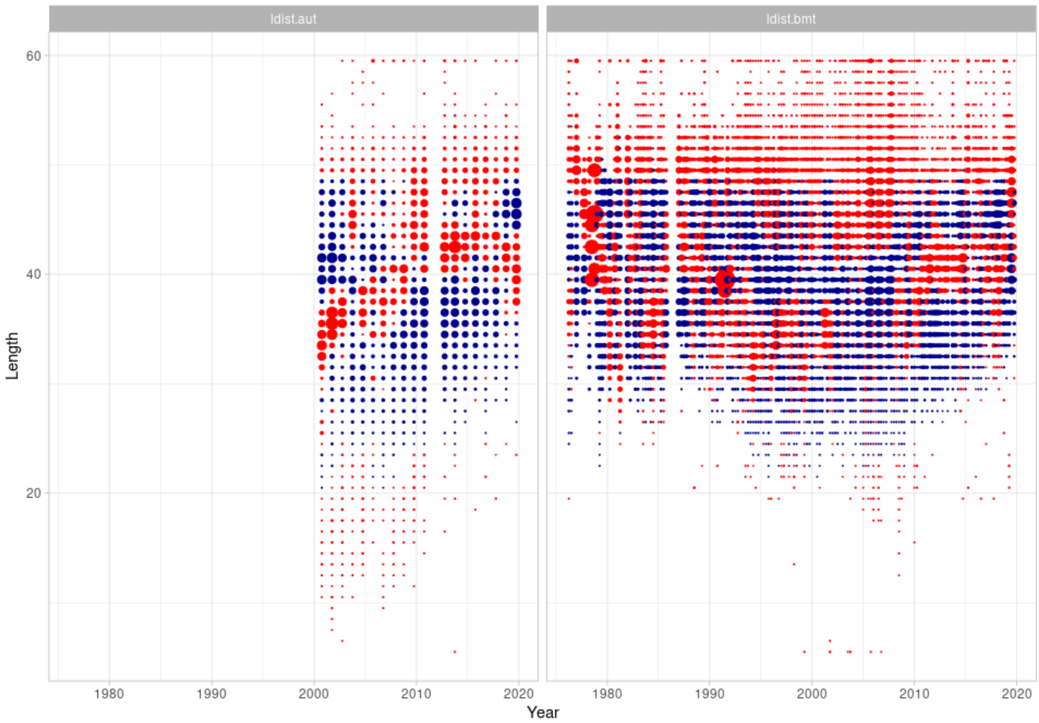

Figure 20. Icelandic slope beaked redfish. Bubble plots illustrating length distribution residuals between model predictions and observed data from the autumn survey (left) and from the commercial catch (right). Red bubbles indicate positive residuals (underestimation); blue bubbles indicate negative residuals (overestimation).

Mynd 20. Djúpkarfi. Aðhvarfsfrávik milli spágildi líkansins og vísitölum úr SMH eftir lengd (vinstri) og úr afla (hringir). Bláir hringir tákna neikvæð aðhvarfsfrávik (niðurstöður mælinga eru stærri en spágildi, þ.e. ofmat).

RETROSPECTIVE PLOTS

In Figure 21, the results of an analytical retrospective analysis are presented. The analysis indicates that there was an upward revision of biomass over the first 4 years of the 5-year peel followed by a downward revision of biomass (SSB) over the last year, and subsequently an downward then upward revision of *F*. Estimates of recruitment are all over the place in the beginning but are since 2000 decently stable for the first 4 years of the 5-year peel. The last year is though strange.

