Northwest Atlantic Fisheries Organization

Serial No. N7532 **NAFO SCR Doc. 24/026**

SCIENTIFIC COUNCIL MEETING – JUNE 2024

Trawl and gillnet survey results from Disko Bay, NAFO Division 1A inshore

by

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Abstract

This paper presents the updated indices for the surveys performed by the Greenland Institute of Natural resources (GINR) in the Disko Bay located in NAFO division 1A inshore. The Disko Bay has been part of the Greenland Shrimp and Fish survey (trawl) in West Greenland (SFW) since 1992. Greenland halibut in the Disko Bay was previously also surveyed with longlines, but in 2001 the longline survey was replaced by a gillnet survey directed at pre-fishery recruits. A larger meshed section (90 mm half mesh) was added to the gillnet survey from 2016 to survey the commercial part of the stock and increase the number of large Greenland halibut for ageing. Biomass and abundance indices from the trawl survey in 2023 were relatively similar compared to previous recent years. CPUE and NPUE from the gillnet survey were higher in 2023 compared to 2022, but lower compared to 2021, which were the highest recorded estimates of the time series.

Introduction

Greenland halibut is of major importance to the people living in the area. Surveys have been conducted since the 1960's with longlines. However, the longline surveys showed high interannual variability and are not presented here. The Disko Bay has been part of the Greenland shrimp and fish survey (SFW) since 1991. In 2001 the longline survey was changed to a gillnet survey intended to target pre-fishery recruits. Gillnets have narrow selection curves targeting certain size groups depending on the mesh size of the gillnets. This document presents the main findings of the SFW survey and the Gillnet survey for the Disko Bay part of the surveys.

Survey area

The *Disko Bay* is characterized by areas of smooth bottom and depths that are mostly less than 600 meters (Fig. 1). Glaciers are located in the North-Eastern part of the bay at *Torssukattak* and in the central Eastern part of the Ilulissat Icefjord, where deeper waters are located (+900m). Ilulissat Icefjord (*Kangia*) was declared a UNESCO World Heritage Site in 2004 because of its natural beauty and the importance of the fast-moving Jakobshavn Glacier. The glacier often fills the icefjord south and east of Ilulissat with massive icebergs that strand at the Ilulissat Icefjord Bank just south of the city Ilulissat. Therefore, the icefjord is rarely accessible during the summer months. The Disko Bay is connected to the Baffin Bay through the western part and in the NorthWestern part through the narrow fjord *Vaigat.*

Materials and methods

Longline surveys (not presented here)
Surveys have been conducted in the area since the mid 1960's, using different types of longlines. The longline surveys were highly variable from year to year and not easily interpreted (for further details see Simonsen *et al*. 2000).

Trawl surveys
The central part of the Disko Bay and the slopes of Vaigat are trawlable with a substantial shrimp fishery occurring. The Disko Bay has been part of the West Greenland Shrimp and Fish survey (SFW) since 1991. From 1991 to 2017 the survey was conducted with the 722 GRT stern trawler M/Tr 'Pâmiut'. In 2005 the gear was changed in this survey, but since then the area coverage and the trawl and its rigging has been unchanged. RV Pâmiut was decommissioned in 2017 and from 2018 to 2020 the survey was updated with a chartered vessel using Pâmiut's gear. No survey was conducted in 2021. Since 2022 the survey is annually updated with the new GINR research vessel R/V Tarajoq.

Gillnet survey

In 2001, a gillnet survey replaced the poorly performing longline survey in the Disko Bay. The main objective for starting the gillnet survey was a well-estimated selectivity and the possibility for targeting pre-fishery sized Greenland halibut (35-55 cm TL). However, with a gradual decrease over two decades in the size of the landed Greenland halibut, commercial landings presently contain Greenland halibut down to about 35 cm. The gillnet survey uses fixed positions of stations arranged in transects towards the important fishing grounds West of Ilulissat city and Torssukattak Icefjord in the northeastern part of the Disko Bay. The gillnets are composed of 60 m long sections with mesh sizes 46, 55, 60 and 70 mm (knot to knot or half mesh). Sections are separated with a 2 m open space to prevent catchability interactions. Soak time is approximately 6-18 hours and fishing occurs both day and night. Stations are paired two and two, close to each other (0,5-1 NM) to allow for analysis of within-station variability. Since 2016 a 90 mm section (half mesh) was added to the gillnet survey to increase the number of large Greenland halibut and also survey the commercial part of the stock. Since 2012 the survey has been conducted annually with the GINR research vessel R/V Sanna.

Biological samples

Length, weight, gutted weight, otoliths, and occasionally DNA samples are regularly collected during the surveys. Otoliths are collected from individual Greenland halibut and frozen in a plastic bag with a printed plastic label with individual information and an automatically created number. At the GINR, otoliths are read digitally after a method originally developed in Norway. In the laboratory otoliths are photographed with translucent light with a Leica S9i stereomicroscope in a 5 mp TIF image. After imaging the otoliths are dried and archived. Digitally archived images are then "read on screen" using imageJ. In ImageJ both contrast and brightness can easily be adjusted, and a calibration beam allows for digital measurements of otolith proportions. Images are standardized and attempts for automated digital reading are being tested.

Age length key

An age length key (ALK) is produced from the aged otoliths for each cm group for the Disko Bay for each year. If the ALK is incomplete for certain lengths, a backup ALK (derived from all northern inshore areas) is used for the missing length combinations. The backup-ALK produced from all inshore areas in a given year, is screened for the missing length-age combinations. To produce a complete backup-ALK, missing ages for certain lengths are estimated from the von Bertalanffy growth equation.

Results

An overview of the most recent surveys and successful stations by year, vessel and gear is given in table 1.

The number of otoliths collected in the survey has been between 500 and 1000 in most years (Table 2). Ageing of the otoliths was previously done by looking at the dried otolith through a stereomicroscope. However, from 2007 to 2009 the method changed to looking at fresh frozen otoliths through a stereomicroscope. Uncertainty about the method led to a lack of reading until 2017. In 2017 the ageing was done by taking a high resolution (14mb) digital image under a Leica S9i digital stereomicroscope, and frozen otoliths are being aged using this method back to 2007 still stored frozen at GINR.

