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Data available for the Greenland Halibut Stock Component inNAFO Subarea 0 + 1 (offshore)

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Abstract

The paper presents the data available for Greenland halibut in Northwest Atlantic Fisheries Organization (NAFO) Subareas 0 and 1 (offshore) that can be used for stock assessment. Since 1995 catches have been near the TAC, increasing in step with increases in the TAC. Greenland and Canada have conducted buffered random stratified bottom trawl surveys in Div. 1CD and 0A-South which are combined for the stock assessment. Surveys were not conducted in 2018, 2020 or 2021 and the 2019 survey was conducted with a charter vessel which after review of gear performance measures was not considered comparable to previous surveys. In 2022, a new survey index starts in 1CD and 0A-South with a new vessel and a new gear. As a result there has been no data from offshore surveys that could be used to give advice, since 2017. The combined 1CD-0A-South biomass index had been relatively stable from 1999 to 2017 and all values were above the Blim for the survey series. Abundance followed a similar pattern. An updated index of abundance of age 1 Greenland halibut from the shallow survey, in1AF, was available for 2022. An index of the exploitable biomass > 35 cm from that survey is also available and can be used for surplus production models. A CPUE index for trawlers fishing in SA 0+1 has been declining since a peak in 2018, and the gillnet CPUE for SA0 declined in 2021 after a continued increase from the beginning of the series in 2003 to 2020. It has been stable from 2020 to 2021. However, CPUE is known to have limitations as an index of population status.

1. Overview of the fishery

1.1.TAC Regulation

Greenland halibut in Subarea 0+1, including 1A inshore, came under quota regulation in 1976 when a TAC of 20,000 t was established (Fig. 1). TAC increased to 25,000 t in 1979. In 1994 analysis of tagging and other biological information resulted in the creation of separate management areas for inshore Div. 1A and Subarea 0+1A (offshore) and 1B-F. The portion of the TAC allocated to Subarea 0+1A (offshore) and 1B-F was 11,000 t and the TAC remained at this level from 1995-2001, during which time the TAC was fished almost exclusively in Div. 0B and Div. 1CD. A series of surveys took place during 1999-2004 in areas of Div. 0A and 1AB that had not been surveyed before. This new information on biomass in the stock area resulted in increases in the overall TAC of 4,000 t in both 2001 and 2003 and 5,000 t in 2006 that were allocated to Div. 0A and 1AB. From 2006 to 2009 the advised TAC in Div. 0A+1AB was 13,000 t and the TAC for 0B and 1C-F remained at 11,000 t. Based on an observed positive trend in the 1CD survey index the TAC for Div. 0B+Div. 1CF was increased by 3,000 t in 2010 and the overall TAC for Subarea 0+1 (offshore) remained at 27,000 t from 2011-2013. In 2014 the TAC for Div. 0A+Div. 1AB was increased by 3,000 t to 16,000 t based on positive trends in the survey indices and the overall TAC of 30,000 t remained through 2016. In 2016 an index based harvest control rule (HCR) was accepted as the basis for TAC advice and an increase of 2,300 t was advised for the entire Subarea 0+1A (offshore) and 1B-F stock area for 2017 and 2018. Scientific Council allocated the increase equally to Div. 0A+1A(offshore) and 1B, and 0B+1C-F. In 2018 the HCR was used to advise an increase of 4,070 t for the whole of Subarea 0+1A(offshore) and 1B-F with allocation among divisions left to the managers. In 2020 separate management areas were established for inshore fishing areas in 1B-F and the TAC for Subarea 0+1A-F (offshore) was maintained at 36,370 t for 2021 and 2022. However, in 2022, SC was unable to assess stock status because of a lack of usable survey data from 2018-2021, which followed a TAC increase in 2018. SC noted that the stock had varied without trend between 2013-2017, prior to the most recent TAC increase, and recommended that the TAC for 2023 and 2024 not exceed the average catch during period, 29,640 t. In 2023 both Canada and Greenland asked SC to determine if surveys conducted in 2022 provided sufficient new information to reconsider TAC advice for 2024; SC reviewed the new data and considered efforts to develop a model-based framework for this fishery, and determined that there was not sufficient new information to provide new TAC advice.

1.2.Catches in Subarea 0 + 1 (offshore)

Catches were first reported in 1964 and rose to 18,303 t in 1975 before declining to 187 t in 1986 (Fig. 1). Catches then increased to 17,888 t in 1992 due to a new trawl fishery in Div. 0B with participation by Canada, Norway, Russia and Faeroe Islands, and an expansion of the 1CD fishery with participation by Japan, Norway and Faeroe Islands (Tables 1 and 2). Catch declined from 1992 to 1995 primarily due to a reduction of effort by non-Canadian fleets in Div. 0B. Since 1995 catches have been near the TAC, increasing in step with increases in the TAC (Fig. 1). The TAC was 36,370 t from 2019 to 2022. In 2022 catches were 36,485 t. In 2023 the TAC was reduced by 9.25% to 33005 t.

Fisheries and Oceans Canada does not include the J-cut, tail off product in its list for Greenland halibut but an interim conversion factor of 1.49 was provided in at-sea observer manuals and used by vessel operators and observers since 2007. In 2021, at the request of the Canadian fishing industry, the CF for J-cut, tail off product was lowered from 1.49 to 1.4. Based on a review of at-sea observer experiments conducted in Subarea 0 the appropriate value to estimate round weight from J-cut, tail off, dressed weight is 1.5 (round weight = J-cut weight x 1.5), which is comparable with J-cut, tail off CF values used by other countries that fish in the SA0+1 stock area (Treble and Hedges 2022). In 2021 the difference amounted to the removal of an additional 1,129 t (round weight) of Greenland halibut (DFO statistics indicated 87% of Arctic Region catch and 90% of Newfoundland Region catch was processed as frozen, gutted, head and tail off, which describes J-cut product). The 2021 SA 0 catches have been adjusted accordingly , but not in 2022(Table 1). In 2022 the two conversion factors were used for quota reconciliation (1.4) and to determine the total biomass removed (1.5), with the difference resulting in the removal of an additional 653 t (round weight) of Greenland halibut.

Inshore fisheries in the fjords of Div. 1A-F and in Cumberland Sound in Div. 0B are managed separately. However, there is no way to differentiate or separate inshore from offshore catch in the totals reported for these divisions in STATLANT 21A statistics, so it is necessary to rely on the Greenland and Canadian authorities to determine the offshore catch for Subareas 0 and 1.

1.3.Distribution of catches

The Greeland halibut fishery took place in two localized areas: the Baffin Bay (North area in 0A and 1AB) and the David Strait (South area in 0B and 1CD). Fishing occurred in comparable areas in 2022 relative to preceding years (Figures 2 and 3). In Subarea 0 fishing was concentrated along the Baffin Island shelfbreak between approximate 61°N and 72°N (Figure 2). In Subarea 1 fishing effort was concentrated on the shelf break in Div. 1A-B and within the David Strait in Div.1C-D (Figure 3).

1.4 Landing trends

Landings split by areas and countries are only available from 1987 (Figure 3). The fishery in the Northern area (0A1AB), in Baffin Bay, started around 2000s. Only very small landings were reported in 0A by foreign countries. In 0A, all landings since the 2000s are from Canada, and in 1AB, 90-95 % by Greenland. In the South area, split data from Canada are available only from 1999. Until 1995, in 0B, catches were caught by foreign countries (Russia, Norway and Faroes) and in Greenland waters, most of the landings are from Japan and Norway. From 1995, all landings in 0B are from Canada. In Greenland, landings in 1CD are a mixture of Greenland and foreign countries (Norway, Faroes, Germany and Russia) (Figure 4, 5 and 6).

Bottom otter trawl gear is primarily used in the Subarea 1 fishery while the Subarea 0 fishery is a mix of trawl and gillnet (30-40% of the catch in recent years has been from the gillnet fleet). Longline gear is used occasionally in both Subareas (Figure 7 and 8). The trawlers have been using both single and double trawl configurations since about 2000. The gillnet fishery in Subarea 0 began in 2005 and has been using baited gillnets since about 2015. These baited gillnets have recently been reported to increase catch of Greenland halibut by 150% to 250%, depending on how the bait is attached to the gear (Bayse and Grant 2020).

All landings in the Northern area from the third and fourth quarters of the year. In the Southern area, a small portion is caught in the first and second quarters (Figure 9).

1.5.Catch per unit of effort:

Subarea 0 + 1 (offshore) Trawl CPUE

The trawl catch rate is standardized using a General Linear Model. Data were aggregated by Year, Month, Gear, catches (t) and hours fished. Values less than 10 are removed. CPUE observations were log-transformed prior to the GLM analysis. Data were fit in R v. 4.40.40. (R Core Team, 2020) and least squares means were estimated with package “emmeans” (Lenth et al. 2018).

Catch rates for SA1 were available from logbooks submitted by all countries to the Greenland authorities. Until 2008 the fleets in the catch rate analysis have been grouped by nation, but information about gross tonnage is now available in the Greenland logbook database and the fleets are grouped based on size and gear. This has not changed the trends in the CPUE series, but the SE and CV of the estimates have been reduced significantly.

The standardized CPUE for trawlers in SA 0 and 1 increased from 1999 to 2018 and has declined since then (Fig. 10) (Appendix 2).
The gillnet catch rate is also standardized using a General Linear Model. Data were aggregated by Year, Month, Gear, Country/region (Newfoundland and Arctic), catches (t) and nets fished (per 100 nets). Gillnet CPUE increased from the beginning of the series in 2003 to 2020, then declined in 2021. It has been stable from 2021 to 2022 (Fig. 11) (Appendix 3).

CPUE indices should be interpreted with caution:

1) It is not known how the technical development of fishing gear has influenced the catch rates. For example the catch from single and double trawl gear was often aggregated as "otter trawl" catch when this gear was first introduced to the fishery in the early 2000s and bait has been attached to the gill nets in SA0 beginning in 2015;
2) Coding of gear type in the log books is not always reliable, which can influence the estimation of catch rates;
3) Changes in fleets and fishing grounds have occurred in both SA0 and SA1.

2. Sampling from Greenland halibut landings

Distribution of the samples

Information on fisheries and sampling in SA 1 for 2022 were available from Greenland (Nogueira and Nyggard, 2022) and Russia (Fomin and Pochtar 2022) research reports. The distribution of commercial samples in 2022 is shown in Figure 12.

2.1 Length Distribution

Trawler

Length frequency samples available from SA0 and SA1 fisheries have been combined to create an overall length frequency. Given the differences observed in length frequencies between Baffin Bay (Div. 0A+1AB) and Davis Strait (Div. 0B+1CD) plots of these areas are also provided. In SA0 and SA1 the modal length has varied from 49 to 51 cm (Fig. 13). From 2004 to 2014 the mode was at or below 50 cm, since 2014 the mode has remained above 50 cm. In the Baffin Bay area (0A+1AB) the length frequency range is typically 20 to 90 cm with a mode fluctuating between 45-51 cm (Fig. 14). In the Davis Strait area (0B+1CD) the length frequency range is typically 30 to 100 cm, with a mode varying between 45 and 53 cm (Fig. 15).

Gillnet

Length samples were available from gillnet fisheries in SA0 and are plotted for 2006 to the present. Lengths typically range from 40 to 90 cm. Prior to 2014 modal size was approximately 61 cm, from 2015 to 2020 it varied around 59 cm. The 2020 sample was much lower than in other years that may have affected the results for that year. In 2021 there was a decline to approx. 56 cm (Fig. 16).

Longline

There is occasionally a longline fishery in SA1. Length frequencies were available from Greenland for Divs. 1AB (2001 and 2016) and 1CD (2001, 2005-2009 and 2013). The longline length frequencies have been combined for the whole SA1. Longlines typically catch larger fish (40 to 100+ cm) and in Div. 1CD the modal length has been in the range of 55 cm (Figure 17).

2.2 Age Distribution

Preliminary results from otoliths sampled during the 2019 SA 0 fishery ranged in age from 4 to 26 years, with a modal age of 12 years (Fig. 18).

2.3 Bycatch and Discards

Discards of Greenland halibut in the trawl fishery in both Subareas is small, normally 1- 2% of retained Greenland halibut. Discards in the Subarea 0 gillnet fishery are slightly higher but usually not more than 3% of the retained catch.

By-catch is estimated by observers on board vessels in SA 0. The targeted at-sea observer coverage is 100% for both the trawl and gillnet fisheries in Div. 0A, 100% for the trawl fishery in Div. 0B and 20% for the gillnet fishery in Div. 0B. The 20% gillnet target is has not always been met, particularly in 2020 and 2021, due to the COVID-19 pandemic. A summary of by-catch was done for 2021 fishing trips licensed by Fisheries and Oceans Arctic Region. Overall bycatch was <2 % of the observed Greenland halibut catch. Bycatch in the gillnet fleet was 2-3%, slightly higher than in the trawl fleet (1-2%). Bycatch in SA0 was mainly comprised of 4 species, Greenland shark, roughhead grenadier, Arctic skate and northern wolffish.

By-catch was available from a number of logbooks of Greenland vessels fishing in SA 1 during. These data are not complete but do provide a rough estimation of the primary by-catch species for 2017 to 2019. The highest in terms of biomass was Greenland shark (*S. microcephalus*), followed by Redfish (Sebastes species), skate species and roundnose grenadier (*C. rupestris*) (Treble et al 2022).

3. Research Survey Data

3.1 Surveys conducted during 1987 to 1996

Surveys began in SA0 and SA1 in the mid 1980's with surveys conducted in 0B by Russia and Germany and in 1BCD jointly by Greenland and Japan (Fig. 18). Since 1997 surveys have been conducted in 0B and 0A-South by Canada and in 1CD by Greenland using the same research vessel (Fig. 18).

3.2 Greenland and Canada Surveys in Divisions 1CD (Davis Strait) and 0A-South (Baffin Bay)

Greenland and Canada have conducted buffered stratified random bottom trawl surveys at depths 400 m to 1500 m in Div. 0A-South (to approximately 72° N) (since 1999) (Figure 20 and in Div. 1CD (since 1997) (Figure 21 (using the GINR RV Paamiut and fishing with an Alfredo bottom trawl gear. The 0A-South area was re-stratified in 2008 to include the full extent of Division 0A and to match the depth categories used in the Greenland Subarea 1 stratification. In 2019 there was a change in the research vessel (CV Helga Maria) and in the survey timing; August instead of Sept for Div. 1CD and August instead of September-October for 0A-South (Treble 2020, Nogueira and Estevez-Barcia 2020, Wheland et al. 2020). The vessel used the same Alfredo gear but comparative analysis shown that the gear performed differently at depths > 700 m. As a result the 2019 index is not comparable with the rest of the time series (Nogueira and Treble 2020). No surveys were conducted in 2018, 2020 and 2021. In 2022, a new survey times series started in 0A and 1CD with a new reseach vessel owned by GINR, R/V Tarajoq and using a different gear, Bacalao bottom trawl.

