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Northwest Atlantic Fisheries Organization

Serial No. N6830 **NAFO SCR Doc.18/040**

SCIENTIFIC COUNCIL MEETING – JUNE 2018

Assessment of the Greenland Halibut Stock Component in NAFO Subarea 0 + Division 1A (Offshore) and Divisions 1B-1F

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Abstract

The paper presents the background and the input parameters from research surveys and the commercial fishery to the assessment of the Greenland halibut stock component in NAFO Subarea 0 + Div. 1A (offshore) and Div. 1B-1F. Since 1995 catches have been near the TAC, increasing in step with increases in the TAC, with catches reaching a high of 34,661 in 2017. Since 1997 Greenland has conducted stratified random bottom trawl surveys during September-October in NAFO Div. 1CD, from 400 to 1500 m. The index of biomass in Div. 1CD in 2017 was similar to levels seen in 2015 and 2016 and above the time series average. Biomass in Div. 0A-South had varied with an increasing trend from 1999 to 2016 followed by a marked decline in 2017. Abundance followed a similar pattern. The 2017 survey missed stations assigned to the most northern portion of the depth strata due to ice conditions but is still considered representative. Recruitment estimated based on biomass of age 1 Greenland halibut from the Greenland shrimp and fish survey was generally increasing from 1988 to 2003, followed by a decline to 2010 and since then the index has been variable with series high values observed in 2011, 2013 and 2017. Length frequencies in the Div. 0A-South survey are variable across years, sometimes with multiple modes (e.g. 27 cm and 45 cm in 2017). A trend to increased numbers of larger fish was observed in Div. 0A-South from 1999 to 2004 and 2008 to 2014. Length frequencies for the Div. 1CD survey have a greater proportion of fish at larger sizes and the length distribution has been dominated by a mode at 51cm since 2006, an increase from a mode of 45 cm observed in 2000. A standardized CPUE index for all trawlers fishing in SA 0+1 has been increasing since 1997. For gillnets in SA0 the index has been increasing since the beginning of the time series in 2003 but since 2015 has been relatively stable. However, CPUE is known to have limitations as an index of population status. In the Div. 1AB Greenlandic trawl fishery the modal length has varied from 50 to 52 cm in, while the Russian trawl fishery has had slightly lower modes ranging from 45 to 50 cm in most years. Length frequencies in Greenland, Norway (16) and Russian fisheries in Div. 1CD had modes between 47- 50 cm for most years prior to about 2014, since then the length frequencies have had a greater proportion of larger fish with modes between 50-55 cm. Modal lengths have varied between 46-50 cm in the trawl fishery in Div. 0A and

in Div. 0B they have been stable at 50 cm, during 2015-2017. There tends to be a larger proportion of fish <50 cm in the Div. 0A trawl length frequency compared to Div. 0B. Modes in the Div. 0A gillnet fishery have been stable at 58 cm during 2015-2017 while the modes for Div. 0B during 2015 and 2016 were 64 cm.

1. Description of the Fishery, Catches and TAC

TAC Regulation

Greenland halibut in Subarea 0+1, including 1A inshore, came under quota regulation in 1976 when a TAC of 20,000 t was established (Fig. 1). TAC was increased to 25,000 t in 1979. In 1994 analysis of tagging and other biological information resulted in the creation of separate management areas for inshore Div. 1A and Subarea 0+1A (offshore) and 1B-F. The portion of the TAC allocated to Subarea 0+1A (offshore) and 1B-F was 11,000 t and the TAC remained at this level from 1995-2001, during which time the TAC was fished almost exclusively in Div. 0B and Div. 1CD. A series of surveys took place during 1999-2004 in areas of Div. 0A and 1AB that had not been surveyed before. This new information on biomass in the overall 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. 1CF was increased by 3,000 t in 2010 and the overall TAC for Subarea 0+1 remained at 27,000 t from 2011-2013. 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 and the overall TAC of 30,000 t remained through 2016. In 2016 an index based harvest control rule was accepted as the basis for TAC advice and an increase of 2,300 t was advised for the overall Subarea 0+1A (offshore) for 2017 and 2018, which was allocated equally to 0A+1A(offshore) and 1B, and 0B+1C-F. Figure 1 contains the plot of TAC over time.

Catches in Subarea 0 + Div. 1A (offshore) + Div.1B-1F

Catches were first reported in 1964 and rose to 20,027 t in 1975 before declining to 2,031 t in 1986.
In 1987 catches began to be reported by Subarea and Division (Tables 1 and 2). Catches increased from 2,927 t in 1989 to 18,457 t in 1992 due to a new trawl fishery in Div. 0B with participation by Canada, Norway, Russia and Faeroe Islands and an expansion of the 1CD fishery with participation by Japan, Norway and Faeroe Islands. Catch declined from 1992 to 1995 primarily due to a reduction of effort by non-Canadian fleets in Div. 0B. Since 1995 catches have been near the TAC, increasing in step with increases in the TAC reaching a high of 34,661 in 2017 (Fig. 1).

There is a small inshore fishery in Div. 1B-F where catches were less than 500 t prior to 2013. Since then catch has varied between 1,000 t and 2,000 t due primarily to increased effort in Div. 1D.

Inshore fisheries in the northern fjords of Div. 1A and in Cumberland Sound in Div. 0B are not included in the catch. However, there is no way to differentiate or separate these inshore catches from the total reported catches for these divisions in STATLANT so it is necessary to rely on the Greenland and Canadian authorities to determine the offshore catch for Div. 1A and 0B.

Bottom otter trawl gear is used by all fleets in the Subarea 1 fishery while the Subarea 0 fishery is a mix of trawl and gillnet (between 30-40% of the catch in recent years) with the occasional use of longline. The trawlers in both Subareas 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.

Bycatch and Discards

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

By-catch is estimated by observers on board vessels in Subarea 0 where targeted at-sea observer coverage is 100% for 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. By-catch of primary species (>1 t as reported by at-sea observers) in 2017 in the Div. 0A trawl fishery was 2.1 % of the corresponding Greenland halibut catch and in the gill net fishery it was 1.3 % (Table 3). The Div. 0B trawl and gillnet fishery had 2.4 and 9.8 % by-catch, respectively. Greenland shark dominated by-catch in the trawl fishery in both Div. 0A and 0B. Skates were the most common by-catch in Div. 0A trawl and gillnet fisheries, while in Div. 0B northern wolfish were common in the trawl fishery and roughhead grenadier were common in both trawl and gill net fisheries (Table 3).

The by-catch in the trawl fishery in Div. 1CD was estimated from survey data to be 13% (in weight) of the Greenland halibut catches (SCR 16/005). *Macrourus berglax* was the most abundant by-catch species and constituted 3.2 % of the weight of Greenland halibut catches, followed by *Antimora rostrata* (2.7%), *Alepocephalus agassizzi* (2.0 %) and *Hydrolagus affinis* (1.2%). None of the remaining species constituted more than 1% of the weight of the Greenland halibut catches.

2. Research Survey Data

2.1 Greenland Survey in Div. 1CD (Davis Strait)

Since 1997 Greenland has conducted stratified random bottom trawl surveys during September-October in NAFO Div. 1CD. Depths covered range from 400 m and 1500. Estimates of Greenland halibut biomass and abundance are calculated (Fig. 2 and 7). In 2013 the survey was incomplete with only 27 valid hauls in Div. 1D (SCR 14/02). The distribution of the biomass had been stable with 63-69% of the Div. 1CD biomass found in Div. 1D. Given this stability it was decided the biomass and abundance in Div. 1C could be estimated using a GLM (model: lnbiomass= year*division) with data from 2010-2014.

Biomass in Div. 1CD in 2017 was estimated at 78,896 t which is similar to levels seen in 2015 and 2016 and above the time series average (72,747 t). The abundance estimate in 2017 ($60{,}010 \times 10^3$) is also similar to levels seen in 2016 and 2017 (Fig. 2). The overall length distribution (weighted by stratum area) has been dominated by a mode at 51cm since 2006, an increase from a mode of 45 cm observed in 2000 (Fig. 3).

2.2 Greenland Deep Sea Survey in Div. 1A (Baffin Bay)

There has been no survey since 2010. Greenland conducted surveys primarily aimed at Greenland halibut in Baffin Bay in 2001, 2004 and 2010. The biomass and abundance of Greenland halibut in 2010 was estimated as 79 332 t and 1.04×10^8 specimens, respectively (SCR 11/10). Lengths in 2010 ranged from 20 cm to 105 cm. The overall length distribution (weighted by stratum area) was dominated by a mode at 45 cm. Generally the length distributions in the deeper depth strata were dominated by a single mode and fish size increased with depth.

2.3 Canadian Deep Sea Surveys in Div. 0A (Baffin Bay)

A stratified-random otter trawl survey has been conducted in southern 0A (0A-South) (to approximately 72° N) during late September to early November in 1999, 2001, every two years from 2004 to 2014, and annually since then.

A 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 were slightly different from those used in surveys conducted between 1999 and 2006 therefore, sets completed in surveys conducted from 1999 to 2006 were assigned to the new strata post-hoc in order to establish consistency with subsequent surveys that used the new depth stratification scheme (SCR 09/26). The survey biomass indices were recalculated in 2014 after removal of areas located in a fishery closure in Div. 0A (SCR 15/030).

Biomass in Div. 0A-South had varied with an increasing trend from 58,320 t (1999) to 135,837 t (2016) followed by a marked decline in 2017 (Fig. 4 and 7). The 2017 estimate of biomass was 58,812 t (S.E. 18,103). Abundance followed a similar pattern with 2017 estimated at 8.97 x 10^7. In 2016 biomass estimates across depths 801 m to 1200 m were the highest in the time series but in 2017 biomass at all depths had changed; 1201-1500 m depths had the highest or second highest biomass in the time series while all other depths were at the lowest or near lowest levels (Fig. 5). The overall length distribution in 2017 ranged from 12 cm to 90 cm with modes observed at 27 and 45 cm, up from 42 cm observed in 2015 and 2016 (Fig. 6).

The 2006 survey suffered from poor coverage in depths greater than 1200 m which resulted in a lower overall mean biomass per km^2 and under-estimate of the biomass compared to previous and subsequent surveys. As a result the 2006 survey has been removed from the indices and further assessment. In 2017 stations assigned to the most northern portion of the depth strata could not be completed due to ice conditions. These stations were randomly re-assigned to the southern portions of the depth strata and 74 of 77 planned stations were completed. All the depth strata had at least two sets so there was no adjustment made to the 2017 survey area.

Northern Div. 0A (73° N to 75° 35’ N) was surveyed in 2004, 2010 and 2012. The 2012 estimates of biomass and abundance were 82,669 t (S.E. 6695 t) and 9.4 x 10^7, respectively. This was a significant increase from previous estimates 45,877 t and 46,689 t. This increase is due to the increase in survey area due to good weather and little ice in the northern strata in (SCR 13/033).

2.4 Canadian Deep Sea Surveys in Div. 0B (Davis Strait)

A stratified-random otter trawl survey has been conducted in September-October in Div. 0B in 2000, 2001, 2011, and annually from 2013-2016. Biomass and abundance for Div. 0B in 2016 were 87,354 t and 7.4 x 10^7, respectively, similar to previous highs observed in 2011 (Fig. 7). Overall lengths in 2016 ranged from 6 cm to 99 cm with modes at 18 and 51 cm. Modal length has increased over the time series from a mode of 45 cm observed in 2001 (Fig. 8).

