ASSESSMENT OF THE GULF OF ST. LAWRENCE (4RST) GREENLAND HALIBUT STOCK IN 2018

Greenland Halibut (Reinhardtius hippoglossoides)
Photo : Claude Nozères, DFO.

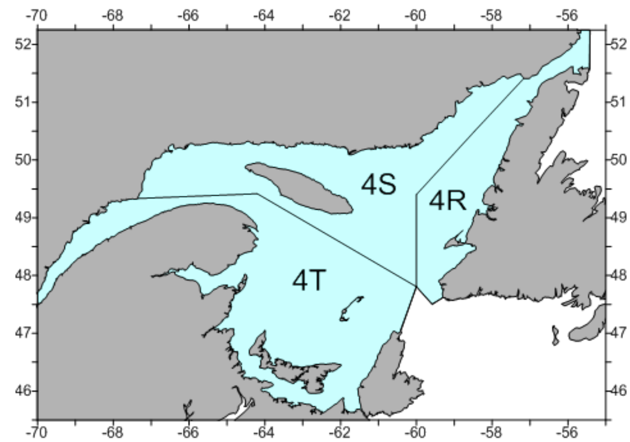

Figure 1. Management zone for Gulf of St. Lawrence Greenland Halibut, NAFO Divisions 4RST.

Context:

Until the mid-1970s, Greenland Halibut (commonly called black Halibut or turbot) from the Gulf of St. Lawrence (4RST) (Figure 1) were not subjected to any directed fishery. At the end of the 1970s, a Greenland Halibut fishery developed using gillnets and bottom trawls. Since the closure of the Atlantic cod mobile gear fishery in 1993, any mobile gear directed fishery for Greenland Halibut has been prohibited. This fishery is currently carried out by boats equipped with gillnets, whose home ports are mainly located in Quebec or on the west coast of Newfoundland.

Since the closure of the mobile gear fishery, part of the total allowable catch (TAC) allocated to that fleet has been transferred to the fixed gear fleet, while the other part is no longer fished. In this document the term fishing allocation is used to indicate the portion of the TAC that can be captured by fixed gear fleet.

The fishery is subject to several management measures including catch control by a TAC to limit the exploitation of the stock and a minimum size of 44 cm which aims to protect the reproductive potential of the population.

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

The present science advisory report results from the peer review meeting on the Assessment of the Gulf of St. Lawrence Greenland Halibut stock (4RST) held February 20th and 21st, 2019 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 Greenland Halibut in the Gulf of St. Lawrence was reduced by 25% in 2018-2019 following fourteen years at 4,500 t. Landings totaled 1,496 t (preliminary as of December 31, 2018), well below the fishing allocation of 2,813 t. These landings are the lowest of the last 16 years.
- Across the Gulf, gillnet fishing effort has been stable since 2015 and below the series average. In 2018, fishing effort increased in northern Anticosti and Esquiman while decreasing in the western Gulf.
- The commercial fishery performance index for the entire Gulf shows a downward trend, with a 48% decrease in 2018 from the 2014-16 peak, reaching the low values observed at the beginning of the series. In 2018, the Northern Anticosti and Esquiman indices improved relative to the lowest values of 2017.
- The biomass indices for fish over 40 cm from DFO's mobile surveys and the sentinel fisheries program show a downward trend over the past decade. These decreases are 62% and 77% respectively, compared to the peak observed in the mid-2000s. The biomasses estimated in 2018 were similar to those of 2017.
- At the Gulf scale, the exploitation rate indicator has remained near the series average in 2018. This indicator is decreasing in the western Gulf area and increasing in northern Anticosti and Esquiman.
- The 2013 cohort, abundant at 1 year, has displayed a lower than expected growth rate. The abundance of this cohort has declined significantly and its contribution to the fishery could be much smaller than expected. The abundance of the 2017 cohort was above average in 2018.
- The Gulf of St. Lawrence Greenland Halibut stock status indicator was in the cautious zone of the proposed precautionary approach in 2018.
- Warming and oxygen depletion of the deep waters of the Gulf of St. Lawrence could result in habitat loss and habitat quality degradation for Greenland Halibut. Furthermore, the arrival of three exceptionally strong cohorts of redfish (2011 to 2013) could increase interspecific competition. These ecosystem conditions are not expected to improve in the short term.
- Given the stock status indicators and ecosystem conditions, a reduction in the exploitation rate may be necessary to promote stock recovery.

INTRODUCTION

Overview of oceanographic conditions and the ecosystem

The ecosystem of the Gulf of St. Lawrence (GSL) has undergone significant changes in recent decades. Deep waters have been warming and dissolved oxygen levels have decreased. In 2018, the water temperature at 150, 200 and 300 m remained above normal. A new temperature record of 6.39°C was reached at 300 m, almost 1°C higher than the average temperature of 5.48 °C for the period 1981-2010. Dissolved oxygen level in bottom waters has decreased significantly in the GSL estuary and deep channels. The lowest levels are found in the deep waters of the St. Lawrence Lower Estuary, the main nursery area for Greenland Halibut. The current levels are the lowest observed over the last 90 years and correspond to values of less than 18% saturation. Recent scientific work has shown that increased deep-water temperature and oxygen depletion could result in habitat loss for Greenland Halibut (*Reinhardtius hippoglossoides*). The GSL's deep water temperatures are forecast to remain high over the next few years. Greenland Halibut is a cold water species and these conditions could be unfavorable to it.

In the 1980s, the northern Gulf of St. Lawrence (nGSL) ecosystem was dominated by groundfish. In the early 1990s, this ecosystem experienced a collapse of major groundfish stocks including Atlantic Cod and Redfish. This decrease in large predators favored an increase in forage species including different shrimp species (Figure 2). Greenland Halibut biomass increased at the same time as Northern Shrimp (*Pandalus borealis*) while the abundance of large groundfish declined (Figure 2). In recent years, there has been a simultaneous decrease in the abundance of shrimp species and Greenland Halibut, while the groundfish biomass, dominated by the massive arrival of redfish, is increasing.

The arrival of three unusually abundant cohorts (2011 to 2013) of Redfish could result in, and/or contribute to, intensifying interspecific competition interactions for food resources or for habitat with Greenland Halibut in the nGSL ecosystem. These species share common prey in their diet, including Northern Shrimp and Pink Glass Shrimp (*Pasiphaea multidentata*). The abundance of Redfish is at the highest level ever observed in the GSL and since they are long-lived species, they will share the ecosystem with Greenland Halibut in the short and medium term. Overall, the ecosystem conditions in GSL indicate that the structure of this ecosystem is changing, which could be favorable for some species such as Redfish but unfavorable for other species such as Northern Shrimp and Greenland Halibut.

