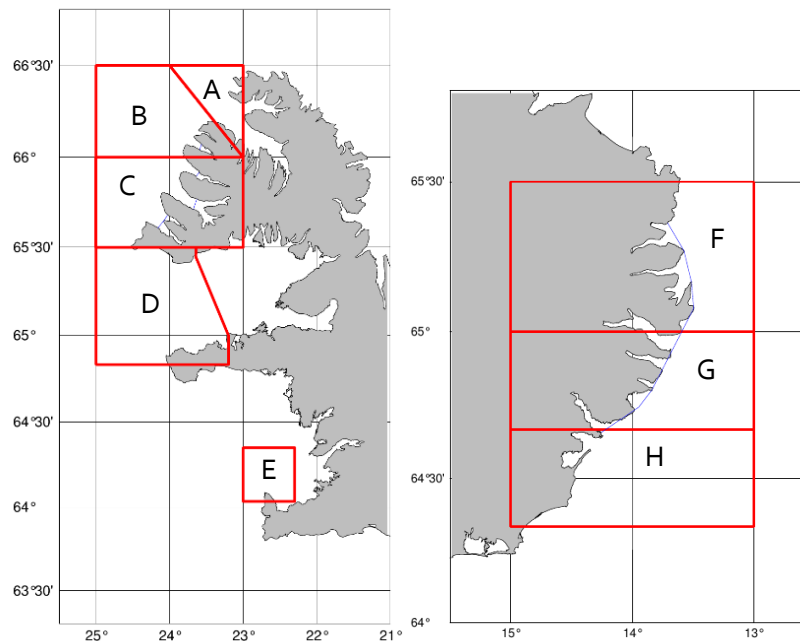


# SEA CUCUMBER

## *Cucumaria frondosa*

### COMMERCIAL FISHING

An experimental fishery for sea cucumber started in Breiðafjörður in 2003, but little was landed until 2008 when fisheries started in Faxaflói (area E, fig. 1) with catch of around 800 t.



**Figure 1. Sea cucumber.** Fishing grounds (A-H) according to regulation from August 2019.

Through the years 2008-2022, annual catches of sea cucumber have fluctuated. The annual catch in Faxaflói (E) ranged from 140-1175 t, off the east coast (areas F & G) from 136-2103 t and 0-559 t in Aðalvík (A). There was an increase in the catches during 2016-2019, but a considerable drop in catches in 2020 and 2021. Maximum landings were 5985 t in 2018; almost twofold increase from 2017, but catches declined to 5606 t in 2019 and to 1098 t in 2020. The low landings in 2020 can partly be explained by the fact that TAC of the 2019/2020 fishing year was almost fully reached during the autumn of 2019 and slower start of the autumn fishery in 2020. According to stakeholders, the slow start was because of a mutual agreement to even out the fishing effort over the full fishing year of 2020/2021. Difficult markets due to the COVID-19 pandemic could also explain the decreased effort. The majority of the 1429 t landed in 2021 were fished during the summer. Catches increased considerably in 2022 to 2822 t.

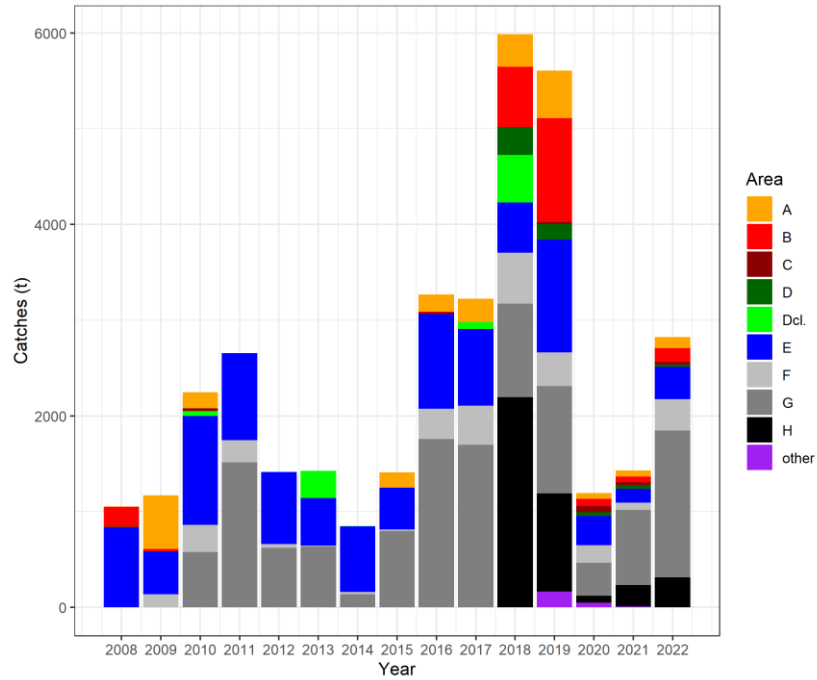


Figure 2. Sea cucumber. Total catch by area during 2008-2022.