2.5 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 100 m to 600m. The survey area was re-stratified in 2004 based on better information about depths. All biomass and abundance indices have been re-calculated. The re-calculation did not change the trends in the development of the different stocks. The Skjervoy trawl was changed to a Cosmos trawl in 2005 and data from 1988 to 2004 have been converted so the time series are comparable.

Greenland halibut is widely distributed along NAFO 1A-F, but highest concentrations are found in nursery areas in Division 1A, 1B-North and Disko Bay. The abundance index 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.

The biomass and abundance indices increased gradually until 2005 (Fig. 9). The index declined from 2005 to 2014, with the exception of record high numbers of one-year old fish observed in 2011 and 2013. The abundance index has been increasing since 2014 with 2017 one of the highest in the time series.

Clear modes can be found in the length distribution at 12-15 cm and 23 cm (Fig. 10), corresponding to year-classes 1 and 2, allowing for the development of a recruitment index using the Petersen-method. The general trend in estimated biomass of age 1 Greenland halibut in the offshore and inshore (e.g. Disko Bay) areas combined was generally increasing from 1988 to 2003, followed by a decline to 2010 and since then the index has been variable with series high values observed in 2011, 2013 and 2017 (Fig. 11). The decrease in biomass from 2005 to 2010 was driven by the 1B index and the peak values were driven by the index in 1AN in 2011, 1AS and 1B in 2013 and 2017 (Fig. 12).

3. Commercial Fishery Data

3.1 Length Distribution

SA1

Length frequencies were available from the Greenlandic trawl fishery in Div. 1AB and from the Greenlandic, Norwegian and Russian trawl fishery in Div. 1CD. In Div. 1AB the modal length has varied from 50 to 52 cm in Greenlandic trawl fishery (Fig. 13) while the Russian trawl fishery has had slightly lower modes ranging from 45 to 50 cm in most years (Fig 14). 2015 saw a greater proportion of larger fish in the Russian fisheries compared to other years. Length frequencies in Greenland (Fig. 15), Norway (16) and Russian (Fig. 17) fisheries in Div. 1CD had modes between 47- 50 cm for most years prior to about 2014, since then the length frequencies have had a greater proportion of larger fish with modes between 50-55 cm.

SA 0

Length distributions were available from trawl and gill net fisheries in Div. 0A and 0B. During 2015-2017 modal lengths have varied between 46-50 cm in the trawl fishery in Div. 0A and in Div. 0B they have been stable at 50 cm. There tends to be a larger proportion of fish <50 cm in the Div. 0A trawl length frequency compared to Div. 0B (Fig. 18). Modes in the Div. 0A gillnet fishery have been stable at 58 cm during 2015-2017 while the modes for Div. 0B during 2015 and 2016 were 64 cm (no data available for 2017 (Fig. 18).

Age distribution

There has been uncertainty in the accuracy of age determination methods for Greenland halibut which were recently 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.

3.2 Catch rate-Standardization

Subarea 0 + Div. 1A (offshore) and Divs. 1B-F Trawl CPUE

A standardized catch rate is produced using a General Linear Model. The fleets used for standardization of catch rates are grouped using NAFO codes (Appendix 1).) We aggregated data by Year, Month, Gear and Country codeand catches (t) and hours fished with values less than 10 were removed. CPUE observations were log-transformed prior to the GLM analysis. Data were fit in R v. 3.4.4. (R Core Team, 2018) and least squares means were estimated with package “emmeans” (Lenth et al. 2018)

Catch rates 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 SA0+1A (offshore) and 1B-F combined has been increasing since 1997, and since 2015 has been greater than the previous high levels observed at the beginning of the time series (Fig 20) (Appendix 1).

The standardized CPUE for gillnets has been increasing since the series began in 2003 but since 2015 has been relatively stable (Fig. 21) (Appendix 2).

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 the catch rates;
3) Changes in fleets and fishing grounds have occurred in both SA0 and SA1.

4. **Assessment**

Age based analysis are not available for this stock due to the challenges concerning age determination for Greenland halibut. Several workshops held over the years to investigate the problems and examine methods. In 2015 agreement was reached on the comparability of methods and labs are now starting to address the back-log of ageing (ICES 2016). An age-length relationship for 2014 in 0A-South was presented for information (Fig. 19).

Several approaches have been attempted over the years but none have been accepted:

1) Yield per Recruit Analysis – 1994-1996 (SCR 96/67);
2) XSA – 1996, 1999, 2002 (SCR 02/68), 2003 (SCR 03/54);

3) ASPIC – 1999, 2009, 2012 (SCR 12/031);
4) Schaefer model – 2014 (SCR 14/027).

Assessment continues to be based on an index of biomass from surveys conducted in 1CD and 0A-South that use the same vessel and gear, allowing for the creation of a combined index for the Subarea 0 + 1A (offshore) and 1B-F stock (Fig. 22). The application of the ICES guidance on data limited stocks (DLS) method 3.2 (ICES 2012a and 2012b, ICES 2014) was adopted by SC in 2016 as the basis for advice on SA0+1A (Offshore) and 1B-F Greenland Halibut. This rule was developed and tested as an empirical approach that uses the trend in the stock response to fishing pressure (ICES 2012a, Jardim et al. 2015). The empirical basis was given a generic expression $C_{y+1}=Catch_{recent}*r$ where:

$Catch_{recent}$ is the average catch over some period,

r is the trend in development of the stock (normally SSB) over some period (e.g. 7 year time frame, r=mean of recent 3 year/mean of next 4 years).

5. Reference Points

B_{msy} is not known for this stock. However, SC has recommeded that a proxy for B_{lim} could be estimated based on a survey index that is used as the primary basis for advice. If the highest value of the index coincides with what is thought to be the unexploited state of the stock, then an 85% decline is considered to be an appropriate Blim. If, on the other hand, the highest value of the index is consistent with when the stock is thought to have been fully exploited, i.e. at Bmsy, then a 70% decline would be appropriate (Report of the NAFO Study Group on Limit Reference Points Lorient, France, 15-20 April, 2004 (SCS 04/12)).

In the case of Subarea 0+1A (offshore) and 1B-F, given the stability in the survey indices during the period 1997-2012 for Div. 1CD and 1999 to 2012 for Div. 0A-South, the stock was considered to be near B_{msy} and the survey indices a proxy for B_{msy}. In 2013 a B_{lim} of 30% of the survey means for Div. 1CD and 0A-South was established for Div. 1CD+0B and Div. 1AB +0A, respectively. In 2014 these two surveys were combined to create a single index for the stock and B_{lim} was recalculated for the period 1999-2012 (Fig. 22).

6. Conclusion

<u>SA 0+1</u>

Since 1995, catches have been near the TAC, increasing in step with increases in the TAC, reaching a high of 34,661 t in 2017.

The Div. 0A-South+Div. 1CD combined survey biomass index had been relatively stable from 1999 to 2014. Since 2014 the index has been more variable with a time series high in 2016 and a level near the series low in 2017, with all values remaining above B_{lim}.

A recruitment index has been developed using the Petersen method applied to the length frequency of Greenland halibut caught in the West Greenland Shrimp and Fish survey (1A-F, 100-600m). This index of age one Greenland halibut has been increasing since 2015 and 3 of the highest values in the time series were observed in 2011, 2013 and 2017.

A standardized CPUE index for all trawlers fishing in SA 0+1 has been increasing since 1997 and for gillnets in SA0 the index has been increasing since the beginning of the time series in 2003 but since

2015 has been relatively stable. However, CPUE is known to have limitations as an index of population status.

Biomass and abundance estimates for surveys in Div. 0A-South have been somewhat more variable than surveys in Div. 1CD. In 2016, the estimate was the highest in the time series but has been followed by one of the lowest estimates in 2017.

Based on LF from both the surveys and the commercial fisheries, fish in Divisions 0A and 1AB are relatively smaller in size than fish in Divisions 0B and 1CD.

Length frequencies in the Div. 0A-South survey are variable across years, sometimes with multiple modes (e.g. 27 cm and 45 cm in 2017). A trend to increased numbers of larger fish was observed from 1999 to 2004 and 2008 to 2014. Length frequencies for the Div. 1CD survey have a greater proportion of fish at larger sizes and the length distribution has been dominated by a mode at 51cm since 2006, an increase from a mode of 45 cm observed in 2000.

Length frequencies for trawl fisheries in Divisions 0A and 1AB had modal lengths that varied between 45 cm and 50 cm. Trawl fisheries in Div. 1CD had modes between 47 cm and 50 cm for most years prior to about 2014. Since then the length frequencies have had a greater proportion of larger fish, with modes varying between 50 cm and 55 cm. Trawl fisheries in 0B had modes of 50 cm during 2015-2017.

Modes in the Div. 0A gillnet fishery length frequencies have been stable at 58 cm during 2015-2017 while the mode for Div. 0B during 2015 and 2016 was 64 cm.

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Table 1. Greenland halibut catches (metric tons) by year and country for Subarea 0 (Split on Div. 0A and 0B) from 1987 to 2017. Minor (300 ton or less) catches from Div. 0A are included in some of the 0B catches prior to 2001. Based on STATLANT, with information from Canada and Greenland authorities used to exclude 1A and 0B inshore catch.

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

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

Table 2. Greenland halibut catches (metric tons) by year and country for Subarea 1 from 987 to 2016. The Greenland catches are <u>excl. inshore catches in Div. 1A</u>.

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

a Excluding 7603 t reported to STATLANT in error
b Catch reported to the Greenland Fisheries License Control Authority.
c Includes Spanish research fishery catch, 75 t in 2003 and 272 t in 2004.
d Excludes 1366 t reported for Div. 1A in error
e STATLANT 21A data for Div. ICD from Greenland includes double reporting.
f STATLANT unknown catches for Greenland were distributed based on information from Greenland Authorities or assumed to come from Div. 1A inshore.
g Norway STATLANT 21A reported catch in Div. 1A that was actually caught in 1D.

Table 3. By-catch (tons) as reported by at-sea observers in the Canadian Greenland halibut fishery, by gear and Div. Species selected based on reported catches > 1t. Corresponding catch of Greenland Halibut and bycatch relative to Greenland Halibut catch (%) is also given.