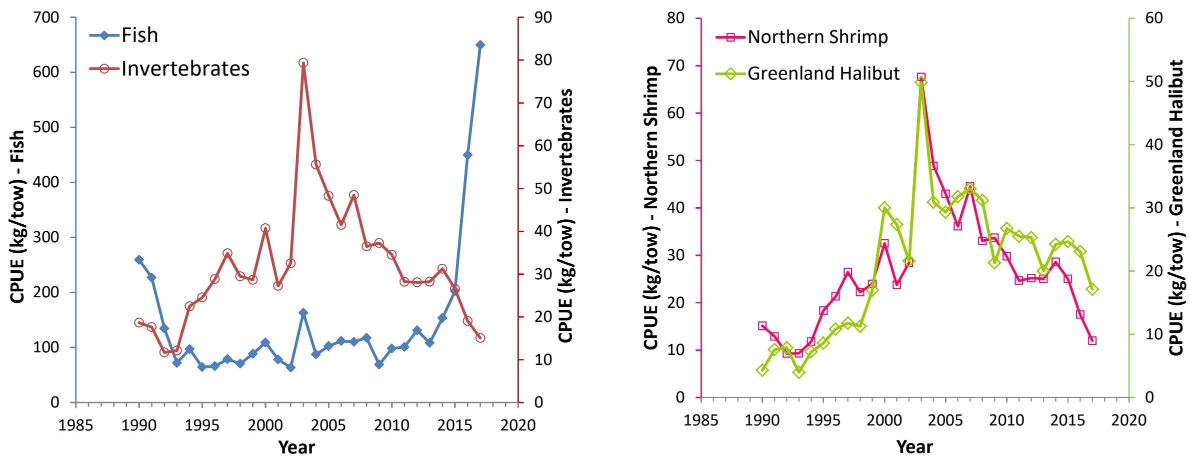

Figure 2. Estimated biomass indices (kg/tow) from nGSL DFO's survey of the main groundfish and invertebrates (left) and of the Greenland Halibut and Northern Shrimp (right) in the nGSL.

Biology

In the early 1990s, parasite studies concluded that Greenland Halibut population of the GSL (Figure 1) is an isolated stock, distinct from the main population of the northwestern Atlantic found east and west of the Grand Banks of Newfoundland. These studies concluded that GSL Greenland Halibut stock completes its life cycle within the Gulf.

Spawning occurs in winter between January and March, in the depths of the Laurentian Channel southwest of Newfoundland. Greenland Halibut produces large eggs (3,4 – 4,7 mm in diameter) and is characterized by low fecundity. This fish spawns only once a year and studies indicate that some individuals may not breed each year. The eggs, released and fertilized near the bottom, spend about 30 days in the water column before hatching within 50 meters 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 at about 36 cm compared to 46 cm for females. Growth decreases after reaching sexual maturity. As a result, there is a sexual dimorphism in Greenland Halibut 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 diet of the Greenland Halibut varies depending on its size. The diet of individuals under 20 cm in length consists of zooplankton, like hyperiid amphipods, krill, and other invertebrates. As Greenland Halibut grow, their diet begins to comprise mainly fish and shrimp. The dominant fish species in the diet is capelin. In recent years (2015-2018), redfish have become more important in the diet of Greenland Halibut longer than 30 cm. Individuals longer than 40 cm consume mainly shrimp, herring, small demersal fish, redfish and capelin. The main predators of Greenland Halibut are seals (Harp Seals (*Phoca groenlandica*), Hooded Seals (*Cystophora cristata*), Grey Seals (*Halichoerus grypus*)) and Atlantic Halibut (*Hippoglossus hippoglossus*).

Greenland Halibut in the Gulf of St. Lawrence

Data from the DFO research survey indicate that Greenland Halibut occupy more than 85,000 km^2 in the nGSL and 95% of its biomass is concentrated over less than 50,000 km^2. It is mainly found in the channels at depths ranging between 200 and 400 m (Figure 3), where bottom temperatures typically range from 4.4 and 5.7°C. Compared to other Atlantic populations, the Gulf population lives in the warmest waters. Greenland Halibut is generally associated with the channels where sediments are fine and consolidated. Juveniles are predominantly found in the Estuary and north of Anticosti, generally at shallower depths than adults. In August, an average of 22% of Greenland Halibut are found in the Estuary.

Information from the DFO surveys indicates that Greenland Halibut continue to occupy the same depths in the GSL despite the temperature increase since 2010. This increase is most pronounced in the Esquiman area where the median temperature has increased from 5°C to 6.6°C between 2010 and 2018.

The fishery

Until the mid-1970s, landings of Greenland Halibut in the GSL were mainly bycatch by trawlers directing for shrimp or groundfish (Figure 4). The largest landings exceeded 8,000 t in 1979 and 1987. These large landings were followed by steep declines.

The TAC remained fixed at 4,500 t with a fixed gear Greenland Halibut fishery allocation of 3,751 t between the management years 2004-2005 (May 15 of the current year to May 14 of the next year) and 2017-2018. This fishing allocation was completely fished annually until the 2011-2012 fishing season. In 2018, following a comprehensive assessment of the state of the Greenland Halibut stock in an intervening year, the TAC was reduced by 25% for the 2018-19 fishing season to 3,375 t (Table 1; Figure 4). For this most recent fishing season, landings totaled 1,496 t (preliminary as of December 31), on a fishing allocation of 2,813 t. These landings represent 53% of the fishing allocation and are the lowest of the last 16 years.

Based on the data available for the 2019 stock assessment, the number of active harvesters in the directed Greenland Halibut fishery decreased between 2014 and 2018, from 85 to 56 in Quebec and from 67 to 29 in Newfoundland. Several factors including management measures may explain this decrease. Fishery management measures include the imposition of a minimum mesh size of 152 mm (6.0 in) and a minimum size for Greenland Halibut of 44 cm in commercial catches as part of a small fish protocol. Harvesters 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 mandatory since 2013 on all vessels except those in the Newfoundland under 35 feet fleet. This fleet accounts for less than 5% of annual landings in the Greenland Halibut directed gillnet fishery. Some harvesters have individual quotas while others are part of a competitive fishery.