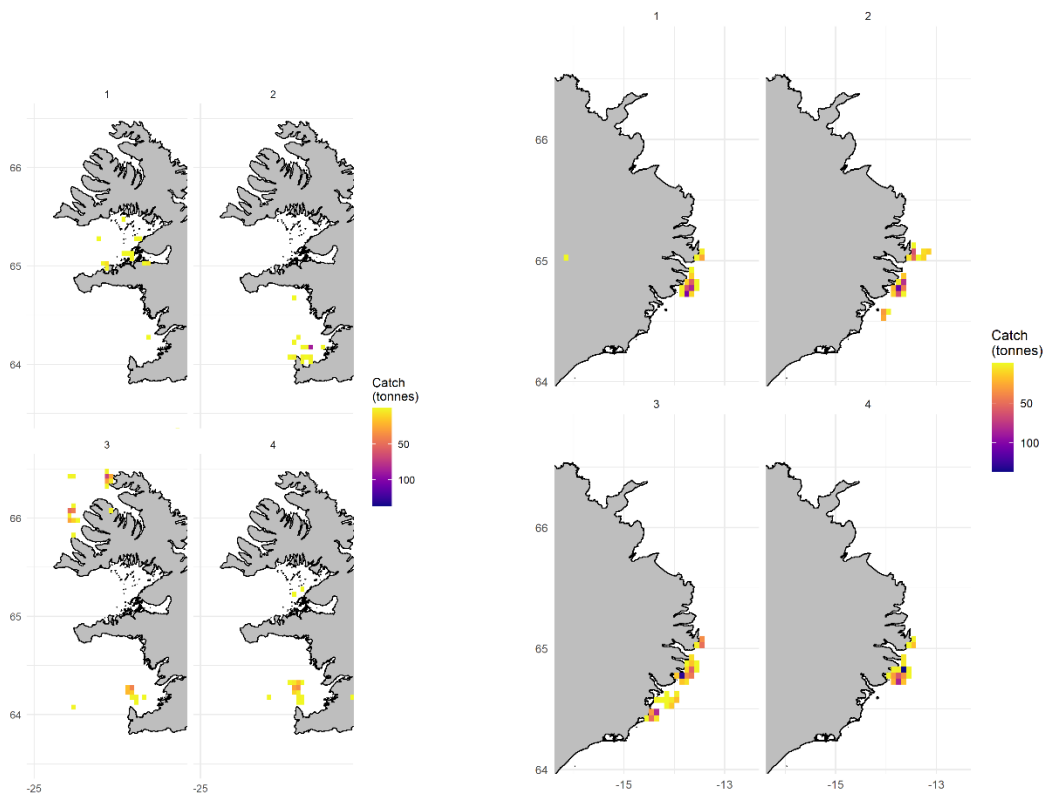


Figure 3. Sea cucumber. Distribution of fishing by quarters (1=Jan-Mar, 2=Apr-Jun, 3=Jul-Sep, 4=Oct-Dec) 2022.

**Table 1. Sea cucumber.** Annual landings by areas (A-H and closed area Dcl., within area D) and total landings.

Year	A	B	C	D	Dcl.	E	F	G	H	Other	Total
2008	2	210	0	8	0	832	0	0	0	0	1052
2009	559	25	0	0	0	448	136	0	0	0	1168
2010	167	0.5	27	0	54	1135	286	577	0	0	2247
2011	0	0	0	0	0	910	231	1514	0	0	2655
2012	0	0	0	0	0	753	39	622	0	0	1414
2013	0	0	0	0	285	493	10	636	0	0	1424
2014	0	0	0	0	2	687	22	137	0.6	0	848.6
2015	163	0	0	0	0	435	15	797	0	0	1410
2016	176	9	15	0	0	989	316	1760	0	0	3265
2017	242	0.7	0.3	0	70	805	408	1695	1.4	0	3222
2018	341	627	0.4	292	496	525	534	975	2195	0	5985
2019	496	1083	23	164	0	1175	354	1121	1024	165	5606
2020	63	74	66	39	0	302	184	345	73	49	1193
2021	64	58	30	39	0	143	78	784	226	7	1429
2022	115	145	28	25	0	337	326	1535	312	0	2822

In 2022, landings from the Westfjord areas were 115 t from Aðalvík (area A), 145 t from area B and 28 t from area C. Landings from area D in outer Breiðafjörður were 25 t and 337 t from Faxaflói (E). In eastern Iceland, 326 t were fished in the north area (F), 1535 t came from the middle area (G), and 312 t from the south area (H).