Species	**0A** **Trawl**	**Gillnet**	**0B** **Trawl**	**Gillnet**
Greenland shark (*S. microcephalus*)	82.689	0.066	31.887	0.327
Black Dogfish (*C. fabricii*)			1.738	3.466
Skates sp.			0.18	1.347
Spinytail skate (*R. spinicauda*)	2.262	0.501	3.195	
Arctic skate (*A. hyperborea*)	6.311	7.497		0.028
Thorny skate (*A. radiata*)	5.537	2.467	1.666	
Roughhead grenadier (*M. berglax*)	2.335	7.993	10.393	28.25
Roundnose grenadier (*C. rupestris*)			2.885	
Blue Hake (*A. rostrata*)			2.004	
Spiny Eel (*N. chemnitzi*)			2.206	
Redfish (Sebastes)	1.232	8.361	3.583	10.863
Northern wolffish (*A. denticulatus*)	5.693	2.222	32.437	6.907
Striped wolfish (*A. lupus*)	0.032	0.019	0.732	
Spotted wolffish (*A. Minor*)	1.202	0.035	0.471	0.323
Spiny crab (*N. grimaldii*)				3.926
Jelly fish (Scyphozoas)			1.22	
Sponge (Porifera)	1.829	0.685	1.686	1.536
TOTAL	109.122	29.846	96.283	56.973
Greenland halibut (*R. hippoglossoides*)	5184.161	2356.119	3982.669	583.106
% of Greenland Halibut catch	2.1	1.3	2.4	9.8

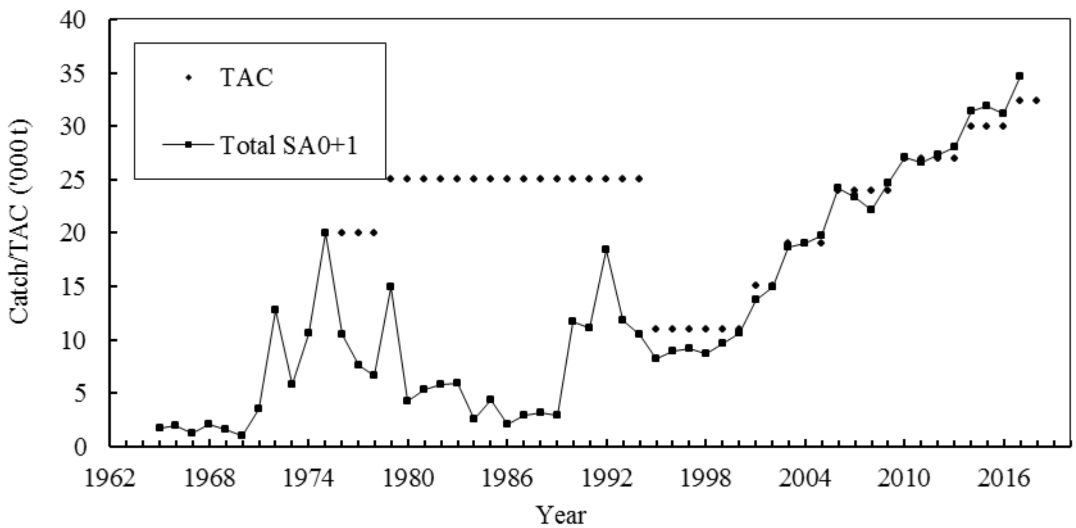


Fig. 1. Catches in SA0 and Div. 1A offshore + Div. 1B-1F and recommended TAC. For TAC before 1995 see text.

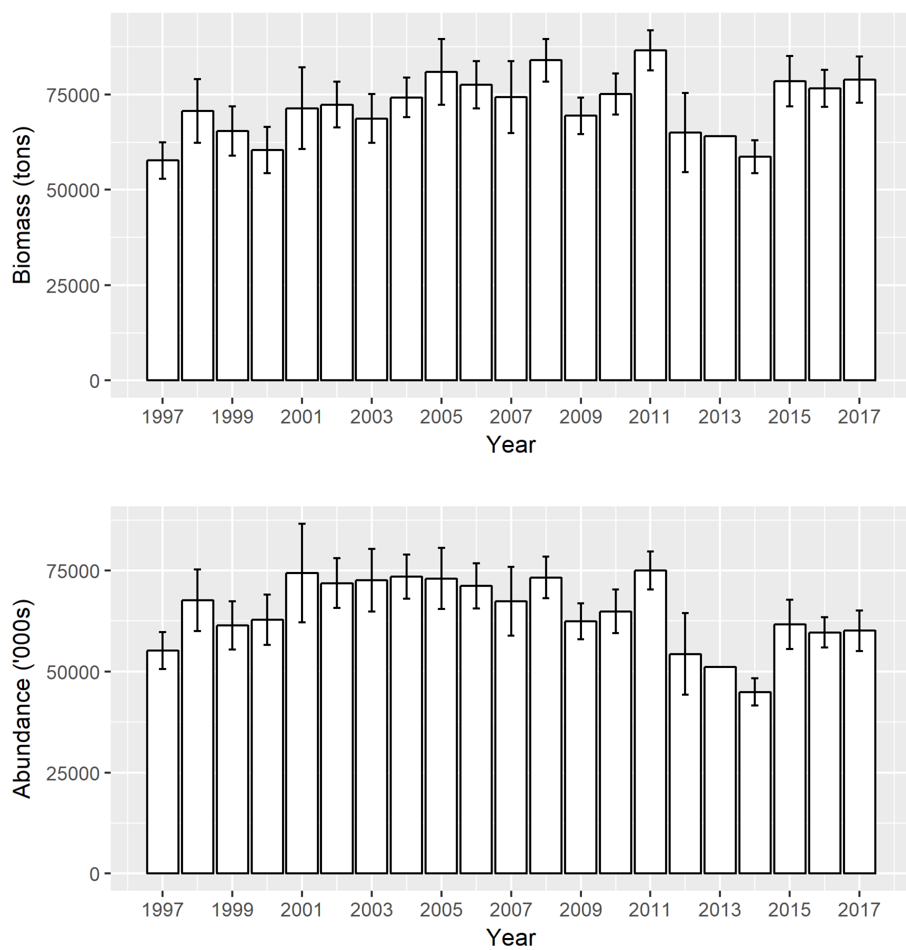
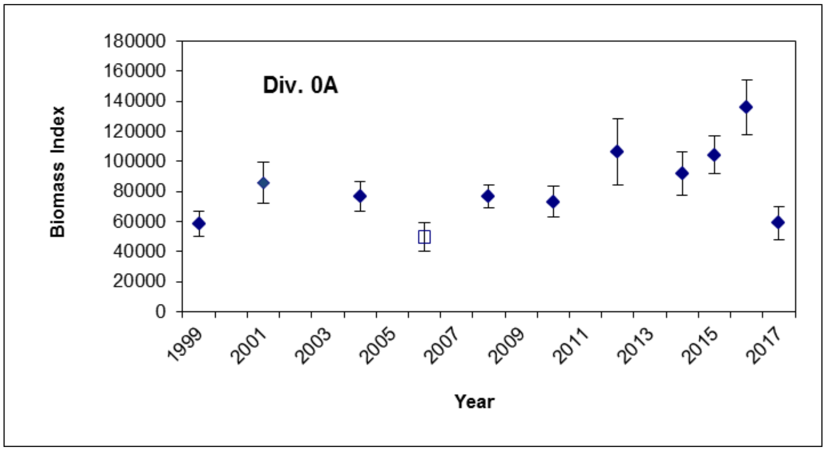


Fig. 2. Biomass (top) and abundance (bottom), with S.E., from the Greenland deep sea survey in 1CD, for the period 1997 to 2017.

Fig. 3. Length distribution of Greenland halibut (numbers weighted by stratum area) for the Div. 1CD survey for 1997-2017.



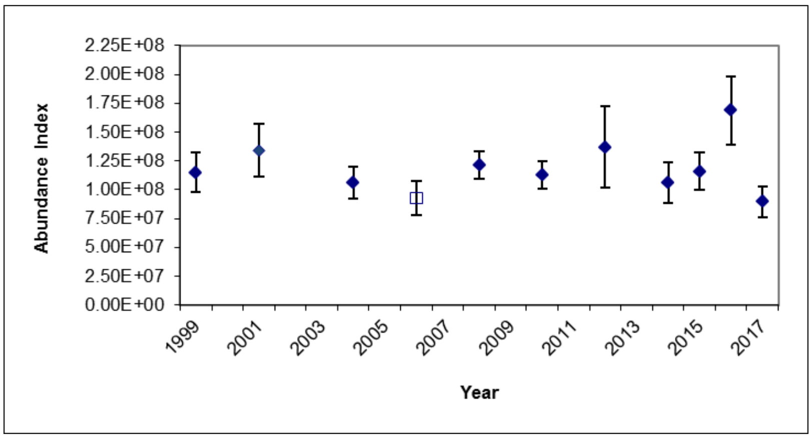


Fig. 4. Biomass (top) and abundance (bottom), with S.E., for Greenland halibut in Div. 0A-South, for years 1999, 2001, 2004, 2006, 2010 and 2014-2017. The 2006 survey was affected by incomplete coverage.

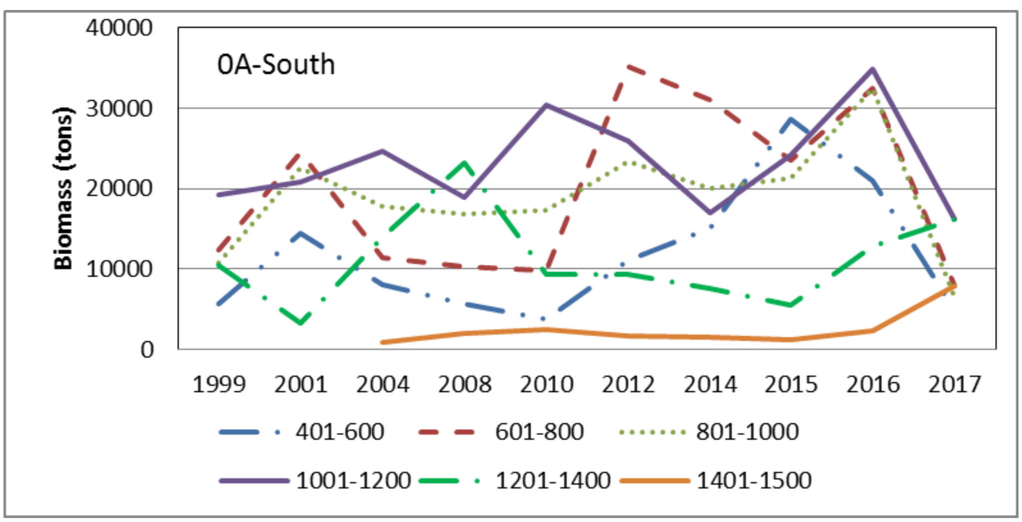


Fig. 5. Biomass trends by depth strata for Division 0A-South.

