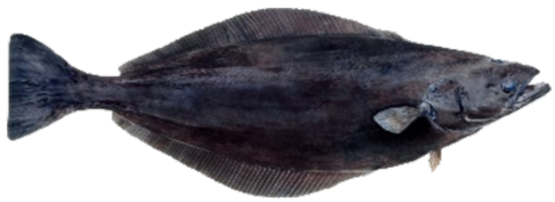
Fisheries and Oceans Canada
Pêches et Océans Canada

Ecosystems and Oceans Science
Sciences des écosystèmes et des océans

Quebec Region

Canadian Science Advisory Secretariat
Science Advisory Report 2021/017

ASSESSMENT OF THE GULF OF ST. LAWRENCE (4RST) GREENLAND HALIBUT STOCK IN 2020



Greenland Halibut (Reinhardtius hippoglossoides)

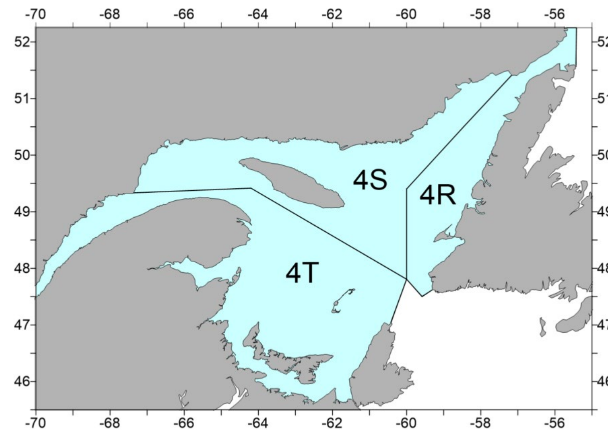


Figure 1. Map of the Gulf of St. Lawrence Greenland halibut Stock Management Area, showing Northwest Atlantic Fisheries Organization (NAFO) Divisions 4RST.

Context:

Greenland halibut (Reinhardtius hippoglossoides) of the Gulf of St. Lawrence (Figure 1) has been considered a separate stock from the Atlantic population since 1993. It is assessed and managed on a two-year cycle. An update of the stock status is produced during the interim years.

Until the mid-1970s, Greenland halibut (commonly called turbot) from the Gulf of St. Lawrence (4RST) were not subjected to any directed fishery. It was in the late 1970s that a directed gillnet and bottom trawl fishery developed. Since 1993, directed fishing has been prohibited for mobile gear. It is currently authorized for the inshore fixed gear fleets of Quebec and the west coast of Newfoundland.

In the current situation, the Total Allowable Catch (TAC) cannot be caught since mobile gear fleets do not have access to the directed Greenland halibut fishery. Part of the TAC allocated to them is transferred to the fixed gear fleet, while the rest is no longer fished. In this document, the terminology "fishing allocation" is used to indicate the portion of the TAC that can be caught by fixed gear fleets.

The fishery is subject to several management measures, including a fishing season, characteristics of fishing gears and control of catches by a TAC to limit exploitation of the stock.

The indicators used for the assessment of the stock status are taken from fishery statistical data, sampling of commercial catches and scientific research surveys.

The present science advisory report results from the regional advisory meeting on the Assessment of the Gulf of St. Lawrence (4RST) Greenland halibut, held February 23th and 24st, 2021 in Mont-Joli, Quebec. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

SUMMARY

- The total allowable catch (TAC) for the Gulf of St. Lawrence Greenland halibut stock was gradually reduced by 50% between the 2017-2018 and 2020-2021 fishing seasons to stand at 2,250 t. Preliminary landings for 2020-2021 totaled 1,330 t.
- For the Western Gulf and Esquiman sectors, fishing effort and landings decreased from 2019 to 2020 and reached some of the lowest values in each of the series. The situation was different for the North Anticosti sector which, after being abandoned from 2015 to 2017, experienced a resumption of activities. Between 2019 and 2020, the effort remained fairly stable while landings increased.
- From 2019 to 2020, the commercial fishery performance indices were stable for the Western Gulf and Esquiman sectors and increased in the North Anticosti sector. The indices of the three sectors are below the average of their respective series.
- The composition of landings changed markedly between 2018 and 2019. The average fish size decreased by 2.5 cm to 45.6 cm (average of 47.0 cm). The proportion of fish smaller than the minimum size of 44 cm increased to 30% (average of 17%). In 2018 and 2019 landings were made up of nearly 85% females (average of 80%). Data for 2020 were partial due to the health measures related to the pandemic.
- According to scientific surveys by DFO and mobile sentinel program, the abundance and biomass indices of Greenland halibut generally showed a downward trajectory from the end of the 2000s to 2019. These indices increased slightly between 2019 and 2020 to levels well below the peaks of the 2000s. This increase is caused by the arrival of the strong 2018 cohort. This cohort is showing a normal growth rate and should start recruiting to the fishery in 2024.
- The cohorts expected to recruit to the fishery in 2021 and 2022 are of average to low abundance.
- At the Gulf level, the exploitation rate indicator decreased from 2019 to 2020 and remained close to the series average.
- The Gulf of St. Lawrence is undergoing major changes: deep waters are warming and becoming depleted of oxygen. These changes can lead to habitat degradation, decreased growth, increased natural mortality and can negatively affect the productivity of Greenland halibut. In addition, changes in the structure of the community (high abundance of redfish and low abundance of shrimp) can modify the interactions of competition for food resources or for habitat. Current environmental conditions and climate projections suggest that the situation is likely to worsen.
- According to the precautionary approach under development, the stock status indicator was on a downtrend with a decline of over 60% between 2008 and 2017, moving from the healthy zone to the cautious zone. The indicator stabilized from 2017 to 2020 and is midway between the limit reference point and the upper stock reference point. Under these conditions, a reduction in catches below recent levels could reduce the exploitation rate and help increase the stock. However, the unfavorable environmental conditions for Greenland halibut that prevail in the Gulf of St. Lawrence could be determining factors in the trajectory of the stock's abundance.

INTRODUCTION

Overview of oceanographic conditions and the ecosystem

The ecosystem of the Gulf of St. Lawrence (GSL, NAFO Divisions 4RST) has undergone significant changes in recent decades. Deep waters have been warming and dissolved oxygen levels have decreased. In 2020, the waters above 150 m warmed up further and new records were observed at 200, 250 and 300 m for a series that began in 1915. The water temperature at 300 m reached 6.77 °C over the entire Gulf, nearly 1.5 °C more than in 2009. For the first time, a zone of deep water with a temperature of 7 to 8 °C was observed in the northeast of the Gulf. Since 1930, the dissolved oxygen (DO) level has decreased by more than 50% in the GSL channels. The lowest levels are recorded in the lower estuary, site of the main nursery for Greenland halibut.

From 1990 to 2020, information provided by the DFO research survey conducted in the northern Gulf of St. Lawrence (nGSL), indicates that Greenland halibut occupy comparable depths annually, despite the increase in temperature and the decrease in DO levels (Figure 2). Across the Gulf, the median temperature at which the majority of Greenland halibut are found increased from 5.2 to 6.1 °C between 2010 and 2020 and the DO saturation level of the waters decreased from 32 to 20%. It is in the Lower Estuary that the biomass of Greenland halibut is found in waters where the DO level is lowest at 16% saturation in 2020 (Figure 2).

Scientific works have shown that increasing deep water temperature and oxygen depletion could lead to loss of habitat quality for Greenland halibut. In addition, observed ecosystem changes are also responsible for the decrease in growth rate and increased mortality in this species. The GSL deep water temperature is forecast to remain elevated for the next several years and DO levels may decline further.

In the 1980s, the nGSL ecosystem was dominated by groundfish. In the early 1990s, this ecosystem experienced a collapse of major groundfish stocks including Atlantic cod (*Gadus morhua*) and redfish (*Sebastes* spp.). This decrease in these top predators, coupled with suitable environmental conditions, has favored an increase in forage species, including different shrimp species. Greenland halibut biomass increased at the same time as northern shrimp (*Pandalus borealis*) while the abundance of large groundfish declined. For the past ten years or so, we have observed a simultaneous decrease in the various species of shrimp and Greenland halibut, while the biomass of redfish is increasing.

In 2020, the combined biomass of the two redfish species (*Sebastes mentella and S. fasciatus*) represents 81% of the biomass of all organisms caught in the DFO research survey conducted in the nGSL, while it averaged 15% between 1995 and 2012. Since these are long-lived species, redfish will share the GSL ecosystem with Greenland halibut for many years. This abundance of redfish could have significant repercussions on Greenland halibut, through interactions of competition for food resources or habitat. Redfish and Greenland halibut present common prey in their diet, including northern shrimp, pink glass shrimp (*Pasiphaea multidentata*) and redfish.

Overall, the signals observed in the GSL indicate that this ecosystem is changing. Current conditions, which are unfavorable for Greenland halibut, will not change and may deteriorate further.