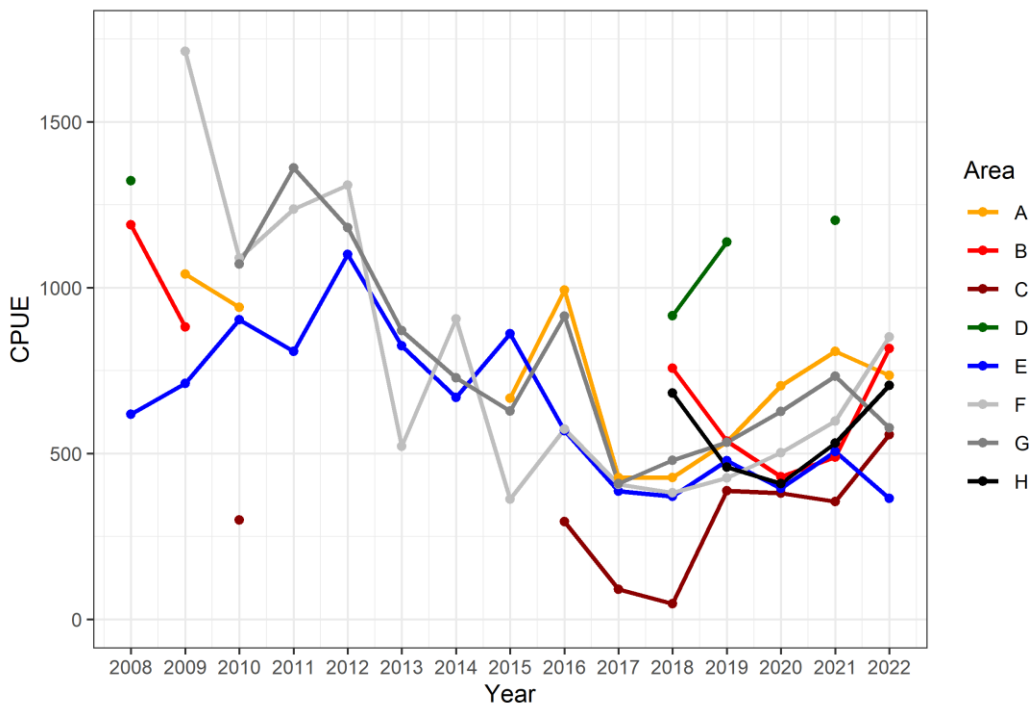
In August of 2019, a new regulation was implemented, and fishing was only allowed on the eight demarcated areas (A-H), experimental license was mandatory for fishing activity outside of those. Within the experimental framework, limited fishing took place in July in northwestern Húnaflói (east of area A), and in August 7 t were fished north of area F.

No fishing is permitted in May and June in the western areas (A-E) and in June and July in other areas due to spawning of sea cucumber. Sea cucumbers are fished by a dredge, 250 cm in width and with minimum mesh size of 80 mm. There is a lack of registration if one or two dredges have been used, but in recent years most of the boats have operated with two dredges (in calculations the effort of those boats was raised by the factor of 1.8).

There has been an overall declining trend in the raw catch per unit effort (CPUE) throughout the history of the sea cucumber fisheries, although a small increase was detected in 2021 on all grounds. Due to technical constraints more than half of the logbook data from 2022 are unavailable.

**Table 2. Sea cucumber.** Raw CPUE by areas (A-H and closed area Dcl., within area D) and CPUE for all areas, during 2008-2022. \*data are partly missing.

Year	A	B	C	D	Dcl.	E	F	G	H	All
2008		1190		1323		618				688
2009	1041	882				712	1713			916
2010	941	334	300		660	904	1090	1071		932
2011						808	1237	1362		1084
2012						1100	1309	1182		1124
2013					757	825	522	871		819
2014					235	669	906	729	159	658
2015	667					861	362	628		676
2016	993	284	295			569	574	914		727
2017	428	181	91		227	386	407	410	162	395
2018	428	757	47	916	732	371	382	479	682	540
2019	535	537	388	1138		478	426	534	459	494
2020	704	430	380			395	502	627	409	452
2021	808	489	355	1203		506	598	733	531	627
2022*	736	817	557			365	852	578	706	603



**Figure 4. Sea cucumber.** CPUE by area during 2008-2022.

## SURVEYS

### Older surveys

From 2008-2010 several surveys were carried out on commercial fishing boats in Aðalvík (A) and Faxaflói (E). Based on 100% gear efficiency biomass was estimated to be 0.3 kg/m<sup>2</sup> in Aðalvík (A) in 2008. In Faxaflói (E) during 2008, biomass was estimated to be 0.13 kg/m<sup>2</sup> at Vestrahraun and 0.18 kg/m<sup>2</sup> at Syðrahraun sub-locations.

In September 2017, a five days drop-frame camera survey was conducted in area G off the east coast of Iceland. In total 55 stations (ten images per station) on two grounds in southern part of the area. The densities of sea cucumbers were 0.6 and 0.7 individuals/m<sup>2</sup>, respectively. The mean whole wet weight (from fish processing) of sea cucumber from this area during the autumn of 2017 was 198 g, that yields a biomass of 0.119 and 0.139 kg/m<sup>2</sup>, respectively (mean 0.13 kg/m<sup>2</sup>).

### Beam trawl surveys (2020 to 2022)

Sea cucumber areas A, B, E, F, G and H were surveyed during a beam trawl survey in autumn 2020. The gear used was a 4 m wide beam trawl, lined with a 40 mm mesh size in the cod end. The beam trawl was towed between 0.5 to 1.2 nautical miles at each station ( $\mu = 0.89$ ) at a speed of 4 nm/h. Start position of each tow and towing direction were randomly generated. Overlapping tows and tows that ended outside known fishing areas based on VMS data were excluded. The second survey was carried out in 2021 and tows from 2020 repeated, one tow was added in area A and two tows were skipped in area E due to a difficult hard bottom. Three tows in area D were added in the survey of 2022.

Average density per nautical mile was from 906 on area H in 2020 to 2346 animals in area D in 2022. In general, small changes were observed within areas between years. Average gutted catch per nm was between 179 kg in area E in 2022 og highest 348 kg on area H in 2021 (Table 3 & figures 7-9). Biomass estimates for each area were based spatial modelling of the average gutted weight and size of know fishing areas (GLMMS model of the sdmTMB R package; Anderson o.fl., 2022). The lowest biomass estimate was in area B, or 1000 t in 2022, but highest 6900 t, on area G in 2022 (Table 3).