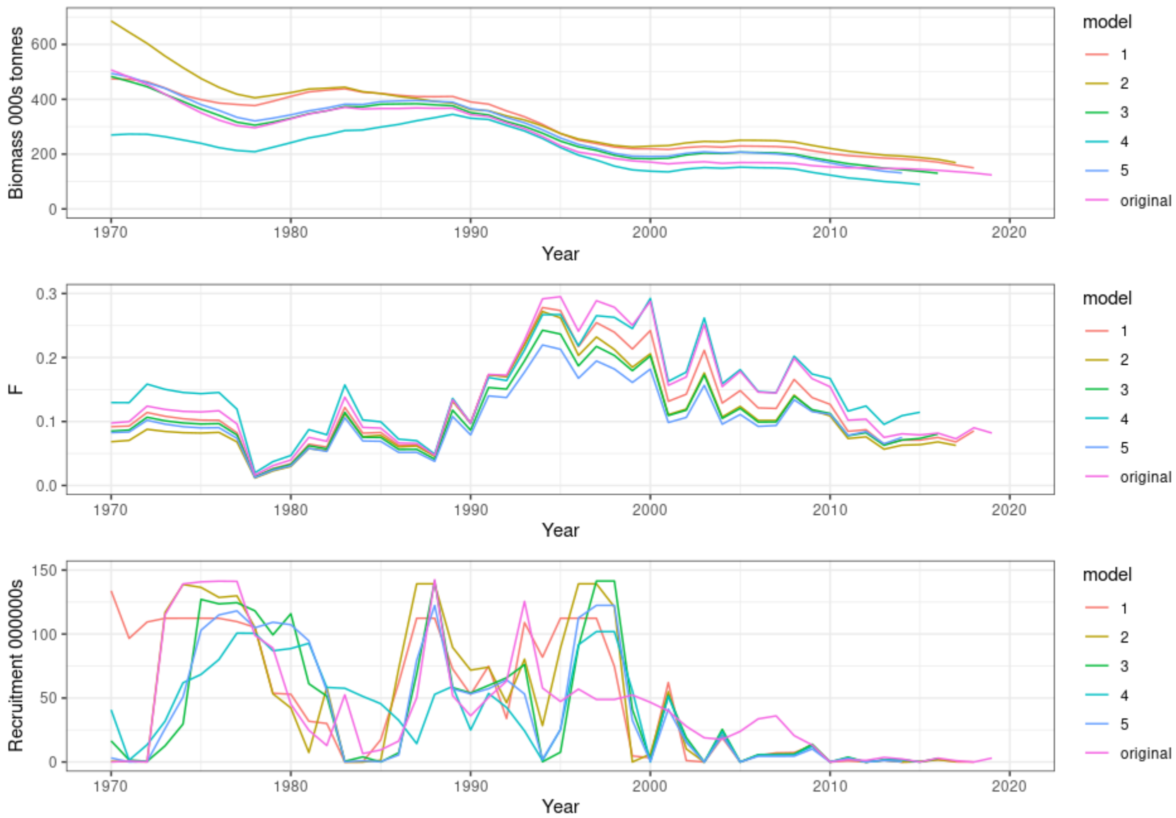

Figure 21. Icelandic slope beaked redfish. Retrospective plots illustrating stability in model estimates over a 5-year 'peel' in data. Results of spawning stock biomass, fishing mortality F, and recruitment (age 3) are shown.

Mynd 21. Djúpkarfi. Endurlitsgreining sem sýnir stöðuleika í mati líkansins fimm ár aftur í tímann. Niðurstöður eru sýndar fyrir hrygningarstofn (SSB), fiskveiðidánartölu, F, og nýliðun (3 ára).

MODEL RESULTS

Growth patterns predicted by the model does not follow closely to the data of fish 10 years old and younger (Figure 22).

