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Assessment of the Arctic surfclam (*Mactromeris polynyma*) stocks of Quebec coastal waters in 2020

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Canada

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.

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ABSTRACT

This research paper presents the Arctic surfclam biology and fishing activities. It also presents data and methodologies used to prepare the Quebec inshore waters Arctic surfclam stock assessment after the 2020 fishing season. This information was presented at the peer review meeting held virtually on February 22, 2021.

Mean annual Arctic surfclam landings in Quebec totalled 587 t from 2018 to 2020, an 8% decrease compared with the 2015–2017 period. The North Shore accounted for 99% of landings and the Magdalen Islands for 1%. The annual Total Allowable Catch (TAC) for the 2018–2020 period averaged over 80% in areas 3A and 3B. There was no fishing in areas 1A and 5B in 2018 and Area 2 was fished in 2018 only. There was no fishing in Area 1B from 2018 to 2020 and areas 4C and 5A remain unexploited. Mean catches per unit effort (CPUE) from 2018 to 2020 are above the time series (1993–2019) median for Area 3A but below it for areas 1A, 2, 3B, 4A, 4B and 5B. Mean sizes at landing of surfclams from 2018 to 2020 are above the time series median for areas 2, 3A, 4B and 5B, but below it for areas 1A, 3B and 4A. The exploitation rate in each area (based on the dredged surface area) was below the recommended rate of 3% in all fishing areas. According to the existing decision rules, only Area 3A meets all the conditions for a 6% quota increase. Maintaining the current quota in the other areas should not affect the status of the resource. Fishing effort in one fishing area should be distributed within and among beds in order to limit the possibility of local overexploitation.

INTRODUCTION

A review and assessment of Arctic surfclam (*Mactromeris polynyma*) stocks in Quebec inshore waters has been conducted for several years by Fisheries and Oceans Canada (DFO). Assessments are conducted every three years. This report presents the data and analytical methods used for the assessment to produce the Science Advisory Report (DFO 2021) after the 2020 fishing season.

ARCTIC SURFCLAM DISTRIBUTION AND BIOLOGY

DISTRIBUTION

Arctic surfclam (Figure 1) can be found along the west coast of the Atlantic, from Labrador to Rhode Island (Rowell and Amaratunga 1986, Roddick and Kenchington 1990); on the Pacific coast, from Alaska to Vancouver Island (Hughes and Bourne 1981); and on the coast of Russia. A Canadian study showed that there were no genetic differences between the Atlantic populations, but there was a difference between the Atlantic and Pacific populations (Cassista and Hart 2007).

Arctic surfclam (*Mactromeris polynyma*) is a sedentary endobenthic bivalve mollusc that lives buried in sediments. Arctic surfclams rarely make voluntary movements, but when dislodged from the sediment, either by currents, waves or fishing gear, they have the ability to rebury themselves as they are strong and active burrowers (DFO 2007). Burying depth depends on the length of their siphon. Larger individuals are found deeper in the sediment. They use their inhalant siphon to feed, filtering small organisms suspended in water.

This species is found buried in sandy sediments. More specifically, the sediment composition of its habitat has been assessed on a few occasions during exploratory fisheries. Bourassa et al. (2008) observed on a surfclam bed on the Middle North Shore that the sediments consisted on average of 98% to 99% sand, 0.5% to 1% gravel and less than 0.5% clay. Using divers, Lambert and Goudreau (1995a) observed the presence of Arctic surfclams on sand and sandy mud sites. Brulotte (1995) did not observe any surfclams at the sites explored where the sediment was muddy.

Surfclams gather in aggregations called “beds” on the sublittoral zone or under the low tide line. During exploratory fisheries on the North Shore, surfclams were observed at depths of 1 to 46 m and maximum densities were observed at depths of 15 to 20 m. The distribution of these beds is closely related to large North Shore rivers. These rivers release large quantities of sediment at their mouths, which favours the presence of this species. Lambert and Goudreau (1999) recorded temperatures ranging from 1 to 9 ºC at a 13-m depth at the Rivière-au-Tonnerre study site from May to November 1996. In the Magdalen Islands, the species can be found at depths ranging from 25 to 60 m.