**Table 3. Sea cucumber.** Summary of the 2020 -2022 beam trawl surveys. Number of tows in each area, average number of sea cucumber per towed nautical mile, average catch of gutted sea cucumbers, biomass index with 95% confidence interval.

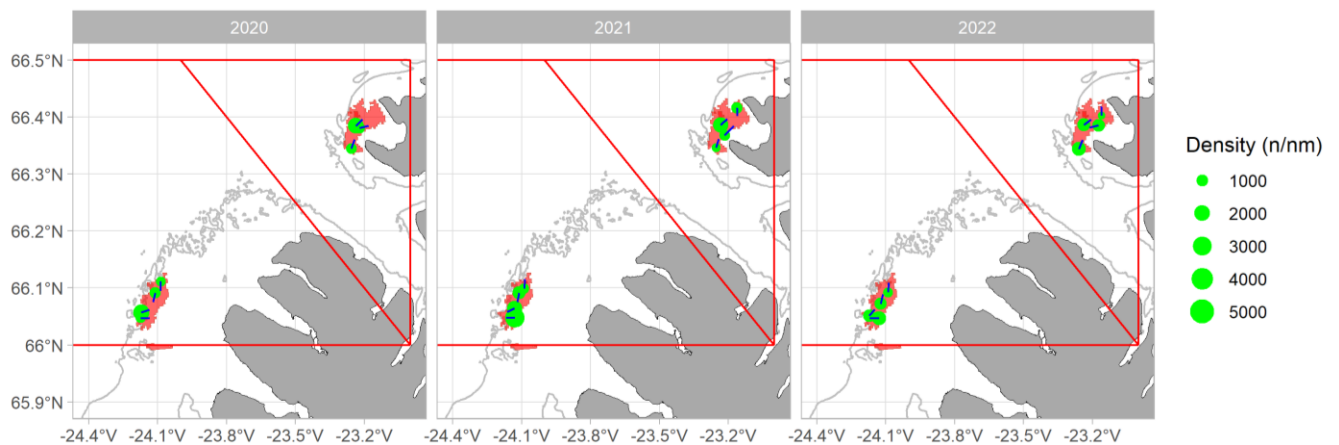
Year	Area	Nr. tows	Numbers	Catch g.	Biom. Index	L. conf.int	U. conf.int
2020	A	3	1229	278	1004725	588007	1716768
2021	A	4	1040	257	1073019	704518	1634265
2022	A	4	1095	237	957479	610323	1502098
2020	B	4	1130	232	788119	517388	1200516
2021	B	4	1757	391	1304225	856161	1986778
2022	B	4	1120	216	720697	480149	1081754
2022	D	3	2346	304			
2020	E	14	1226	179	2935642	2499009	3448565
2021	E	12	1274	188	3050297	2592050	3589558
2022	E	10	1384	190	3091128	2572448	3714388
2020	F	10	1226	253	2074998	1711565	2515603
2021	F	10	1202	275	2191321	1812370	2649507
2022	F	10	1077	228	1926812	1588424	2337290
2020	G	14	1713	347	4733063	4137481	5414378
2021	G	13	1539	348	4996997	4319308	5781015
2022	G	14	1424	317	5090731	4485373	5777791
2020	H	7	906	187	1275780	876973	1855945
2021	H	7	1094	230	1572756	1121180	2206214
2022	H	7	931	196	1339807	929168	1931927

It can be difficult to properly measure the length of the sea cucumbers, as the animal often contracts itself and becomes round shaped. To estimate changes in size frequency, both length and circumference was used, and the new length called "adjusted length". The surface area of the animals was calculated as a cylinder, but without the top and the bottom area (as they are contracted at the ends), and the square root of that number calculated ( $L_a = \sqrt{2 * \pi * r * L}$ ). Length–weight relationship of the new adjusted length was stronger compared to using length or circumference (Fig. 8).

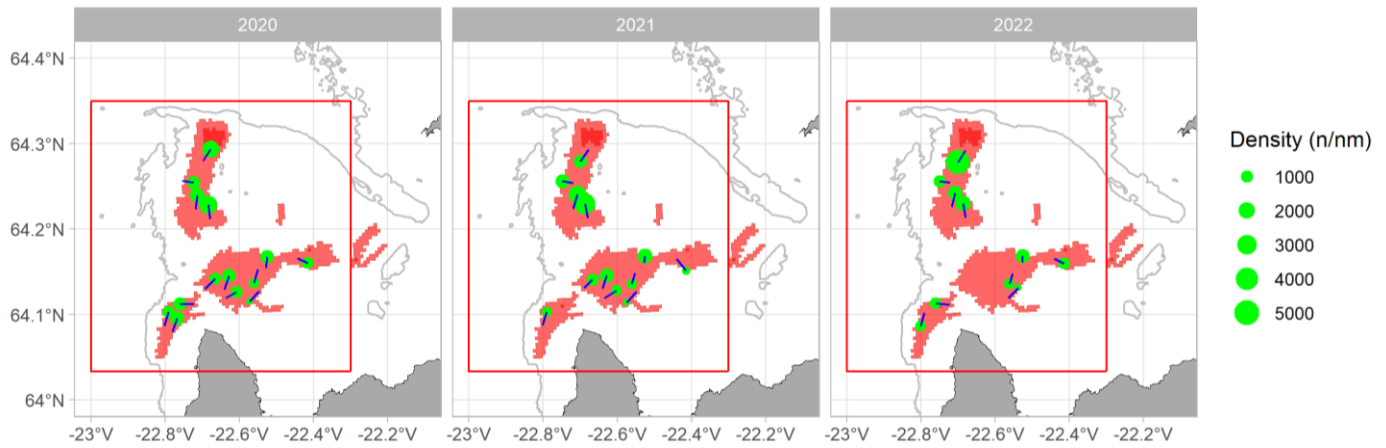
In general sea cucumbers are heavier in eastern Iceland (Areas F-H) compared to areas in western Iceland (Areas A, B & E). The average adjusted length was also larger in the east and in general the cucumbers had thinner walls and were full of water (Figure 8 & table 4).