Trawl survey in the Disko Bay

The Greenland Shrimp and Fish survey in the Disko Bay, identified increasing abundance during the 1990s and high abundances were found from 1998 to 2005 (Skjaervoy trawl timeseries) (Fig. 2). In 2005 the Cosmos trawl was introduced, and the time series was broken. After 2006 the abundance indices returned to the lower levels except for the high abundances identified in 2011, 2013 (Fig. 2). Although such large recruitment events of age 1 have not been observed since then, the abundance indices have remained stable or slightly increasing. The length distribution in the survey shows higher than average numbers of ages 2 and 3 in most of the recent 5 years, indicating good recruitment. Especially the abundance of 2-year-old Greenland halibut in 2017-2019 and 2022-2023 (2015 YC, 2017 YC respectively) and 3-year-old in 2018, 2020, and 2022 (2015, 2017 and 2019 YC, respectively) seems far above average (Fig. 3). Greenland halibut are found all over the Disko Bay (Fig. 4 and 5).
The biomass indices in the trawl survey indicate a steady increase during the 1990s, with a substantial increase observed in 2003 and 2004 (Fig. 2, right). However, the indices in 2003 and 2004 were based on fewer stations (Table 1) and seem unreliable. After the gear change in 2005, the biomass index gradually decreased until 2014. Subsequently, the biomass index has gradually increased. In 2023, the biomass index decreased slightly compared to 2022 but remains far above the recent decade (Fig. 2).

Gillnet survey in the Disko Bay

The gillnet survey CPUE and NPUE indicated low levels of pre-fishery recruits in 2006 and 2007 but returned to above average levels in 2008 and 2010 (Fig. 6). The increase in 2011 NPUEs was observed in the northern area of the Bay, while in the main fishing grounds at the Icefjord bank around Ilulissat the NPUEs remained low (Fig. 6). The high numbers of larger fish in 2011, did not seem to have any origin in the previous year estimated populations. From 2013 to 2017 the gillnet CPUE and NPUE indices gradually decreased to below average. However, from 2017 to 2021 the NPUE and CPUE gradually increased to the highest levels observed in the timeseries (Fig. 6). The substantial decrease observed in the 2022 gillnet survey seems far outside the trend in the most recent years and may be an outlier. In 2023, the CPUE returned to above average levels.
The 90 mm section added in 2016 has in general not impacted the overall length distribution observed in the Disko Bay, indicating few larger individuals (55-70 cm) are present in the surveyed area (Fig. 7).
Although the distribution of the stations varies from year to year, biomass and abundance increases in recent years appear evenly distributed over all stations (Fig. 8).
The strong year-classes observed in the trawl survey are also visible in the gillnet survey from 2018 and onwards (Fig. 9). Overall, the gillnet survey implies very good recruitment in recent years with the 2015 YC being particularly large, potentially followed by good 2017 and 2018 year classes.

A Catch-At-Age (CAA) for the survey is calculated on basis of the new digital age readings (Table 3 and Fig. 9). The method holds several advantages that will not be mentioned here. The LW relationship for the sampled Greenland halibut is given in table 6.

Discussion

Trawl calibration experiments indicated that the difference in catchability between the gears was length dependant for Greenland halibut and was at equilibrium at lengths around 12 cm, but twice as high at 40 cm. Since the abundance is highly influenced by 1-year-old recruits (10-17 cm), which normally constitute 80-90% of the abundance in the survey, there is little impact on the abundance index. This is not true for the biomass index, where calibration has a higher impact. However, since the calibration experiments revealed an almost 1:1 relationship between the most abundant individuals, but a stronger difference of individuals that must have

been rare in the experiments, this could also imply that the catchability difference between the trawls are overestimated. The indices prior to and non-calibrated indices after the gear change are at the same level for Greenland halibut (but also other species), indicating that the effect of the gear change on the indices may be overestimated.

The correlation between the abundance of Greenland halibut >35 cm in the trawl survey and the NPUE indices from the gillnet survey, provides increased credibility in the survey indices of both surveys. The surveys generally occur separated by a month or less and in the same overall areas at the same depth intervals. The trawl survey covers most of the bay and relies on randomly distributed stations, whereas the gillnet survey relies on fixed stations.
If comparing the gillnet NPUE (all sizes) to the trawl survey indices of Greenland halibut larger than 35 cm, the surveys seem correlated to some extent. This correlation between the surveys seems to disappear in the 2019 and 2020 survey. The correlation between the surveys could be caused by an evenly distributed stock with a high overlap in size selectivity of the two very different gears in relation to the present length distribution of the stock.

In the beginning of the Disko Bay gillnet survey time series commercially landed Greenland halibut were larger in the area and fish smaller than 55 cm were regarded pre-fishery recruits. However, in the recent decade smaller and smaller Greenland halibut have been landed and nowadays the fishery targets Greenland halibut as small as 30 cm with smaller hooks and a legal reduction of the mesh size in the commercial gillnets from 110mm to 95mm (half mesh). Ocationally use of finer meshed gillnets (80 mm) selecting Greenland halibut around 1 kg most efficiently has also been documented (illegal use of cod gillnets used to target Greenland halibut). Therefore, the gillnet survey is increasingly surveying both recruits and the fished stock.

Recruitment
Although recruitment seems variable from year to year at age 1, in most years this does not seem to apply for age 2 or 3. Often strong or weak YC estimates at age one seem close to average levels a year or two later. It has been suggested that this may be related to density dependant mortality in years of extra high recruitment (Sünksen et al. 2009). However, the recent year classes (2015 YC and later) that can be followed in the length distribution in the trawl survey from 2016 to 2018 and in the gillnet survey from 2018 to 2021 tell a different story. The length frequencies in both the gillnet survey and the trawl survey indicates an unusually good recruitment in recent years of 3year old Greenland halibut around 30cm. These year classes are showing up in the CAA plot as age 4, 5 and 6. Age 6 in this case has reached a size of close to 50 cm and 1 kg corresponding to the mean size in the commercial catches.

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Table 1. Number of stations by gear and area (Table is incomplete).

