Fisheries and Oceans Canada
Pêches et Océans Canada

Ecosystems and Oceans Science
Sciences des écosystèmes et des océans

Canadian Science Advisory Secretariat (CSAS)

Research Document 2019/039

Quebec Region

Gillnet scientific survey in the Saguenay fjord, 2000-2018

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November 2019

Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

Published by:

Fisheries and Oceans Canada
Canadian Science Advisory Secretariat
200 Kent Street
Ottawa ON K1A 0E6

http://www.dfo-mpo.gc.ca/csas-sccs/
csas-sccs@dfo-mpo.gc.ca

ISSN 1919-5044

Correct citation for this publication:

Gauthier, J., Marquis, M.-C., Ouellette-Plante, J. and Nozères, C. 2019. Gillnet scientific survey in the Saguenay fjord, 2000-2018. DFO Can. Sci. Advis. Sec. Res. Doc. 2019/039. iv + 45 p.

Aussi disponible en français :

Gauthier, J., Marquis, M.-C., Ouellette-Plante, J. et Nozères, C. 2019. Relevé de recherche aux filets maillants dans le fjord du Saguenay de 2000 à 2018. Secr. can. de consult. sci. du MPO. Doc. de rech. 2019/039. iv + 46 p.

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ABSTRACT

The status of exploited marine species in the Saguenay Fjord is assessed every two years and is based on various indicators from the recreational winter fishery (1995-2018), a research survey conducted by Fisheries and Oceans Canada (2000-2018) and logbook (2015-2018) data. This document presents the data and methods used to derive indicators from the research survey. Estimates of the number of fish per gillnet (NUE) are presented for each of the four species primarily targeted by the winter groundfish recreational fishery in the Saguenay Fjord: Atlantic redfish (*Sebastes mentella*), Atlantic cod (*Gadus morhua*), Greenland cod (*Gadus ogac*), and Greenland halibut (*Reinhardtius hippoglossoides*) also called turbot. Biological data including size structures and condition indices are presented for the different species. Information on the diet of Greenland halibut is also presented. Oceanographic data collected during scientific surveys are provided for temperature, salinity and oxygen saturation at some stations in the study area.

INTRODUCTION

The Saguenay Fjord (Figure 1) is a fascinating environment where more than 50 species of fish fauna have been identified (Drainville and Brassard 1961; Drainville 1970). Studies published in the late 2000s (Sévigny et al. 2009; Sirois et al. 2009) suggest that groundfish populations in the Saguenay appear to be sink populations whose recruitment depends on the arrival of juveniles from the Estuary and Gulf of St. Lawrence (Bui et al. 2012). Although groundfish reproduction does occur in the Saguenay, larval survival of these species would be compromised by conditions in the warm, brackish surface water layer, preventing a significant local contribution to recruitment, mainly for Atlantic cod (*Gadus morhua*) and redfish (Sirois et al. 2009).

The winter recreational groundfish fishery in the Saguenay Fjord took off in the early 1980s, and the main species caught are, in order of importance, Deepwater redfish (*Sebastes mentella*), Atlantic cod, Greenland cod (*Gadus ogac*) and Greenland halibut (*Reinhardtius hippoglossoides*), also referred to as turbot. As a result of the growing interest in this recreational and tourism activity in the mid-1990s, several stakeholders were concerned about resource conservation and sustainable development of this fishery. In this context, a winter recreational fishery monitoring program was launched in 1995 (Lambert and Bérubé 2002; Gauthier and Marquis 2017; Gauthier 2018). In 2000, Fisheries and Oceans Canada (DFO) also began a gillnet research survey in the Saguenay (Bourdages et al. 2011; Gauthier et al. 2017) with the objective of producing abundance indices of harvested resources that are independent of recreational fishing.

This document provides an update on the data and methods used to produce the research survey indicators that are described in Bourdages et al. (2011). In addition, this document compiles information gathered during the surveys, including temperature, salinity and dissolved oxygen saturation profiles based on depth, as well as biological data on several species. These data were submitted during the peer review on November 21, 2018. For the conclusions on the status of groundfish populations in the Saguenay Fjord, please consult the Science Advisory Report (DFO 2019).

SURVEY DESCRIPTION

Since 2000, the DFO's Regional Science Branch in Quebec has been using Canadian Coast Guard ships (CCGS) to conduct a research survey in the Saguenay Fjord. For the 2003 survey, a commercial fishing vessel, the MV *L'Échourie*, was chartered to carry out the survey (Table 1A). This gillnet survey, conducted annually from 2000 to 2010, has been carried out every two years since. It is conducted in April–May, as soon as possible after the closure of the winter recreational fishery and once the Saguenay Fjord is ice-free. The main objective is to produce stock status indicators for four groundfish species: Deepwater redfish, Greenland halibut, Atlantic cod and Greenland cod. These indicators include the number of fish per unit effort (NUE), as well as biological parameters, such as size structure, weight–length relationship, fish condition indices and diet information.

The location of all stations sampled since 2000 is shown in Figure 2. The sampling plan has varied over the years with the occasional exploration of new sites. In 2010, new statistical analyses were carried out on all survey data (Bourdages et al. 2011), and the conclusions were to focus the study area in the Baie des Ha! Ha! and Bras-du-Nord areas, with each of these areas divided into fishing sectors: Les Battures, Grande-Baie, Anse-à-Philippe and Anse-à-Benjamin for the Baie des Ha! Ha! area and Les Îlots, Cap Jaseux and Saint-Fulgence for the Bras-du-Nord area (Figure 2). All of these sectors are located upstream from the boundary of the Saguenay–St. Lawrence Marine Park (SSLMP).

The number of sets used for the analyses is presented by sector in Table 2. Note that the Saint-Fulgence sector is subdivided into northern and southern sub-sectors, which explains why the number of stations is generally double that of the other sectors. During the analyses, the sets for these sub-sectors are grouped together to form the Saint-Fulgence sector.

The fishing gear used is a bottom gillnet with a mesh size of 140 mm (5.5 inches). A set consists of three nets (Table 1A) and has a total length of approximately 274 m (150 fathoms). The nets are installed on the bottom for a target immersion time of 24 hours at depths ranging mainly from 40 m to 100 m (Table 1A, Figure 3A). The average immersion time for each survey is nearly 24 hours (Table 1A), except for 2002 when a mechanical failure on the vessel delayed the recovery of a series of sets by nine days.

In 2014 and 2016, gillnets with smaller mesh sizes of 38 mm (1.5 inches) and 67 mm (2.63 inches) were also deployed during the survey to obtain information on the presence of juveniles of different species (Table 1B). In 2018, these nets were replaced by experimental nets. Each of these new nets has a total length of 61 m and a height of 2 m. They consist of four sections of 15.24 m with mesh sizes of 51, 76, 102 and 140 mm (2, 3, 4 and 5.5 inches). These nets were deployed in series of three for a total length of 183 metres. The deployment depth of these sets is shown in Table 1B and Figure 3B.

As of 2010, the survey sampling plan includes 10 sets per sector per year for a total of 80 sets per year for gillnets of 140 mm mesh size. The number of sets selected for the analyses ranged from 20 to 86, with an average of 55, and in 2018, it was 72 (tables 1A and 2). For the small-mesh gillnets, no target was set for the number of sets to be deployed. In 2014 and 2016, respectively, 17 and 14 sets of small-mesh nets were deployed (Table 1B). In 2018, nine sets were carried out with the experimental nets.

Since 2014, the deployment of a Sea-Bird SBE19+ probe equipped with an oxygen sensor has made it possible to produce temperature, salinity and oxygen saturation profiles based on depth. The locations of the gillnet sets and water column profile stations for the 2014 to 2018 surveys are shown in Figure 4.

During the surveys, all species caught are identified and counted. The list of species and their numbers are shown in Table 3A for catches in 140-mm mesh nets and in Table 3B for catches in small-mesh and experimental nets. The most common species are Deepwater redfish, Greenland halibut, Atlantic cod and Greenland cod.

For each survey, all specimens are measured and weighed. From 2000 to 2010, the length data collected for fish were total length data. This type of length was chosen to be comparable to the data collected during the winter recreational fishery. The sampling of the biological characteristics of catches in the winter recreational fishery is done by fishers, and it was easier to take the total length of fish that are often frozen than the fork length. In order to compare the different length types, the fork lengths and total lengths of each fish have been collected since 2012. These data, presented in Appendix 1, provide conversion factors between the two length types.

Sex determination of fish was not performed systematically, but, since 2012, this information has been collected for all individuals caught. Additional data have also been collected since 2014, such as sexual maturity stage, liver weight, gonad weight, stomach weight and stomach contents weight. In addition, the percentage of fat in the muscle of Greenland halibut was determined using the *fatmeter* device from the Distell company. Ongoing analyses should make it possible to convert these fat percentages into a fish condition index. Preliminary data are presented in Appendix 2.

In 2016, otoliths and fin samples of Greenland halibut were collected as part of a research project on genomic variation and connectivity of Greenland halibut populations in the North Atlantic. This three-year project is funded by the Natural Sciences and Engineering Research Council of Canada (NSERC). The analyses are underway and will be published shortly.

Lastly, the stomachs of Greenland halibut and of Atlantic and Greenland cod were preserved to determine the diet of these species in the Saguenay. Parks Canada is conducting analyses of the stomach contents of cod at the SSLMP. Cod otoliths have also been collected since 2014 so that a DFO expert technician can determine the age of these fish.

LOCATION OF CATCHES OF DIFFERENT SPECIES

Spatial distributions of Deepwater redfish, Greenland halibut, Atlantic cod and Greenland cod catches are shown in Figures 5 to 8, respectively. Three maps are presented for each species: the map of catches for all surveys combined (2000–2018) and the catch distribution maps for 2016 and 2018. These maps indicate that Deepwater redfish are found in all of the sectors, while Greenland halibut are more prevalent in the Saint-Fulgence sector. Figure 8 shows that Greenland cod have never been caught in the Les Battures sector.

The cumulative catch frequencies of these four species by depth (Figure 9) indicate that Atlantic cod, Greenland cod and Greenland halibut are generally caught at shallower depths than Deepwater redfish in 140-mm gillnets. Half of the cumulative catches of cod and Greenland halibut are made at nearly 65 m, compared with 80 m for Deepwater redfish (Table 4).

ESTIMATED NUMBER PER UNIT EFFORT

The number of fish caught per unit effort (NUE) is calculated for the four main species—redfish, Greenland halibut, Atlantic cod and Greenland cod—using the following formula:

$$NUE = \frac{C}{E} = \frac{number\ of\ fish\ caught}{effort\ in\ number\ of\ nets}$$

The annual descriptive statistics (number of sets, average, standard deviation, median, minimum, maximum, catch probability) of the NUEs by species are presented in Table 5 for the stations that were used in the calculation of the NUE indicator estimate. The annual NUEs by species and sector are presented in Figure 10. The anomalies of the NUEs relative to the 2000–2018 series average for the species/sector/year combination are also shown in Figure 10. The anomaly is calculated by subtracting the species/sector series average from the species/sector/year NUE. These values are then divided by the standard deviation of the series in order to standardize them and allow them to be compared with each other. Empty cells indicate missing values. Cells with an NUE value within ±0.5 standard deviations of the series average are white. Cells where the NUE is greater than the series average by more than 0.5 standard deviation are red. The deeper the red is, the greater the species/sector/year NUE value is than the average. Conversely, blue cells are those where the NUE is lower than the series average. At the time of the survey in April, the average NUEs for redfish in the Baie des Ha! Ha! sectors (Anse-à-Benjamin, Anse-à-Philippe, Grande-Baie and Les Battures) are higher than in the Bras-du-Nord sectors (Cap-Jaseux, Les Îlots and Saint-Fulgence), whereas the opposite is observed for Greenland halibut. The NUEs for Atlantic cod are similar between the regions. During the 15 years of surveys, Greenland cod were never caught in the Les Battures sector. The best catches for this species were made in the Saint-Fulgence sector (Figures 8 and 10).

A generalized linear model is used to analyze the time series of the NUEs to determine whether there are any differences among years. The model uses a log link function with a Poisson error allowing overdispersion (GENMOD procedure in SAS, SAS Institute Inc.). The explanatory variables in the model are the year (2000 to 2018) and the sector. The model appears as follows:

$$\ln(C_{ijk}) = \ln(E_{ijk}) + \beta_0 + \beta_{1i} + \beta_{2j} + \varepsilon_{ijk}$$

where C_{ijk} is the number of fish caught and E_{ijk} is the effort in number of nets in the set k in the year i and the sector j, β_0 is a constant, β_1 is the parameter vector of the year effect and β_2 is the parameter vector of the sector effect.

The probability of catching a fish in a set (a set is composed of three nets) was analyzed using a generalized linear model. The number of fish caught (C) was converted into a binary variable, i.e. 0 if no fish are caught in the set and 1 if there is at least one fish caught. The model uses a logit link function (GENMOD procedure in SAS, SAS Institute Inc.). The explanatory variables are the year and sector. The model appears as follows:

$$ln\left(\frac{P_{ijk}}{1 - P_{ijk}}\right) = \beta_{1i} + \beta_{2j}$$

where p_{ijk} is the probability of catching a fish in the set k in the year i and the sector j, β_1 is the parameter vector of the year effect and β_2 is the parameter vector of the sector effect.

The series averages presented for the NUE and catch probability indicators correspond to the period from 2000 to 2016.

The NUEs for redfish in the latest surveys are significantly lower than those observed from 2000 to 2004 (Figure 11A). This number has decreased from approximately five redfish per net (2000 to 2004) to less than one for the years 2008 to 2018. The value for 2018 remains low and below the series average. The probability of catching redfish in a set remained high, at nearly 90%, until 2007 (Figure 11B). The lowest probability was observed in 2010, at nearly 40%. Subsequently, the probability of catching redfish increased, and in 2018 it was estimated at nearly 74%, which is slightly below the series average of 80%.

The NUE for Greenland halibut doubled between the 2000–2004 and 2005–2012 periods (Figure 12A). Subsequently, this indicator declined, and the values observed from 2014 to 2018 are low, close to the 2000–2004 level and below the series average. The probability of catching Greenland halibut varied around an average of 65% (Figure 12B). The value for 2018 is below this average, at 53%.

The NUE and catch probability values for Atlantic cod are low (Figures 13A and B). The NUE, which had shown an increase from 2005 to 2010, has been steadily decreasing since then and is below the series average in 2018. The same trends are observed for the catch probability index.

The NUE and catch probability values for Greenland cod are low (Figure 14). They have been below the averages of their respective series since 2006.

BIOLOGICAL PARAMETERS

SIZE STRUCTURE

It should be noted that the 140-mm mesh gillnet, the gear used for this survey, has a fairly narrow selectivity and catches a limited range of sizes of the various fish species, which made it impossible to assess the arrival of juveniles and properly monitor the cohorts present in the Saguenay. In 2014 and 2016, small-mesh nets were therefore added to the survey sampling plan to address these shortcomings. In 2018, the small-mesh nets were replaced with experimental nets. Descriptive statistics (number, average, median, maximum and minimum standard deviation) of the length of fish caught variable are presented in Table 6 by species, year and mesh size. Figure 15 shows the length frequency distributions by species for 140-mm gillnets.

The size range of redfish caught during the survey generally varies from 25 cm to 37 cm (Figure 15). The addition of small-mesh gillnets (Figure 16, Table 6) made it possible to catch redfish smaller than 25 cm in 2016 and 2018. These small redfish would be representatives of the strong 2011, 2012 and 2013 cohorts observed in the Estuary and Northern Gulf of St. Lawrence (Bourdages et al. 2017) (Appendix 3). The individuals measuring 8 cm caught in 2016 could be from the 2014 cohort, whose abundance is considered average in the Gulf of St. Lawrence.

Two redfish species cohabitate in the Gulf of St. Lawrence: the Acadian redfish (*Sebastes fasciatus*) and the Deepwater redfish (*Sebastes mentella*). Distinguishing between these species is very difficult because of their great similarity. One of the characteristics used to distinguish them is the number of soft rays in the anal fin (AFC) (Senay et al. 2018). AFCs made during the 2000, 2001, 2014, 2016 and 2018 surveys show a dominance of eight and nine rays (Figure 17), indicating that the species encountered in the Saguenay is probably *Sebastes mentella*. Genetic testing on redfish from the 2011 to 2013 cohorts harvested in the Saguenay Fjord and St. Lawrence Estuary indicate that they are all *Sebastes mentella* and originate from the Gulf of St. Lawrence population (DFO 2016; Éric Parent DFO, Mont-Joli, pers. comm.). Previous studies had also shown that the redfish species present in the Saguenay is *Sebastes mentella* (Bourgeois 1993; Roques et al. 2002; Valentin 2006).

For the other species—Greenland halibut, Atlantic cod and Greenland cod—the size structures show a wide range of sizes, suggesting the presence of several cohorts of each of these species in the Saguenay. The use of small-mesh nets has resulted in catching a limited number of small fish of these three species (Figure 18).

