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Assessment of the Greenland Halibut Stock Component in NAFO Subarea 0 + 1 (Offshore)

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This paper presents the stock assessment of Greenland halibut in Northwest Atlantic Fisheries Organization Subareas 0 and 1 (offshore). Since 1995, catches have been near the Total Allowable Cath (TAC). Until 2022, catches increased in step with increases in the TAC. However, catches decreased in 2023, following advice from the NAFO Scientific Council. Greenland and Canada have conducted buffered random stratified bottom trawl surveys in Divisions 1CD and 0A-South since 1999 using the same vessel and the same gear. The combined index has been relatively stable and at a high level. 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 time series started with a new vessel, R/V Tarajoq, and a new gear, the Bacalao trawl. An index of abundance of age 1 Greenland halibut from a shallow survey in Divs. 1AF was calculated for 1991 to 2023 (no survey was conducted in 2021). A standardized index produced using a delta-GAM with exploitable biomass > 35 cm fork length from the shallow survey in Divs. 1AF and deep water surveys in Divs. 1CD and 0A-south, and commercial harvest data were used as inputs for Stochastic Surplus Production models in Continous Time (SPiCT). The SPiCT model was reviewed and accepted for use in providing advice regarding stock status and harvest levels. Projections for the medium term were conducted, and the results are presented within a precautionary approach framework.

1. Description of the Fishery, Catches and TAC

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). The TAC was increased to 25,000 t in 1979. In 1994, analysis of tagging and other biological information led to 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 an increase 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 tons and the TAC for 0B and 1C-F remained at 11,000. Based on an observed positive trend in the 1CD survey index the TAC for Div. 0B+Div. Based on an observed positive trend in the 1CD survey index, the TAC for Divisions 0B+1CF was increased by 3,000 tons in 2010. The overall TAC for Subarea 0+1 (offshore) remained at 27,000 t from 2011 to 2013. In 2014, the TAC for Div. 0A+Div. 1AB was increased by 3,000 tons to 16,000 t based on positive trends in the survey indices. 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 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 SA0+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 Divisions 1B-F, and the TAC was maintained at 36,370 t for 2021 and 2022. In 2022, considering that survey indices were not calculated in 2018-2022 because the survey vessel (RV Paamiut) was retired in winter 2018 and a contract vessel used in 2019 fished differently below 700 m, it was advised that the TAC be reduced to the mean level during 2013-2017 (29,640 t), a recent period when the stock was stable. Half of the advised reduction was applied, and the TAC was set at 33,305 t in 2023 and 2024.

1.2 Catches in Subarea 0 + 1 (offshore)

Catches of Greenland halibut were first reported in 1965, rising 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 Division 0B with participation by Canada, Norway, Russia and Faeroe Islands, as well as the 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 the TAC (Fig. 1). The TAC has been 36,400 t from 2019 to 2022. In 2023 catches were 32,990 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 1.48 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 Hedged, 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 (Table 1). 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. Therefore, 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 in 2023 occurred in comparable areas relative to preceding years (Figures 2 and 3). In Subarea 0, fishing was concentrated along the Baffin Island shelf break 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 4). The fishery in the Northern area (0A and 1AB), 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, catches in 0B, were caught by foreign countries (Russia, Norway and Faroes) and in Greenland waters, most of the landings were from Japan and Norway. Since 1995, all landings in 0B are from Canada. In Greenland, landings in 1CD are a mixture of Greenland and foreign countries (Norway, the Faroes, Germany and Russia) (Figure 4, 5 and 6). In 2023, there were no landings from Russia.

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**). A small longline fishery occurred in 0A and 0B in 2023.

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. 4.4.0 (R Core Team, 2024) and least squares means were estimated with package “emmeans” (**Lenth R. and M., 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 declined until 2022, but maintaining high levels. In 2023, CPUE increased again to the 2018 levels (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 2023 (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.

1.6 Bycatch and Discards:

Discards of Greenland halibut in the trawl fishery in both Subareas has been normally small, 1- 2% of retained Greenland halibut. Discards in the Subarea 0 gillnet fishery used to be slightly higher but usually not more than 3% of the retained catch. In 2023, discards increased, being around 6 to 11 % for the trawl and gillnet fisheries, and 43% of discards in the lonline fishery.

By-catch is estimated by observers on board vessels in SA 0 (Table 3). 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 2023 fishing trips licensed by Fisheries and Oceans Arctic Region. Overall bycatch was <11% of the observed Greenland halibut catch for trawl and gillnet, and almost 50% for longline (Table 3). 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, until 2022. In 2023, discard of redfish, skates and dogfish increased.

2. Sampling from Greenland halibut landings

Distribution of the samples Information on fisheries and sampling in SA 1 for 2023 was available from Greenland (**C. H. Nogueira A and R., 2024**). The distribution of commercial samples in 2023 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. Locations of the samples collected by Greenland are shown in Figure 12. 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).

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. 19). Since 1997 surveys have been conducted in 0B and 0A-South by Canada and in 1CD by Greenland using the same research vessel (Fig. 20 abd 21).

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. 1CD (since 1997) and in Div. 0A-South (to approximately 72o N) (since 1999) using the Greenland Institute of Natural Resources (GINR) research vessel RV Paamiut. 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 Wheeland L. and A. (**2020**). As a result the 2019 index is not comparable with the rest of the time series (**A. Nogueira and Treble, 2020**). No surveys were conducted in 2018, 2020 and 2021.From 2022-2023, a new time-series started with the RV Tarajoq and a Bacalao trawl, without the possibility of conducting calibration experiments between the 2 vessels and gears. Given the common research vessel and survey protocols it was possible to develop a combined biomass and abundance index for 1CD and 0A-South for years 1999, 2001, 2004, 2008, 2012, 2014-2017 and 2019 , and 2022-2023(Figs. 3 and 4) (see (**A. Nogueira and Estebez-Barcia, 2024**) and (**J., 2024**) for individual survey details). Biomass in 1CD and 0A-South combined was relatively stable from 1999 to 2014, varying between 124,000 t and 172,000 t (Fig. 3). 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 the index of the new time-series with R/V Tarajow increased from 2022 to 2023. (Fig. 22).

The overall length distribution (weighted by stratum area) in 0A1CD combined typically ranges from 5 cm to just over 100 cm.It was dominated by a mode at 49-51 cm from2006 to 2017, an increase from a mode of 46 cm observed in 2001. With the new time-series, in 2022 we observed different clear mode at 48-49 cm , and secondary modes at 20-21, 28, 31, and 43-44. In 2023 the mode was at 48-50 cm. The frequency distribution for 1CD and 0A-South combined In 2023 length ranged from 11 to 114 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 (Fig. 23).

3.3 Greenland Shrimp and Fish Survey

Since 1988 surveys with a shrimp trawl have been conducted off West Greenland during July-September. The survey covers the area between 59o N and 72o 30' N (Div. 1A-1F) from 50 m to 600 m. The survey area was re-stratified in 2004 based on better information about depths. All biomass and abundance indices have been re-calculated, but 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 (M. and K. (**2005**)), and data from 1988 to 2004 were converted so the time series are comparable. Calibration is used for to estimate the Age 1 abundance. The RV Paamiut was used for the survey from 1991 to 2017. In 2018 the CV Sjuderberg was used to conduct the survey and in 2019 and 2020 the CV Helga Maria. An examination of gear parameters found that the effects of these vessel changes had a minimal effect on trawl performance (A. Nogueira and Treble (**2020**)). 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. Biomass has varied with a general increasing trend from 2010 to 2020 (Fig. 24). Abundance has been more variable, 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 (R. and Nogueira (**2024**)).

Clear modes can be found in the length distribution at 12-15 cm and 23 cm, corresponding to fish at age 1 and 2 (R. and Nogueira (**2024**)). 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 (Fig. 27). The index declined from 2017 to 2019 but in 2020 it had increased to a level near average for the last 10 years.There was no survey in 2021. The index has been below the long-term average the last 5 years. It is unclear if the age 1 abundance index is representative of future recruitment.

3.4 Standardized combined index 1AF -0A1D

A standardized combined index for the exploitable biomass of the stock (biomass > 35 cm fork length) was produced using a Delta-Lognormal Generalized Additive Model (Delta-GAM) (Fig.28).The model used density, depth and distribution data on Greenland halibut from three buffered stratified random surveys: the shallow survey in 1A-F, the deep survey in 1CD and the deep survey in 0A (B. and A. (**2024**))

3.5 Biological information: age and maturity

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 (Fig. 6). Survey Length-at-maturity

Maturity information collected during surveys in SA0 were examined in 2006 and updated in 2009 (Harris L. N and J. (**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.

4. Assessment results

During the 2024 SC June meeting a surplus production model in continuous time (SPiCT) model was presented and accepted as a valid assessment tool for this stock (C. B. Nogueira A and J. (**2024**)). The SPiCT model used a standardized combined index for the exploitable biomass of the stock (biomass> 35 cm fork length), as well as commercial catch data as input. The index combined the shallow survey (1991-2023, biomass> 35 cm) in 1AF and the deep surveys in 0A-1CD (1999, 2001, 2004, 2008, 2012, 2014-2017, 2019 and 2022-2023) with a Delta-Lognormal Generalized Additive Model (Delta-GAM) (B. and A. (**2024**)).

The relative B/Bmsy was 1.3 , and the relative F/Fmsy was 0.78

Precautionary Approach Framework

The surplus production model outputs indicate that the stock is presently 1.3 times BMSY and F is below FMSY. 30% BMSY is considered a suitable limit reference point (Blim) for stocks where a production model is used. At present, the risk of the stock being below Blim = 30% Bmsy is very low (<1%) and risk of F> FMSY is 34%. The stock is, therefore, in the safe zone as defined in the NAFO Precautionary Approach Framework (NAFO 2004) (Table 3 and 4).

Projections

Medium-term projections were carried forward to the year 2026 for catch scenarios with catch = TAC = 33 305 t for 2024. Constant removals were applied from 2025-2026 at several levels of F (F=0, Fstatus quo, 75% Fmsy, and 85% Fmsy, Fmsy,) or catch (TAC and 90% TAC). At the end of the projection period, the risk of biomass being below Blim was less than 1 % in all cases. For the Fstatus quo projections, the probability that F > Flim=Fmsy in 2025-2026 was 34%, and with 2/3 Fmsy the probability was 23%. At 75% Fmsy, the probability that F > Flim was 30%. Projected at the level of 85% Flim, the probability that F > Flim was 39% and for Fmsy projections, this probability increased to 50%. For biomass projections, in all scenarios for 2025-2026 the probability of biomass being below Blim was less than 1%. The probability that biomass in 2026 is less than biomass in 2024 is between 19 and 70% for all projections. Figure 29 shows the projected relative biomass over 2024-2026 for catch in 2024 = TAC = 33 305 t.

The high probababilities for F> Flim are probably due to the high uncertainties on the model.

6. Conclusion

Biomass of Greenland halibut has been very stable for the last 20 years, and above Bmsy. F has been below Fmsy during the whole studied period. The stock is not projected to decrease below Blim in the medium term (to 2026).

7. Future Research

The uncertainty in the assessment model should be explore. However, it will likely decrease with longer time-series or more contrast in fishing mortality.

GINR and DFO have undertaken research on lenght-based models. DFO effors were presented in 2022 (Annex 4- Treble et al. 2022).

A big effort in otolith reading has been made over the last couple of years. This will make it possible to explore age-based models.

Table 1. Greenland halibut catches (metric tons) by year and country for Subarea 0, 1987 to 2023. Based on STATLANT, with information from Canada used to exclude 0B inshore catch.

Year	0A-CAN	0A-OTHER	0A-TOTAL	0B-CAN	0B-OTHER	0B-TOTAL	SA0-TOTAL
1987					388	388	388
1988				2	1022	1024	1024
1989				180	907	1087	1087
1990				844	8909	9753	9753b
1991				395	8350	8745	8745
1992				2624	10164	12788	12788
1993	681		681	592	6605	7197	7879c
1994				402	4274	4676	4676
1995	82		82	1859	1292	3151	3233
1996		576	576d	2354	1678	4032	4608
1997	3		3	3868	452	4320	4323
1998				3924		3924	3924
1999	517		517	4267		4267	4784
2000				5438		5438	5438e
2001	2628	445	3073	5034		5034	8107
2002	3561		3561	3910		3910	7471f
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	18327g
2020	9429		9429	8489		8489	17918g
2021	10061		10061	9033		9033	19094gh
2022	9582		9582	9033		9033	18616i
2023	8522		8522	7796		7796	16318 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 1.48 conversion factor for J-cut, tailed product; 1,129 t increase over reported catch

Table 2. GHL catches (metric tons) by year and country for Subarea 1 from 1987 to 2023, not including inshore areas. Based on STATLANT, with information from Greenland used to exclude 1A-F inshore catch.

Year	1AB-GRL	1AB-RUS	1AB-FRO	1AB-TotaL	1CF-GRL	1CF-RUS	1CF-FRO	1CF-EU	1CF-NOR	1CF-JPN	1CF-Total	SA1-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	4887a
2000			96	96	2059	792	147	444b	1590		5032	5128
2001	340	85	150	575	2012	829	150	537b	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	9495cd
2004	3500	241	153	4035	2102	1214	150	665f	1364		5495	9530ce
2005	3363	549	125	4037	2380	1147	149	549	1456b		5681	9718e
2006	5530	565	128	6223	2430	1222	147	544	1379		5722	11945e
2007	5596	575	125	6296	1805	689	150	1516	1441		5601	11897e
2008	5524	570	149	6243	1592	763	184	1517	1452b		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	13374e
2012	5810	546	103	6459	2660	1227		1784	1761		7432	13891
2013	5865	546	102	6513	3514	1223		2017	1496		8250	14763e
2014	7333	550	102b	7985	4072	1224		1751	1464		8511	16496f
2015	7366	548	102	8016	3834	1215		1880	1503		8432	16448f
2016	7682	550	103	8335g	4367	1215		1885	1382		8849	17184f
2017	8003	549	103	8655	4968	1224		1929	1495		9616	18271f
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	18124f
2021	7791	550	104	8445	4902	893		1673	1429		8897	17342
2022	8419	433	100	8952	6035	686		1660	1524		9905	18857
2023	8199		103	8302	5378			1660	1227		8265	16567h

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 Greenlan d 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

Table 3. By-catch (tons) as reported by at-sea observers assigned to the 2023 Canadian Greenland halibut fishery (Fisheries and Oceans Canada Arctic Region). Species selected based on reported catches > 1t. Corresponding catch of Greenland Halibut and bycatch relative to Greenland Halibut catch (%) is also given.

