Northwest Atlantic Fisheries Organization

Serial No. N7051 **NAFO SCR Doc. 20/007REV**

SCIENTIFIC COUNCIL MEETING – JUNE 2020

Report on Greenland halibut caught during the 2019 trawl survey in Division 0A

M. A. Treble

Fisheries and Oceans Canada, Freshwater Institute,
501 University Cres., Winnipeg, Manitoba, Canada R3T 2N6

Abstract

A stratified-random otter trawl survey extending to approximately 72° N was conducted in southern Division 0A (0A-South) in 2019. The survey took place from August 15-25 about 6 weeks earlier than was typical for this survey. An Alfredo III trawl was used at randomly selected stations between 401 and 1500 m. All depth strata had at least two sets, with 72 of 77 planned stations successfully completed. Missed stations were located in depths <800 m. There was not enough time to complete the Broughton Island and Cape Christian oceanographic transect lines. Near-bottom temperatures varied between -0.01 °C and 1.96 °C with the maximum value approximately one degree lower than in 2017. Greenland halibut were distributed throughout the survey area and were present in all tows. A majority of both females (88%) and males (82%) were immature. An examination of survey timing (using General Additive Models to examine abundance at depth) and the change in vessel (using gear metrics such as net height and door spread) concluded the 2019 survey in 0A-South was not comparable to previous surveys . The results are therefore not presented in comparative terms. The 2019 estimate of biomass was 80,625 t (S.E. 10,883). Abundance in 2019 was 8.0 x 10^7 (S.E. 1.1 x 10^7). The overall length distribution in 2019 ranged from 15 to 87 cm with modes observed at 36 and 51 cm. The proportion of fish <45 cm was 40%. Typically the mode for length frequency increases with depth. However, in 2019 the mode was near 51 cm for all but the 1400-1500 m depths suggesting a change in distribution during this earlier part of the season. There is no obvious pattern in the survey time series prior to 2019 for abundance of fish by size class (>60cm, 40-60 cm and <40 cm). The back log of Greenland halibut otoliths is being aged and results are provided for the 2017 survey, as representative of the age-length relationship for Greenland halibut in Div. 0A. Female ages ranged from 3-32 years and males from 3-28 years.

Introduction

A multi-species bottom trawl survey of southern 0A (0A-South) (to approximately 72° N) was carried out in the Northwest Atlantic Fisheries Organization Subarea 0 during August 15-25, 2019. This is the earliest the survey has been conducted, about 6 weeks compared to most previous surveys, and 10 weeks earlier than the 2017 survey (Treble 2018) (Table 4). The FV Helga Maria was chartered to conduct the 2019 survey, following the 2018 retirement of the RV Pâmiut. The Alfredo III trawl gear remained unchanged and was used at randomly selected stations between 400 and 1500 m. Deep-water surveys began in 0A-South in 1999 and were completed every second year between 2004 and 2014, then annually between 2015 and 2017. Surveys in 0B have been less frequent, 2000, 2001, 2011 and 2013 to 2016.

The objectives were to:

1. Collect the data required to establish age structure, estimate population abundance, biomass, and recruitment of Greenland halibut;

2. Collect the data required to establish age structure, estimate population abundance, biomass, and recruitment of shrimp;
3. Record numbers caught and collect length and weight data on all other commercial species caught, to allow calculation of abundance, biomass, and size structure of these species;
4. Record numbers and collect weight data on all non-commercial species caught, to allow calculation of abundance and biomass of these species;
5. Collect additional data and biological samples as desired and as time permits (e.g. lengths for by-catch, maturity information, coral samples, other special requests);
6. Collect temperature data at each fishing station;
7. Collect oceanographic data at pre-determined standard stations.

Materials and Methods

Stratification and Set Selection

A depth stratification scheme similar to that used by the Greenland Institute of Natural Resources for the Division 1CD survey was developed in 2008 to facilitate comparisons between surveys conducted in Canadian and Greenland waters. The depth bins are slightly different from those used in surveys conducted between 1999 and 2006, therefore, sets completed during 1999-2006 were assigned to the new depth strata post-hoc in order to establish consistency with the new strata scheme (Table 1 and Figure 1).

In 2014 it was decided to remove stratum B1 from the 0A-South survey area; a portion of this stratum fell within a fishery closure that was partially closed to Greenland halibut fishing in 1998 to protect Narwhal over-wintering grounds and fully closed in 2006 to protect deep-water coral habitat. Surveys completed prior to 2014 were re-analyzed with sets that fell within strata group B1 removed (Treble 2015). In 2016 it was discovered that the area for two strata (B1-8 and B2-8) had been reversed since the strata were created in 2008 (actual value for B2-8 was 1779 km^2 not 3330 km^2), therefore, the survey area was adjusted and indexes recalculated for the full time series to correct for this error (Treble 2016).

The survey area between 401 and 1500 m in Div. 0A-South (to approximately 72^o N) is 47,924 km^2 (Table 1) within which there are 77 sets randomly assigned to 30 sub-strata (5 sub-stratum in each of 6 depth strata). Set selection is based on a coverage level of approximately 1 set per 750 km^2. A minimum of two sets are randomly selected from numbered units within each sub-stratum using a buffered random design (Kingsley et al. 2004). If a set cannot be fished due to bad bottom, ice, etc. then the tow is taken in an adjacent unit as close to the missed site within the sub-stratum as feasible given the conditions. When this is not possible then the tow may be re-located to an area of the sub-stratum where there are "holes" in the set coverage and a unit location selected at random from those available in that area.

Vessel and Gear

The surveys prior to 2019 were conducted by the RV Pâmiut, a 1084 GRT (updated from the 722 GRT reported previously, based on 1947 tonnage convention) stern trawler measuring 53 m in length. An Alfredo III bottom otter trawl with rock hopper ground gear was used. Mesh size was 140 mm with a 30 mm mesh liner in the cod end. Trawl doors were Injector International, measuring 7.5 m^2 and weighing 2800 kg. These doors replaced the Greenland Perfect doors (9.25 m^2 and 2420 kg) in 2004. The average net height was 20 cm higher with the new doors but the overall net performance was not significantly different (95% level) (Jørgensen personal communication). More information about the trawl and gear can be found in Jørgensen 1998. A Furuno based system mounted on the head rope measured net height and was used to determine bottom contact and the start/finish of each tow. Scanmar sensors measured the distance between the trawl doors and since 2010 the wingspread.

The 2019 vessel, FV Helga Maria, is a 1470 GRT and 57 m in length. The trawl gear and rigging as described above remained unchanged. The warps, bridle, ground gear and distance from the hanging blocks were kept

the same as on the RV Paamiut. The fishing procedures were also the same, the RV Paamiut captain and crew were involved prior to and during the survey. See Treble and Nogueira (2020) for additional information on vessel comparison and gear performance.

Oceanographic Sampling

A Seabird 19© CTD (conductivity, temperature and depth recorder) was mounted on the head-rope beginning in 2010 and was used to determine temperature, depth and time spent on the bottom. In the few cases where there were no data from the CTD, data from the Furuno trawl eye sensor was used to determine bottom temperature.

There are two oceanographic lines that cross the shelf and slope at Broughton Island (near 68° N) and Cape Christian (near 71° N). These transect lines are completed when conditions (time and/or ice) allow.

Trawling Procedure

The targeted tow duration was 30 minutes, however, tows down to 15 minutes in length were considered acceptable. Average towing speed was 3.0 knots. Trawling took place throughout a 24 hr period in order to maximize the use of the ship's time and complete the necessary tows.

Biological Data Collection and Analysis

Numbers and total weight caught were recorded on a set by set basis for each species. Detailed sampling was carried out on Greenland halibut and shrimp. For other commercial species (e.g. redfish, grenadiers, skates) sexed length measurements were collected. Lengths were measured to the lowest 1 cm total length (0.5 cm pre anal fin length for grenadiers) using a standard meter board. Large catches of either Greenland halibut or shrimp were sub-sampled. Sub-samples of Greenland halibut were comprised of at least 200 fish. Adjustments were made during analysis to estimate total number caught in each case.

Greenland halibut sampling consisted of a visual assessment of maturity for all individuals based on maturity stages described in Riget and Boje 1989. For each sampled fish the whole weight was recorded at sea using an electronic balance. Otoliths for age determination were collected, 10 per 1 cm length group per sex. Otolith samples were not analyzed for this survey. However, an age determination method has been developed and we have started to age samples from previous surveys.

Various species from the catch were collected or had tissue samples taken for use by other researchers within DFO.

Biomass and Abundance Indices

The swept area method was used in the estimation of biomass and abundance for Greenland halibut: Swept area (km^2) = (wingspread (m) x haul-length)/1,000,000. When wingspread (aka outer bobbin distance) was not available it was calculated as: 10.122 + distance between trawl doors (m) x 0.142. This relationship is based on flume tank measurements of the trawl and rigging (Jørgensen 1998). If neither wingspread or doorspread was available and the tow was valid then an average of wingspread values for that trip was used. The haul-length used in the sweptarea calculations was calculated as the great-circle distance between the start and end positions of the tow. Abundance and biomass were calculated for each set and standardized to 1 km^2:

Abundance (n/km^2)=catch (n)/sweptarea (km^2)

Biomass ($tons/km^2$)=catch (kgs)/swept area (km^2)/1000.

A sub-stratum area may be included in the analysis even if it contains less than 2 sets, if the total number of sets for the depth stratum are greater than 2. In other words sets are assigned at the sub-strata level but the analysis and threshold for inclusion is done at the depth strata level. This approach to the analysis was reviewed in 2014 and considered acceptable, given the index based nature of the assessment. The biomass index for 0A-South and 1CD for 1999-2017 calculated using the 6 depth strata were compared to the index

calculated using the 30 smaller strata used to assign survey sets and was found to be comparable for 2 of the 4 years examined so far (Appendix 2). Work will be completed to assess the impact of this approach and adjust analysis of future surveys accordingly.

Mean and standard error for abundance and biomass were calculated for each depth strata containing 2 or more sets. As noted above these estimates are not calculated at the finer sub-strata level (30 small strata) but at the larger depth strata level (6 strata). An estimate of total abundance and biomass was then calculated for each depth strata (mean x area surveyed (km^2)) as well as for all depth strata combined. Standard error values were calculated for the overall total.

Abundance at length was calculated for each depth strata (standardized to km^2 and weighted by tow), and a total abundance at each length (weighted by the area within each depth strata) was calculated (mean number/ km^2 x area surveyed (km^2)). The sum across all lengths and depth categories was calculated and compared to the overall abundance value determined above as a means of confirming the results.

Note that the 1400-1500 m depth strata was poorly covered in 1999, 2001 and 2006 and the survey area was adjusted (reduced) accordingly for those years (Table 2).