The known distribution of Arctic surfclam in Quebec inshore waters is presented in Figure 2. This distribution is based on several sources of information, namely exploratory fisheries, scientific surveys and fishers’ logbooks. From these positions, it was possible to delineate the beds by setting their spatial boundaries at positions where the surfclam density becomes zero or very low over a distance of 1 km (Lambert and Goudreau 1997). This delineation is adjusted based on new data in each stock assessment and was done using ArcGIS Pro (version 2.5.0) by creating polygons around georeferenced positions where the surfclam was present. The distributions of mean densities and probabilities of occurrence, having been calculated within each 2-minute latitude and longitude square, are presented in Figures 26 and 27 in Bourdages et al. (2012).

GROWTH

Arctic surfclams have a slow growth rate, which appears to vary according to the species' distribution (Table 1 and Figure 3; Landry et al. 1992, Lambert and Goudreau 1999, Bourassa et al. 2008; Ziccardi et al. 2012, Trottier and Goudreau 2015). On the North Shore, they require between 13 and 16 years to reach a size of 80 mm (anteroposterior length); in the Magdalen islands, they require more than 20 years. Reaching a size of 100 mm takes 20 to 25 years on the North Shore and about 35 years in the Magdalen Islands. The mean size of surfclams fished on the North Shore and in the Magdalen Islands is around 110 and 100 mm, respectively, which would represent individuals of at least 25 years of age. The maximum size observed in the commercial fishery is 150 mm on the North Shore and 130 mm in the Magdalen Islands. These specimens could be more than 75 years old, which indicates that this mollusc has a long lifespan.

Lambert and Goudreau (1999) and Bourassa et al. (2008) studied the growth of the surfclam in the wild. To do this, in 1995 and 2004, they marked surfclams with a small numbered tag glued to their shell. These surfclams were then returned to the study site. The next year, 36 surfclams were recaptured. According to these studies, growth is highly variable among individuals. Individuals between 40 and 80 mm had a growth of about 5 mm while those over 100 mm had a mean growth of about 1 mm. Lambert and Goudreau (1999) studied growth in the laboratory. They observed increases greater than what had been observed in the wild in the smallest individuals. A graphical representation of different annual growth models was made using data from the work done by Bourdages and Goudreau (2012).

There also appears to be a negative relationship between individual density and growth (Lambert and Goudreau 1999).

REPRODUCTION

The Arctic surfclam is dioecious, meaning that the sexes are separated. Lambert and Goudreau (1997) studied its reproductive cycle and observed a sex ratio of nearly 1:1 for individuals between 50 and 80 mm and clearly in favour of females for individuals over 80 mm. They also observed that the majority of individuals over 62 mm had spawned or possessed mature gonads, but that at this size, their contribution to the population's reproductive potential was low because like other bivalve species, gamete production is considered to increase with size (Langton et al. 1987). Similarly, they observed that spawning occurred primarily from late June through mid-July and that there may be secondary spawning in the fall. Reproduction is synchronous and gamete fertilization occurs in the water column. After eggs hatch, a pelagic larval stage extending over a few weeks precedes benthic life. From laboratory observations, Davis and Shumway (1996) estimated that larval metamorphosis occurred after 24 days of growth at 15 ºC and after 42 days at 10 ºC.

DESCRIPTION OF THE FISHERY

The first exploratory fisheries in the northern Gulf took place in 1990 in the Magdalen Islands and in 1991 on the North Shore (Landry et al. 1992). Subsequently, other exploratory fisheries took place on the North Shore (Mercier 1992, Cyr 1994, Lambert and Giguère 1994, Lambert and Goudreau 1995b, Lepage 1994), on the shores of the Lower St. Lawrence, and on the north shore of the Gaspé Peninsula (Brulotte 1995). These exploratory fisheries located several beds. From that time onward, the fishery began to develop more abundantly on the North Shore and in the Magdalen Islands. The first landings were recorded in 1993 (Lambert and Goudreau 1997). In Quebec, the Arctic surfclam fishery is complementary because fishers engage in other fisheries during the year.

The Arctic surfclam fishery is conducted using a New England hydraulic dredge (Figure 4). It is a sophisticated dredge designed to (1) be extremely efficient, (2) have a low bycatch rate and (3) retain few undersized surfclams (Northeast Region Essential Fish Habitat Steering Committee 2002). According to Lambert and Goudreau (1995a), the effectiveness of this type of dredge is estimated at more than 90% for surfclams measuring more than 80 mm.