WEIGHT–LENGTH RELATIONSHIP

The relation between total weight and total length of fish is calculated annually for each species (Table 7). The non-linear relationship between these two variables is shown as follows:

$$P = aL^b$$

where P is the total weight (g), L is the total length (cm) and a and b are the parameters estimated by the model.

CONDITION INDICES

Condition analysis provides a measure of the energy reserves and general health of fish. Fish in good condition will have a better chance of survival if adverse environmental conditions occur. The condition level affects, among other things, the growth, fertility and productivity of the stock. The condition level of fish is a factor that can vary quite quickly depending on environmental factors. The total Fulton index (*K*), a condition index of a fish, is calculated using the following formula:

$$K = 100 \text{ x} \frac{P}{L^3}$$

where P is the total weight (g) and L is the total length (cm). Descriptive statistics for this condition index of fish caught during the survey are presented by species and year in Table 8. A length interval was chosen for each species to eliminate the effect of length on the condition index. The length intervals are 28 cm to 35 cm for Deepwater redfish, 40 cm to 55 cm for Greenland halibut, 50 cm to 80 cm for Atlantic cod and 40 cm to 65 cm for Greenland cod (Table 8).

Since 2014, the collection of additional data during the DFO survey has made it possible to produce a Fulton condition index for Atlantic cod using the somatic weight, i.e. the total weight minus the stomach content weight and gonad weight. This Fulton condition index (Ksom), based on somatic weight, eliminates variability in the measurement of the condition index that can be caused by different feeding intensities and/or level of gonad maturation among fish. It provides a health check-up at a specific time:

$$Ksom = 100 \text{ x} \frac{Psom}{L^3}$$

where P_{som} is the somatic weight (g) and L is the fork length (cm).

The additional data is also used to calculate the hepatosomatic index (HSI), which measures the lipid energy reserves of cod. This index reflects the recent success in fish feeding:

$$HSI = (\text{liver weight (g) / somatic weight (g)}) \text{ x } 100$$

These new data were used to compare the condition of Atlantic cod in the Saguenay Fjord with that of Atlantic cod in the Northern Gulf of St. Lawrence (Figure 19). The information on Atlantic cod in the Northern Gulf of St. Lawrence comes from the sentinel fisheries program (Brassard et al. 2016). Atlantic cod in the northern and southern Gulf of St. Lawrence are known to demonstrate an annual condition cycle with significant seasonal variations (Schwalme and Chouinard 1999; Swain et al. 2011). The minimum condition levels are observed in the spring following the wintering period when cod feed little or not at all. The maximum condition levels are observed in the fall following an intense feeding period. The accumulation of energy reserves is critical for cod in the Gulf of St. Lawrence and must be sufficient to allow them to survive the winter and the spawning period the following spring.

Figure 19 shows that for the same size and month (April), Atlantic cod in the Saguenay Fjord are in better condition than those in the Northern Gulf of St. Lawrence. The Fulton (Ksom) and hepatosomatic (HSI) indices are significantly higher in April in Atlantic cod in the Saguenay, compared to those in the Northern Gulf of St. Lawrence. These differences in condition could be partly explained by the fact that Atlantic cod in the Saguenay appear to feed year round (Figure 20), while Atlantic cod in the northern Gulf hardly feed in winter. Previous studies (Lalancette 1984; Richard 1997) had also indicated that Atlantic cod in the Saguenay Fjord were in better condition than those in the Gulf and that they fed year round. However, although Saguenay cod are in better condition than Gulf cod, the age lengths determined by analyzing otoliths do not seem to indicate any differences between the two populations (Figure 21). However, note that a limited number of otoliths of Atlantic cod from the Saguenay were analyzed (n = 35).

DIET OF GREENLAND HALIBUT

During the 2014 and 2018 research surveys, Greenland halibut stomachs were kept for dietary analyses. During each of these surveys, 52 stomachs were frozen. Stomachs that appeared empty were not preserved. After analysis, one stomach harvested in 2018 was found to be empty. The average size of the fish from which stomachs were harvested was 49 cm (43 to 59 cm) and 45 cm (35 to 57 cm) in 2014 and 2018, respectively.

The stomachs were thawed just before being analyzed in the laboratory. Each prey found in a stomach was identified at the most accurate taxonomic level possible and weighed. The stage of digestion of the prey was also taken into account: stage 1 for undigested prey, stage 2 for partially digested but still identifiable prey, and stage 3 for the rest. The information was then entered into a database.

For this study, parasites and debris (e.g. rock, sand, liquid, mucus, etc.) were excluded from the stomach content analyses.

Two measurements were used to provide information on the diet of Greenland halibut in the Saguenay: frequency of occurrence (F_{occ}) and mass content (C_M). The methods used to calculate these indicators and the biases are described in Bernier and Chabot (2013).

The prevalence or frequency of occurrence is calculated as follows:

$$F_{occ} = N_i \text{ x } N^{-1} \text{ x } 100$$

where N_i is the number of stomachs containing prey i divided by the total number of stomachs in the sample. For a given sample, the sum of the F_{occ} of all prey exceeds 100%. This is a qualitative index indicating whether a small or large proportion of predators eat a given prey (Bernier and Chabot 2013).

The mass contribution (C_M) is calculated as follows:

$$C_M = M_i \text{ x } M_{tot} \text{ x } 100$$

where M_i is the total mass of this prey in all stomachs of the sample, divided by the total mass of the stomach contents of the same sample, expressed as a percentage. This index is directly related to a prey's significance for a species' energy needs. The sum of the C_M of all prey equals 100%. When the sample contains predators of very variable sizes, C_M gives more weight to the larger predators, as they contribute proportionally more material to M_{tot}.

The average masses of the stomach contents of fish harvested in 2014 and 2018 are similar, at nearly 16 g per stomach. In 2014 and 2018, respectively, 18 and 11 taxa were identified in the stomachs sampled, for a total of 23 different taxa. Of these, 17 taxa were recorded in only one of the two years considered.

Fish are prey of choice for Greenland halibut ranging in size from 35 cm to 59 cm sampled in the Saguenay in April 2014 and 2018. They are found in 77% and 98% of stomachs and contribute the vast majority of food intake based on the mass contribution of 63% and 99% for 2014 and 2018, respectively (Table 9, Figure 22). American smelt (*Osmerus mordax*) and redfish (*Sebastes spp.*) were identified in stomachs sampled in both years. In 2014, the fourbeard rockling (*Enchelyopus cimbrius*) (F_{occ} = 3.9%), the checker eelpout (*Lycodes vahlii*) (F_{occ} = 1.9%) and representatives of the Gadidae family (F_{occ} = 1.9%) were also identified. In 2018, capelin (*Mallotus villosus*) (F_{occ} = 44%) and Arctic cod (*Boreogadus saida*) (F_{occ} = 1.9%) were added to the list.

American smelt was the most frequently observed taxon identifiable by species (F_{occ} = 50%) in the stomachs sampled during the 2014 survey and were the main food source based on the mass percentage (41%). This species is also very prevalent in 2018, with a frequency of occurrence of 40% and a mass contribution of 19%. However, in 2018, capelin was the most frequently observed prey identifiable by species (44%) and contributed most to the diet of Greenland halibut (C_M = 55%). Redfish were present in a greater proportion of stomachs in 2018 than in 2014, with a frequency of occurrence of 21%, compared with 6%, and a mass contribution of 8%, compared with 1%.

Six shrimp taxa were identified in the stomachs during the two surveys. This group of prey was found in more than half of the stomachs in 2014 (F_{occ} = 54%), but in less than 5% of the stomachs in 2018. Only Northern shrimp (*Pandalus borealis*) was identified in stomachs harvested in 2014 and 2018. The other shrimp taxa identifiable by species were found only in the 2014 stomach contents. These are, in decreasing order of frequency of occurrence, the grey sand shrimp (*Crangon septemspinosa*, 40%), sculptured shrimp (*Sclerocrangon boreas*, 12%) and polar shrimp (*Lebbeus polaris*, 6%).

Zooplankton and other invertebrates are two smaller prey groups for Greenland halibut sampled in the 2014 and 2018 surveys.

PHYSICAL OCEANOGRAPHIC CONDITIONS

During the last three surveys, the deployment of a SBE19+ probe equipped with an oxygen sensor made it possible to produce temperature, salinity and oxygen saturation profiles based on depth at several sites in the Baie des Ha! Ha! and Bras-du-Nord areas. Among the profiles produced, the data are presented for a station at the junction of Baie des Ha! Ha! and Bras-du-Nord, where the depth is over 180 metres (Figure 4).

The salinity profiles (Figure 23A) show a surface layer of brackish water (about 7.5 psu). The salinity increases rapidly to nearly 25 psu at 10 metres and 29 psu at 25 metres and remains between 29 and 31 psu to the bottom. The salinity profiles from 2014 to 2018 are very similar.

The temperature profiles (Figure 23B) of the water column show a warmer surface layer that cools rapidly, forming a cold intermediate layer followed by warming, with a warmer and almost isothermal deep water layer. CTD data for 2014 and 2016 show generally comparable temperature profiles. However, in 2016, the intermediate layer was colder and thinner, while the deep water layer was nearly 0.7°C warmer than in 2014. The 2018 profile shows a very thick cold intermediate water layer of about 70 metres. This intermediate layer is colder and thicker than in the 2014 and 2016 surveys. Recent studies show that the waters of the Saguenay Fjord are very dynamic and that they are renewed relatively quickly by the intake of water from the cold intermediate layer of the St. Lawrence Estuary (Galbraith et al. 2018).

The oxygen saturation profiles (Figure 23C) show levels of more than 80% at the surface and more than 60% at depth. The waters of the Saguenay Fjord are well oxygenated at levels that are not limiting for aquatic life.

ACKNOWLEDGMENTS

The authors thank the crews of the CCGS *Leim* and would like to acknowledge their excellent work. Thanks are extended to: Marie-Lyne Dubé for her teaching on the Winkler technique; Marie-Noëlle Bourassa and Laure Devine for processing CTD data; Roger Pigeon and Félix Saint-Pierre for loaning the CTD and providing training on using the device; and Jean-François Lussier for his analysis of cod otoliths. Lastly, thanks to Denis Bernier and Hugo Bourdages for reviewing this document.

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TABLES

Table 1A. Description of the 2000 to 2018 surveys for the sets with gillnets of 140-mm (5.5-inch) mesh size selected for the analyses.

Year	Vessel	Start	End	Total Number of moorings	Number of moorings selected for analysis	Gillnets per mooring (Avg.)	Immersion (Avg. (h))	Depth (Avg. (m))
2000	CCGS Calanus II	April 18	April 24	33	26	3.1	22.8	57
2001	CCGS Calanus II	April 12	April 20	32	20	3.0	28.6	75
2002	CCGS Calanus II	April 2	April 16	23	22	2.8	79.6	81
2003	MV L'Échourie	April 22	April 29	35	31	3.0	21.8	73
2004	CCGS Calanus II	April 9	April 15	35	32	2.7	23.8	77
2005	CCGS Calanus II	April 16	April 25	59	52	3.0	25.9	82
2006	CCGS Calanus II	April 13	April 25	81	77	3.0	26.8	85
2007	CCGS Calanus II	April 17	April 28	70	70	3.0	27.9	78
2008	CCGS Calanus II	April 12	April 22	68	68	3.0	26.2	64
2009	CCGS Calanus II	April 6	April 19	83	76	3.0	26.1	63
2010	CCGS Calanus II	April 7	April 21	103	86	3.0	25.9	68
2012	CCGS Calanus II	April 12	April 23	80	80	3.0	23.9	66
2014	CCGS Leim	April 26	May 5	76	76	3.0	23.4	68
2016	CCGS Leim	April 17	April 25	56	56	3.0	27.2	81
2018	CCGS Leim	April 16	April 28	72	72	3.0	25.4	79

Table 1B. Description of the 2014 to 2018 surveys for the small-mesh gillnet sets.

Year	Vessel	Start	End	Mesh size (mm)	Number of moorings	Gillnets per mooring (Avg.)	Immersion (Avg. (h))	Depth (Avg. (m))
2014	CCGS Leim	April 26	May 5	38	9	3	22.3	61
				67	8	3	22.7	61
2016	CCGS Leim	April 17	April 25	38	7	3	28.5	33
				67	7	3	27.4	50
2018	CCGS Leim	April 16	April 28	Exp*	9	3	25.5	53

* Experimental nets. Mesh size of 51, 76, 102 and 140 mm.

Table 2. Number of sets selected by fishing sector for the analyses of 140-mm gillnets, 2000–2018 surveys.

Area	**Sector**	**Year**														
		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2012	2014	2016	2018
Baie des Ha!Ha!	Anse Benjamin	5	4	4	2	4	8	11	9	8	7	11	11	9	7	9
	Anse Philippe	1	-	4	10	8	9	9	9	9	10	8	9	11	7	8
	Grande-Baie	6	3	2	3	4	7	10	9	9	5	7	10	10	7	11
	Les Battures	5	3	3	2	1	7	9	8	10	9	14	10	10	7	10
	Total	17	10	13	17	17	31	39	35	36	31	40	40	40	28	38
Bras-du-Nord	Cap-Jaseux	-	-	3	4	5	7	15	8	12	6	7	10	9	7	9
	Les Îlots	2	5	2	4	5	7	14	7	5	-	4	10	9	7	9
	St-Fulgence	7	5	4	6	5	7	9	20	15	39	35	20	18	14	16
	Total	9	10	9	14	15	21	38	35	32	45	46	40	36	28	34
Total		26	20	22	31	32	52	77	70	68	76	86	80	76	56	72

Table 3A. Number of individuals caught by species during the 2000 to 2018 surveys and total number of 140-mm nets deployed.

	Year															
Species	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2012**	**2014**	**2016**	**2018**	Total
Deepwater redfish	537	484	384	639	389	456	415	259	129	285	131	208	92	152	168	4 728
Greenland halibut	39	60	48	77	30	249	269	214	270	292	620	357	141	133	90	2 889
Atlantic cod	11	2	3	42	8	3	7	8	19	27	66	30	21	9	3	259
Greenland cod	23	3	7	5	12	12	6	7	1	14	6	8	8	5	3	120
Crab sp.	4	2	-	-	-	4	4	3	-	4	17	-	-	-	-	38
Plaice sp.	2	-	-	1	3	4	5	4	14	3	1	-	-	-	-	37
Skate sp.	1	1	-	-	1	-	11	3	2	6	-	-	-	-	-	25
American plaice	-	-	-	-	-	-	-	-	-	1	6	5	4	2	2	20
Snow crab	-	-	-	-	-	-	-	-	-	-	-	-	1	1	16	18
Thorny skate	-	-	-	-	-	-	-	-	-	-	1	2	5	1	5	14
Herring	-	-	-	-	12	-	-	-	-	-	-	-	-	-	-	12
Atlantic halibut	-	-	-	-	-	-	-	-	1	-	2	2	1	-	-	6
Toad crab	-	-	-	-	-	-	-	-	-	-	-	-	3	1	-	4
Winter flounder	-	-	-	-	-	-	-	-	-	-	-	-	2	-	1	3
Eelpout sp.	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	2
White hake	1	-	-	-	-	-	-	-	-	1	-	-	-	-	-	2
Sea raven	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	2
Shrimp sp.	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1
Smelt	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1
Ocean pout	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1
Arctic cod	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1
Lumpfish	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
Total effort (number of gillnets)	102	96	64	105	95	177	243	210	204	249	309	240	228	168	216	2706

Table 3B. Number of individuals caught by species during the 2014 to 2018 surveys and total number of small-mesh and experimental nets deployed.

Species	2014		2016		2018			
	Mesh size (mm)		Mesh size (mm)		Mesh size (mm)			
	38	67	38	67	51	76	102	140
Sculpin sp.	-	-	-	1	-	-	-	-
Smelt	-	-	2	-	-	-	-	-
Eelpout sp.	1	-	2	-	-	-	-	-
Atlantic cod	2	1	1	-	-	-	-	-
Greenland cod	-	1	-	-	-	-	-	-
American plaice	-	1	-	1	-	-	-	-
Arctic cod	-	-	1	-	-	-	-	-
Deepwater redfish	9	16	27	20	39	11	5	4
Greenland halibut	-	1	-	-	-	3	7	1
Total effort (gillnet)	27	24	21	21	27	27	27	27

Table 4. Percentile of the depth (m) of cumulative catches by species in 140-mm nets.

Species	**Cumulative catch depth (m)**						
	p5	**p10**	**p25**	**p50**	**p75**	**p90**	**p95**
Atlantic cod	40	40	50	64	77	85	99
Greenland cod	37	40	45	60	78	90	95
Greenland halibut	40	40	51	64	79	96	107
Deepwater redfish	45	50	63	80	96	107	120

Table 5. Descriptive statistics of NUEs (number of fish per 140-mm net), by species and by year, during the 2000 to 2016 surveys for the fishing sectors used to estimate the NUE.