Year	Trawl	Vessel	Longline	Gillnet	Vessel	Mesh size and notes
1990	*	Pa			AJ	
1991	41	Pa			AJ	
1992	39	Pa			AJ	
1993	31	Pa	31	-	AJ	
1994	27	Pa	32	-	AJ	
1995	33	Pa	-	-	--	
1996	33	Pa	29	-	AJ	
1997	34	Pa	24	-	AJ	
1998	33	Pa	-	-	-	
1999	34	Pa	26	-	AJ	
2000	23	Pa	35	-	AJ	
2001	23	Pa	15	8	AJ	46,55,60,70
2002	22	Pa		55	AJ	46,55,60,70
2003	19	Pa		56	AJ	46,55,60,70
2004	14	Pa	8	50	AJ	46,55,60,70
2005	16	Pa	9	47	AJ	46,55,60,70
2006	21	Pa	3	44	AJ	46,55,60,70
2007	18	Pa	2	30	AJ	46,55,60,70
2008	16	Pa	0	35	Ch	46,55,60,70
2009	24	Pa	-	-	-	
2010	25	Pa	0	48	AJ	46,55,60,70
2011	26	Pa	0	50	AJ	46,55,60,70
2012	21	Pa	0	41	Sa	46,55,70. (60 mm defect)
2013	17	Pa	0	27	Sa	46,55,60,70
2014	21	Pa	0	37	Sa	46,55,60,70
2015	17	Pa	0	26	Sa	46,55,60,70 floats changed from rings to danline.
2016	12	Pa	0	54 (76)	Sa	46,55,60,70,90. 22 extra stations to survey cod.
2017	30	Pa	0	36	Sa	46,55,60,70,90
2018	20	Sj	0	42	Sa	46,55,60,70,90
2019	17	HM	0	32	Sa	46,55,60,70,90
2020	22	HM	0	40	Sa	46,55,60,70,90
2021	0	-	0	44	Sa	46,55,60,70,90
2022	25	TA	0	46	Sa	46,55,60,70,90
2023	25	TA	0	53	Sa	46,55,60,70,90

Note: Research vessels: RV Paamiut (Pa), RV Adolf Jensen (AJ), RV Sanna (Sa), CV Sjurdaberg (Sj), CV Helga Maria (HM), Chartered vessel (Ch), R/V Tarajoq (TA).

Table 2. Number of Greenland halibut otoliths collected in the surveys.

Year	Area	Number of otoliths				
Year		Gillnet	Trawl	Total	Aged	Method
2003	Disko Bay	?	212	212		Dried whole
2004	Disko Bay	?	120	120		Dried whole
2005	Disko Bay	442	95	537		Dried whole
2006	Disko Bay	207	47	254		Dried whole
2007	Disko Bay	285	67	352	59	Frozen whole
2008	Disko Bay	0	307	307	59	Frozen whole
2009	Disko Bay	0	527	527	476	mixed
2010	Disko Bay	363	347	710	91	Frozen image
2011	Disko Bay	344	565	909	0	Frozen image
2012	Disko Bay	320	194	514	78	Frozen image
2013	Disko Bay	264	300	564	235	Frozen image
2014	Disko Bay	343	286	629	53	Frozen image
2015	Disko Bay	233	290	523	125	Frozen image
2016	Disko Bay	347	431	778	345	Frozen image
2017	Disko Bay	346	467	813	179	Frozen image
2018	Disko Bay	741	472	1213	212	Frozen image
2019	Disko Bay	364	371	735	343	Frozen image
2020	Disko Bay	372	401	773	750	Frozen image
2021	Disko Bay	465	0	465	440	Frozen image
2022	Disko Bay	747	518	1265	289	Frozen image
2023	Disko Bay	366	464	830	296	Frozen image

Table 3. Greenland halibut *Reinhardtius hippoglossoides* abundance and biomass indices from the GINR shrimp and fish trawl survey.

Year	Stations	Abundance			Biomass		
		Skjaervoy	Cosmos		Skjaervoy	Cosmos	
		Million	Million	CI	1.000 tonnes	1.000 tonnes	
1992	39	96.73		27	4.992		22
1993	31	33.96		28	2.507		27
1994	27	62.96		22	3.598		26
1995	33	89.41		32	5.786		51
1996	33	102.5		25	8.593		22
1997	34	112.1		22	6.456		29
1998	33	209.6		29	11.874		35
1999	34	95.4		35	8.060		44
2000	23	172.8		30	9.537		30
2001	23	223.7		28	10.161		32
2002	22	148.1		38	9.070		40
2003	19	227.0		36	16.556		28
2004	14	199.1		34	28.229		36
Gear change				CV			CV
2005	16		186.5	12		22.580	12
2006	21		96.9	11		20.246	12
2007	18		128.5	13		13.137	18
2008	16		64.6	12		16.422	13
2009	24		72.9	8		19.902	20
2010	25		123.3	9		17.559	11
2011	26		230.7	16		23.977	10
2012	21		105.9	8		16.168	7
2013	17		187.9	16		15.103	9
2014	21		103.7	15		11.463	12
2015	17		84.1	11		13.180	15
2016	12		115.1	16		11.772	12
2017	30		113.2	14		12.040	13
2018	20		95.3	15		17.355	11
2019	17		81.7	16		11.602	12
2020	22		138.1	8		15.130	9
2021							
2022	25		126.0	9		21.052	9
2023	25		129.5			18.945	

Table 4. CPUE and NPUE from the gillnet survey in the Disko Bay.

Year	Number of stations	CPUE	SE	NPUE	SE	remarks
2001	8	18.08	4.35	19.96	5.38	Few stations
2002	55	9.44	1.68	8.97	1.35	
2003	58	12.94	4.98	14.55	5.24	
2004	51	14.86	2.76	18.94	4.16	
2005	47	16.32	3.12	17.88	2.45	
2006	44	8.89	2.46	10.30	2.38	
2007	30	7.12	1.97	8.36	2.04	
2008	35	14.80	3.88	18.60	4.76	
2009	0		0		0	No survey
2010	48	14.01	2.83	15.78	3.72	
2011	51	25.10	2.83	24.96	3.72	
2012	41		0		0	Defect 60 mm
2013	27	12.53	2.38	13.53	2.86	
2014	37	12.42	2.50	13.69	2.34	
2015	25	10.11	1.78	10.48	1.57	
2016	52	9.69	1.01	10.14	0.97	
2017	36	9.14	1.21	10.61	1.63	
2018	42	10.91	1.41	16.34	1.66	
2019	32	16.44	3.43	19.84	3.62	
2020	40	18.86	1.79	24.84	1.94	
2021	44	27.40	3.04	35.56	3.04	
2022	46	12.87	1.34	18.70	1.56	
2023	53	17.35	2.05	20.31	2.05	

Table 5. Catch-At-Age table for the gillnet survey (index=Number/100 hrs).