Depending on the management measures specific to each region, the typical dredge used in Quebec is 1.83 or 2.13 m (6 or 7 ft.) wide by 1.83 m (6 ft.) long. Spacing between the basket bars must be at least 3.175 cm. The dredge's cutting bar is adjusted to fish at a depth of about 20 cm and the water jet pressure is adjusted to about 414 to 715 kPa (60 to 75 PSI). The water jets penetrate the sediment in front of the dredge to a depth of about 20 cm, liquefying the sediment. The endobenthic organisms thus released are then collected in the bucket when the dredge passes. The dredge is towed at a speed of about 11 m/min (0.35 knots) for about 10 minutes per tow at depths between 10 and 20 m, but the depth may vary depending on the fishing site.

FISHERY MANAGEMENT

Quebec has 10 fishing areas: 8 on the North Shore and 2 in the Magdalen Islands (Figure 5). This inshore fishery is managed throughout the area by a number of licences, a fishing season, a total allowable catch (TAC) and a minimum catch size of 80 mm (Table 2). In 2020, 15 permanent licences and 3 exploratory licences were issued. Some licences give access to more than one fishing area. The TAC by fishing area and year is presented in Table 6.

CONSERVATION APPROACH

A workshop on biological reference points for invertebrates was held in Halifax in 2002 (Smith 2003). The findings of this workshop were presented for several species that were divided by life cycle category. The Arctic surfclam was in the group of species with a larval dispersal phase and with sessile adults that are open-water spawners (and release their gametes into the water where fertilization occurs). These species are found in beds and are highly fecund, and fishing operations can be very disruptive to the habitat. Most conservation strategies for these species include providing a refuge area for spawners or maintaining a spawning density at a level that ensures effective reproduction. Catch control generally involves effort limitation through restricted access, seasons or protected areas. A minimum catch size equivalent to the size at sexual maturity is commonly brought into force. Gear restrictions exist for several fisheries. Rotational fishing is strongly recommended.

The objective of the Arctic surfclam conservation approach is to protect the reproductive potential and genetic integrity of Quebec populations and to limit the fishery's impact on the ecosystem. Management measures to achieve these objectives are effort control, sampling method, escapement control (selectivity) and the development of a precautionary approach.

To achieve this, Quebec is divided into several fishing areas where access is limited to only a few fishers (one to five per area, Table 2). Generally, they have access to the area for a few months (from July to November) and they have a TAC. In most fishing areas, there are also shellfish areas that are closed on account of unsafe shellfish. Although these areas are closed within the scope of the Canadian Shellfish Sanitation Program, these closures protect some of the surfclam population from being harvested, but their abundance and contribution to reproductive potential remains unknown. The density of spawners is critical for reproductive success, and protecting small areas with a high density of adults may be beneficial for the population. In addition, portions of beds with a high density of pre-commercial size (< 80 mm) surfclams should be protected from the fishery because they are less evenly distributed within the beds compared with commercial-size surfclams. The exploitation rate per bed must remain low given the species' low productivity. Currently, the dredged area remains relatively small compared with the known area of the beds.

The current minimum catch size of 80 mm allows individuals to reproduce a few years before being vulnerable to the fishery. In addition, the regulated spacing of the dredge bars minimizes catching surfclams smaller than 80 mm; however, even if they are not caught, the survival rate of these surfclams is unknown after the dredge passes.

Population monitoring and management measures are necessary for this conservation approach. The monitoring tools already in place should be maintained and others should be developed (*in italics*):

- Tracking of catch per unit effort (CPUE) by logbook and purchase receipt.
- Dockside sampling with appropriate spatial coverage.
- Using the logbook to monitor spatial distribution of fishing effort.
- *A vessel monitoring system (VMS) would improve knowledge of bed distribution, exploited areas and fishing patterns.*
- *Knowledge of bycatch and incidental mortality could be improved.*

Research surveys provide basic knowledge of the species' biology. Such surveys conducted before exploiting a bed would provide information on the demographic structure of the virgin population. A periodic survey would allow for management based on exploitable biomass and on reference points.