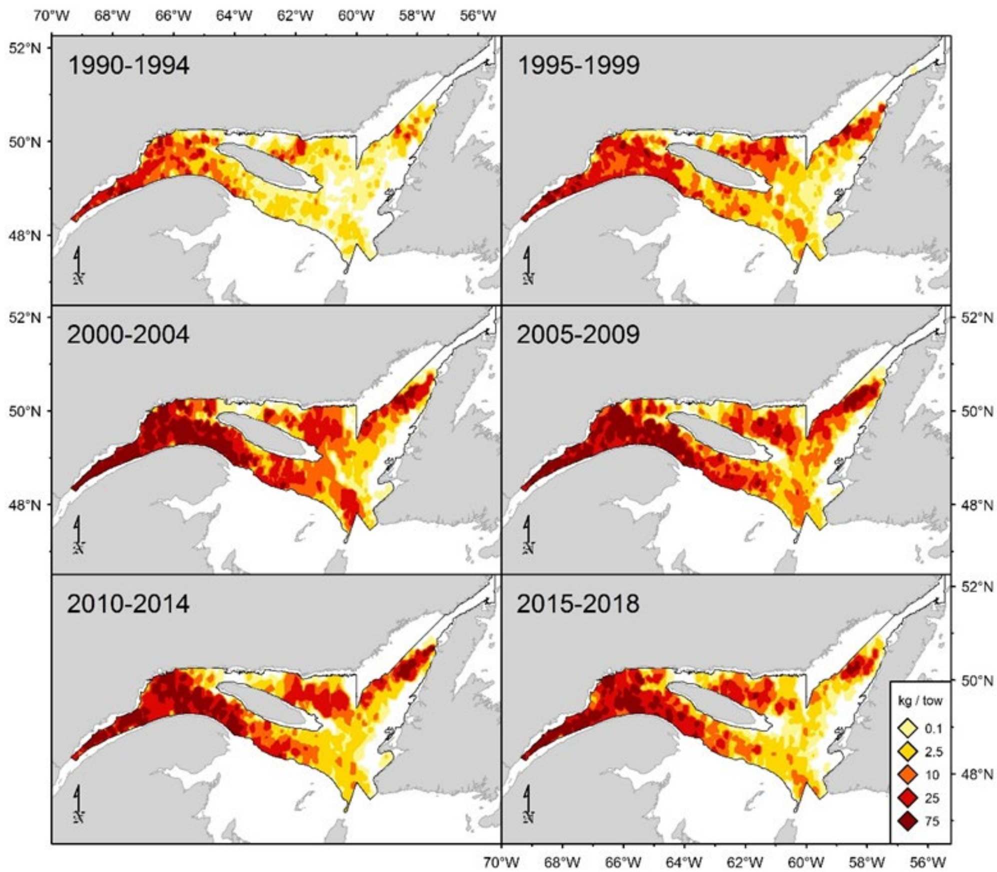

Figure 3. Greenland Halibut catch rates (kg/15 minutes tow) distribution during the nGSL DFO survey.

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

	Gear			
Period	Fixed	Mobile	Total	TAC
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	4,500
2017-2018[1]	1,751	16	1,767	4,500
2018-2019[1]	1,482	13	1,496	3,375

Preliminary data as of December 31st 2018.

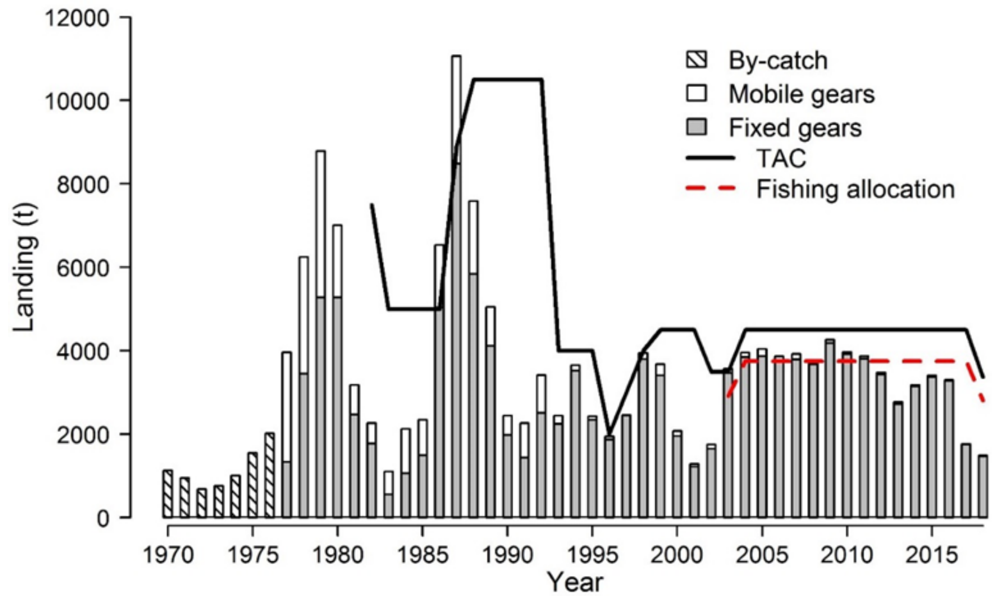

Figure 4. Reported landings (t) for the Greenland Halibut since 1970, and total allowable catch (TAC). In 2000, the management year was changed from the calendar year to the quota year (May 15 of the current year to May 14 of the following year). 2017 and 2018 data are preliminary. Fishing allocation for the fixed gear fishery (red dotted line) was 2,813 t for the 2018-2019 fishing season.

RESOURCE ASSESSMENT

Sources of information

The Greenland Halibut (4RST) stock status assessment is based primarily on the analysis of commercial fishery and research survey data. The fishery data come from four sources of information: purchase slips, the weight of the landings measured 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 1995-2018) and the second in August by DFO (nGSL 1990-2018). A third survey conducted by DFO in September in the southern Gulf of St. Lawrence (sGSL, 1971-2018) was also considered for this assessment. These three surveys are conducted using bottom trawls according to a stratified random sampling design. When sampling commercial catches and during research surveys, fish are measured and sexed. In addition, data on maturity stage and condition of fish are collected during the DFO nGSL survey.

Commercial fishery fishing effort and catches

The directed gillnet fishery occurs in three main areas: western GSL, northern Anticosti and Esquiman. Over the 2000-2018 period, the proportion of the effort deployed in each of these sectors was respectively 67, 6 and 24%.

For the entire GSL (4RST), fishing effort has been stable since 2015 with nearly 129,000 gillnets deployed annually, below the 1999-2017 series average (Figure 5). Landings that had fallen by nearly 50% between 2016 and 2017 were down further in 2018, totaling 1,482 t. These are the lowest landings since 2002.

In 2018, there was a shift in fishing effort from the western GSL to north Anticosti. The proportion of fishing effort deployed in the western GSL decreased from 80% to 56% between 2017 and 2018. Landings were also down 69% compared to 2016, from 2,723 t to 840 t. These were the lowest landings recorded for this sector since 2002.

The northern Anticosti sector is sporadically frequented by Greenland Halibut harvesters. This sector experienced an increase in effort and landings from 2006 to 2009, followed by high and sustained effort and landings between 2009 and 2013. This sector was then abandoned until 2018, when landings totaled 210 t for a fishing effort of more than 15,700 nets (Figure 5).

Landings in the Esquiman sector increased significantly from the late 1990s to the early 2010s, peaking in 2011-2012. They then dropped, despite a sustained level of effort. In 2018 fishing effort and landings were up compared to 2017 but they were still below the average of their respective series (Figure 5).