Results and Discussion

All of the depth strata had at least two sets in 2019, with 72 of 77 planned stations successfully completed, so there was no adjustment made to the survey area (Table 2). Missed stations were located in depths <800 m. Near-bottom temperatures varied between -0.01 °C and 1.96 °C with the maximum value approximately one degree lower than in 2017. Mean temperature on the shelf (400-800m) was slightly warmer (1.2 °C) than on the slope, declining with depth from 1.2 °C to -0.1 °C (Table 3). There were no bottom temperatures >2 °C compared to 6 sets in the 2017 survey (Fig. 2).

There was not enough time during the survey to complete oceanographic profiles at the stations along the Broughton Island and Cape Christian transect lines.

Catches of most species other than Greenland halibut were small in number therefore analysis of these species is not presented here.

Survey Timing

Most of the 0A surveys have taken place between the end of September and the end of October (Table 7). In 2006, 2010 and 2017 the survey took place a few weeks later (late October and early November) and in 2019 the survey dates were a few weeks earlier (August). While Greenland halibut have been shown to exhibit seasonal differences in distribution in SA1 (Jorgensen 1997) and in other regions (Siwike and Coutré 2020) it is not known if Greenland halibut in Div. 0A exhibit similar behavior.

A General Additive Modal (GAM) was used to assess the effect of survey timing (Wheeland et al. 2020). The analysis found that in 2019 Greenland halibut were located shallower than typical for this survey. There was high abundance and biomass near the shallowest extent of the survey in areas closest to shore; this distribution is not characteristic of previous 0A-south surveys. This suggests that a portion of the stock may have extended beyond the surveyed area and the 2019 survey point for 0A-South should not be considered comparable to the earlier series.

The GAM analysis also suggests there may be a difference in distribution in the 2017 survey that occurred about 4 weeks later than usual. Catches were higher in the deepest strata than what was typical for previous surveys. However, these observations were considered less concerning for 2017 than the distributional change observed in 2019 given length frequencies by depth are within the normal range, which doesn't suggest a greater than usual abundance of a particular size group of fish moving through the survey area (as with the large fish in the shallow water in 2019). Also, in 2017 there were 2 large sets that were adjacent and rather

isolated that seem to be driving the trend, suggesting the 2017 survey happened upon an area of higher abundance that may not have been representative across the surveyed area. Further analysis is proposed to determine whether the shift in distribution observed in 2017 has implications for comparability of this index to the rest of the time series.

These findings demonstrate the importance of keeping survey timing as consistent as possible, to reduce the uncertainty around results which is often difficult to understand.

Vessel Change

In 2017, the RV Pâmiut was retired and in 2019 the FV Helga Maria was used for the 0A-South survey. To standardize fishing operations the Greenland Institute of Natural Resources took steps to ensure the same gear (trawl, bridle, warps, ground gear, and distance from blocks) found on the R/V Pâmiut were used on the FV Helga Maria. However, differences in mean net height (23%) and door spread (-7%) were observed in 2019 compared to 2005 to 2017, suggesting an impact of the vessel change on the survey (Nogueira and Treble 2020). Similar differences were observed for the 1CD survey and so gear geometry was further examined for this survey by depth: 401-700 m, 701-1000 m, and 1001-1500 m. The difference in net height and door distance increased between 701-1000 m and 1001-1500 m from 22% to 36% and from -9 to -12%, respectively. The RV Pâmiut and the FV Helga Maria seemed to be fishing differently at depths beyond 701 m and this could have had an effect on catchability. There was sufficient uncertainty in the gear performance at depths >701 m (where Greenland halibut are known to be abundant) to question the direct comparability between 2019 and previous surveys of 0A-South and 1CD (Nogueira and Treble 2020, Treble and Nogueira 2020). As a result the 2019 surveys in both 0A-South and 1CD were not considered comparable to previous surveys.

Greenland Halibut

Division 0A-South

Greenland halibut were present in all tows in 2019 (Fig. 3 and Appendix 1). There were no sets where the catch weight was <1kg, compared to 8 sets in 2017, and 0-3 sets in earlier surveys. Distribution of biomass has not changed substantially across years, with the largest catches located along the shelf slope between 67° N and 72° N (Fig. 4). The number of fish caught in 0A-South varied from 2-623. Catch weight ranged from 4-682 kg (Appendix 1). The catch was comprised of 47% males and 53% females, similar to proportions observed in previous surveys (Table 4). A majority of both females (88%) and males (82%) were classed as immature. The proportion mature for males (6-68%) is more variable than that observed for females (1-21%) during surveys conducted from 2012 to 2019, with no clear link to survey timing (Table 4).

The 2019 estimate of biomass was 80,625 t (S.E. 18,103) (Table 5, Fig. 5). Mean catch per tow was 1.68 t/km^2 (Table 6). In 2016 biomass estimates across depths 801-1200 m were the highest in the time series. In 2017 biomass at depths 1201-1500 m was the highest or second highest in the time series, while biomass at all other depths were at the lowest or near lowest levels (Table 7, Fig. 6). In 2019 biomass at 1201-1500 m was the lowest in the time series and estimates for depths 400-800 m were near the highest.

The impact of the removal of the 1400-1500m strata to the overall estimate of Greenland Halibut biomass and abundance in 1999, 2001 and 2006 was considered minor, as this depth stratum does not cover a large area and had contained only 1-3% of the overall biomass prior to the 2017 survey (13%). However, the reduced coverage (only 3 sets) in depths 1200-1400 m in the 2006 survey was considered to have had an effect on the mean biomass/km^2 and the total biomass, compared to estimates in 2004 and 2008 for this depth strata and the adjacent 1001-1200 m depth strata (Table 7 and 8), therefore, the overall biomass and abundance for 2006 are considered to be under-estimated (Fig. 5).

Abundance in 2019 was 8.0 x 10^7 (S.E. 1.1 x 10^7) (Table 5, 8 and Fig. 5). The pattern in abundance at depth is similar to that observed for biomass.

Abundance of fish >60 cm (5352) was above the series average (2289), while the number of 40-60 cm fish (55400) was near average (48754), and the number of fish <40 cm (25890) was below average (63728) (Fig. 7).

The overall length distribution in 2019 ranged from 15 to 87 cm with modes observed at 36 and 51 cm (a shift to the left in the frequency distribution, compared to 2017) (Table 8, Figs. 8 and 9). Abundance was reduced compared to previous years for all but lengths >50 cm. A trend to increased numbers of larger fish was observed from 1999 to 2004, 2008 to 2014 and 2015 to 2019 (Fig. 9). In 2015 the distribution had shifted left with increased numbers at smaller sizes (e.g. 18-36 cm) then in 2016 and 2017 the distribution was similar to that observed in 2012 and 2014 (Fig. 9). In 2019 the proportion of fish <45cm was 40%, the lowest in the time series (Table 8). The observed variation in abundance at length could be consistent with three strong pulses of recruitment moving through the time series.

Generally, the number of fish at larger length classes increases with depth. However, in 2019 the primary mode for the frequency of abundance at length (3 cm length categories, weighted by set) was near 51 cm for all but the deepest depth strata (Fig. 10). Abundance for depths 401-600 and 601-800 m were greater than observed in 2017 for lengths >30 cm, with an increase in abundance for fish >50 cm compared to 2015 and 2016.

Our age determination lab has begun to age Greenland halibut otoliths using the left section method (ICES 2017). We provide results for the 2014 and 2017 surveys as representative of the age-length relationship for Greenland halibut in Div. 0A (Fig. 11). In 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.

Acknowledgements

The 2019 survey could not have been conducted without the financial support provided by Fisheries and Oceans Canada. Thanks to Wojciech Walkusz the Biologist-in-charge of the survey who was supported by Fisheries and Oceans Canada science staff, Greenland Institute of Natural Resources science staff, and the FV Helga Maria crew.

References

BOJE, J. 2002. Intermingling and seasonal migrations of Greenland halibut (*Reinhardtius hippoglossoides*) populations determined from tagging studies. Fish. Bull. 100:414–422.

BOWERING, R. 1984. Migrations of Greenland Halibut, Reinhardtius hippoglossoides, in the Northwest Atlantic from Tagging in the Labrador-Newfoundland Region. J. Northw. Atl. Fish. Sci., Vol. 5: 85-91.

ICES. 2017. Report of the Workshop on age reading of Greenland halibut 2 (WKARGH2), 22-26 August 2016, Reykjavik, Iceland. ICES CM 2016/SSGIEOM:16. 40 pp.

JØRGENSEN, O. A. 1997. Movement Patterns of Greenland Halibut, *Reinhardtius hippoglossoides* (Walbaum), at West Greenland, as Inferred from Trawl Survey Distribution and Size Data. J. Northw. Atl. Fish. Sci., Vol. 21: 23–37.

JØRGENSEN, O. A. 1998. Survey for Greenland halibut in NAFO Division 1C-1D. NAFO SCR Doc. 98/25. Serial No. N3010, 26 pp.

KINGSLEY, M.C.S., KANNEWORFF, P. AND CARLSSON, D.M. 2004. Buffered random sampling: a sequential inhibited spatial point process applied to sampling in trawl survey for northern shrimp *Pandalus borealis* in West Greenland waters. ICES J. Mar. Sci. 61:12-24.

RIGET, F., BOJE, J. 1989. Fishery and some biological aspects of Greenland halibut (*Reinhardtius hippoglossoides*) in West Greenland waters. NAFO Sci. Con. Studies 13:41-52.

SIWICKE, A. and COUTRÉ , K. 2020. Periodic movements of Greenland turbot Reinhardtius hippoglossoides in the eastern Bering Sea and Aleutian Islands. Fisheries Research 229, 13 pp.

TREBLE, M. A. 2015. Report on Greenland halibut caught during the 2014 trawl survey in NAFO Divisions 0A and 0B. NAFO SCR Doc. 15/030, Serial No. N6454, 35 pp.

TREBLE, M. A. 2016. Report on Greenland halibut caught during the 2015 trawl survey in NAFO Divisions 0A and 0B. NAFO SCR Doc. 16/025, Serial No. N6568, 33 pp.

TREBLE, M. A. 2018. Report on Greenland halibut caught during the 2017 trawl survey in NAFO Division 0A. NAFO SCR Doc. 18/015, Serial No. N6799, 23 pp.

TREBLE, M. A. and Nogueira, A. 2020. Assessment of the Greenland Halibut Stock Component in NAFO Subarea 0 and 1 (Offshore). NAFO SCR 20/038, Serial No. N7086, 31 pp.

NOGUEIRA, A. and Treble, M. A. 2020. Comparison of vessels used and survey timing for the 1CD and 0A-South deep-water surveys and the 1A-F west Greenland shelf surveys. NAFO SCR 20/15, Serial No. N7060, 43 pp.

WHEELAND, L. J., Novaczek, E., Treble, M. A., and Nogueira, A. 2020. Impacts of survey timing on distribution and indices of Greenland halibut in NAFO Div. 0A and Divs. 1CD. NAFO SCR 20/32, Serial No. N7080, 18 pp.

Table 1. Stratification scheme for Division 0A-South.