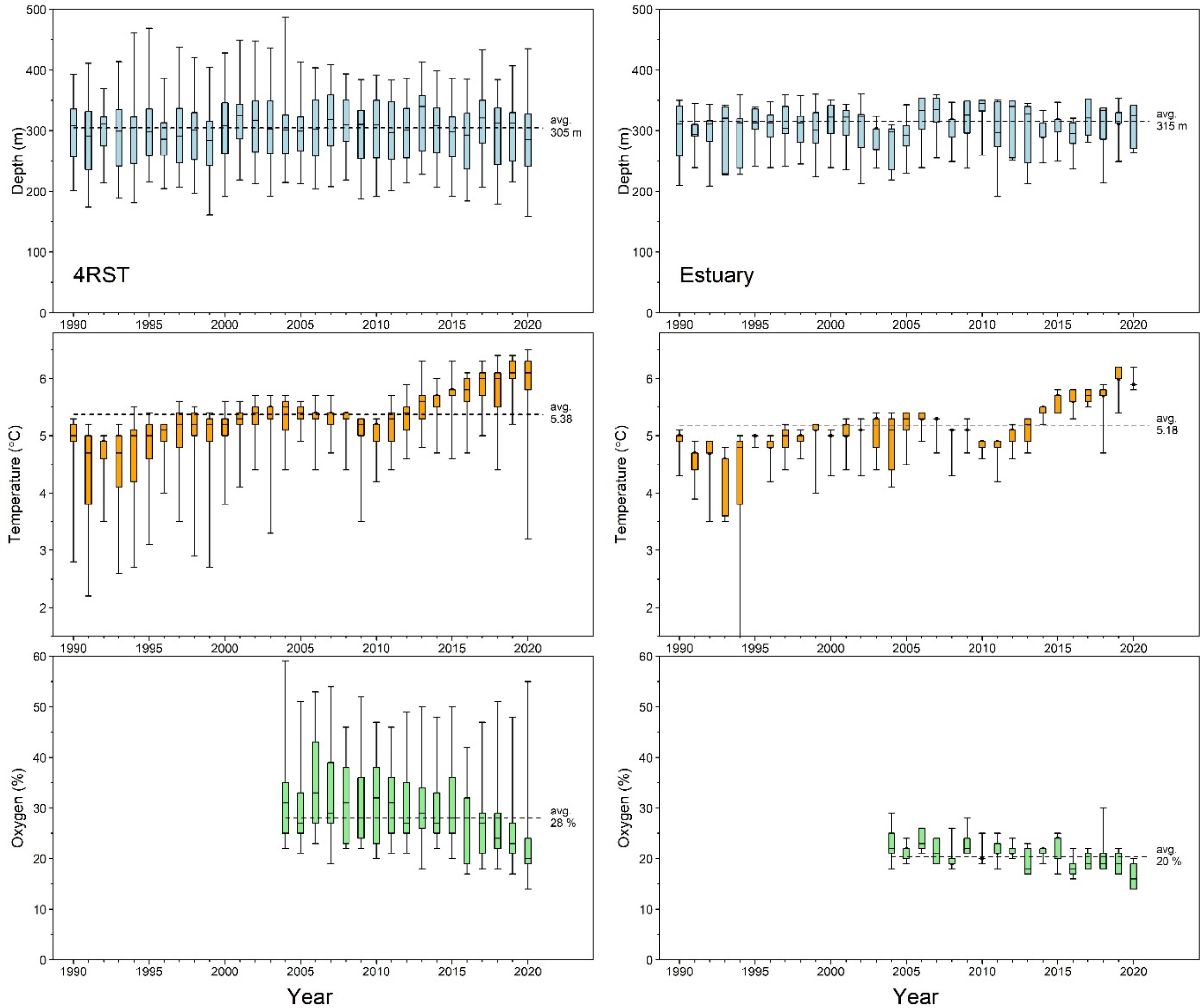


Figure 2. Distributions of Greenland halibut biomass as a function of depth, temperature and oxygen saturation level for the entire Gulf (4RST) and the Lower Estuary during the DFO nGSL survey. Box and whisker plot: the line inside the box represents the median, the box extends from percentiles 25 to 75, and the whiskers (vertical lines on either side of the box) extend from percentiles 5 to 95. The dotted horizontal line on each of the graphs represents the series average.

Biology

Greenland halibut occupies more than 85,000 km^2 in the nGSL and 95% of its biomass is concentrated in less than 50,000 km^2. It is mainly found in channels at depths varying from 200 to 400 m (Figure 3). This is one of the Atlantic populations living in the warmest waters. Juveniles are predominant in the Lower Estuary and north of Anticosti Island and are generally found at shallower depths than adults. In August, an average of 22% of the Greenland halibut abundance is found in the Lower Estuary.

Spawning occurs in winter between January and March, in the depths of the Laurentian Channel southwest of Newfoundland. Greenland halibut is characterized by low fecundity, it produces large eggs (3,4 – 4,7 mm in diameter) and spawns only once a year. The eggs, released and fertilized near the bottom, spend about 30 days in the water column before hatching within 50 m of the surface. Larval development occurs in this surface layer and could last up to four months. Subsequently, the larva settle on the bottom at metamorphosis.

In this species, males reach sexual maturity at smaller sizes than females. There is dimorphism and females reach larger sizes. Finally, Greenland halibut is a vigorous swimmer, it makes large daily vertical migrations and spend nearly 25% of its time in the water column.

The Greenland halibut diet varies depending on its size. Individuals smaller than 20 cm have a mixed diet consisting of zooplankton (hyperid amphipods and euphausids) and small fish. As Greenland halibut grow, their diet begins to comprise mainly fish and shrimp. The dominant fish species in the diet is capelin (*Mallotus villosus*). In recent years (2015-2020), redfish have become more important in the diet of Greenland halibut larger than 30 cm. Individuals larger than 40 cm consume mainly shrimp, herring (*Clupea harengus*), small demersal fish, redfish and capelin. The main predators of Greenland halibut are seals (Harp seal (*Phoca groenlandica*), Hooded seal (*Cystophora cristata*), Grey seal (*Halichoerus grypus*)) and Atlantic halibut (*Hippoglossus hippoglossus*).

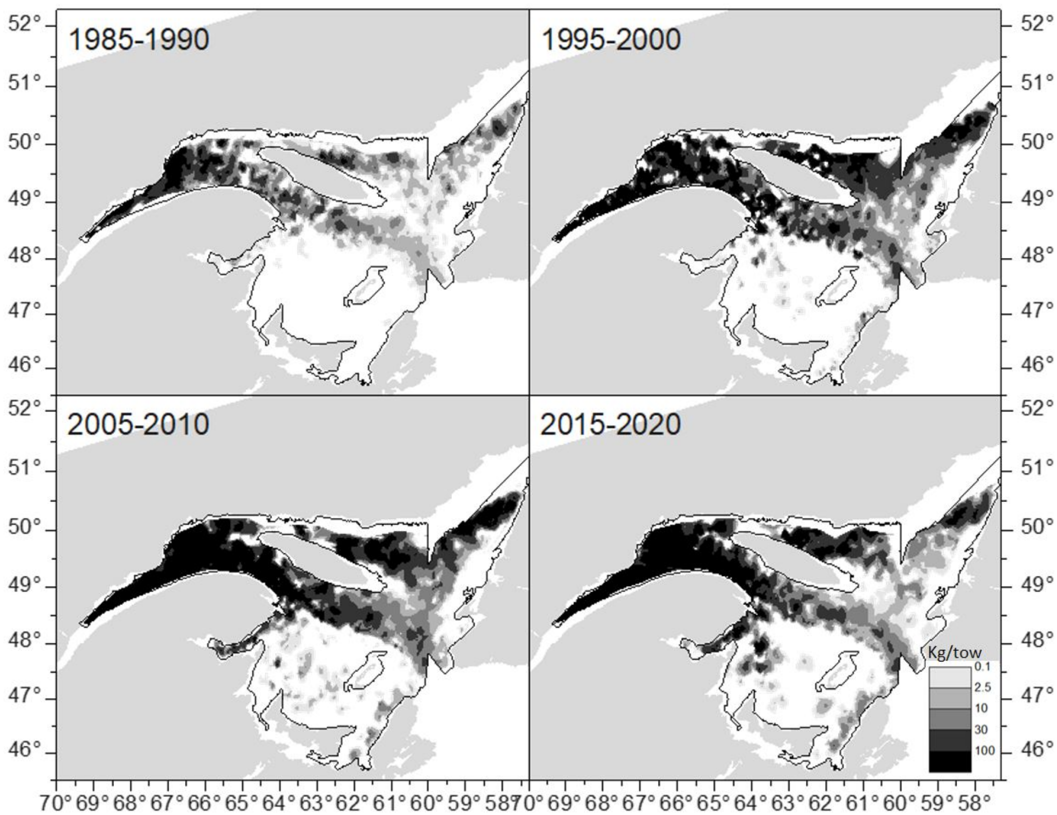


Figure 3. Distribution of catch rates (kg / tow) of Greenland halibut in the combined DFO nGSL and sGSL series.

The fishery

Until the mid-1970s, landings of Greenland halibut in the GSL were primarily bycatch from trawlers targeting shrimp and groundfish (Figure 4). The directed gillnet fishery for Greenland Halibut developed from 1977. A first TAC of 7,500 t was established in 1982. From 1982 to 1992, GSL Greenland Halibut was managed as a component of the Atlantic stock. The highest landings exceeded 8,000 t in 1979 and 1987. These high landings were followed by steep declines. In the early 1990s, studies of parasite species composition separated Greenland halibut populations and demonstrated that the GSL population represented a distinct stock. A TAC of 4,000 t was put in place for this stock in 1993.

The TAC remained fixed at 4,500 t with a fishing allocation of 3,751 t between the management years 2004-2005 and 2017-2018 (Figure 4, Table 1). The fishing allocation was completely fished annually until the 2011-2012 fishing season. For the 2017-2018 fishing season, greatest difference between the fishing allocation and the landings was observed. Since then, the TAC has been gradually reduced by 50% and was 2,250 t with a fishing allocation of 1,875 t for the 2020-2021 fishing season. As of December 12, 2020, landings totaled 1,326 t or 71% of the fishing allocation. The fishing allocation is divided between the Quebec (82%) and the Newfoundland (18%) fleets. The Quebec and Newfoundland fixed gear fleets have so far landed respectively 66% and 96% of their fishing allocation. These landings data are preliminary, but should not increase significantly with the continuation of fishing by the Quebec fleets next spring.

The number of active fishers in the directed Greenland halibut fishery decreased by almost 35 % between the 2014-2016 and 2017-2020 seasons, from an average of 154 to 101 fishers. The decrease is similar for the Quebec and Newfoundland fleets. Several factors, including participation in more lucrative fisheries and management measures in place, could explain this decrease.

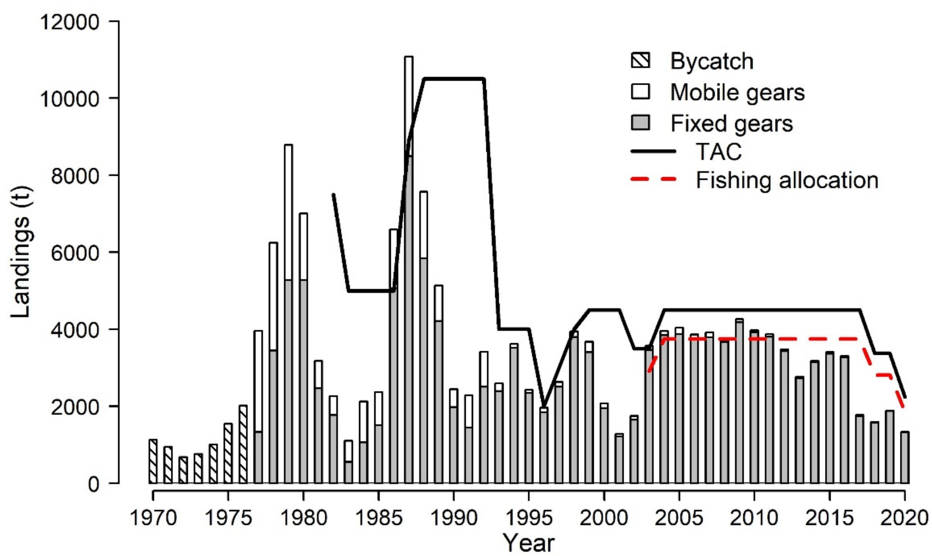


Figure 4. Greenland halibut reported landings (t) since 1970, TAC, and fixed gear fishing allocation. In 2000, the management year was changed from the civil year to the quota year (May 15 of the current year to May 14 of the following year). Data for 2020 are preliminary.