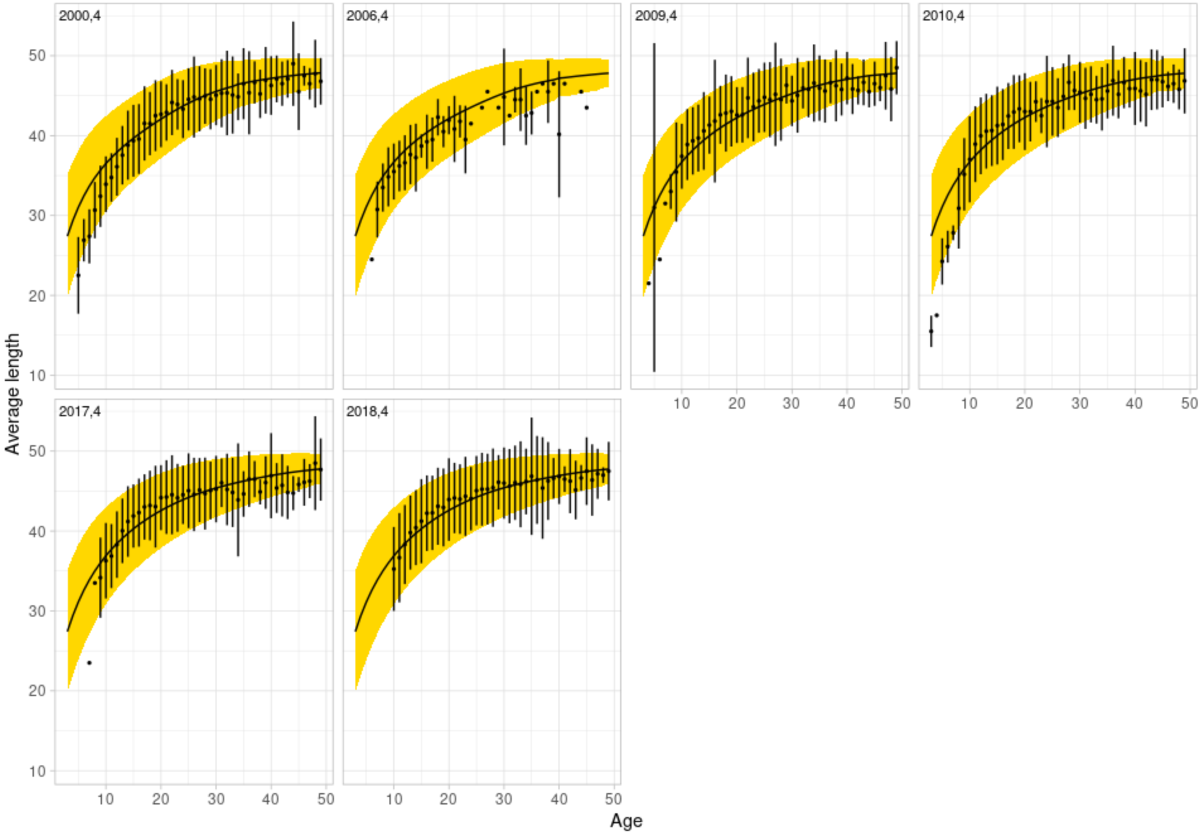

Figure 22. Icelandic slope beaked redfish. Growth estimation in the autumn survey from the Gadget model. Yellow bands and the black line show where the mean and 95% confidence intervals of the of model predictions, whereas the points and error bars show the mean and 95% confidence intervals of the data.

Mynd 22. Djúpkarfi. Mat á vexti í haustralli úr Gadget líkani. Gula svæðið og svarta línan sína meðaltal og 95% öryggis-mörk metins vaxtar en punktar og lóðréttar línur sína meðaltal og 95% öryggismörk gagna.

MODEL RESULTS

Summary of the exploratory assessment is shown in Figure 23. The spawning stock has since 1990 decreased and has since 2010 been below B_{lim} (defined as the median SSB for 2000-2005). The total biomass has also decreased and is now at similar level as the SSB indicating very few immature fish in the stock. Fishing mortality has decreased substantially from highest level in the late 1990s. Fishing mortality were relatively stable around F_{lim} in 2013-2019, but above F_{MSY}. Recruitment after 2010 is record low for the time series.