Stratum	Depth (m)	Area (km2)	Assigned Sets (1/750km2)
A1-4	400-600	2152	3
A2-4	400-600	4649	6
A3-4	400-600	785	2
A4-4	400-600	1922	3
B2-4	400-600	2519	3
		12027	17
A1-5	600-800	795	2
A2-5	600-800	2250	3
A3-5	600-800	760	2
A4-5	600-800	2483	3
B2-5	600-800	5108	7
		11396	17
A1-6	800-1000	604	2
A2-6	800-1000	1145	2
A3-6	800-1000	1020	2
A4-6	800-1000	1376	2
B2-6	800-1000	2656	4
		6801	12
A1-7	1000-1200	745	2
A2-7	1000-1200	1873	2
A3-7	1000-1200	1307	2
A4-7	1000-1200	1636	2
B2-7	1000-1200	1789	2
		7349	10
A1-8	1200-1400	813	2
A2-8	1200-1400	2151	3
A3-8	1200-1400	1146	2
A4-8	1200-1400	1072	2
B2-8	1200-1400	1779	2
		6961	11
A1-9	1400-1500	498	2
A2-9	1400-1500	1153	2
A3-9	1400-1500	684	2
A4-9	1400-1500	710	2
B2-9	1400-1500	346	2
		3390	10
Total		47924	77

Table 2. 0A-South set distribution. Area removed from the survey due to incomplete set coverage (sets <2) is highlighted.

Stratum	Depth (m)	Area (km^2)	1999	2001	2004	2006	2008	2010	2012	2014	2015	2016	2017	2019
A1-4	400-600	2152	4	0	6	4	3	3	3	3	3	3	4	1
A2-4	400-600	4649	2	3	1	6	6	6	6	4	5	6	4	6
A3-4	400-600	785	3	0	0	2	2	2	2	2	2	1	2	2
A4-4	400-600	1922	0	2	0	0	3	3	3	2	3	3	0	3
B2-4	400-600	2519	2	0	1	2	3	3	2	6	3	3	4	2
		12027	11	5	8	14	17	17	16	17	16	16	14	14
A1-5	600-800	795	3	2	1	3	2	2	2	2	2	2	2	2
A2-5	600-800	2250	0	3	1	3	3	3	3	3	3	3	4	2
A3-5	600-800	760	1	1	1	2	2	2	2	2	2	2	2	2
A4-5	600-800	2483	1	1	3	0	1	3	3	3	3	3	0	3
B2-5	600-800	5108	7	6	5	8	7	7	7	8	7	7	9	6
		11396	12	13	11	16	15	17	17	18	17	17	17	15
A1-6	800-1000	604	1	1	1	2	2	2	2	1	2	2	2	2
A2-6	800-1000	1145	2	0	1	2	2	2	2	2	2	2	3	2
A3-6	800-1000	1020	3	2	3	1	2	2	2	2	2	2	3	2
A4-6	800-1000	1376	1	1	2	0	1	2	2	3	2	2	0	2
B2-6	800-1000	2656	4	3	5	1	4	4	4	6	4	4	4	4
		6801	11	7	12	6	11	12	12	14	12	12	12	12
A1-7	1000-1200	745	2	0	1	1	2	2	2	1	2	2	2	2
A2-7	1000-1200	1873	3	2	2	5	2	2	2	4	2	2	4	2
A3-7	1000-1200	1307	2	0	4	0	2	2	2	2	2	2	2	2
A4-7	1000-1200	1636	0	0	0	0	2	2	2	3	2	2	0	2
B2-7	1000-1200	1789	2	3	3	0	2	2	2	4	2	2	2	2
		7349	9	5	10	6	10	10	10	14	10	10	10	10
A1-8	1200-1400	813	2	3	1	0	2	2	2	2	2	2	2	2
A2-8	1200-1400	2151	3	4	4	3	3	3	3	4	3	3	5	3
A3-8	1200-1400	1146	2	0	2	0	2	2	2	2	2	2	2	2
A4-8	1200-1400	1072	1	0	4	0	2	2	2	2	2	2	0	2
B2-8	1200-1400	1779	2	2	1	0	4	2	2	2	2	2	2	2
		6961	10	9	12	3	13	11	11	12	11	11	11	11
A1-9	1400-1500	498	0	0	0	0	2	2	2	2	2	2	2	2
A2-9	1400-1500	1153	0	0	1	1	2	2	2	2	2	2	4	2
A3-9	1400-1500	684	0	0	0	0	2	2	2	2	2	2	2	2
A4-9	1400-1500	710	0	0	0	0	0	2	2	2	2	2	0	2
B2-9	1400-1500	346	1	0	1	0	2	2	1	0	2	2	2	2
		3390	1	0	2	1	8	10	9	8	10	10	10	10
Total		47924	54	39	55	46	74	77	75	83	76	76	74	72
	Adjusted		44534	44534		44534								

Table 3. Mean temperature and S.E. in ( ) for Division 0A-South.

	Depth Stratum (m)					
Year	401-600	601-800	801-1000	1001-1200	1201-1400	1401-1500
1999						
2001						
2004	1.4 (0.18)	1.1 (0.08)	0.9 (0.04)	0.6 (0.05)	0.1 (0.04)	-0.2 (0.09)
2006	1.1 (0.08)	1.3 (0.07)	1.1 (0.05)	0.9 (0.10)	0.2 (0.07)	0.3 (-)
2008	1.1 (0.11)	1.4 (0.03)	1.3 (0.04)	0.8 (0.05)	0.4 (0.03)	0.1 (0.04)
2010	1.3 (0.09)	1.1 (0.13)	0.9 (0.09)	0.7 (0.07)	0.2 (0.05)	0.0 (0.02)
2012	1.4 (0.14)	1.6 (0.06)	1.1 (0.11)	0.7 (0.07)	0.3 (0.07)	0.0 (0.03)
2014	1.7 (0.17)	1.5 (0.05)	1.3 (0.02)	0.8 (0.08)	0.4 (0.04)	0.2 (0.04)
2015	1.4 (0.06)	1.4 (0.04)	1.2 (0.09)	0.7 (0.07)	0.2 (0.04)	0.0 (0.02)
2016	1.3 (0.08)	1.2 (0.09)	0.8 (0.07)	0.6 (0.06)	0.3 (0.05)	0.1 (0.04)
2017	1.3 (0.42)	1.5 (0.65)	0.7 (0.24)	0.4 (2.21)	0.3 (0.06)	0.1 (0.17)
2019	1.2 (0.09)	1.2 (0.07)	1.0 (0.07)	0.6 (0.05)	0.2 (0.03)	-0.1 (0.03)

Table 4. Sex and maturity proportions, for Division 0A-South.

Year	Survey Dates	Sex	% of catch	Mat	% of Sex
2012	Sept. 29-Oct. 27	F	47	Immature	99
				Mature	1
		M	52	Immature	94
				Mature	6
2014	Sept. 22-Oct. 18	F	48	Immature	98
				Mature	2
		M	51	Immature	87
				Mature	13
2015	Sept. 26-Oct. 9	F	51	Immature	79
				Mature	21
		M	49	Immature	82
				Mature	18
2016	Oct. 7-Oct. 20	F	52	Immature	96
				Mature	4
		M	48	Immature	32
				Mature	68
2017	Oct. 27-Nov. 8	F	52	Immature	97
				Mature	3
		M	48	Immature	61
				Mature	39
2019	Aug. 15-25	F	53	Immature	88
				Mature	12
		M	47	Immature	82
				Mature	18

Table 5. Greenland halibut biomass and abundance with standard error by stratum for the 2019 survey.

Div.	Stratum (m)	Mean Biomass (t/sq km)	Biomass (tons)	SE	Mean Abundance (#/sq km)	Abundance	SE
0A-South	401-600	2.067	24855	7115	2155	2.6E+07	6.0E+06
	601-800	2.723	31039	7543	3043	3.5E+07	8.4E+06
	801-1000	2.262	15382	3008	1865	1.3E+07	2.2E+06
	1001-1200	0.833	6122	1309	649	4.8E+06	1.0E+06
	1201-1400	0.325	2260	317	201	1.4E+06	2.1E+05
	1401-1500	0.286	969	219	160	5.4E+05	1.2E+05
	Overall	1.682	80625	10883	1669	8.0E+07	1.1E+07

Table 6. Mean catch-per-tow (tons) standardized to km2 of Greenland Halibut from SA0, Divisions 0B and 0A-South during the period 1999-2019.

Division	1999	2000	2001	2004	2006	2008	2010	2011	2012	2013	2014	2015	2016	2017	2019
0B		0.77	0.91					1.18		0.78	0.95	0.98	1.28		
0A-South	1.31		1.93	1.60	1.11	1.60	1.52		2.22		1.92	2.17	2.83	1.23	1.68

Table 7. Biomass (tons) of Greenland Halibut by depth stratum for Div. 0A-South.

Year	Survey Dates	Depth Strata (m) 401-600	601-800	801-1000	1001-1200	1201-1400	1401-1500	Total
1999	Oct. 7-19	5596	12349	10799	19162	10414		58320
2001	Sept. 16-23	14481	24551	22621	20868	3249		85769
2004	Oct. 14-24	7979	11397	17810	24712	13997	908	76802
2006	Oct. 27-Nov. 7	3367	6253	7471	27070	5410		49571
2008	Oct. 8-Nov. 4	5684	10312	16798	18876	23155	1970	76794
2010	Oct. 17-Nov. 6	3655	9835	17271	30412	9285	2453	72911
2012	Sept. 29-Oct. 27	11042	35158	23405	25970	9327	1717	106619
2014	Sept. 22-Oct. 18	15095	30952	20023	16905	7484	1565	92024
2015	Sept. 26-Oct. 9	28559	23468	21330	24100	5520	1210	104187
2016	Oct. 7-20	20923	32388	32442	34891	12826	2368	135837
2017	Oct. 27-Nov. 8	4197	7961	6481	16214	16122	7837	58812
2019	Aug. 15-25	24854	31038	15382	6122	2260	969	80625

Table 8. Greenland Halibut abundance (000s) by depth stratum for Div. 0A-South.

Year	Survey Dates	Depth Strata (m) 401-600	601-800	801-1000	1001-1200	1201-1400	1401-1500	Total
1999	Oct. 7-19	17207	33792	24233	30329	9540		115101
2001	Sept. 16-23	22540	51821	27888	28836	3300		134385
2004	Oct. 14-24	23372	23016	23360	25583	10100	660	106091
2006	Oct. 27-Nov. 7	13442	17839	15753	40264	5210		92508
2008	Oct. 8-Nov. 4	15900	23730	30033	27710	22300	1563	121236
2010	Oct. 17-Nov. 6	10134	24497	34352	34445	7670	1661	112759
2012	Sept. 29-Oct. 27	26533	54365	27343	21397	6740	1120	137498
2014	Sept. 22-Oct. 18	22008	45381	20819	12308	4840	1027	106383
2015	Sept. 26-Oct. 9	44598	30043	19645	17576	3411	719	115992
2016	Oct. 7-20	40330	52336	36423	28588	9500	1463	168640
2017	Oct. 27-Nov. 8	16801	19657	11144	20486	15868	5733	89689
2019	Aug. 15-25	25919	34681	12685	4767	1402	542	79996

Table 9. Length distribution (3cm groups) estimated total number (000's) for Greenland halibut from Division 0A-South surveys (weighted by survey area).