Species	0A-Gillnet	0A-Longline	0A-Trawl	0B-Gillnet	0B-Longline	0B-Trawl	TotalSA0 (t)	%
Greenland shark	3.4	0	216.3	0.9	0	201.6	422.1	33.4
Roughhead grenadier	63.4	5.6	22.7	26.3	8.6	72.9	199.5	15.8
Northern wolffish	3.1	0.4	14.3	2	3	152.7	175.6	13.9
Arctic skate (A.hyperborea)	46.6	22.2	89.9	0.2	0.9	1.1	160.9	12.7
Spinytail skate	3	0	13.2	0.3	2.1	32.1	50.8	4
Redfishes (Sebastes)	19.2	0	0.4	12.4	0	17.9	49.8	3.9
Skates sp.	5.2	0	27.7	0	0	7.1	40	3.2
Sperm whales	0	0	0	30	0	0	30	2.4
Grenadiers sp.	0.3	0	5.8	0.5	0	13.7	20.2	1.6
Thorny skate (A.radiata)	3.6	0	10.1	0.1	0	0.9	14.6	1.2
Black dogfish (C. frabricii)	0.1	0	0	6.1	0	5.8	12	1
Jensen's skate (A.jenseni)	2.2	0	4.3	0	0	2.5	8.9	0.7
Threebeard rockling	0.1	0.1	7.3	0	0	0.9	8.4	0.7
Sponges (Porifera)	0.9	0	0.6	0.3	0	5.6	7.5	0.6
Scyphozoans	0.2	0	1.4	0.2	0	5.5	7.3	0.6
Rock grenadier (C. rupestris)	0	0	0.8	0.1	0	5.2	6.1	0.5
Blue hake (A. rostrata)	0	0	0	0.2	0.2	4.7	5.1	0.4
Spiny eel (N.chemnitzi)	0	0	0.1	0	0	4.2	4.3	0.3
Winter skate (L. ocellata)	3.8	0	0.1	0	0	0	3.9	0.3
Spotted wolffish (A. minor)	0.2	0	1.5	0.1	0	2.1	3.9	0.3
Norway king crab (L. maja)	1.8	0	0	0.3	0	0.5	2.6	0.2
American plaice (H.	0.5	0	1.5	0.2	0	0.4	2.6	0.2
Polar sculpin (C.microps)	0	0	0.4	0	0	1.9	2.3	0.2
Sea anemones (Actiniaria)	0.1	0	0.6	0.1	0	1.3	2.1	0.2
Northern bottlenose whale (H. ampullatus)	2	0	0	0	0	0	2	0.2
Barndoor skate (D.laevis)	0.1	0	0	0	0	1.2	1.3	0.1
Others	5.3	0.1	4.6	3.8	0	6.6	20.4	1.6
Total Bycatch	165.2	28.5	423.7	84	14.8	548.3	1264.5	100
Greenland halibut catch	2609.7	66.8	5895	2590.5	27.4	5208.4	16397.8	0
% of Greenland halibut catch	6%	43%	7%	3%	54%	11%	8%	8%
Greenland halibut discards	306.5	1.4	224.3	47.2	0.5	216.5	796.5	0
% of Greenland halibut catch	12%	2%	4%	2%	2%	4%	5%	5%

Table 4. Medium-term projections for Greenland halibut. Estimates for yield and relative biomass (B/Bmsy) with 80% confidence interval are shown, for projected F values of F0, Fstatus quo, 75%Fmsy, 85%Fmsy and Fmsy. Catch in 2024 were assumed at 33 305 t (TAC).

Projections with Catch 2024 = 33305 t		
Year	Yield (´000t)	Projected relative Biomass (B/Bmsy) median (80%CL)
F =0		
2024	33.3	1.3 (0.91-1.84)
2025	0	1.28 (0.89 - 1.85)
2026	0	1.4 (1.02-1.92)
Fstatusquo = 0.102		
2024	33.3	1.3 (0.91-1.84)
2025	32.33	1.28 (0.89-1.85)
2026	32.04	1.27 (0.87-1.86)
2/3Fmsy= 0.085		
2024	33.3	1.3 (0.91-1.84)
2025	27.23	1.28 (0.89- 1.85)
2026	27.39	1.28(0.91-1.88)
75%Fmsy = 0.096		
2024	33.3	1.3 (0.9-1.85)
2025	30.51	1.28 (0.89- 1.86)
2026	30.4	1.26 (0.89-1.87)
85%Fmsy = 0.109		
2024	33.3	1.3 (0.91-1.84)
2025	34.42	1.27 (0.89-1.85)
2026	33.91	1.26 (0.86-1.85)
Fmsy = 0.128		
2024	33.3	1.3 (0.91-1.84)
2025	40.21	1.28 (0.89-1.85)
2026	38.92	1.24 (0.83-1.84)
TAC = 33 305		
2024	33.3	1.3 (0.91-1.84)
2025	33.3	1.28 (0.89-1.85)
2026	33.3	1.27 (0.86-1.85)
90% TAC = 29 975		
2024	33.3	1.3 (0.91-1.84)
2025	29.97	1.28 (0.89-1.85)
2026	29.97	1.28 (0.88-1.86)

Table 5. Yield (000 t) and risk (%) of ByFmsy (Flim=Fmsy) at projected F values of F0, Fstatus quo, 75% Fmsy, 85% Fmsy Fmsy, TAC and 90%TAC. Catch in 2024 was assumed at 33305 t (TAC).

	yield (´000t)		P (F> Flim)			P(B<Blim)			P(B>Bmsy)			P(B2026 < B2024)
Catch2024= 33305t	2025	2026	2024	2025	2026	2024	2025	2026	2024	2025	2026	
F=0	0	0	34%	<1%	<1%	<1%	<1%	<1%	83%	81%	91%	19%
F statusquo	32.33	32.04	34%	34%	34%	<1%	<1%	<1%	83%	81%	79%	60%
2/3 Fmsy	27.23	27.39	34%	23%	23%	<1%	<1%	<1%	83%	81%	81%	53%
75 % Fmsy	30.51	30.4	34%	30%	30%	<1%	<1%	<1%	83%	81%	80%	58%
85% Fmsy	34.42	33.91	34%	38%	39%	<1%	<1%	<1%	83%	81%	78%	63%
Fmsy	40.21	38.92	34%	50%	50%	<1%	<1%	<1%	83%	81%	76%	70%
TAC	33.3	33.3	34%	36%	37%	<1%	<1%	<1%	83%	81%	79%	62%
90%TAC	29.97	29.97	34%	29%	29%	<1%	<1%	<1%	83%	81%	80%	57%

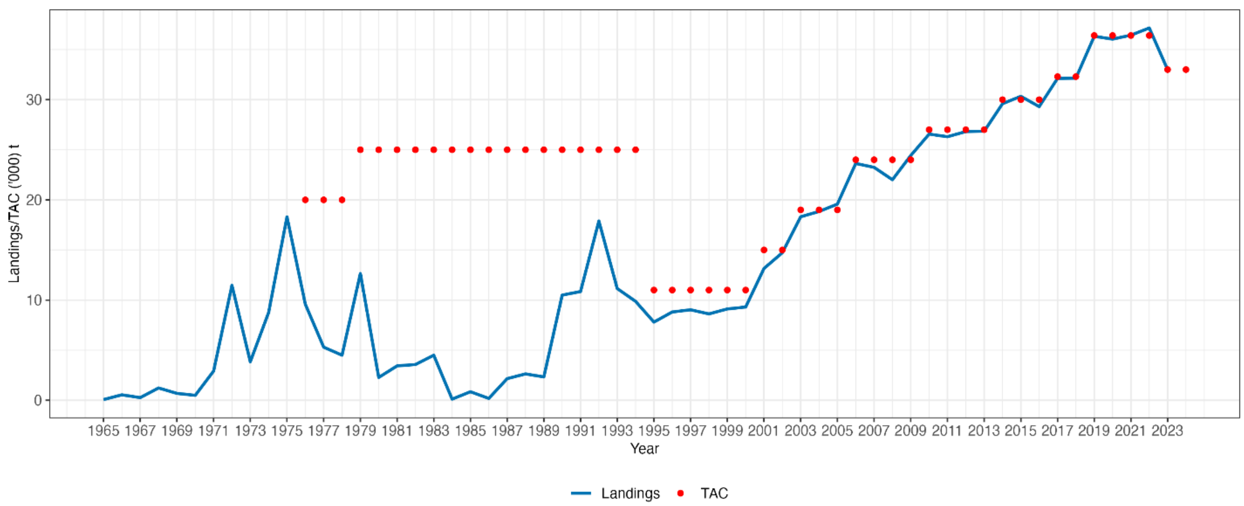

Figure 1. Catches and recommended TAC for SA0+1 (offshore) Greenland halibut.

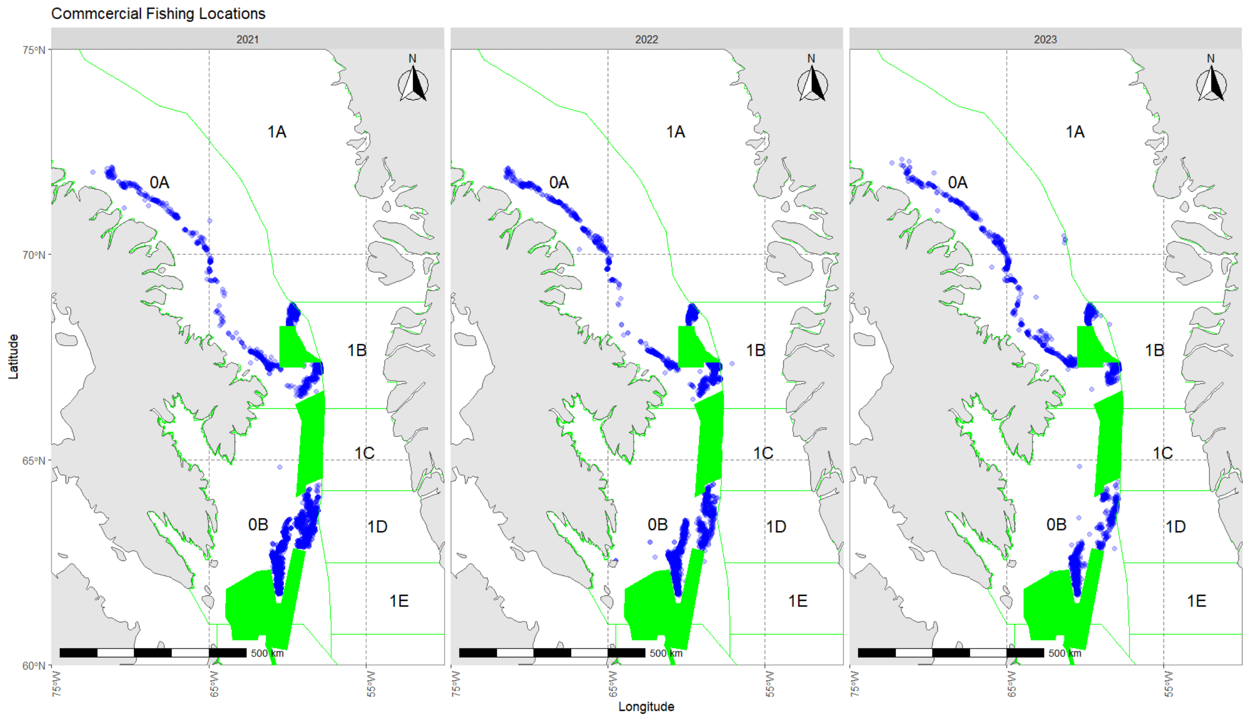

Figure 2. Greenland halibut commercial catch distribution for Subarea 0 in 2023. Three marine refuges that are closed to bottom contact fishing are in shown in green. From north to south: Disko Fan, Davis Strait and Hatton Basin.

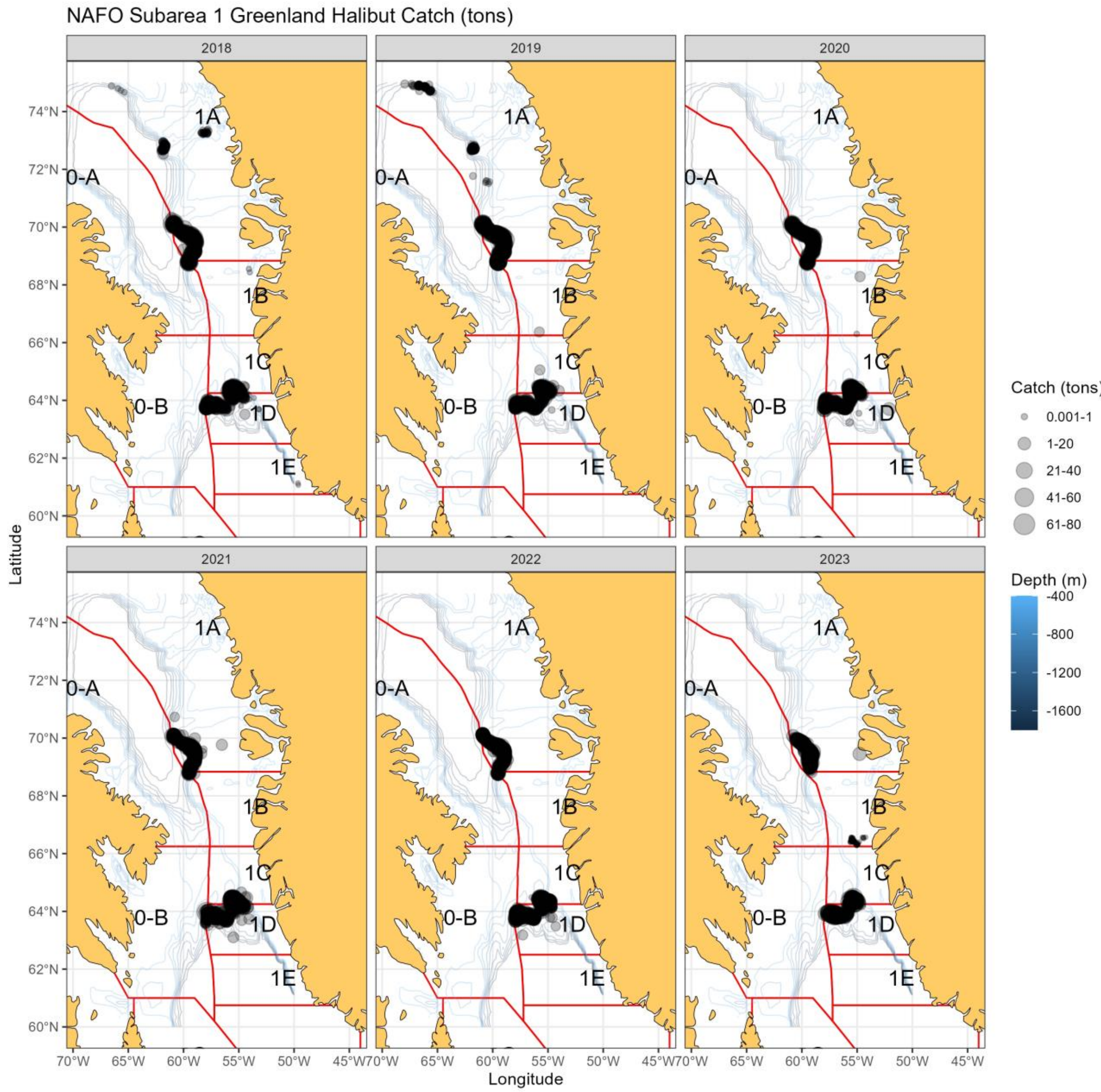

Figure 3. Greenland halibut commercial catch distribution for offshore Subarea 1 in 2023.