Deepwater redfish

Year	Moorings (n)	NUE					Catch probability
		Avg.	**S.D.**	**Med.**	**Min.**	**Max.**	
2000	33	5.4	7.4	2.0	0	28.0	0.82
2001	32	5.0	7.2	1.8	0	32.7	0.88
2002	23	6.1	8.0	2.5	0	35.0	0.78
2003	35	6.1	12.1	2.0	0	62.3	0.83
2004	35	4.6	6.4	2.7	0	27.5	0.86
2005	59	2.6	3.1	1.3	0	14.0	0.83
2006	81	1.7	2.2	1.0	0	12.0	0.84
2007	70	1.2	2.0	0.7	0	16.0	0.84
2008	68	0.6	0.8	0.3	0	3.3	0.62
2009	83	1.1	1.4	0.7	0	6.7	0.73
2010	103	0.4	0.8	0.0	0	3.7	0.41
2012	80	0.9	0.9	0.7	0	4.0	0.76
2014	76	0.4	0.5	0.3	0	2.3	0.59
2016	56	0.9	1.2	0.3	0	5.7	0.70
2018	72	0.8	1.1	0.3	0	5.0	0.71

Greenland halibut

Year	Moorings (n)	NUE					Catch probability
		Avg.	**S.D.**	**Med.**	**Min.**	**Max.**	
2000	33	0.4	0.6	0.0	0	2.0	0.48
2001	32	0.6	0.8	0.5	0	2.7	0.63
2002	23	0.8	1.3	0.5	0	5.0	0.61
2003	35	0.7	1.0	0.3	0	3.3	0.57
2004	35	0.4	0.7	0.0	0	2.5	0.43
2005	59	1.4	1.5	1.0	0	7.0	0.90
2006	81	1.1	1.8	0.3	0	10.7	0.70
2007	70	1.0	1.7	0.3	0	7.3	0.56
2008	68	1.3	2.0	0.3	0	8.3	0.69
2009	83	1.2	1.5	0.7	0	6.0	0.63
2010	103	2.0	2.4	1.0	0	12.3	0.76
2012	80	1.5	2.9	0.5	0	17.0	0.73
2014	76	0.6	1.2	0.3	0	6.7	0.54
2016	56	0.8	1.0	0.7	0	6.0	0.82
2018	72	0.4	0.6	0.3	0	3.0	0.54

Table 5. (continued)

Atlantic cod

Year	Moorings (n)	NUE					Catch probability
		Avg.	S.D.	Med.	Min.	Max.	
2000	33	0.1	0.2	0	0	0.7	0.27
2001	32	0.0	0.1	0	0	0.3	0.06
2002	23	0.1	0.1	0	0	0.5	0.13
2003	35	0.4	0.8	0	0	3.7	0.37
2004	35	0.1	0.2	0	0	1.0	0.17
2005	59	0.0	0.1	0	0	0.3	0.05
2006	81	0.0	0.1	0	0	0.7	0.06
2007	70	0.0	0.1	0	0	0.7	0.09
2008	68	0.1	0.3	0	0	1.3	0.18
2009	83	0.1	0.2	0	0	1.3	0.24
2010	103	0.2	0.5	0	0	4.3	0.33
2012	80	0.1	0.2	0	0	1.0	0.28
2014	76	0.1	0.2	0	0	0.7	0.24
2016	56	0.1	0.2	0	0	1.0	0.13
2018	72	0.01	0.1	0	0	0.3	0.04

Greenland cod

Year	Moorings (n)	NUE					Catch probability
		Avg.	S.D.	Med.	Min.	Max.	
2000	33	0.2	0.8	0	0	3.7	0.15
2001	32	0.0	0.1	0	0	0.3	0.09
2002	23	0.1	0.3	0	0	1.0	0.22
2003	35	0.0	0.2	0	0	0.7	0.09
2004	35	0.1	0.3	0	0	1.3	0.23
2005	59	0.1	0.2	0	0	1.0	0.15
2006	81	0.0	0.1	0	0	0.3	0.07
2007	70	0.0	0.1	0	0	0.3	0.10
2008	68	0.0	0.0	0	0	0.3	0.01
2009	83	0.1	0.2	0	0	1.0	0.12
2010	103	0.0	0.1	0	0	0.7	0.05
2012	80	0.0	0.1	0	0	0.7	0.09
2014	76	0.0	0.1	0	0	0.7	0.09
2016	56	0.0	0.1	0	0	0.3	0.07
2018	72	0.01	0.1	0.0	0	0.3	0.04

Table 6. Descriptive statistics of the total length of fish caught with gillnet by species, mesh size and year, during the 2000 to 2018 surveys.

Deepwater redfish

Year	Mesh size (mm)	Length (cm)					
		n	Avg.	S.D.	Med.	Min.	Max.
2014	38	9	29.1	2.5	29.5	24.8	32.2
2016	38	26	13.6	4.2	14.0	8.4	31.0
2018	51	39	19.9	5.8	18.7	12.2	34.5
2014	67	16	32.3	2.2	31.7	28.6	36.2
2016	67	20	29.1	4.5	29.8	17.5	35.2
2018	76	11	31.2	1.3	31.3	29.1	33.6
2018	102	5	29.9	2.1	29.3	27.6	32.1
2000	140	537	30.4	1.9	30.5	23.5	38.0
2001	140	484	31.0	1.9	31.0	24.7	37.1
2002	140	342	31.1	2.2	31.0	24.0	40.0
2003	140	389	31.4	1.9	31.3	24.1	37.5
2004	140	388	31.4	2.0	31.4	25.3	36.8
2005	140	452	31.8	2.0	31.7	24.2	38.2
2006	140	414	31.5	2.2	31.5	25.9	40.2
2007	140	258	31.3	2.2	31.1	24.4	37.2
2008	140	127	31.3	2.2	31.4	24.5	36.0
2009	140	278	31.7	2.2	31.6	25.5	41.0
2010	140	126	32.1	2.1	32.0	25.5	38.4
2012	140	208	32.0	2.5	32.0	25.0	38.7
2014	140	92	31.6	2.6	31.8	24.0	38.3
2016	140	150	32.3	2.7	32.0	24.6	38.2
2018	140	171	33.2	2.9	33.5	17.5	39.9

Table 6. (continued)

Greenland halibut

Year	Mesh size (mm)	Length (cm)					
		n	Avg.	S.D.	Med.	Min.	Max.
2014	67	1	50.0	-	50.0	50.0	50.0
2018	76	3	38.0	1.8	38.5	36.0	39.6
2018	102	7	40.2	2.6	40.0	37.2	45.2
2000	140	36	52.3	5.2	52.3	40.0	63.5
2001	140	60	46.1	7.2	44.4	35.1	62.8
2002	140	48	45.8	3.2	45.5	39.4	52.7
2003	140	77	46.7	4.3	47.2	36.0	61.2
2004	140	26	48.1	4.4	49.4	39.5	57.8
2005	140	245	46.5	3.8	46.0	36.1	58.7
2006	140	260	46.1	3.3	46.0	38.2	61.4
2007	140	202	47.0	3.4	46.7	39.6	59.2
2008	140	257	45.7	4.2	46.1	33.4	57.3
2009	140	262	45.3	4.0	44.5	37.1	60.2
2010	140	576	47.1	3.6	47.0	38.0	64.7
2012	140	357	48.2	3.9	47.5	38.7	75.7
2014	140	140	49.3	3.9	49.0	41.0	59.0
2016	140	122	49.9	4.1	49.6	36.6	59.2
2018	140	84	46.3	5.4	45.1	35.0	60.0

Atlantic cod

Year	Mesh size (mm)	Length (cm)					
		n	Avg.	S.D.	Med.	Min.	Max.
2014	38	2	29.6	1.0	29.6	28.9	30.3
2016	38	1	38.6	-	38.6	38.6	38.6
2014	67	1	40.5	-	40.5	40.5	40.5
2000	140	11	66.9	14.9	65.5	43.0	87.5
2001	140	2	81.6	5.4	81.6	77.7	85.4
2002	140	3	69.1	9.9	67.4	60.2	79.7
2003	140	42	71.0	16.0	63.8	44.2	119.0
2004	140	8	61.5	10.4	58.7	52.5	85.6
2005	140	3	75.0	8.3	71.0	69.4	84.5
2006	140	7	66.5	10.6	66.1	50.2	79.4
2007	140	7	52.7	9.8	56.1	31.0	58.2
2008	140	19	57.8	9.3	59.4	23.5	70.7
2009	140	25	59.8	11.4	56.1	42.5	90.0
2010	140	59	62.3	8.7	60.8	46.5	105.0
2012	140	30	62.6	6.2	60.7	53.0	76.9
2014	140	21	63.6	5.6	62.0	56.5	84.6
2016	140	10	68.9	11.6	67.8	55.1	96.6
2018	140	3	54.0	16.7	63.2	34.8	64.1

Table 6. (continued)

Greenland cod

Year	Mesh size (mm)	Length (cm)					
		n	Avg.	S.D.	Med.	Min.	Max.
2014	67	1	38.8	-	38.8	38.8	38.8
2000	140	23	45.2	4.7	45.0	34.0	57.0
2001	140	3	50.4	3.4	51.4	46.7	53.2
2002	140	5	51.1	5.7	50.6	45.4	60.4
2003	140	5	47.2	3.5	48.5	43.0	50.4
2004	140	12	52.2	6.7	53.4	36.0	64.0
2005	140	12	59.4	11.4	58.3	44.5	88.9
2006	140	6	55.9	8.0	54.1	49.8	71.1
2007	140	7	58.1	5.4	57.0	50.8	67.6
2008	140	1	49.5	-	49.5	49.5	49.5
2009	140	14	53.5	6.5	53.1	44.1	72.0
2010	140	6	53.6	6.2	56.5	43.0	59.1
2012	140	8	50.3	5.7	50.6	39.0	58.5
2014	140	8	55.2	3.2	55.8	48.4	59.6
2016	140	4	56.8	5.3	54.8	53.0	64.5
2018	140	3	52.4	6.2	56.0	45.3	56.0

Table 7. Parameters of the ratio between the weight (g) and total length (cm) of fish, by species and by year, during the 2000 to 2018 surveys.

	Deepwater redfish			Atlantic cod		
Year	n	a	b	n	a	b
2000	537	0.052	2.589	9	0.000	4.304
2001	484	0.019	2.873	2	0.027	2.762
2002	342	0.070	2.484	3	0.069	2.533
2003	388	0.011	3.020	42	0.012	2.992
2004	388	0.017	2.915	7	0.014	2.925
2005	451	0.015	2.953	3	0.014	2.939
2006	414	0.031	2.746	7	0.016	2.900
2007	256	0.016	2.926	4	0.092	2.466
2008	124	0.009	3.110	19	0.004	3.255
2009	277	0.021	2.859	17	0.084	2.487
2010	9	0.031	2.739	6	0.007	3.005
2012	207	0.006	3.203	30	0.086	2.458
2014	90	0.010	3.061	21	0.062	2.544
2016	141	0.006	3.193	10	0.023	2.765
2018	165	0.012	3.022	3	0.008	3.020
total	4273	0.018	2.894	183	0.003	3.284

	Greenland halibut			Greenland cod		
Year	n	a	b	n	a	b
2000	36	0.001	3.668	23	0.024	2.826
2001	60	0.008	3.040	3	0.020	2.887
2002	47	0.010	2.977	5	0.005	3.235
2003	77	0.009	2.997	5	0.027	2.798
2004	26	0.007	3.102	12	0.524	2.070
2005	245	0.005	3.153	12	0.121	2.432
2006	260	0.006	3.118	6	0.270	2.238
2007	202	0.007	3.081	6	0.251	2.273
2008	252	0.003	3.277	1	0.691	2.000
2009	260	0.009	3.020	11	1.826	1.736
2010	110	0.006	3.079	1	0.429	2.000
2012	357	0.021	2.770	7	0.001	3.682
2014	140	0.004	3.215	7	0.110	2.467
2016	118	0.003	3.236	4	0.047	2.673
2018	82	0.009	2.976	3	-	-
Total	2272	0.009	2.994	106	0.082	2.524

Weight (g) = a x Length^{b} (cm)

Table 8. Descriptive statistics of the Fulton condition index (K) of fish caught with 140-mm gillnet, by species and by year, during the 2000 to 2018 surveys. See text for the length intervals selected for each species.

Deepwater redfish

	Condition Index					
Year	n	Avg.	S.D.	Med.	Min.	Max.
2000	493	1.28	0.12	1.27	0.85	1.77
2001	451	1.22	0.10	1.22	0.96	1.55
2002	312	1.18	0.12	1.18	0.75	1.70
2003	370	1.23	0.10	1.22	0.89	1.61
2004	361	1.30	0.10	1.31	0.80	1.61
2005	417	1.28	0.10	1.28	0.93	1.56
2006	377	1.28	0.11	1.28	0.97	1.69
2007	228	1.26	0.11	1.26	0.88	1.62
2008	110	1.29	0.13	1.28	0.87	1.75
2009	247	1.28	0.16	1.26	0.88	2.09
2010	8	1.24	0.10	1.23	1.11	1.42
2012	176	1.22	0.11	1.21	0.93	1.91
2014	90	1.20	0.10	1.20	0.95	1.45
2016	141	1.18	0.09	1.18	0.90	1.52
2018	165	1.27	0.11	1.27	0.93	1.60

Greenland halibut

	Condition Index					
Year	n	Avg.	S.D.	Med.	Min.	Max.
2000	27	0.89	0.10	0.91	0.69	1.07
2001	39	0.92	0.06	0.92	0.76	1.03
2002	45	0.91	0.07	0.89	0.76	1.02
2003	71	0.93	0.07	0.92	0.82	1.12
2004	23	1.00	0.10	0.98	0.83	1.32
2005	231	0.90	0.09	0.89	0.43	1.51
2006	254	0.93	0.07	0.93	0.75	1.14
2007	198	0.90	0.07	0.90	0.74	1.20
2008	224	0.88	0.07	0.88	0.64	1.20
2009	245	0.92	0.07	0.92	0.71	1.29
2010	108	0.86	0.06	0.86	0.72	1.09
2012	340	0.86	0.07	0.86	0.43	1.08
2014	140	0.88	0.06	0.87	0.71	1.04
2016	118	0.86	0.06	0.85	0.70	1.01
2018	82	0.86	0.08	0.86	0.60	1.06

Table 8. (continued)

Atlantic cod

	Condition Index					
Year	n	Avg.	S.D.	Med.	Min.	Max.
2000	7	0.90	0.10	0.89	0.76	1.04
2001	1	0.94	-	0.94	0.94	0.94
2002	3	0.95	0.09	0.92	0.88	1.05
2003	27	1.05	0.15	1.04	0.78	1.57
2004	6	1.00	0.17	1.03	0.72	1.19
2005	2	1.11	0.04	1.11	1.08	1.13
2006	7	1.07	0.04	1.07	1.01	1.14
2007	4	1.07	0.06	1.06	1.02	1.16
2008	18	1.02	0.12	1.05	0.79	1.19
2009	16	1.05	0.15	1.00	0.89	1.47
2010	6	0.80	0.08	0.81	0.70	0.90
2012	30	0.92	0.12	0.90	0.75	1.28
2014	21	0.94	0.09	0.91	0.81	1.17
2016	10	0.88	0.09	0.85	0.77	1.05
2018	3	0.86	0.07	0.83	0.82	0.94

Greenland cod

	Condition Index					
Year	n	Avg.	S.D.	Med.	Min.	Max.
2000	22	1.24	0.20	1.28	0.63	1.55
2001	3	1.26	0.02	1.26	1.24	1.28
2002	5	1.27	0.12	1.34	1.10	1.37
2003	5	1.25	0.14	1.31	1.01	1.33
2004	11	1.32	0.19	1.32	0.98	1.64
2005	10	1.30	0.23	1.28	0.98	1.71
2006	5	1.31	0.08	1.34	1.23	1.42
2007	6	1.34	0.14	1.31	1.18	1.56
2008	1	1.40	-	1.40	1.40	1.40
2009	11	1.25	0.16	1.26	0.98	1.42
2010	1	0.75	-	0.75	0.75	0.75
2012	6	1.16	0.15	1.20	0.89	1.34
2014	7	1.28	0.05	1.27	1.23	1.37
2016	4	1.17	0.22	1.21	0.82	1.39
2018	3	1.56	0.67	1.32	1.05	2.33

Table 9. Diet of Greenland halibut harvested during the 2014 and 2018 surveys in the Saguenay Fjord. For each year, the values presented are the frequency of occurrence (F_{occ}) and the mass contribution (C_M, in % of the mass of all prey).