Given the common research vessel and survey protocols it was possible to develop a combined biomass and abundance time series index for 1CD and 0A-South for years 1999, 2001, 2004, 2008, 2012, 2014-2017 with R/V Paamiut. The combined index was also estimated in 2019 with C/V Helga Maria and in 2022 with R7V Tarajoq although they are not comparable the indices from the different vessels(see Nogueira and Estévez-Barcia 2022, Hedges 2022 for individual survey details). The combined biomass indices from the 3 vessels and the length distributions are in figures 20 and 21. Biomass in 1CD and 0A-South combined was relatively stable from 1999 to 2014, varying between 124,000 t and 172,000 t. It then increased to 213,000 t in 2016, followed by a decline to 138,000 t in 2017. In 2019 biomass was 164,000 t and in 2022, it was 222 400 t (Figure 22).

The overall length distribution (weighted by stratum area) in 1CD was dominated by a mode at 51cm from 2006 to 2017, an increase from a mode of 45 cm observed in 2000. In 2019 and 2022 the mode was 53 cm (Nogueira and Estévez-Barcia 2020, Nogueira and Estévez-Barcia 2022). There has been more variability in the 0A-south length frequency, with a primary mode around 45 cm and secondary modes varying between 20 and 30 cm (Treble 2020). The frequency distribution for 1CD and 0A-South combined typically ranges from 5 cm to just over 100 cm. In 2019 length ranged from 5 to 108 cm. Modal length has varied between lows of 42 cm and 43 cm in 1999 and 2001, respectively, to a high of 51 cm in 2015. In 2019 the modal length was 51cm. Secondary modes are clearly present in 2008, 2012-2017. In 2022, distribution has a similar range to preceding years but there were higher numbers of small fish in the catch, likely because of the change to using a Bacalao trawl. (Fig. 23).

3.3 Greenland Shrimp and Fish shallow survey

Since 1988 surveys with a shrimp trawl at shallow waters have been conducted off West Greenland during July-September. The survey covers the area between 59° N and 72° 30' N (Div. 1A-1F) from 50 m to 600 m (Figure 24). The survey area was re-stratified in 2004 based on better information about depths. All biomass and abundance indices have been re-calculated. The re-calculation did not change the trends in the development of the different stocks. The Skjervoy trawl was changed to a Cosmos trawl in 2005. Calibration experiments were conducted (Rosing and Wieland, 2005), and data from 1988 to 2004 were converted so the time series are comparable. The RV Paamiut was used for the survey from 1991 to 2017. In 2018 the CV Sjuderberg was used to conduct the survey, in 2019 and 2020 the CV Helga Maria and in 2022 the new vessel R/V Tarajoq. An examination of gear parameters found that the effects of these vessel changes had a minimal effect on trawl performance (Nogueira and Treble 2020, Nogueira et al. 2022). No survey was conducted in 2021.

Greenland halibut is widely distributed throughout the 1A-F survey area, but highest concentrations are found in nursery areas in Division 1A, 1B-North and Disko Bay (Fig. 19). Biomass has varied with a general increasing trend from 2014to 2022 (Fig. 25). Abundance of age 1 has been more variable (Fig. 26), with notable peaks of high abundance in 2011, 2013 and 2017. Abundance is mainly driven by year to year variability in the number of one- and two-year old recruits, which typically constitute 80-90% of the Greenland halibut caught during the survey (Nygaard and Nogueira, 2022).

Clear modes can be found in the length distribution at 12-15 cm and 23 cm (fig. 27), corresponding to fish at age 1 and 2, using the Peterson method to assign age based on length frequencies (Nygaard and Nogueira, 2021). This allows for the development of an age-1 index. Since 2003 there has been an overall declining trend, with the exception of three large year classes producing high abundances of age 1 fish in 2011, 2013 and 2017. The index declined from 2017 to 2019 but in 2020 and 2022 it had increased to a level near average for the last 10 years. It is unclear if the age 1 abundance index is representative of future recruitment.

Greenland halibut larger than 35 cm forklength in the Greenland shrimp and fish survey were examined separately as these fish are available to the Subarea 0+1 (offshore) fishery, and was used to explore a Stochastic Surplus Production Model in Continous Time (SPICT) (Nogueira et al. 2023). A biomass index for fish >35 cm increased from 1991 to a peak in 2004, subsequently declined and has varied without trend from 2006 to 2022. Length frequency data for these fish showed gradual increases in the maximum length observed and number of fish between 35 and 45 cm forklength prior to 2004 (Fig. 28 and 29). Since 2004 the maximum length has been relatively stable and the majority of fish have fallen between 35 and 55 cm forklength.

3.4.Survey Age distribution

There has been uncertainty in the accuracy of age determination methods for Greenland halibut which were resolved at a workshop held in Iceland in 2016 (ICES 2017). Effort is currently under way to age the back log of otoliths in order to provide age data for future assessments. Growth curves are available for male and female Greenland halibut for 2017. Female ages ranged from 3-32 years and males from 3-28 years. Age at 45 cm was approximately 10 years for both males and females.

Survey Length-at-maturity

Maturity information collected during surveys in SA0 were examined in 2006 and updated in 2009 (Harris et al. 2009). Few fish were found to be mature. For females in 0A-South and 0B the length at 50% maturity (L50) ranged from 67-84 cm and 62-67 cm, respectively. Males don't grow to be as large as females and their L50s in 0A-South were 54-65 cm and in 0B it was 39-43 cm.

6. Conclusion

The surveys that provide the main index for this stock were not conducted in 2018, 2020 or 2021. The survey in 2019 was conducted with a charter vessel and after review of gear performance measures it was not considered comparable to previous surveys. In 2022, a new time series started with a new research vessel, R/V Tarajoq, using a new trawl gear, Bacalao. As a result there has been no data from offshore surveys since 2017. From 1999-2017 the 0A-South+1CD combined survey biomass index had been relatively stable with more variability observed near the end of the time series and all values were above Blim.

There is an update from 2022 for the Greenland fish and shrimp survey in Divs. 1A-F. Although the survey experienced vessel changes during 2018-2020 and 2022, the results are considered comparable with previous years. Since 2003 the abundance index has had an overall declining trend, with the exception of three large year classes in 2011, 2013 and 2017. Abundance of age-1 fish was near average in 2020. It is unclear if the age-1 abundance index is representative of future recruitment. An index of exploitable biomass > 35 cm has been estimated from that survey and it has been used as input in a surplus production model,

Since 1995, catches have been near the TAC, increasing in step with increases in the TAC, reaching a high of 36,446 t in 2019. The TAC from 2019 to 2022 has been 36,400 t and catches in 2022 were 36 400 t.

The surveys and trawl fisheries have almost all seen slight increases in modal lengths over the last 10 to 15 years, from values below 50 cm (48-49cm) to values above 50cm (51-52cm). However, the modal size in the SA0 gillnet fishery has declined, from approx. 61 cm to 59 cm, and in 2021 it was approx. 56 cm.

A standardized CPUE index for trawlers fishing in SA 0+1 has been declining since a peak in 2018 and the gillnet CPUE for SA0 declined in 2021, after a continued increase from the beginning of the series in 2003 to 2020. In 2022, the CPUE was stable. However, CPUE is known to have limitations as an index of population status.

Data collected in 2022 are not sufficient to give a new advice in 2023.

7. Research Projects

Fisheries and Oceans has undertaken research on geospatial and other population models that could be used to improve the stock assessment. Preliminary findings were reviewed during a DFO meeting to be held in late fall 2022. Outcomes of the DFO meeting, with particular details regarding an approach for a model-based survey calibration, were presented to STACFIS in June 2023. The model-based calibration approach will be furthere developed during 2023-2024 for consideration during the next stock assessment at the NAFO SC meeting in June 2024 (Huynh and Carruthers, 2023).

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Table 1. Greenland halibut catches (metric tons) by year and country for Subarea 0, 1987 to 2019. Based on STATLANT, with information from Canada used to exclude 0B inshore catch.

	0A			0B			SA0
Year	CAN	Other[a]	TOT 0A	CAN	Other[a]	TOT 0B	Total
1987					388	388	388
1988				2	1022	1024	1024
1989				180	907	1087	1087
1990				844	8909	9753	9753[b]
1991				395	8350	8745	8745
1992				2624	10164	12788	12788
1993	681		681	592	6605	7197	7879[c]
1994				402	4274	4676	4676
1995	82		82	1859	1292	3151	3233
1996		576	576[d]	2354	1678	4032	4608
1997	3		3	3868	452	4320	4323
1998				3924		3924	3924
1999	517		517	4267		4267	4784
2000				5438		5438	5438[e]
2001	2628	445	3073	5034		5034	8107
2002	3561		3561	3910		3910	7471[f]
2003	4142		4142	5059		5059	9201
2004	3751		3751	5771		5771	9522
2005	4209		4209	5789		5789	9998
2006	6634		6634	5585		5585	12219
2007	6173		6173	5318		5318	11491
2008	5257		5257	5175		5175	10432
2009	6627		6627	5622		5622	12249
2010	6390		6390	6941		6941	13331
2011	6365		6365	6814		6814	13179
2012	6365		6365	7257		7257	13622
2013	6314		6314	7352		7352	13666
2014	7934		7934	7003		7003	14937
2015	7922		7922	7491		7491	15413
2016	7559		7559	6402		6402	13961
2017	8458		8458	7932		7932	16390
2018	8408		8408	7563		7563	15971
2019	9708		9708	8619		8619	18327[g]
2020	9429		9429	8489		8489	17918[g]
2021	10061		10061	9033		9033	19094[gh]
2022	9582		9582	9033		9033	18616[i]

a Other countries may include Faroe Islands, Poland, Russia, Estonia, Latvia, Japan, or Norway.
b Norwegian catch double reported.
c The Russian catch is reported as area unknown, but has previously been reported from Div. 0B
d Caught under a Canadian charter.
e STACFIS estimate
f Excluding 782 tons reported by error
g STATLANT 21A data are not available
h STACFIS estimate using 1.5 conversion factor for J-cut, tailed product; 1,129 t increase over reported catch.
i Logbook data

Table 2. Greenland halibut catches (metric tons) by year and country for Subarea 1 from 1987 to 2019, not including inshore areas. Based on STATLANT, with information from Greenland used to exclude 1A-F inshore catch.

	1AB				1CF							SA1
Year	GRL	RUS	FRO	TOT 1AB	GRL	RUS	FRO	EU	NOR	JPN	TOT 1CD	Total
1987					1646					855	2501	2501
1988					605					1576	2181	2181
1989					540					1300	1840	1840
1990					841		54			985	1880	1880
1991					933		123		611	673	2340	2340
1992					191		151		2432	2895	5669	5669
1993					186	5	128	46	2344	1161	3870	3870
1994					872		780	266	3119	820	5857	5857
1995					1399	296		527	2472	323	5017	5017
1996					1876	254		455	1785		4370	4370
1997					2312		127	446	1893		4778	4778
1998			117	117	2295	543	125	350	1338		4651	4768
1999					2529	552	116	330	1360		4887	4887[a]
2000			96	96	2059	792	147	444[b]	1590		5032	5128
2001	340	85	150	575	2012	829	150	537[b]	1550		5078	5653
2002	1619	279	150	2048	2284	654	150	536	1734		5358	7406
2003	3558	259	117	4007	2059	1328	135	543	1423		5488	9495[cd]
2004	3500	241	153	4035	2102	1214	150	665f	1364		5495	9530[ce]
2005	3363	549	125	4037	2380	1147	149	549	1456[b]		5681	9718[e]
2006	5530	565	128	6223	2430	1222	147	544	1379		5722	11945[e]
2007	5596	575	125	6296	1805	689	150	1516	1441		5601	11897[e]
2008	5524	570	149	6243	1592	763	184	1517	1452[b]		5508	11751
2009	6094	517	124	6735	1457	1057	149	1511	1514		5688	12423
2010	5682	654	126	6462	2491	1214	152	1818	1581		7256	13718
2011	5722	648	102	6472	2493	865		1824	1720		6902	13374[e]
2012	5810	546	103	6459	2660	1227		1784	1761		7432	13891
2013	5865	546	102	6513	3514	1223		2017	1496		8250	14763[e]
2014	7333	550	102[b]	7985	4072	1224		1751	1464		8511	16496[f]
2015	7366	548	102	8016	3834	1215		1880	1503		8432	16448[f]
2016	7682	550	103	8335[g]	4367	1215		1885	1382		8849	17184[f]
2017	8003	549	103	8655	4968	1224		1929	1495		9616	18271[f]
2018	7953	550	104	8607	3079	1121		1878	1488		7566	16173
2019	8821	550	103	9474	3995	1119		1881	1526		8521	17995
2020	7107	550	105	7762	5932	1118		1883	1429		10362	18124[f]
2021	7791	550	104	8445	4902	893		1673	1429		8897	17342
2022	8052	442	100	8594	5577	693		1556	1449		9275	17869[h]

a Excluding 7603 t reported to STATLANT in error

b Catch reported to the Greenland Fisheries License Control Authority.

c Includes Spanish research fishery catch, 75 t in 2003 and 272 t in 2004.

d Excludes 1366 t reported for Div. 1A in error

e STATLANT 21A data for Div. ICD from Greenland includes double reporting.

f STATLANT unknown catches for Greenland were distributed based on information from Greenland authorities or assumed to come from Div. 1A inshore.

g Norway STATLANT 21A reported catch in Div. 1A that was actually caught in 1D.

h GLKF catches

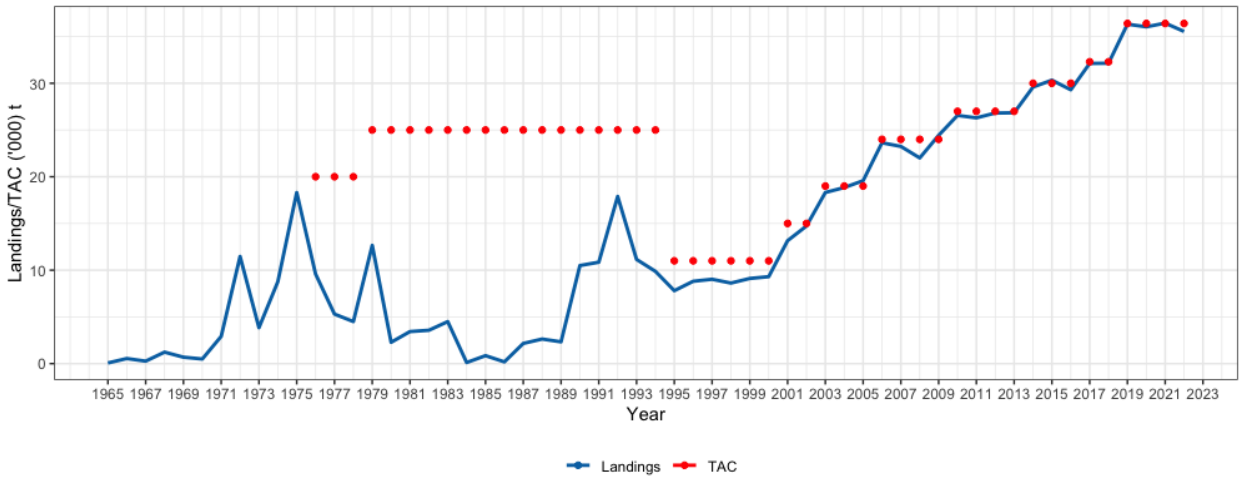

Figure 1. Catches and recommended TAC for SA0+1 (offshore) Greenland halibut.