Length Class (3cm)	1999	2001	2004	2008	2010	2012	2014	2015	2016	2017	2019
6	73				57		48	118	9		
9	26	10			55			145	9		
12	61		69	8	42	130	48	454	27	223	
15	21	33	1518	338	319	133	108	1163	38	359	10
18	322	204	865	949	586	5717	**1983**	**3263**	2527	3199	1242
21	639	887	2628	2181	1566	**6388**	1261	2544	**5107**	4119	1740
24	2902	2741	3108	2703	3592	2192	2052	3261	2659	5474	1504
27	8512	3360	7647	6419	6897	4105	3570	6771	6052	**9411**	2091
30	12473	6014	7036	11312	11026	7102	7424	13511	9338	5547	3299
33	15944	10961	8369	**17461**	12460	10345	**11324**	**17526**	11016	5499	4342
36	16947	20188	9658	16467	14320	14054	9177	13403	14785	6550	**6355**
39	**17014**	**25928**	10321	15574	**15958**	18210	9088	12285	23757	7107	5307
42	14621	26912	12462	13859	14302	**20637**	11461	**13381**	**29326**	8491	6469
45	10750	18027	**13697**	11816	11300	18256	**14580**	11856	21642	**11229**	7104
48	6443	10721	12176	8765	6999	13052	13558	7954	15514	10376	10579
51	4122	4892	8418	5548	5279	8284	10131	4089	10106	6039	**11305**
54	2247	1762	4036	3529	3532	3835	5553	2020	7865	2838	8773
57	1250	834	1988	2180	2079	2074	2483	1202	4258	1400	4525
60	704	503	937	1234	1074	1175	1167	535	2220	870	2364
63	471	169	509	459	848	876	675	213	1256	434	1611
66	242	105	306	314	290	544	365	103	666	296	559
69	117	103	103	61	80	186	172	124	238	125	477
72	127	28	125	24	24	110	122	59	167	25	122
75	9		41	16	24	36	30	6	22		132
78	18		51		15	31	6			38	24
81	9		20			17		7		24	16
84	0	19	6	15	17				13	7	20
87	0		26						4		25
90	0		7			10			26	7	
93	9			9							
96	0		6								
99	0			9	12						
Total	116073	134402	106134	121249	112755	137498	106384	115992	168646	89689	79996
Total <45 cm	89555	97239	63682	87270	81180	89013	57544	87826	104650	55978	32359
% <45 cm	77.15	72.35	60.00	71.98	72.00	64.74	54.09	75.72	62.05	62.41	40.45

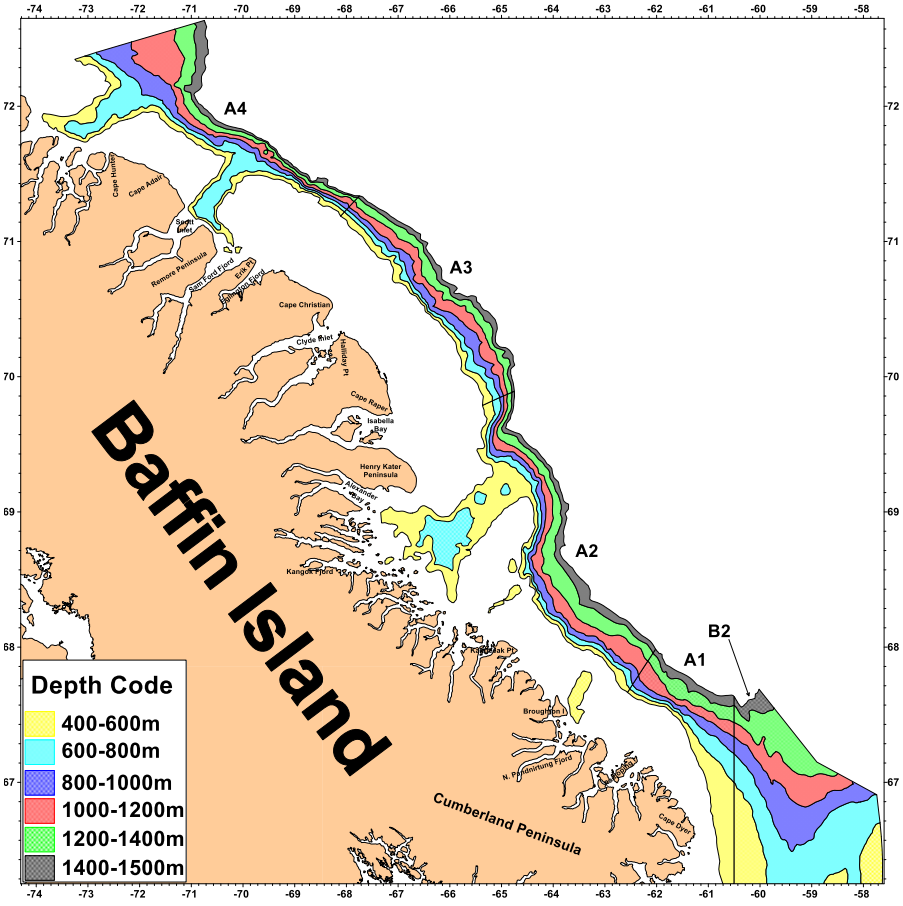


Figure 1. Stratification scheme for Division 0A-South, 66° N to 72° N.

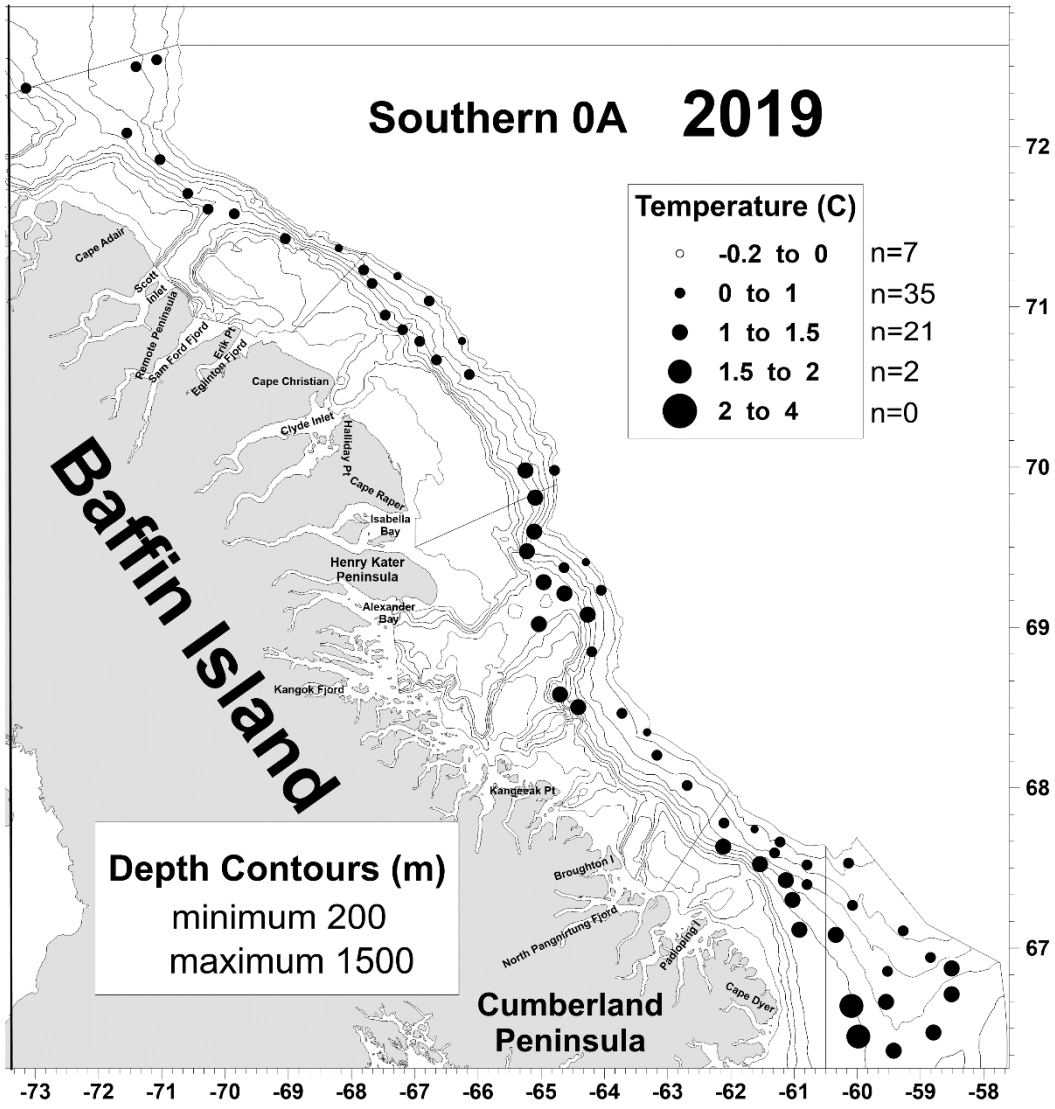


Figure 2. Bottom temperatures in Division 0A during 2019 survey.