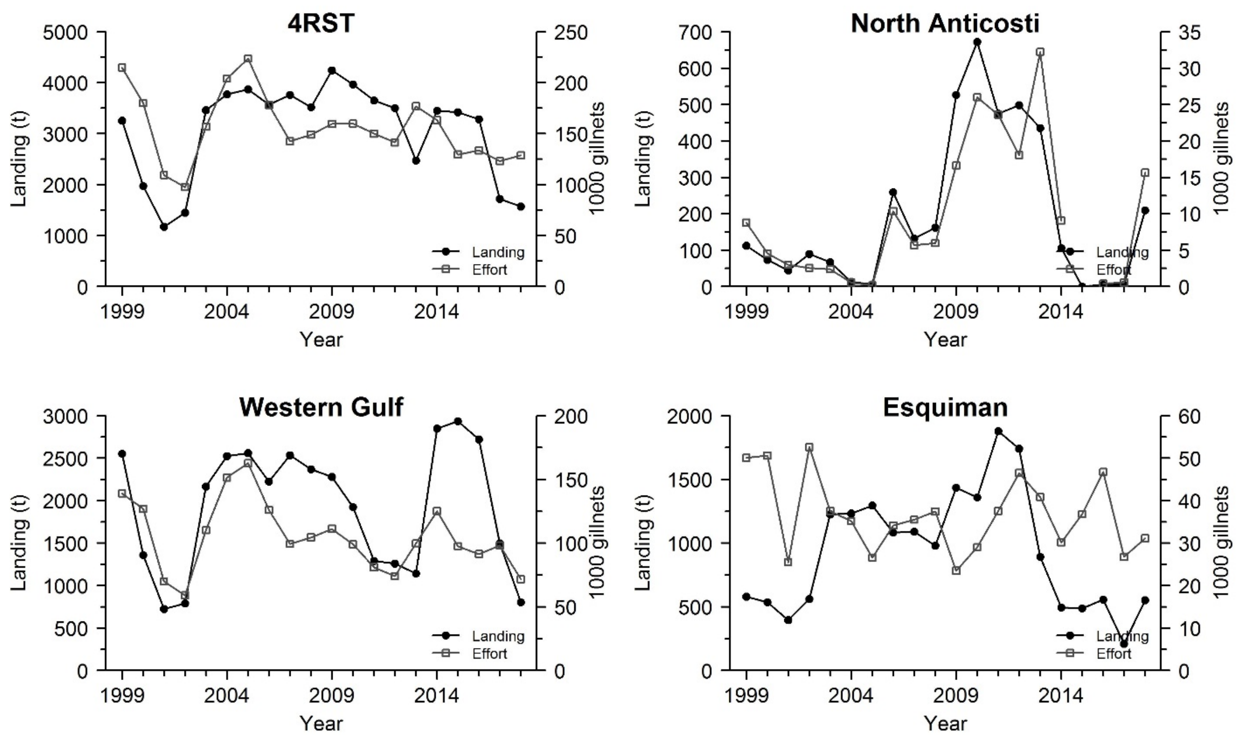

Figure 5. Landing (t) and fishing effort (number of gill nets) for the Gulf (4RST) and by fishing area: western Gulf, northern Anticosti and Esquiman

Commercial fishery performance

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 account for the effects of NAFO subareas, immersion time, and seasonal patterns. Between 2016 and 2018, the GSL (4RST) CPUE decreased by almost 50%, and has been below the 1999-2017 series average since 2017 (Figure 6). In the Western GSL sector, the CPUE index decreased by 66% from the historical highs of 2015 and 2016 and has been below the series average since 2017. In the North Anticosti and Esquiman sectors, the index has been below the average of each series since 2013, increasing in 2018 compared to 2017.

It is worth noting that seasonal patterns in daily CPUE values can vary amongst years in certain sectors, such as in the western GSL. In some years, the daily CPUE in the western GSL sector remained fairly stable over the entire fishing season (2011-2012 and 2016-2017). In other years, the daily CPUE showed a general downward trend from the beginning to the end of the fishing season (2012-2013 and 2017-2018). Finally, in some years, such as 2014-2015 and 2018-2019, CPUE generally increased over the entire fishing season.

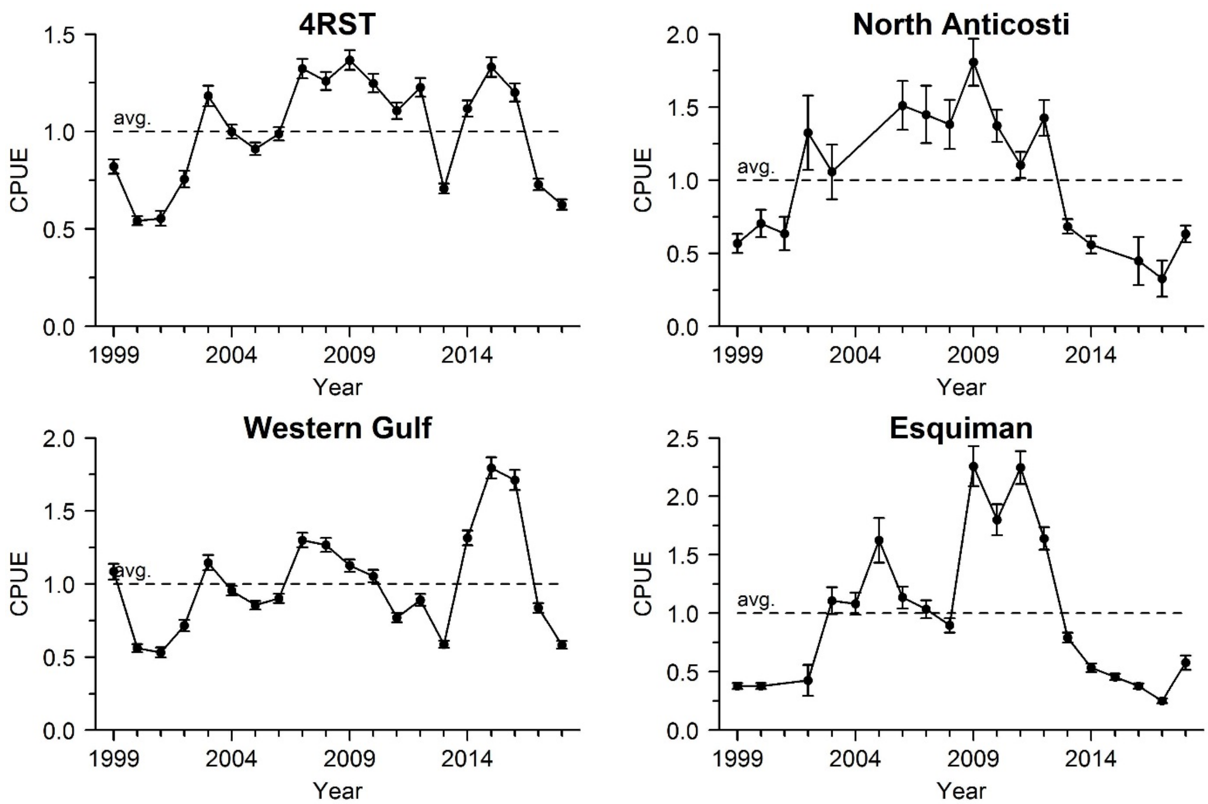

Figure 6. Commercial fishery performance indices (standardized CPUE) for the Gulf of St. Lawrence (4RST) and by fishing sector. The dotted lines represent series averages.

Length composition of fish in commercial fishery catches

The average length of Greenland Halibut caught in the commercial fishery increased steadily from 2002 to 2012, from 44.8 cm to 48.8 cm (Figure 7). This increase is due, among other things, to the growth of the large cohorts of 1997 and 1999, which made up a large part of the catches. Between 2012 and 2016 this size fluctuated, before returning to a value comparable to that of 2012, the largest sizes of this series. The average size subsequently decreased and was 47.8 cm in 2018, slightly above the average of 47.2 cm.

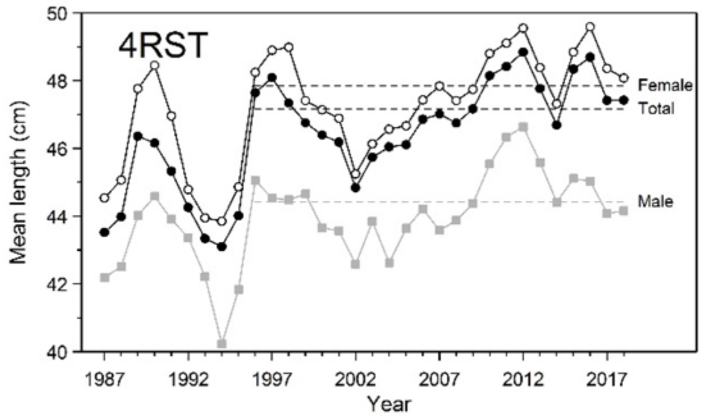

Figure 7. Average length of fish caught in the commercial gillnet fishery. The horizontal dashed lines indicate the average for each series. The regulatory mesh size in the commercial fishery increased from 5.5 to 6 inches in 1996.