Fishery management measures include the imposition of a minimum mesh size of 152 mm (6.0 inches) and a minimum size for Greenland halibut of 44 cm in commercial catches as part of a small fish protocol. Quebec fishers are allowed a maximum of 120 gillnets while the maximum is 90 for Newfoundland fishers. Fishers are required to complete a logbook (100%), have their catches weighted at dockside (100%) and agree to take an at-sea observer on board at the request of DFO (5 to 15% coverage of trips, depending on the fleet). The use of the vessel monitoring system (VMS) has been gradually implemented in Quebec since 2013 and has been mandatory on all vessels since 2017. In Newfoundland, the use of VMS is not required for the entire fleet. The majority of Quebec fishers holds individual transferable quotas while all Newfoundland fishers are under a competitive regime.

Table 1. Landings (t) by gear type and total, fishing allocation, and TAC. Average by period and annual landings per fishing season beginning in 2017-2018.

Period	Gear		Total landings (t)	Fishing allocation (t)	TAC
	Fixed	Mobile			
1980-1989	3,612	1,215	4,827	-	7,175
1990-1999	2,558	309	2,868	-	5,700
2000-2010	3,144	108	3,252	-	4,300
2010-2017	3,384	28	3,424	3,751	4,500
2017-2018	1,750	15	1,765	3,751	4,500
2018-2019	1,590	14	1,604	2,813	3,375
2019-2020	1,887	9	1,896	2,813	3,375
2020-2021[1]	1,326	4	1,330	1,875	2,250

[1] *Preliminary data as of December 12th, 2020.*

Bycatch in the Greenland halibut fishery

Bycatch in the Greenland halibut gillnet fishery was estimated for the period 2000 to 2020 using data from the at-sea observer program. No data from this program was available in 2020 for the west coast of Newfoundland. Close to 480 t of bycatch are caught annually and it represents on average 19% of the weight of Greenland halibut landings. A decrease in Greenland halibut landings has increased this percentage since 2017. It is respectively 24% and 32% for 2019 and 2020. The most frequent bycatch species are, in order of importance, American plaice (*Hippoglossoides platessoides*), Redfish, Snow crab (*Chionoecetes opilio*), Thorny skate (*Amblyraja radiata)*, Spiny crab (*Lithodes maja*), Atlantic halibut, skates and Witch flounder (*Glyptocephalus cynoglossus*, Table 2). The occurrence of Redfish and Atlantic halibut increased in 2019 and in 2020 compared to the series average, reflecting the increased abundance of these species in the GSL ecosystem. More than a third of all bycatch is landed, the rest is discarded at sea. Discards at sea include species that can be released by the fishers such as Black dogfish (*Centroscyllium fabricii)*, Atlantic lumpfish (*Cyclopterus lumpus*), Hagfish (*Myxine glutinosa*) and Atlantic wolfish (*Anarhichas lupus*); mandatory release species such as Atlantic halibut < 85 cm, Snow crab and, skates; and species of no commercial value such as starfish, skate eggs, and polychaetes.

Greenland halibut bycatch in the shrimp fishery

The shrimp fishery is carried out using small-meshed trawls that catch and retain several fish and marine invertebrate species. Although large fish escape from trawls due to the mandatory use of a separator grate, catches still contain a certain number of small specimens. Greenland halibut bycatch from the shrimp fishery from 2000 to 2020 were examined using the at-sea observer database. Greenland halibut were present on average in 92% of the observed activities. Greenland halibut bycatch are mostly of the order of 3 kg or less per tow and are mostly made up of 1 year-old individuals, and to a lesser extent 2 year-old individuals. The average annual Greenland halibut bycatch from the shrimp fishery in the Estuary and GSL from 2000 to 2020 are around 92 t. In 2019 and 2020, they were estimated at 212 t and 73 t respectively, representing approximately 1.18 and 0.22% of the biomass of small Greenland halibut (< 30 cm) estimated from the nGSL DFO survey.

Table 2. Occurrence, Greenland halibut catch, and bycatch of the most frequent species (occurrence > 10 %) caught during directed gillnet fishing activities for Greenland halibut in 2019 and 2020 and average for the period 2000 to 2018.

	Occurrence (%)			Catch (t)		
Taxon	2000-2018	2019	2020	2000-2018	2019	2020
Greenland halibut*	100	100	100	3,053	2,056	1,213
American plaice*	77	82	81	45	73	62
Redfish*	59	95	71	27	59	24
Snow crab	59	29	19	66	15	9
Thorny skate	50	71	66	62	76	34
Spiny crab	49	38	29	23	13	7
Atlantic halibut*	48	54	41	105	94	41
Skates	40	31	37	45	18	36
Witch flounder*	37	86	82	8	38	32
Anthozoan	25	52	37	6	8	7
Atlantic cod*	20	11	10	18	18	2
Monkfish*	18	28	43	7	6	13
White hake	18	55	58	8	19	15
Smooth skate	15	17	11	8	11	1
Black dogfish	13	7	17	24	1	91

**Species landed in the Greenland halibut fishery.*

RESOURCE ASSESSMENT

Sources of information

This assessment is based on the analysis of commercial fishery and scientific research survey data. The fishery data come from four sources: purchase slips, landings weighted at dockside, logbooks and commercial catch sampling. Catch sampling is undertaken by two separate programs; the at-sea observer program and the DFO port sampling program. Two research surveys, independent of the commercial fishery, are conducted annually in the nGSL. The first in July by the mobile sentinel fisheries program (MSP 1995-2020) and the second in August by DFO (nGSL 1990-2020). A third survey conducted by DFO in September in the southern Gulf of St. Lawrence (sGSL, 1971-2020) was also considered. These three surveys are conducted using bottom trawls according to a stratified random sampling design.

Commercial fishery fishing effort and catches

Close to 99% of Greenland halibut landings are from the gillnet fishery directed at this species. The fishing effort is deployed in three main sectors (Figure 5). The Western Gulf and Esquiman sectors are frequented annually while the North Anticosti sector has sporadic use (Figures 5 and 6). In years when the North Anticosti sector is not frequented, the fishing effort shifts mainly in the Western Gulf sector. In 2020, the proportion of effort deployed in the Western Gulf, North Anticosti and Esquiman was 68%, 11%, and 20% respectively. These proportions are quite similar to the averages for the period 1999-2019, which were 67%, 6% and 25% respectively for the same sectors.

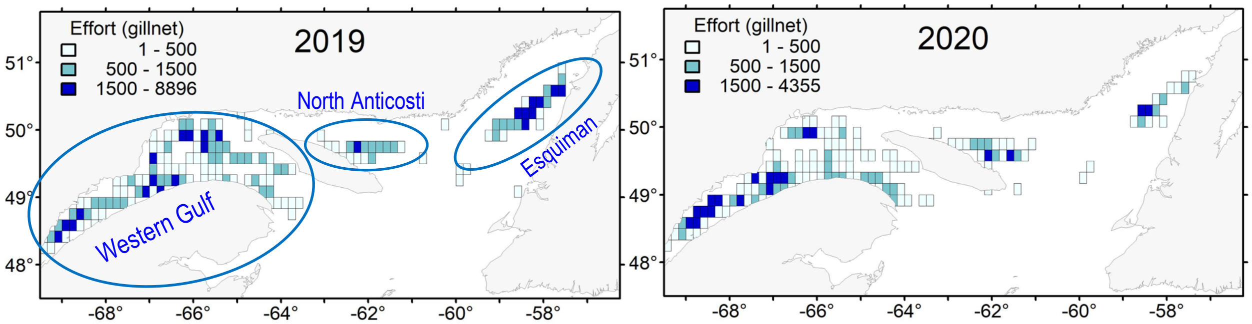


Figure 5. Distribution of fishing effort (number of gillnets) by fishing statistical square for 2019 and 2020. Effort data are available for more than 95% of landings in the Western Gulf and North Anticosti sectors. For the Esquiman sector, effort data are available for more than 80% of landings in 2019 and nearly 45% in 2020.

For the entire Gulf (4RST) and for the Western Gulf and Esquiman sectors, fishing effort and landings decreased between 2019 and 2020 (Figure 6). These are among the lowest landings and efforts values in each series.

The situation is different for the North Anticosti sector which, after being deserted from 2015 to 2017, experienced an increase of fishing activities from 2018 to 2020. The effort remained fairly stable between 2019 and 2020 while landings increased and totaled 232 t for a fishing effort of more than 11,000 nets (Figure 6).

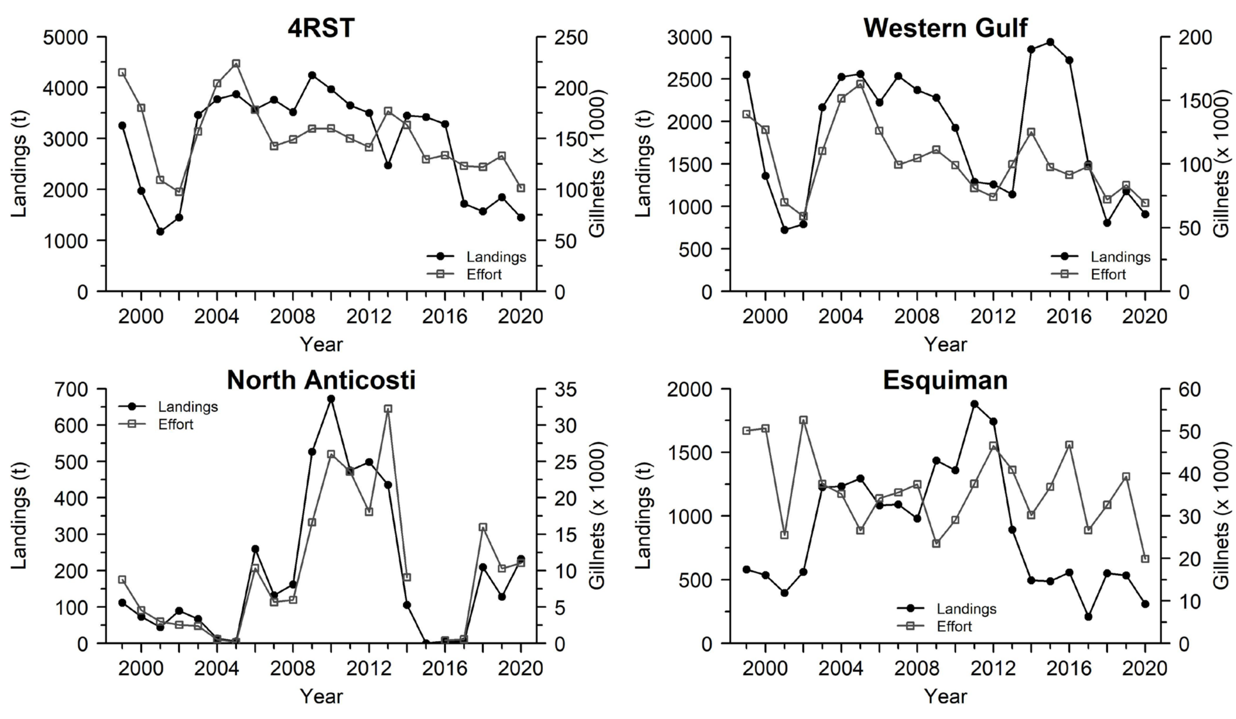


Figure 6. Landings (t) and fishing effort (number of gillnets) for the Gulf (4RST) and by fishing sectors.