Prey	**2014** (*n=52*)		**2018** (*n=52*)	
	F_{occ}	C_M (%)	F_{occ}	C_M (%)
Capelin (*Mallotus villosus*)	0	0	44.23	55.15
American smelt (*Osmerus mordax*)	50	41.16	40.38	18.71
Gadidae	1.92	3.98	0	0
Arctic cod (*Boreogadus saida*)	0	0	1.92	1.97
Fourbeard rockling (*Enchelyopus cimbrius*)	3.85	0.15	0	0
Checker eelpout (*Lycodes vahlii*)	1.92	3.62	0	0
Redfish (*Sebastes spp.*)	5.77	1.25	21.15	7.57
Digested round fish	25	10.47	44.23	15.8
Digested fish	13.46	2.46	0	0
Fish, total	**76.92**	**63.09**	**98.08**	**99.19**
Shrimp (generic)	9.62	2.07	0	0
Polar shrimp (*Lebbeus polaris*)	5.77	0.79	0	0
Shrimp (*Pandalus sp.*)	5.77	0.23	0	0
Northern shrimp (*Pandalus borealis*)	9.62	3.17	3.85	0.67
Sculptured shrimp (*Sclerocrangon boreas*)	11.54	6.04	0	0
Grey sand shrimp (*Crangon septemspinosa*)	40.38	15.02	0	0
Shrimp, total	**53.85**	**27.33**	**3.85**	**0.67**
Gammarid (*Oedicerotidae*)	0	0	1.92	0.01
Mysids (*Boreomysis sp.*)	1.92	0.05	1.92	0.07
Mysids (*Mysis sp.*)	0	0	1.92	0.03
Krill (*Meganyctiphanes norvegica*)	1.92	0.04	1.92	<0.01
Euphausiids (*Thysanoessa sp.*)	0	0	1.92	0.02
Zooplankton, total	**3.85**	**0.1**	**9.62**	**0.14**
Crustaceans (*Crustacea*)	11.54	0.99	0	0
Snow crab (*Chionoecetes opilio*)	1.92	0.62	0	0
Other invertebrates, total	**13.46**	**1.61**	**0**	**0**
Invertebrates, total	**55.77**	**29.03**	**11.54**	**0.81**
Unidentified digested material	26.92	7.88	0	0

FIGURES

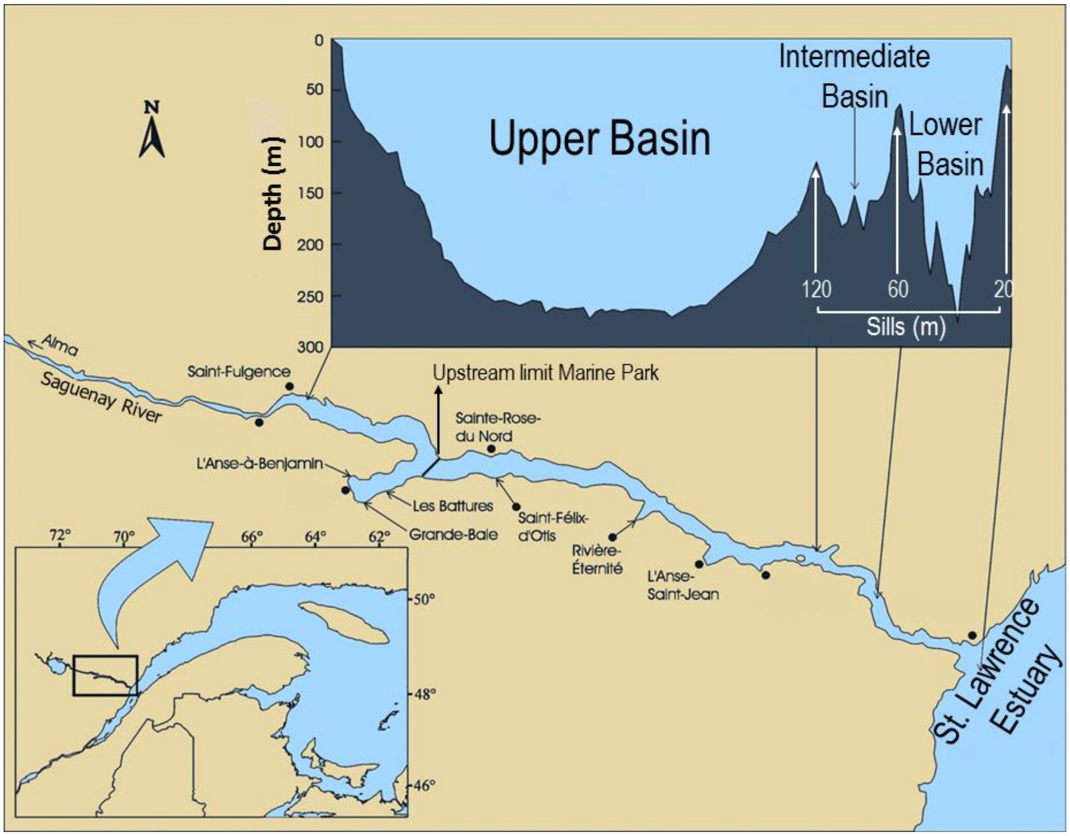


Figure 1. Location of the study area.

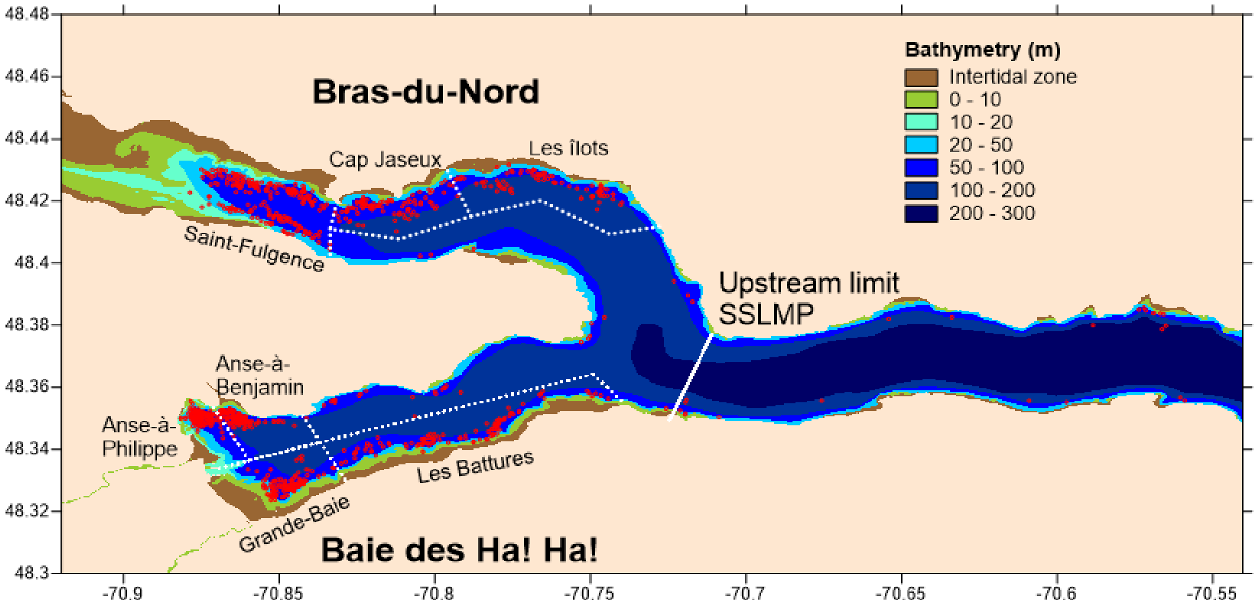


Figure 2. Location of all sets carried out during the 2000 to 2018 surveys. The sectors of the Bras-du-Nord and Baie des Ha! Ha! areas, selected for the analyses, are marked by dotted lines. The solid white line shows the upstream boundary of the Saguenay–St. Lawrence Marine Park (SSLMP). The bathymetry is also shown.

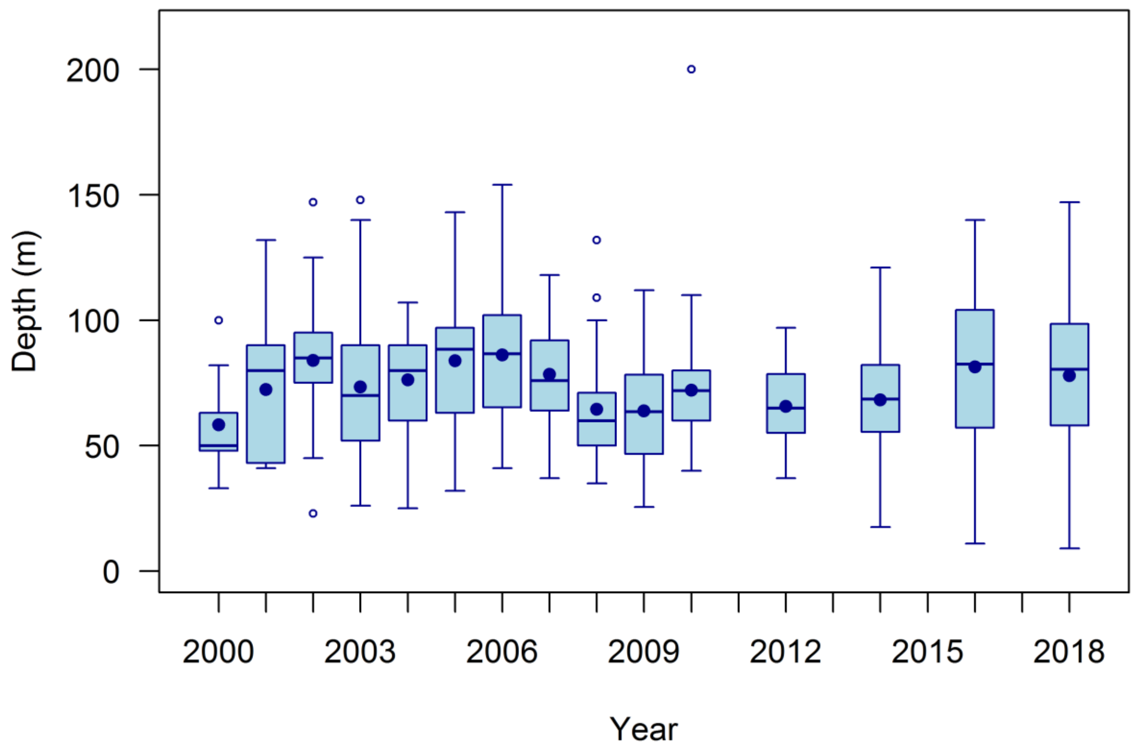


Figure 3A. Deployment depth of 140-mm mesh gillnets during the 2000 to 2018 surveys. Graphic representation in box-and-whisker plots: the line inside the box represents the median and the solid circle is the average. The box ranges from the 25th to the 75th percentile, the whiskers range from the 5th to the 95th percentile, and the circles represent outliers.

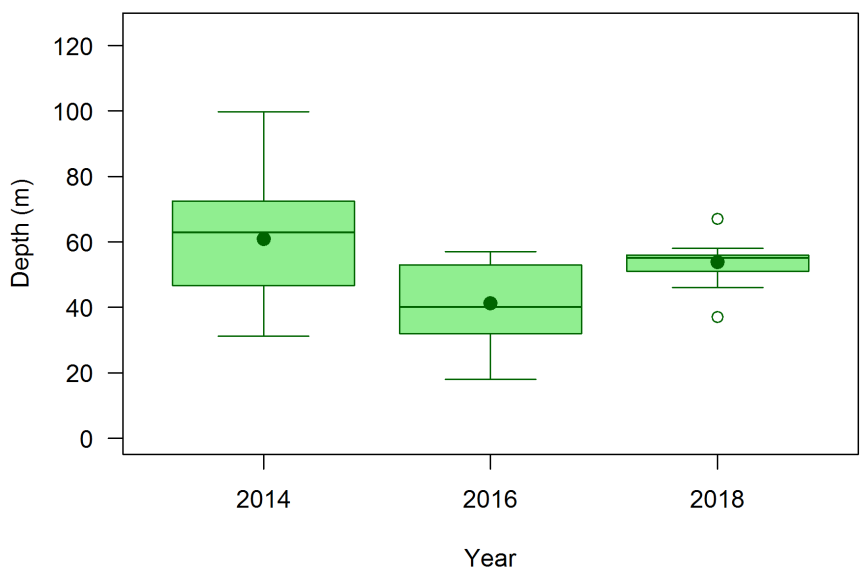


Figure 3B. Deployment depth of small-mesh gillnets (1.5 and 2.63 inches) during the 2014 and 2016 surveys and experimental nets in 2018. Graphic representation in box-and-whisker plots: the line inside the box represents the median and the solid circle is the average. The box ranges from the 25th to the 75th percentile, the whiskers range from the 5th to the 95th percentile and the circles represent outliers.

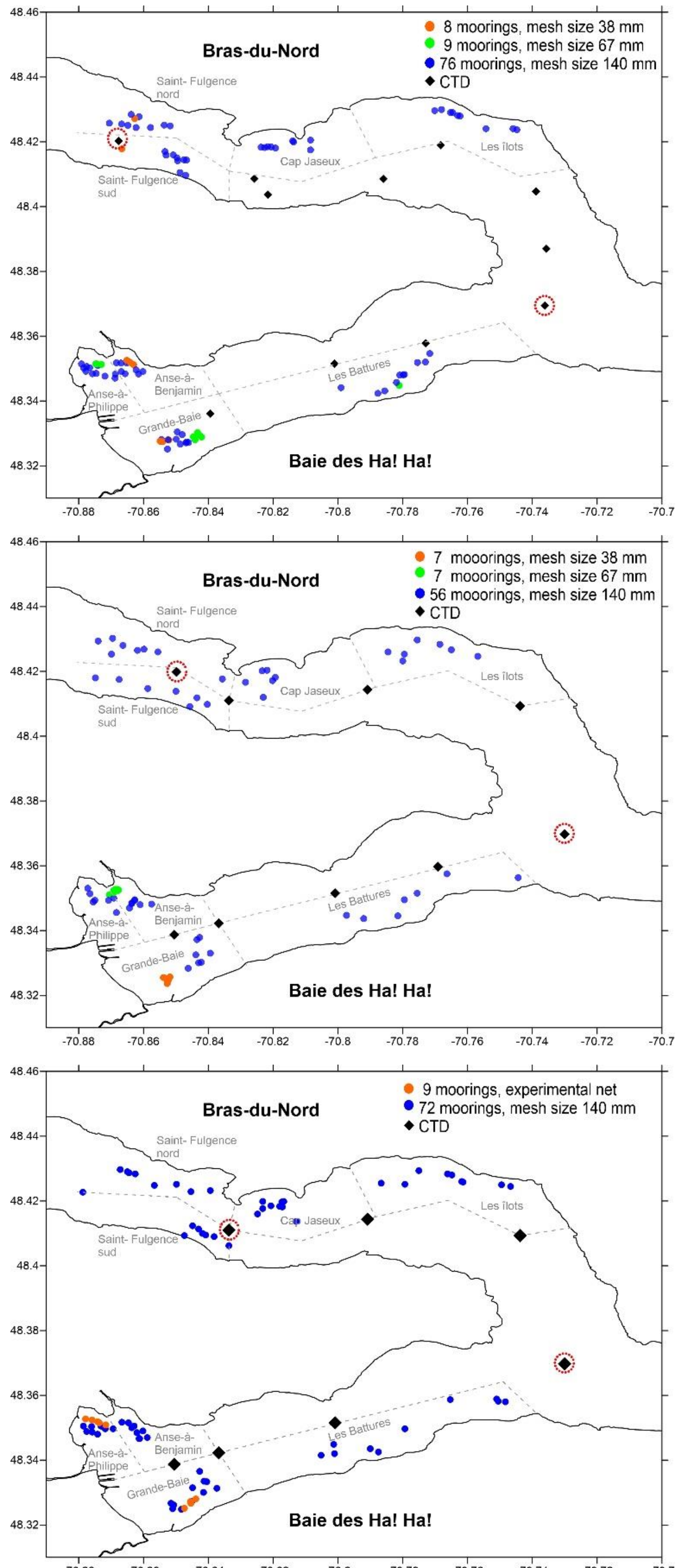


Figure 4. Location of sets of gillnets of different mesh sizes and location of CTD deployments during the 2014 (top map), 2016 (centre map) and 2018 (bottom map) surveys. The CTD positions surrounded by a red dotted circle are those for which profiles are shown in Figures 21 and 22.