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, and remained relatively stable at the average level from 2004 to 2014. Subsequently, the L_{50} decreased to reach the lowest value of the series in 2016 for both sexes (Figure 8). The L_{50} for males and females has been below the average of their respective series since 2015. The values for 2018 were 41.8 cm for females (average of 46 cm) and 34.3 cm for males (average of 36 cm). Given that growth rate decreases after reaching sexual maturity, a larger proportion of females compared to males reaches the commercial size of 44 cm. In 2018, the proportion of females in commercial catches was close to 83%, a percentage comparable to the average of the 1996-2017 series.

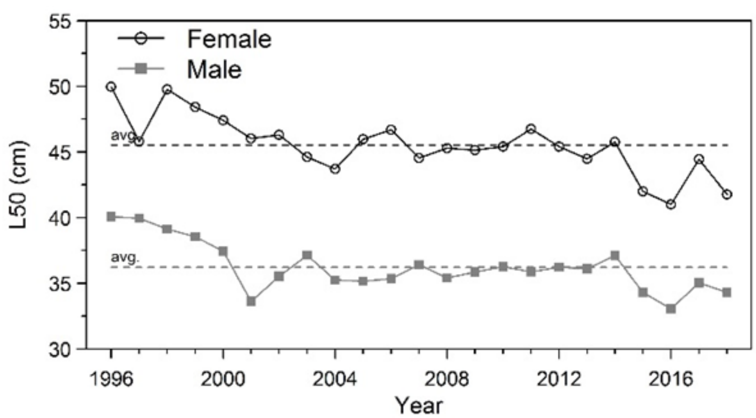

Figure 8. Size at which 50% of Greenland Halibut caught during the nGSL DFO research survey were sexually mature (L_{50}). The horizontal dotted lines indicate the average of each series.

Recruitment

The recruitment index at age 1 is defined as the abundance of 12 cm to 21 cm fish caught in the nGSL survey. According to estimates of average growth, females and males reach the commercial size of 44 cm at the age of 6 and 7 years, respectively.

The recruitment index has varied greatly from year to year (Figure 9). The cohorts from 2014 to 2016 were of medium or low abundance, while that of 2017 is of high abundance.

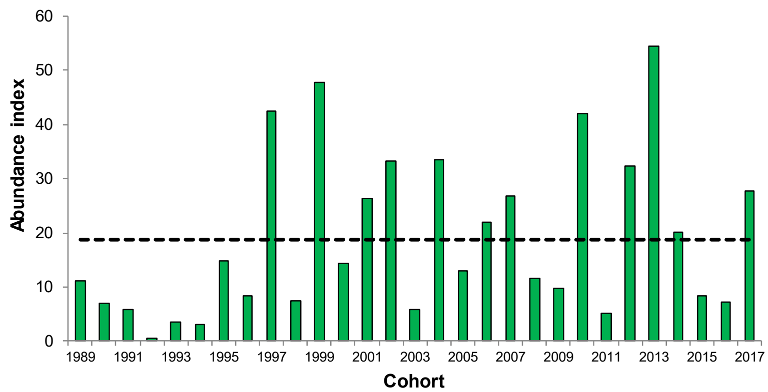

Figure 9. Annual recruitment index (number per tow). Abundance of Greenland Halibut determined for each cohort at age 1 during the nGSL DFO research survey. The dashed line indicates the series average.

Growth and size structure

There are marked differences in the size composition of Greenland Halibut caught during the DFO nGSL survey and MSP survey. The selectivity of trawls used in these surveys explains some of the differences. The DFO survey uses a smaller mesh size, allowing for more effective sampling of small, 1-year-old individuals (~16 cm) (Figure 10, left). Conversely, the MSP samples a higher proportion of large individuals (Figure 10, right). Moreover the MSP does not cover the estuary, which is the main nursery for Greenland Halibut.

Figure 10 shows the arrival and growth of two very large cohorts in the history of this stock, that of 1997 (modal size ~ 16 cm at 1 year in 1998) and that of 1999 (modal size ~ 16 cm at 1 year in 2000). The fish from these cohorts contributed to the significant increase in stock abundance in the 2000s and supported the fishery for several years. Other abundant cohorts including the 2001, 2004, and 2007 cohorts also contributed to the exploitable biomass. In more recent years, the 2010 cohort generated a significant biomass of >40 cm in 2014, increasing the catch rates of the commercial fishery from 2014 to 2016. The entry of the 2010 cohort into the fishery is also seen in the decreasing size of fish in commercial catches in 2014 (Figure 7).

The 2013 cohort (Figure 9 and Figure 10, which measured ~16 cm at 1 year in 2014) appeared to be the most abundant cohort in recent stock history. It was preceded by a large cohort (2012) and followed by a cohort of intermediate abundance (2014). A scenario similar to that of the late 1990s when the strong cohorts of 1997 and 1999 led to a significant increase in the abundance of this stock were expected. Instead, growth rates for the 2013 cohort were particularly low. In Figure 10, the blue dashed lines indicate the expected sizes for the 1, 2 and 3 year old fish. At two years of age in 2015, the 2013 cohort only reached a modal size of 21 cm compared to the expected 27 cm. This represents a reduction in growth of about 45%. This is the first time in more than 25 years that such a reduction in growth has been observed. The length frequency distribution also indicates that the abundance of fish over 40 cm has decreased since 2009 and fish of these sizes have been rare since 2015.