Commercial fishery performance index

The annual commercial catch rate (catch per unit effort, CPUE) is used as an indicator of the performance of the fishery and not as an index of abundance of the exploitable stock. This index is standardized to take into account the variability that could be attributable to various factors such as the duration of the immersion of the gear, changes in fishing area and the seasonal fishing pattern. This standardization allows to identify annual trends in catch rates.

In 2020, for the entire Gulf (4RST) and for the three fishing sectors, the fishery performance indices are below each series average (Figure 7).

The trajectory of the indices is similar for the Gulf and the Western Gulf sector. The indices showed a decrease of more than 50% between 2015 and 2018 and fell below the series average in 2017. In 2019 and 2020, the indices are stable.

In the North Anticosti and Esquiman sectors, the fishing performance indices decreased by more than 75% between 2012 and 2017 and have been below their series average since 2013. Between 2019 and 2020, the index increase in North Anticosti and is stable in Esquiman.

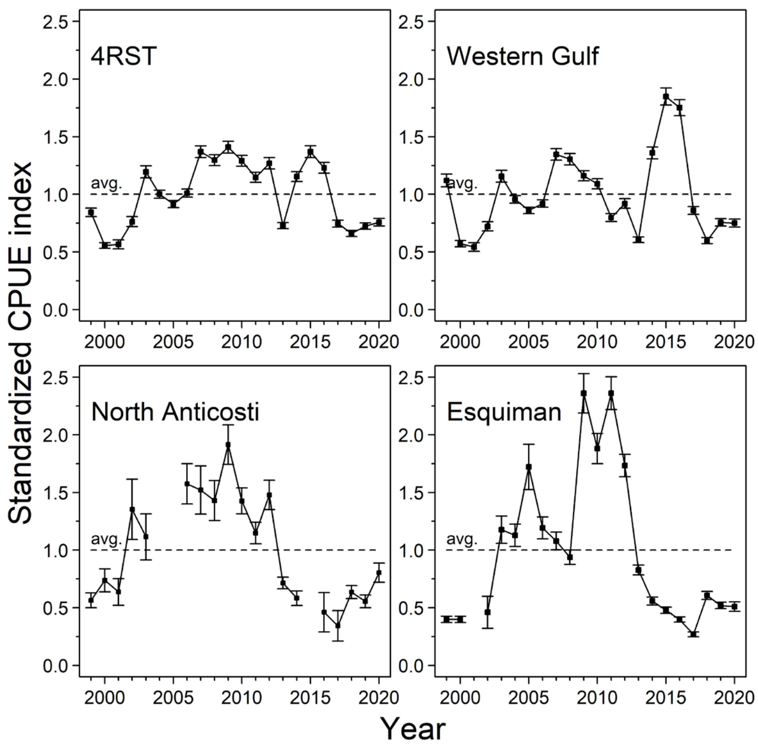


Figure 7. Commercial fishery performance indices (standardized CPUE) for the GSL (4RST) and by fishing sector. Error bars indicate the 95% confidence interval. The horizontal lines represent each series average.

Length composition of fish in commercial fishery catches

The average size of Greenland halibut caught in the commercial fishery increased steadily from 2002 to 2012, from 44.8 cm to 48.8 cm (Figure 8). This increase is explained, among other things, by the growth of the strong 1997 and 1999 cohorts which made up a large part of the catches. Between 2012 and 2018, the average size fluctuated and was above or at the level of the series average. Data for 2020 were partial due to health measures related to the pandemic. In 2019, the average sizes of male and female fish decreased and were among the lowest since 1996. The average size of males was 41 cm, almost 3 cm lower than the series average and below the series minimum size of 44 cm. The average size of females was 46.0 cm, almost 2 cm less than the series average. The average size of fish landed for the sexes combined is

45.3 cm, below the average of 47.1 cm. The decrease in the average size of fish has a significant impact on the number of fish landed for a given landing counted by weight. Between 2017 and 2020, annual landings in tonnes decreased by 16% while the number of fish landed decreased by only 9%.

From 1996 to 2018, 17% of the fish landed were smaller than the minimum size of 44 cm. In 2019 this percentage increased to 30%.

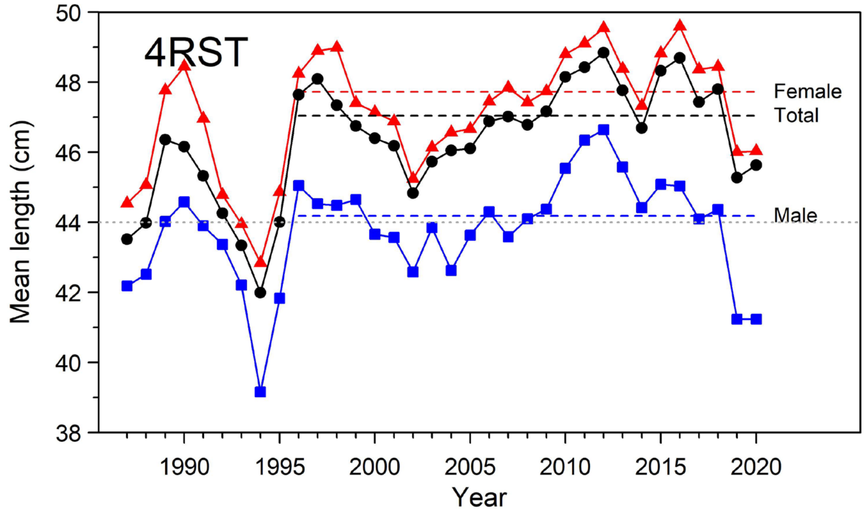


Figure 8. Average size of Greenland halibut landed in the commercial fishery by sex. The horizontal lines indicate the 1996-2020 average for each series. The regulatory mesh size in the commercial fishery increased from 140 to 152 mm (5.5 to 6 inches) in 1996. The dotted horizontal line across the graph indicates the minimum size of 44 cm. Due to the health measures linked to the pandemic, the data for 2020 were partial.

Biological data

Size at sexual maturity

The size at which 50% of Greenland halibut are mature (L_{50}) decreased significantly between 1997 and 2001 for males and between 1998 and 2004 for females(Figure 9). It remained relatively stable at the average level from 2004 to 2014 for both sexes. Subsequently, the L_{50} generally decreased to reach the lowest values of the series in 2019 and 2020. In 2020, the L_{50} is estimated at 37 cm in females (series average 45 cm) and 31 cm in males (series average 36 cm). Growth in Greenland halibut decreases after reaching sexual maturity. Since the L_{50} is declining, there will likely be fewer large fish in this stock in the coming years. In addition, since females display a higher L_{50}, they attain larger size than males. This characteristic combined with the selectivity of 152 mm gillnets results in a higher proportion of females in the commercial catches. In 2018 and 2019, females made up 85% of commercial catches, which is above the average of 80% for the 1996-2019 series.

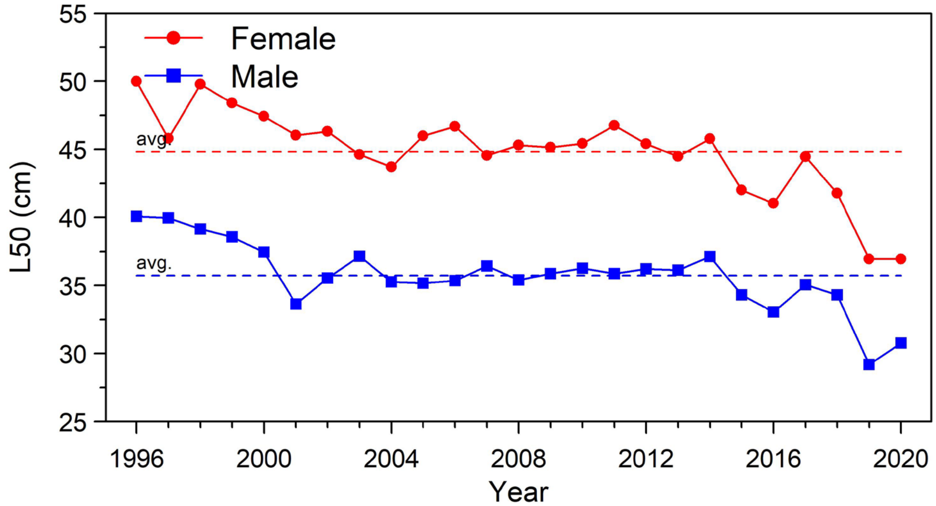


Figure 9. Size at which 50% of Greenland halibut caught during the nGSL DFO research survey were sexually mature (L_{50}). The horizontal lines indicate the average of each series.

Demographic structure and recruitment

The general pattern of the demographic structure of Greenland halibut caught during the nGSL and MSP surveys is similar, but differences in trawl selectivity and the area sampled produce a better representation of smaller fish in the nGSL survey, while the larger ones are better represented in the MSP survey (Figure 10).

The abundance of the different year classes, their growth and the prevailing environmental conditions influence the abundance of the stock and are directly related to the future success of the fishery. Based on their normal growth curve, Greenland halibut generally recruit to the fishery at a size of 44 cm at an average age of 6 years for females and 7 years for males.

The strength of the new cohorts is estimated by the annual abundance of fish of the size class ≥ 12 and ≤ 21 cm captured during the DFO nGSL survey, which represent 1-year-old fish (Figures 10 and 11). Since the late 1990s, this stock has produced alternately high and low abundance cohorts without showing a clear stock-recruitment relationship. The first strong cohorts observed, those of 1997, 1999, 2001 and 2002 led to a significant increase in the abundance of the stock and supported the fishery until the early 2010s (Figures 10 and 11). Subsequently, the 2010 cohort generated a significant biomass of individuals > 40 cm in 2014, increasing the catch rates of the commercial fishery from 2014 to 2016. The recruitment of the 2010 cohort to the fishery generated a decrease in fish size in commercial catches in 2014 (Figure 8).

In the history of the stock, the recent 2013 cohort appeared to be the most abundant in the series (Figure 11). It was preceded by a high abundance cohort (2012) and followed by a medium abundance cohort (2014). It would have been expected that these cohorts would generate a significant increase in the abundance of the stock as observed in the early 2000s. Instead, a decrease of about 45% in the growth rate of the 2013 cohort between one and two years was observed. This was the first time in over 25 years that such a decrease in growth had been observed. Since then, the abundance of these cohorts has declined significantly. They could have started to recruit to the fishery in 2019-2020, which could in part explain the significant decrease in the average size of fish in commercial catches (Figure 8).