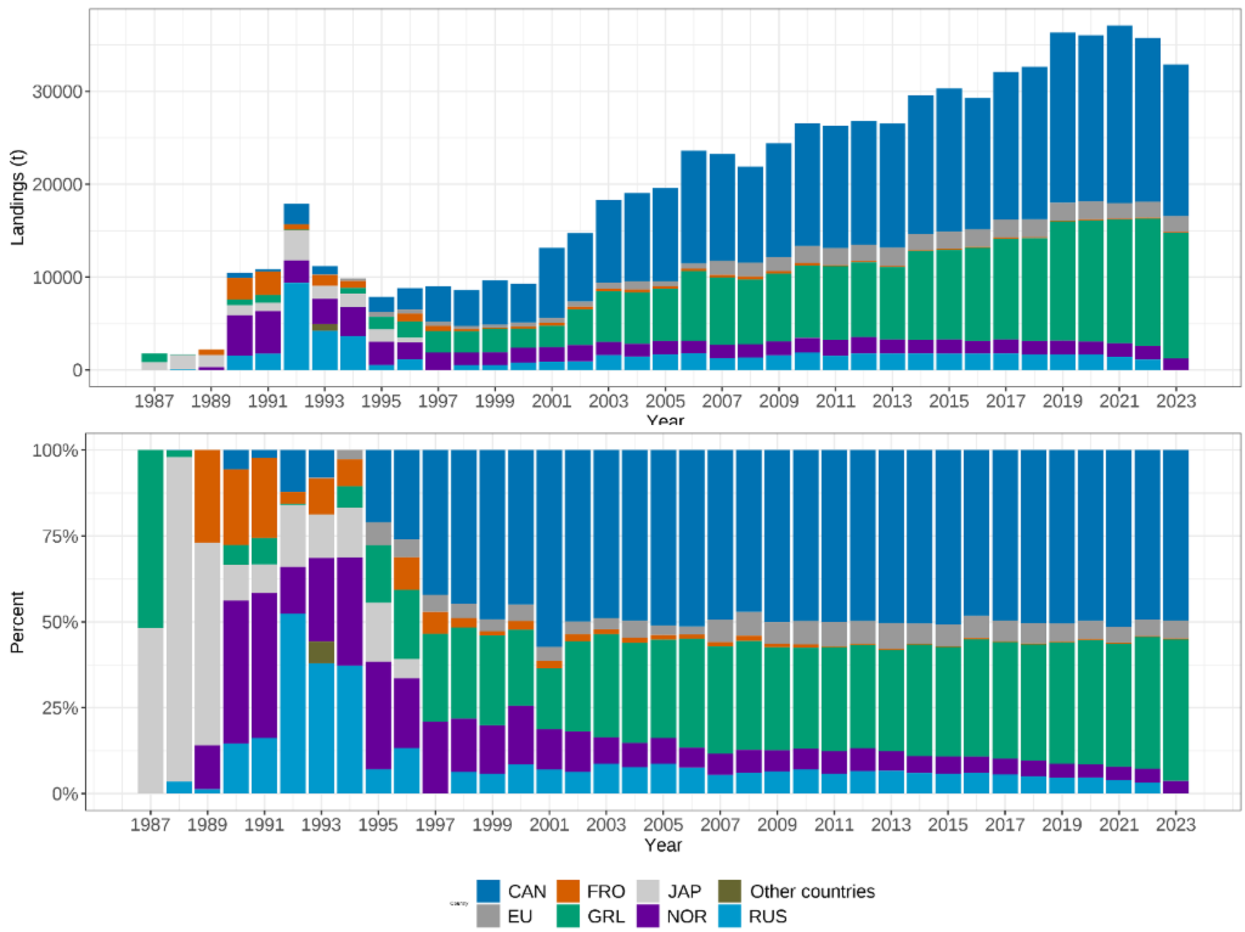

Figure 4. Commercial landings (t) of Greenland halibut in Subareas 0+1 offshore from 1987 to 2023 by country as total landings (upper panel) and percentage of total landings (lower panel).

Figure 5. Commercial landings (t) of Greenland halibut from 1987 to 2023 by country in Divions. Upper panel: 0A+1AB; lower panel: 0B+1CD.

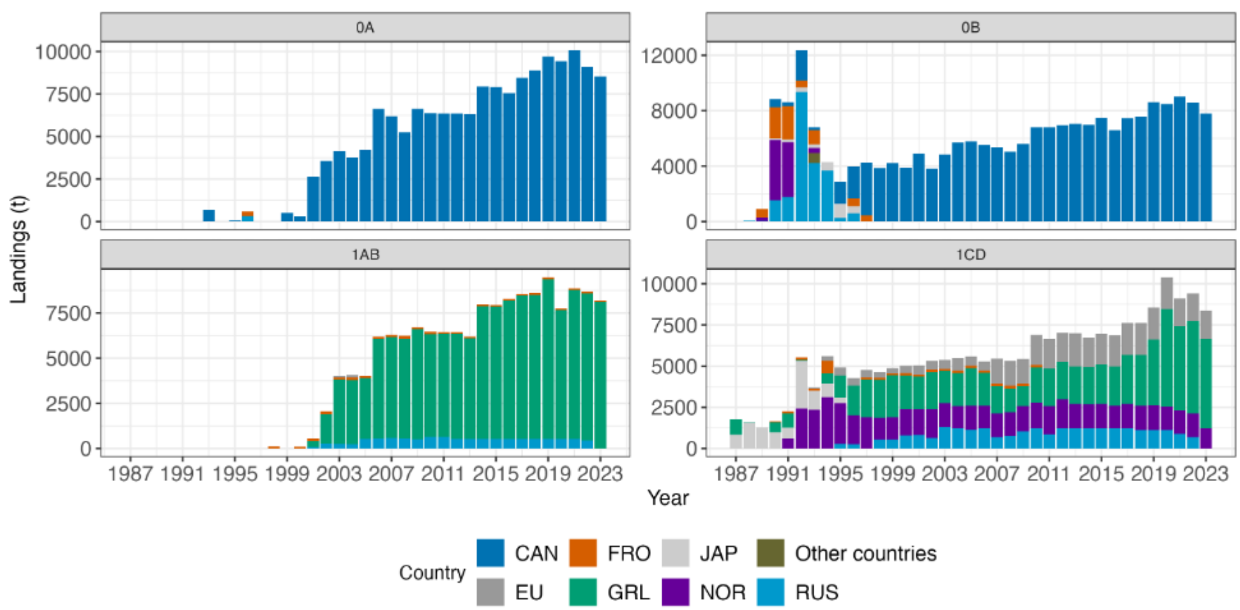

Figure 6. Commercial landings (t) of Greenland halibut from 1987 to 2023 by country and Division. Upper left: 0A; upper right: 0B; lower left: 1AB; lower right: 1CD.

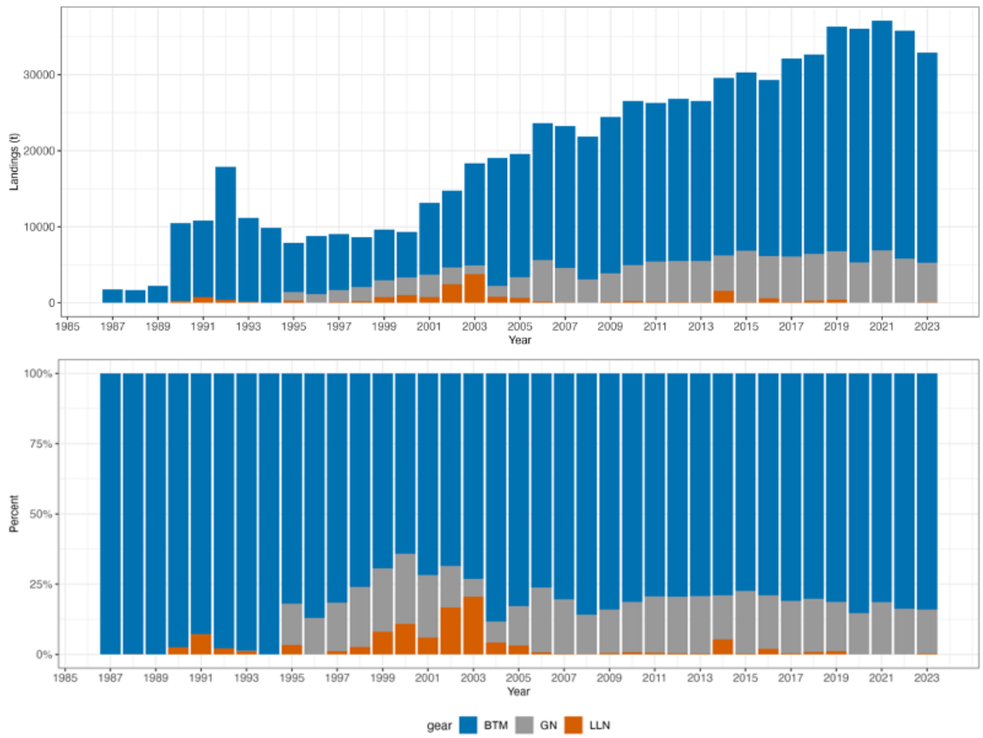

Figure 7. Commercial landings (t) of Greenland halibut in Subareas 0+1 offshore from 1987 to 2023 by gear type as total landings (upper panel) and percentage of total landings (lower panel).

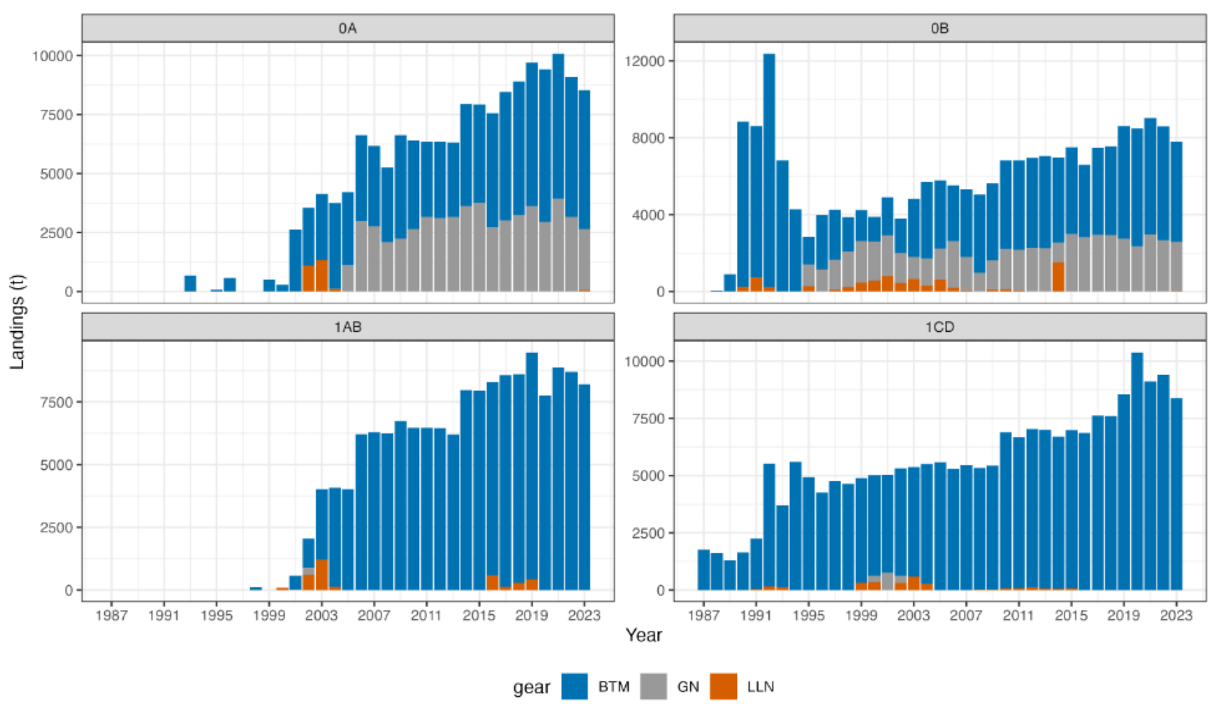

Figure 8. Commercial landings (t) of Greenland halibut from 1987 to 2023 by gear type and Division. Upper left: 0A; upper right: 0B; lower left: 1AB; lower right: 1CD.

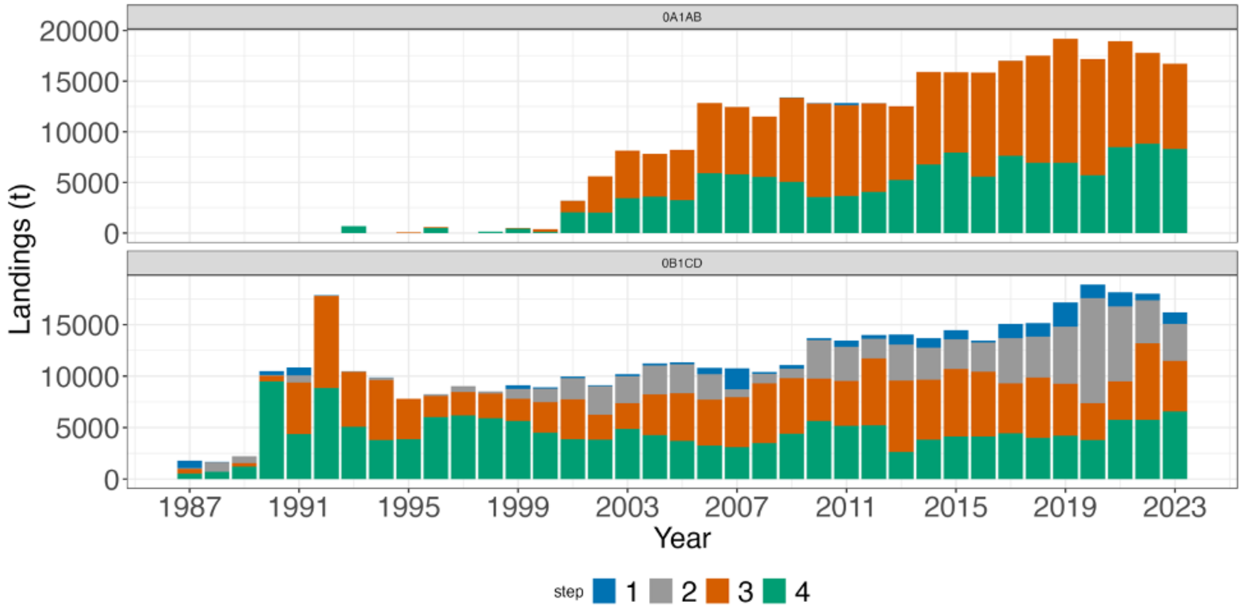

Figure 9. Commercial landings (t) of Greenland halibut from 1987 to 2023 by step and Divisions. Upper panel: 0A+1AB; lower panel: 0B+1CD.