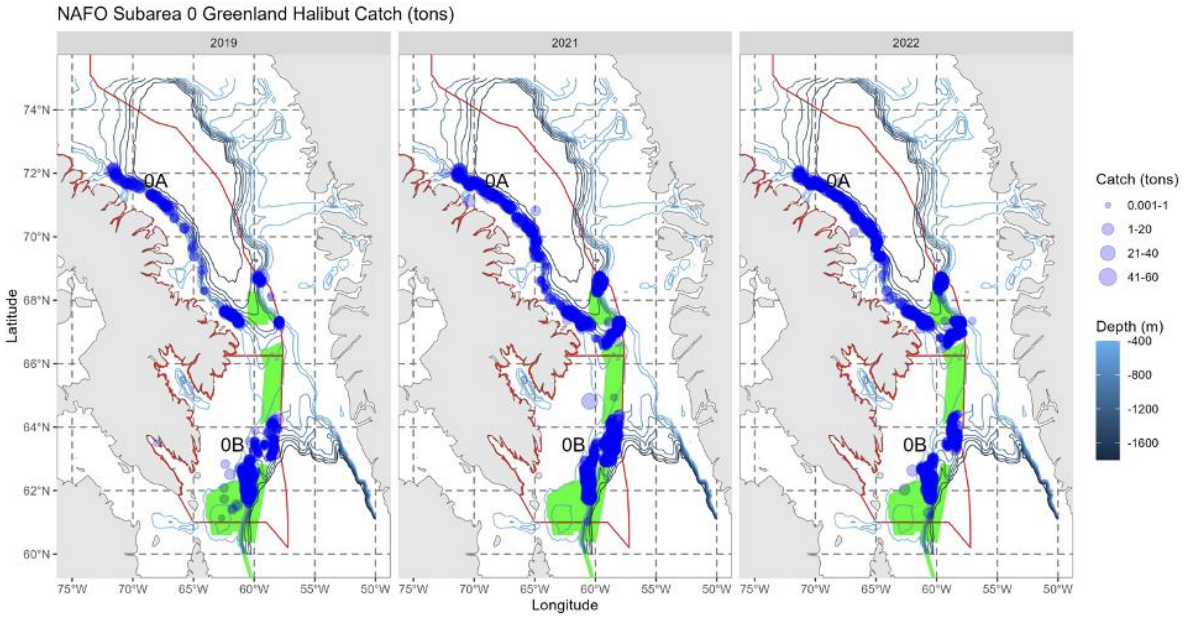

Figure 2. Greenland halibut. Catches distribution in Sub 0 years 2019, 2021 and 2022.

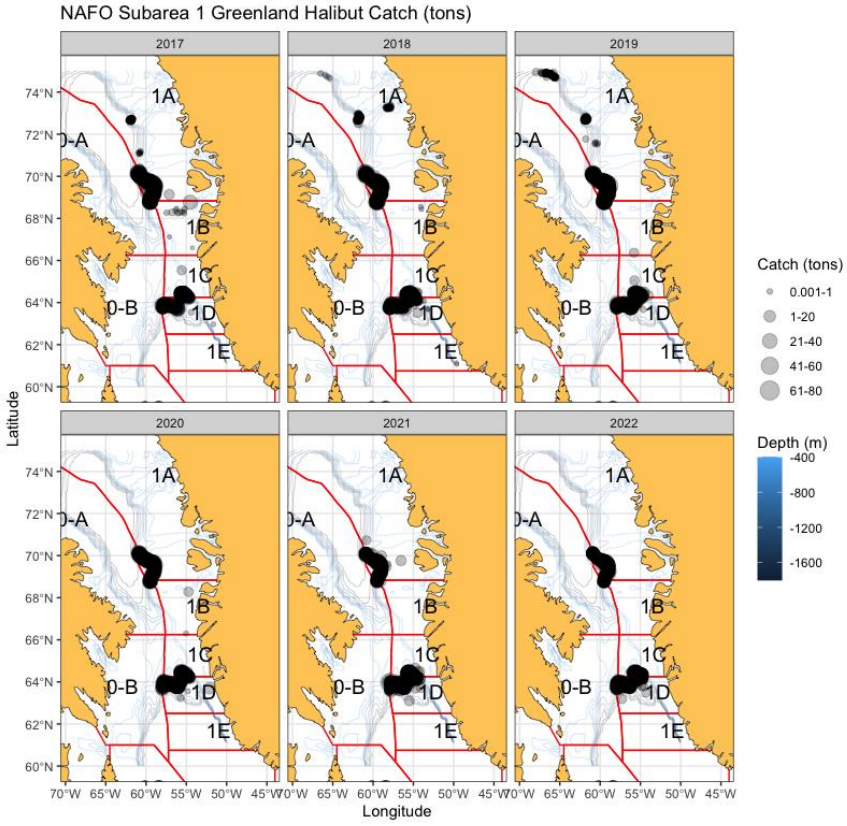

Figure 3. Greenland halibut. Catches distribution in Sub 1 years 2019- 2022.

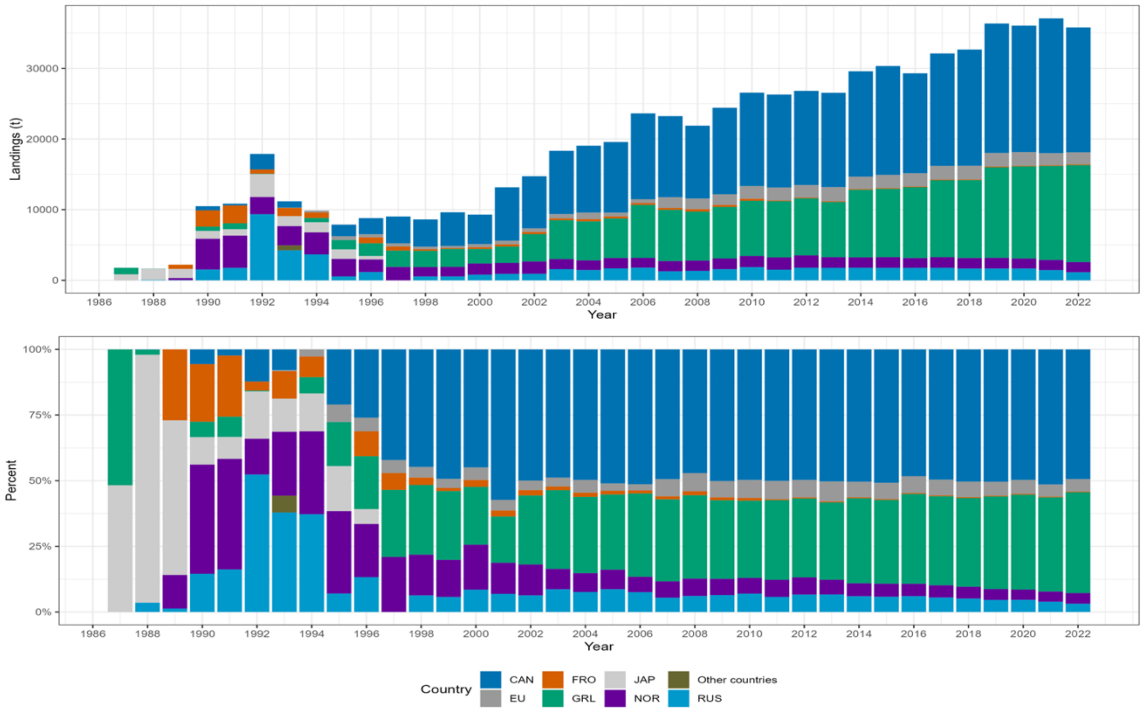

Figure 4. Greenland halibut. Landings from NAFO 0+1 offshore by nations (Canada, Greenland, Faroes, Japan, EU, Norway and Russia) in 1987-2022. All gears combined.

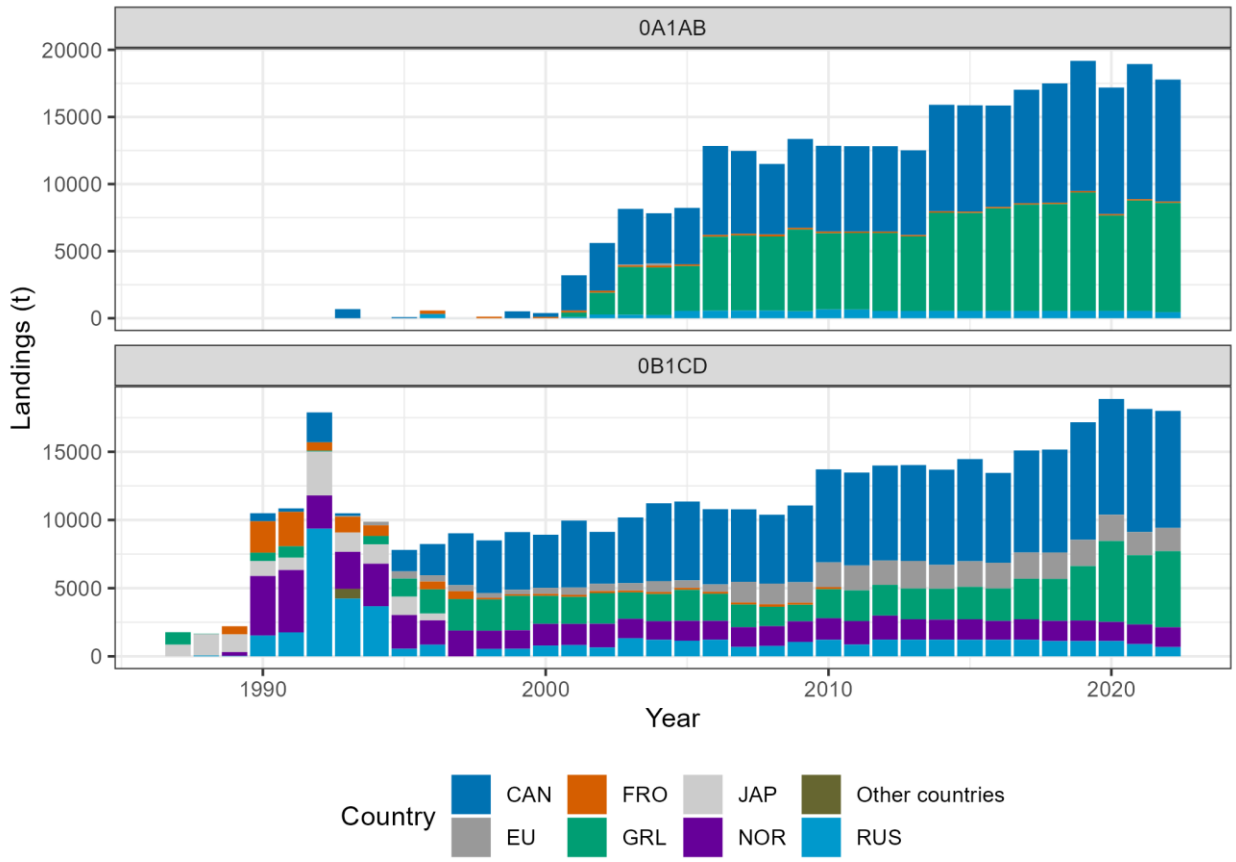

Figure 5. Greenland halibut. Landings from NAFO 0+1 offshore by nations (Canada, Greenland, Faroes, Japan, EU, Norway and Russia) and by areas (South and North) in 1987-2022. All gears combined.

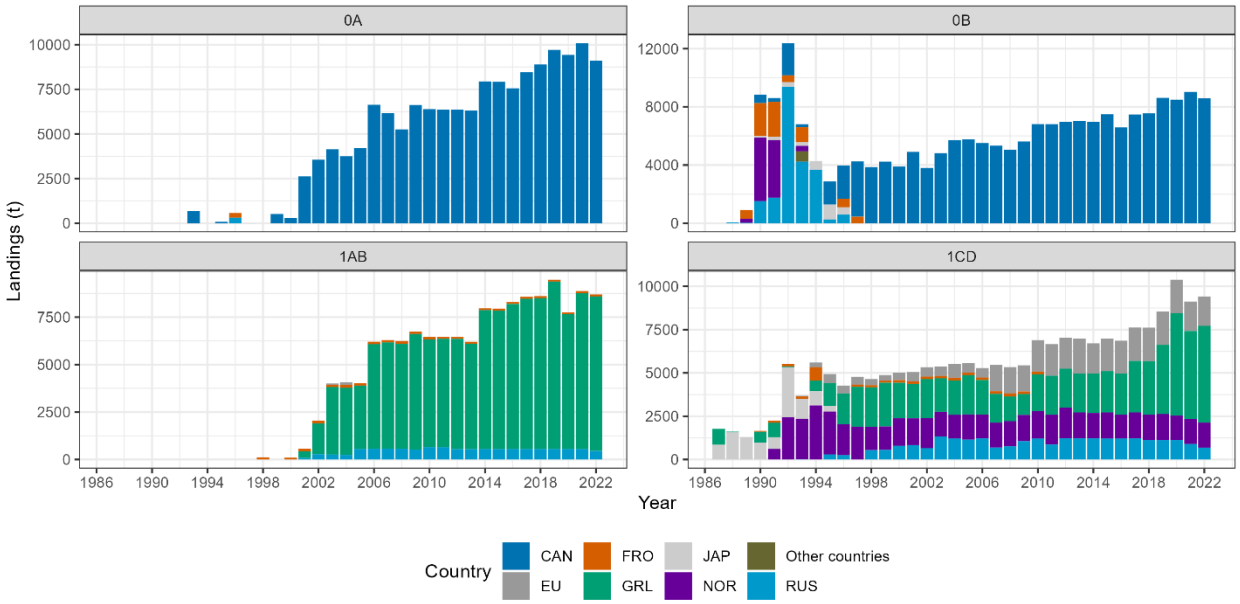

Figure 6. Greenland halibut. Landings from NAFO 0+1 offshore by nations (Canada, Greenland, Faroes, Japan, EU, Norway and Russia) and by divisions (0A, 0B, 1AB and1CD) in 1987-2022. All gears combined.