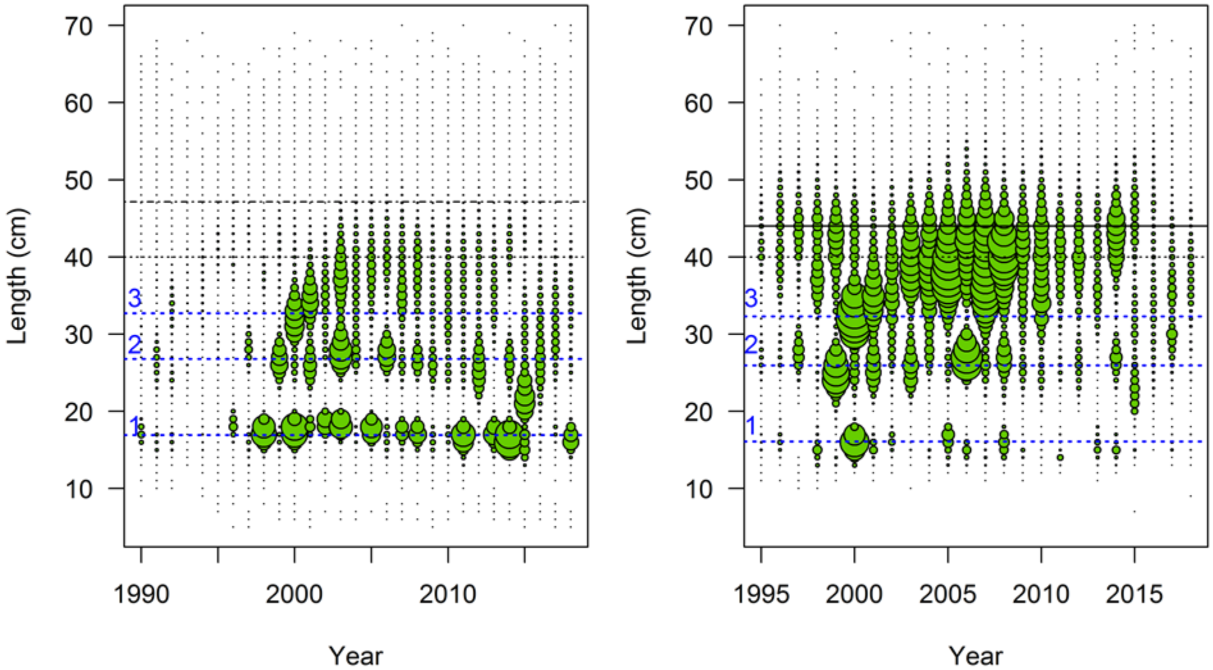

Figure 10. Length frequency distributions for Greenland Halibut from the nGSL DFO survey (mean number per 15-minute tow) (left) and the MSP survey (mean number per 30-minute tow) (right). The horizontal dotted blue lines indicate the expected average length for fish of 1 , 2 and, 3 years. The solid black lines indicate commercial size (44 cm), while the dotted black lines delimit the > 40 cm size class.

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 (> 5 years) (Figure 11). The condition of 1-year-old fish fluctuated from 1990 to 2018, 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, 2012-2014 (Figure 9) which had Fulton indices below the average of the 15 cm series (2013-2015) (Figure 11). Fish from these cohorts maintained low condition indices (series 25 cm, 35 cm and 45 cm from 2015 to 2017). Another factor that could affect the condition of the recent cohorts of Greenland Halibut is a possible competition for food and habitat with the mass arrival of juvenile redfish in the Gulf of St. Lawrence between 2011 and 2013. In 2018, the condition index of 15 and 25 cm fish is comparable to the average of their series while condition of 35 and 45 cm fish is slightly below the average of their respective series.

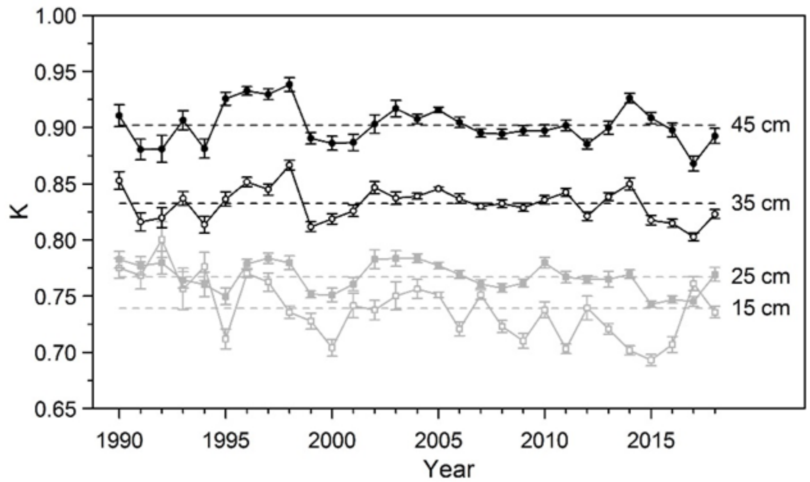

Figure 11. Fulton condition index by year for Greenland Halibut of 15, 25, 35 and 45 cm measured during the nGSL DFO survey. The dotted lines represent the respective series average.

Stock status indicators

Trends in abundance indices (mean numbers per tow) of Greenland Halibut in the DFO nGSL survey and MSP survey vary by size class and slightly between surveys (Figure 12). Abundance indices for the 0-20 and 20-30 cm size classes increased significantly in the late 1990s, fluctuating around the long-term average since then in the DFO survey, and fluctuating below average for the past 10 years in MSP survey. For larger fish, abundance indices increased to the early (30-40 cm fish) or mid-2000s (> 40 cm fish), and declined subsequently. Based on typical growth estimates for individuals in this stock, fish from the high abundance cohorts of 2010, 2012, and 2013 would normally reach a modal size of approximately 49, 43, and 40 cm in 2018. A significant increase in fish abundance in the >40 cm size class was therefore expected but did not occur (Figure 12).

Biomass indices for > 40 cm fish in the nGSL DFO survey and MSP survey have shown a declining trend over the past decade (Figure 13). This represents a decrease of 62% and 77%, respectively, compared to the peaks observed in the mid-2000s. The biomasses estimated in 2018 were similar to those of 2017. The sGSL DFO survey shows a trend similar to that of the surveys carried out in the nGSL for the period common to all of these surveys (Figure 13). In addition, the sGSL survey indicates that in the 20 years prior to the nGSL survey, from 1971 to 1989, the Greenland Halibut biomass >40 cm was low.