**Table 4. Sea cucumber.** Summary of the 2020 -2022 beam trawl surveys. Average length (cm), circumference (cm), weight (g) and drained weight (g, without sea and intestines), by areas.

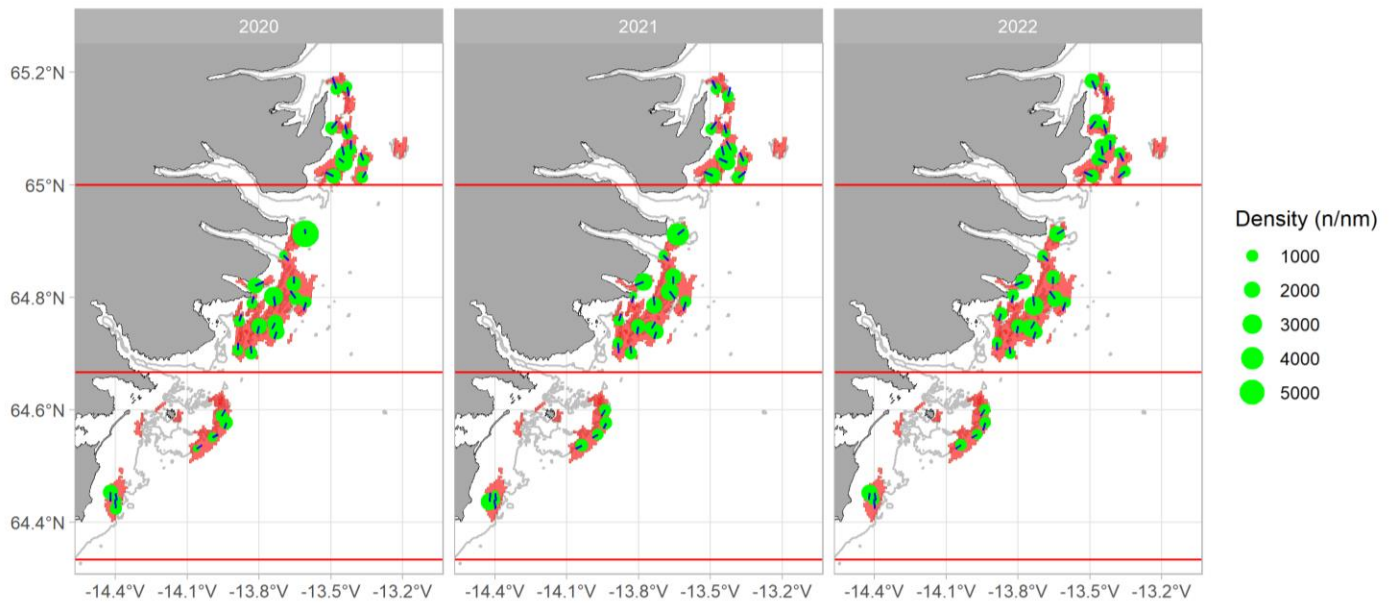
Year	Area	Length	Circum.	Adj. length	Weight	G. weight
2020	A	12.5	24.7	18.8	439.8	234.4
2020	B	12.0	22.5	17.8	366.4	207.1
2020	E	11.9	20.4	16.3	291.7	156.3
2020	F	14.7	28.1	20.8	654.6	207.8
2020	G	14.1	28.5	21.3	664.7	204.3
2020	H	14.1	27.4	20.8	609.4	201.1
2021	A	13.4	25.9	19.6	497.8	241.5
2021	B	14.0	26.4	18.7	443.5	225.1
2021	E	11.5	21.4	16.3	311.5	159.2
2021	F	13.9	28.3	21.0	629.2	225.7
2021	G	14.7	27.5	21.0	643.9	226.5
2021	H	14.1	26.9	21.0	628.5	215.6
2022	A	14.2	25.2	19.5	486.9	212.0
2022	B	12.5	26.0	18.8	459.4	194.2
2022	D	10.3	24.1	16.3	343.6	136.8
2022	E	11.2	21.3	16.3	292.0	151.6
2022	F	14.1	28.7	20.9	658.4	212.5
2022	G	14.3	29.9	21.9	709.3	224.0
2022	H	14.5	29.8	22.2	764.7	220.0



**Figure 5. Sea cucumber.** Density (n/nm) in the 2020-2022 beam trawl surveys in areas A (top right) and B (lower left). Blue lines are tows, red lines define the fishing areas and red polygons represent fishing grounds based on VMS.