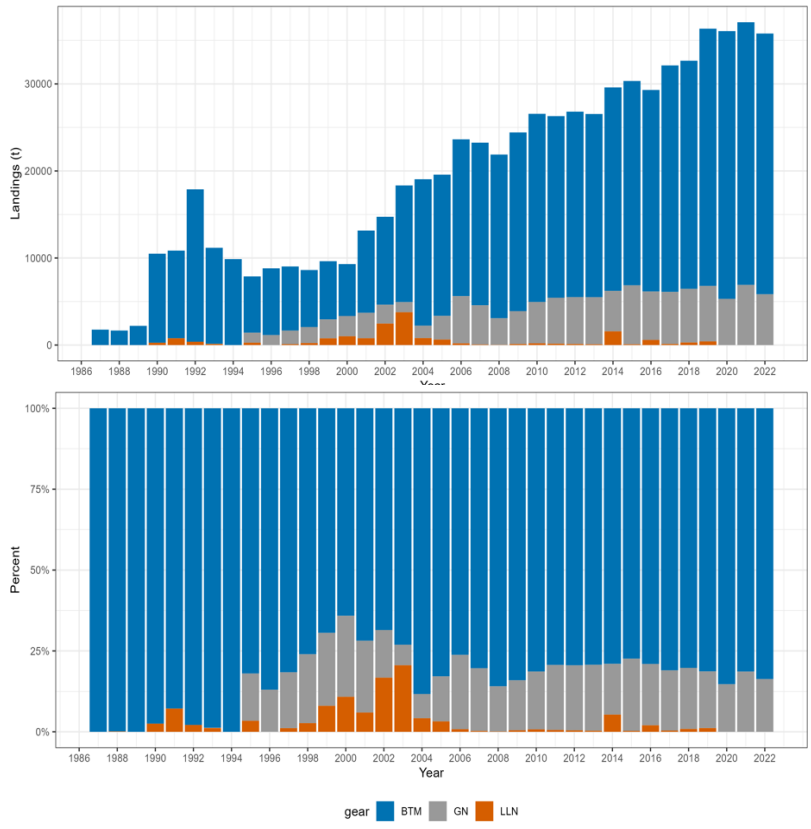

Figure 7. Greenland halibut. Landings from NAFO 0+1 offshore by gear (Trawl, Gillnet and Longliners) in 1987-2022.

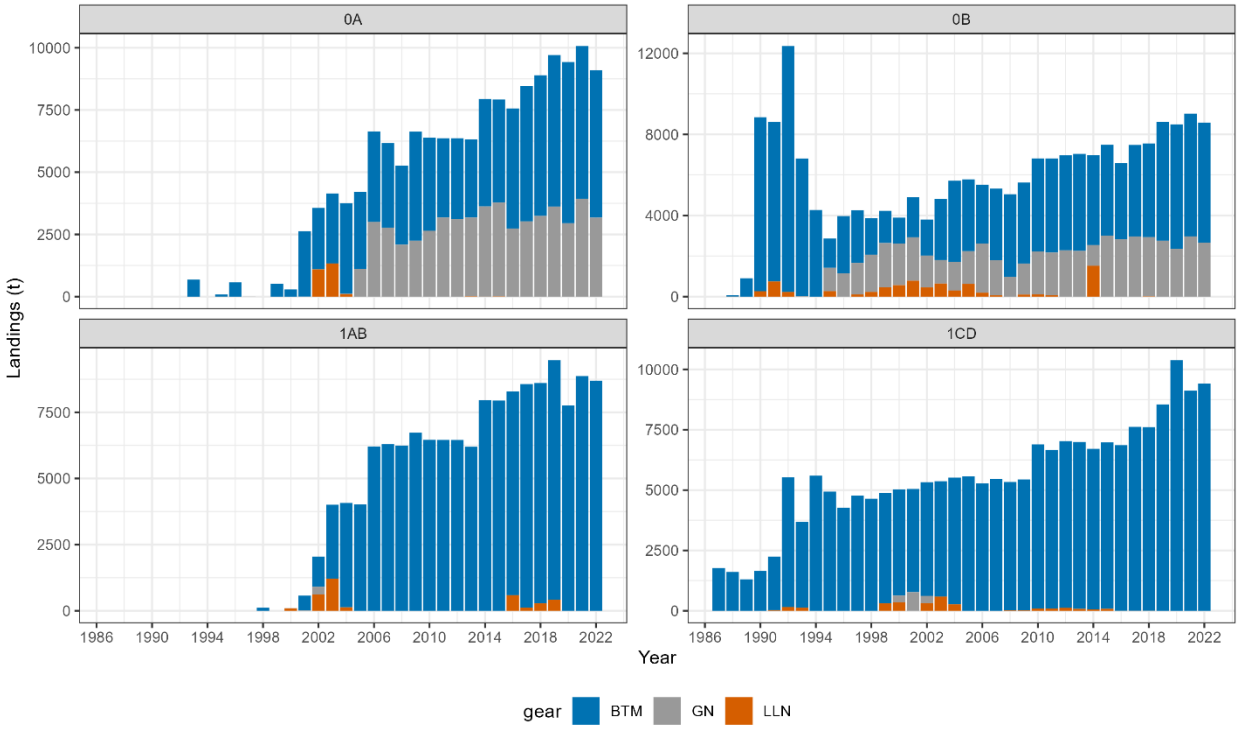

Figure 8. Greenland halibut. Landings from NAFO 0+1 offshore by gear (Trawl, Gillnet and Longliners) and divisions (0A, 0B, 1AB and 1CD) in 1987-2022.

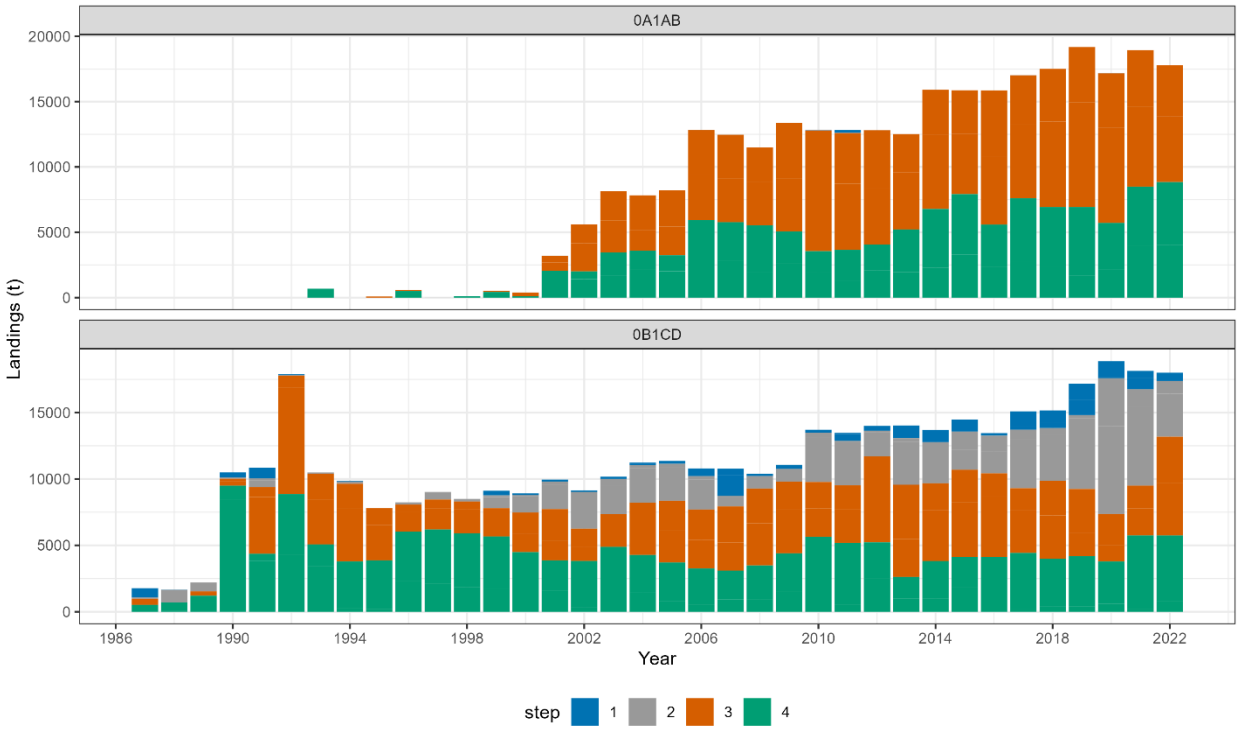

Figure 9. Greenland halibut. Landings from NAFO 0+1 offshore quarter in both aras (South and North) in 1987-2022.

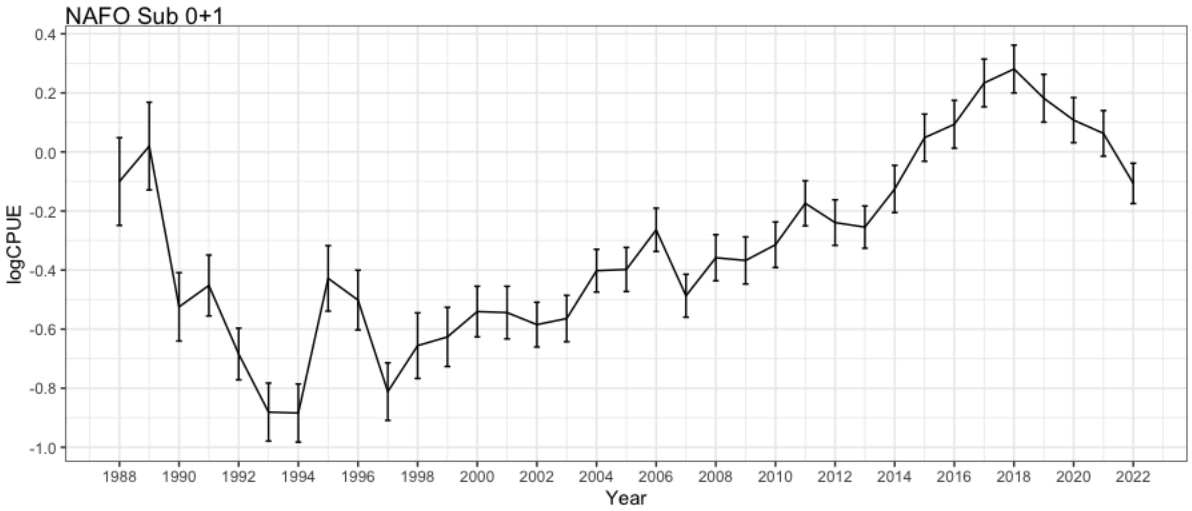

Figure 10. Greenland halibut. Standarize CPUE for trawlers years 1988-2022.

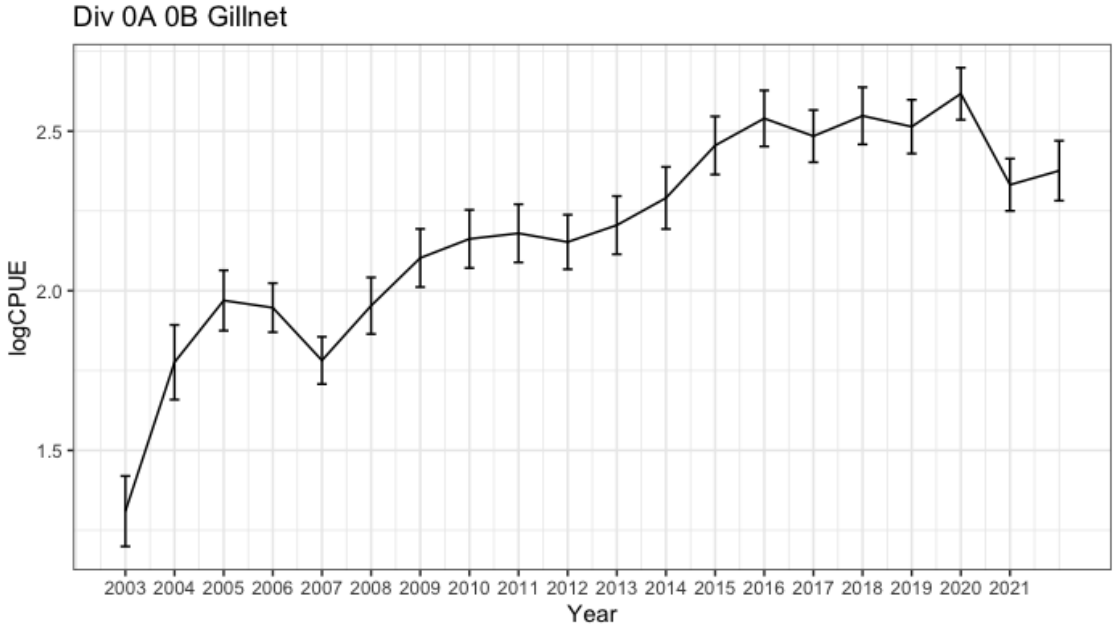

Figure 11. Greenland halibut. Standarize CPUE for gillnets in Sub.0 years 2003-2022.

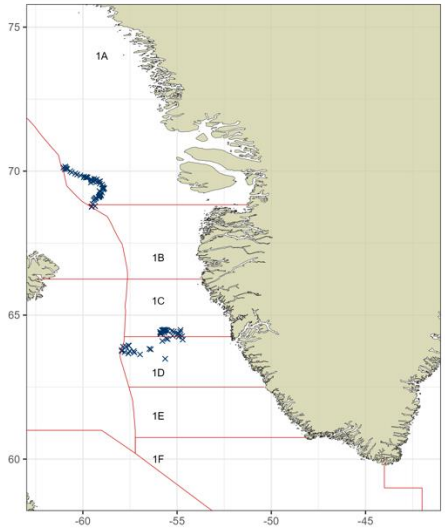

Figure 12. Greenland halibut. Commercial samples in 2022.