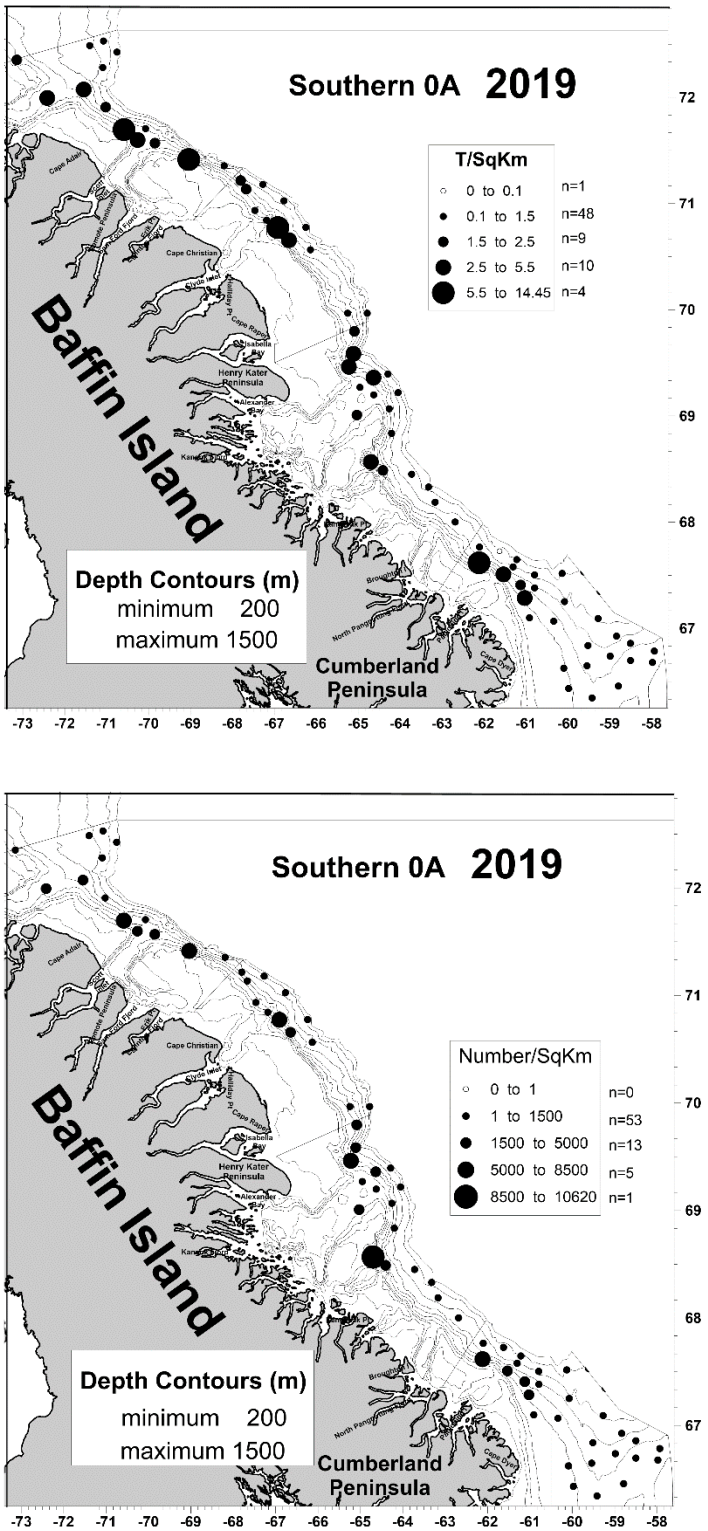


Figure 3. Biomass (top) and abundance (bottom) distribution for Greenland halibut in Division 0A, 2019.

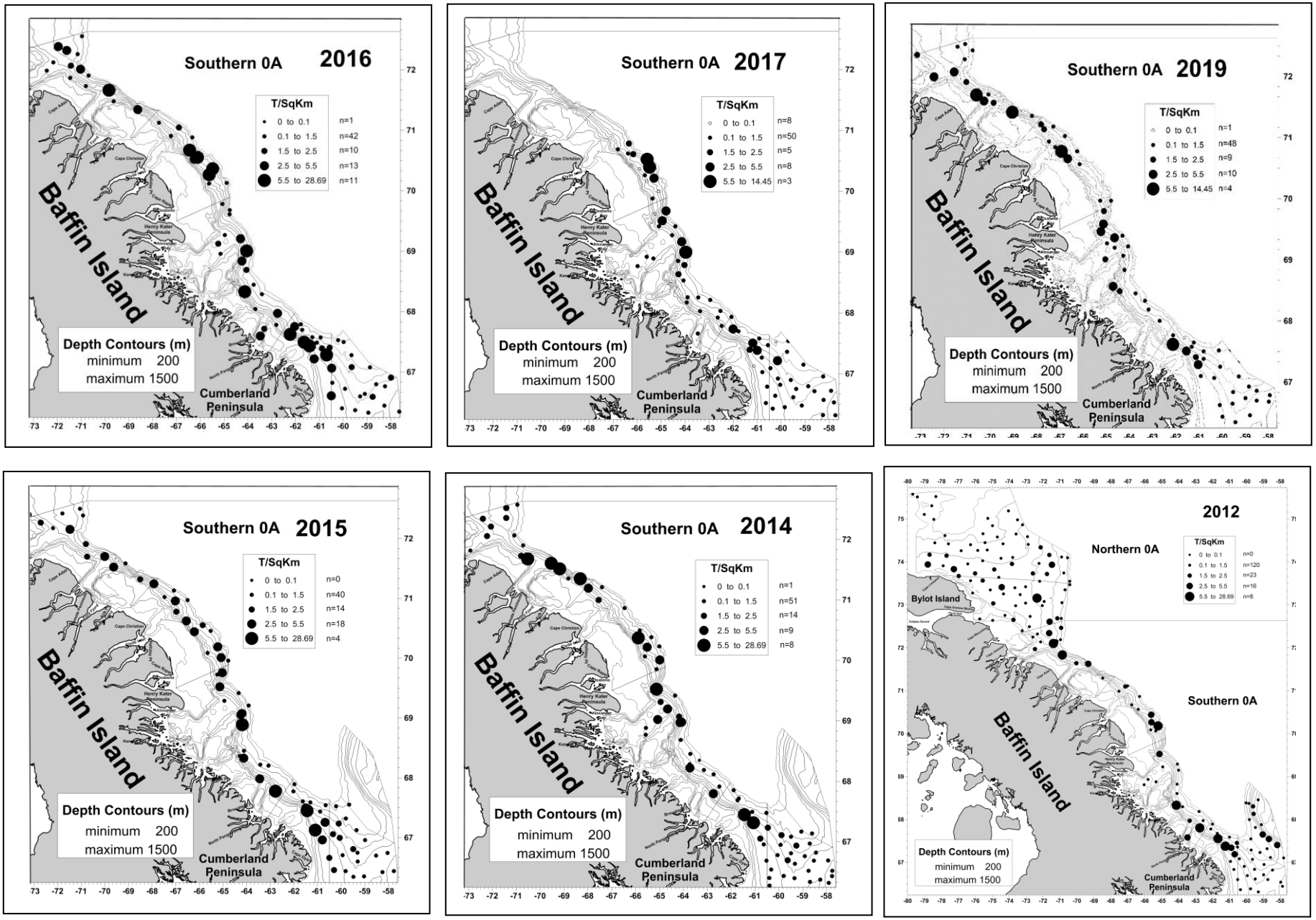
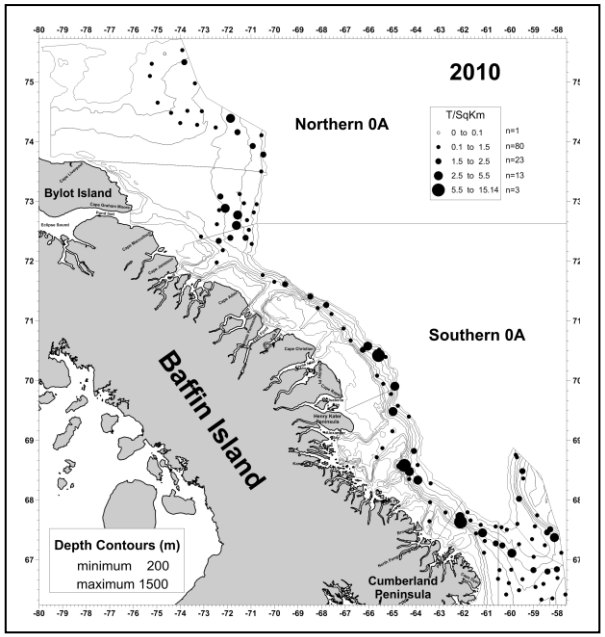
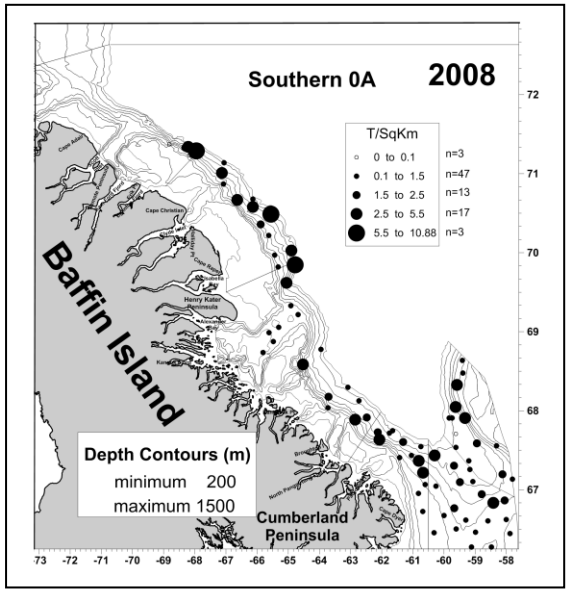
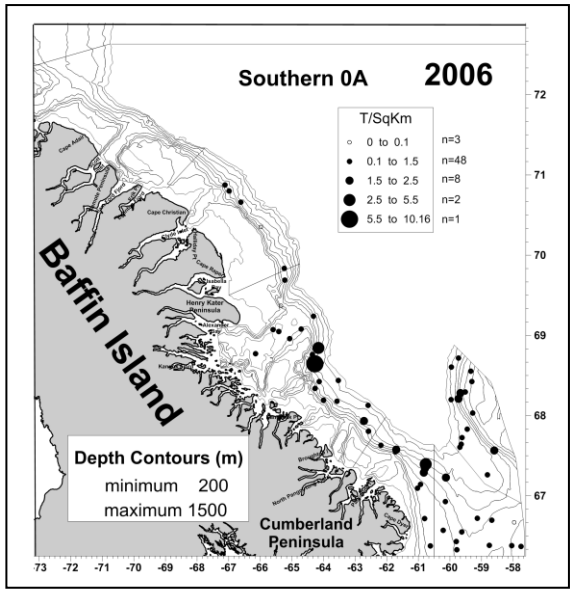
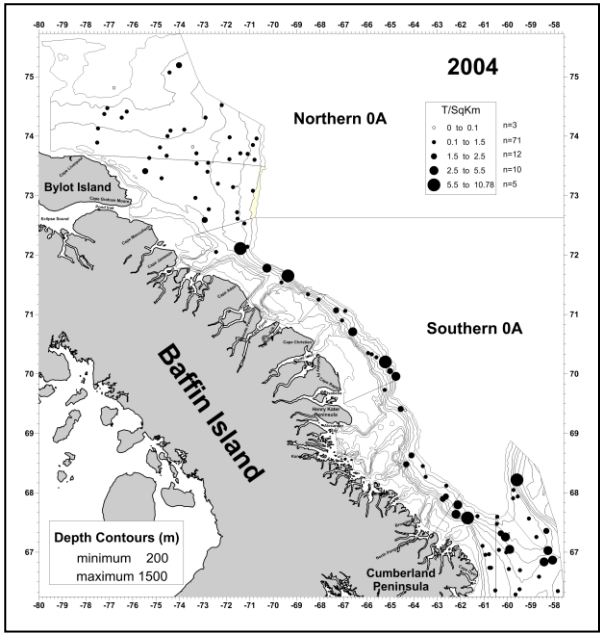


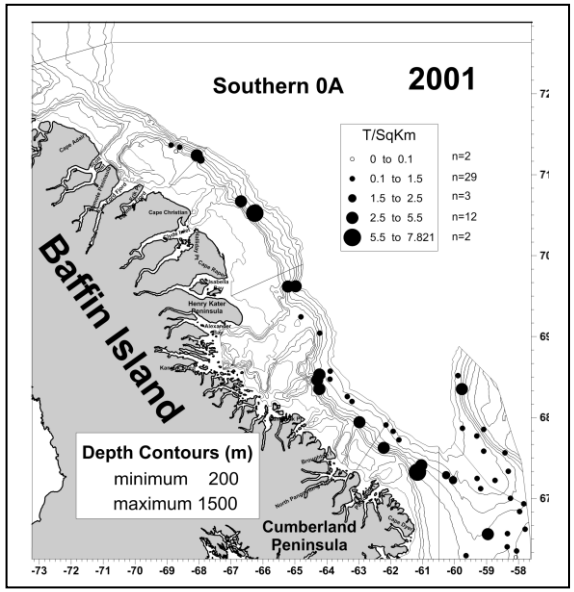
Figure 4. Biomass distribution (t/sq km) for Greenland halibut in Division 0A, 1999 to 2017.