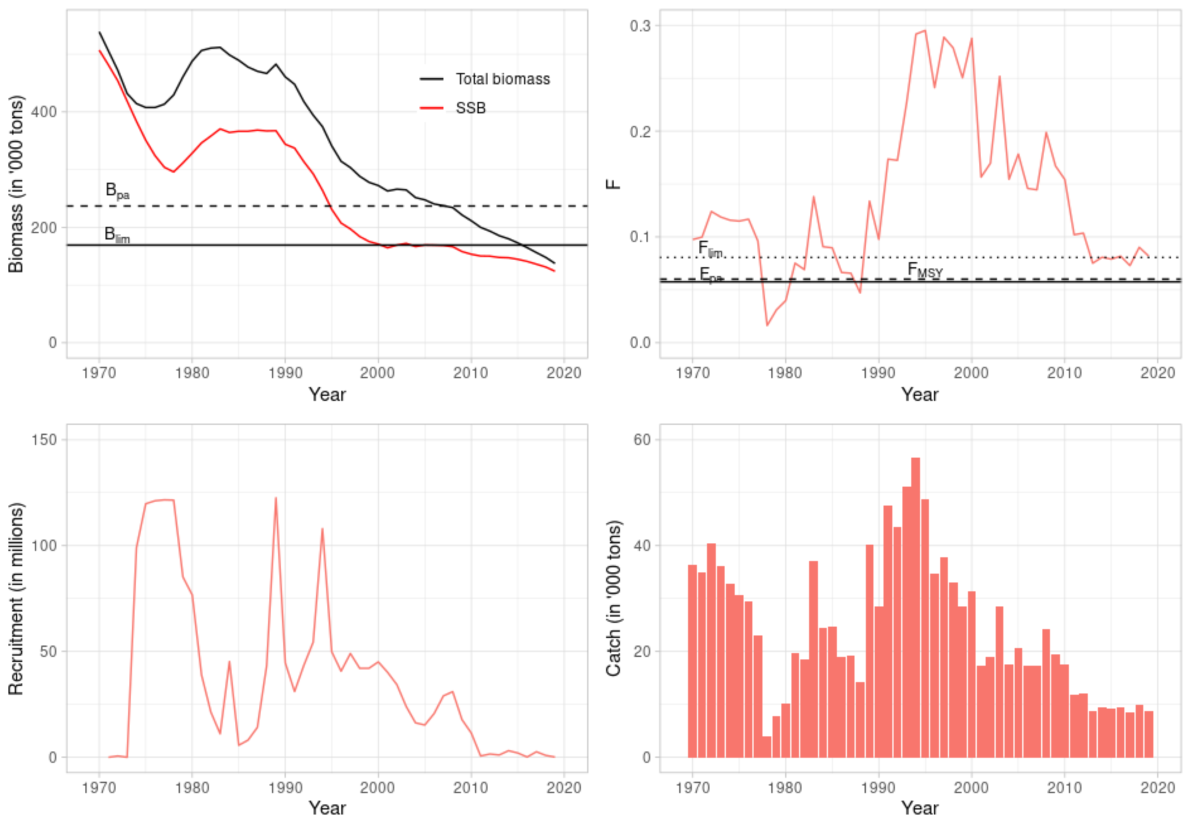

Figure 23. Icelandic slope beaked redfish. Summary from the exploratory assessment (Gadget) 2020.

Mynd 23. Djúpkarfi. Niðurstöður stofnsmats (Gadget) árið 2020.

The relationship between spawning stock and recruitment at age 3 is shown, with a minimum spawning stock biomass in 2019 (Figure 24). Spawning stock biomass has decreased since the 1990 with correspondent decrease in recruitment.

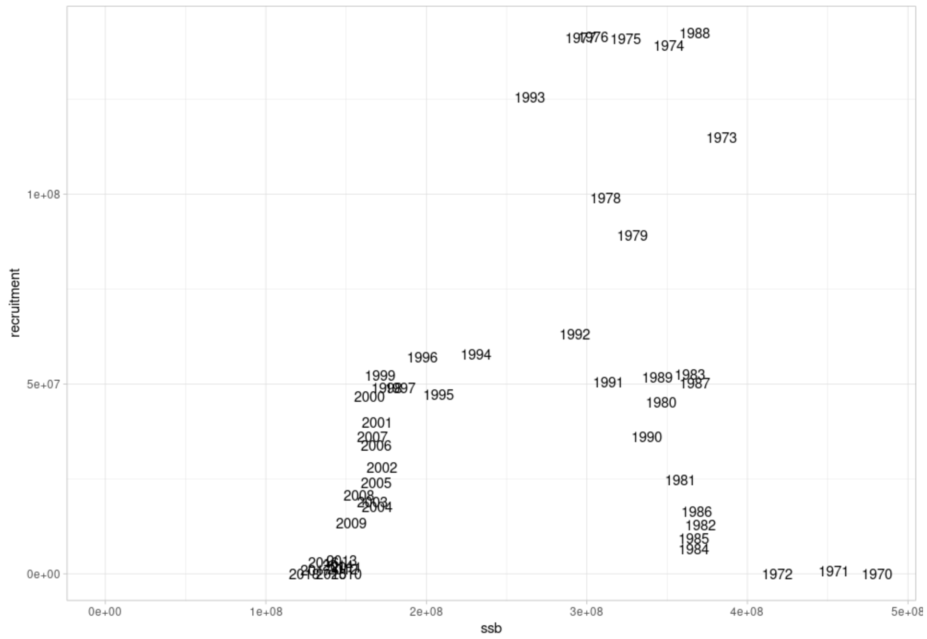

Figure 24. Icelandic slope beaked redfish. Plots of the estimated recruitment age 3 versus spawning stock biomass (lagged by 1 year).