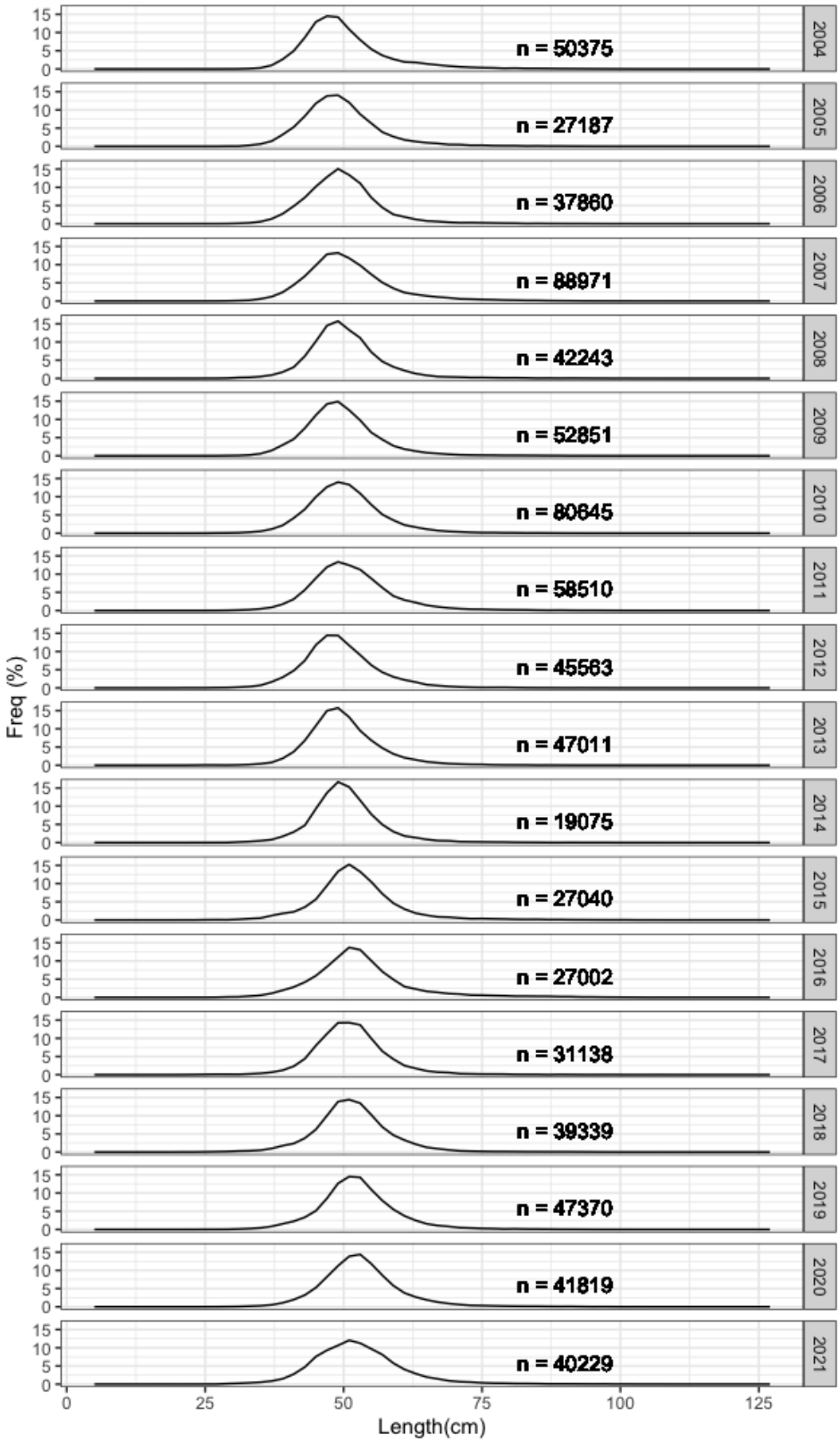

Figure 13. Length distribution from the trawl fisheries in Subarea 0+1 (offshore).

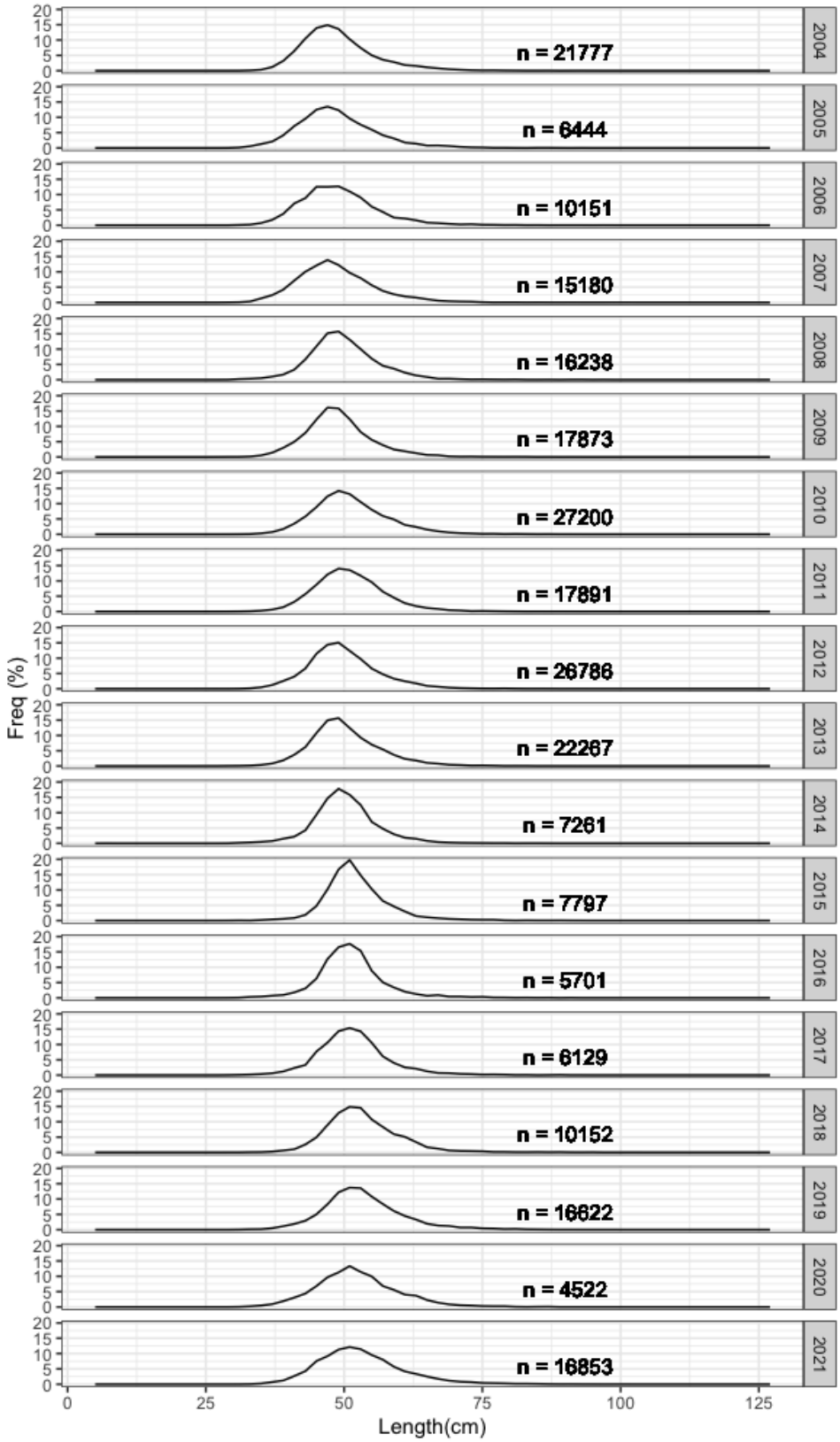

Figure 14. Length frequencies in commercial catches from trawlers in Div. 0A and 1AB .

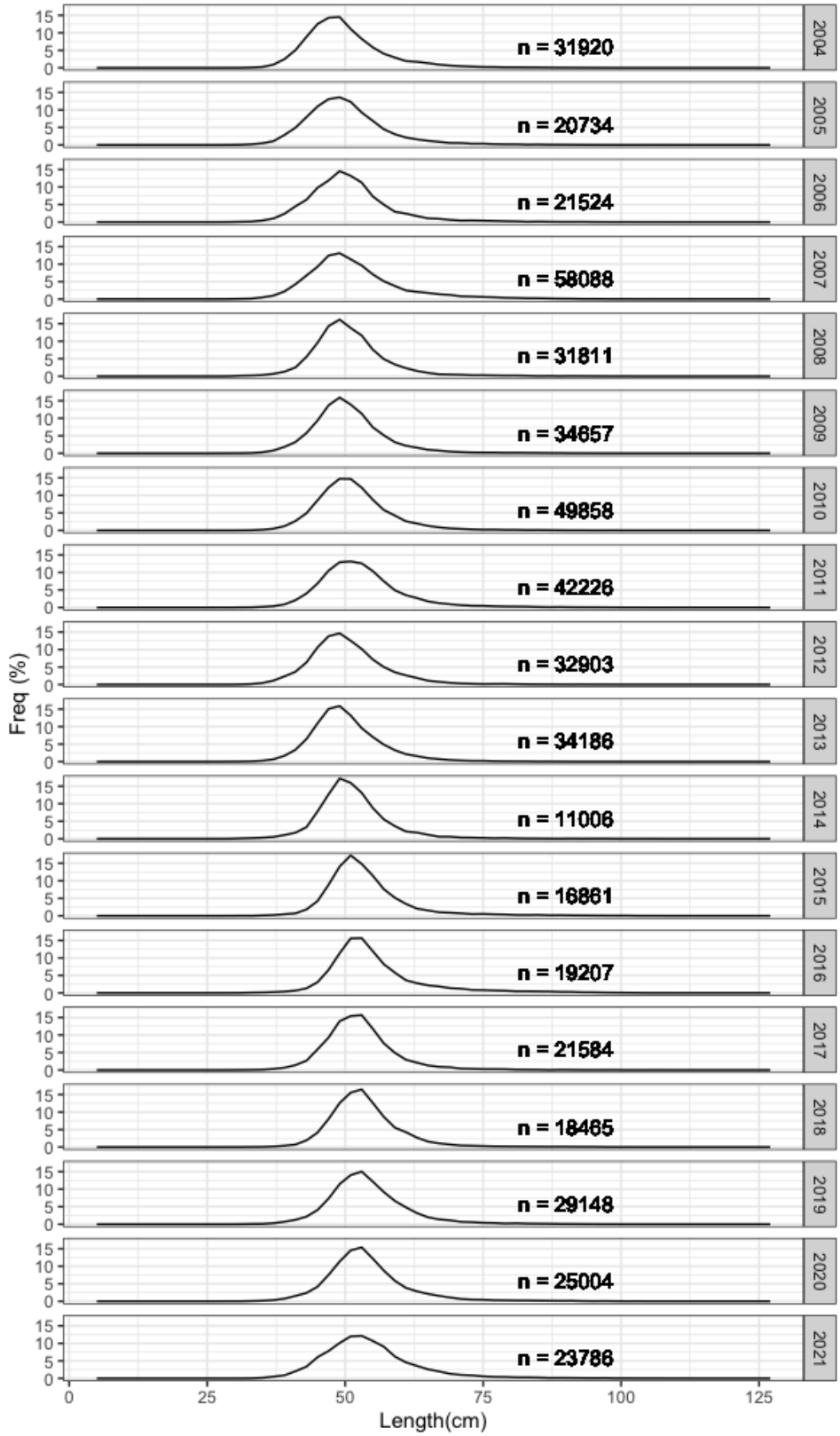

Figure 15. Length frequencies in commercial catches from trawl gear for Div. 0B and 1CD.

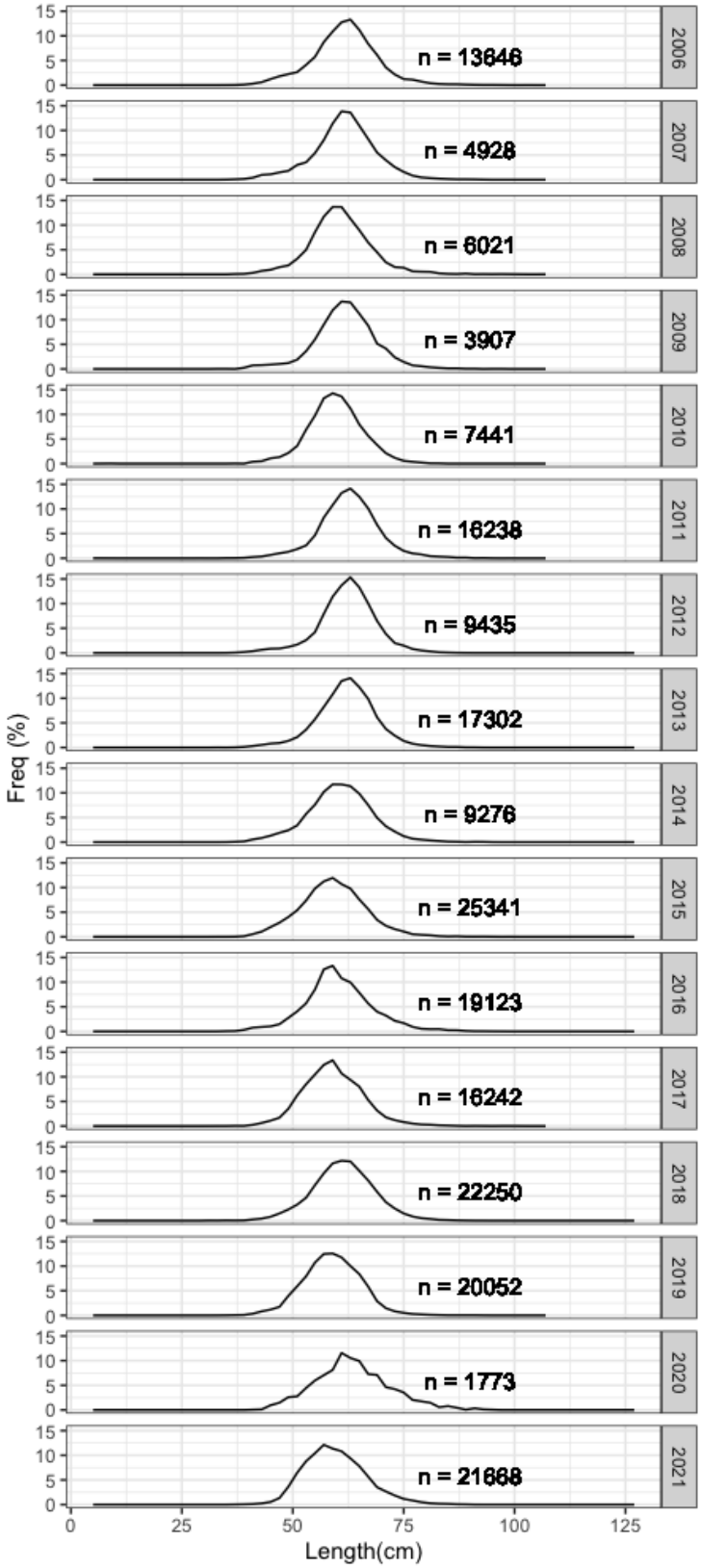

Figure 16. Length frequencies in commercial catches from gillnet gear for Subarea 0.