Although the 2017 cohort had above-average abundance at one year (Figure 11), its abundance decreased significantly at 2 years and in 2020 it is below average (Figure 10). The 2018 cohort seems particularly interesting since it is of high abundance at one and two years and it displays a normal growth rate for this stock (modal size of 16 cm at one year in 2019 and 26 cm at two years in 2020, Figure 10). The condition index for fish in this cohort was below average at 1-year-old (15 cm in 2019) and increased to the average for 2-year-old fish (25 cm in 2020, Figure 12) .This cohort could start recruiting to the fishery in 2024.

The length frequency distribution of the MSP survey also indicates that the abundance of fish larger than 40 cm has declined since 2009 and has been low since 2016 (Figure 10).

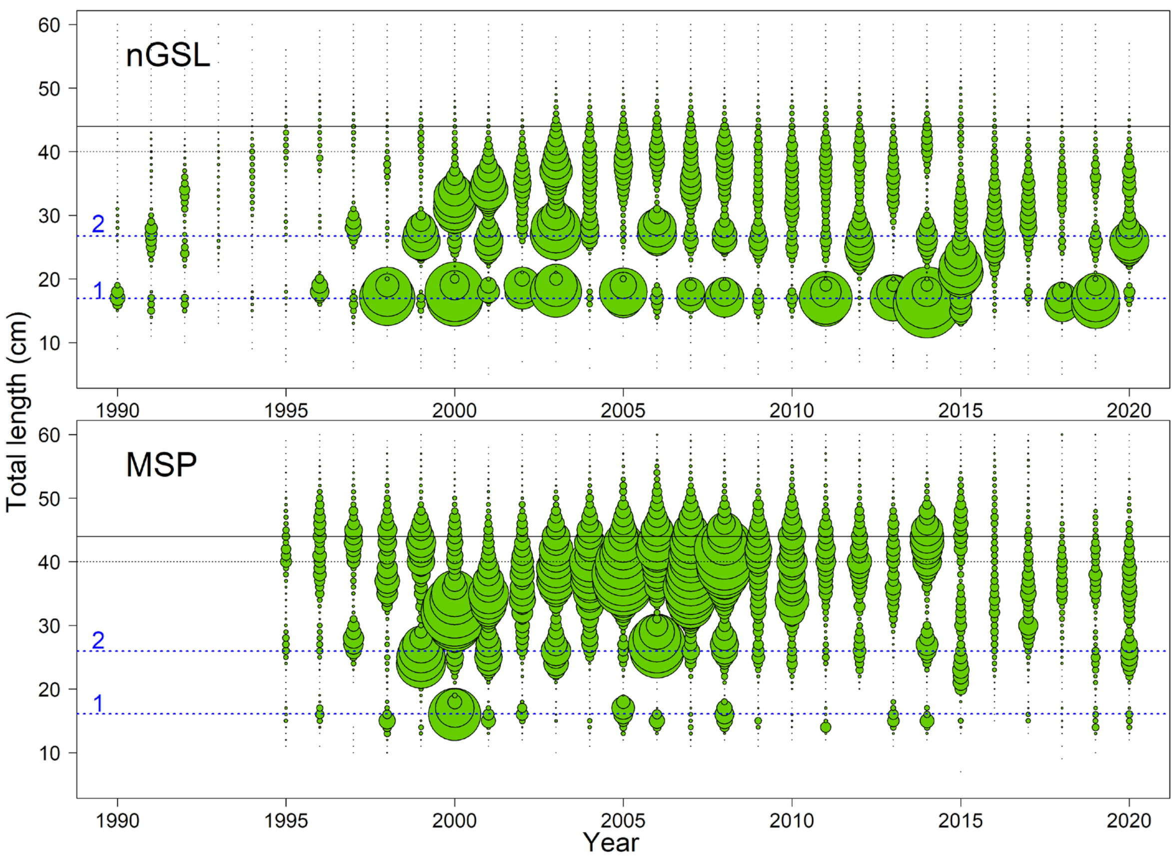


Figure 10. Greenland halibut length frequency distributions observed during the nGSL (1990-2020) and the MSP (1995-2020) scientific surveys. The size of the bubbles is proportional to the abundance in a given survey. The horizontal blue dotted lines show the average size expected for one and two-year-old fish. The black dotted horizontal lines delimit the size class > 40 cm and the solid black lines indicate the minimal size of 44 cm.

Condition

The Fulton condition index (K = weight (g) / length^3 (cm)) is estimated for four sizes of Greenland halibut: 15 cm (~ 1 year); 25 cm (~ 2 years); 35 cm (3 to 5 years) and 45 cm (≥ 6 years) (Figure 12). The condition of 1-year-old fish fluctuated from 1990 to 2018, often varying inversely to the abundance of different cohorts. Thus, the abundant 1999 and 2010 cohort at 1 year (15 cm) in 2000 and 2011 had a Fulton index below the series average. Recently, this stock experienced three consecutive years of medium to high abundance cohorts, 2012 to 2014 (Figure 11) which had Fulton indices below the average of the 15 cm series (2013-2015) (Figure 12). Fish from these cohorts maintained low condition indices (series 25 cm, 35 cm and 45 cm from 2015 to 2017). Another factor that could have affected the condition of the recent cohorts of Greenland halibut is a possible competition for food and habitat with the massive arrival of juvenile redfish in the GSL between 2011 and 2013. The condition index estimated for all sizes of Greenland halibut increased to the average level in 2020.

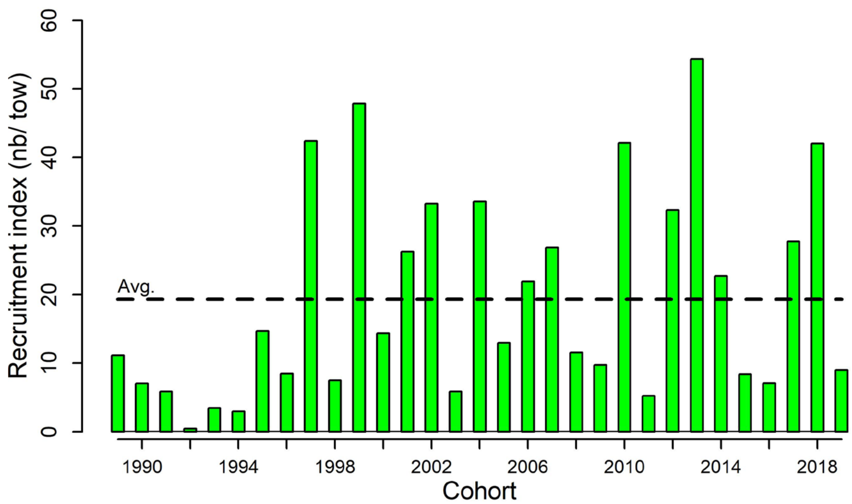


Figure 11. Recruitment index (number / tow) of Greenland halibut estimated by annual abundance of 12- 21 cm fish (age 1) from the DFO nGSL survey. The dotted horizontal line represents the series mean.

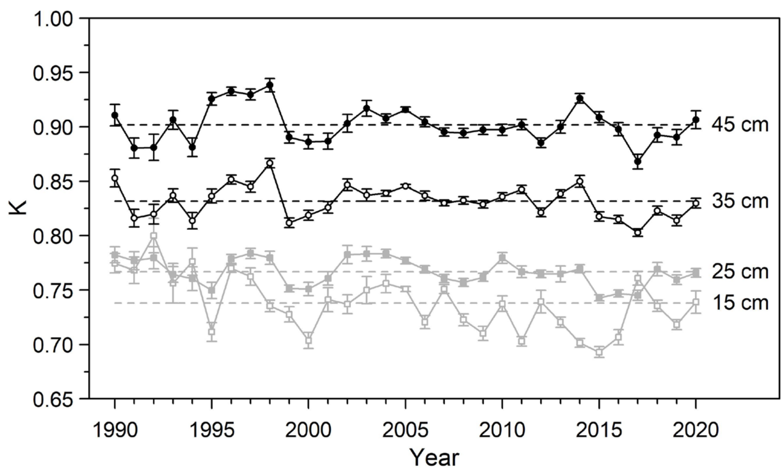


Figure 12. Annual Fulton (K) condition indices estimated for 15, 25, 35 and 45 cm Greenland halibut captured during the nGSL survey. Error bars indicate the 95% confidence interval. The horizontal lines represent the average of each series.

Stock status indicators

The series of abundance and biomass indices of Greenland halibut from the sGSL, nGSL and PSM surveys show quite similar trends, with a significant increase until the mid-2000s, a period of stability, then a trend generally declining from the late 2000s to 2019. The indices increased slightly in 2020 (Figure 13). This increase is partly attributable to the arrival of the strong 2018 cohort (Figures 10 and 11).