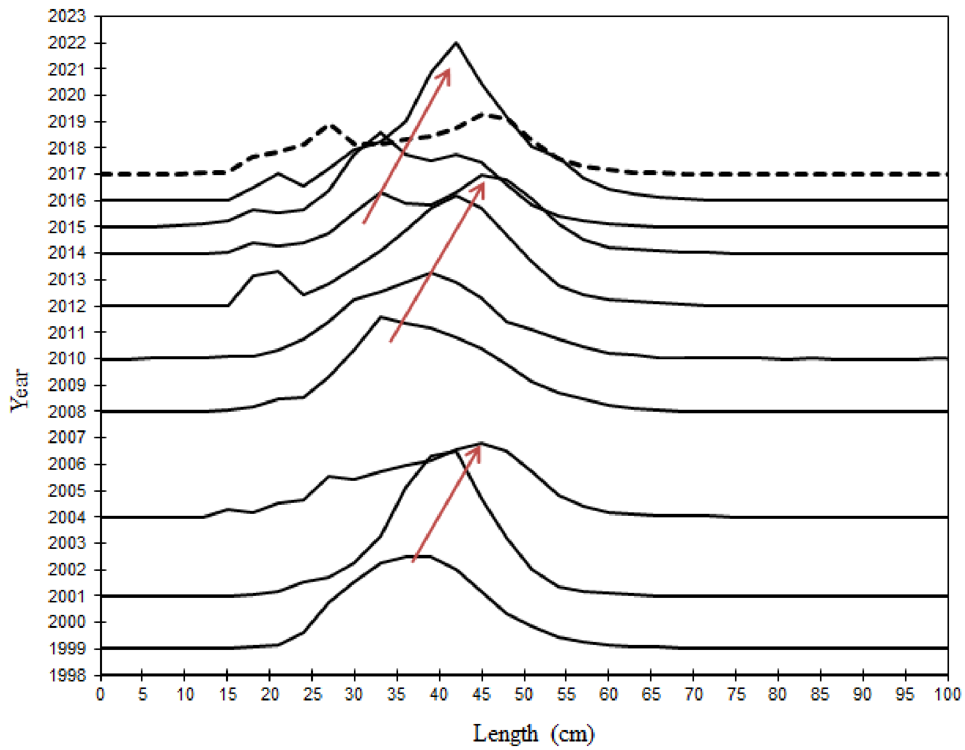


Fig. 6. Abundance at length for the Greenland halibut in NAFO Division 0A-South, 1999 to 2017 (weighted by stratum area).

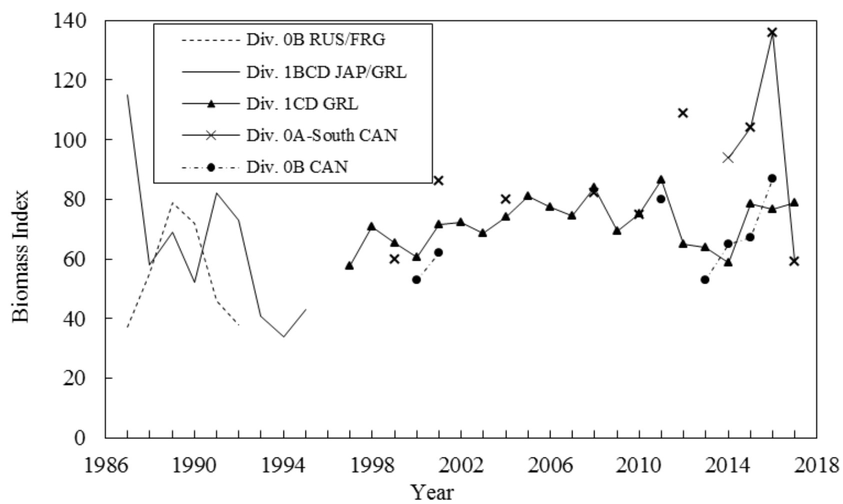


Fig. 7. Biomass estimates from various surveys in SA 0 and 1. Japon/Greenland survey (1986 to 1995) in 1BCD, Greenland survey (1997-2017) in 1CD, Russian survey in 0B (years XXX) Canadian survey (years XXX) in 0B, Canadian survey (years XXX) in 0A .

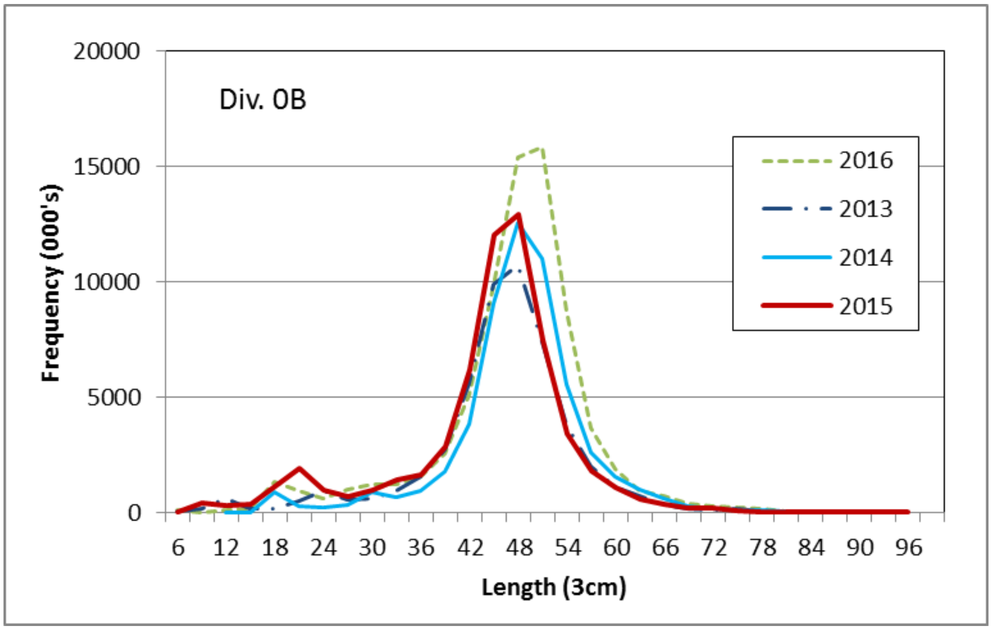


Fig. 8. Div. 0B survey overall length distribution.

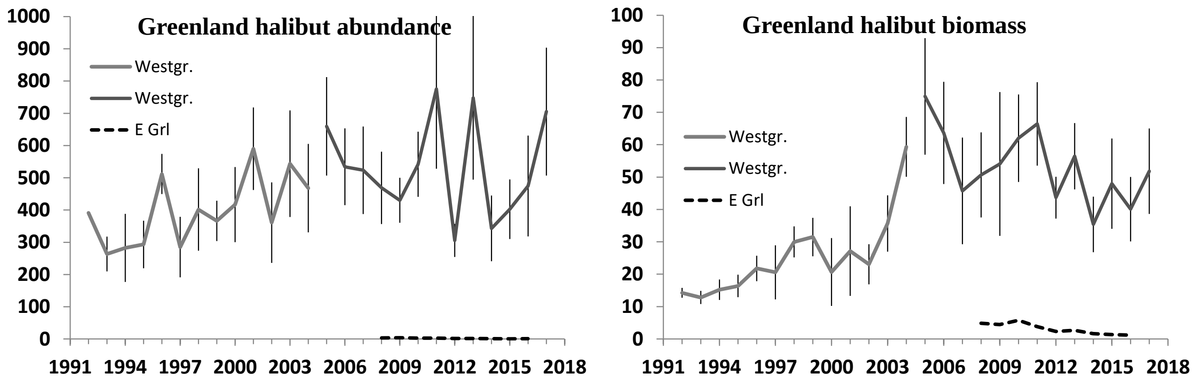


Fig. 9. Greenland halibut abundance (million) and biomass (Kt) in Divisions 1A-F, from the West Greenland Shrimp and Fish Survey, 100 m to 600 m, for the period 1991-2018.

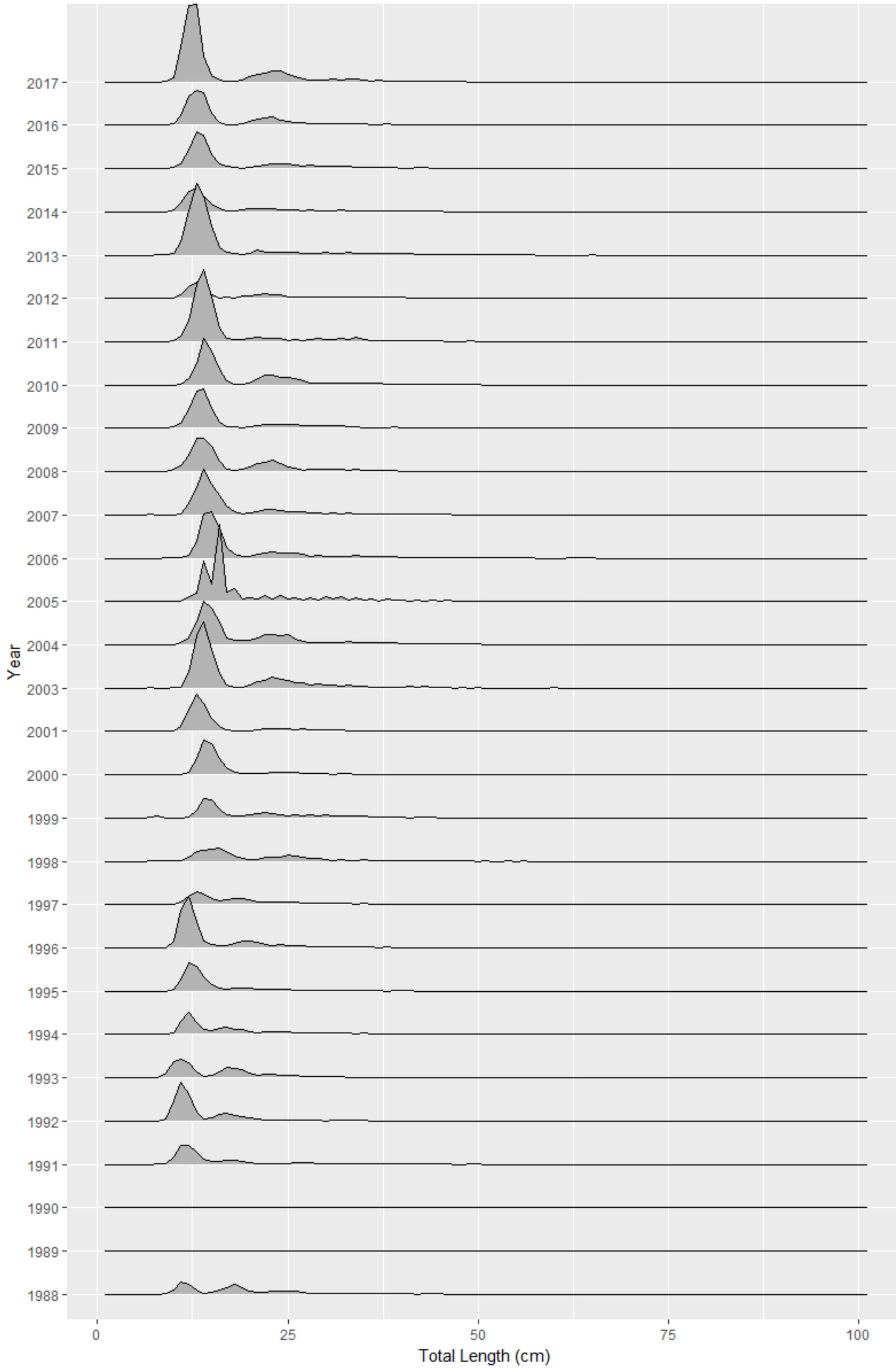


Fig. 10. Length frequency for Greenland halibut caught in the offshore area of the Greenland Shrimp and Fish Survey (100 m to 600 m), 1988 to 2017.