Year	Index	Age2	Age3	Age4	Age5	Age6	Age7	Age8	Age9	Age10	Age11	Age12	Age13	Age14	Age15	Age16
2012	157	0	1	24	41	34	26	23	4	1	2	0	0	0	0	0
2013	225	0	7	41	85	48	27	13	4	1	0	0	0	0	0	0
2014	228	0	0	7	15	68	48	68	19	3	0	0	0	0	0	0
2015	168	0	3	15	47	41	30	20	7	4	0	0	0	0	0	0
2016	163	0	2	25	47	42	23	14	5	2	0	0	0	0	0	0
2017	177	1	3	3	28	45	42	29	14	11	0	1	0	0	0	0
2018	272	7	28	66	55	46	36	20	7	3	3	0	0	0	0	0
2019	331	1	2	33	127	92	42	19	9	2	1	2	0	0	0	1
2020	414	2	26	144	169	51	17	3	1	0	0	0	0	0	0	0
2021	593	1	14	125	251	149	42	8	4	1	0	0	0	0	0	0
2022	312	0	0	1	12	79	155	44	13	5	1	0	0	0	0	0
2023	338	0	7	63	151	50	36	26	5	1	0	0	0	0	0	0

Table 6. **M**odelled length-weight relationship for Greenland halibut.

Year	Area	Number fish	Log a	b	R^2
2008	Disko Bay	578	-12.616	3.244	0.989
2009	Disko Bay	827	-12.516	3.224	0.997
2010	Disko Bay	348	-12.687	3.270	0.994
2011	Disko Bay	563	-12.595	3.246	0.990
2012	Disko Bay	513	-12.541	3.235	0.987
2013	Disko Bay	564	-12.479	3.212	0.995
2014	Disko Bay	628	-12.275	3.144	0.992
2015	Disko Bay	523	-12.515	3.221	0.995
2016	Disko Bay	778	-12.626	3.256	0.996
2017	Disko Bay	813	-12.344	3.189	0.986
2018	Disko Bay	1210	-12.557	3.241	0.994
2019	Disko Bay	733	-12.589	3.249	0.995
2020	Disko Bay	771	-12.584	3.252	0.996
2021	Disko Bay	461	-12.949	3.345	0.988
2022	Disko Bay	1258	-12.361	3.176	0.992
2023	Disko Bay				

Weight = exp(log (a)) * $Length^b$

Figure 1. Map of the Disko Bay.

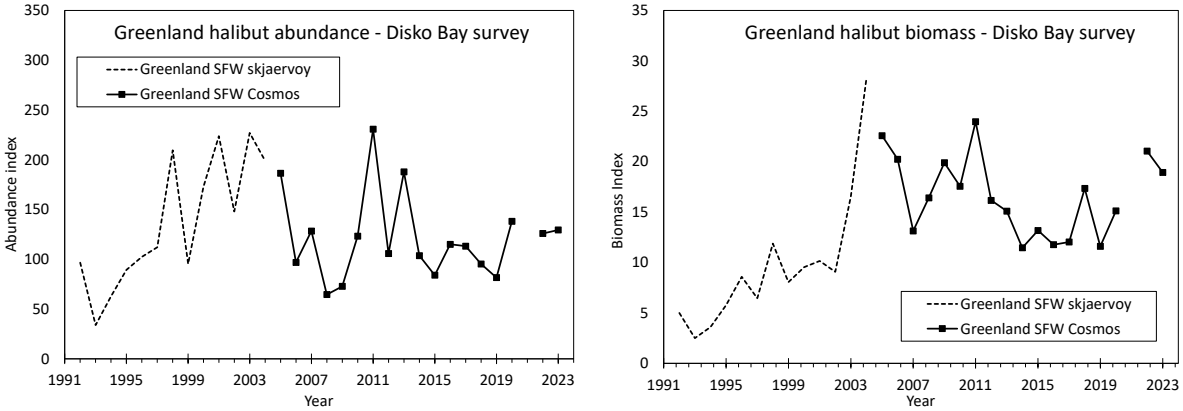

Figure 2. Trawl survey (SFW) in the Disko Bay: Abundance (left) and biomass (right). No survey was conducted in 2021.