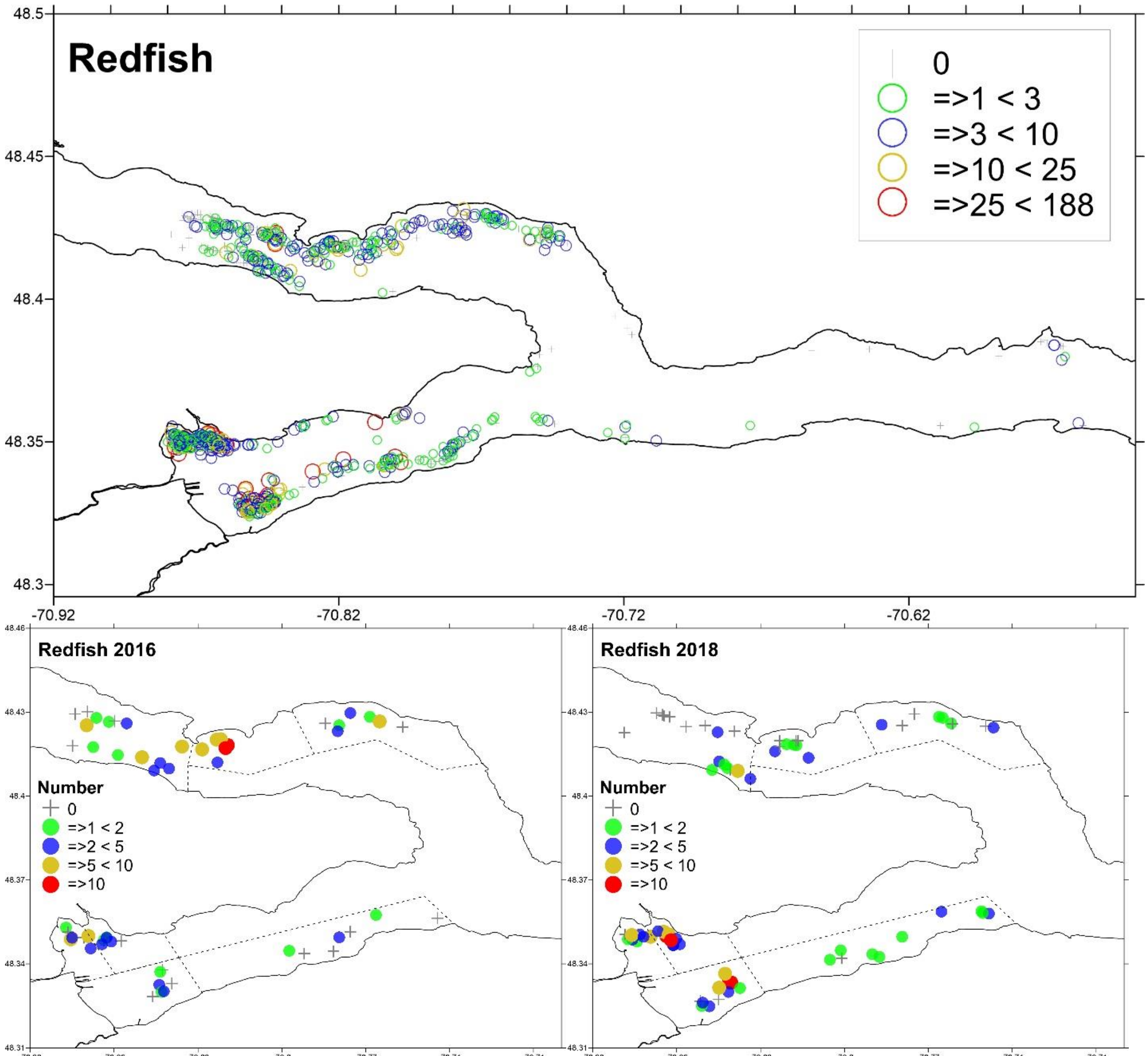


Figure 5. Distribution of Deepwater redfish catches (number of fish per set) during 140-mm gillnet surveys: 2000–2018 (top map), 2016 (bottom left) and 2018 (bottom right).

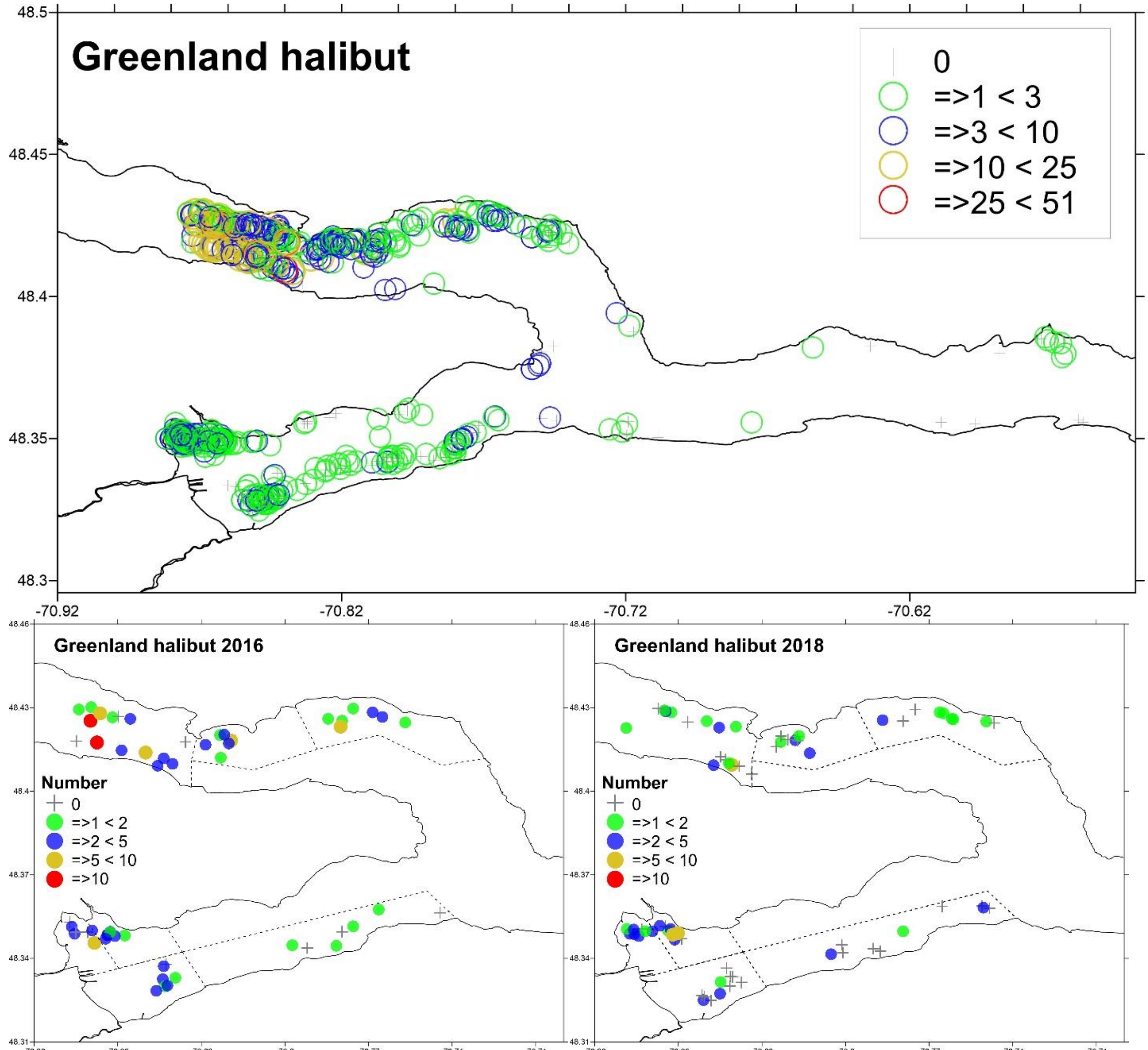


Figure 6. Distribution of Greenland halibut catches (number of fish per set) during 140-mm gillnet surveys: 2000–2018 (top map), 2016 (bottom left) and 2018 (bottom right).

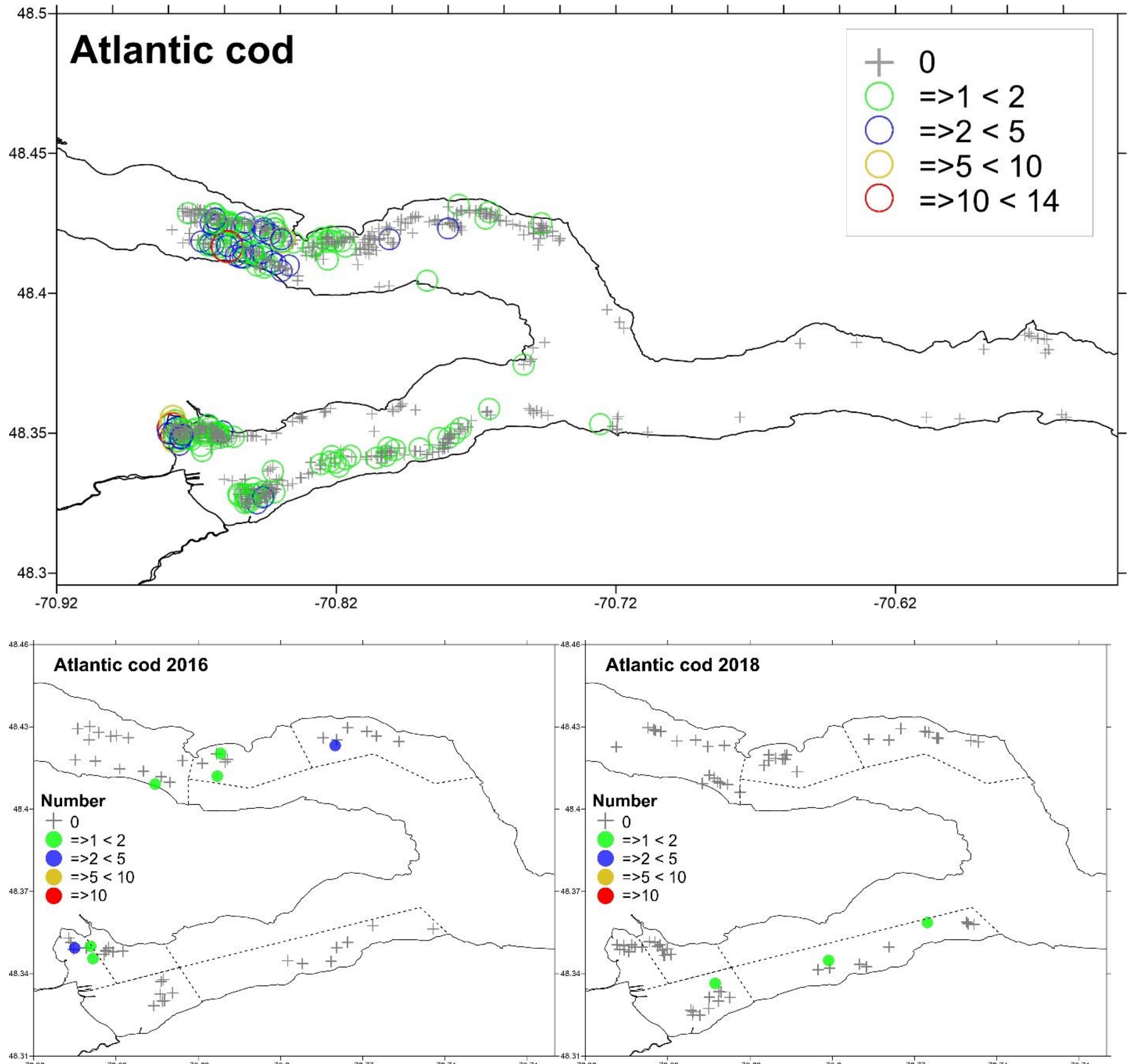


Figure 7. Distribution of Atlantic cod catches (number of fish per set) during 140-mm gillnet surveys: 2000–2018 (top map), 2016 (bottom left) and 2018 (bottom right).

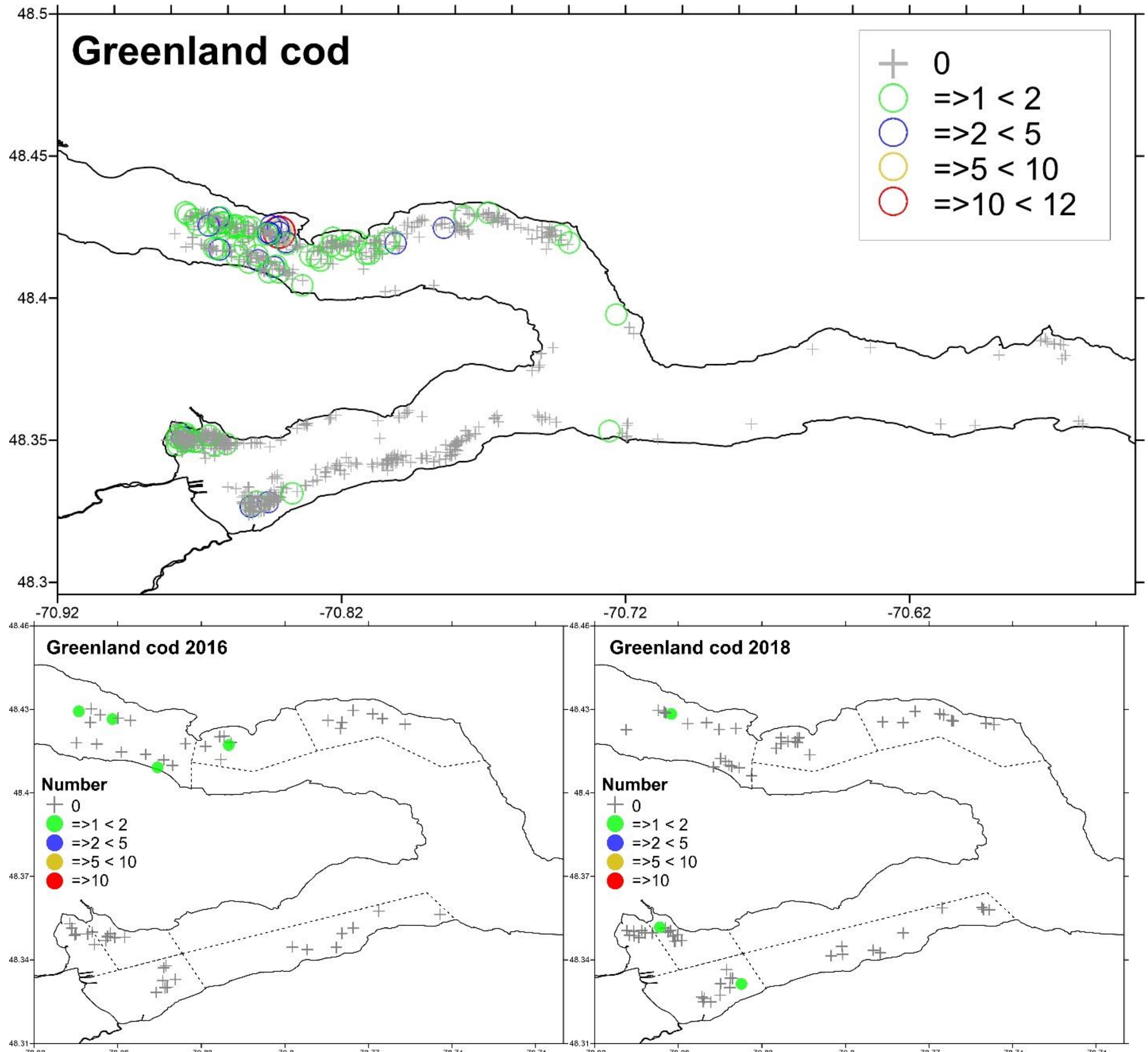


Figure 8. Distribution of Greenland cod catches (number of fish per set) during 140-mm gillnet surveys: 2000–2018 (top map), 2016 (bottom left) and 2018 (bottom right).

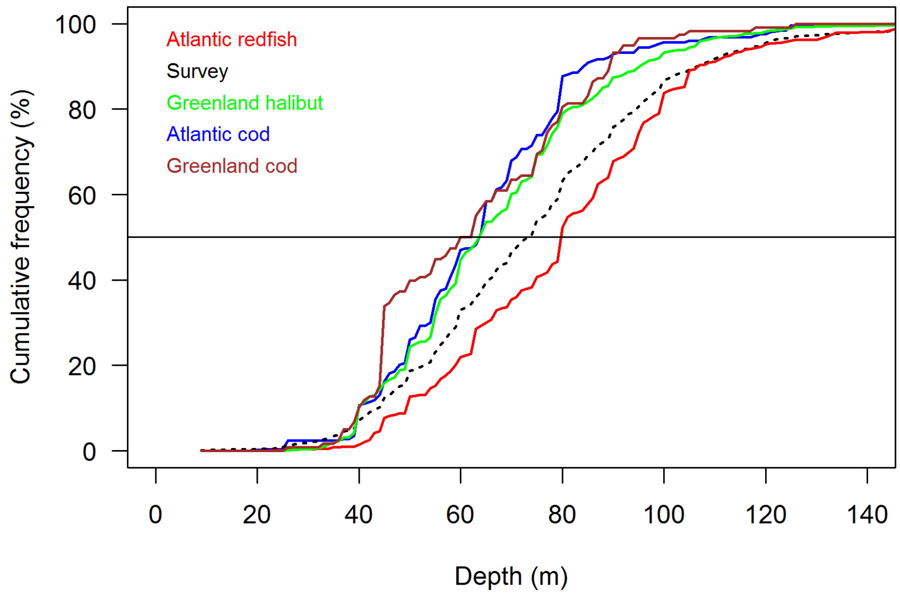


Figure 9. Relative cumulative frequency of Deepwater redfish, Greenland halibut, Atlantic cod and Greenland cod catches based on the deployment depth of 140-mm gillnets for the entire survey series, 2000–2018. The dotted line depicts the relative cumulative frequency of the number of stations sampled by depth in the study area.