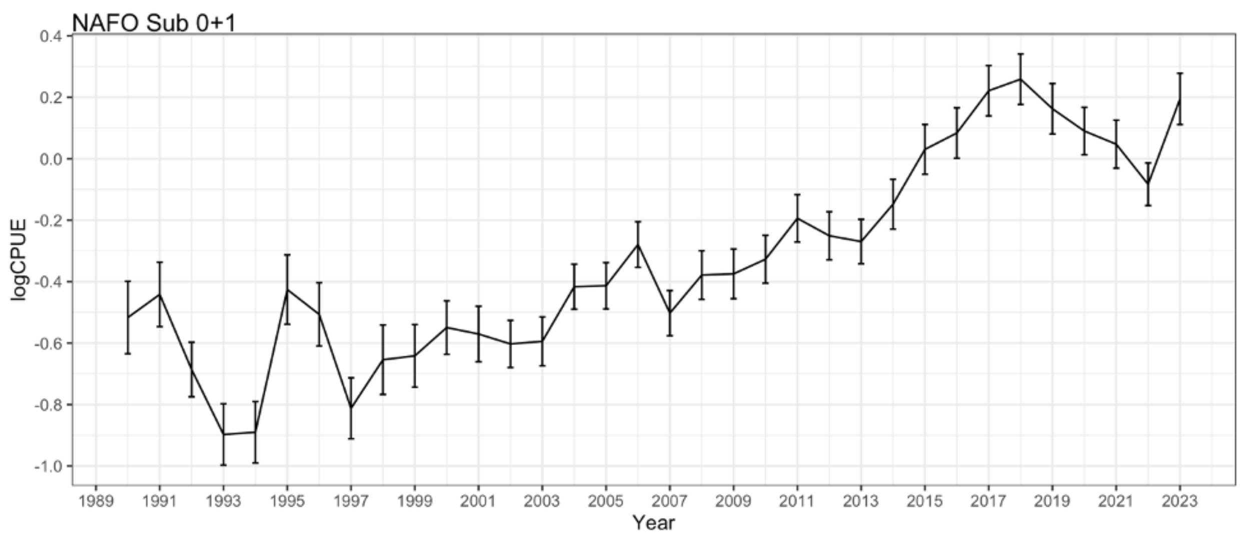

Figure 10. Combined standardized trawl CPUE index for Greenland halibut from trawlers in Subareas 0+1 offshore, with S.E.

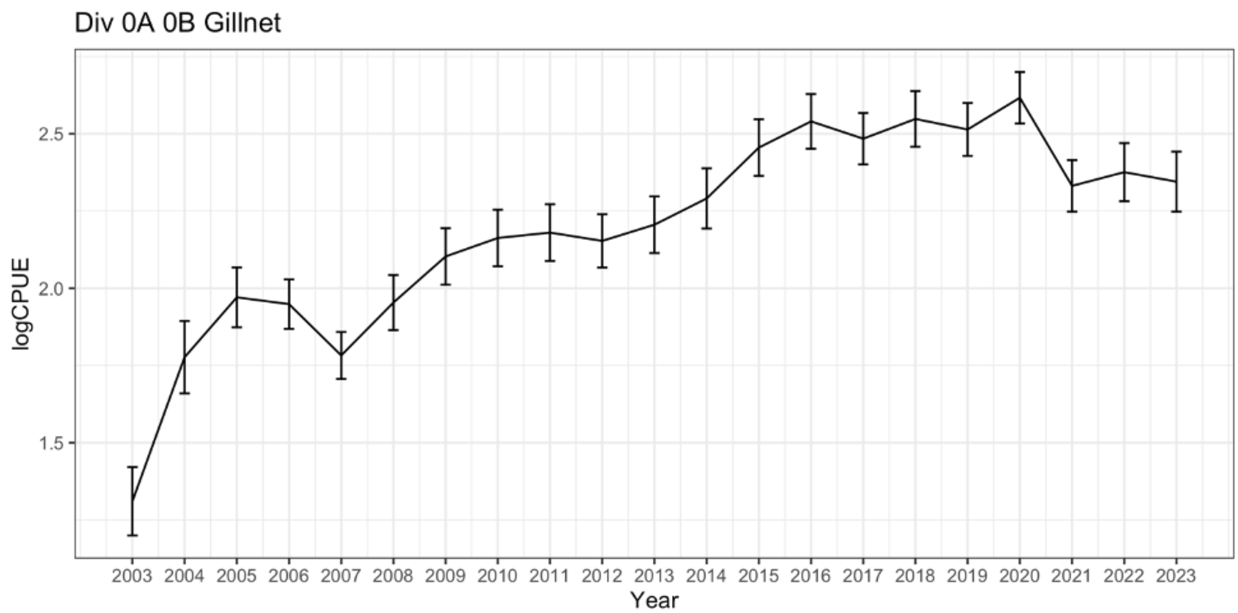

Figure 11. Standardized CPUE index from for Greenland halibut gillnets in Subarea 0, with S.E. Note that bait bags have been added to the gillnets since 2015.

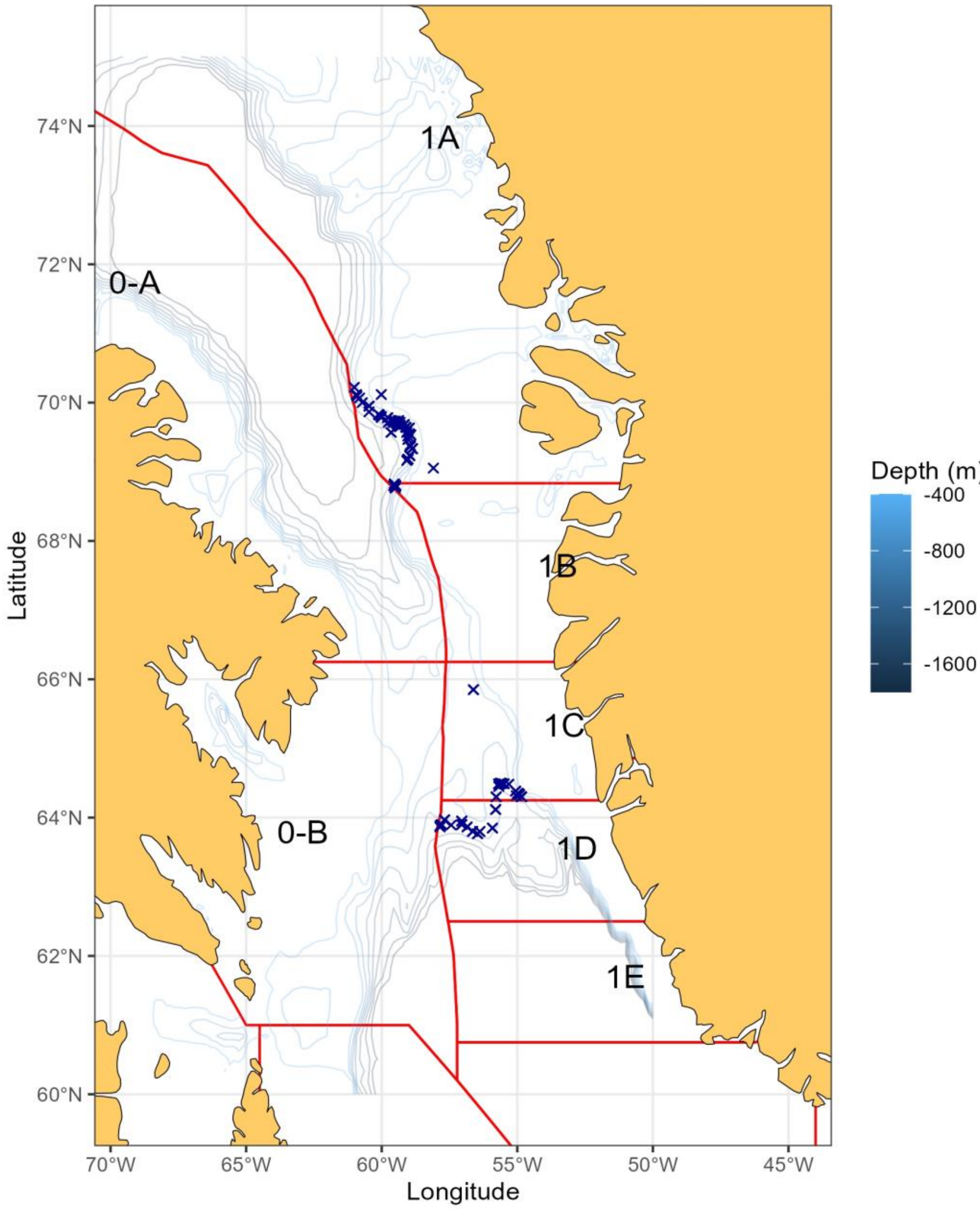

Figure 12. Locations of fish measurements from for Greenland halibut commercial fishing in Subarea 0 in 2023.

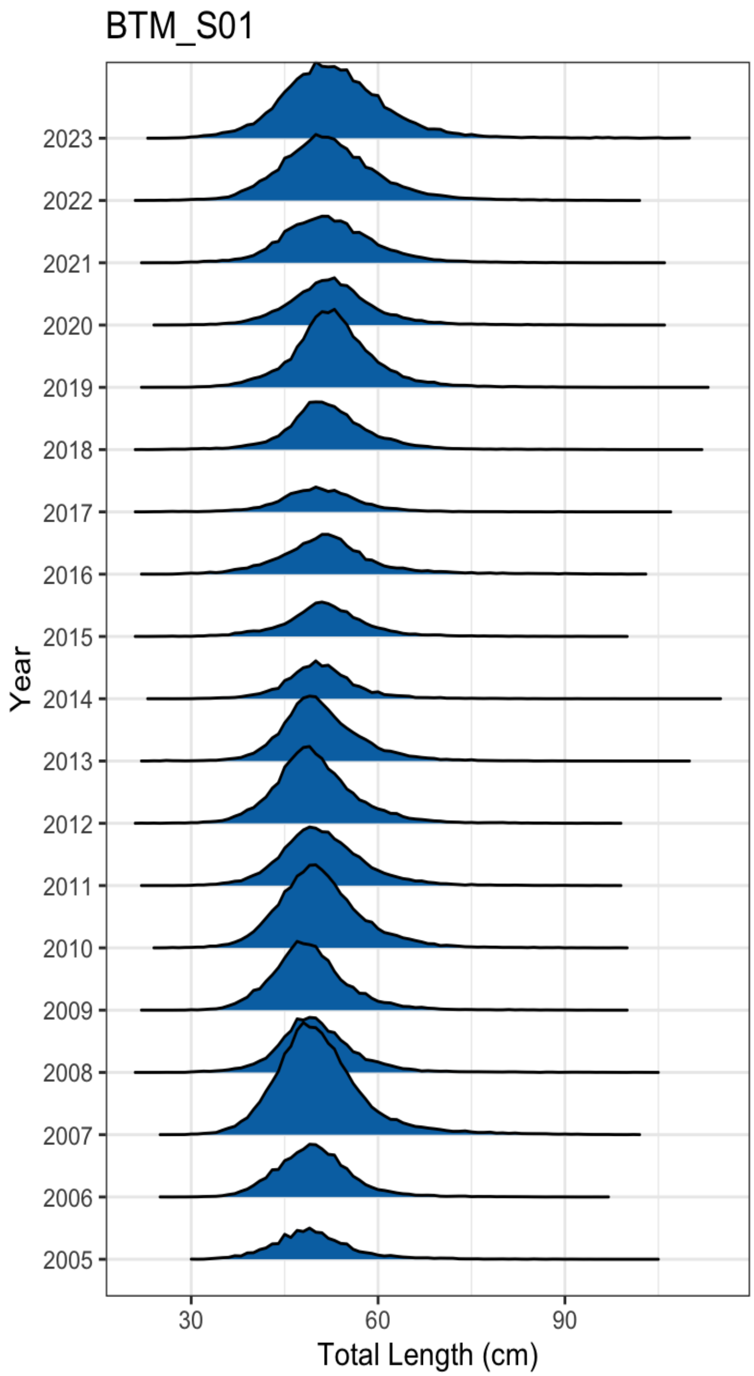

Figure 13. Length distribution of Greenland halibut sampled from the trawling fleets in Subareas 0+1 offshore in 2023.

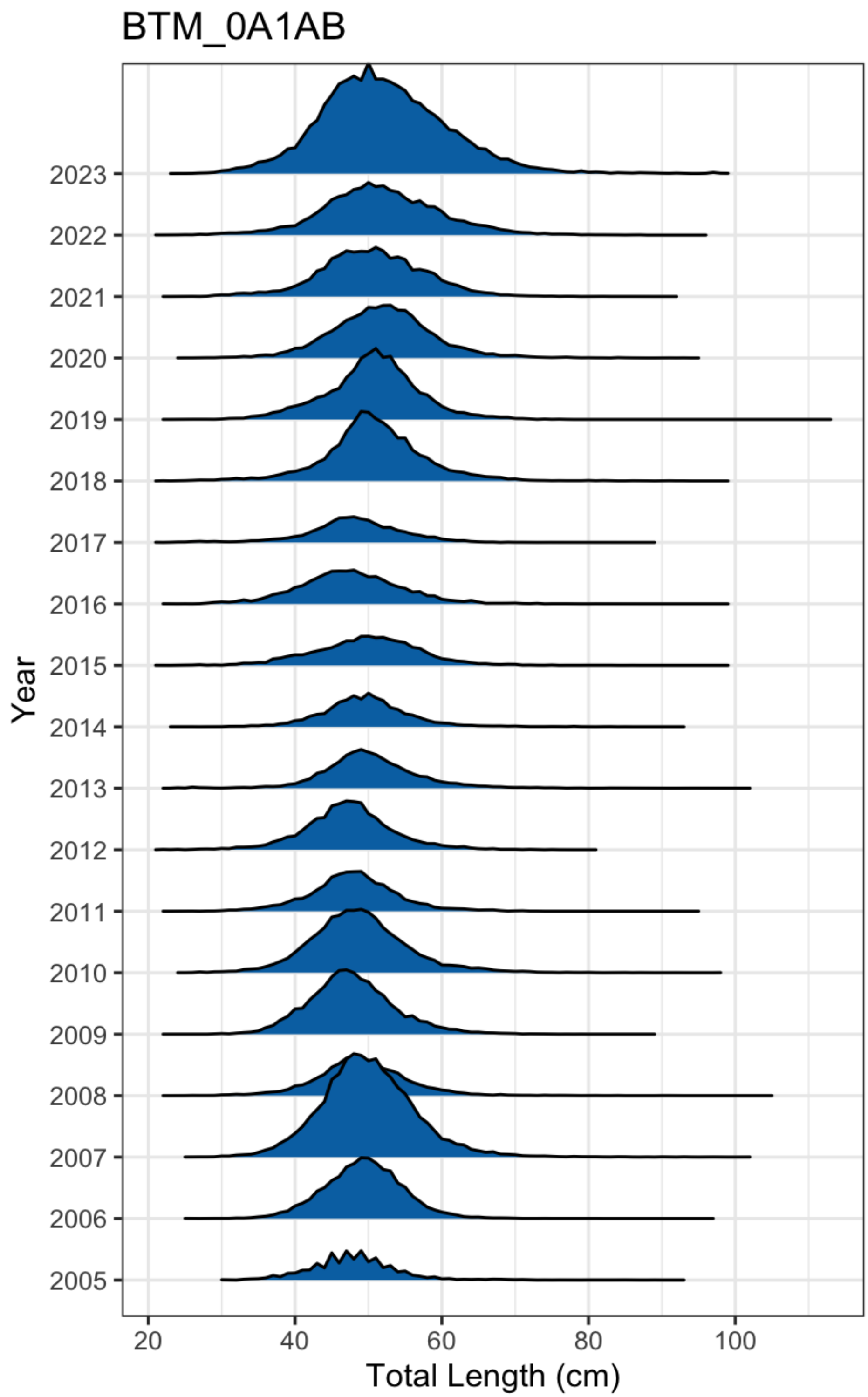

Figure 14. Length distribution of Greenland halibut sampled from the trawling fleets in Divisions 0A+1AB in 2023.