According to Richard and Maguire (1998), future harvesting strategies should be based on stock-specific reference points and pre-established decision rules. Objectives and reference points associated with the Arctic surfclam fishery are not yet developed. Discussions between the fishing industry and DFO will be required in order to develop this precautionary approach. Development of reference points based on virgin biomass will not be possible for beds that have already been exploited where few or no data are available before exploitation begins. However, it would be wise to acquire a good knowledge before exploitation starts if new beds are discovered in the future.

DATA SOURCE AND ANALYSES

COMMERCIAL FISHERY DATA

Commercial Arctic surfclam fishery data are derived from three separate sources of information: the fisher's logbook, the purchase receipt and commercial catch sampling conducted by DFO.

The fishers fill in their logbooks on each fishing day. The logbooks contain the date, the weight of the catch, the position (latitude and longitude) at the beginning and end of the fishing day, the fishing quadrilateral (10-minute latitude and longitude square), the fishing duration, the number of tows, the width of the dredge and the number of crew members. The logbook data are entered into a database by DFO area offices. The fishing activities reported in the logbooks are then paired with the plant purchase receipts to account for each operator's landings. At the end of the season, these data are extracted for DFO's Ecosystems and Oceans Science Sector. The data are then validated and corrected as needed by the scientists. Outliers are removed from the calculations. In late fall, fishing statistics are updated for the current year and the two previous years. Data from the two previous years are still considered preliminary.

At the beginning of this fishery, from 1993 to 1997, with some exceptions, fishers cooperated with DFO by completing a detailed logbook for each fishing tow. The position, depth, duration and weight caught in each tow were recorded in the logbook. In those days, fishers did a lot of exploring. The information obtained was very helpful in defining the extent of the Arctic surfclam beds. In addition, from these data, the mean duration of a tow was estimated, as was the fishing speed. In order to make these data comparable with the data currently collected in the logbooks, i.e., data per fishing day, the information from the fishing tows on the same day was summed up or an average per day was calculated. These aggregate data were used to estimate CPUE and to define the areas exploited.

The function of the DFO commercial sampling program is to characterize the individuals harvested by the fishery in order to complete the information essential to the assessment of the impact of exploitation on marine resources. In the case of the Arctic surfclam, this sampling takes place at the dock given that:

1. the dredge is very selective in catching only individuals of legal size, so the release of Arctic surfclams is minimal.
2. the species is not processed at sea; it is landed in its entirety.
3. bycatch is very low.

Since 2004, dockside sampling has taken place either upon landing or at the plant. A sample of about 150 surfclams is taken and the size of each is measured along the longitudinal axis to the nearest millimetre. Information on the source of the catch is also compiled. The number of samples requested annually by Science is presented in Table 3. Because of the surfclam's slow growth during the fishing season, there are no details on when to collect the samples. Landings can therefore be sampled at any time during the fishing season. The goal is to sample 6 to 10 fishing activities per area annually.

Landings

Landings are expressed in live weight (the whole surfclam with shells). Landings from the same bed, fishing area or marine region are totalled by year.

Fishing effort

Much of the information available in the logbook can be used to define the fishing effort (for example, the fishing duration expressed in hours, the number of fishing days, the number of tows and the width of the dredge). The number of fishing tows was preferred to describe fishing effort since it is more consistently noted among fishers.

The number of tows can be converted to dredged area. To do this, knowledge of the mean duration of a tow, the fishing speed and the width of the dredge is required. The mean duration of a tow was estimated at 10.346 minutes in the logbooks from 1993 to 1997. It would be appropriate to reassess this duration, which may have varied over time because the duration varies from tow to tow. However, analysis of these historical data did not reveal any significant effects from fishers or the fishing area. The fishing speed used is 11 m/min (0.35 knots) (Jean Lambert, DFO, pers. comm.). This fishing speed is comparable to speeds observed in research projects conducted with fishers from 1993 to 1997. However, a dredging speed of 22 m/min (0.7 knots) has been used since 2013 for areas 2, 3A and 3B after a change in the fishing pattern. The width used is the width of the dredge cutting bar provided in the logbook. Effort is also expressed in fishing days. In this case, it is the number of daily trips made by fishers in the area.