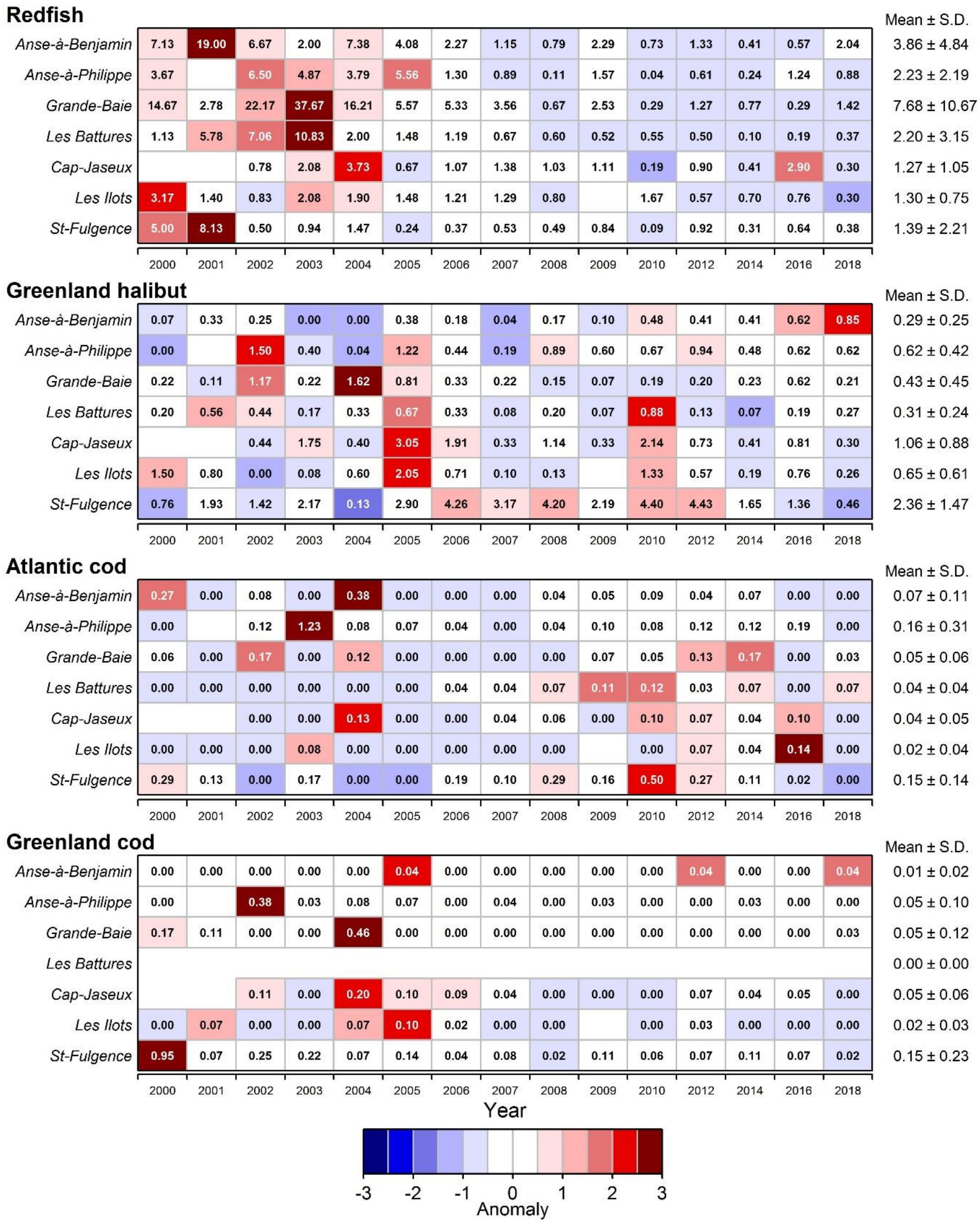
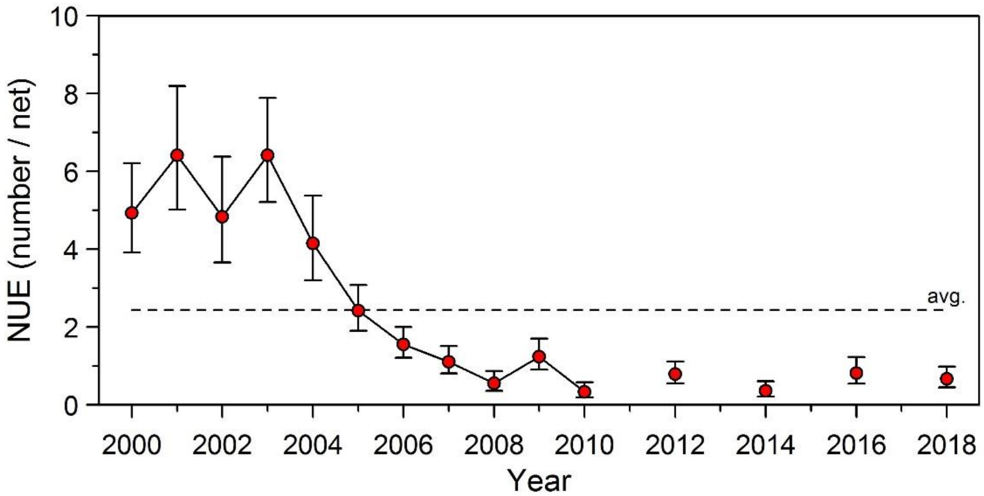


Figure 10. Annual NUE (average number of fish per net) by species and fishing sector and measurement of the anomaly compared with the series average during the 2000 to 2018 surveys. Blue cells have negative anomalies compared with the average, while red cells have positive anomalies. The intensity of the colour reflects the difference between the cell value and the series average. Empty cells indicate missing values. The Baie des Ha! Ha! area includes the Anse-à-Benjamin, Anse-à-Philippe, Grande-Baie and Les Battures sectors. The Cap-Jaseux, Les Îlots and Saint-Fulgence sectors are located in the Bras-du-Nord area.

A)



B)

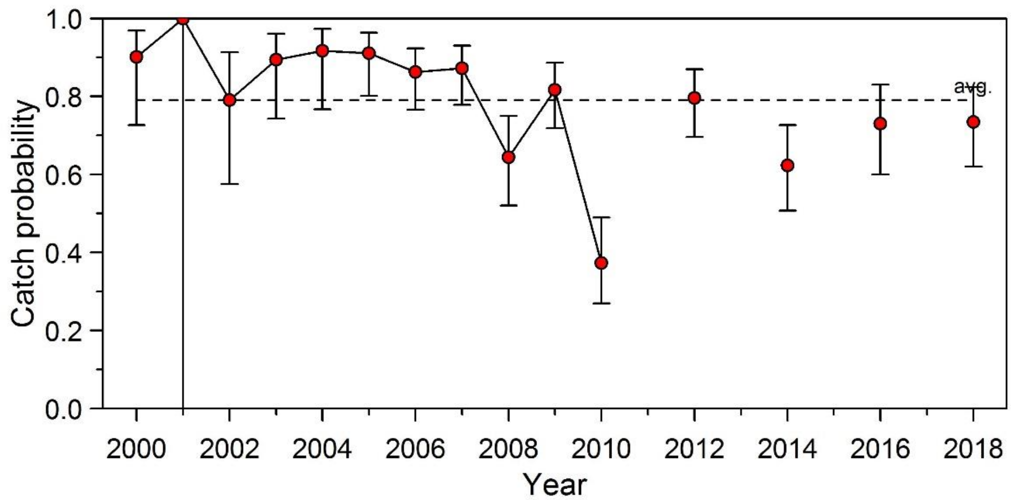
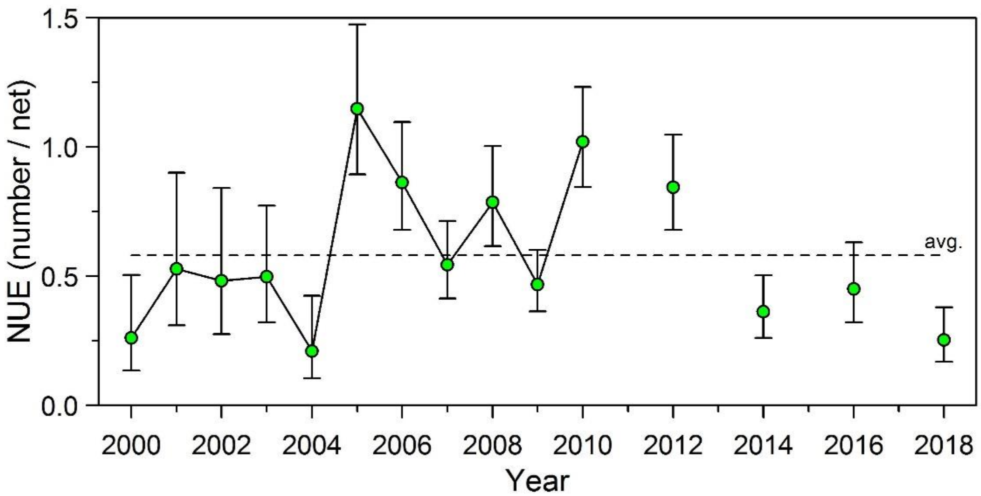


Figure 11. Average number of fish per net (NUE) (A) and catch probability per set (B) during the 2000 to 2018 surveys for Deepwater redfish. The error bars indicate the 95% confidence interval, and the dotted horizontal line indicates the 2000–2016 series average.

A)



B)

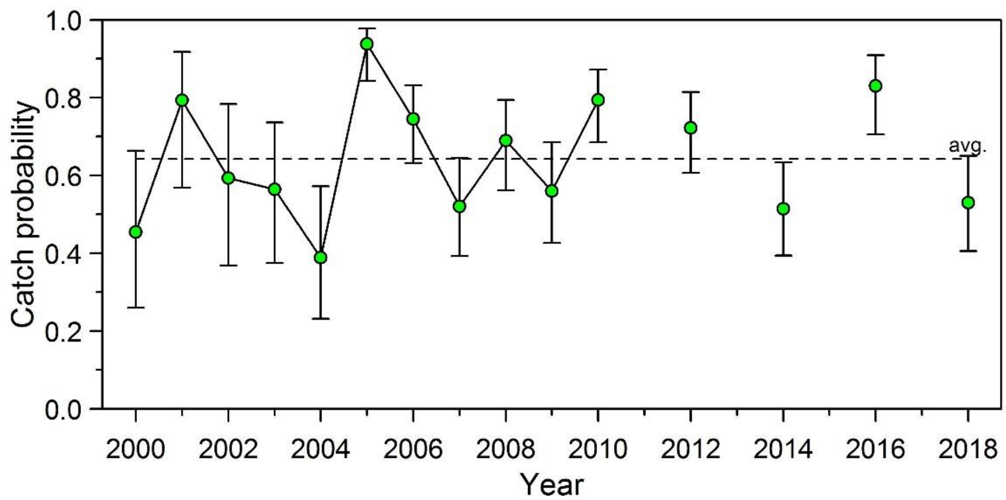
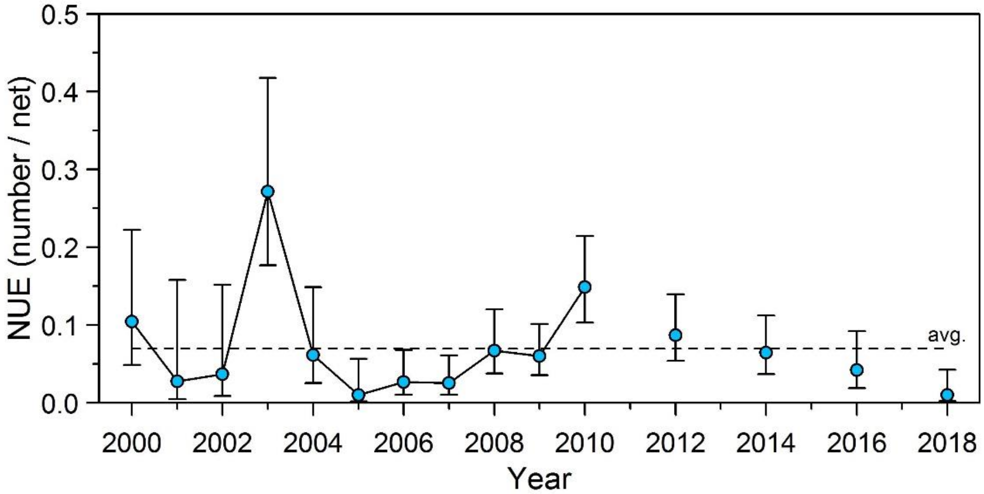


Figure 12. Average number of fish per net (NUE) (A) and catch probability per set (B) during the 2000 to 2018 surveys for Greenland halibut. The error bars indicate the 95% confidence interval, and the dotted horizontal line indicates the 2000–2016 series average.

A)



B)

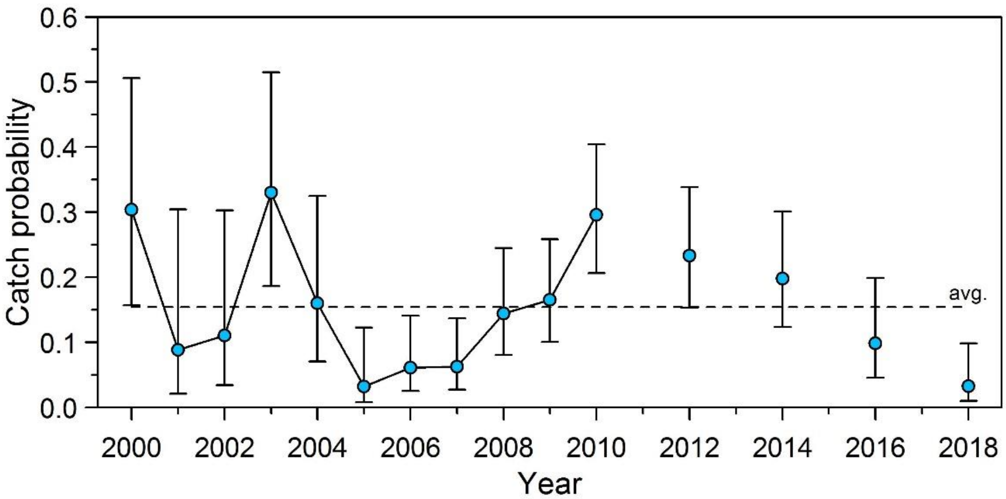


Figure 13. Average number of fish per net (NUE) (A) and catch probability per set (B) during the 2000 to 2018 surveys for Atlantic cod. The error bars indicate the 95% confidence interval, and the dotted horizontal line indicates the 2000–2016 series average.

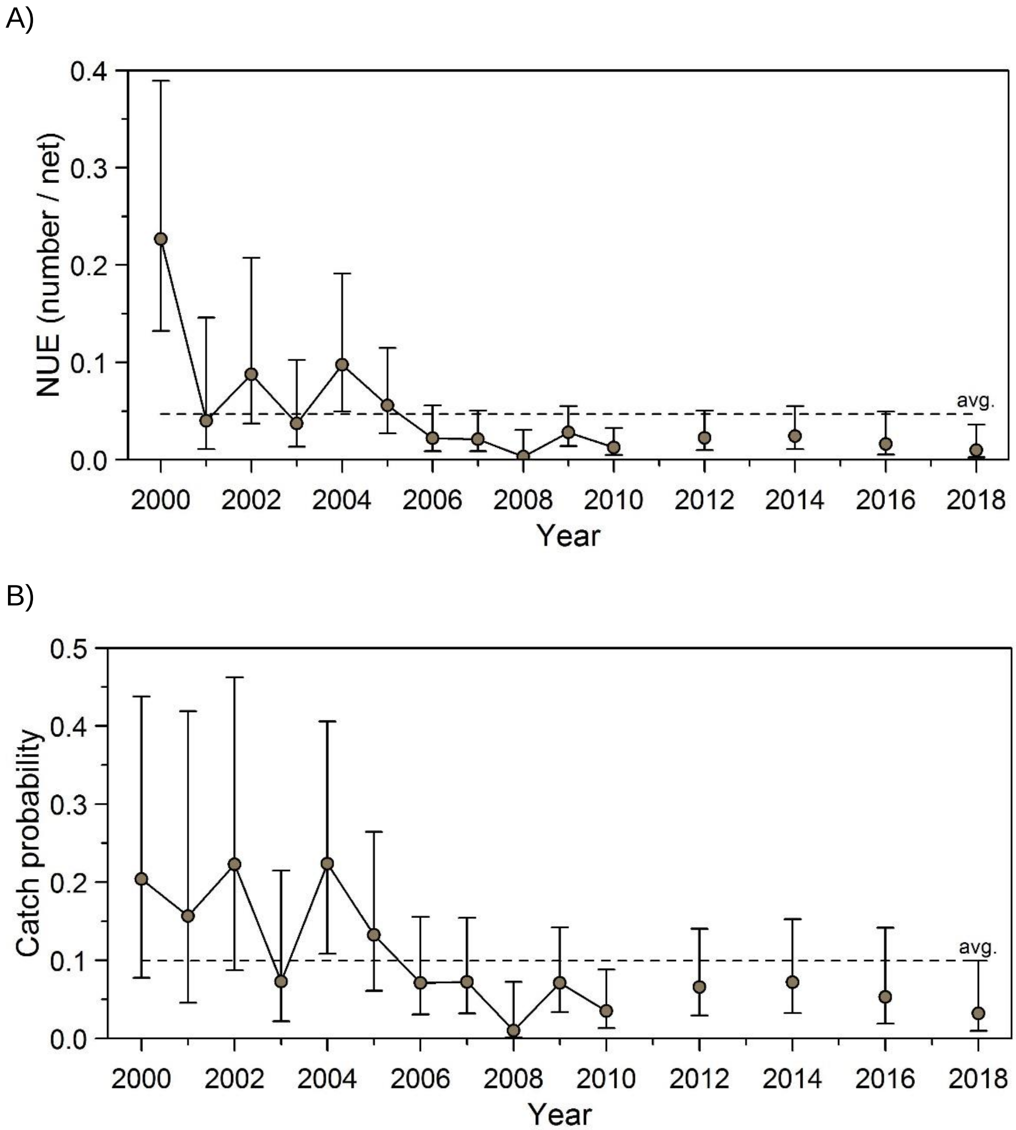


Figure 14. Average number of fish per net (NUE) (A) and catch probability per set (B) during the 2000 to 2018 surveys for Greenland cod. The error bars indicate the 95% confidence interval, and the dotted horizontal line indicates the 2000–2016 series average.