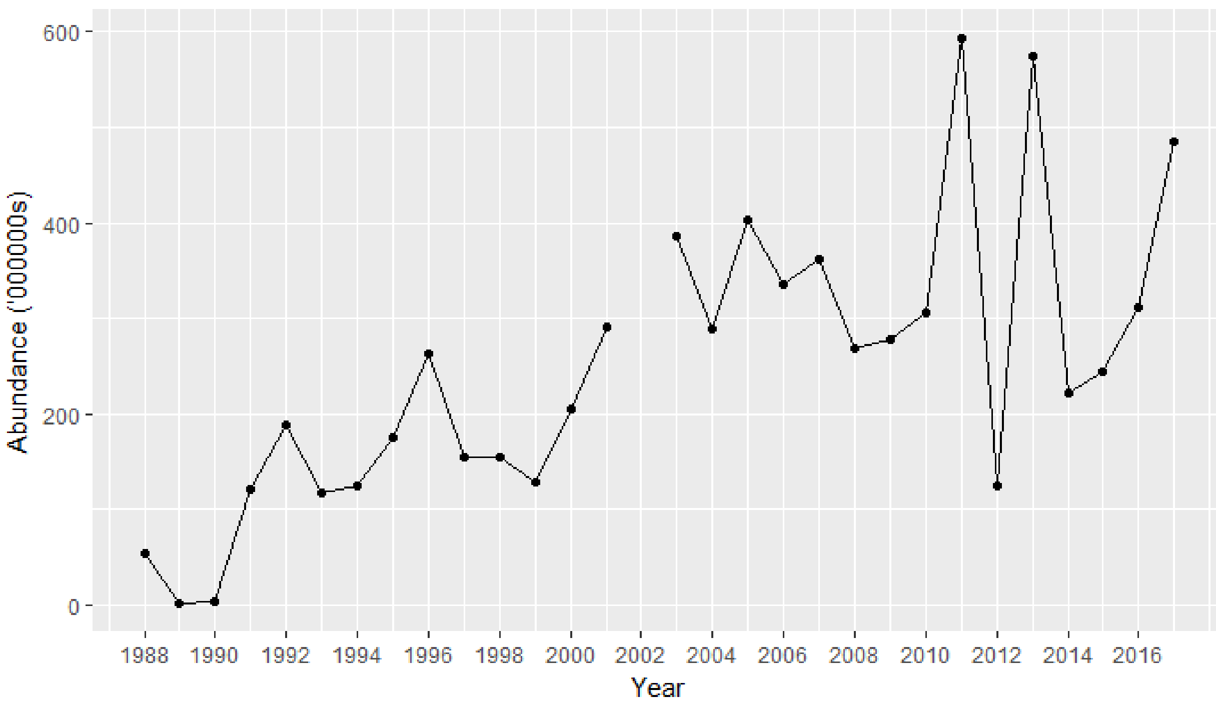


Fig. 11. Abundance of age 1 Greenland halibut in the entire area covered by the Greenland Fish and Shrimp Survey including inshore Disko Bay and Div. 1AN (North of 70°37.5′N) adjusted for change in survey gear in 2005. Data for 2002 is available but not in a format that could be incorporated into the plot for this assessment.

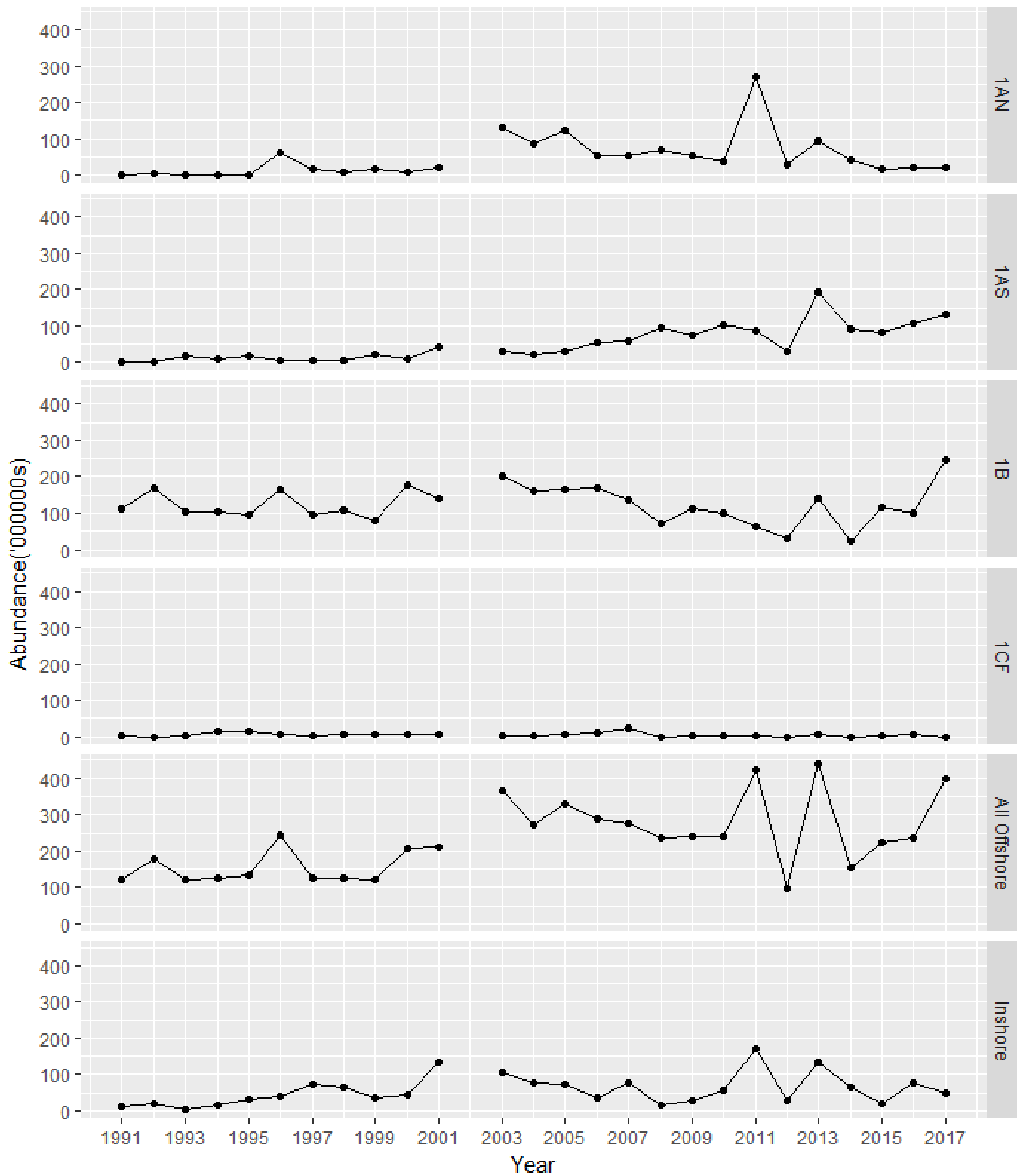


Fig 12. Number of one-year old Greenland halibut by division and year, from the Greenland Shrimp and Fish Survey, 1991 to 2017.

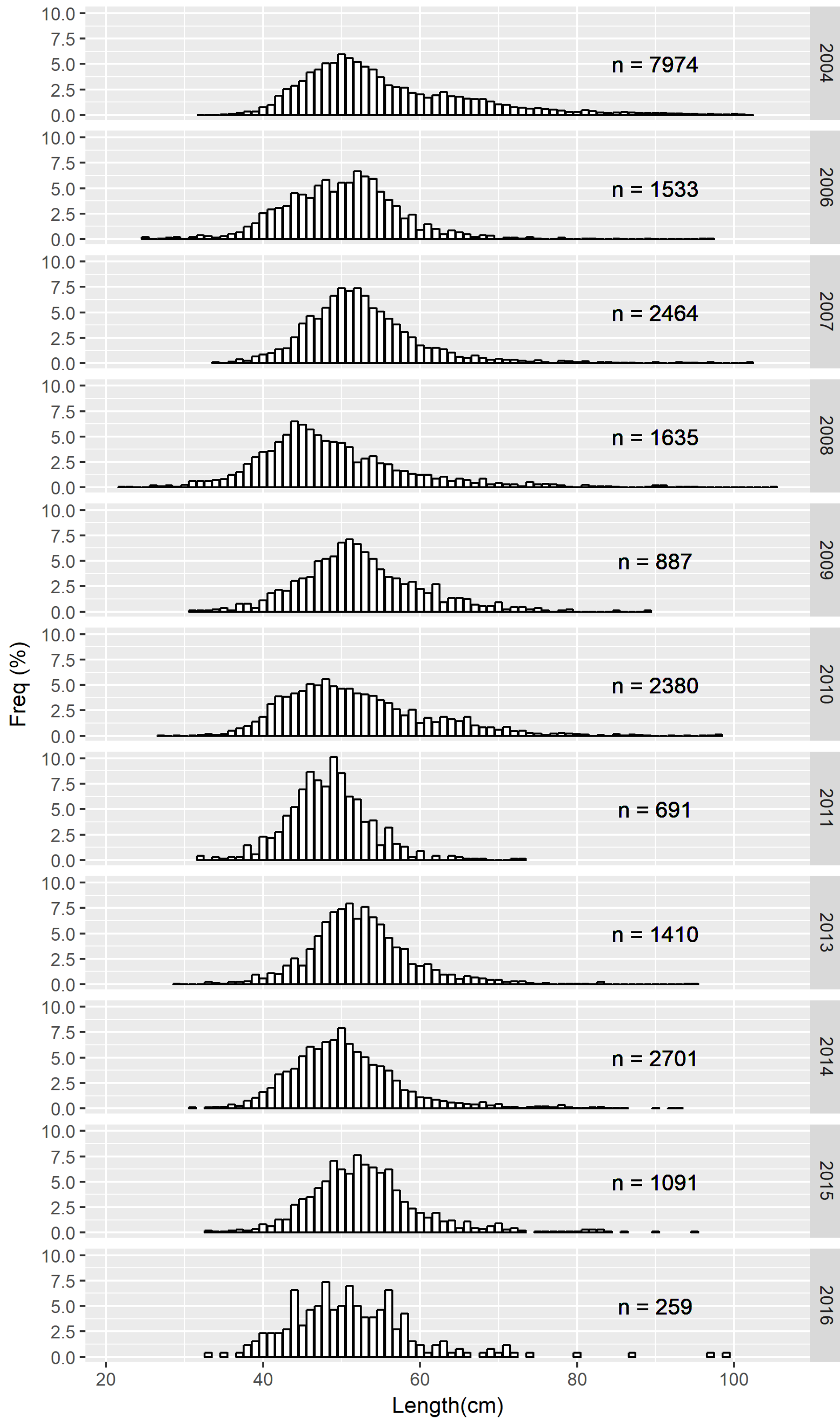


Fig. 13. Greenland Div. 1AB trawl fishery length frequency.