2010
Northern 0A
Southern 0A
Bylot Island
Baffin Island
Cumberland Peninsula
Depth Contours (m)
minimum 200
maximum 1500
T/SqKm
0 to 0.1 n=1
0.1 to 1.5 n=80
1.5 to 2.5 n=23
2.5 to 5.5 n=13
5.5 to 15.14 n=3


2008
Southern 0A
Baffin Island
Cumberland Peninsula
Depth Contours (m)
minimum 200
maximum 1500
T/SqKm
0 to 0.1 n=3
0.1 to 1.5 n=47
1.5 to 2.5 n=13
2.5 to 5.5 n=17
5.5 to 10.88 n=3


2006
Southern 0A
Baffin Island
Cumberland Peninsula
Depth Contours (m)
minimum 200
maximum 1500
T/SqKm
0 to 0.1 n=3
0.1 to 1.5 n=48
1.5 to 2.5 n=8
2.5 to 5.5 n=2
5.5 to 10.16 n=1


2004
Northern 0A
Southern 0A
Bylot Island
Baffin Island
Cumberland Peninsula
Depth Contours (m)
minimum 200
maximum 1500
T/SqKm
0 to 0.1 n=3
0.1 to 1.5 n=71
1.5 to 2.5 n=12
2.5 to 5.5 n=10
5.5 to 10.78 n=5


2001
Southern 0A
Baffin Island
Cumberland Peninsula
Depth Contours (m)
minimum 200
maximum 1500
T/SqKm
0 to 0.1 n=2
0.1 to 1.5 n=29
1.5 to 2.5 n=3
2.5 to 5.5 n=12
5.5 to 7.821 n=2

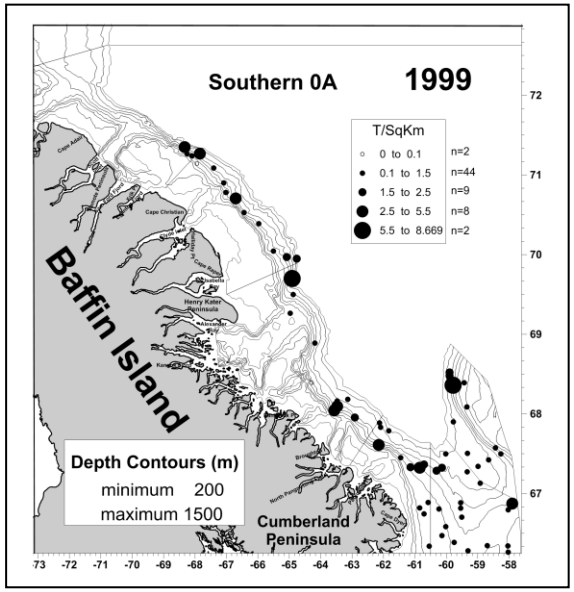

1999
Southern 0A
Baffin Island
Cumberland Peninsula
Depth Contours (m)
minimum 200
maximum 1500
T/SqKm
0 to 0.1 n=2
0.1 to 1.5 n=44
1.5 to 2.5 n=9
2.5 to 5.5 n=8
5.5 to 8.669 n=2

Fig.4 (Con't).

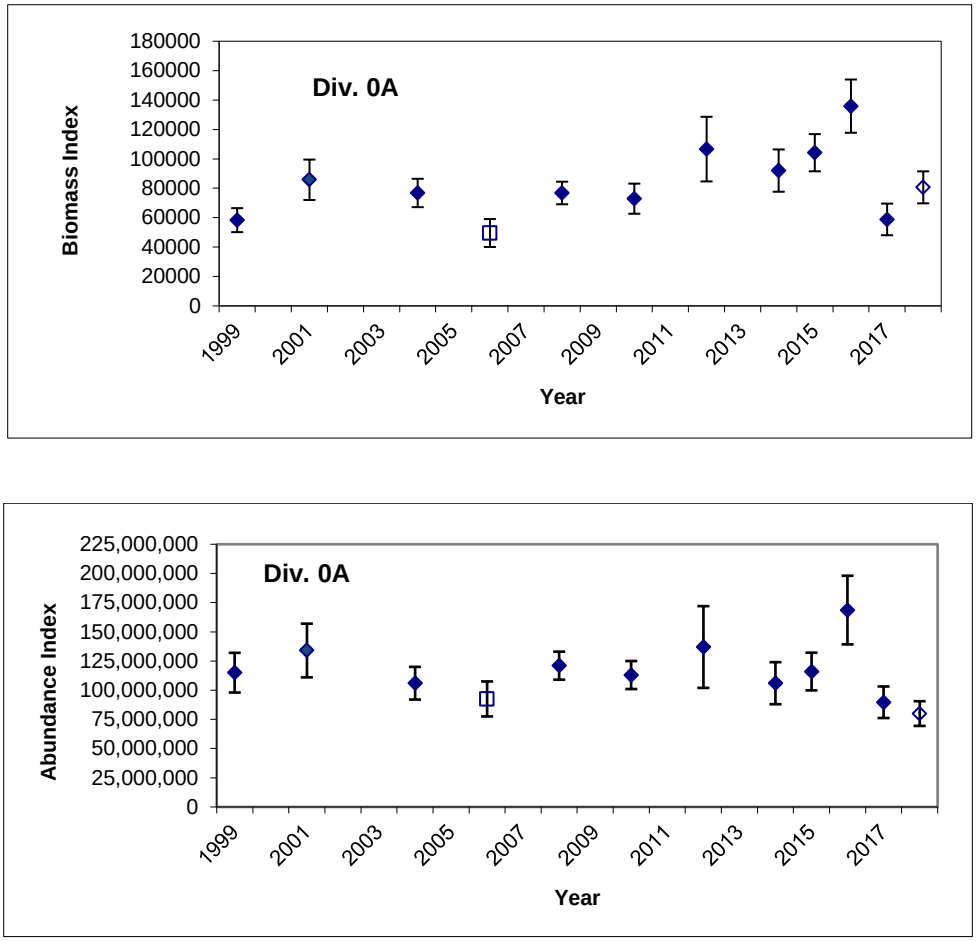


Figure 5. Biomass (top) and abundance (bottom) estimates (with SE) for Greenland halibut in Division 0A-South. The 2006 biomass and abundance (open square) may be under-estimated due to reduced coverage in the 1200-1400 m depth strata. The 2019 estimates (open diamond) were done using a different vessel (Helga Maria) but the same gear (Alfredo otter trawl).

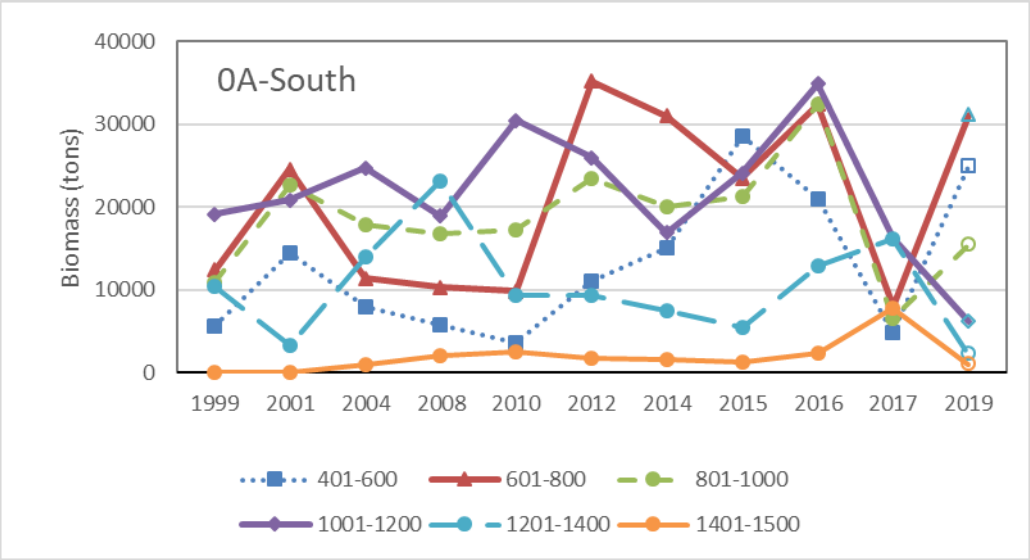


Figure 6. Biomass trends by depth strata for Division 0A-South.

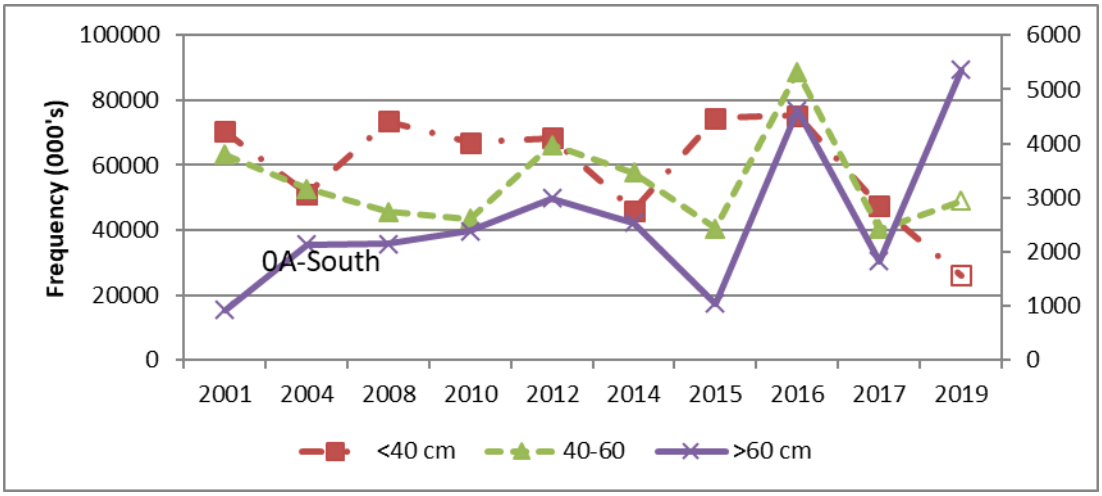


Figure 7. Abundance by size class for Divisions 0A-South: <40 cm (recruitment, left axis); 40-60 cm (size range for trawl catches, left axis); >60 cm (size range for gillnet catches, right axis).