The distribution of daily fishing positions was studied in relation to the longitude of the activities. The longitude represents the axis of the coast on the North Shore and the distribution of the beds. The latitudinal extent of the fishing sites is relatively small. The number of fishing days was added up by year for each 10-second longitude interval, which corresponds to a distance of about 310 m. The distribution of this effort is presented by year and by area and provides information on the dynamics of the spatial distribution of fishing effort, i.e., which beds are exploited and how effort shifts within a bed and between years.

The calculation of fishing effort is mostly based on variables derived from logbooks and some constants assessed during the 1993–1997 commercial fishery. Any change in fishing technique (for example, an increase in dredging speed) would have a direct impact on areas dredged and exploitation rates.

Catch per unit effort

Annually, CPUE is estimated from logbook data using a Jackknife estimator (Smith 1980). The Jackknife estimator R_J is the average of n quantities:

$$R_{-j'} = n\frac{P}{E} - (n-1)R_{-j},$$

where n is the number of activities in the fishing area, P and E are the total catch and total effort in the area in question, and $R_{-j} = \sum P_{ij} \,/ \sum E_{ij}$ with the *j*th observation removed. The catch is expressed in kg live weight and the effort in number of tows for a 1-metre-wide dredge (number of tows multiplied by the width of the dredge).

The variance estimate of R_J is calculated as follows:

$$V\left(R_J\right) = \frac{1}{n(n-1)}\sum^{n}(R_{-j'} - R_J)^2$$

CPUE is presented with its 95% confidence interval and is expressed in kg per tow for a 1-metre-wide dredge and in g/m^2, assuming that an area of 113.8 m^2 is covered during a tow by a 1-metre-wide dredge, as defined above.

Exploitation rate indicator

From the daily positions provided in the logbooks since 1993, it was possible to map the intensity of exploitation on the beds with the Kernel density analysis tool in the ArcGIS Pro (version 2.5.0) Spatial Analyst suite. Intensity of exploitation was estimated on a 5x5-metre grid by implementing a search ellipse constraint with a 200-m radius. This radius approximates the fishers’ range as revealed by logbook data from 1993 to 1997. At that time, fishers recorded the positions of all the day’s tows and focused their effort locally within a radius of about 200 m before heading out.

The area of the exploited zone in each bed that circumscribes 100% of the fishing intensity (fishing intensity > 0) was estimated from the maps of intensity of exploitation. Subsequently, a second area corresponding to the area where 95% of the intensity of exploitation is distributed was estimated. The number of observations used to estimate these surface areas and the two estimated areas are presented by bed in Table 10.

An exploitation rate indicator was developed using the quotient between the area dredged annually by fishers and the area where 95% of the intensity of exploitation is concentrated; that is:

$$Exploitation\ rate_{bed,year} = \frac{dredged\ area_{bed,year}}{exploited\ area_{bed,year}}$$

The exploitation rate is estimated by year and by bed. However, the exploitation rate for some beds was calculated using the total area of these beds because of the low fishing intensity (less than 30 fishing days in all years). An exploitation rate for each area is also calculated for this assessment period using the mean dredged area for the years 2018–2020 divided by the area where 95% of the fishing intensity for that same area is concentrated.

COMMERCIAL SAMPLING

A boxplot is used to measure the size at landing of surfclams by year and by bed. The boxplot is a quick way to present several descriptive statistics of the variable being studied. To begin with, the rectangle drawn runs from the first quartile to the third quartile and is intersected by the median so that 50% of the observations fall within the boundaries of the box. The lower end of the whisker represents the minimum value of an observation that is above the low boundary value while the upper end represents the maximum value of an observation that is below the high boundary value. These limits deviate by 1.5 times the height of the box above or below the box boundaries. Lastly, extreme observations lie outside the boundaries of the whisker and are represented by dots. The 5th and 95th percentiles of the distribution were also added to the graph.

An analysis of variance model (LS Means Analysis of Variance) was used to estimate the mean size at landing of surfclams to account for differences among the beds. The fixed factors in the model are year and bed and a random factor is assigned to the sample. The year and bed factors are significant in the analyses. For some areas, a few beds had to be removed from the analysis because they had not been sampled frequently enough. Therefore, the Îles de Mai (Area 2) and northwest of Grosse-Île (Area 5B) beds were not used to estimate the mean size indicator, nor was the sample collected in 1998 at Natashquan.