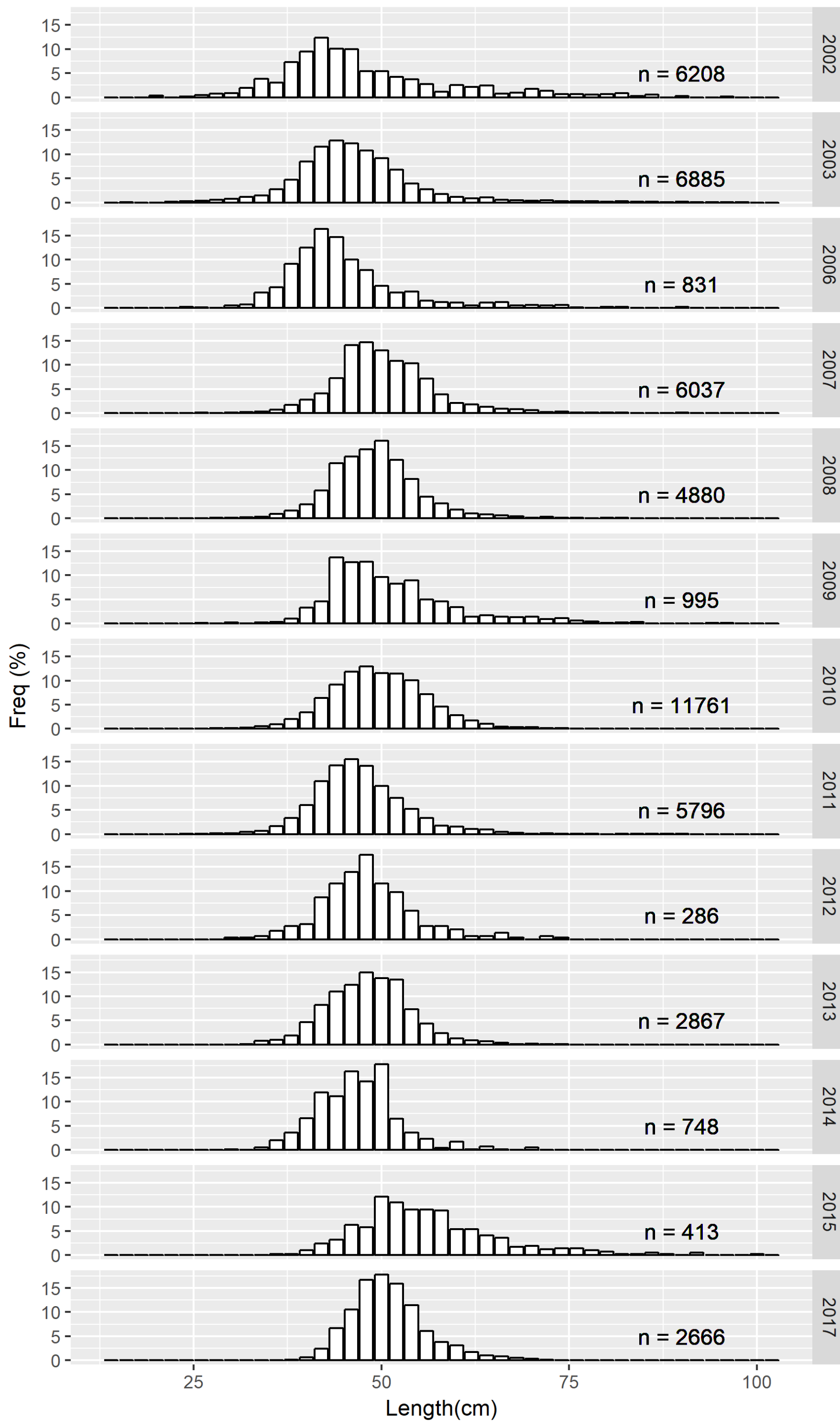


Fig. 14. Russian Div. 1AB trawl fishery length frequency.

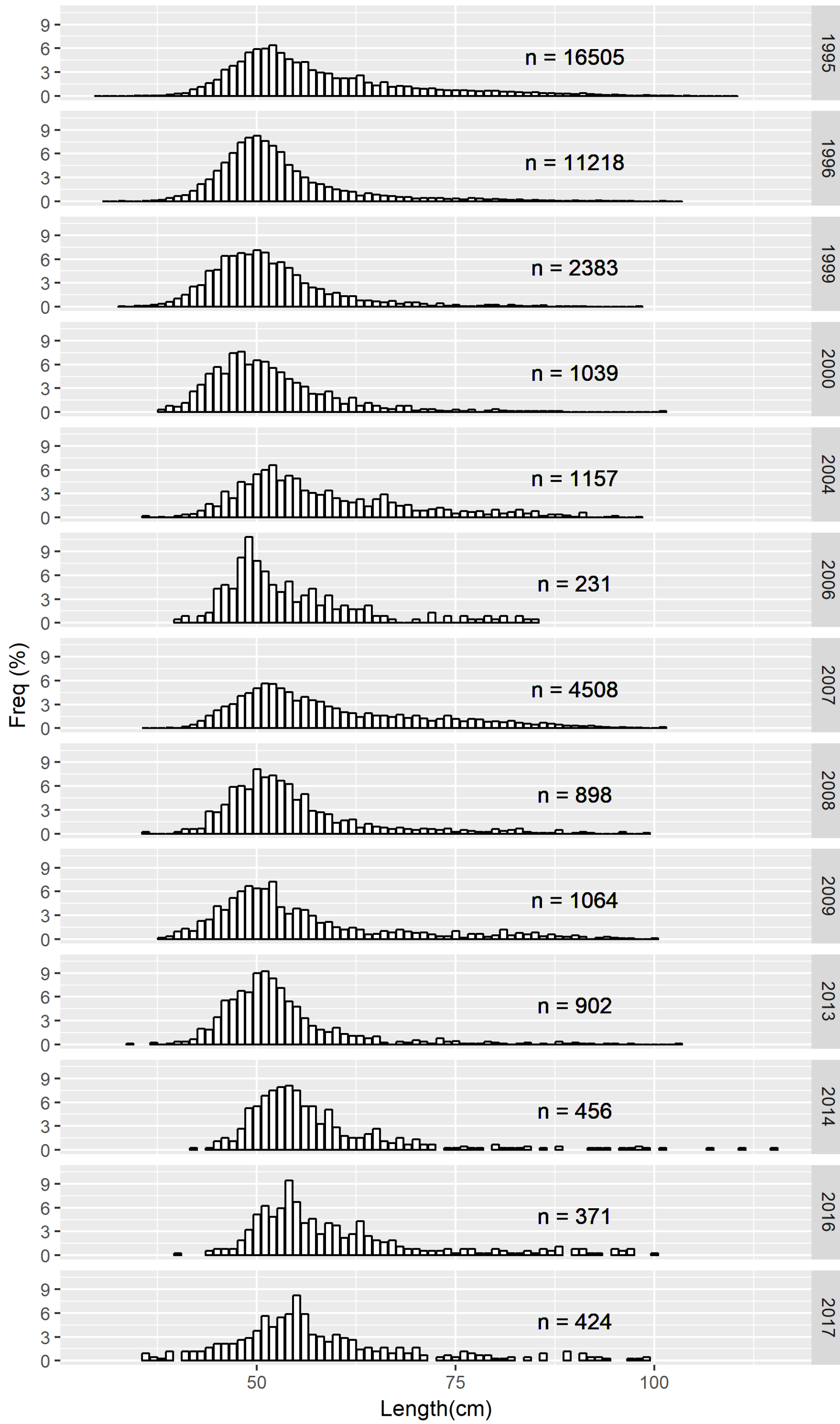


Fig. 15. Greenland Div. 1CD trawl fishery length frequency.

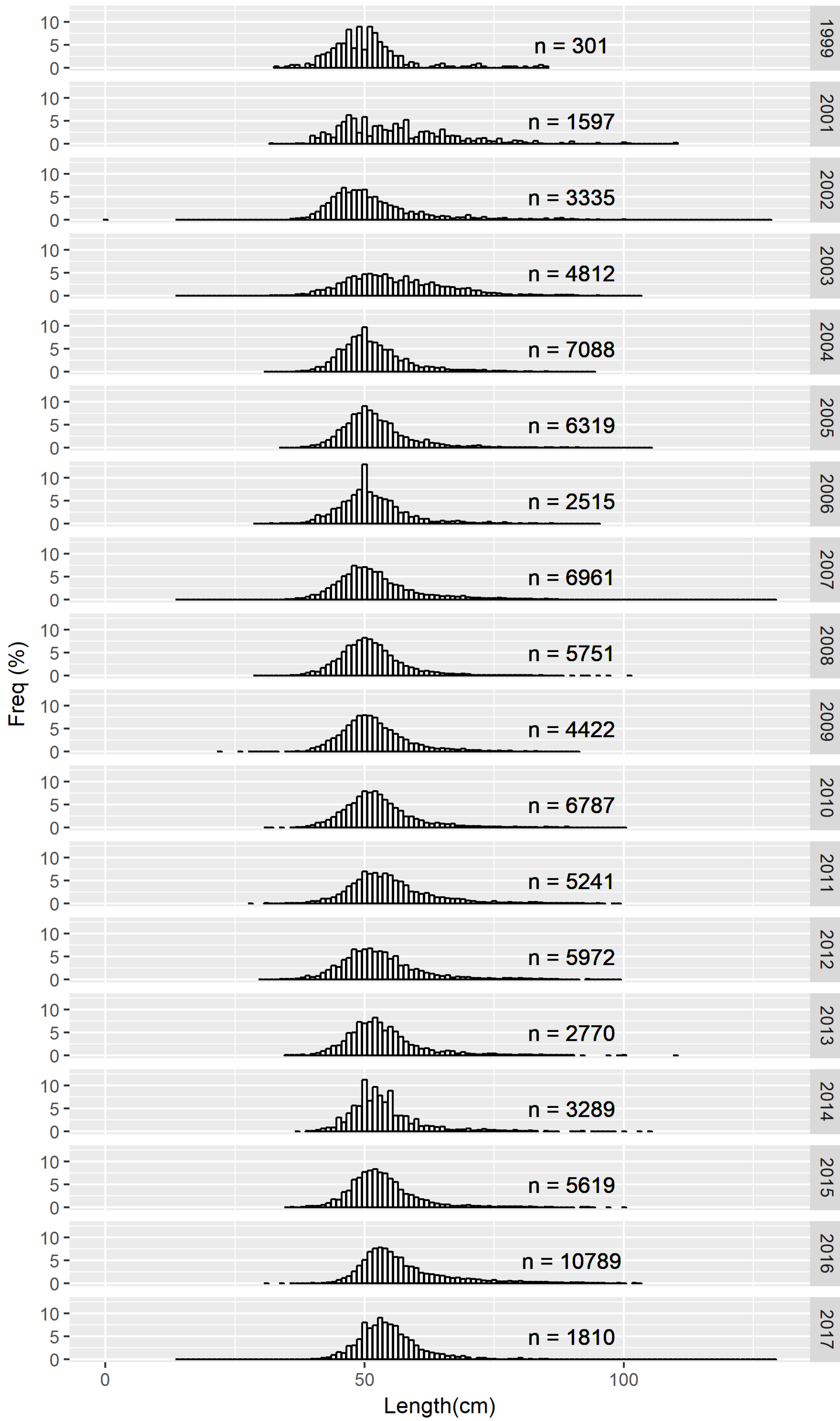


Fig. 16. Norway Div. 1CD trawl fishery length frequency.