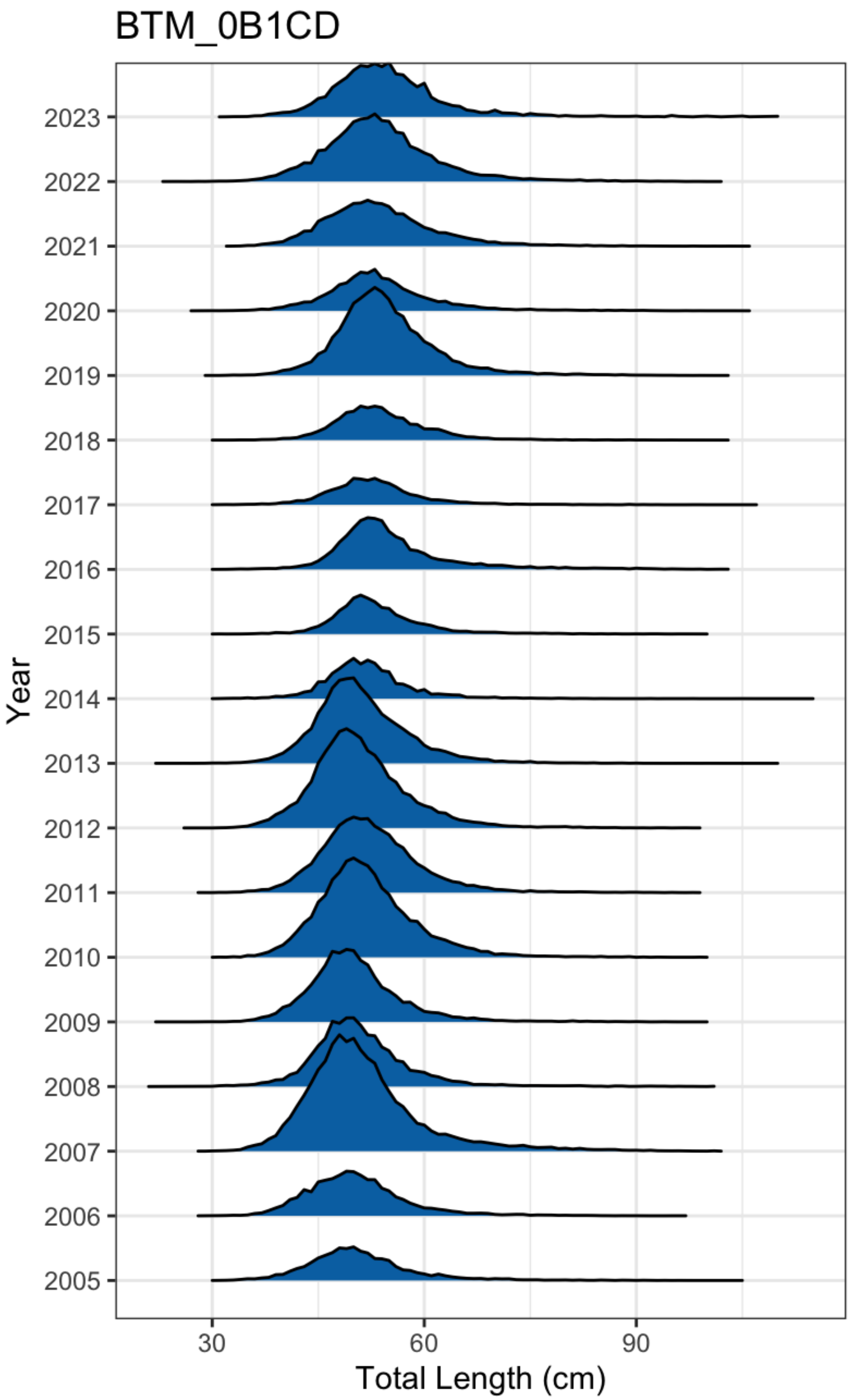

Figure 15. Length distribution of Greenland halibut sampled from the trawling fleets in Divisions 0B+1CD in 2023.

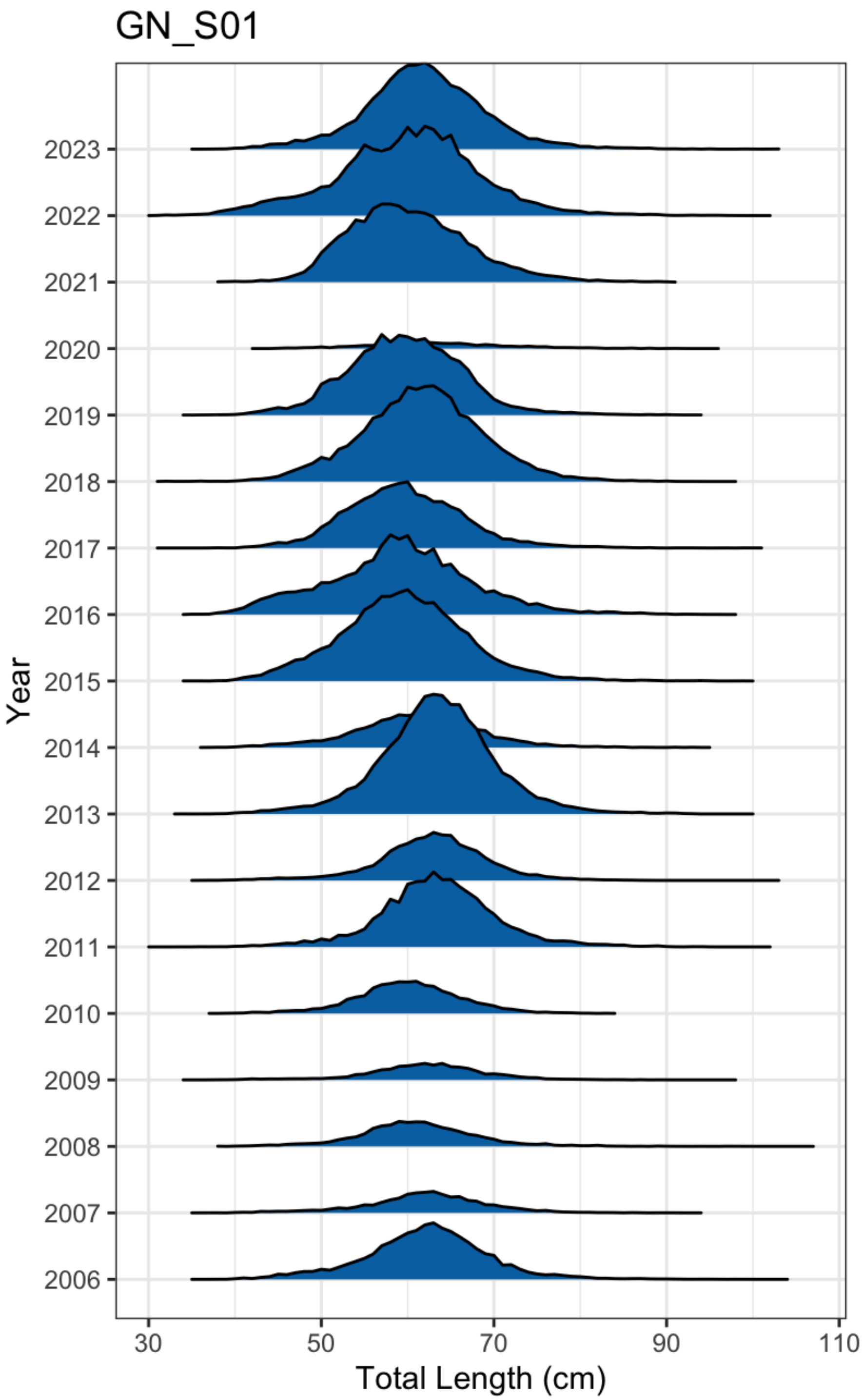

Figure 16. Length distribution of Greenland halibut sampled from the gillnet fleets in Subareas 0+1 offshore in 2023.

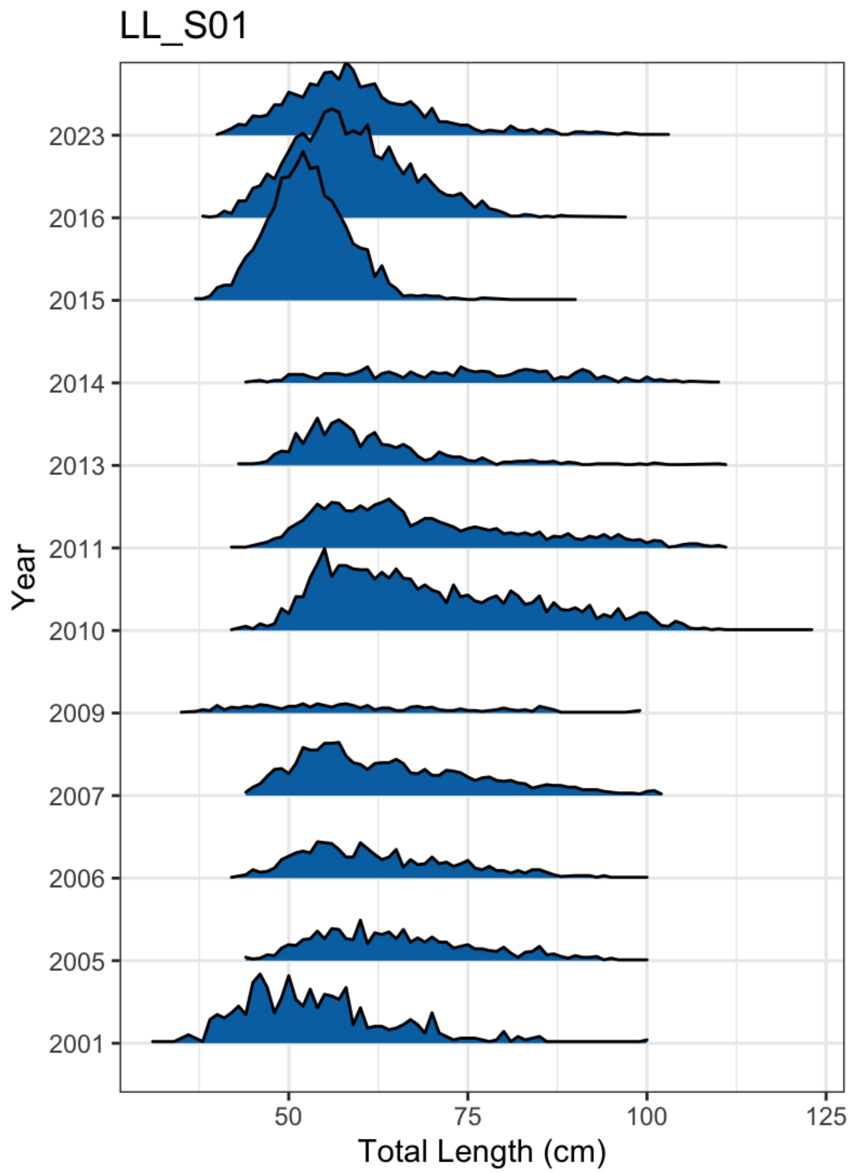

Figure 17. Length distribution of Greenland halibut sampled from the longline fleets in Subareas 0+1 offshore in 2023.

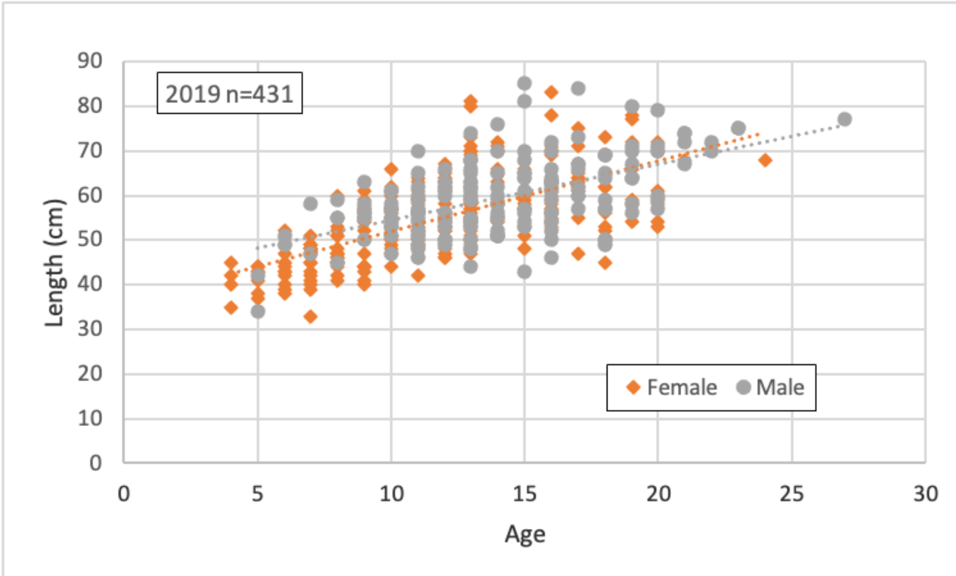

Figure 18. Growth curves for Greenland halibut by sex for the 2019 survey in Subarea 1.