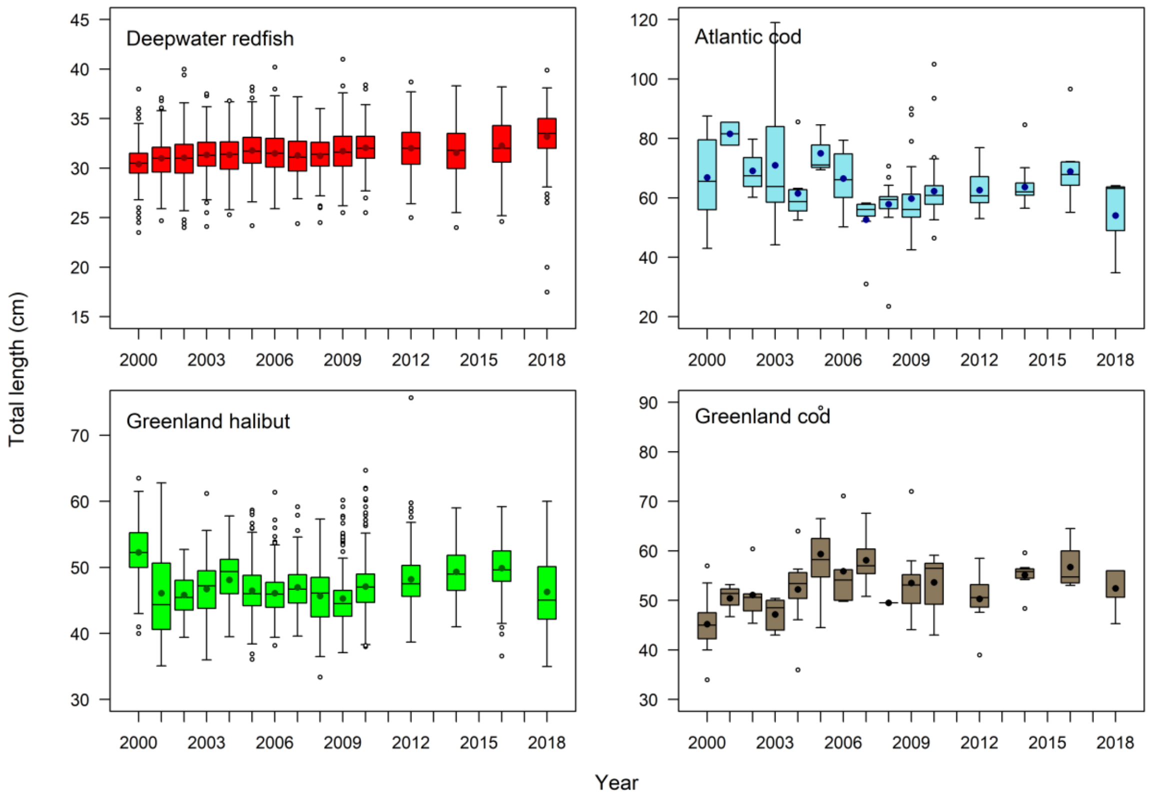


Figure 15. Total length (cm) frequency distributions for Deepwater redfish, Greenland halibut, Atlantic cod and Greenland cod caught in 140-mm gillnets. Graphic representation in box-and-whisker plots: the line inside the box represents the median and the solid circle is the average. The box ranges from the 25th to the 75th percentile, the whiskers range from the 5th to the 95th percentile and the empty circles represent outliers.

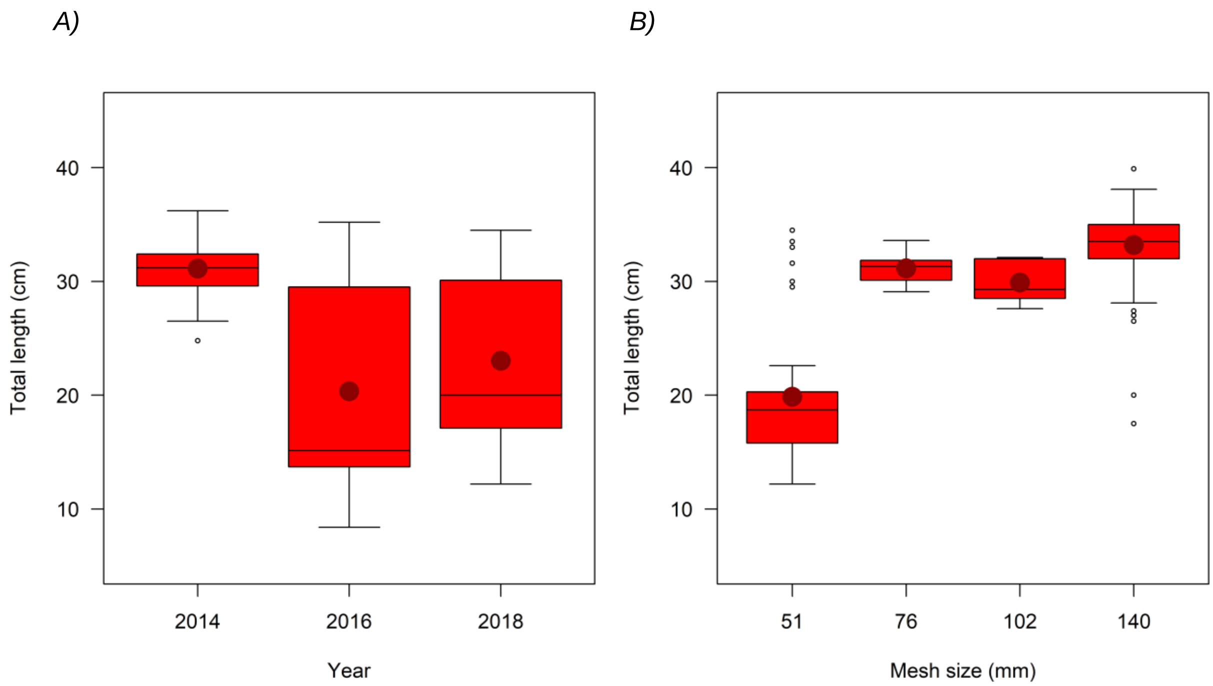


Figure 16. A) Length frequency distributions of redfish caught in < 140-mm nets during the 2014, 2016 and 2018 surveys. B) Length frequency distributions of redfish caught in 2018 in experimental nets of various mesh sizes. Graphic representation in box-and-whisker plots: The line inside the box represents the median and the solid circle is the average. The box ranges from the 25th to the 75th percentile, the whiskers range from the 5th to the 95th percentile and the open circles represent outliers.

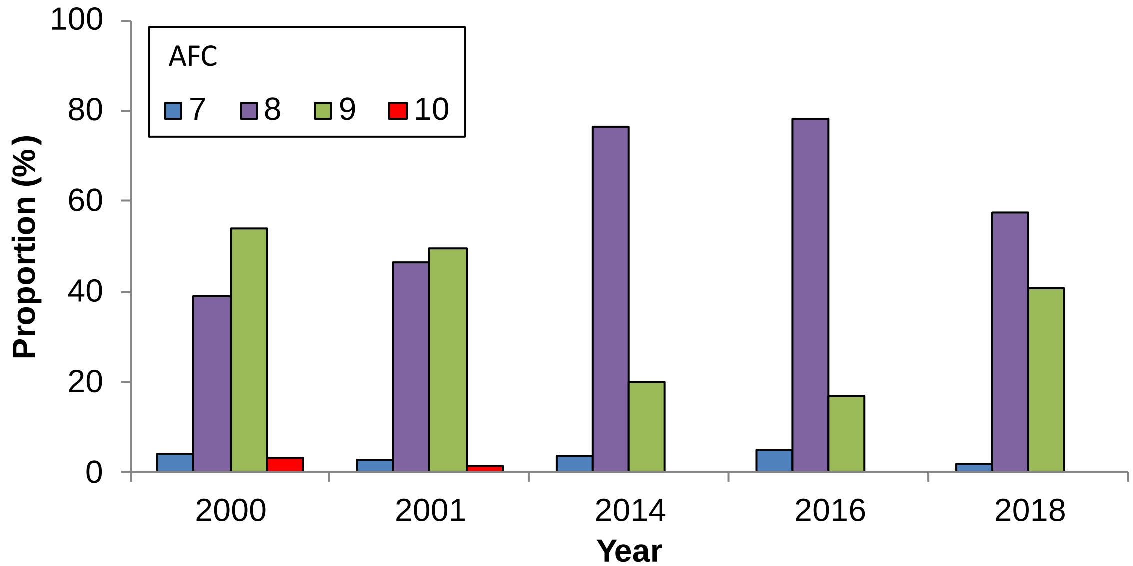


Figure 17. Proportion of the number of soft rays in the anal fin (AFC) of redfish caught during the 2000, 2001, 2014, 2016 and 2018 surveys.

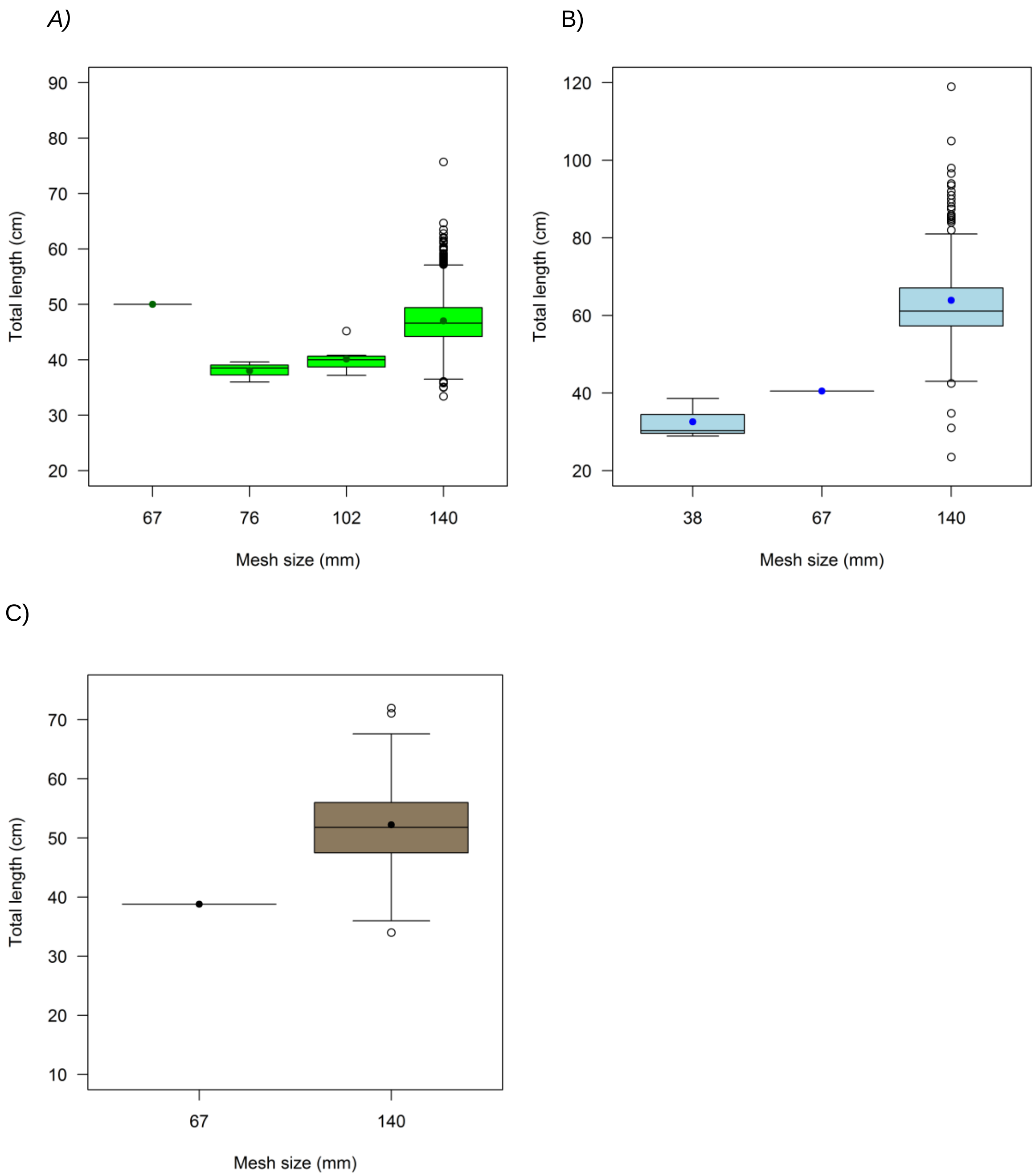


Figure 18. Length frequency distributions of fish caught in nets of various mesh sizes for A) Greenland halibut, B) Atlantic cod and C) Greenland cod. Graphic representation in box-and-whisker plots: The line inside the box represents the median and the solid circle is the average. The box ranges from the 25th to the 75th percentile, the whiskers range from the 5th to the 95th percentile, and the open circles represent outliers.

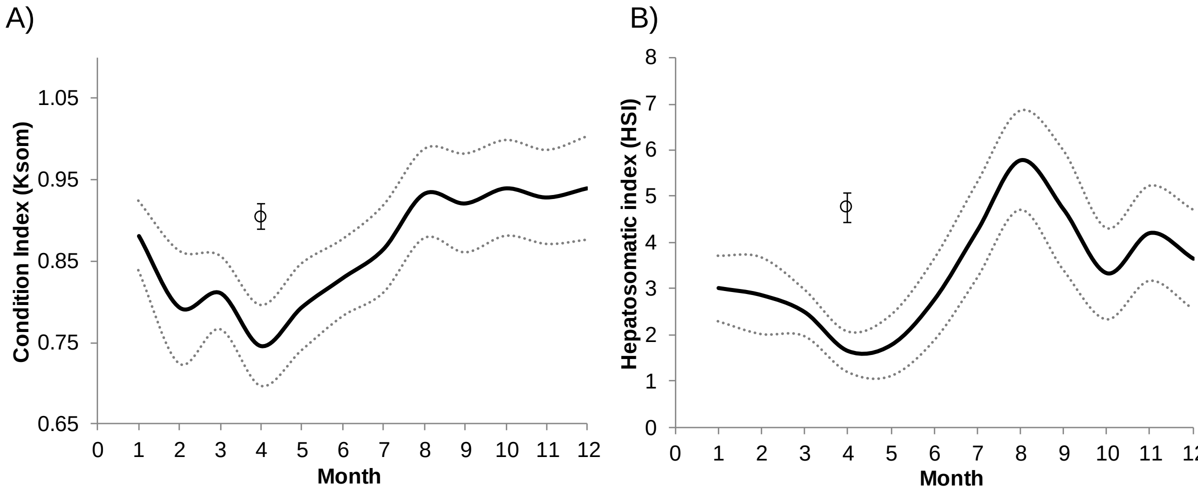


Figure 19. Monthly condition indices of Atlantic cod ranging in size from 55 cm to 85 cm caught with 140-mm gillnets. A) Somatic Fulton index (Ksom) and B) Hepatosomatic index. The solid lines depict the monthly averages (1998–2015) of the indices for Atlantic cod in the Northern Gulf of St. Lawrence and the dotted lines depict ±½ standard deviation from the averages. These data come from the Sentinel Fisheries Program. The open circles in April (month 4) represent the average for the condition indices (± the 95% confidence interval) for Atlantic cod caught during the 2014 to 2018 surveys in the Saguenay Fjord.