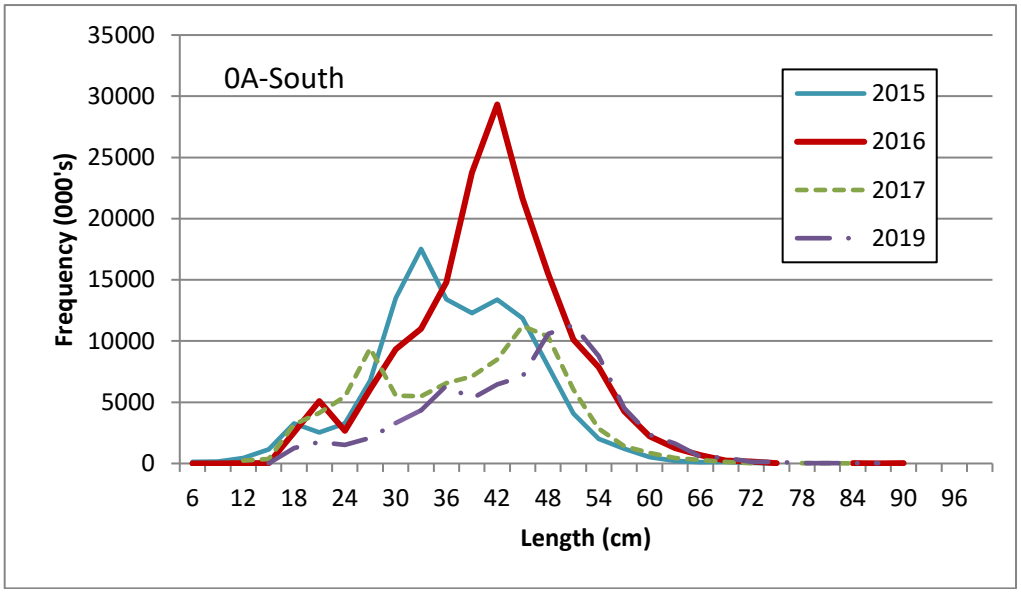


Figure 8. Abundance-at-length for Greenland halibut in Divisions 0A-South, weighted by stratum area.

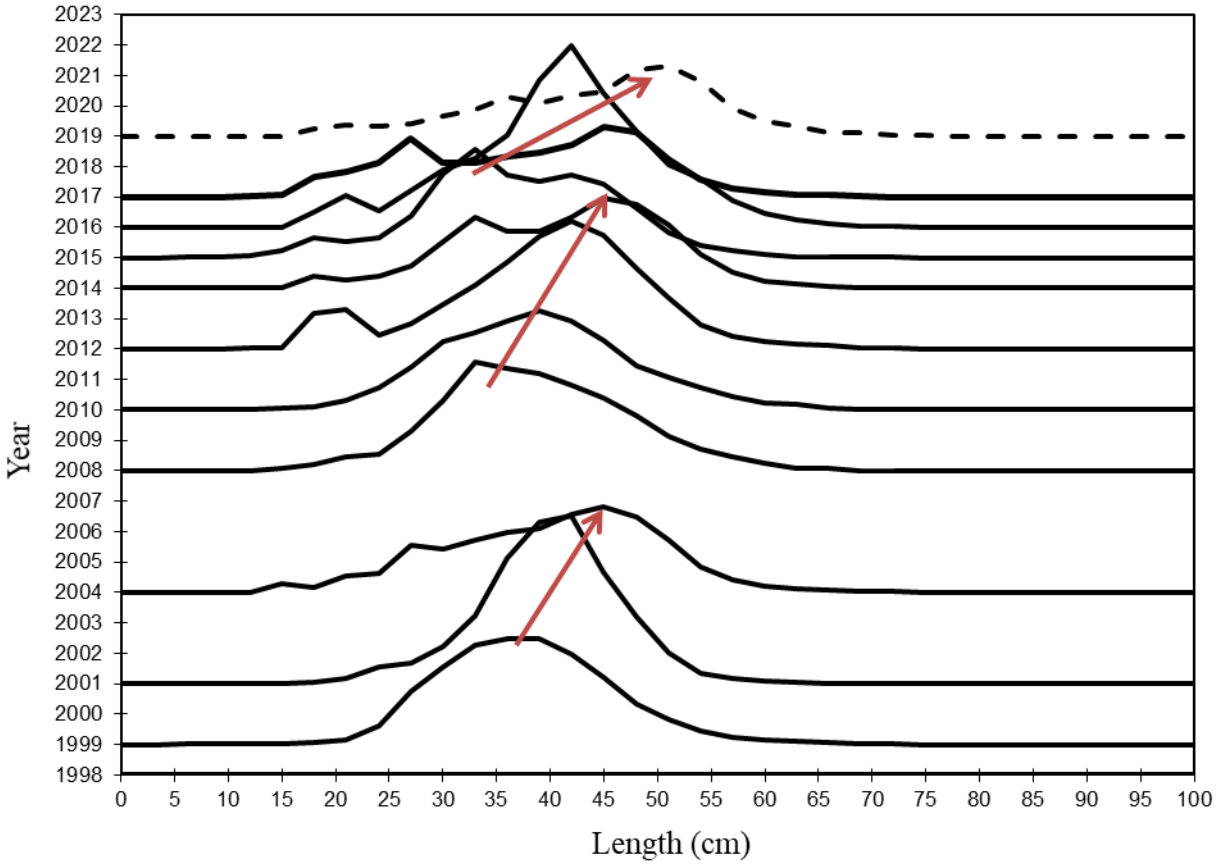


Figure 9. Length frequency distribution for Division 0A-South 2001-2019 (numbers/km2 weighted by stratum area). NB MOVE RED ARROW to PEAK FOR 2015…

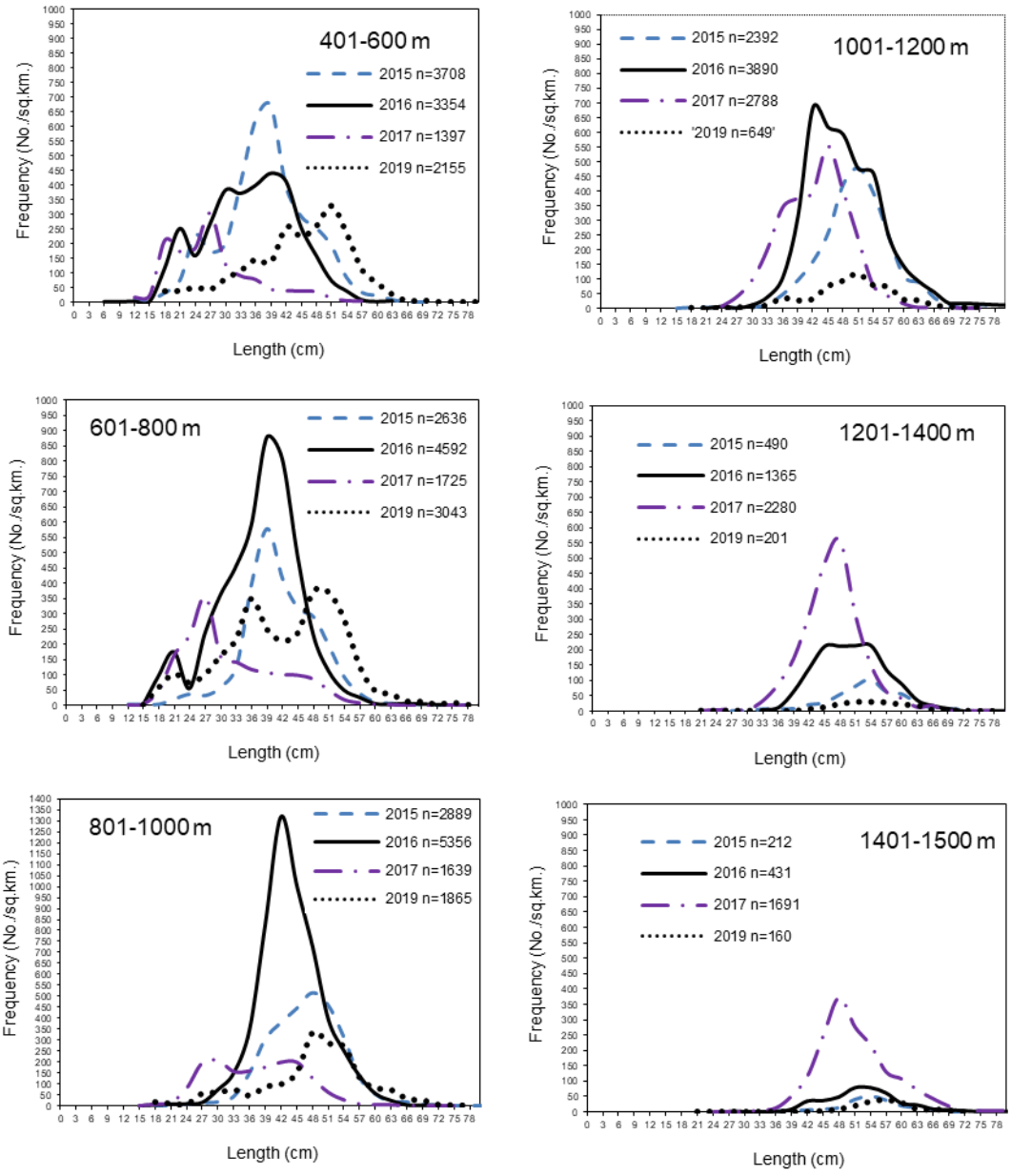


Figure 10. Greenland halibut length distribution by depth for Divisions 0A-South, 2015 to 2019. Abundance values are per sqkm and weighted by set.