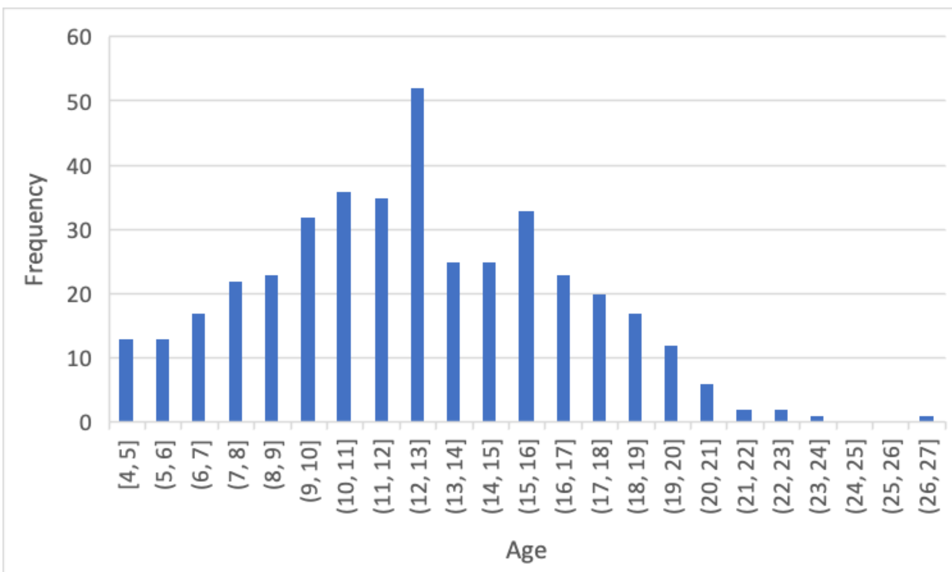

Figure 19. Frequency distribution of Greenland halibut by age for the 2019 survey in Subarea 1.

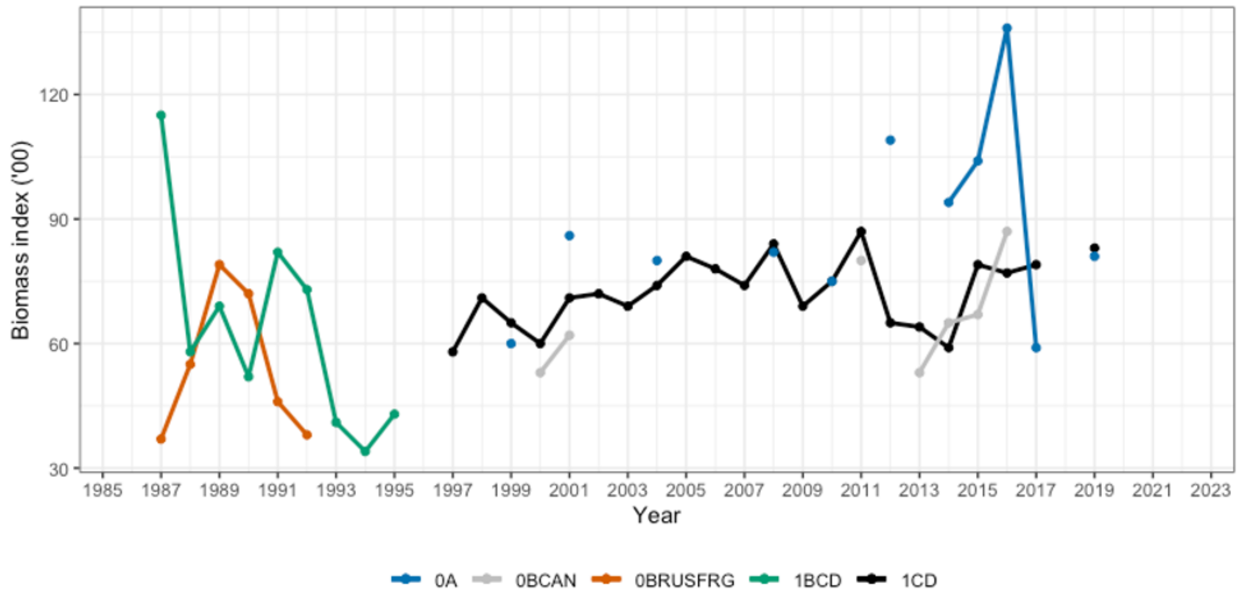

Figure 20. Biomass estimates from surveys conducted in SA 0 and 1 since 1986. There was a change in vessel for the 2019 surveys in 1CD and 0A-South and these estimates are not considered comparable to previous years.

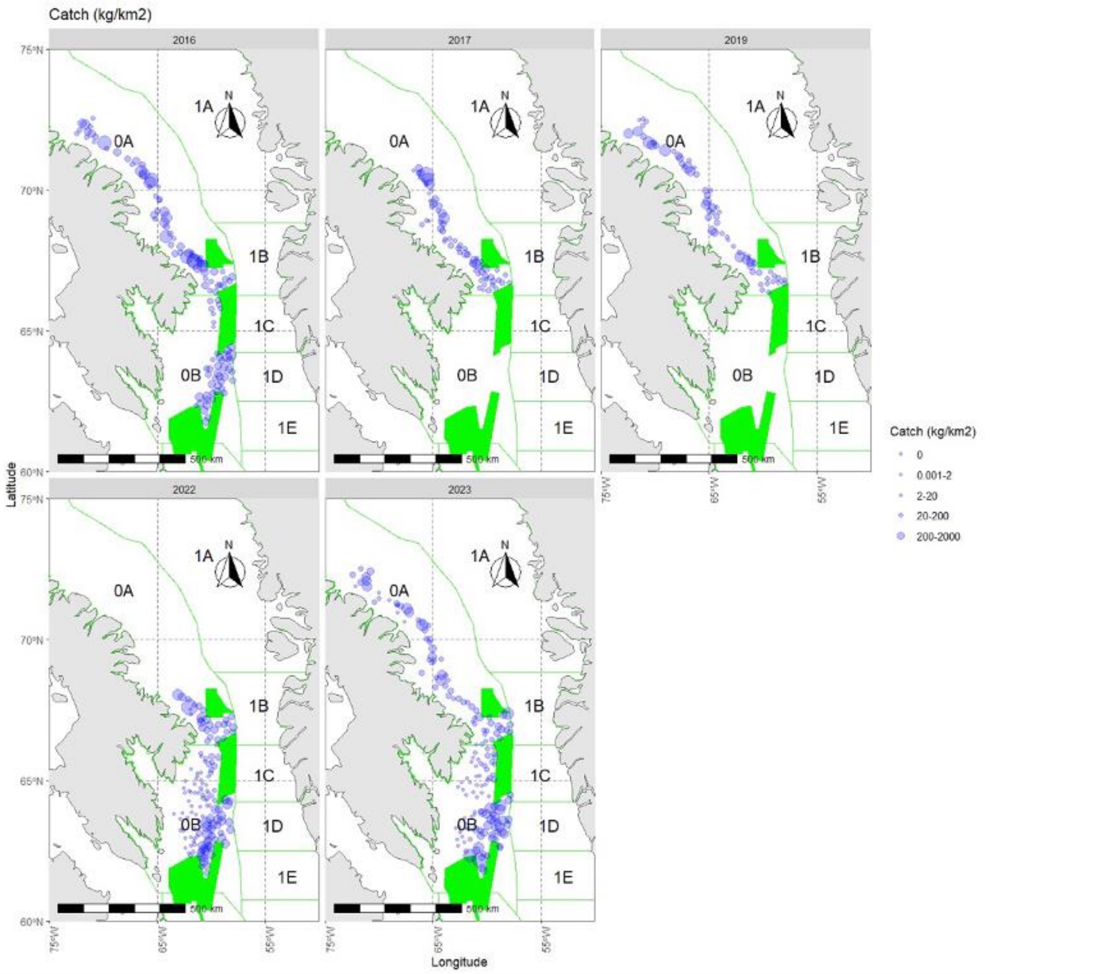

Figure 21. Locations of fishery-independent survey stations in Subarea 0 by year from 2016 to 2023.

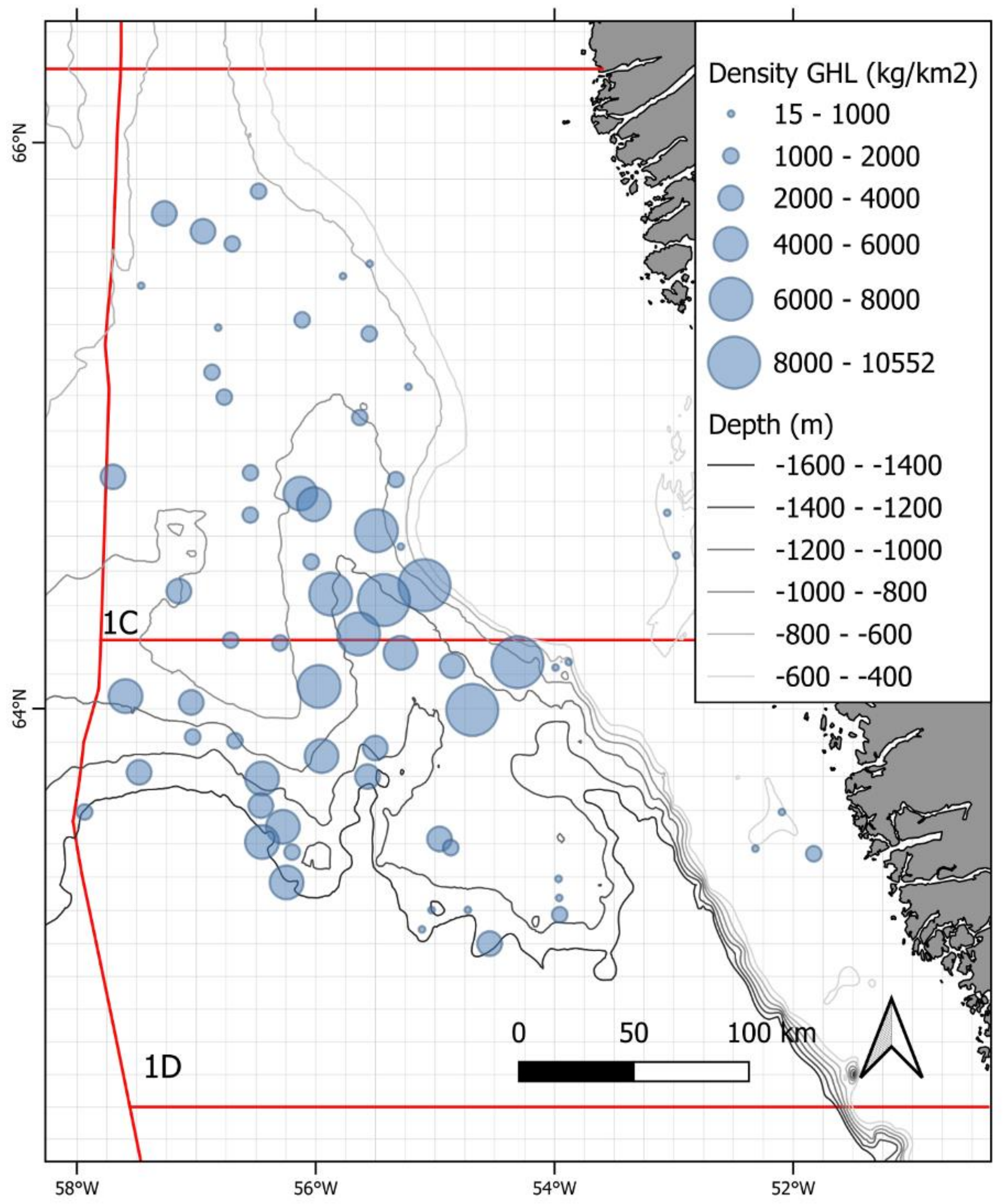

Figure 22. Locations of fishery-independent survey stations in Subarea 1 in 2023.

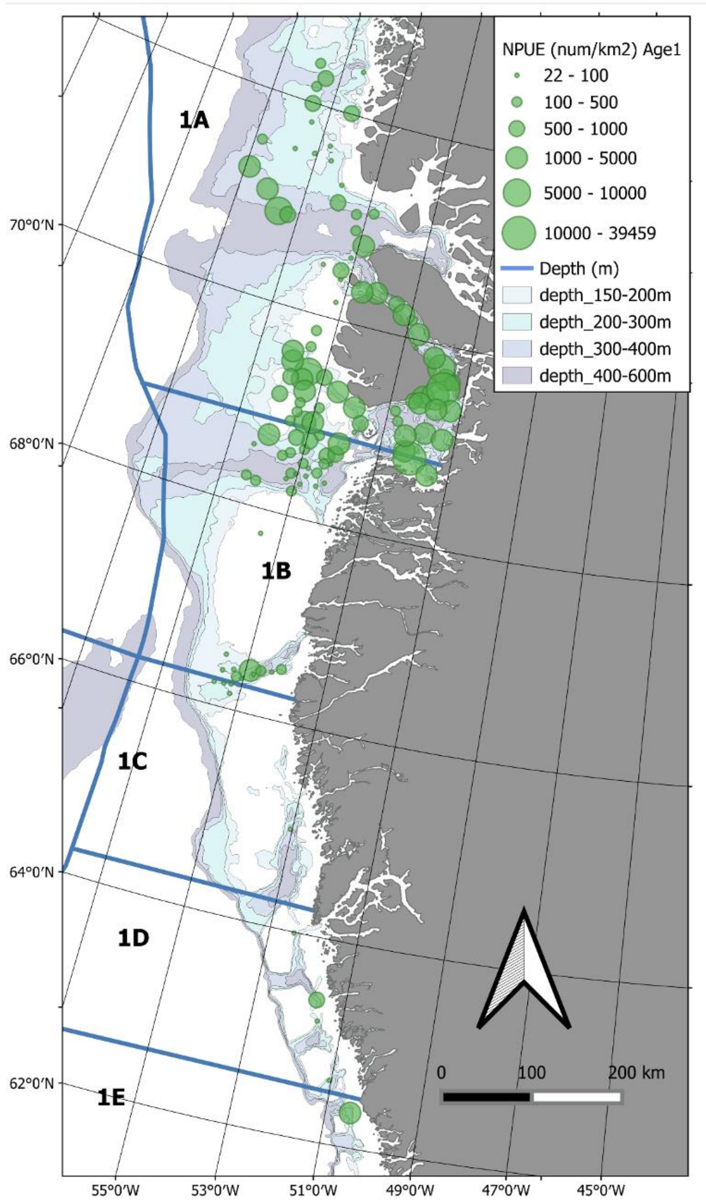

Figure 23. Locations of sampling stations during the Greenland Fish and Shrimp Survey in 1A-F (50-600 m) in 2023.