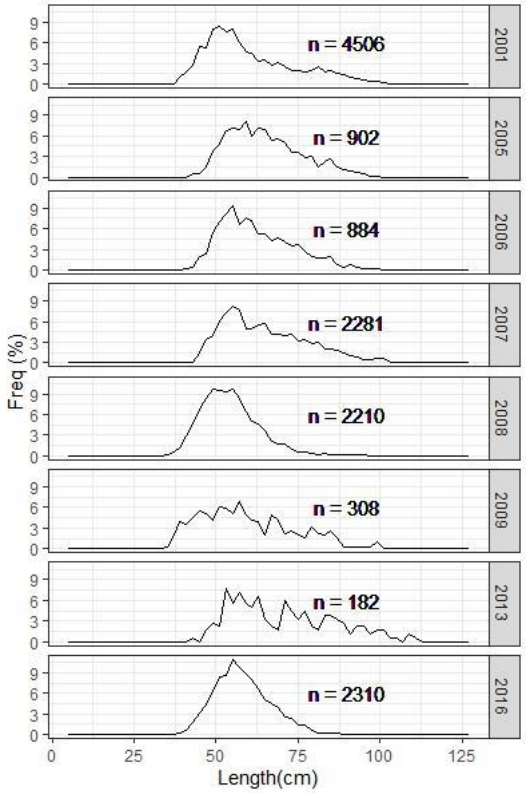

Figure 17. Length frequencies in commercial catches from longline gear for Division 1A-D.

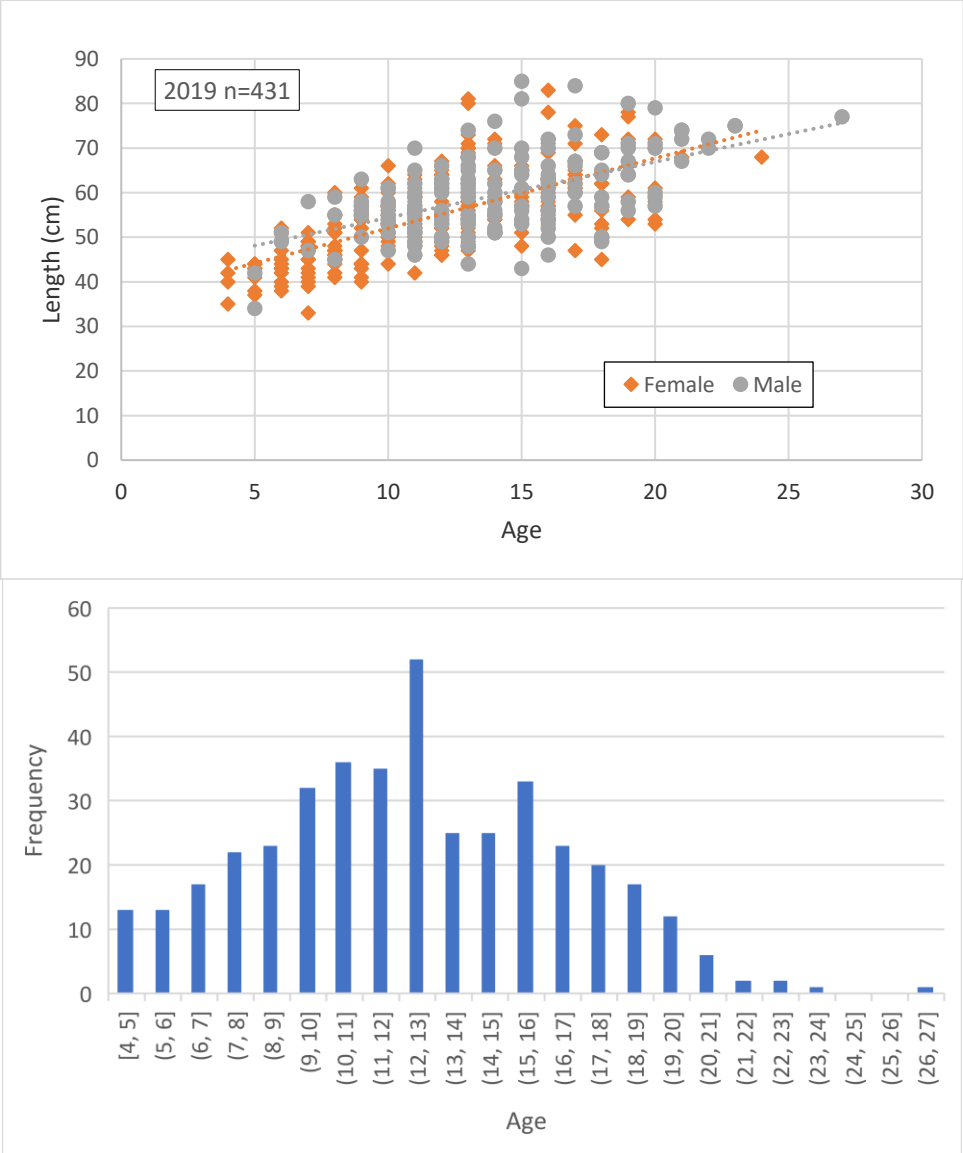

Figure 18. Age-length distribution (top) and frequency (bottom) for samples from commercial trawl and gillnet vessels fishing in SA0 in 2019.

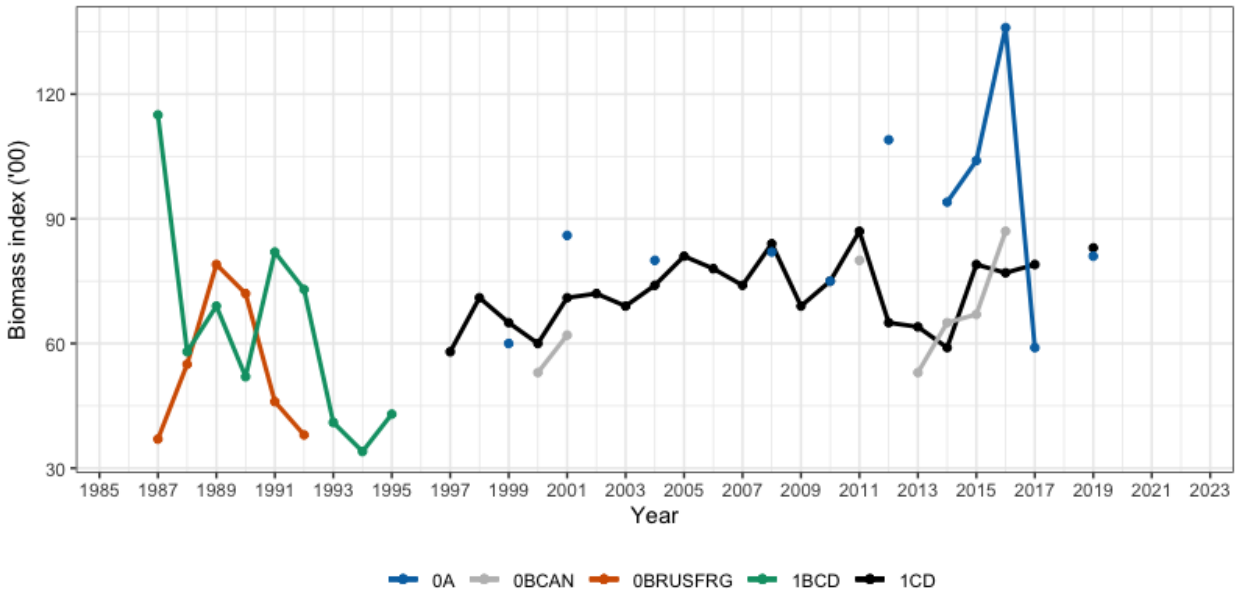

Figure 19. Biomass estimates from surveys conducted in SA 0 and 1 since 1986. There was a change in vessel for the 2019 surveys in 1CD and 0A-South and these estimates are not considered comparable to previous years.

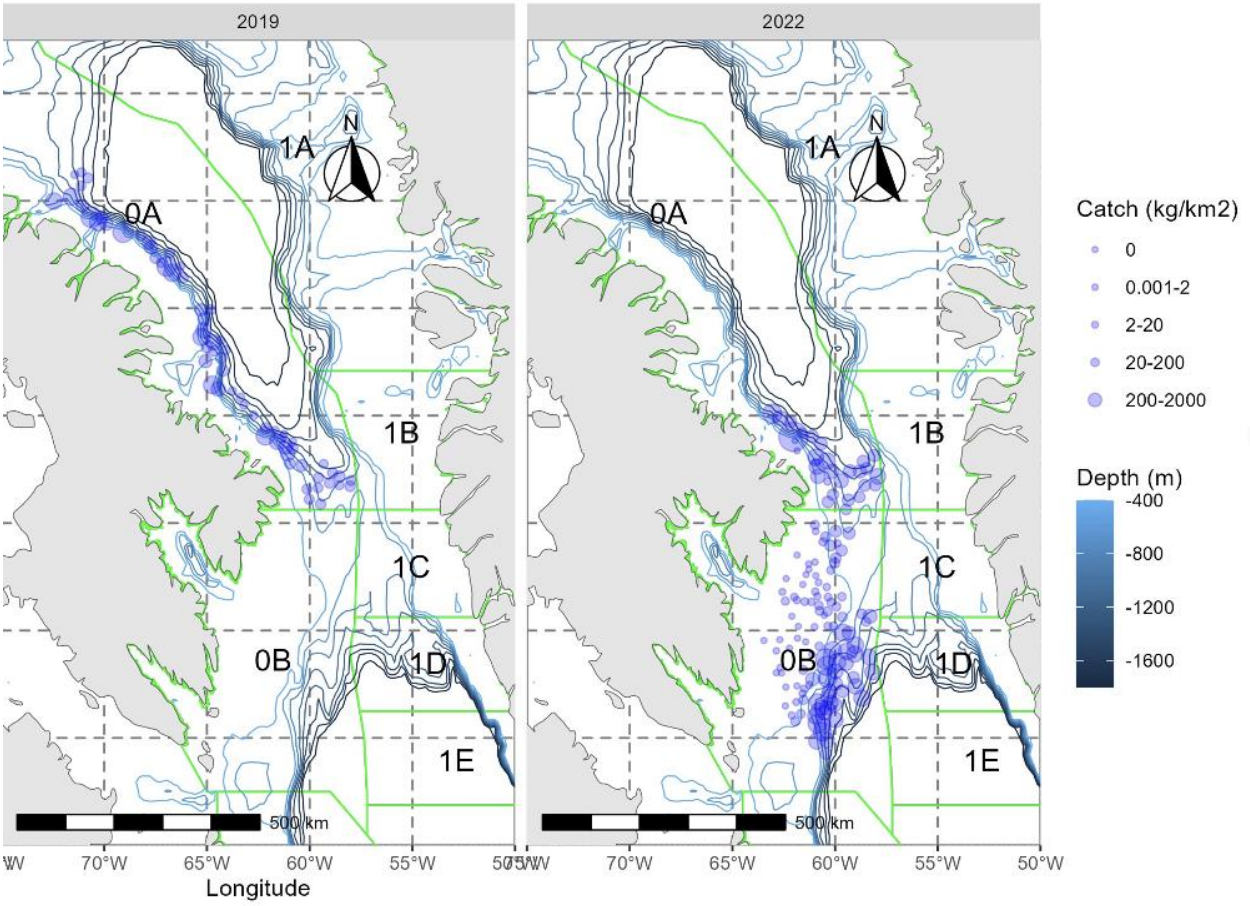

Figure 20. Distribution of the GHL density (kg/km2) during the 0A survey in 2019 and the 0A0B survey in 2022.

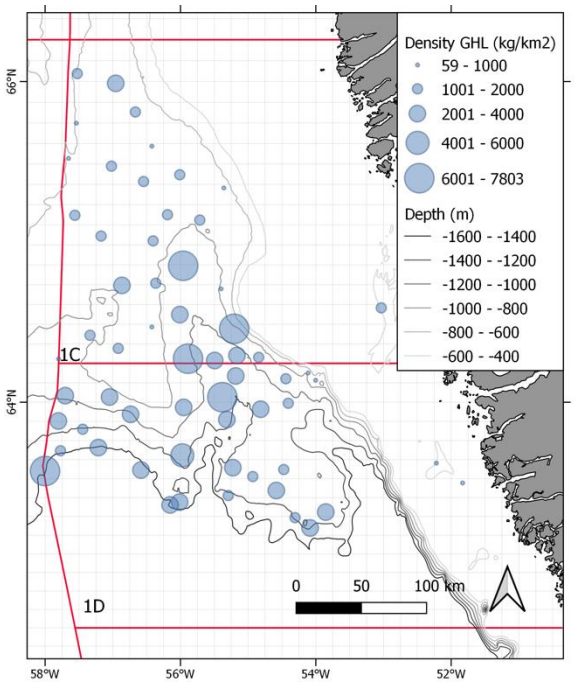

Figure 21. Distribution of the GHL density (kg/km2) during the 1CD survey in 2022.

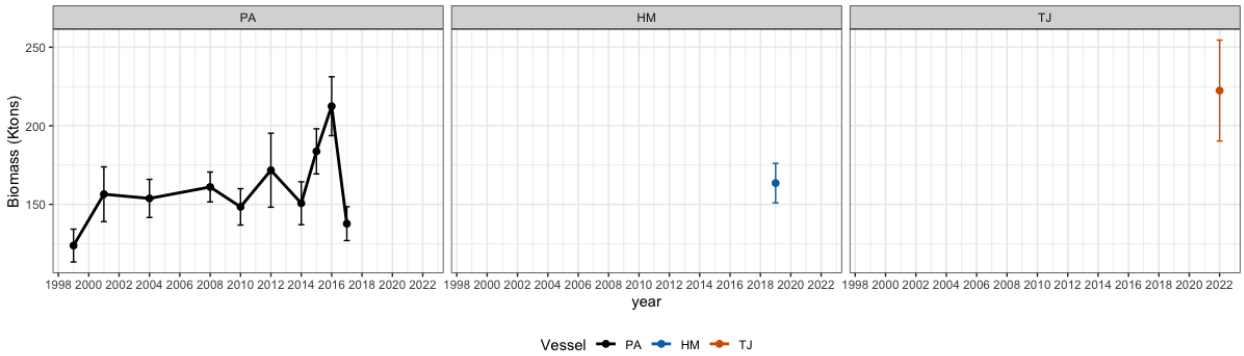

Figure 22. Combined survey biomass index for Div. 0A-South+Div. 1CD for the 3 surveys series: R/V Paamiut and Alfredo III gear (left panel), C/V Helga Maria and Alfredo III gear (midle panel) and R/V Tarajoq and Bacalao 476 gear (right panel).