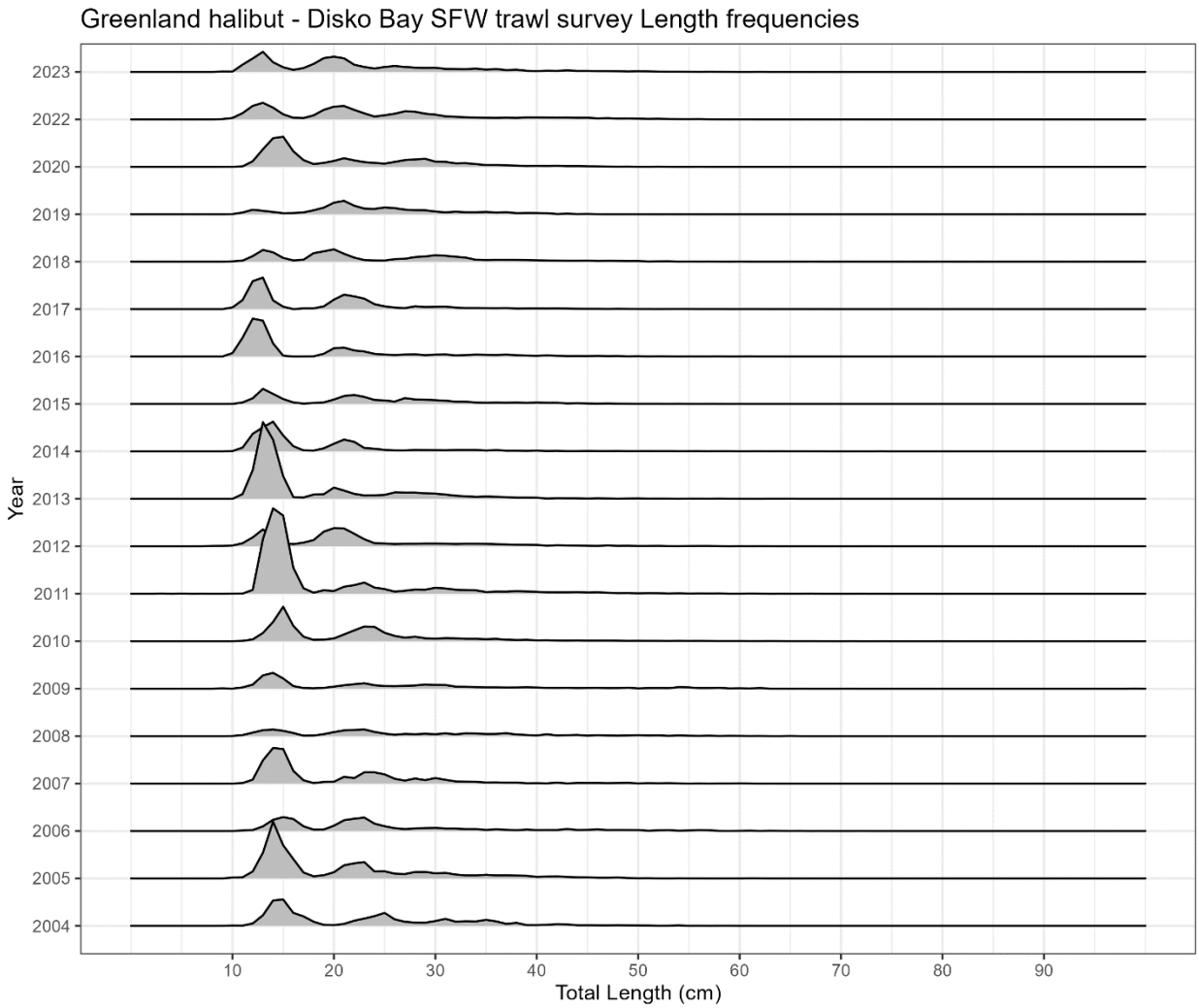

Figure 3. Greenland halibut length frequency distributions from the Disko Bay part of the GINR Shrimp and fish survey.

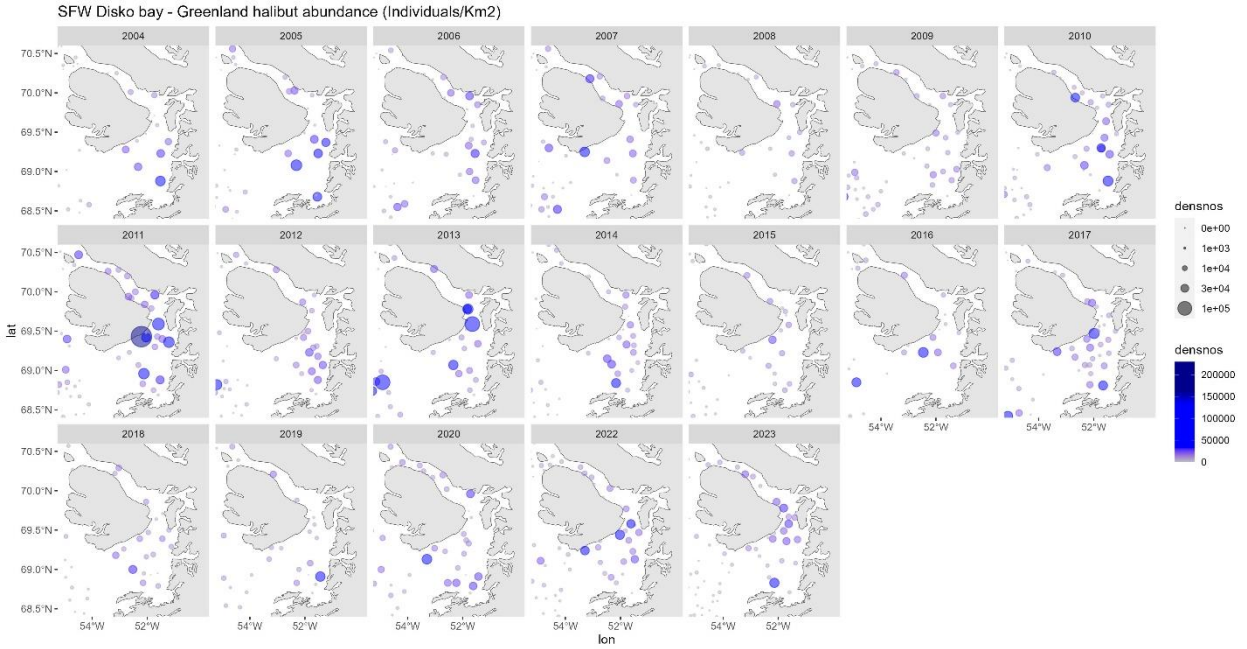

Figure 4. Abundance distribution (individuals/km²) from the Disko Bay part of the GINR Shrimp and fish survey.