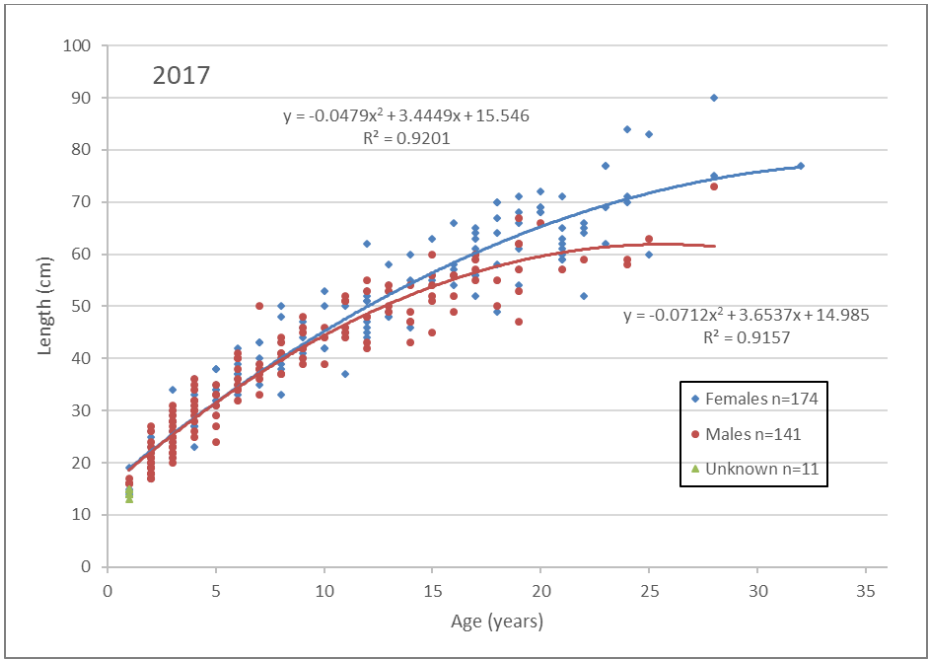


Figure 11. Growth curves for Greenland halibut, by sex, for the 2017 survey in Div. 0A-South.

Appendix 1. Greenland halibut raw catch weight, numbers (not standardised to kg/km2), temperature and depth for each set in the 2019 survey of Divisions 0A-South.

Obs	Div.	Set	Date	Mean Depth (m)	Sweptarea (sq km)	Temp (oC)	Number	Weight (kg)
1	0A	1	8/15/2019	650	0.08429	.	105	62.84
2	0A	2	8/15/2019	721	0.08091	.	61	43.86
3	0A	3	8/15/2019	739	0.08169	1.11	40	24.20
4	0A	4	8/16/2019	954	0.08283	.	58	54.44
5	0A	5	8/16/2019	930	0.07890	1.02	87	79.05
6	0A	6	8/16/2019	1065	0.08010	0.77	39	50.28
7	0A	7	8/16/2019	953	0.07950	0.94	49	44.92
8	0A	8	8/16/2019	1237	0.08059	0.27	24	25.50
-9	0A	9	8/16/2019	1354	0.08515	0.07	10	20.80
10	0A	10	8/17/2019	1067	0.08551	0.62	24	26.96
11	0A	11	8/17/2019	1426	0.08485	-0.01	8	13.72
12	0A	12	8/17/2019	1429	0.08170	0.05	15	27.28
13	0A	13	8/17/2019	1311	0.07693	0.2	9	11.70
14	0A	14	8/17/2019	1298	0.07998	0.26	23	27.24
15	0A	15	8/17/2019	1426	0.07931	0.02	5	9.49
16	0A	16	8/17/2019	1464	0.07716	-0.04	2	3.64
17	0A	17	8/18/2019	1069	0.08098	0.76	45	53.62
18	0A	18	8/18/2019	1133	0.08322	0.51	15	21.20
19	0A	19	8/18/2019	1274	0.07449	0.22	6	9.46
20	0A	20	8/18/2019	1401	0.07859	-0.03	11	16.14
21	0A	21	8/18/2019	1329	0.08725	0.13	10	15.86
22	0A	22	8/18/2019	1067	0.08238	0.78	80	96.39
23	0A	23	8/18/2019	1285	0.08229	0.27	17	30.24
24	0A	24	8/19/2019	933	0.07909	0.89	164.274	246.48
25	0A	25	8/19/2019	1445	0.07701	-0.11	11	16.40
26	0A	26	8/19/2019	1258	0.08160	0.18	31	51.60
27	0A	27	8/19/2019	1432	0.07757	-0.13	6	12.46
28	0A	28	8/19/2019	1316	0.08140	0.1	23	39.24
29	0A	29	8/20/2019	1444	0.07995	-0.2	15	28.60
30	0A	30	8/20/2019	1063	0.07982	0.55	116.65	149.57
31	0A	31	8/20/2019	1422	0.07907	-0.07	33	52.60
32	0A	32	8/20/2019	931	0.07921	.	48	94.98
33	0A	33	8/20/2019	1131	0.08206	0.5	69	123.74
34	0A	34	8/20/2019	1324	0.08381	.	17	35.42
35	0A	35	8/20/2019	1456	0.08219	-0.22	22	48.88
36	0A	36	8/21/2019	1348	0.08554	0.06	11	26.02
37	0A	37	8/21/2019	1145	0.08038	0.38	4	9.01
38	0A	38	8/21/2019	432	0.07574	0.77	81	113.80
39	0A	39	8/21/2019	731	0.07834	.	258.534	319.88
40	0A	40	8/21/2019	830	0.08150	0.57	215.808	363.78
41	0A	41	8/21/2019	735	0.08336	0.78	468.32	681.64
42	0A	42	8/21/2019	490	0.07919	0.88	318.99	367.32
43	0A	43	8/21/2019	693	0.08288	0.85	125	141.24
44	0A	44	8/22/2019	442	0.07510	0.94	430.839	598.31
45	0A	45	8/22/2019	855	0.07436	0.75	107.93	137.60
46	0A	46	8/22/2019	464	0.07410	0.96	71	67.09

47	0A	47	8/22/2019	434	0.07458	0.85	30	31.40
48	0A	48	8/22/2019	672	0.07903	0.93	585.756	532.08
49	0A	49	8/22/2019	872	0.08284	0.84	292.5	397.84
50	0A	50	8/22/2019	1088	0.08075	0.63	55	75.18
51	0A	51	8/22/2019	671	0.08386	1.03	112	113.94
52	0A	52	8/22/2019	645	0.08087	1.1	134.078	137.66
53	0A	53	8/23/2019	815	0.07811	1.02	213.351	256.42
54	0A	54	8/23/2019	563	0.07854	1.28	410.308	370.16
55	0A	55	8/23/2019	520	0.07454	1.3	71	67.58
56	0A	56	8/23/2019	557	0.07470	1.31	52	51.86
57	0A	57	8/23/2019	530	0.07458	1.3	94	71.52
58	0A	58	8/23/2019	521	0.07703	1.31	227.025	140.76
59	0A	59	8/23/2019	684	0.06256	1.29	623.168	311.10
60	0A	60	8/23/2019	493	0.07450	1.25	307.008	184.88
61	0A	61	8/24/2019	728	0.07290	1.48	374.99	411.66
62	0A	62	8/24/2019	922	0.07568	1.19	256.496	249.88
63	0A	63	8/24/2019	919	0.07749	1.05	212.06	189.74
64	0A	64	8/24/2019	1025	0.07969	0.8	78	69.72
65	0A	65	8/24/2019	702	0.08358	1.48	346.472	225.48
66	0A	66	8/24/2019	556	0.07947	1.49	92	70.72
67	0A	67	8/24/2019	722	0.08038	1.44	99.586	92.52
68	0A	69	8/25/2019	567	0.07937	1.84	55	40.35
69	0A	70	8/25/2019	533	0.07570	1.96	70	39.20
70	0A	71	8/25/2019	851	0.07959	1.34	63	35.84
71	0A	72	8/25/2019	718	0.07915	1.32	103	54.24
72	0A	73	8/25/2019	685	0.07644	1.22	41	27.34

Appendix 2. Greenland halibut biomass index for Divisions 0A-South and 1CD estimated based on the 6 depth strata for the 0A survey as has been done to date for the analysis of results from this survey (Figure 1), and the 30 sub-strata that are used to assign sets within the survey (Figure 2) (prepared by Adriana Nogeira). Calculation of estimates and their se for 1999-2012 are pending. Change for 2014 and 2015 is minimal while it is somewhat greater for both 2016 and 2017.

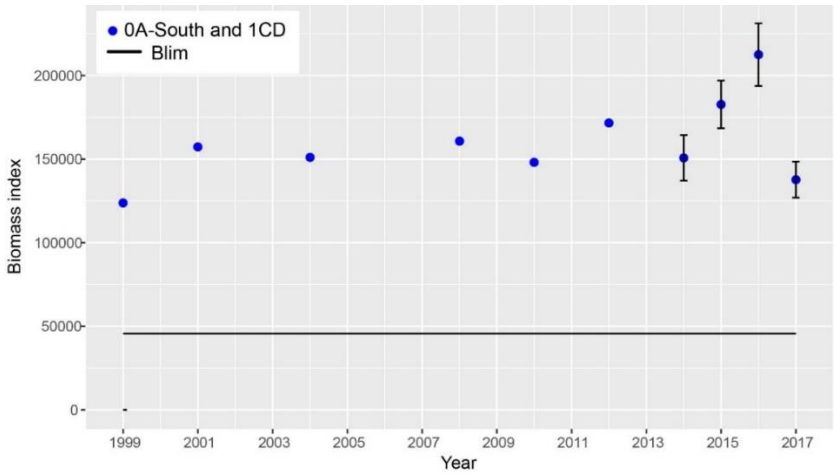


Figure 1. Biomass index using 6 depth strata.

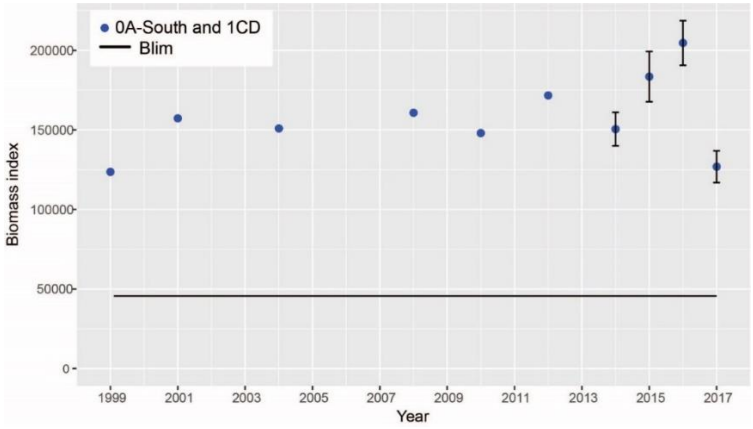


Figure 2. Biomass index using 30 smaller strata.

Table 1. Values for 2014-2017.

Biomass and se calculation using 6 depth strata			Biomass and se calculation using 30 smaller strata			
year	biomass	se	year	biomass	se	Difference
2014	150690.1	13661.92	2014	150505.9	10536.57	184.2
2015	182689.5	14264.75	2015	183538.8	15836.98	-849.3
2016	212467.0	18731.69	2016	204656.0	14024.88	7810.9
2017	137708.9	10784.34	2017	126866.7	9965.45	10842.2