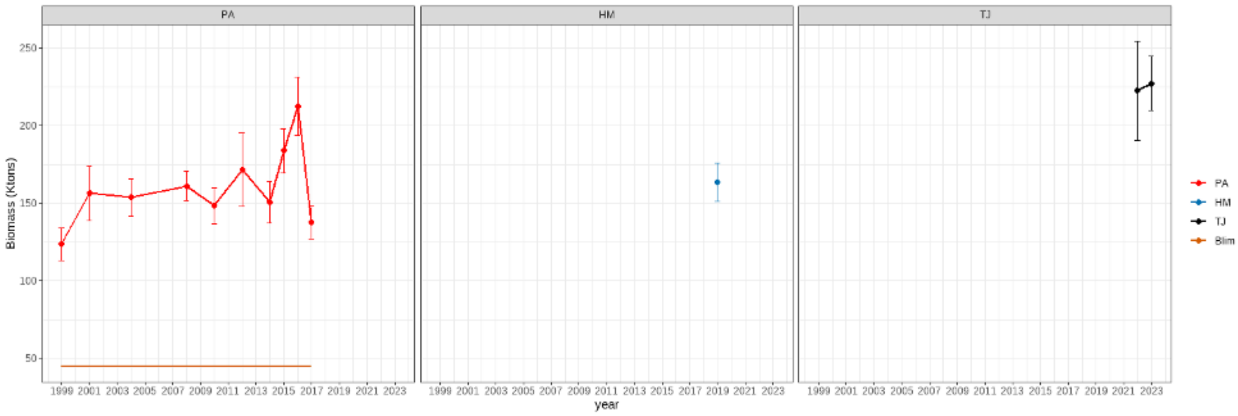

Figure 24. Combined survey biomass index for Div. 0A-South+Div. 1CD for the 3 surveys series: R/V Paamiut and Alfredo III gear (left panel), C/V Helga Maria and Alfredo III gear (midle panel) and R/V Tarajoq and Bacalao 476 gear (right panel).

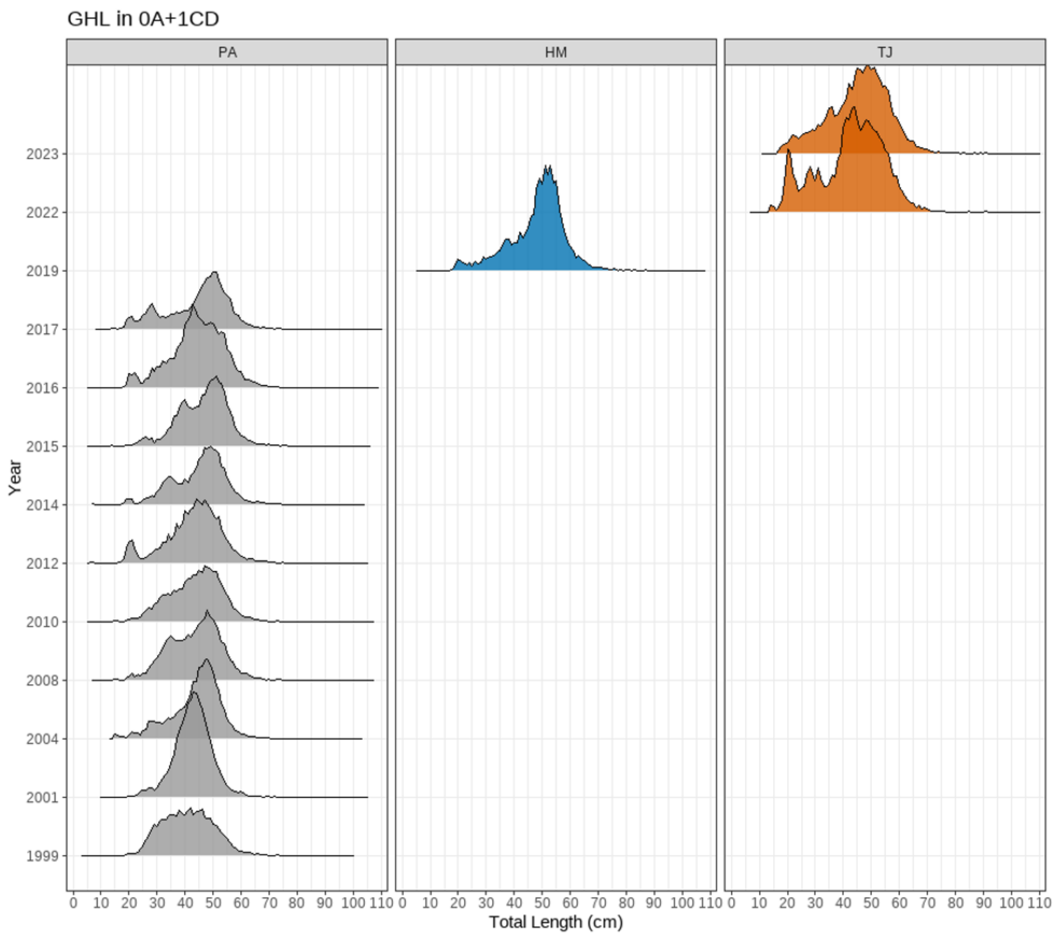

Figure 25. Length distribution of Greenland halibut (numbers weighted by stratum area) for the Div. 0ASouth+Div. 1CD for the 3 surveys series: R/V Paamiut and Alfredo III gear (left panel), C/V Helga Maria and Alfredo III gear (midle panel) and R/V Tarajoq and Bacalao 476 gear (right panel)

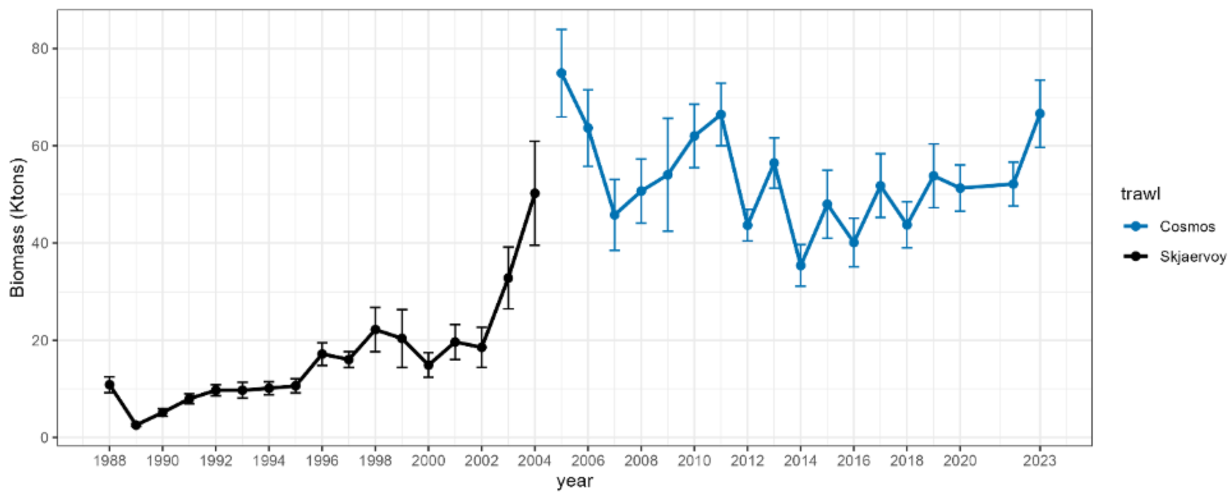

Figure 26. Greenland halibut biomass indices from the Greenland Fish and Shrimp Survey in 1A-F (50-600 m). Change of gear in 2004 is not calibrated in this plot.

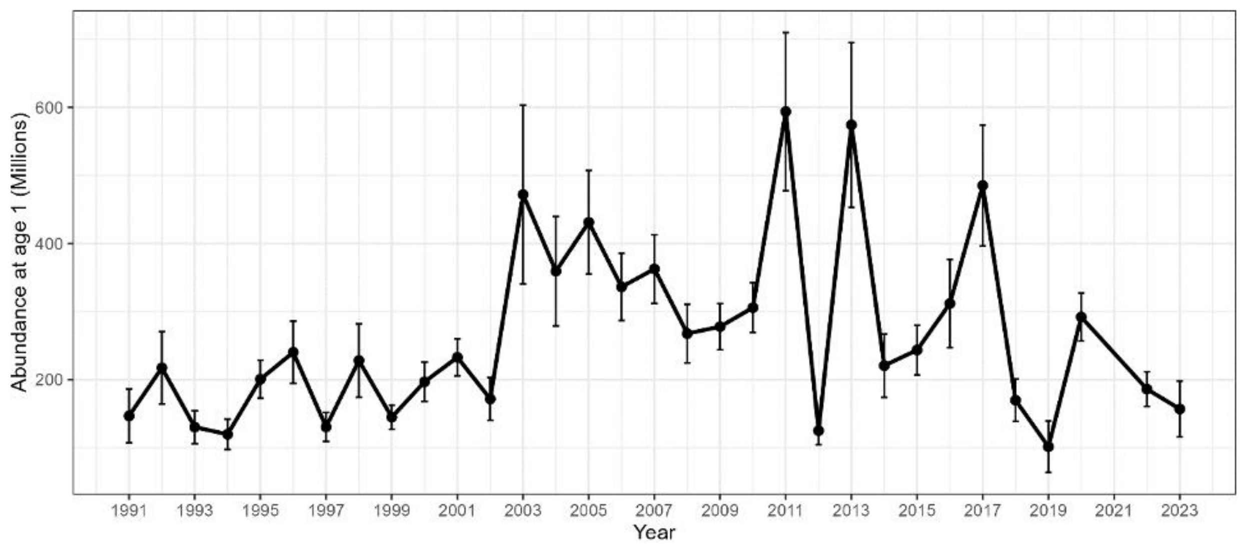

Figure 27. Abundance of age 1 Greenland halibut from the Greenland Fish and Shrimp Survey, for the entire survey area, including inshore Disko Bay, Div. 1A (North of 70○37.5'N) and several sets on the adjacent shelf in 0A. The indices 1988- 2004 have been calibrated with conversion factor due to the change of gear.

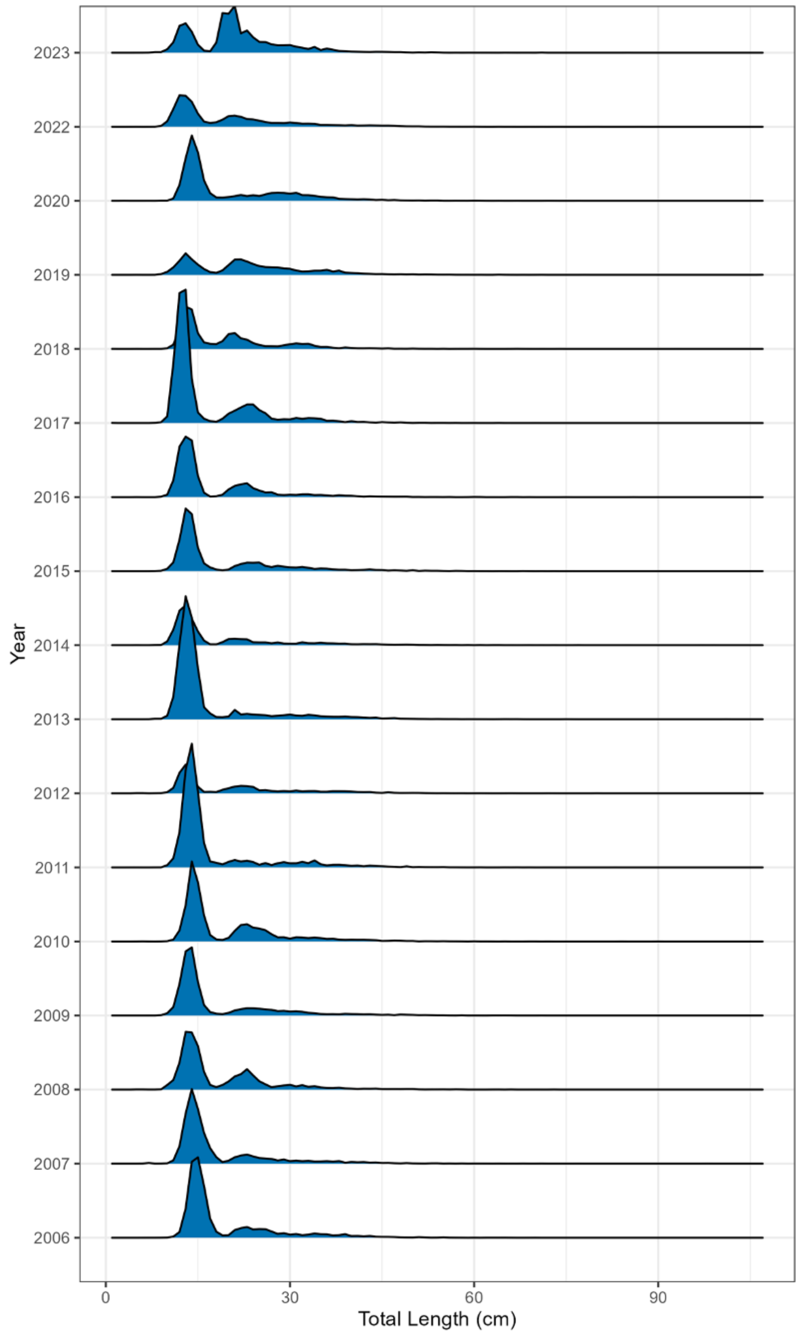

Figure 28. Length distribution of Greenland halibut (numbers weighted by stratum area) for the Div. 1AF surveys. The indices 1988- 2004 have been calibrated with conversion factor due to the change of gear.