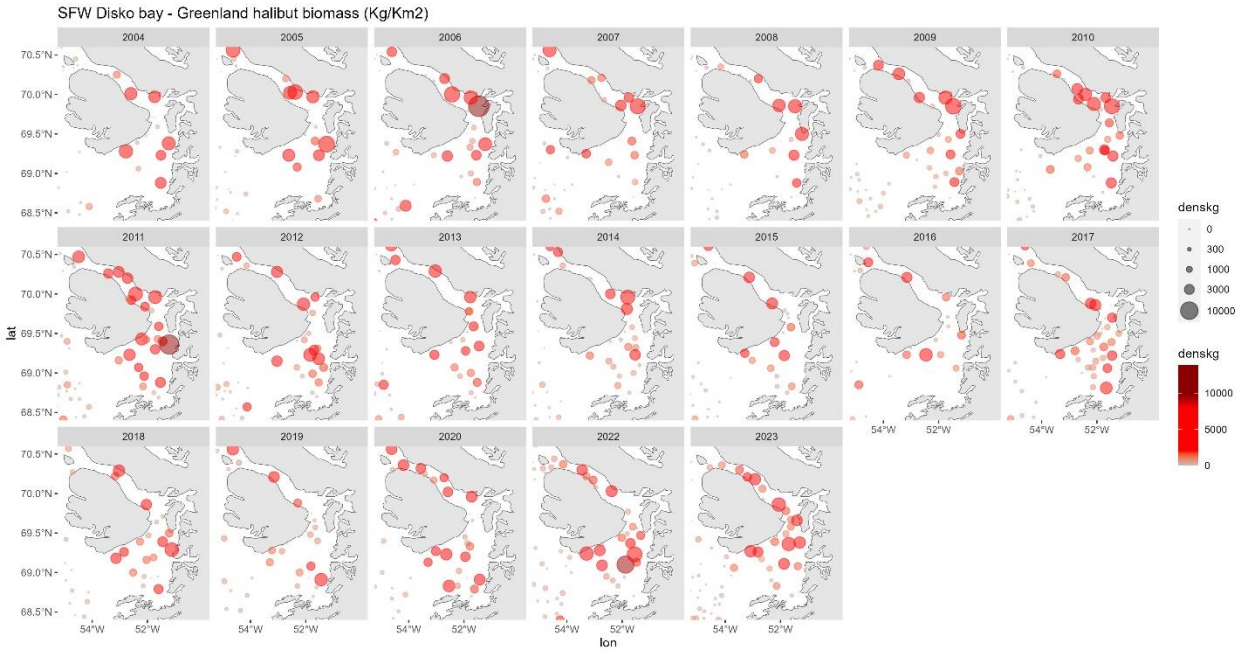

Figure 5. Biomass distribution (Kg/km²) from the Disko Bay part of the GINR Shrimp and fish survey.

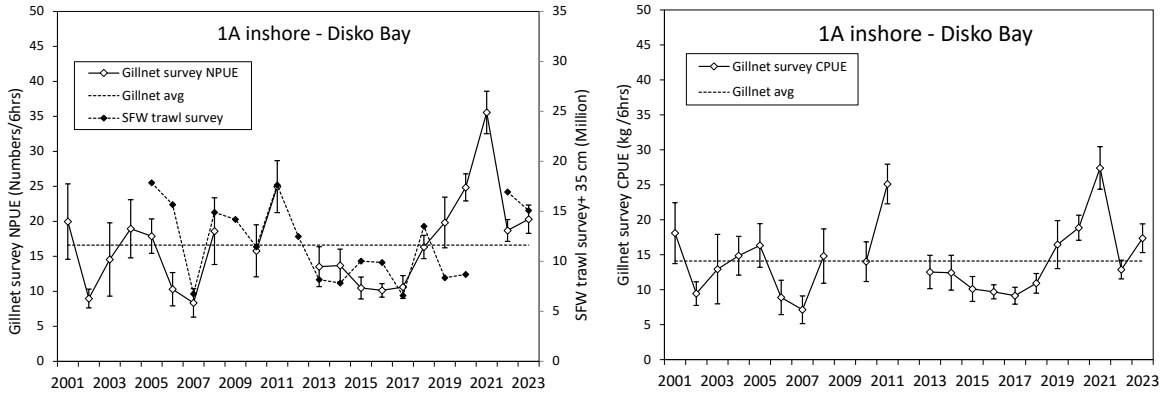

Figure 6. Disko Bay gillnet survey NPUE of Greenland halibut (all sizes) combined with SFW trawl survey abundance estimates of Greenland halibut sizes 35-100 cm (left) and gillnet survey CPUE (right).