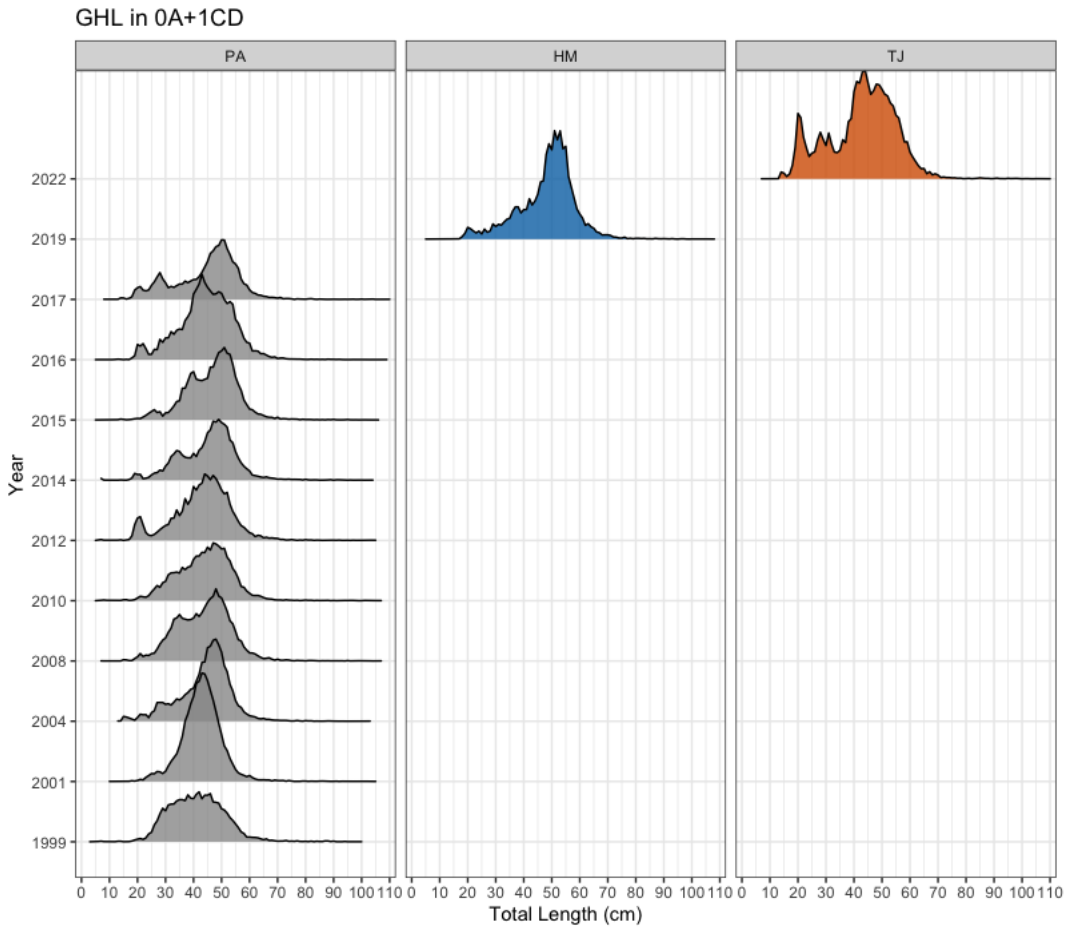

Figure 23. Length distribution of Greenland halibut (numbers weighted by stratum area) for the Div. 0A-South+Div. 1CD for the 3 surveys series: R/V Paamiut and Alfredo III gear (left panel), C/V Helga Maria and Alfredo III gear (midle panel) and R/V Tarajoq and Bacalao 476 gear (right panel).

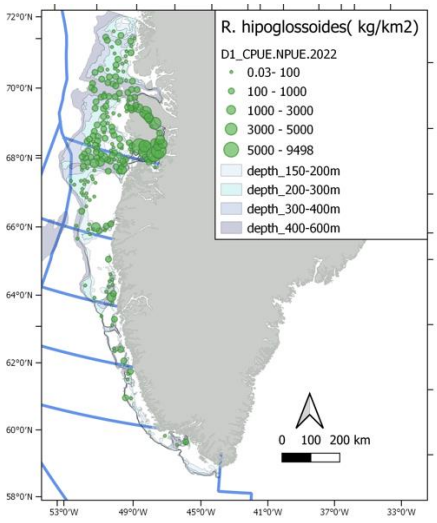

Figure 24. Distribution of the GHL density (kg/km2) during the 1AF survey in 2022.

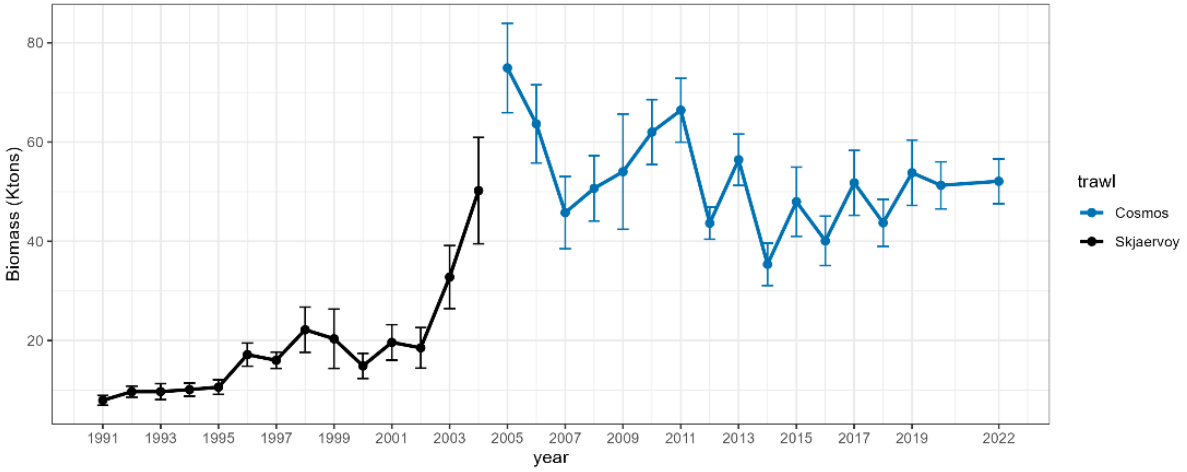

Figure 25. Greenland halibut biomass indices from the Greenland Fish and Shrimp Survey in 1A-F (50-600 m). Change of gear in 2004 is not calibrated in this plot.

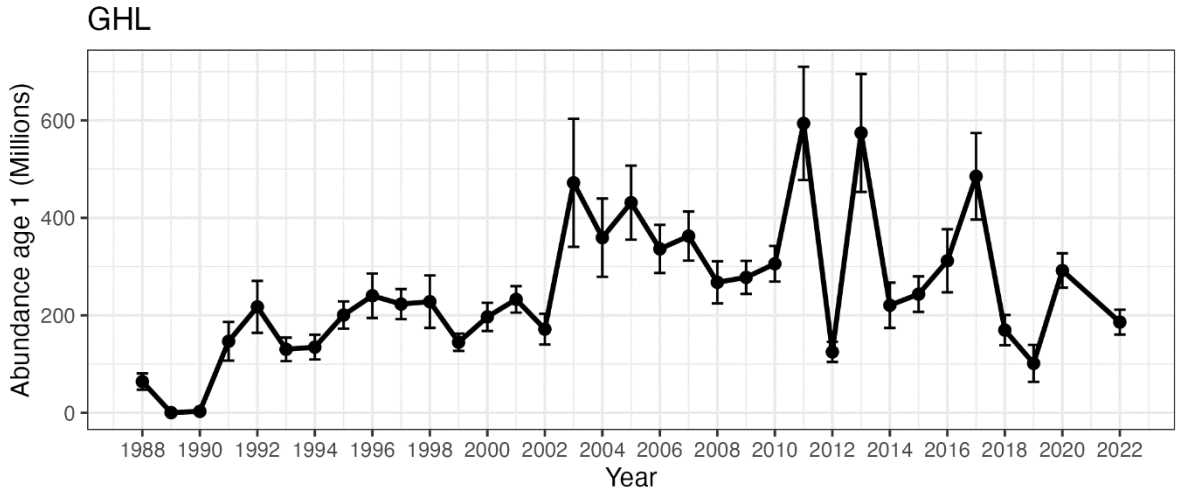

Figure 26. Abundance of age 1 Greenland halibut from the Greenland Fish and Shrimp Survey, for the entire survey area, including inshore Disko Bay, Div. 1A (North of 70○37.5'N) and several sets on the adjacent shelf in 0A. The indices 1988- 2004 have been calibrated with conversion factor due to the change of gear.

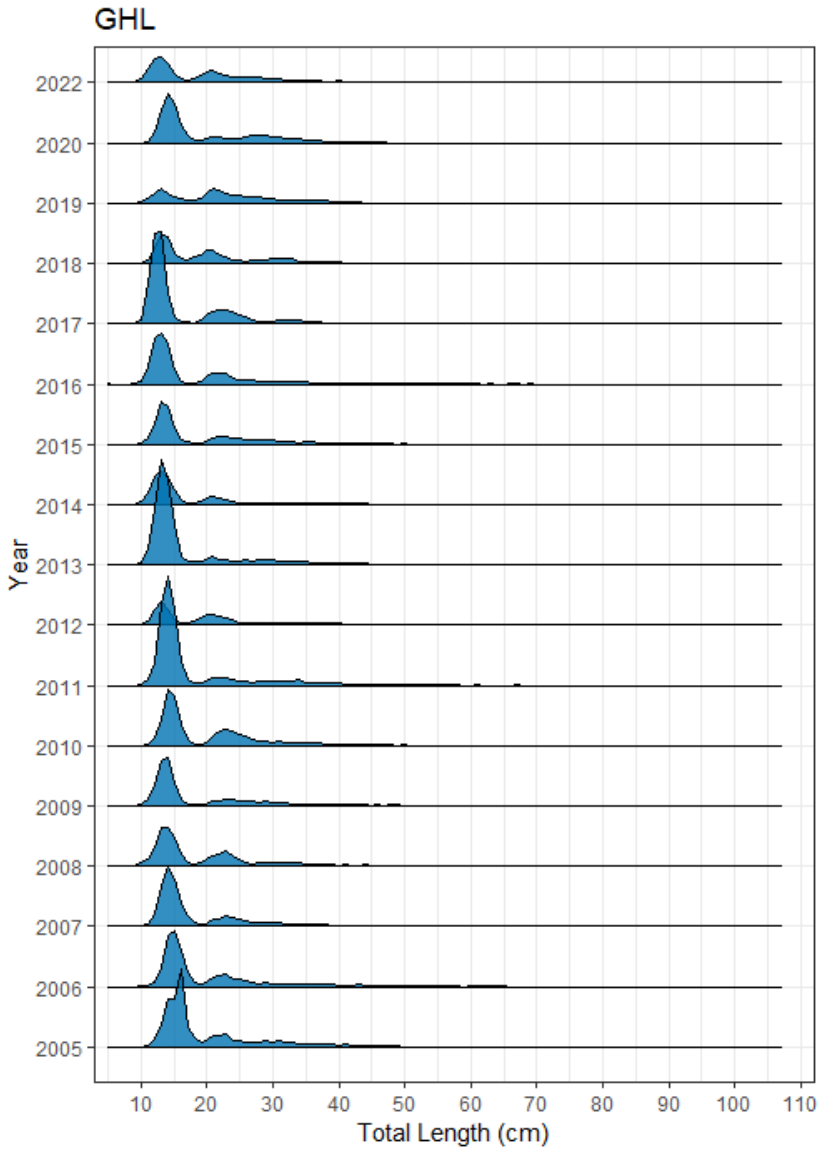

Figure 27. Length distribution of Greenland halibut (numbers weighted by stratum area) for the Div. 1AF surveys. The indices 1988- 2004 have been calibrated with conversion factor due to the change of gear.

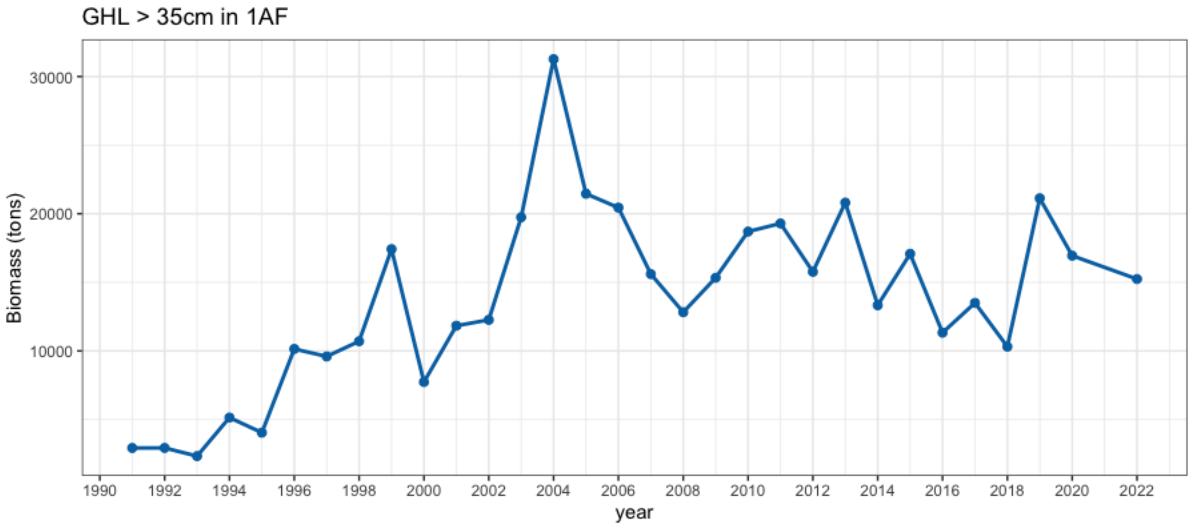

Figure 28. Biomass index of Greenland halibut > 35 cm(numbers weighted by stratum area) for the Div. 1AF surveys. The indices 1988- 2004 have been calibrated with conversion factor due to the change of gear.