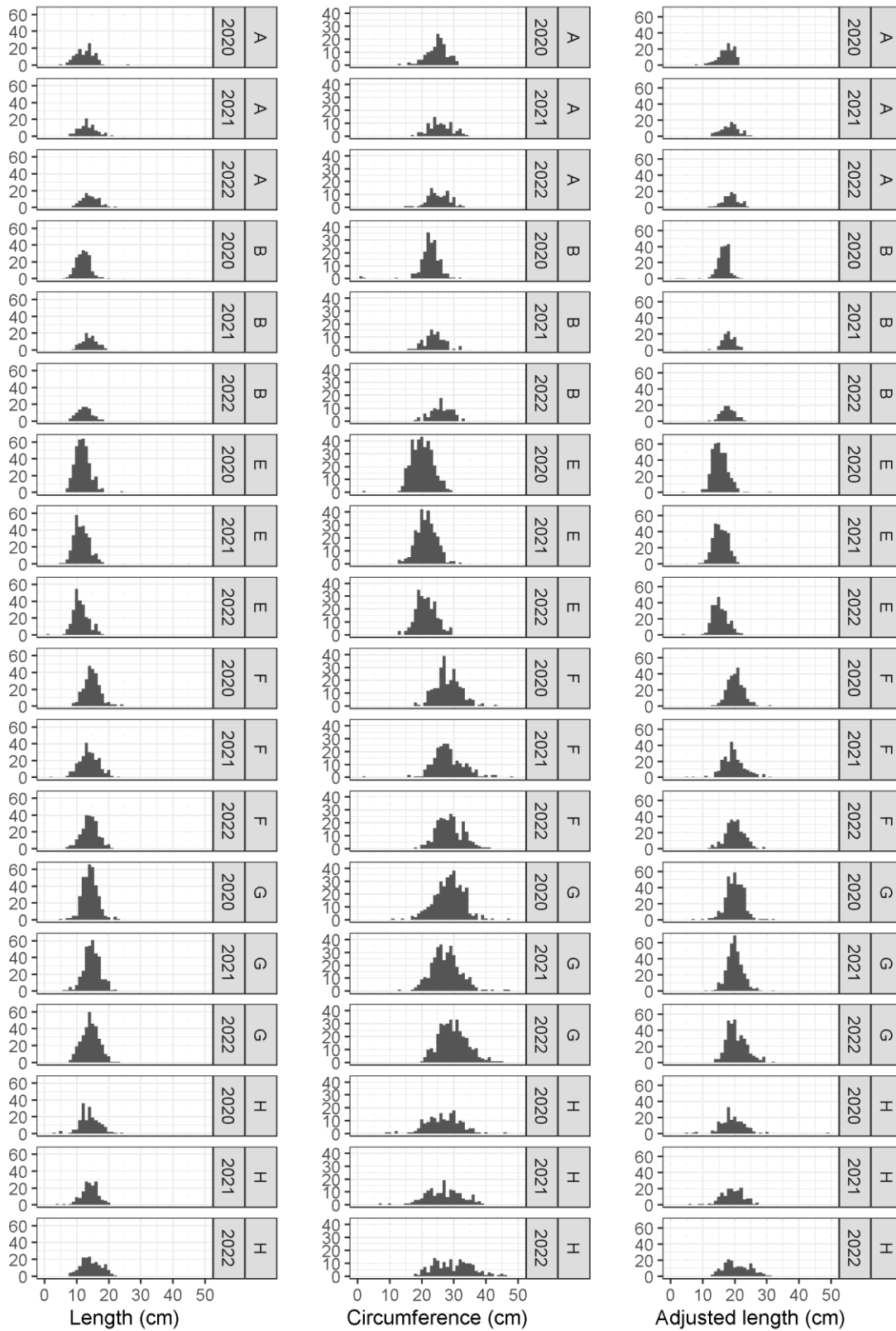


**Figure 6. Sea cucumber.** Density (n/nm) in the 2020 - 2022 beam trawl surveys in area E. Blue lines are tows, red lines define the fishing areas and red polygons represent fishing grounds based on VMS.



**Figure 7. Sea cucumber.** Density (n/nm) in the 2020 - 2022) beam trawl surveys in area F (top), G (middle) and H (lowest). Blue lines are tows, red lines define the fishing areas and red polygons represent fishing grounds based on VMS.





**Figure 8. Sea cucumber.** Length, circumference (girth) and adjusted length distributions in the 2020 – 2021 beam trawl surveys in areas A, B, E-H.

## MANAGEMENT

The Ministry of Food, Agriculture and Fisheries is responsible for management of the Icelandic fisheries and implementation of legislation. The sea cucumber stocks were included in the ITQ system in 2022, but prior to that when the issued TAC had been reached the area was closed with a regulation issued by the Ministry.

In 2009 three fishing zones were demarcated by the Ministry: 1) Western area: Reykjanes to Skagatá, 2) Northern area: Skagatá to Glettinganes and 3) Southern and eastern area: Glettinganes to Reykjanes. For each of these zones three fishing licenses were issued and it was not allowed to move from one zone to another. However, no fishing was conducted in the Northern area as limited fishing trials did not give positive results. In 2013, the Ministry abolished the area restriction. Initially, the main fishing areas were in Faxaflói and Aðalvík in the Western area, and since 2009 also off the east coast belonging to the Southern and eastern area. In 2013, the main fishing areas were defined by coordinates (Regulation 795/2013).