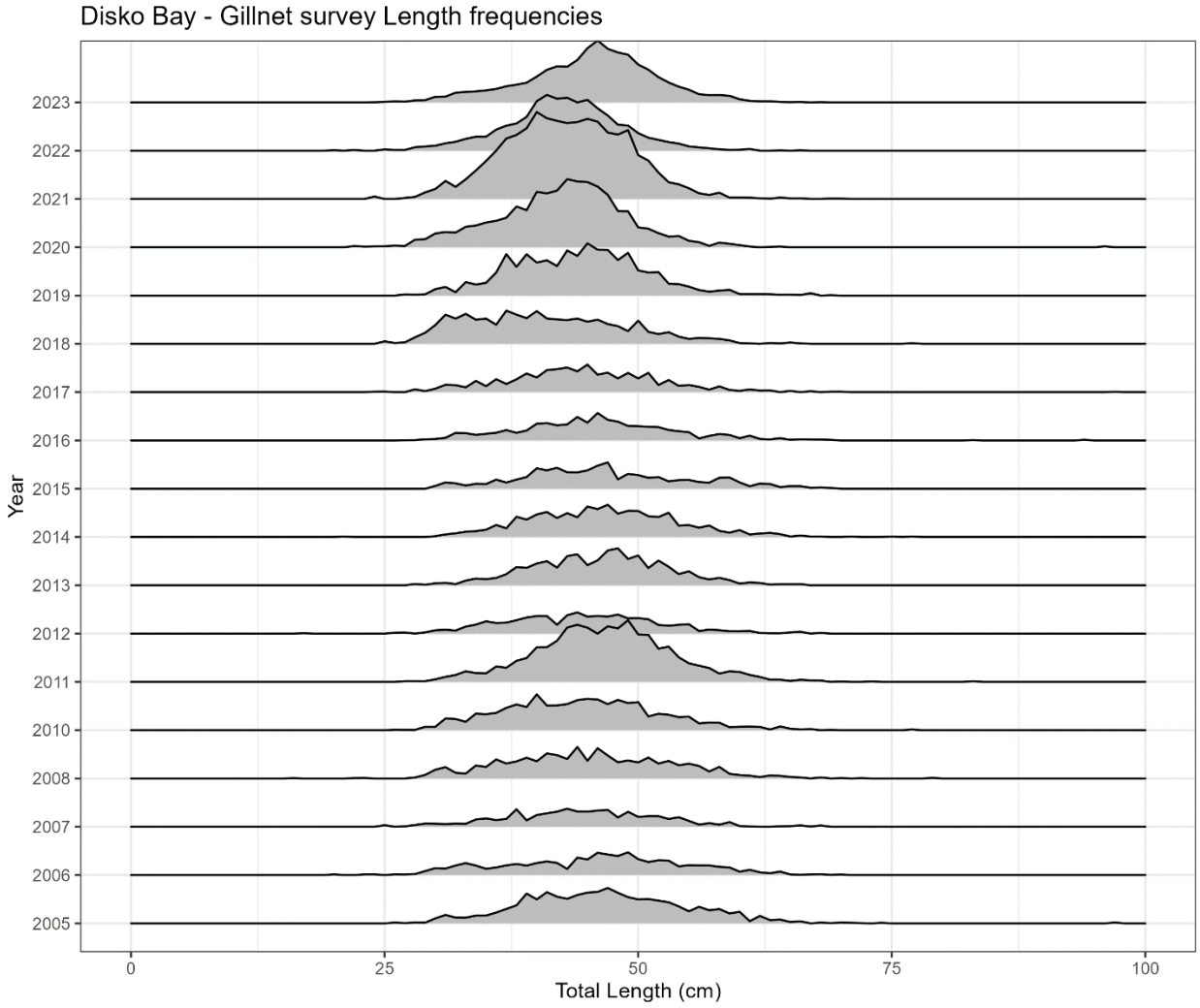

Figure 7. Observed length frequency distributions (N/100hr) for Greenland halibut from the gillnet survey in Disko Bay (45, 55, 60, and 70 mm mesh size).

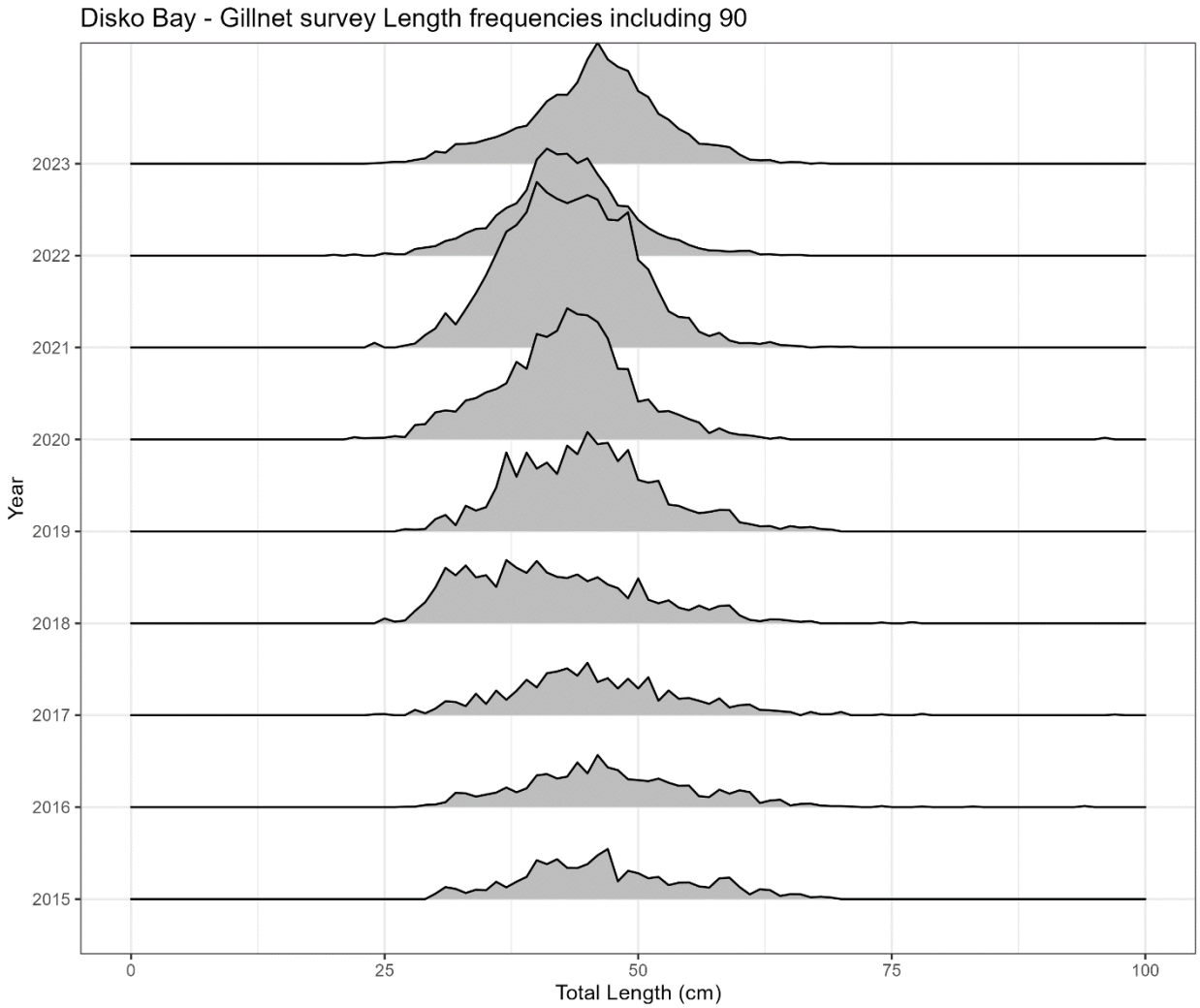

Figure 8. Observed length frequency distributions (N/100hr) for Greenland halibut from the gillnet survey in Disko Bay including 90 mm mesh (i.e. 45, 55, 60, 70, and 90 mm mesh size).