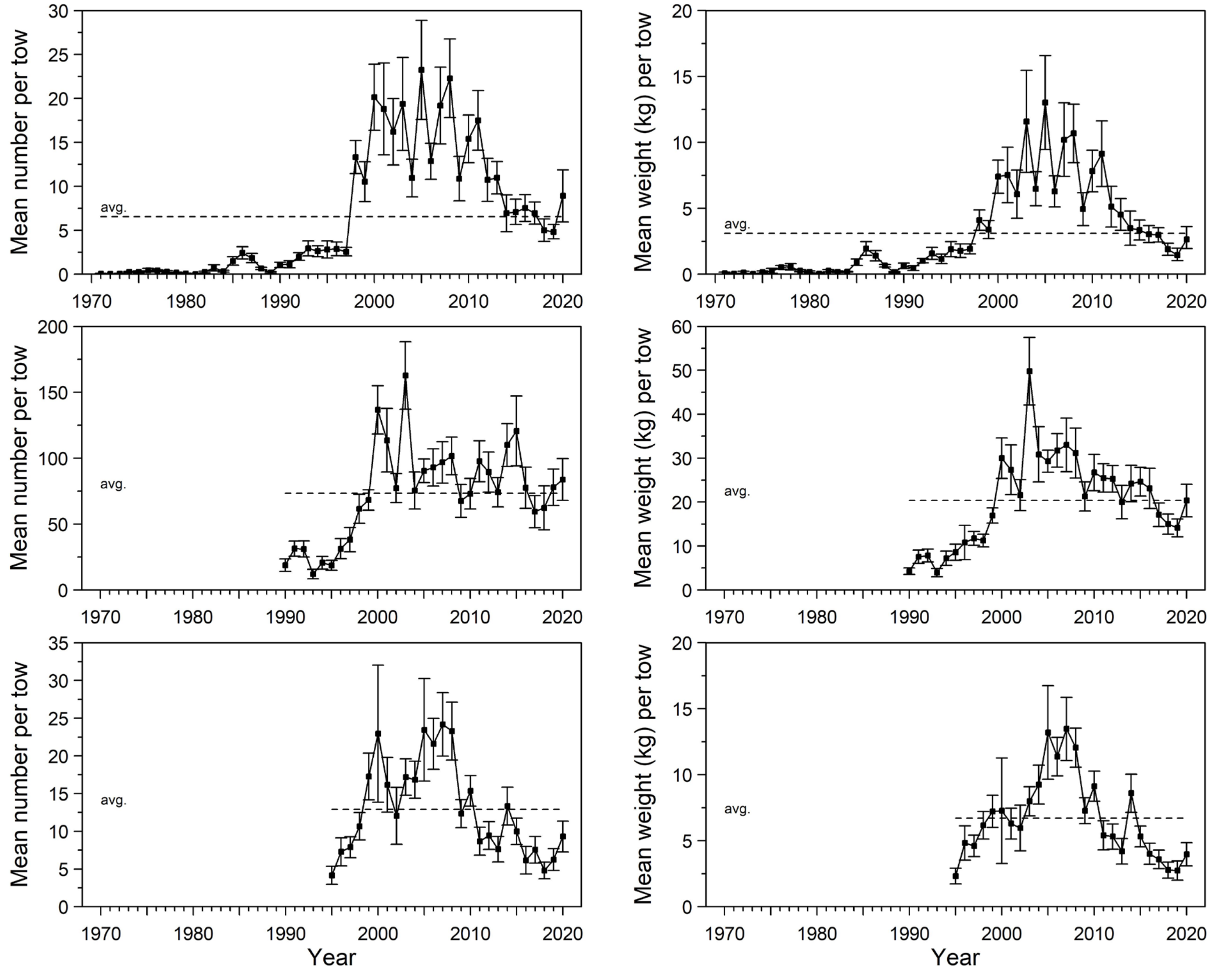


Figure 13. Greenland halibut abundance (mean number per tow) and biomass (mean weight per tow) indices observed during the scientific surveys of the sGSL (top), the nGSL (middle) and the MSP (bottow). Error bars indicate the 95% confidence interval. The dotted lines represent the average of each series.

Trends in abundance indices (mean number per tow) of Greenland Halibut from nGSL and PSM surveys varied across size classes and may have diverged between surveys (Figure 14). In the nGSL survey, indices for the 0-20 and 20-30 cm size classes increased significantly in the late 1990s and then fluctuated around the mean. There is a good correlation between the abundance of 0-20 cm fish (~ 1 year) and 20-30 cm (~ 2 years) the following year. Between 2019 and 2020, the abundance of 0-20 cm fish declined below the series average. The PSM survey is not very informative for this size class given the selectivity of the trawl and the area covered by the survey.

The abundance trends for the 20-30 cm size class were generally similar for the two surveys although at different scales. The trend is increasing in 2019 and 2020.

For larger fish, abundance indices from both surveys increased until the early (30-40 cm fish) or mid-2000s (fish > 40 cm), and then trended downward. The indices of 30-40 cm increased slightly from 2019 to 2020. For the size class > 40 cm, we observe a stabilization of the indices of abundance below the average of the series from 2017 to 2020. According to the estimates of typical growth for individuals of this stock, fish from the abundant cohorts of 2012, 2013 and 2014 would normally have reached a respective modal size of around 49, 47 and 44 cm in 2020. An increase in the abundance of fish > 40 cm was expected, but did not materialize (Figure 14). These abundant cohorts of juveniles did not lead to subsequent increases in the abundance indices of the larger fish.

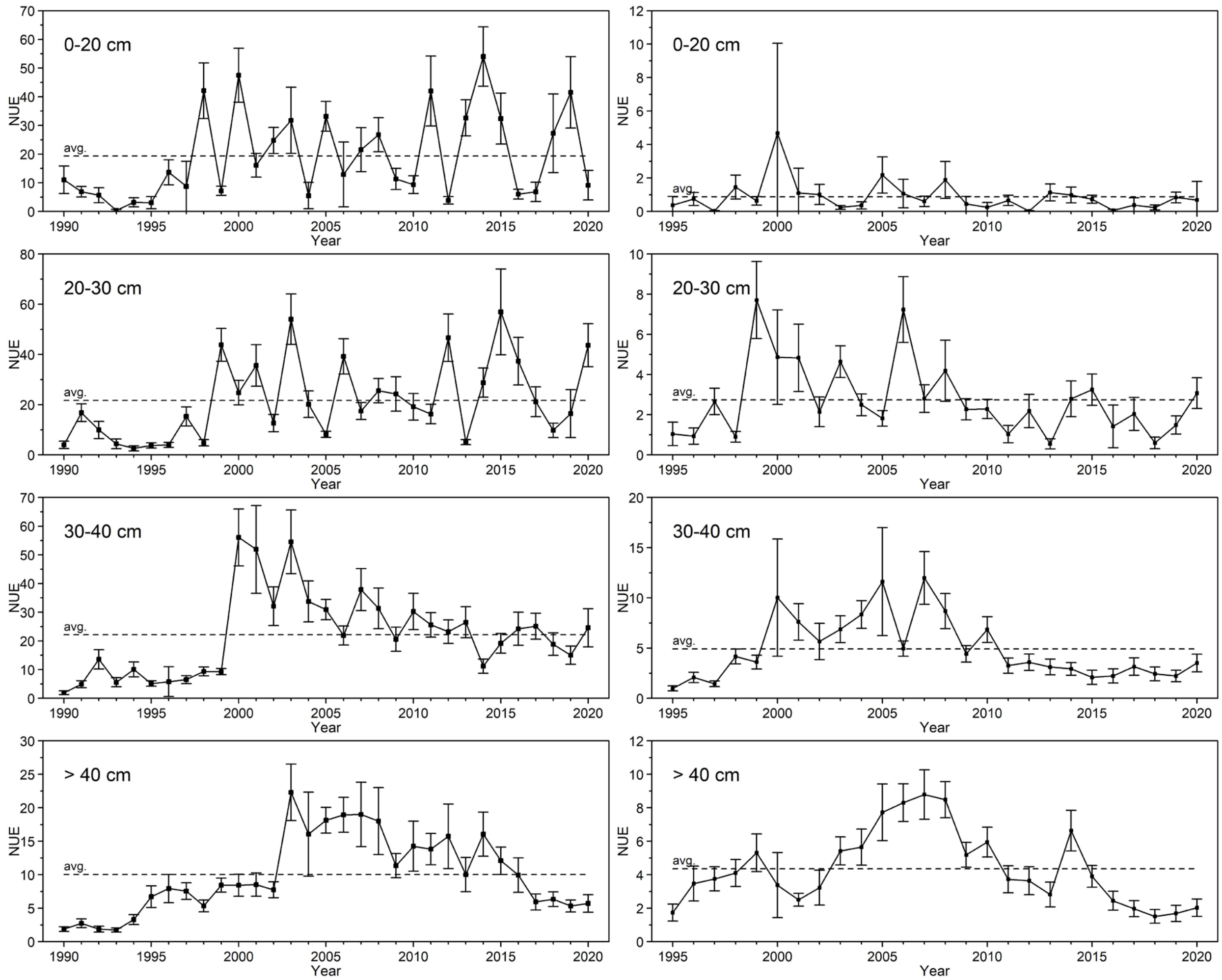


Figure 14. Abundance indices (mean number per tow, NUE) for Greenland halibut of different size categories observed in the nGSL (left) and the MSP (right) surveys. Error bars indicate the 95% confidence interval. Horizontal lines indicate the 1990-2019 average of each series.

New series of indices combining scientific surveys of nGSL and sGSL (1984-2020)

Recent re-analyzes of data from comparative fishing experiments undertaken in 1990 in the nGSL made it possible to reconstruct the series of surveys up to 1984 and combine it with the series of sGSL. The increase in spatial coverage over a longer period allows a new interpretation of the distribution of the GSL Greenland Halibut stock. In the late 1980s, when abundance was low, Greenland halibut were mostly concentrated in the St. Lawrence Estuary (Figure 3). As abundance increased in the 1990s, densities expanded eastward along the Laurentian Channel and at the head of the Anticosti and Esquiman channels, as well as in

Chaleur Bay and in the Cape Breton trough. The recent decline in abundance has resulted in a more marked decrease in stock density in the eastern part of its range. Overall, this pattern is consistent with the extension and contraction of the geographic range as a function of density, with the St. Lawrence Estuary being the core of this distribution.

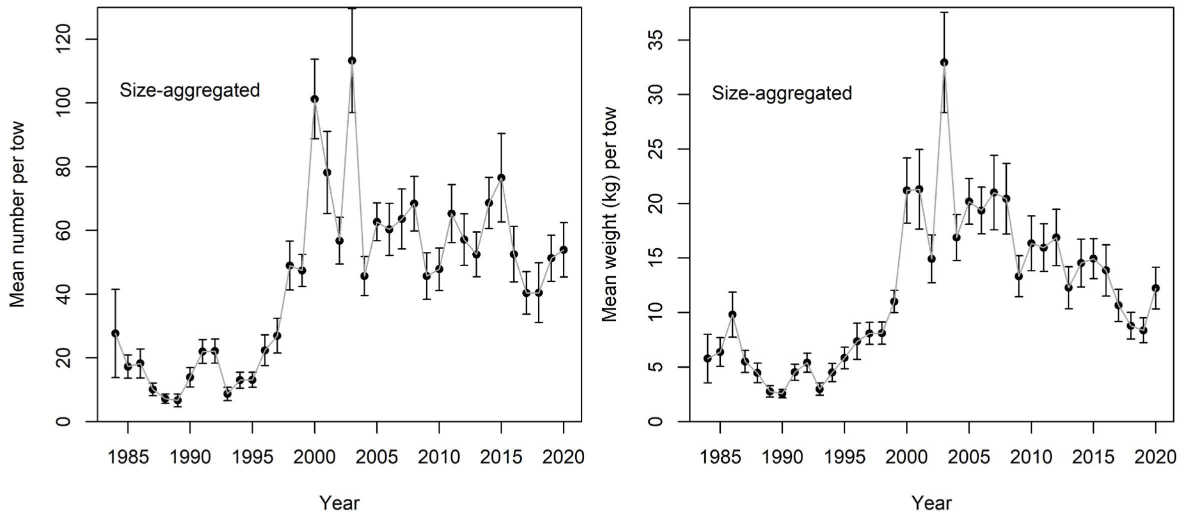


Figure 15. Abundance (mean number per tow, left) and biomass (mean weight per tow, right) indices for Greenland halibut in the combined series of nGSL and sGSL surveys, 1984-2020. Error bars indicate the 95% confidence interval.

Greenland Halibut Stock Productivity Outlook in the Context of Climate Change

An empirical model suggests that the surplus production of the Greenland halibut stock declines with increasing deep water temperature. This general relationship suggests that with the increased warming of deep waters observed since 2010, a decline in the productivity of the stock is expected. The climate forecast for the GSL shows that significant levels of warming can be expected in surface and deep waters over the next 10 to 20 years. Several observations indicate conditions which are not currently favorable for the productivity of Greenland halibut: (1) sharp increases in deep water temperature, (2) decreases in oxygen saturation of deep water, (3) increase in redfish as competitors and (4) decline in northern shrimp as prey. Although the general predictions of the empirical model have a large amount of uncertainty which makes the specifics of the prediction somewhat uncertain, the general trajectory is robust. Factors known to negatively impact Greenland halibut have strengthened and will continue to do so, adding some weight to the evidence suggesting that the productivity outlook for this stock is not encouraging. Fisheries management strategies and short, medium and long term stock objectives should take this into account.