Mynd 24. Djúpkarfi. Samband hrygningarstofns og nýliðunar (3 ára).

REFERENCE POINTS

From the Gadget model it is possible to define reference points for this stock (Table 6 and Figure 25).

Stochastic simulations show that the F_{MSY} = 0.06. B_{lim} = 169 200 t is defined as the median of SSB in 2000-2005 when the stock was stable at low levels. B_{pa} was defined as 236 880 t by adding precautionary buffer to the proposed B_{lim} * 1.4 (approximation of 169 000*exp(0.2*1.645). The plot of the average spawning stock against fishing mortality show that F_{lim} = 0.08 and F_{pa} is then 0.08/exp(1.645*0.2) = 0.058 (Figure 25)

Table 6: Proposed reference points based on the exploratory assessment.

Tafla 6. Djúpkarfi. Tillaga að gátmörkum byggt á stofnmati með Gadget.

Framework	Reference points	Value	Technical basis
MSY approach	MSY $B_{trigger}$	236 880 t	B_{pa}
	HR_{MSY}	0.06	F_{MSY}
	F_{MSY}	0.06	Stochastic simulations.
Precautionary approach	B_{lim}	169 200 t	Median SSB for 2000-2005
	B_{pa}	236 880 t	B_{lim}* 1.4
	HR_{lim}	0.08	F_{lim}
	F_{lim}	0.08	Equilibrium F that will maintain the stock above B_{lim} with a 50% probability
	F_{pa}	0.058	F_{lim}/exp(0.2*1.645)
	HR_{pa}	0.055	F_{pa}

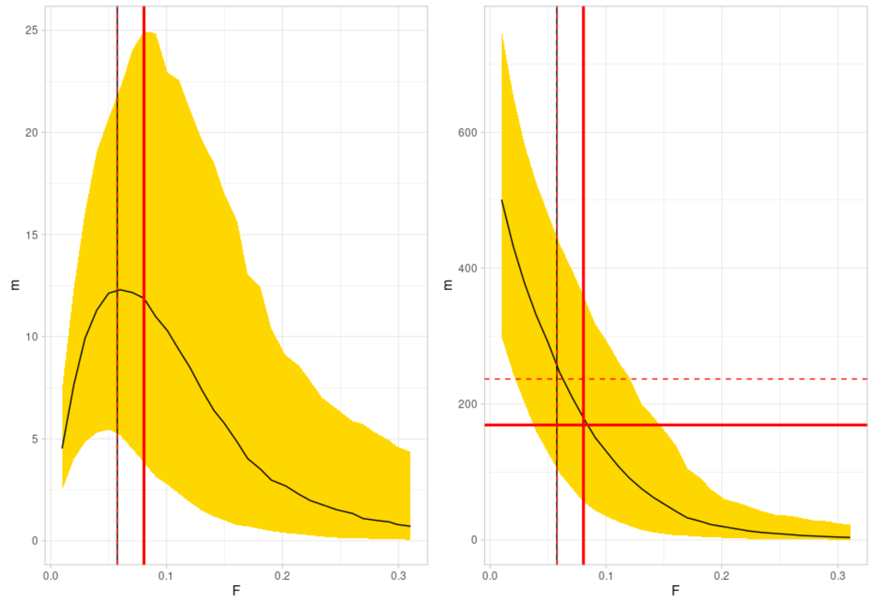

Figure 25. Icelandic slope beaked redfish. Yield-per-recruit (left) and average SSB against average fishing mortality (right). Also shown are the defined reference points.

Mynd 25. Djúpkarfi. Samband afrakstur á nýliða og meðalfiskveiðidauða (vinstri) og samband meðalstærðar hrygningar-stofns og meðalfiskveiðidauða. Einnig er sýnd tillaga að skilgreindum gátmörkum.