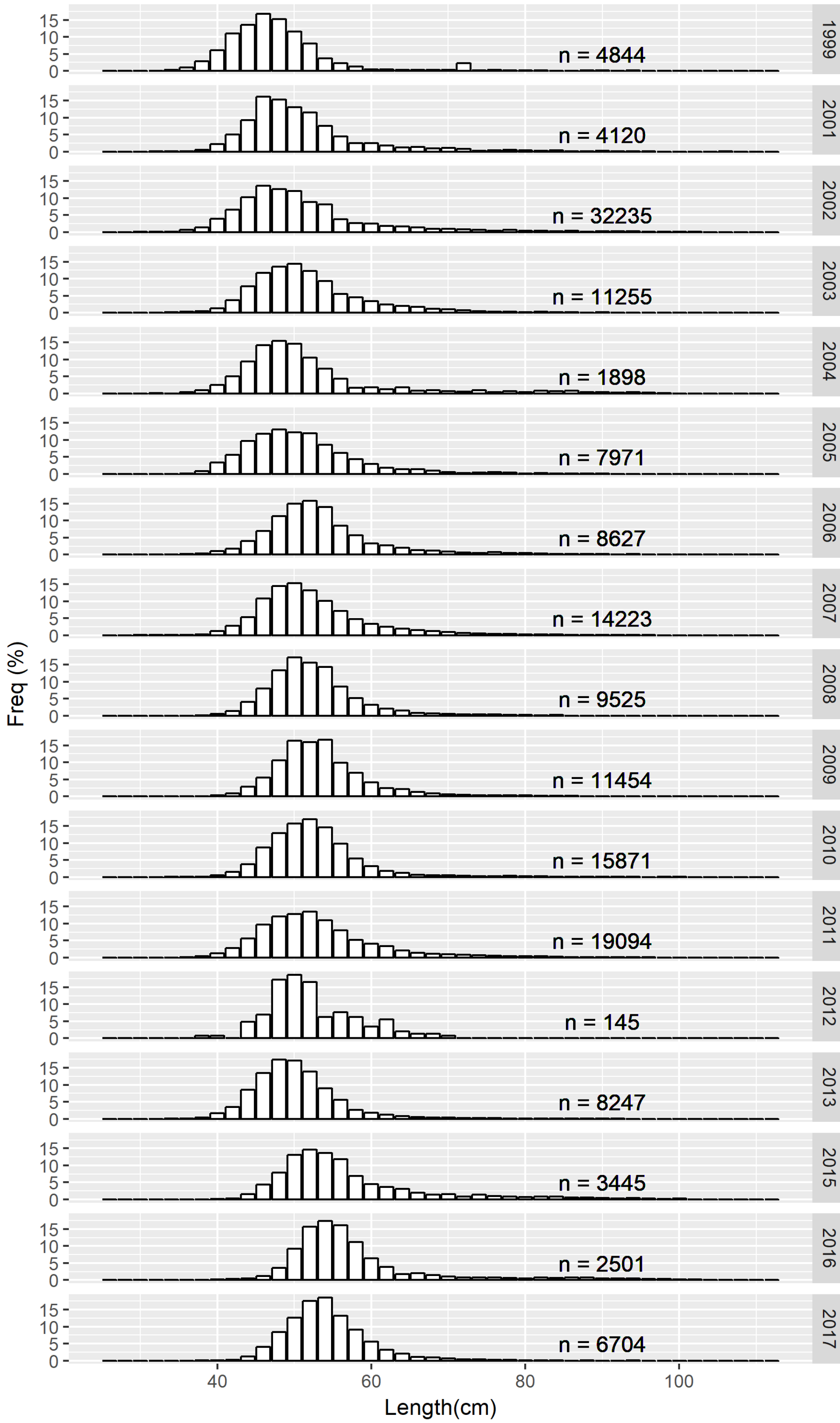


Fig. 17. Russian Div. 1CD trawl fishery length frequency.

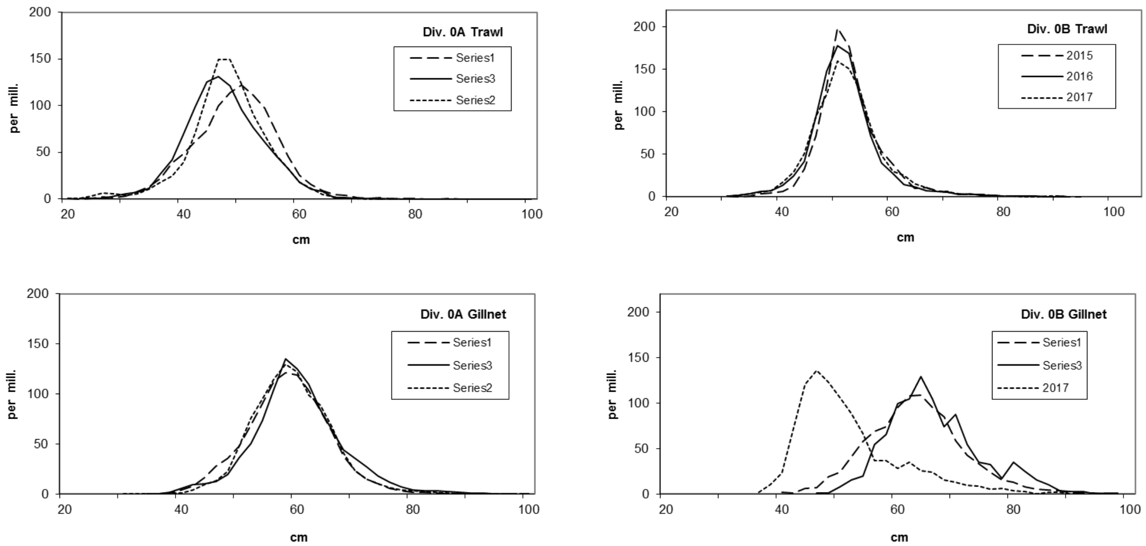


Fig. 18. Length distribution from the fishery in Subarea 0 in 2015-2017 in per mill., 2 cm groups.

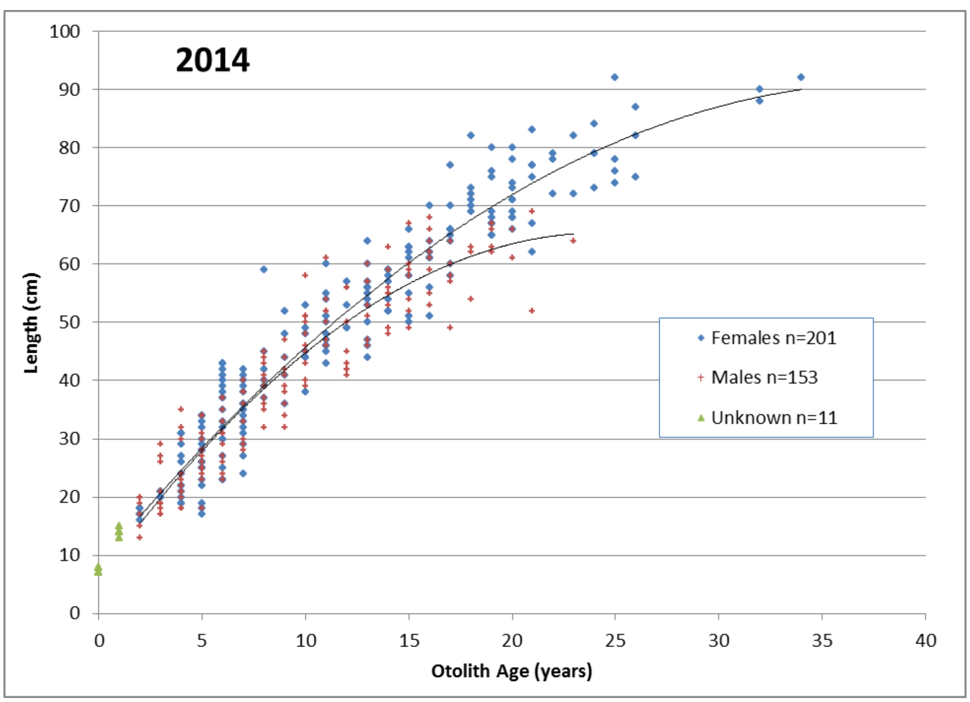


Fig. 19. Representation of expected growth relationship for Greenland halibut in Div. 0A-South.

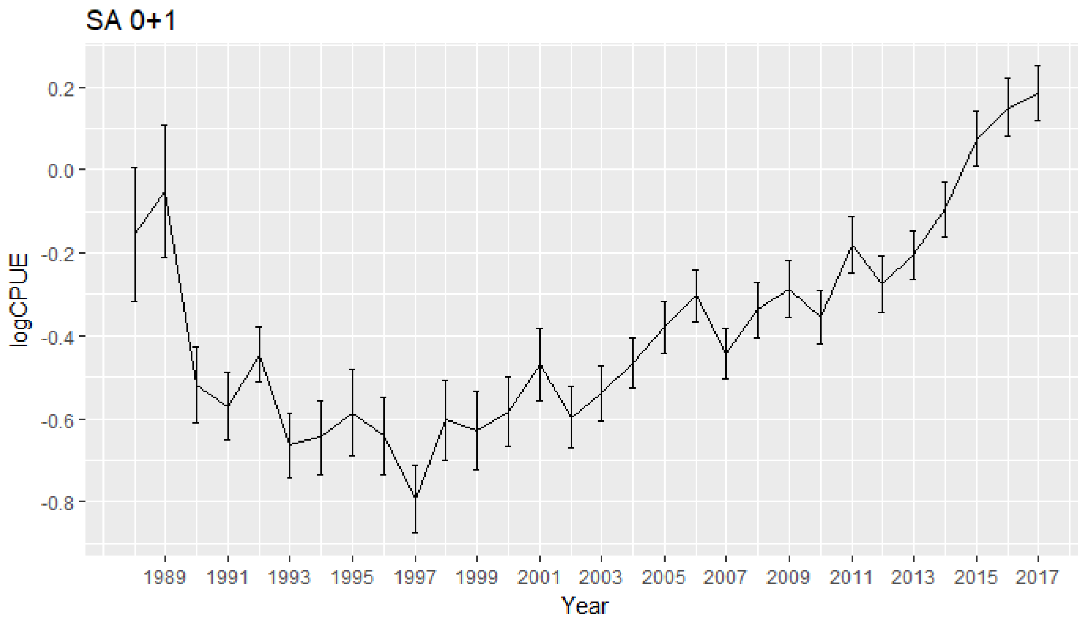


Fig. 20. Combined standardized trawl CPUE index from trawlers in SA 0+1, with S.E., for 1989 to 2017.