Relative exploitation rate indicator

An indicator of relative annual exploitation rate was obtained by dividing the weight of the landings by the biomass of fish > 40 cm estimated by the nGSL scientific survey. The method does not allow to estimate an absolute exploitation rate, nor to relate it to target exploitation rates. However, it tracks changes over time and between fishing areas.

In 2020, the relative exploitation rate for the entire Gulf (4RST) was 5.9% below the series average of 6.5% for the 1996-2020 period (Figure 16). The average exploitation rate was 4.8% for the period 2001-2008, a period when the stock increased and remained abundant. The period from 2009 to 2020, characterized by a near-average exploitation rate, corresponded to a period of fairly constant decline in the biomass of fish > 40 cm (Figure 16). This could indicate that the exploitation rates of the last ten years were too high.

In the Western Gulf sector, the exploitation rate indicator was increasing between 2012 and 2017, then it hovered around the series average. Following a decrease in landings and a rather stable level of biomass, the exploitation rate for this sector decreased in 2020 to be 5.7% below the series average of 7.5%. For the North Anticosti and Esquiman sectors, exploitation rates are increasing from 2017 to 2020 and are well above the average of their respective series. For the North Anticosti sector, the exploitation rate for 2020 was the second highest in the series. For the Esquiman sector, this is the highest exploitation rate since 1996 and the lowest fish biomass > 40 cm estimated by the nGSL survey.

Precautionary approach and reference points

A precautionary approach is being developed for the GSL Greenland halibut stock. The indicator selected for monitoring stock status is fish biomass > 40 cm estimated from the nGSL survey. This indicator corresponds to the longest time series available (1990-2020) and represents an approximation of the spawning stock biomass.

The limit reference point (LRP) adopted is the geometric mean of the indicator during the period 1990 to 1994, which corresponds to the period when the population was at its lowest level and from which a recovery of the stock was observed. This LRP was evaluated at 10,000 t (Figure 17).

A first upper stock reference point (USR) was proposed as early as 2018 (DFO 2019). This USR was based on the concept of stable biomass during the 2004-2012 productive period. The high productivity of the stock during this period was largely attributable to the excellent recruitment produced in the late 1990s.

The stock status indicator has been decreasing since the end of the 2000s with a more rapid decline between 2014 and 2016. This period of strong decline would be linked to a decline in the productivity of the stock possibly due to rapid changes in the deep waters of the GSL. These unfavorable changes for the Greenland halibut include an increase in the temperature of the deep water, a decrease in the level of dissolved oxygen and the massive influx of redfish which are potential competitors.

Recent work showing the long-term impacts of these climate changes on the productivity of the stock has suggested that a USR based on the biomass during the period of high productivity 2004-2012 may no longer be achievable even without fishing. Another USR proposal was made on the basis of the biomass from the 1996-2002 productivity period which was not the result of a single unusually large recruitment event and which could be considered more realistic. However, since the GSL environment is currently changing rapidly, it is not easy to determine which USR is most appropriate for this stock.

Under these conditions, a USR proposal was made to take into account the significant ecosystem changes occurring in the GSL as well as the decrease in stock productivity. This new USR is based on both productivity period, the 1996-2002 and the 2004-2012. In this proposal, the biomass at the maximum sustainable yield (B_{msy}) represents the average of the biomasses of these two periods, i.e. 47,170 t, and the USR corresponds to 80% of this B_{msy}, i.e. 37,740 t.

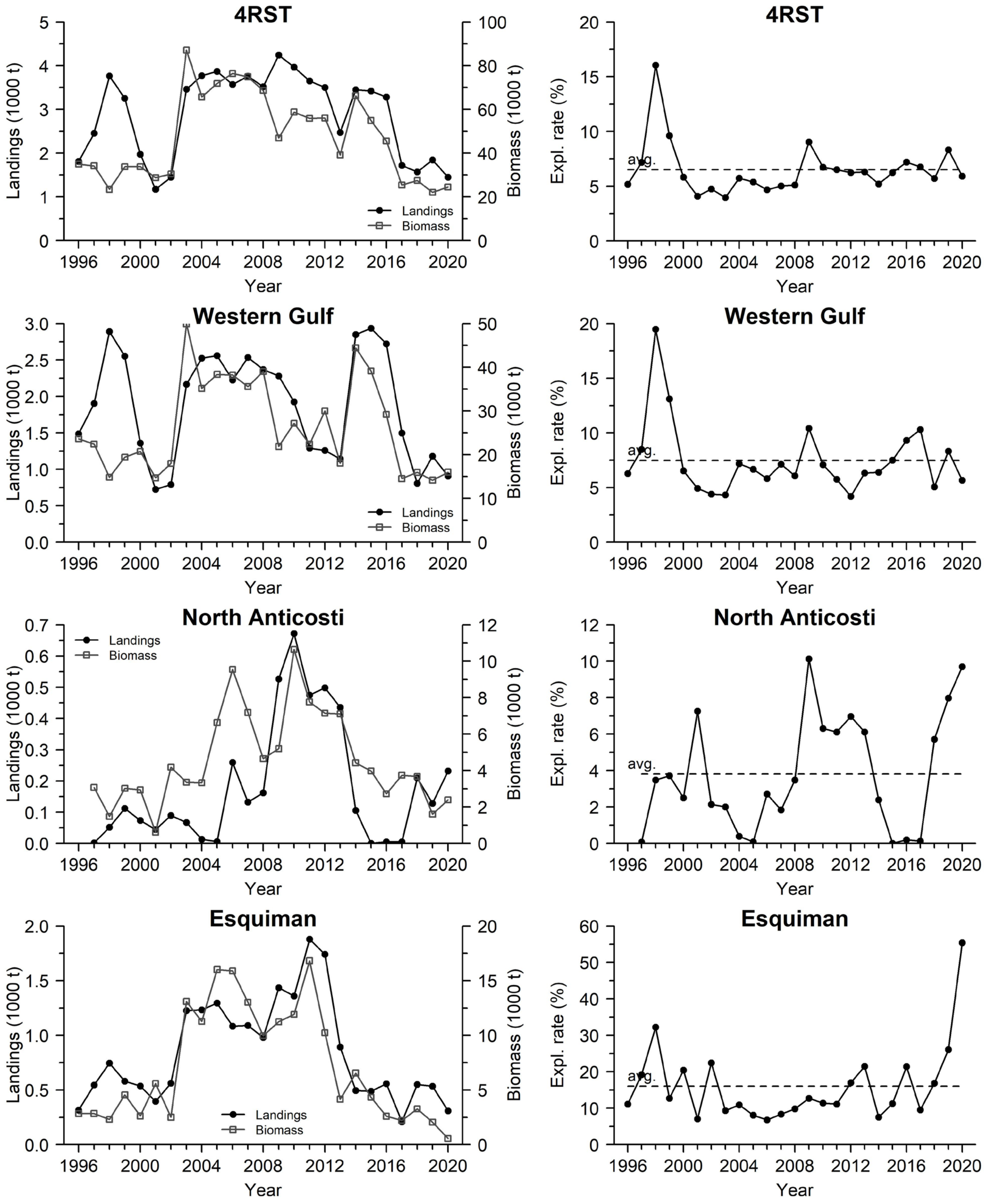


Figure 16. Landings, fish biomass > 40 cm, and relative exploitation rate for the GSL (4RST) and by fishing sector. The dotted lines represent the average exploitation rate for each series.

The development of this precautionary approach is based on the best data currently available. The proposed points (B_{msy}, LRP and USR) will have to be re-evaluated with the acquisition of new data which may allow to changed them for more appropriate values.

A working group, made up of representatives of the fixed gear fleets, the provincial governments of Quebec and Newfoundland and Labrador, as well as Indigenous groups, was created in the fall of 2018 to participate in the development of a proposal of the precautionary approach. Three workshops have been held with this group since its formation, and at the last workshop in February 2020, the group accepted the USR proposal at 37,740 t. The current framework of the precautionary approach of the GSL Greenland halibut stock is defined by a 10,000 t LRP delimiting the critical zone from the cautious zone and a 37,740 t USR delimiting the cautious zone from the healthy zone. Defining harvest control rules remain difficult due to the current state of the stock.

The stock status indicator was on a downtrend with a decrease of over 60% between 2008 and 2017 moving from the healthy zone to the cautious zone. The indicator is rather stable from 2017 to 2020 and is in the cautious zone, halfway between the LRP and the USR.

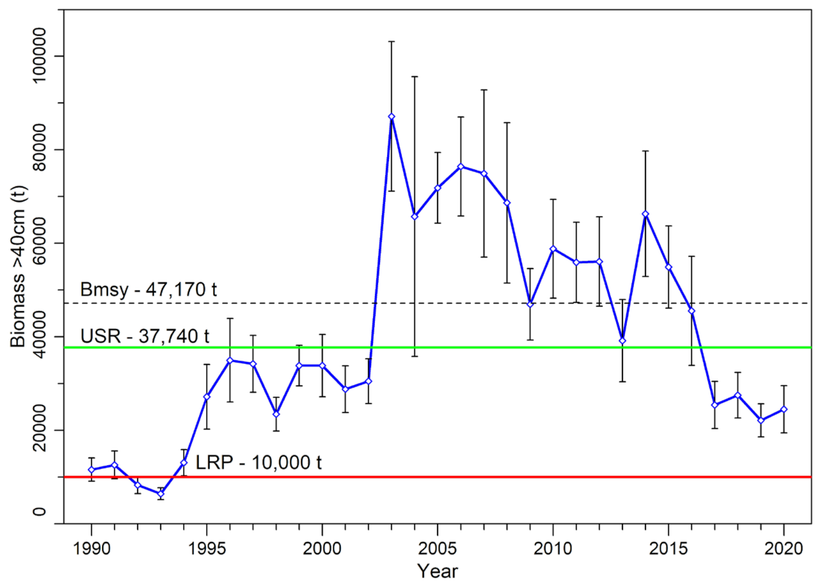


Figure 17. Annual biomass indicator for Greenland halibut > 40 cm from the nGSL survey. The red horizontal line at the bottom indicates the limit reference point (LRP) as part of the precautionary approach. The LRP is the boundary between the critical and cautious zones. The green horizontal line at the top indicates the upper stock reference (USR). The USR is the boundary between the cautious and healthy zones. Error bars indicate the 95% confidence interval. The dotted black line indicates the proxy for biomass at maximum sustainable yield (B_{msy}).