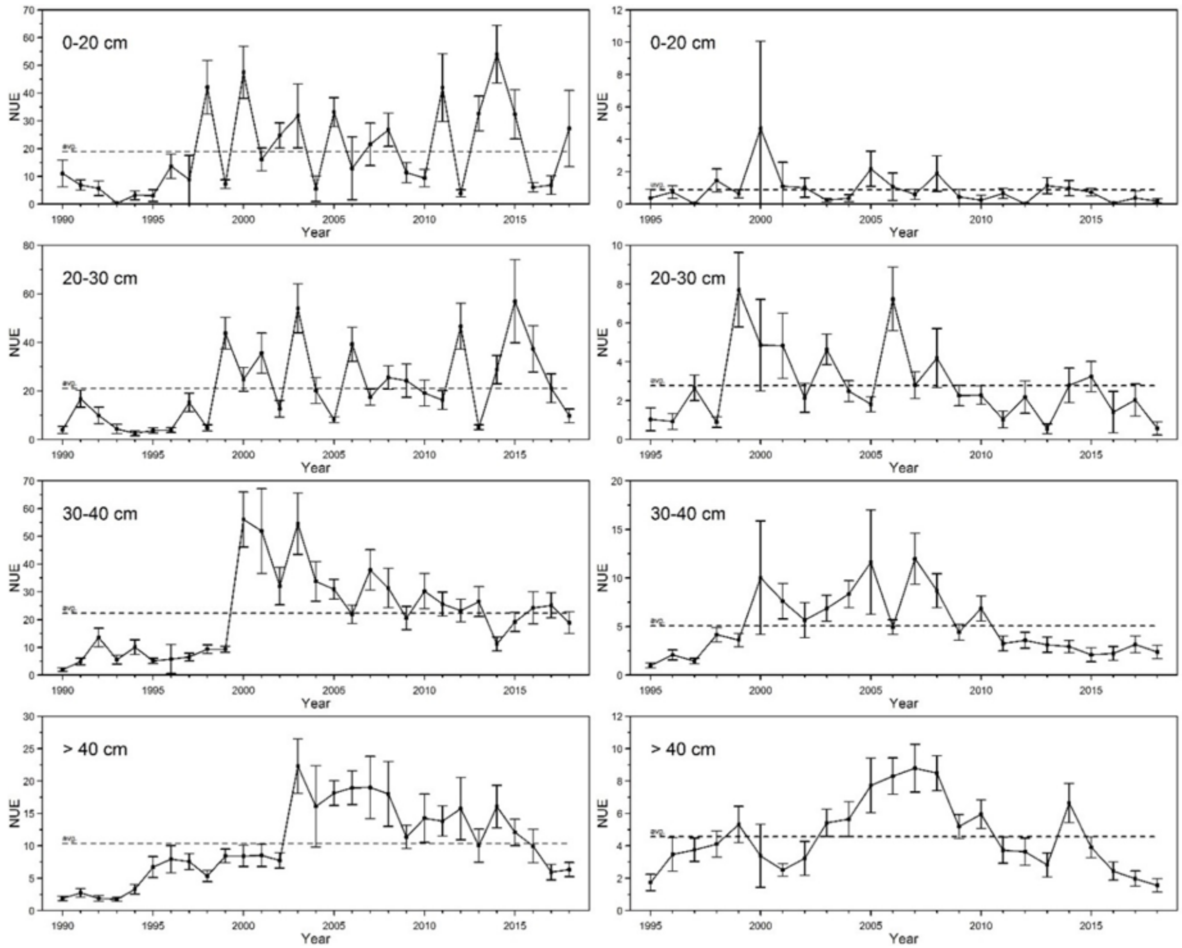

Figure 12. Abundance indices (mean number per tow) for Greenland Halibut for the different size categories observed in the nGSL DFO survey (Left) and in the MSP survey (Right). The dotted lines indicate the average of each series.

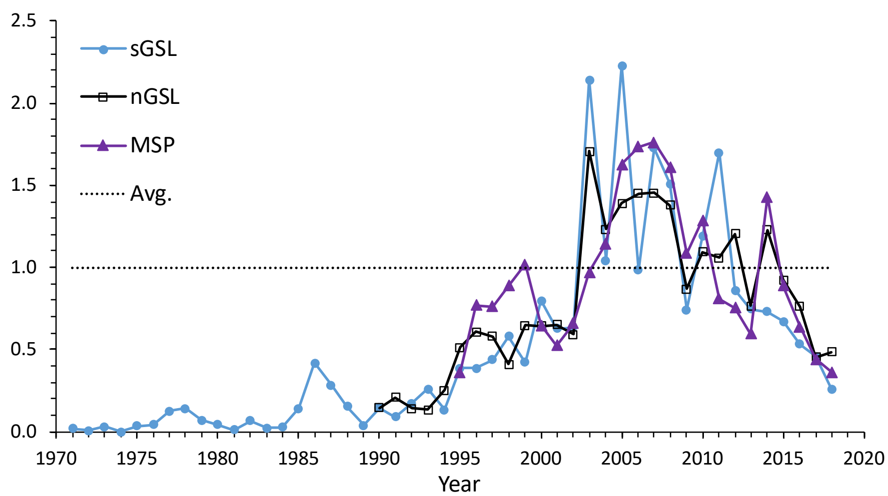

Figure 13. Standardized biomass indices for Greenland Halibut greater than 40 cm from the DFO southern (sGSL) and northern (nGSL) surveys of the Gulf of St. Lawrence and the MSP survey. The dotted line indicates the average.

Exploitation rate indicator

An indicator of the annual exploitation rate was obtained by dividing the weight of the commercial catch by the biomass of fish >40 cm estimated by the nGSL DFO research 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. At the GSL (4RST) scale, the significant decrease in landings in 2017 and 2018 kept the exploitation rate at the 1997-2017 series average level (Figure 14). The period from 2001 to 2008, during which the exploitation rate was below average, corresponds to the period during which the abundance of fish >40 cm increased and remained at a high level (Figures 12 and 14). The period that followed, 2009-present, characterized by an average exploitation rate, corresponds to a period of more or less constant decrease in the abundance of these big fish.

In the western GSL, the exploitation rate indicator increased between 2012 and 2017. Following a significant decrease in landings and a stable level of biomass, the exploitation rate for this sector decreased in 2018 to below the average for the series. The increase in landings in 2018 in the northern Anticosti and Esquiman sectors resulted in an increase exploitation rates to above the average of their respective series.

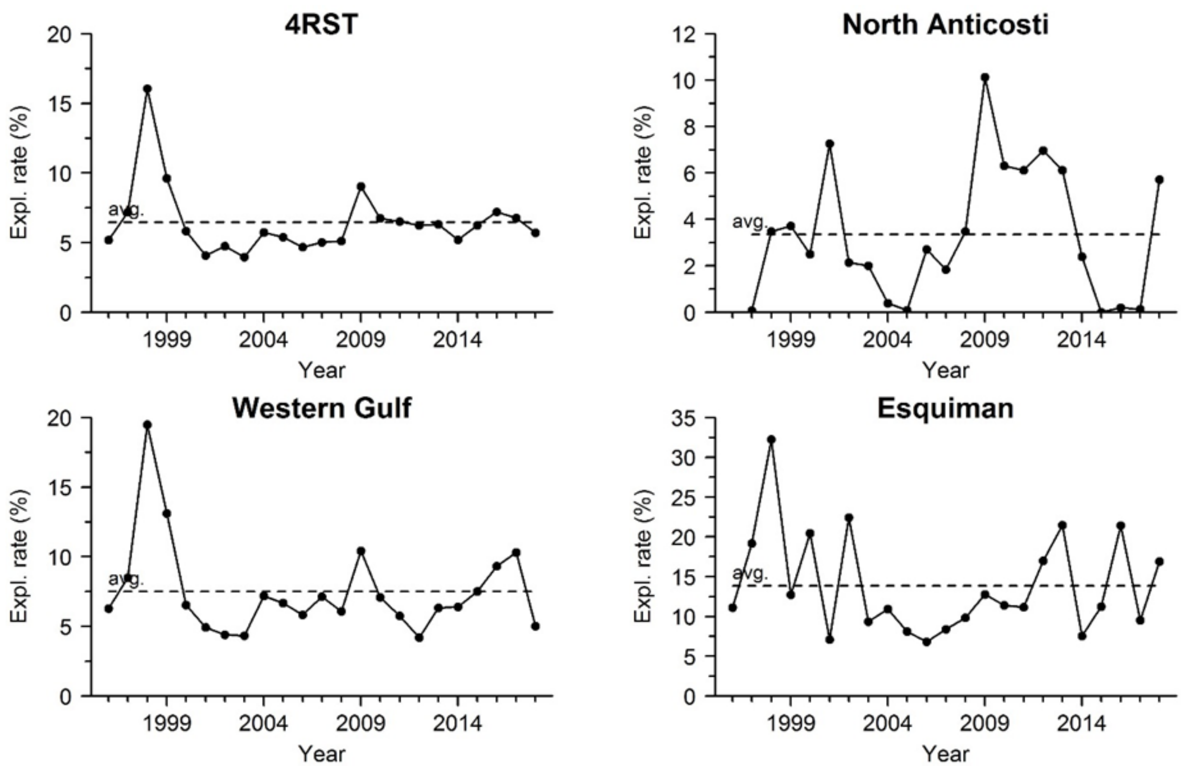

Figure 14. Relative exploitation rates for the Gulf (4RST) and by sector. The dotted lines indicate the respective series averages.