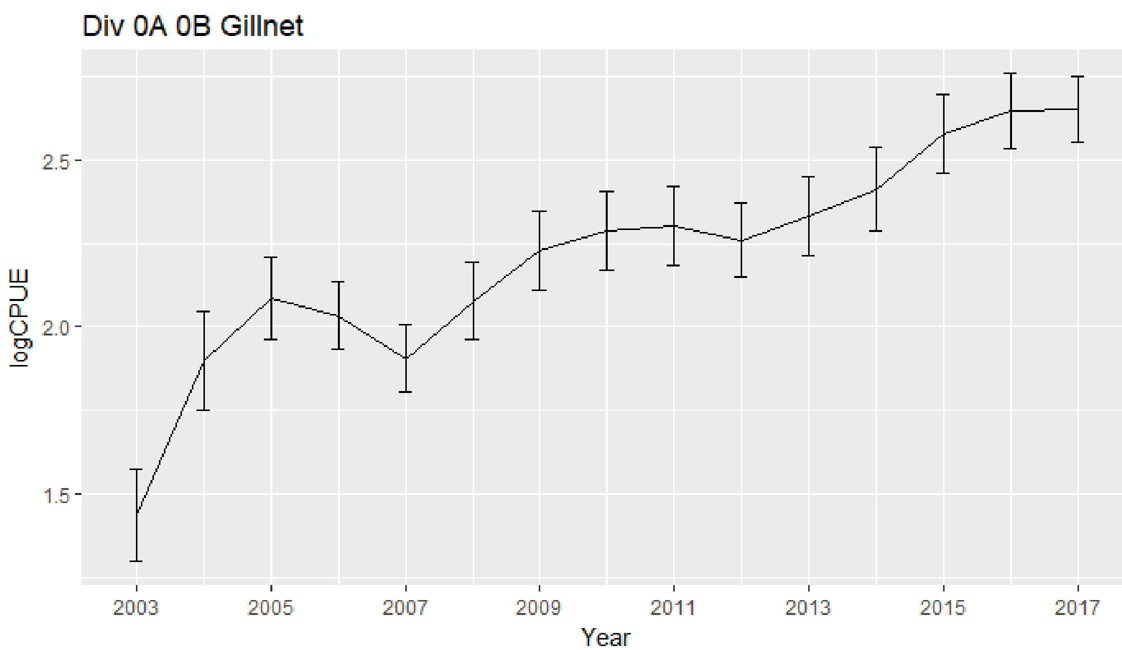


Fig. 21. Combined standardized trawl CPUE index from gillnets in SA 0, with S.E, for 2003-2017.

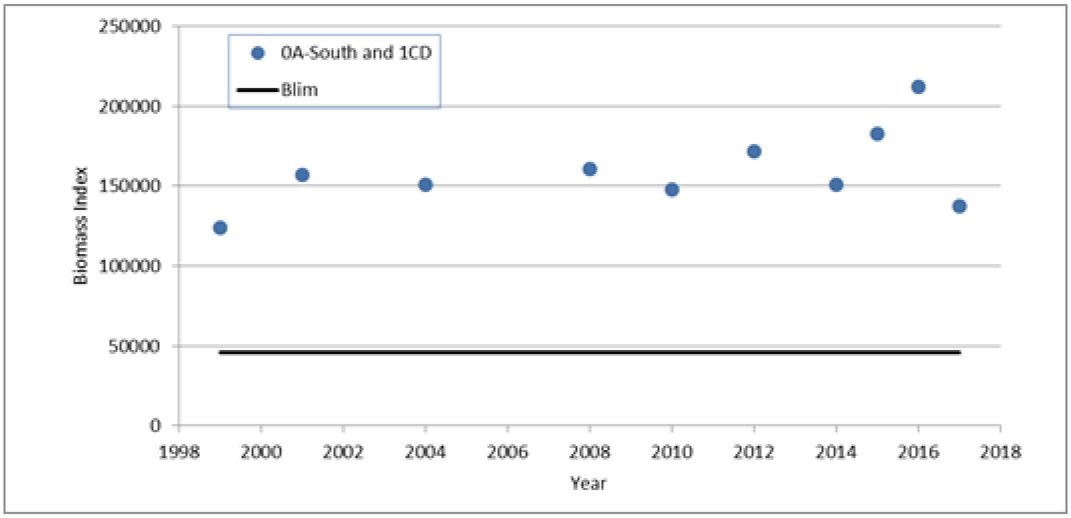


Fig. 22. Combined survey index for Div. 0A-South+Div. 1CD and the series B_{lim} (30% of the mean biomass from 1999 to 2012.

Appendix 1. NAFO codes used in the CPUE standardization.

Code for country

2	CAN-MQ	Canada Maritimes & Quebec
3	CAN-N	Canada Newfoundland
5	FRO	Faroe Islands
6	GRL	Denmark Greenland
7	E/DNK	Denmark Mainland
8	E/FRA-M	France Mainland
9	FRA-SP	France St. Pierre et Miquelon
10	E/DEU	Federal Republic of Germany
14	JPN	Japan
15	NOR	Norway
16	E/POL	Poland
18	ROM	Romania
19	E/ESP	Spain
20	SUN	Union Soviet Socialist Republics
27	CAN-M	Canada Maritimes
28	CAN-Q	Canada Quebec
31	E/LVA	Latvia
32	E/EST	Estonia
33	E/LTU	Lithuania
34	RUS	Russia
38	EU	European Union
39	CAN	Canada
40	CAN-CA	Canada Central & Arctic

Code for Trawl Gear

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

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

Example is 401927: where 40=Canada Central & Arctic, 192= Otter twin trawl, 7=Over 2000 Gross Tonnage

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

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

Min	1Q	Median	3Q	Max
-1.2731	-0.1873	0.0120	0.1861	2.0662

Coefficients:

	Estimate	Std. Error	t value	Pr(>|t|)	
(Intercept)	-0.13829	0.18303	-0.756	0.450133	
Year1989	0.10280	0.21762	0.472	0.636771	
Year1990	-0.36219	0.18434	-1.965	0.049785	*
Year1991	-0.41446	0.17957	-2.308	0.021244	*
Year1992	-0.28929	0.17130	-1.689	0.091649	.
Year1993	-0.50831	0.17545	-2.897	0.003866	**
Year1994	-0.48921	0.18125	-2.699	0.007098	**
Year1995	-0.42918	0.18658	-2.300	0.021683	*
Year1996	-0.48576	0.17966	-2.704	0.007000	**
Year1997	-0.63928	0.17583	-3.636	0.000295	***
Year1998	-0.44781	0.18286	-2.449	0.014536	*
Year1999	-0.47217	0.17976	-2.627	0.008784	**
Year2000	-0.42728	0.17490	-2.443	0.014779	*
Year2001	-0.31307	0.17754	-1.763	0.078215	.
Year2002	-0.44039	0.16997	-2.591	0.009740	**
Year2003	-0.38174	0.16753	-2.279	0.022945	*
Year2004	-0.30958	0.16572	-1.868	0.062110	.
Year2005	-0.22337	0.16625	-1.344	0.179449	
Year2006	-0.14718	0.16703	-0.881	0.378510	
Year2007	-0.28712	0.16725	-1.717	0.086410	.
Year2008	-0.18113	0.16758	-1.081	0.280066	
Year2009	-0.13180	0.16888	-0.780	0.435359	
Year2010	-0.19879	0.16699	-1.190	0.234231	
Year2011	-0.02605	0.16834	-0.155	0.877063	
Year2012	-0.11974	0.16813	-0.712	0.476552	
Year2013	-0.04881	0.16585	-0.294	0.768604	
Year2014	0.06108	0.16747	0.365	0.715401	
Year2015	0.23049	0.16774	1.374	0.169781	
Year2016	0.30645	0.16834	1.820	0.069053	.
Year2017	0.34053	0.16697	2.039	0.041725	*
Month2	-0.34705	0.11917	-2.912	0.003688	**
Month3	-0.36851	0.21197	-1.739	0.082497	.
Month4	0.10748	0.12162	0.884	0.377099	
Month5	0.34248	0.08688	3.942	8.77e-05	***
Month6	-0.14315	0.08033	-1.782	0.075114	.
Month7	-0.18950	0.07593	-2.496	0.012765	*
Month8	-0.07008	0.07241	-0.968	0.333470	
Month9	0.03398	0.07101	0.479	0.632388	
Month10	0.02671	0.07092	0.377	0.706556	
Month11	-0.02757	0.07122	-0.387	0.698809	

```
Month12      0.12115    0.07511   1.613 0.107144
Boat2127     0.15794    0.07179   2.200 0.028088 *
Boat3125    -0.82618    0.12993  -6.359 3.39e-10 ***
Boat5126     0.30276    0.17766   1.704 0.088742 .
Boat5127     0.30878    0.10477   2.947 0.003297 **
Boat6125    -0.54282    0.09546  -5.686 1.81e-08 ***
Boat6126    -0.20072    0.07151  -2.807 0.005125 **
Boat6127     0.21578    0.07222   2.988 0.002895 **
Boat14124   -0.27038    0.11308  -2.391 0.017026 *
Boat15126    0.47407    0.15529   3.053 0.002340 **
Boat15127    0.41051    0.15047   2.728 0.006505 **
Boat20126   -0.56773    0.10677  -5.317 1.36e-07 ***
Boat20127   -0.48811    0.12294  -3.970 7.81e-05 ***
Boat21926    0.58040    0.10126   5.732 1.40e-08 ***
Boat21927    0.43939    0.07409   5.930 4.47e-09 ***
Boat61926    0.11664    0.10227   1.141 0.254370
Boat61927    0.31833    0.07718   4.125 4.09e-05 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.3423 on 814 degrees of freedom
Multiple R-squared:  0.6391,    Adjusted R-squared:  0.6143
F-statistic: 25.74 on 56 and 814 DF,  p-value: < 2.2e-16
```

Appendix 3. Standardized CPUE index for gillnets in SA 0.

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

Residuals:
    Min       1Q   Median       3Q      Max
-1.34550 -0.13710  0.00804  0.14549  1.56010

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)  1.63491    0.36518   4.477 1.48e-05 ***
Year2004     0.46424    0.16538   2.807 0.005656 **
Year2005     0.65064    0.15279   4.258 3.59e-05 ***
Year2006     0.59758    0.14517   4.116 6.29e-05 ***
Year2007     0.47049    0.13768   3.417 0.000812 ***
Year2008     0.64181    0.14227   4.511 1.28e-05 ***
Year2009     0.79165    0.14495   5.462 1.88e-07 ***
Year2010     0.85140    0.14495   5.874 2.59e-08 ***
Year2011     0.86896    0.14495   5.995 1.42e-08 ***
Year2012     0.82305    0.14077   5.847 2.96e-08 ***
Year2013     0.89444    0.14495   6.171 5.89e-09 ***
Year2014     0.97649    0.15034   6.495 1.12e-09 ***
Year2015     1.14409    0.14495   7.893 5.42e-13 ***
```

```
Year2016     1.20913    0.14317   8.446 2.25e-14 ***
Year2017     1.21689    0.14372   8.467 1.99e-14 ***
Month5      -0.04796    0.31617  -0.152 0.879638
Month6      -0.37457    0.31579  -1.186 0.237420
Month7      -0.54350    0.31531  -1.724 0.086796 .
Month8      -0.11964    0.31410  -0.381 0.703802
Month9      -0.10910    0.31416  -0.347 0.728855
Month10     -0.06671    0.31632  -0.211 0.833262
Month11     -0.20729    0.31857  -0.651 0.516234
Month12     -0.36482    0.43637  -0.836 0.404447
Boat3414    -0.38098    0.13366  -2.850 0.004973 **
Boat3415     0.13953    0.16580   0.842 0.401340
Boat40413    0.30054    0.25167   1.194 0.234276
Boat40414   -0.03741    0.13719  -0.273 0.785459
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.2966 on 152 degrees of freedom
Multiple R-squared:  0.6849,	Adjusted R-squared:  0.631
  F-statistic: 12.71 on 26 and 152 DF,  p-value: < 2.2e-16
```