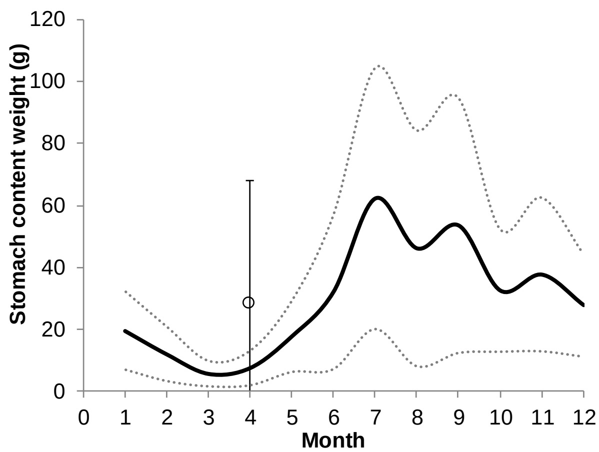


Figure 20. Weight of stomach contents, monthly average, of Atlantic cod ranging in size from 55 cm to 85 cm caught with 140-mm gillnets. The solid line depicts the monthly average (1998–2015) of the stomach content weight for Atlantic cod in the Northern Gulf of St. Lawrence and the dotted lines depict ±½ standard deviation from the average. These data come from the Sentinel Fisheries Program. The open circle in April (month 4) represents the average (± the 95% confidence interval) for Atlantic cod caught during the 2014 to 2018 surveys in the Saguenay Fjord.

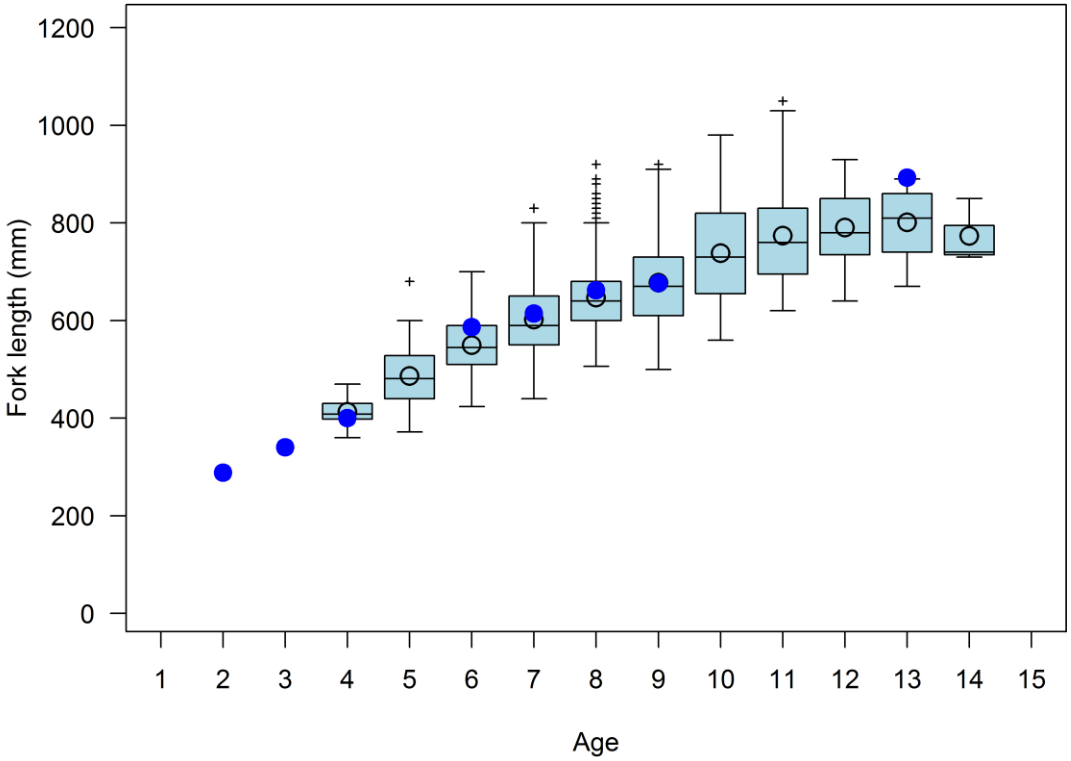


Figure 21. Graphic representation in box-and-whisker plot of the age length relation of Atlantic cod in the Northern Gulf of St. Lawrence caught with gillnets in the Sentinel Fisheries Program. The line inside the box represents the median and the open circle is the average. The box ranges from the 25th to the 75th percentile, the whiskers range from the 5th to the 95th percentile, and the crosses represent outliers. The average age length for Atlantic cod caught in April–May during the 2014, 2016 and 2018 surveys in the Saguenay Fjord is represented by a solid blue circle.

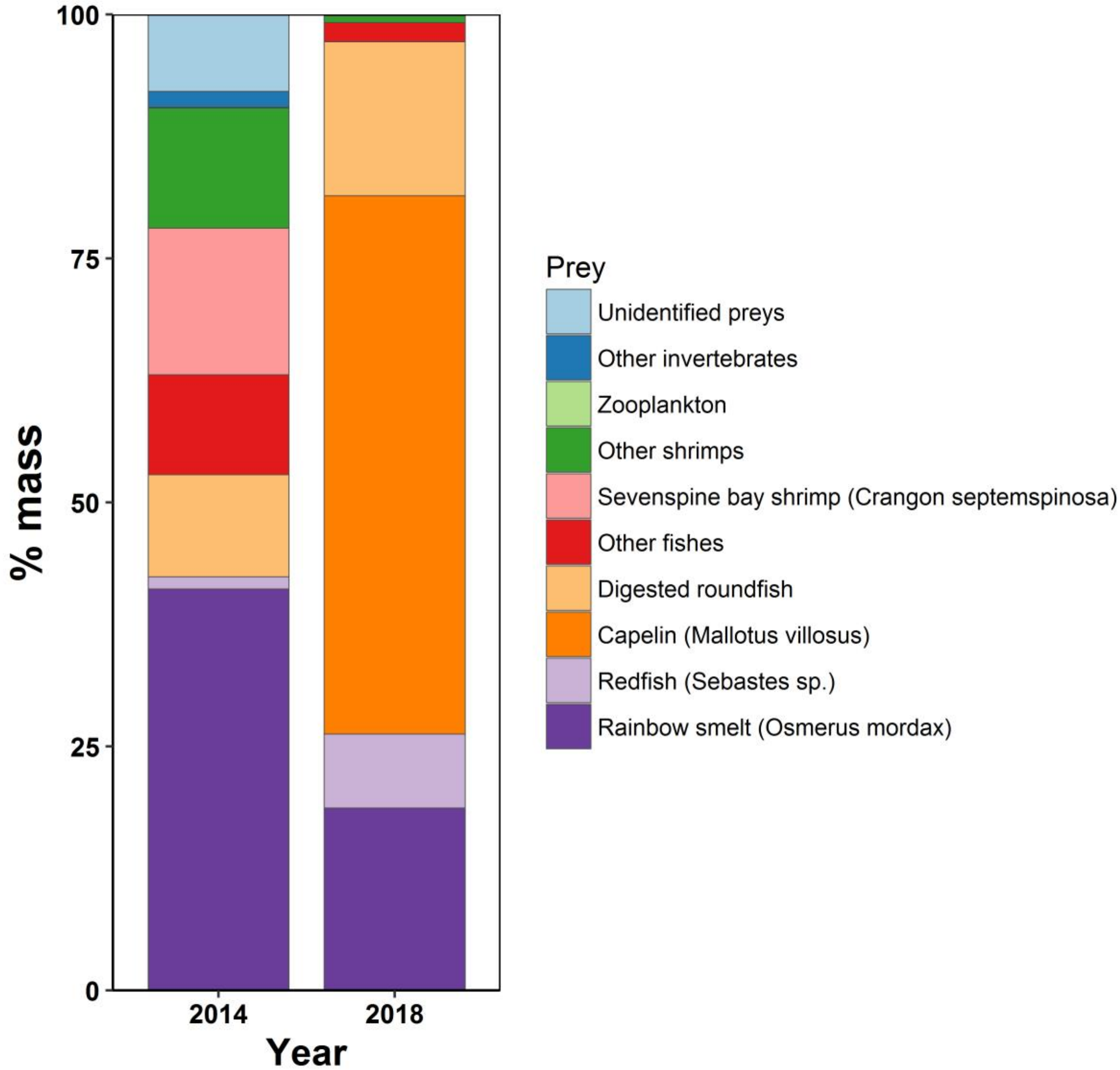


Figure 22. Mass contribution of the various prey found in the stomachs of Greenland halibut caught in April during the 2014 and 2018 surveys. See Table 9 for details.

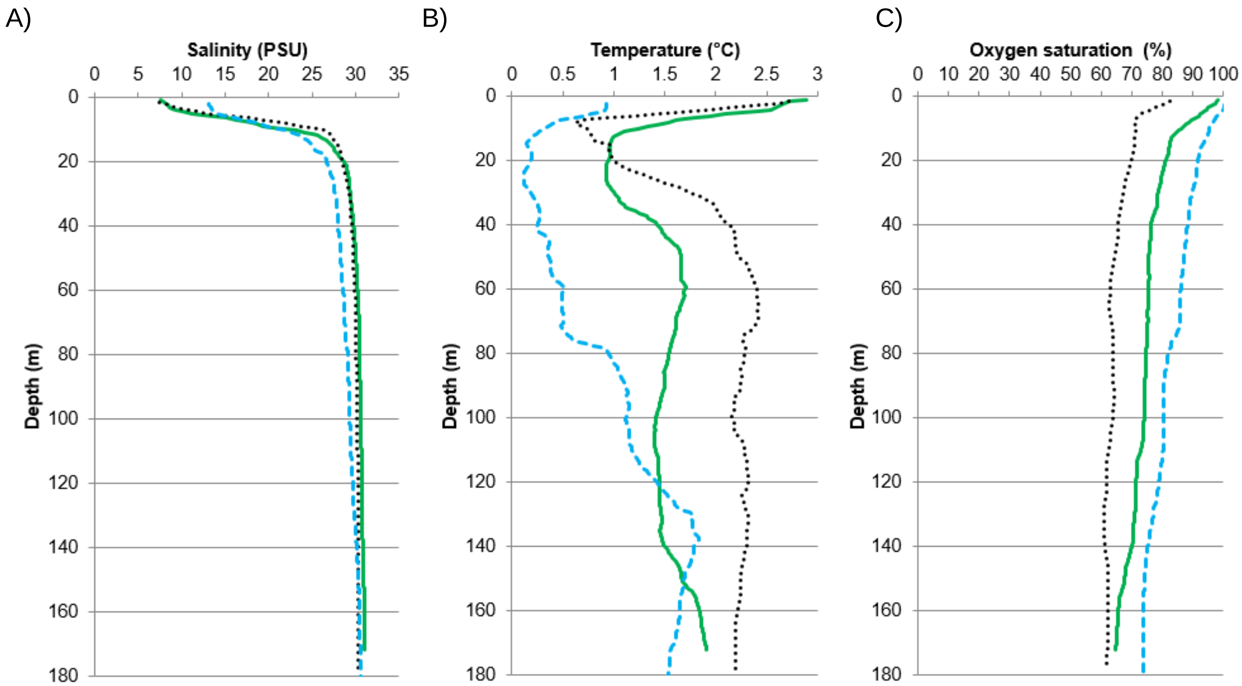
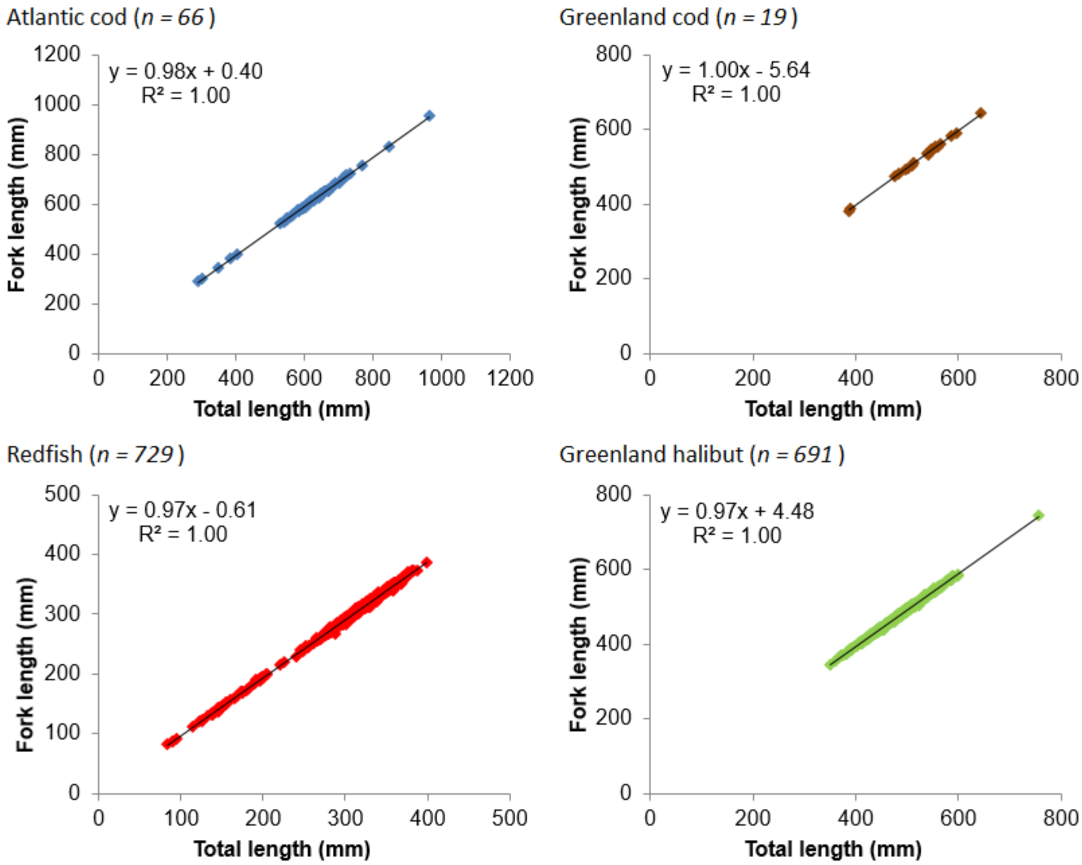


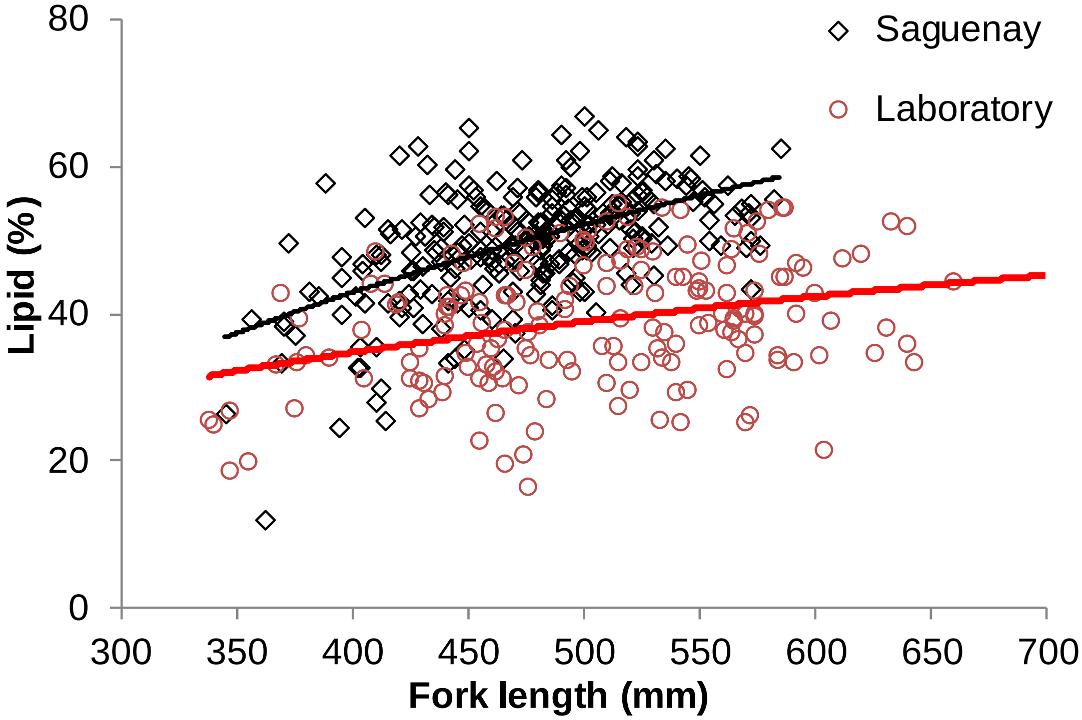
Figure 23. Comparison of the CTD profiles for 2014 (solid green line), 2016 (black dotted line) and 2018 (blue dashed line) for salinity (A), temperature (B) and oxygen saturation (C).

APPENDICES

Appendix 1. Relationship between fork length (mm) and total length (mm) for the main species caught during gillnet research surveys in the Saguenay Fjord from 2012 to 2018.



Appendix 2. Ratio between the fat content, determined as a percentage using the "fatmeter" apparatus, and the fork length of Greenland halibut caught in the Saguenay Fjord during the 2014 and 2016 surveys and comparison with Greenland halibut kept in captivity in tanks at the Maurice Lamontagne Institute (Laboratory).



Appendix 3. Redfish from the 2011 to 2014 cohorts caught in experimental gillnets during the 2018 Saguenay survey.