Assessment schedule and trigger for a full assessment during an interim year

The GSL Greenland halibut stock is currently assessed and managed on a two-year cycle. In the interim years, an update of key resource indicators is prepared to provide fisheries management with an overview of the most recent stock status. The indicators used to monitor the status of the stock are landings and abundance indices from the nGSL DFO survey. The element that could trigger a re-assessment is a decrease of more than 30% in the biomass index of fish > 40 cm when this biomass is in the cautious or critical zone defined according to the precautionary approach.

Sources of Uncertainty

The length at which 50% of Greenland halibut are mature is determined through a visual inspection of gonads during the DFO research survey in August. Since spawning occurs in winter, the timing of the survey is not ideal for this type of work. A detailed histological study is in progress and should allow a more precise determination of the L_{50} of both sexes for this species.

Greenland halibut make significant daily vertical migrations and may spend more than 25% of their time in the water column. The effect of water temperature and DO level on the duration and frequency of these vertical movements is unknown. The annual proportion of fish that may be found outside the volume swept by the trawl in scientific surveys in response to ecosystem changes is unknown. The varying availability of fish in these surveys would have implications for catchability and abundance estimates.

Age determination of GSL Greenland Halibut by reading otoliths is not currently possible. Thus, length-based population dynamics models have been investigated. However, recent variations in the growth rate of the species have delayed the development of such models. The development of a population dynamics model would be an asset for monitoring the status of this stock.

At the time of writing this Science Advisory Report, 2020 data from the at-sea observer program were not available for the west coast of Newfoundland (NAFO Division 4R). The size structure of Greenland Halibut landed in 4R in 2020 was produced using data from Division 4S.

CONCLUSIONS AND ADVICE

The outlook for the Greenland halibut stock in the GSL is of concern given the observed ecosystem changes and the decreasing indices of abundance and biomass of fish > 40 cm. These indices have stabilized over the past four years.

From 2019 to 2020, commercial fishing performance indices were stable for the Western Gulf and Esquiman sectors and increasing in the North Anticosti sector. The indices of the three sectors are below the average of their respective series.

The cohorts (2014, 2015 and 2016) that are expected to recruit and contribute to the fishery in 2021 and 2022 are of average to low abundance. The recent abundant cohort of 2018 looks promising and is currently showing a normal growth rate. She is expected to start recruiting for the fishery in 2024.

The GSL Greenland Halibut exploitation rate indicator declined from 2019 to 2020 and remained near the series average. This indicator is decreasing in the Western Gulf sector and increasing strongly in the North Anticosti and Esquiman sectors.

The stock status indicator (fish biomass > 40 cm) showed a downward trajectory with a decrease of more than 60% between 2008 and 2017 from the healthy zone to the cautious zone. The indicator is rather stable from 2017 to 2020 and is in the caution zone halfway between the PRL and the PRS.

According to the decision-making framework for fisheries incorporating the precautionary approach, when a stock is in the cautious zone and its recent trajectory is stable, management actions should promote stock growth in the short term. Since the current status of the GSL Greenland halibut stock meets these conditions, in accordance with this framework, a reduction in catches below recent levels could reduce the exploitation rate and promote an increase in the stock. However, the unfavorable environmental conditions for Greenland halibut prevalent in the GSL could be determining factors in the trajectory of the stock.

Other considerations

In the GSL, the area occupied by redfish and Greenland halibut has a large area of overlap. The upcoming reopening of the commercial redfish fishery will result in a significant increase in fishing effort that could increase Greenland halibut bycatch. The effectiveness of fishing zone closures and the selectivity of redfish fishing gear should be assessed in order to minimize Greenland halibut bycatch.

LIST OF MEETING PARTICIPANTS

Name	Affiliation	February 23	February 24
Bélanger, Michel	MAPAQ	x	x
Benoit, Hugues	DFO – Science	x	x
Bermingham, Tom	DFO – Science	x	x
Bernier, Denis	DFO – Science	x	x
Bois, Samantha	ACPG	x	
Boucher, Jean-René	RPPNG/OPFGQ	x	x
Boudreau, Mathieu	DFO – Science	x	
Bourdages, Hugo	DFO – Science	x	x
Bourbonnière, Jean-Patrick	DFO – Science	x	
Brassard, Claude	DFO – Science	x	x
Chabot, Denis	DFO – Science	x	
Chamberland, Jean-Martin	DFO – Science	x	x
Chlebak, Ryan	DFO – Science Ottawa	x	x
Cyr, Charley	DFO – Science	x	x
Denis, Marcel	ACPG	x	x
Desgagnés, Mathieu	DFO – Science	x	
Dobbin, Shannon	Fisher	x	x
Dubé, Sonia	DFO – Science	x	x
Dubé, Frank	Fisher		x
Dugas, Franky	Fisher	x	x
Duplisea, Daniel	DFO – Science	x	x
Dupuis, Mario	RPPNG	x	x
Dwyer, Shelley	DFO – Fisheries Management NL	x	x
Gauthier, Johanne	DFO – Science	x	x
Hardy, Magaly	DFO – Fisheries Management Quebec	x	x
Hébert, Denyse	DFO – Fisheries Management Quebec	x	x
Karbowski, Chelsey	Oceans North Canada	x	x
Isabel, Laurie	DFO – Science	x	x
Langelier, Serge	AMIK	x	x
Lapierre, Daniel	DFO – Fisheries Management Gulf	x	x
Lussier, Jean-François	DFO – Science	x	
Marquis, Marie-Claude	DFO – Science	x	x
Martin, Lucas	ISMER/UQAR	x	x
Méthot, Chantal	DFO – Science		x
Nicolas, Pierre	OPFGQ	x	x
Ouellette-Plante, Jordan	DFO – Science	x	x
Parent, Geneviève	DFO – Science	x	x

Name	Affiliation	February 23	February 24
Pond, Nancy	DFO – Fisheries Management NL	x	x
Pomerleau, Corinne	DFO – Science	x	
Plourde, Stéphane	DFO – Science	x	
Roux, Marie-Julie	DFO – Science	x	x
Sandt-Duguay, Emmanuel	AGHAMM	x	
Senay, Caroline	DFO – Science	x	x
Simard, Émilie	DFO – Science	x	x
Spingle, Jason	FFAW/UniFor	x	x
Tilley, Anna	Province of NL	x	x
Tremblay, Yan	UAPAN	x	

SOURCES OF INFORMATION

This Science Advisory Report is from the regional advisory meeting of February 23-24, 2021 on the Assessment of the Gulf of St. Lawrence (4RST) Greenland halibut. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

Blais, M., Galbraith, P.S., Plourde, S., Devine, L., and Lehoux, C. 2021. Chemical and Biological Oceanographic Conditions in the Estuary and Gulf of St. Lawrence during 2019. DFO Can. Sci. Advis. Sec. Res. Doc. 2021/002. iv + 66 p.

Bourdages, H., Marquis, M.C., Ouellette-Plante, J., Chabot, D., Galbraith, P., and Isabel, L. 2020. Assessment of northern shrimp stocks in the Estuary and Gulf of St. Lawrence in 2019: commercial fishery and research survey data. DFO Can. Sci. Advis. Sec. Res. Doc. 2020/012. xiii + 155 p.

DFO. 2018. Assessment of Greenland Halibut in the Gulf of St. Lawrence (4RST) in 2017. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2018/035.

DFO. 2020. Update of stock status indicators for Greenland Halibut in the Gulf of St. Lawrence (4RST) in 2019. DFO Can. Sci. Advis. Sec. Sci. Resp. 2020/005.

Duplisea, D. E., Roux, M.-J., Hunter, K. L., and Rice, J. 2021. Fish harvesting advice under climate change: A risk-equivalent empirical approach. PLoS ONE 16(2): e0239503.

Dupont-Prinet, A., Vagner, M., Chabot, D., and Audet, C. 2013. Impact of hypoxia on the metabolism of Greenland Halibut (*Reinhardtius hippoglossoides*). Can. J. Fish. Aquat. Sci. 70: 461–469.

Galbraith, P.S., Chassé, J., Shaw, J.-L., Dumas, J., Caverhill, C., Lefaivre, D., and Lafleur, C. 2020. Physical Oceanographic Conditions in the Gulf of St. Lawrence during 2019. DFO Can. Sci. Advis. Sec. Res. Doc. 2020/030. iv + 84 p.

Gauthier, J., Marquis, M.-C., Bourdages, H., Ouellette-Plante, J. and Nozères, C. 2020. Gulf of St. Lawrence (4RST) Greenland Halibut Stock Status in 2018: Commercial Fishery and Research Survey Data. DFO Can. Sci. Advis. Sec. Res. Doc. 2020/016. v + 127 p.

Ghinter, L., Lambert, Y., and Audet, C. 2021. Juvenile Greenland halibut (*Reinhardtius hippoglossoides*) growth in the context of rising temperature in the Estuary and Gulf of St. Lawrence. Fish. Res. 233.

Lavoie, D., Lambert, N., Rousseau, S., Dumas, J., Chassé, J., Long, Z., Perrie, W., Starr, M., Brickman, D., and Azetsu-Scott, K. 2020. Projections of future physical and biochemical conditions in the Gulf of St. Lawrence, on the Scotian Shelf and in the Gulf of Maine using a regional climate model. Can. Tech. Rep. Hydrogr. Ocean Sci. 334: xiii + 102 p.

Senay, C., Ouellette-Plante, J., Bourdages, H., Bermingham, T., Gauthier, J., Parent, G., Chabot, D., and Duplisea, D. 2021. Unit 1 Redfish (*Sebastes mentella* and *S. fasciatus*) stock status in 2019 and updated information on population structure, biology, ecology, and current fishery closures. DFO Can. Sci. Advis. Sec. Res. Doc. 2021/015. xi + 119 p.

Stortini, C.H., Chabot, D. and Shackell, N.L. 2016. Marine species in ambient low-oxygen regions subject to double jeopardy impacts of climate change. Global Change Biology. 23, 2284–2296.

Youcef, W. A., Lambert, Y. and Audet, C. 2015. Variations in length and growth of Greenland Halibut juveniles in relation to environmental conditions. Fish. Res. 167, 38–47.

THIS REPORT IS AVAILABLE FROM THE:

Center for Science Advice (CSA)
Quebec Region
Fisheries and Oceans Canada
Maurice Lamontagne Institute
850 route de la Mer
P.O. Box 1000
Mont-Joli (Quebec)
Canada G5H 3Z4

Telephone: (418) 775-0825
E-Mail: bras@dfo-mpo.gc.ca
Internet address: www.dfo-mpo.gc.ca/csas-sccs/

ISSN 1919-5087
ISBN 978-0-660-38496-2 Cat. No. Fs70-6/2021-017E-PDF

Correct Citation for this Publication:

DFO. 2021. Assessment of the Gulf of St. Lawrence (4RST) Greenland halibut stock in 2020. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2021/017.

Aussi disponible en français :

MPO. 2021. Évaluation du stock de flétan du Groenland du golfe du Saint-Laurent (4RST) en 2020. Secr. can. de consult. sci. du MPO, Avis sci. 2021/017.