catch

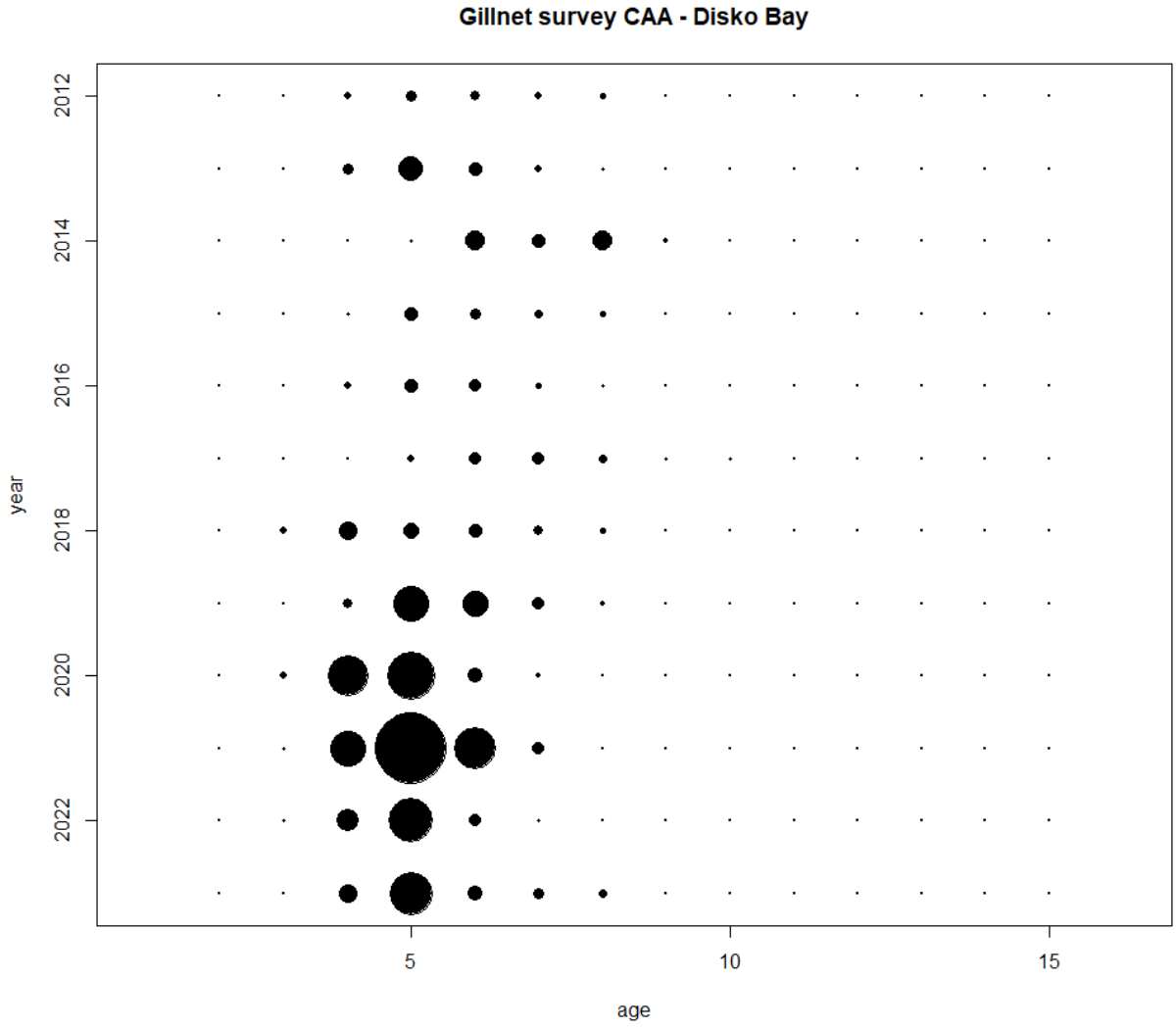

Figure 9. Disko Bay survey Catch-At-Age (CAA) bubble plot.

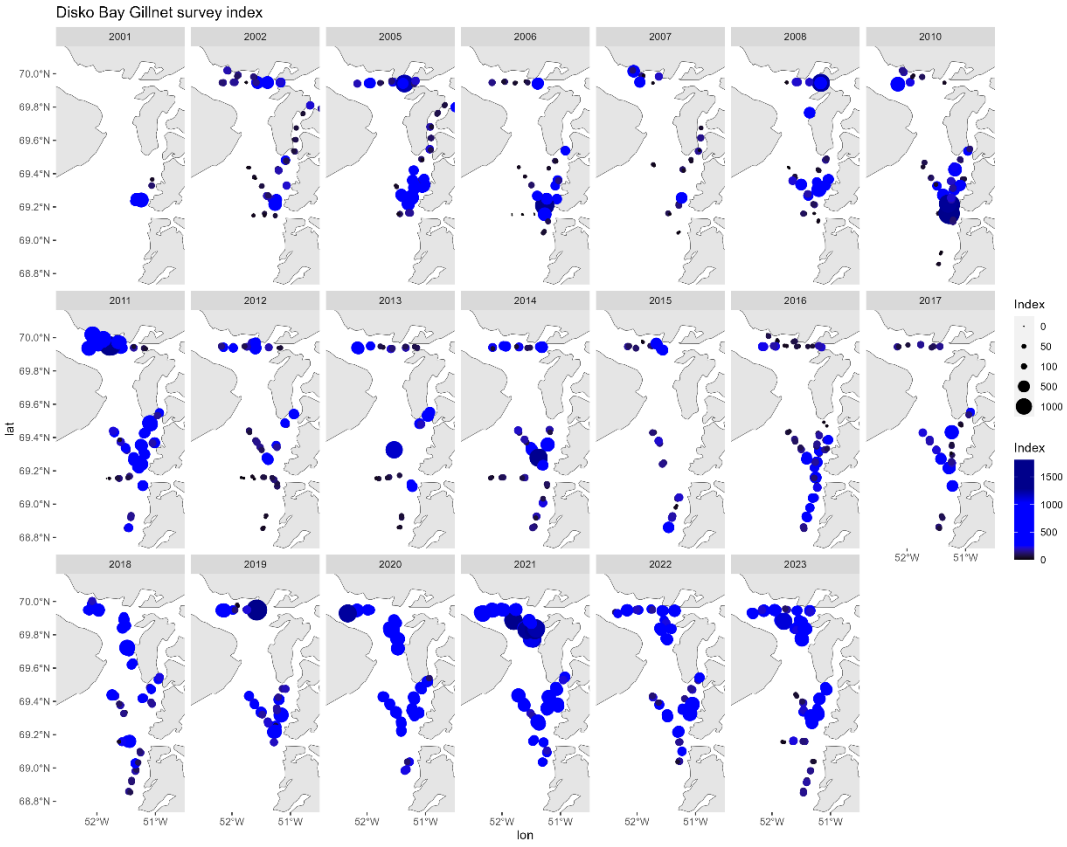

Figure 10. Distribution of NPUE (Number/gillnet/100 hrs) from the gillnet survey in Disko Bay by year.