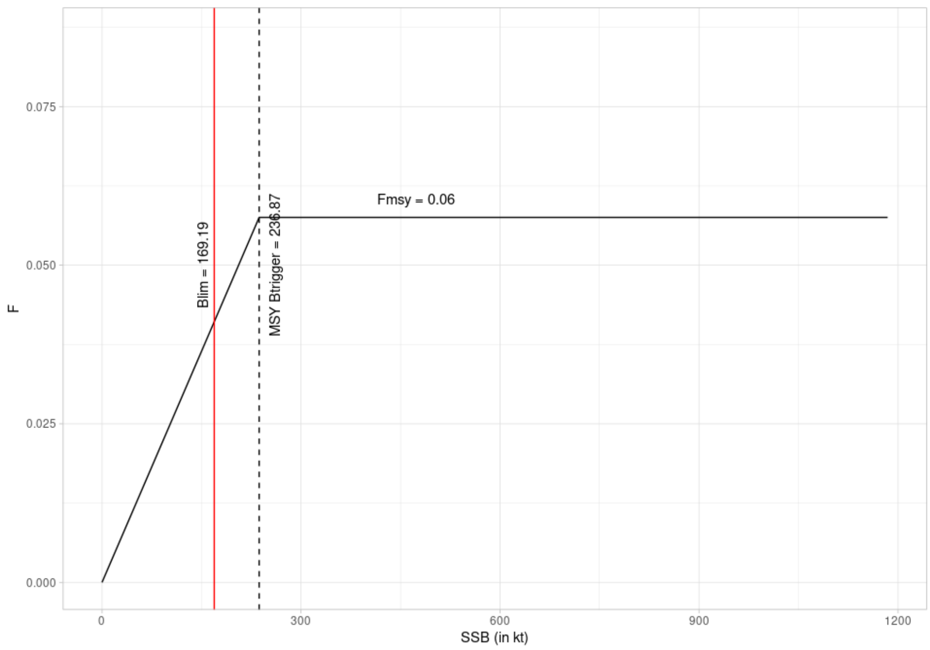

Figure 26. Icelandic slope beaked redfish. Proposed management plan based on the exploratory assessment.

Mynd 26. Djúpkarfi. Tillaga að aflareglu byggt á Gadget líkani.

TABLES

Table 7. Icelandic slope beaked redfish. Nominal landings (in tonnes) of Icelandic slope *S. mentella* 1950-2019 ICES Division 5.a.

Tafla 7. Djúpkarfi. Landaður afli (í tonnum) á Íslandsmiðum 1950-2019.

Year	Belgium	Faroe Islands	Germany	Greenland	Iceland	Norway	UK	Total
1950			36269		1458			37727
1951			45825		1944			47769
1952			55554		885			56439
1953			86011		658			86669
1954			75972		577			76549
1955			52784		654			53438
1956			40047		674			40721
1957			35993		558			36551
1958			43820		409			44229
1959			40175		398			40573
1960			38428		407			38835
1961			31534		307			31841
1962			35122		264			35386
1963			38338		456			38794
1964			45414		362			45776
1965			55930		473			56403
1966			47491		332			47823
1967			47313		357			47670
1968			50892		494			51386
1969			38858		486			39344
1970			35800		500			36300
1971			34376		495			34871
1972			39874		593			40467
1973			35251		794			36045
1974			32103		806			32909
1975			29301		1404			30705
1976			28632		715			29347
1977			22427		590			23017
1978	172	27			3693	10		3902
1979	166	75			7448	5		7694
1980	195	149			9849	5		10198
1981	190	250			19242	7		19689
1982	45	166			18279	2		18492
1983	116	404			36585	10		37115

Year	Belgium	Faroe Islands	Germany	Greenland	Iceland	Norway	UK	Total
1984	65	154			24271	3		24493
1985	108	78			24580	2		24768
1986	92	55			18750			18897
1987	87	72			19132	2		19293
1988	56	56			14177	1		14290
1989	83	172			40013			40268
1990	22	194			28214			28430
1991	71	202			47378			47651
1992					43414			43414
1993					51221			51221
1994			46		56674			56720
1995			229		48479			48708
1996			233		34508			34741
1997					37876			37876
1998			284		32841			33125
1999			527		27475		588	28590
2000			462		30185	50	697	31394
2001			760		15415	26	1030	17231
2002			462		17870	16	697	19045
2003			1094		26295	19	1070	28478
2004			614		16226		724	17564
2005			784		19109		670	20563
2006			509		16339		360	17208
2007				48	17090		234	17372
2008					24125			24125
2009					19429			19429
2010					17642			17642
2011					11738			11738
2012					11965			11965
2013					8761			8761
2014					9500			9500
2015					9311			9311
2016					9536			9536
2017					8371			8371
2018					9995			9995
2019					8716			8716