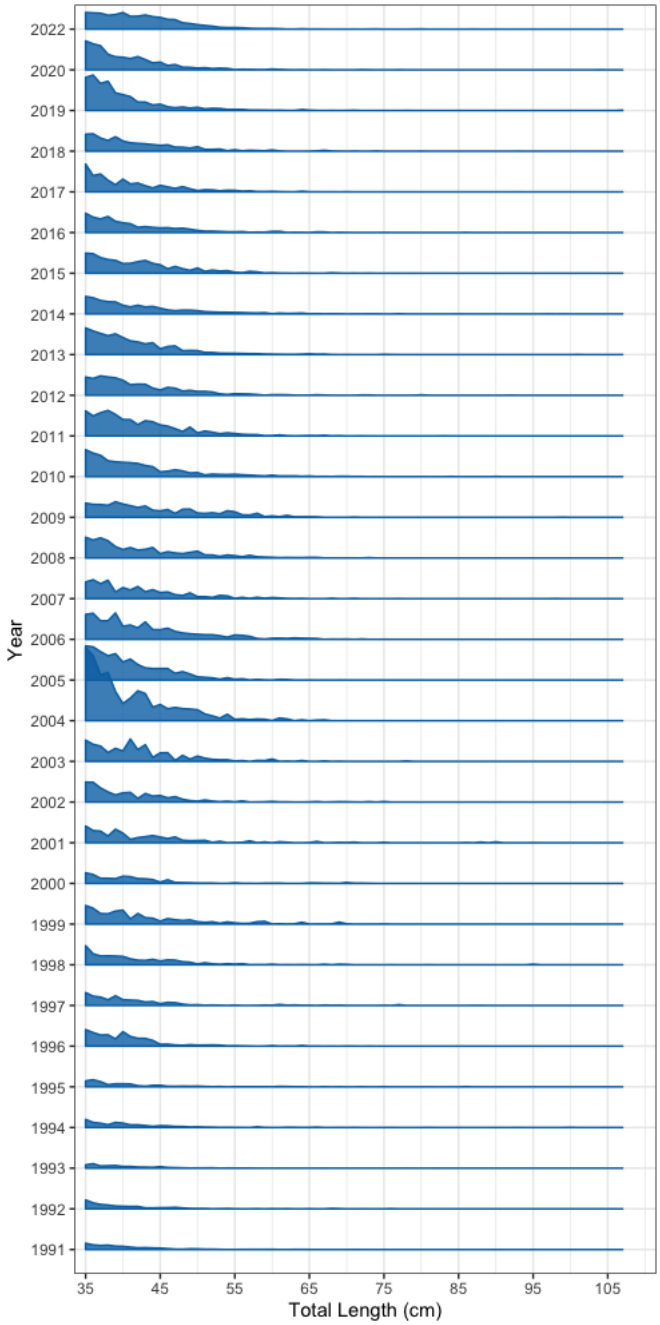

Figure 29. Length distribution of Greenland halibut > 35 cm (numbers weighted by stratum area) for the Div. 1AF surveys. The indices 1988- 2004 have been calibrated with conversion factor due to the change of gear.

Appendix 1. NAFO codes used in the CPUE standardization.

Code for Trawl Gear
Bottom otter trawl (charters), 8, OTB
Bottom otter trawl (side or stern not specified), 10, OTB
Bottom otter trawl, 12, OTB-2
Otter twin trawl, 192, OTT

Code for Boat (Tonnage)
0 Not known
2 0-49.9
3 50-149.9
4 150-499.9
5 500-999.9
6 1000-1999.9
7 2000 and over

e.g. BoatC1924 = vessel (BoatC), twin trawl (192), class (4)
Boat3414= Newfoundland region vessel (Boat3), gillnet (41), class (4)
Boat40413= Arctic region vessel (Boat 40), gillnet (41), class (3)

Appendix 2. Standardized CPUE index for trawlers in SA 0+1

Call:
lm(formula = lcpue ~ Year + Month + Boat)

Residuals:

Min	1Q	Median	3Q	Max
-1.19437	-0.17290	0.01111	0.17743	1.10557

Coefficients:

	Estimate	Std. Error	t value	Pr(>|t|)	
(Intercept)	-0.901795	0.351038	-2.569	0.010404	*
Year1989	0.119963	0.196165	0.612	0.541037	
Year1990	-0.424381	0.174609	-2.430	0.015326	*
Year1991	-0.351937	0.167204	-2.105	0.035657	*
Year1992	-0.583928	0.158465	-3.685	0.000246	***
Year1993	-0.780740	0.165115	-4.728	2.73e-06	***
Year1994	-0.783843	0.164940	-4.752	2.44e-06	***
Year1995	-0.327910	0.172149	-1.905	0.057209	.
Year1996	-0.401260	0.165791	-2.420	0.015759	*
Year1997	-0.711488	0.163199	-4.360	1.50e-05	***
Year1998	-0.555734	0.171290	-3.244	0.001232	**
Year1999	-0.526122	0.164373	-3.201	0.001432	**
Year2000	-0.440313	0.156526	-2.813	0.005043	**
Year2001	-0.443720	0.158584	-2.798	0.005281	**
Year2002	-0.484515	0.154237	-3.141	0.001751	**
Year2003	-0.463850	0.152586	-3.040	0.002453	**
Year2004	-0.301842	0.149697	-2.016	0.044140	*
Year2005	-0.297780	0.150867	-1.974	0.048792	*
Year2006	-0.163521	0.150507	-1.086	0.277641	
Year2007	-0.386722	0.151101	-2.559	0.010692	*
Year2008	-0.258009	0.152690	-1.690	0.091514	.
Year2009	-0.267205	0.153996	-1.735	0.083149	.
Year2010	-0.214008	0.152205	-1.406	0.160145	
Year2011	-0.073670	0.151728	-0.486	0.627442	
Year2012	-0.139003	0.152235	-0.913	0.361510	
Year2013	-0.154361	0.150057	-1.029	0.303979	
Year2014	-0.025133	0.153806	-0.163	0.870245	
Year2015	0.148477	0.153486	0.967	0.333691	
Year2016	0.193838	0.154112	1.258	0.208888	
Year2017	0.333870	0.153963	2.169	0.030451	*
Year2018	0.381015	0.154036	2.474	0.013611	*
Year2019	0.282048	0.153961	1.832	0.067378	.
Year2020	0.208005	0.151558	1.372	0.170358	
Year2021	0.163007	0.152365	1.070	0.285050	
Year2022	-0.006287	0.153550	-0.041	0.967350	
Month2	-0.203459	0.088001	-2.312	0.021062	*
Month3	-0.131595	0.131395	-1.002	0.316917	
Month4	0.041299	0.096639	0.427	0.669254	
Month5	0.220384	0.071223	3.094	0.002050	**
Month6	-0.258506	0.067024	-3.857	0.000125	***
Month7	-0.286213	0.065168	-4.392	1.29e-05	***
Month8	-0.154059	0.062615	-2.460	0.014116	*
Month9	-0.064483	0.061612	-1.047	0.295643	

```
Month10    -0.070246   0.061443  -1.143 0.253312
Month11    -0.079764   0.061679  -1.293 0.196359
Month12     0.079940   0.064564   1.238 0.216067
BoatC107    1.543831   0.328933   4.693 3.22e-06 ***
BoatC1126   0.871220   0.389629   2.236 0.025660 *
BoatC124    0.760988   0.327830   2.321 0.020554 *
BoatC125    0.370703   0.320223   1.158 0.247400
BoatC126    0.748364   0.316910   2.361 0.018473 *
BoatC127    1.096325   0.316791   3.461 0.000571 ***
BoatC1926   1.193070   0.319085   3.739 0.000200 ***
BoatC1927   1.310119   0.316960   4.133 4.00e-05 ***
---
Signif. codes:
0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.3089 on 710 degrees of freedom
Multiple R-squared:  0.7142,     Adjusted R-squared:  0.6928
F-statistic: 33.47 on 53 and 710 DF,  p-value: < 2.2e-16
```

Appendix 3. Standardized CPUE index for gillnets in SA 0

Call:
lm(formula = lcpue ~ Year + Month + Boat)

Residuals:
```
    Min      1Q  Median      3Q     Max
-1.37624 -0.11479  0.00772  0.14298  0.67326
```

Coefficients:
```
             Estimate Std. Error t value Pr(>|t|)
(Intercept)  1.379860   0.294705   4.682 5.04e-06 ***
Year2004     0.466697   0.139604   3.343 0.000978 ***
Year2005     0.660309   0.128951   5.121 6.78e-07 ***
Year2006     0.637708   0.121815   5.235 3.93e-07 ***
Year2007     0.472506   0.115892   4.077 6.43e-05 ***
Year2008     0.643940   0.119474   5.390 1.86e-07 ***
Year2009     0.793456   0.121619   6.524 4.86e-10 ***
Year2010     0.853206   0.121619   7.015 2.97e-11 ***
Year2011     0.870761   0.121619   7.160 1.28e-11 ***
Year2012     0.843473   0.118164   7.138 1.45e-11 ***
Year2013     0.896243   0.121619   7.369 3.68e-12 ***
Year2014     0.981446   0.126119   7.782 3.01e-13 ***
Year2015     1.145891   0.121619   9.422  < 2e-16 ***
Year2016     1.230666   0.120077  10.249  < 2e-16 ***
Year2017     1.175194   0.118138   9.948  < 2e-16 ***
Year2018     1.238820   0.122913  10.079  < 2e-16 ***
Year2019     1.204761   0.119704  10.065  < 2e-16 ***
Year2020     1.308040   0.119770  10.921  < 2e-16 ***
Year2021     1.022786   0.118739   8.614 1.56e-15 ***
Year2022     1.066809   0.124013   8.602 1.68e-15 ***
Month5       0.007056   0.265376   0.027 0.978811
Month6      -0.377830   0.265021  -1.426 0.155424
Month7      -0.473596   0.264743  -1.789 0.075046 .
Month8      -0.099807   0.264053  -0.378 0.705819
Month9      -0.058652   0.264390  -0.222 0.824651
Month10     -0.032619   0.265957  -0.123 0.902501
Month11     -0.152410   0.267185  -0.570 0.568986
Month12     -0.324854   0.368005  -0.883 0.378364
Boat3414    -0.166058   0.082196  -2.020 0.044601 *
Boat3415     0.334294   0.119860   2.789 0.005763 **
Boat40413    0.143295   0.109313   1.311 0.191308
Boat40414    0.175659   0.083150   2.113 0.035799 *
---
Signif. codes:
0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Residual standard error: 0.2505 on 214 degrees of freedom
Multiple R-squared: 0.7427,	Adjusted R-squared: 0.7054
F-statistic: 19.92 on 31 and 214 DF, p-value: < 2.2e-16

Appendix 4: DFO CSAS meeting documents

Terms of Reference

Review of candidate stock assessment frameworks for the Northwest Atlantic Fisheries Organization Subarea 0+1 (Offshore) Greenland Halibut stock

Regional Peer Review – Ontario & Prairie Region

December 12-15, 2022
Winnipeg, MB and Virtual Meeting

Chairperson: Mary Thiess

Context
Fisheries and Oceans Canada (DFO) Science and the Greenland Institute of Natural Resources conduct multi-species bottom trawl surveys in Northwest Atlantic Fisheries Organization (NAFO) Subareas 0 and 1 to support assessment of the Subarea 0+1 (offshore) Greenland Halibut stock. The vessel and gear (*RV Paamiut*, Alfredo trawl) used for the surveys during 1999-2017 was retired in 2018 without opportunity to conduct paired trawling experiments with an interim or replacement vessel. An interim vessel and the Alfredo trawl were used in 2019 and a new long-term vessel (*RV Tarajoq*) and new gear (Bacalao trawl) will be used in 2022 and beyond. Typically, the ability to assess time series data relies on an assumption that consistent methods and effort are used over time to ensure inter-year comparability (i.e., any differences in gear or sampling effort are known or can be estimated). Survey time series are typically standardized through periods of change in data collection methods by conducting paired trawling experiments.

Given the absence of these experiments, DFO Fisheries Management has requested DFO Science to explore analytical method(s) and/or frameworks for the Subarea 0+1 (offshore) stock assessment that could incorporate data collected by multiple vessels and gears, including fishery-independent surveys and commercial fishery data. This review aims to support the NAFO Scientific Council's assessment of this stock and industry led Marine Stewardship Council certification process.

Objectives
The main objectives of the Canadian Science Advisory Secretariat (CSAS) process is to identify potential analytical methods and/or frameworks that could be used to improve the Subarea 0+1 (offshore) Greenland Halibut stock assessment. Specifically, the review will include:

1. Identify factors contributing to differences in catchability of Greenland Halibut and other fish and invertebrate species; and,
2. Examine analytical methods and/or frameworks that could allow integration and/or comparison of data collected by different vessels and gear configurations.

Expected Publications
- Science Advisory Report
- Proceedings
- Research Documents

Expected Participation
- Fisheries and Oceans Canada (DFO) (Ecosystems and Oceans Science and Fisheries Management sectors)
- Academia
- Industry
- Other invited experts

Resulting Publications

DFO. 2023. Proceedings of the Regional Peer Review on the Review of Candidate Stock Assessment Frameworks for the Northwest Atlantic Fisheries Organization Subarea 0+1 (Offshore) Greenland Halibut Stock; December 12-15, 2022. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2023/015.
Proceedings 2023/015

DFO. 2023. Review of candidate stock assessment frameworks for the Northwest Atlantic Fisheries Organization Subarea 0+1 (Offshore) Greenland Halibut stock. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2023/020.
Science Advisory Report 2023/020

Hedges, K.J., and Raffoul, D. 2023. Summary of factors that affect survey and fishing catchability and data available regarding the NAFO Subarea 0+1 (offshore) Greenland Halibut (*Reinhardtius hippoglossoides*) stock and fishery. DFO Can. Sci. Advis. Sec. Res. Doc. 2023/037. iv + 11 p.
Research Document 2023/037

Huynh, Q.C., and Carruthers, T. 2023. Development of Spatial Operating Models to Test Survey Design and Calibrate a New Survey Index for Northwest Atlantic Fisheries Organization Subarea 0+1 (offshore) Greenland Halibut (*Reinhardtius hippoglossoides*). DFO Can. Sci. Advis. Sec. Res. Doc. 2023/038. iv + 35 p.
Research Document 2023/038

Johnson, S.D.N, and Cox, S.P. 2023. A modeling framework for stock assessment and harvest strategy evaluation for the NAFO 0+1 (offshore) Greenland Halibut (*Reinhardtius hippoglossoides*) fishery. DFO Can. Sci. Advis. Sec. Res. Doc. 2023/039. iv + 88 p.
Research Document 2023/039