In 2009, the stock status in Faxaflói and Aðalvík were estimated, the fishing areas defined, and total allowable catch (TAC) advice issued for the first time. In 2012, the stock status off the east coast was estimated, which resulted in advice for demarcated area during the fishing year 2013/2014. Total TAC was given for the eastern area even though it was divided into two areas, until 2018/2019 when the TAC was divided (area F and G). When the maximum allowable catch had been reached within an area, the area was closed, but further fishing could be continued outside the defined areas.

In a letter in February 2019, the Ministry of Industries and Innovation requested an advice on fishing opportunities for sea cucumber by increasing number of sea cucumber management areas built on fishing ventures outside the previously managed areas (A, E, F & G). The new (mostly adjacent) areas were granted, and the management areas are now eight (A-H) (Anon, 2019).

## STOCK ASSESSMENT

The catch advice for the quota year of 2023/2024 follows the ICES framework for stock's where analytical stock assessment can't be implemented but biomass indices and information on life history are available (Areas A, B, E-H). The advice follows the *rfb*-rule of ICES (ICES, 2021):

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

where  $A_{y+1}$  is recommended catch,  $A_{y-1}$  is recommendation of previous year,  $r$  is the biomass ratio of last two years (Index A) vs the three previous years (Index B):

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

This year, due to short available time series (Table 3) and insufficient log-book data of 2022, the ratio of last year survey biomass index compared to the previous two years, was used.

$f$  is a fishing proxy for the exploitation (mean catch length divided by an MSY reference length):

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

where  $\bar{L}$  is the mean catch length above  $L_C$  (The length where frequency is half that of the modal value, see figure 9). For the sea cucumber, adjusted length from survey was used (Figure 10).

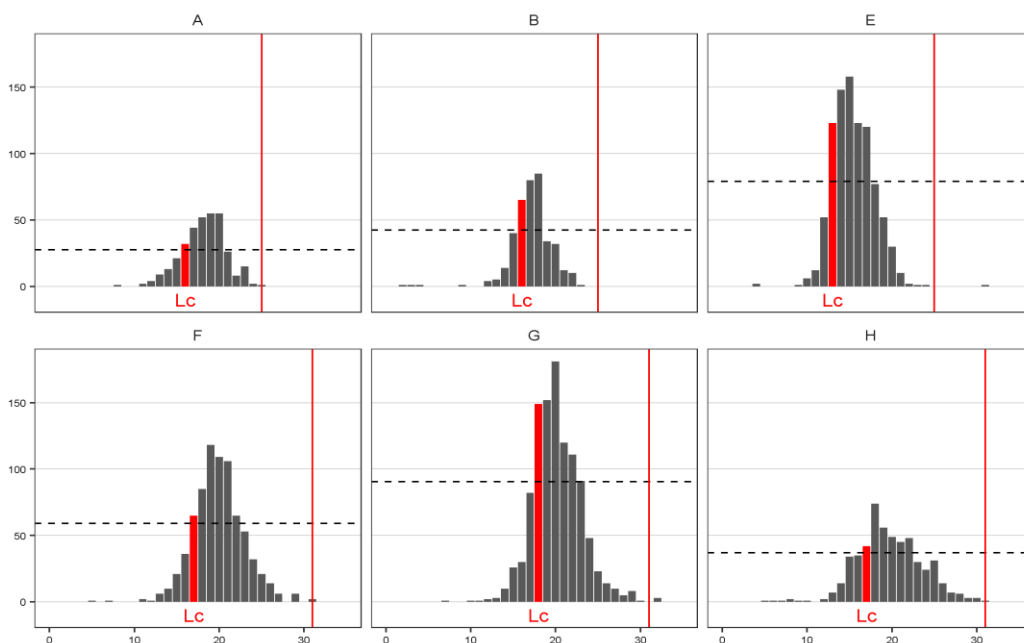
$L_{F=M}$  is calculated as:

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

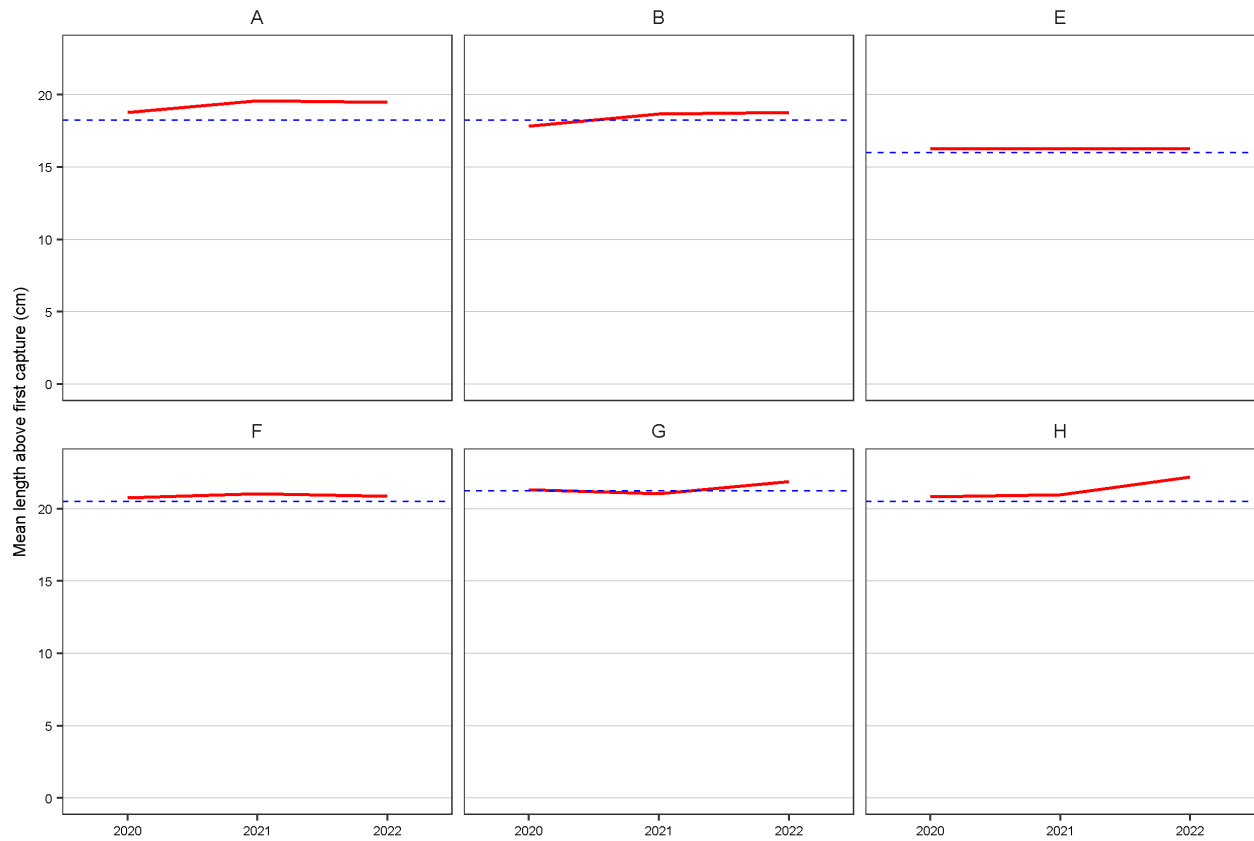
where  $L_C$  is the length where the frequency is half that of the modal value, and  $L_\infty$  is von Bertalanffy  $L_\infty$ .

$b$  is the biomass safeguard and is used to reduce catch advice when index falls below trigger, but that value has not yet been defined for the sea cucumber stocks.

$m$  is a multiplier based on stock growth. For slow growing species like the sea cucumber (Hamel & Mercier, 1996),  $m = 0.95$ , but for fast growing species,  $m = 0.9$ . In general, advice according to the  $rfb$  rule is applied for two years (ICES, 2023), but due to short biomass time series, the advice is given for one year.



**Figure 9. Sea cucumber.** Adjusted length frequency distribution from surveys on areas A, B, E, F, G & H. Red bars indicate the length where the frequency is greater than half that of the modal value ( $L_C$ , broken line indicates the 50% frequency). Red horizontal line denotes  $L_\infty$ .



**Figure 10. Sea cucumber.** Mean adjusted length higher  $L_c$ , from surveys in fishing areas A, B, E, F, G & H. Broken blue lines shows MSY reference length ( $L_{F=M}$ ).

Catch advice for each area is given in advice sheets but a summary table for previous years is found below.

**Sea cucumber.** Recommended TAC, national TAC, and landings 2007/2008-2022/2023 by areas.

Quota year	Area A (Aðalvík)			Area B (Westfjord; middle)			Area C (Westfjord; south)			Area D (Breiðafjörður, outer)			Area E (Faxaflói)		
	R.TAC	TAC	Landings	R.TAC	TAC	Landings	R.TAC	TAC	Landings	R.TAC	TAC	Landings	R.TAC	TAC	Landings
2007/2008			2			107						8			478
2008/2009			469			124						0		*	477
2009/2010	350		173			3						0	950	*	1066
2010/2011	310	*	85			0,5			27			0	1500	*	900
2011/2012	310	*	0			0			0			0	1500	*	1015
2012/2013	310	*	0			0			0			0	1500	*	349
2013/2014	170	*	0			0			0			0	1030	*	814
2014/2015	170	*	160			0			0			0	1000	*	446
2015/2016	170	*	169			9			15			0	1000	*	981
2016/2017	190	*	244			0			0			0	644	*	684
2017/2018	102	*	248			523			1			198	644	*	700
2018/2019	102	*	321			860			23			207	644	*	833
2019/2020	102	*	276	131	*	324	50	*	51	56	*	52	515	*	539
2020/2021	122	*	126	131	*	131	50	*	45	56	*	56	330	*	317
2021/2022	146	*	115	105	*	145	50	*	28	56	*	47	328	*	224
2022/2023	176			105			40			45			371		
	Area F+G (East)			Area F (East; north)			Area G (East; middle)			Area H (East; south)					
2007/2008			0												
2008/2009			0												
2009/2010			572			414			159						
2010/2011			1880			229			1651						
2011/2012			791			39			752						
2012/2013			807			19			787						
2013/2014	1400	*	72		*	7		*	65						
2014/2015	1400	*	600		*	4		*	596						
2015/2016	1400	*	1740		*	115		*	1625						
2016/2017	623	*	1738		*	415		*	1323			0.2			
2017/2018			1482	245	*	481	740	*	1001			1710			
2018/2019				245	*	345	740	*	781			1089			
2019/2020				245	*	240	740	*	1091	406	*	392			
2020/2021				280	*	239	828	*	848	406	*	270			
2021/2022				303	*	297	994	*	1006	325	*	302			
2022/2023				346			1192			325					

\*Areas were closed by regulation issued by the Ministry when the TAC is reached.

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