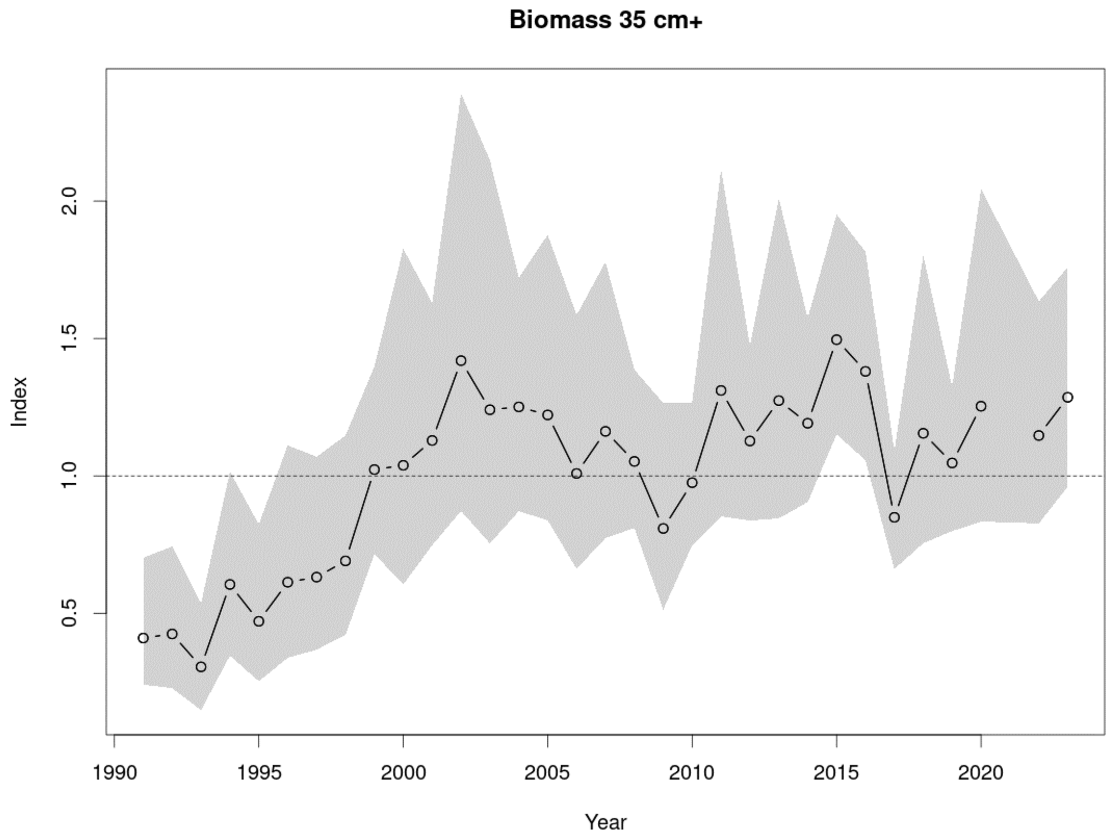

Figure 29. Biomass index of Greenland halibut > 35 cm(numbers weighted by stratum area) for the Div. 1AF surveys. The indices 1988- 2004 have been calibrated with conversion factor due to the change of gear.

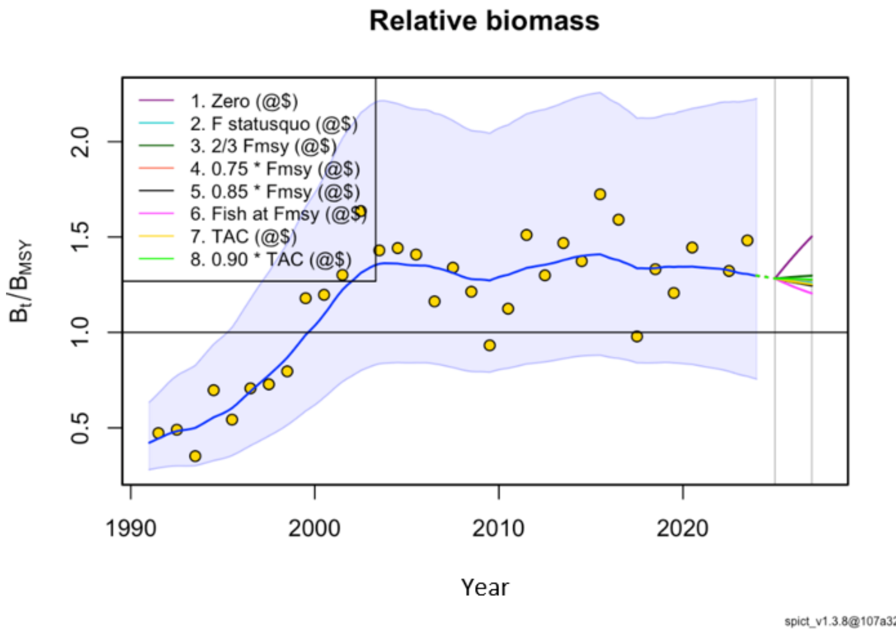

Figure 30. Greenland halibut 0+1 offshore: stochastic projections from 2025-2026 at five levels of removals (F=0, Fstatus quo, 75% Fmsy, 85% Fmsy , Fmsy, TAC, 90%TAC) with catch equal to 33 305 t for 2024. Plot shows projected relative biomass ratios (B/Bmsy)

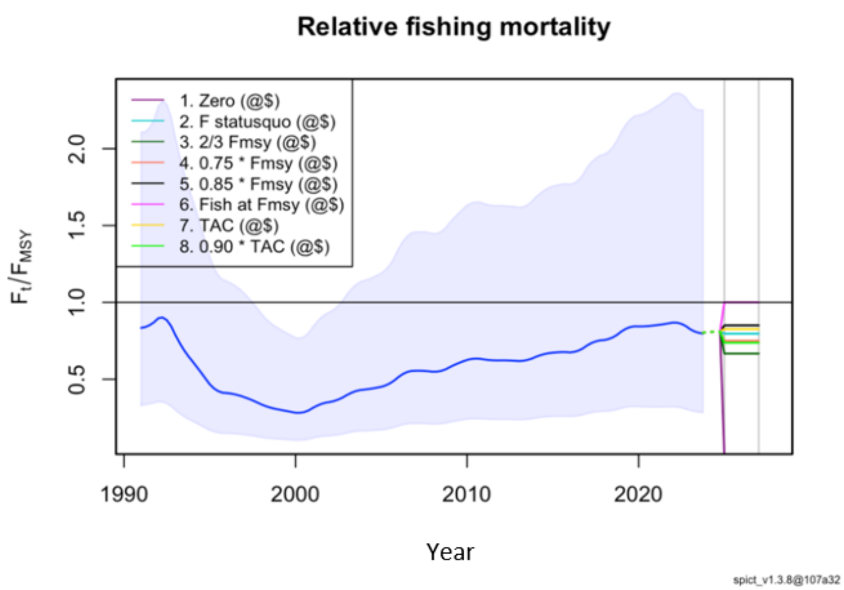

Figure 31. Greenland halibut 0+1 offshore: stochastic projections from 2025-2026 at five levels of removals (F=0, Fstatus quo, 75% Fmsy, 85% Fmsy , Fmsy, TAC, 90%TAC) with catch equal to 33 305 t for 2024. ower plot is projected relative fishing ratios (F/Fmsy).

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Colophon

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#>  version  R version 4.4.1 (2024-06-14 ucrt)
#>  os       Windows 10 x64 (build 19045)
#>  system   x86_64, mingw32
#>  ui       RTerm
#>  language (EN)
#>  collate  Spanish_Spain.utf8
#>  ctype    Spanish_Spain.utf8
#>  tz       Europe/Madrid
#>  date     2024-07-31
#>  pandoc   3.1.1 @ C:/Program Files/RStudio/resources/app/bin/quarto/bin/tools/ (via rmarkdown)
#>
#> ─ Packages ───────────────────────────────────────────────────────────────────
#>  package          * version date (UTC) lib source
#>  askpass            1.2.0   2023-09-03 [1] CRAN (R 4.4.0)
#>  bookdown           0.40    2024-07-02 [1] CRAN (R 4.4.1)
#>  cachem             1.1.0   2024-05-16 [1] CRAN (R 4.4.0)
#>  cellranger         1.1.0   2016-07-27 [1] CRAN (R 4.4.0)
#>  cli                3.6.3   2024-06-21 [1] CRAN (R 4.4.1)
#>  colorspace         2.1-1   2024-07-26 [1] CRAN (R 4.4.1)
#>  crayon             1.5.3   2024-06-20 [1] CRAN (R 4.4.1)
#>  crul               1.4.2   2024-04-09 [1] CRAN (R 4.4.1)
#>  curl               5.2.1   2024-03-01 [1] CRAN (R 4.4.0)
#>  data.table         1.15.4  2024-03-30 [1] CRAN (R 4.4.0)
#>  devtools           2.4.5   2022-10-11 [1] CRAN (R 4.4.0)
#>  digest             0.6.36  2024-06-23 [1] CRAN (R 4.4.1)
#>  dplyr            * 1.1.4   2023-11-17 [1] CRAN (R 4.4.0)
#>  ellipsis           0.3.2   2021-04-29 [1] CRAN (R 4.4.0)
#>  evaluate           0.24.0  2024-06-10 [1] CRAN (R 4.4.1)
#>  fansi              1.0.6   2023-12-08 [1] CRAN (R 4.4.0)
#>  fastmap            1.2.0   2024-05-15 [1] CRAN (R 4.4.0)
#>  flextable        * 0.9.6   2024-05-05 [1] CRAN (R 4.4.1)
#>  fontBitstreamVera  0.1.1   2017-02-01 [1] CRAN (R 4.4.0)
#>  fontLiberation     0.1.0   2016-10-15 [1] CRAN (R 4.4.0)
#>  fontquiver         0.2.1   2017-02-01 [1] CRAN (R 4.4.1)
#>  fs                 1.6.4   2024-04-25 [1] CRAN (R 4.4.0)
#>  gdtools            0.3.7   2024-03-05 [1] CRAN (R 4.4.1)
#>  generics           0.1.3   2022-07-05 [1] CRAN (R 4.4.0)
#>  gfonts             0.2.0   2023-01-08 [1] CRAN (R 4.4.1)
#>  ggplot2          * 3.5.1   2024-04-23 [1] CRAN (R 4.4.0)
#>  ggridges           0.5.6   2024-01-23 [1] CRAN (R 4.4.1)
```

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#>  ggthemes          5.1.0    2024-02-10 [1] CRAN (R 4.4.1)
#>  glue              1.7.0    2024-01-09 [1] CRAN (R 4.4.0)
#>  gtable            0.3.5    2024-04-22 [1] CRAN (R 4.4.0)
#>  highr             0.11     2024-05-26 [1] CRAN (R 4.4.0)
#>  htmltools         0.5.8.1 2024-04-04 [1] CRAN (R 4.4.0)
#>  htmlwidgets       1.6.4    2023-12-06 [1] CRAN (R 4.4.0)
#>  httpcode          0.3.0    2020-04-10 [1] CRAN (R 4.4.1)
#>  httpuv            1.6.15   2024-03-26 [1] CRAN (R 4.4.0)
#>  jsonlite          1.8.8    2023-12-04 [1] CRAN (R 4.4.0)
#>  knitr             1.47     2024-05-29 [1] CRAN (R 4.4.1)
#>  later             1.3.2    2023-12-06 [1] CRAN (R 4.4.0)
#>  lifecycle         1.0.4    2023-11-07 [1] CRAN (R 4.4.0)
#>  magrittr          2.0.3    2022-03-30 [1] CRAN (R 4.4.0)
#>  memoise           2.0.1    2021-11-26 [1] CRAN (R 4.4.0)
#>  mime              0.12     2021-09-28 [1] CRAN (R 4.4.0)
#>  miniUI            0.1.1.1 2018-05-18 [1] CRAN (R 4.4.0)
#>  munsell           0.5.1    2024-04-01 [1] CRAN (R 4.4.0)
#>  NAFOdown        * 0.0.1    2024-07-03 [1] Github (nafc-assess/NAF
Odown@b5689f8)
#>  officedown        0.3.1    2023-09-02 [1] CRAN (R 4.4.1)
#>  officer           0.6.6    2024-05-05 [1] CRAN (R 4.4.1)
#>  openssl           2.2.0    2024-05-16 [1] CRAN (R 4.4.0)
#>  pillar            1.9.0    2023-03-22 [1] CRAN (R 4.4.0)
#>  pkgbuild          1.4.4    2024-03-17 [1] CRAN (R 4.4.0)
#>  pkgconfig         2.0.3    2019-09-22 [1] CRAN (R 4.4.0)
#>  pkgload           1.4.0    2024-06-28 [1] CRAN (R 4.4.1)
#>  profvis           0.3.8    2023-05-02 [1] CRAN (R 4.4.0)
#>  promises          1.3.0    2024-04-05 [1] CRAN (R 4.4.0)
#>  purrr             1.0.2    2023-08-10 [1] CRAN (R 4.4.0)
#>  R6                2.5.1    2021-08-19 [1] CRAN (R 4.4.0)
#>  ragg              1.3.2    2024-05-15 [1] CRAN (R 4.4.0)
#>  Rcpp              1.0.12   2024-01-09 [1] CRAN (R 4.4.0)
#>  readxl            1.4.3    2023-07-06 [1] CRAN (R 4.4.0)
#>  remotes           2.5.0    2024-03-17 [1] CRAN (R 4.4.1)
#>  rlang             1.1.4    2024-06-04 [1] CRAN (R 4.4.1)
#>  rmarkdown         2.27     2024-05-17 [1] CRAN (R 4.4.0)
#>  rstudioapi        0.16.0   2024-03-24 [1] CRAN (R 4.4.0)
#>  rvg               0.3.3    2023-05-10 [1] CRAN (R 4.4.1)
#>  scales            1.3.0    2023-11-28 [1] CRAN (R 4.4.0)
#>  sessioninfo       1.2.2    2021-12-06 [1] CRAN (R 4.4.0)
#>  shiny             1.8.1.1 2024-04-02 [1] CRAN (R 4.4.0)
#>  showtext          0.9-7    2024-03-02 [1] CRAN (R 4.4.1)
#>  showtextdb        3.0      2020-06-04 [1] CRAN (R 4.4.1)
#>  stringi           1.8.4    2024-05-06 [1] CRAN (R 4.4.0)
#>  stringr           1.5.1    2023-11-14 [1] CRAN (R 4.4.0)
#>  sysfonts          0.8.9    2024-03-02 [1] CRAN (R 4.4.1)
#>  systemfonts       1.1.0    2024-05-15 [1] CRAN (R 4.4.0)
#>  textshaping       0.4.0    2024-05-24 [1] CRAN (R 4.4.0)
#>  tibble            3.2.1    2023-03-20 [1] CRAN (R 4.4.0)
#>  tidyr           * 1.3.1    2024-01-24 [1] CRAN (R 4.4.0)
#>  tidyselect        1.2.1    2024-03-11 [1] CRAN (R 4.4.0)
#>  urlchecker        1.0.1    2021-11-30 [1] CRAN (R 4.4.0)
```

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#>  usethis            2.2.3   2024-02-19 [1] CRAN (R 4.4.0)
#>  utf8               1.2.4   2023-10-22 [1] CRAN (R 4.4.0)
#>  uuid               1.2-0   2024-01-14 [1] CRAN (R 4.4.0)
#>  vctrs              0.6.5   2023-12-01 [1] CRAN (R 4.4.0)
#>  withr              3.0.0   2024-01-16 [1] CRAN (R 4.4.0)
#>  xfun               0.45    2024-06-16 [1] CRAN (R 4.4.1)
#>  xml2               1.3.6   2023-12-04 [1] CRAN (R 4.4.0)
#>  xtable             1.8-4   2019-04-21 [1] CRAN (R 4.4.0)
#>  yaml               2.3.8   2023-12-11 [1] CRAN (R 4.4.0)
#>  zip                2.3.1   2024-01-27 [1] CRAN (R 4.4.0)
#>
#>  [1] D:/Usuarios/anogueira/AppData/Local/Programs/R/R-4.4.1/library
#>
#> ──────────────────────────────────────────────────────────────────
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