Precautionary approach and reference points

A precautionary approach is being developed for the GSL Greenland Halibut stock. A stock status index has been defined, along with a limit reference point (LRP) (DFO 2017). The biomass of fish >40 cm estimated during the DFO nGSL survey was chosen as the indicator of Greenland Halibut stock status. This indicator corresponds to the longest time series available (1990-2018) and represents a proxy for mature stock biomass. During this period, the stock experienced significant variations in productivity and biomass; these variations are taken into account in the establishment of reference points.

The selected LRP is geometric mean of the stock status indicator for the period 1990 to 1994, which corresponds to the period of lowest population abundance from which recovery of the stock was observed. This LRP has been estimated at 10,000 t (Figure 15).

During the winter 2018 peer review, an upper stock reference (USR) was proposed by the Science Sector. This USR represents 80% of biomass at maximum sustainable yield (B_{msy}). The proposed proxy for B_{msy} is the geometric mean of the indicator for the 2004-2012 productive period, namely 63,211 t, resulting in a USR of 50,500 t. The GSL Greenland Halibut stock is presently in the cautious zone of the proposed precautionary approach. Fishery managers at DFO, with support from the Science Sector, are holding consultations with the fishing industry and other stakeholders to adopt he USR. Harvest control rules for adjusting catches with respect to the reference points are also being developed during these consultations.

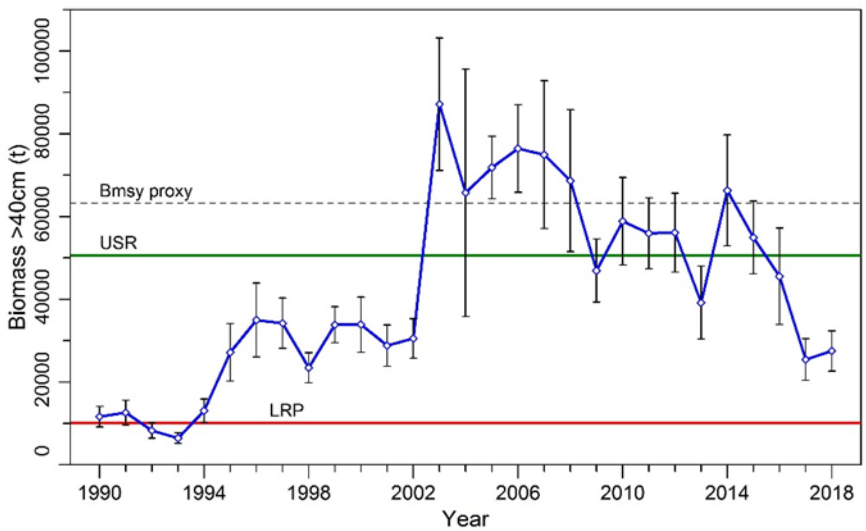

Figure 15. Annual biomass indicator for Greenland Halibut over 40 cm from the DFO survey series. The red horizontal line at the bottom indicates the limit reference point (LRP) as part of the precautionary approach. The LRP is the boundary between the critical and cautious zones. The green horizontal line at the top indicates the upper stock reference (USR) proposed by the Science Sector. The USR is the boundary between the cautious and healthy zones. 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 4RST 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 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 in the DFO survey when this biomass is in the caution 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 from

January to March, the timing of the DFO survey is not ideal for this kind of work. A more detailed histological study would be more appropriate for determining L_{50} for males and females of this species.

Studies have shown that Greenland Halibut can spend more than 25% of its time in the water column. The effect of temperature and oxygen levels on the duration and frequency of these vertical movements is unknown. The annual proportion of fish that may be outside the volume swept by mobile surveys in response to ecosystem changes is unknown. The variable availability of fish in mobile surveys would have implications for catchability and abundance estimates.

Determining the age of GSL Greenland Halibut by reading otoliths is currently not possible. Thus, models of population dynamics, based on length have been examined. However, recent changes in the growth rate of the species have delayed the development of such a model. The development of a population dynamics model would be an asset for assessing the status of this stock.

CONCLUSIONS AND ADVICE

The short-term outlook for the Greenland Halibut stock in the GSL is poor given the observed ecosystem changes, a slowdown in the growth of the 2013 cohort, and decreases in the abundance and biomass indices for fish >40 cm. The decrease in abundance and biomass indices for fish >40 cm corresponds to a period during which the exploitation rates have been higher than in the previous period where the stock rebuilt and remained abundant. This could indicate that the exploitation rates of the last ten years were too high. As a result, a reduction in the exploitation rate seems necessary to stop the decline in the stock and promote its recovery

OTHER CONSIDERATIONS

The GSL ecosystem has undergone significant changes in recent decades. Deep waters have warmed and become poorer in dissolved oxygen. These factors can lead to habitat loss and degradation, and reduced growth for Greenland Halibut. In addition, the arrival of three very abundant cohorts (2011-2013) of Redfish could result in, and/or contribute to intensifying interspecific competitive interactions with Greenland Halibut in the GSL ecosystem. These conditions will continue in the short and medium term.

Bycatch in the Greenland Halibut fishery

Bycatch in the Greenland Halibut gillnet fishery was estimated for the period 2000 to 2018 using data from the at-sea observer program. This fishery captured an average of just over 460 t of bycatch, representing on average 18% of the weight of landings of Greenland Halibut. Nearly one-third of the by-catch is landed, the rest being discarded at sea. A decrease in landings of Greenland Halibut and an increase in bycatch increased this percentage in 2017 and 2018 to 42% and 30% respectively. The most common species were, in order of importance, American Plaice, Snow Crab, Redfish, Thorny Skate, Spiny Crab, Atlantic Halibut, skates and Witch Flounder (Table 2). The occurrence of Redfish and Atlantic Halibut increased in 2017 and in 2018 compared to the series average, reflecting the increased abundance of these species in the GSL ecosystem. Discards at sea include species that can be released by the harvesters such as Dogfish, Atlantic Lumpfish, Hagfish and Atlantic Wolffish; ma ndatory 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 2018 were examined using the at-sea observer database. Greenland Halibut were present on average in 89% 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 2017 are around 91 tons. In 2018, they were estimated at 80 t, representing approximately 0.57% of the biomass of small Greenland Halibut (<30 cm) estimated from the DFO survey.

Table 2. Occurrence and bycatch of the most common species (occurrence > 10%) in the Greenland Halibut directed gillnet fishery in 2017 and 2018 and average values for the period 2000 to 2016.

	Occurrence (%)			Catch (t)		
Taxon	2000-2016	2017	2018	2000-2016	2017	2018
Greenland Halibut*	100	99	100	3 121	1 989	1 755
American Plaice*	77	70	82	37	89	72
Snow Crab	62	45	30	66	19	15
Redfish*	56	87	92	23	65	51
Thorny Skate	50	66	42	58	90	22
Spiny Crab	49	51	41	25	17	9
Atlantic Halibut*	46	65	74	92	150	118
Skates	40	43	55	43	111	46
Witch Flounder*	34	87	52	6	41	19
Anthozoan	23	60	30	6	11	4
Atlantic Cod*	20	26	20	15	34	64
Monkfish*	18	18	24	6	7	8
White Hake	15	35	47	5	40	24
Smooth Skate	15	24	10	9	9	2
Black Dogfish	12	26	13	17	124	36

* Species landed in commercial fisheries.

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SOURCES OF INFORMATION

This Science Advisory Report is from the meeting of February 20-21, 2019 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.

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