RESEARCH SURVEYS

Research surveys conducted on the North Shore in 2009 and 2010 as part of the Fisheries Science Collaborative Program (FSCP) showed a very localized presence of high densities of surfclams measuring less than 80 mm in the Longue-Pointe-de-Mingan (Area 4A) and Natashquan (Area 4B) beds and lower densities in the Forestville (Area 1A) bed (Bourdages and Goudreau 2012). Furthermore, commercial size surfclams were more evenly distributed within these beds compared with pre-commercial size surfclams (< 80 mm) (Trottier and Goudreau 2015). This work also showed that the highest densities of surfclams (< 80 mm and ≥ 80 mm) were found in the same locations on the Longue-Pointe-de-Mingan bed compared with the 1994 study by Lambert and Goudreau (1995b) (Trottier and Goudreau 2015).

Age readings were taken on a sample of surfclams collected during Bourdages and Goudreau's work (2012) in 2010 on the Natashquan bed. Age was estimated by assessing the number of growth rings on the shell chondrophore of each individual. The parameters of the growth curve according to the von Bertalanffy model were estimated and these parameters are presented in Table 1 and Figure 3.

Given this species' sedentary nature and slow growth, it would be worthwhile to consider the cumulative effects of exploitation on the beds. Moreover, the density and biomass of several beds are not known, and it would be useful to acquire new knowledge on this subject.

ASSESSMENT OF THE RESOURCE STATUS

In order to facilitate the reading and use of this research paper, the various tables and figures are placed in continuous form at the end of the document. Initially, the overall results are presented by region or by area grouping. Therefore, there are landings (Tables 4 and 5 and Figures 6 and 7), fishing effort in days (Table 7) and dredged area (Table 8), CPUE (Table 9), exploitation rate (Table 11) and mean size estimate (Table 12).

Thereafter, the results are presented by fishing area (Figures 8 to 74). All information from one area is grouped together. For each fishing area, the order of the different figures is the same, i.e., bed location (Figures 8, 16, 24, 32, 40, 48, 56, 64 and 65), landings (Figures 9, 17, 25, 33, 41, 49, 57 and 66), fishing effort in dredged area (Figures 10, 18, 26, 34, 42, 50, 58 and 67), CPUE (Figures 11, 19, 27, 35, 43, 51, 59 and 68), distribution of sizes at landing of surfclams by bed (figures 12, 20, 28, 36, 44, 52, 60 and 69), mean size (Figures 13, 21, 29, 37, 45, 53, 61 and 70), intensity of exploitation (Figures 14, 22, 30, 38, 46, 54, 62 and 71) and, lastly, distribution of fishing effort (Figures 15, 23, 31, 39, 47, 55, 63 and 72).

The median presented on the effort, CPUE and mean size figures represents the time series median value from 1993 to 2019, which excludes the last year.

REVIEW OF INDICATORS

Arctic surfclam is distributed in heterogeneous densities along the entire North Shore, from the Lower Estuary (Les Escoumins) to the Lower North Shore (Blanc-Sablon). There are more than 25 known beds along this coast; these beds cover a total area of 197 km^2 (Figure 2 and Table 11). In the Magdalen Islands, surfclam is present everywhere around the islands at a distance of about 25 to 40 km from the coast and at depths ranging from 25 to 60 m (Figure 65). There are four known beds in this region, and they cover a total area of 464 km^2 (Table 11). The area of the beds varies greatly. For example, on the North Shore, the smallest bed is 0.6 km^2 while the largest is 60 km^2, while in the Magdalen Islands, the smallest is 9 km^2 and the largest is 214 km^2.

Fishing effort is not distributed uniformly in the surfclam's known habitat. Fishers prefer to go to sites with high concentrations of commercial size surfclams in the beds. Over the past three years, fishing efforts have been made on 14 beds on the North Shore and on one bed in the Magdalen Islands (Table 11).

In Quebec, mean landings over the last three years totalled 587 t, down 8% compared with the 2015–2017 period (Table 4, Figures 6 and 7). This decrease is due to fishing inactivity in areas 1A and 5B in 2018 and in Area 2 in 2019 and 2020. In addition, Area 1B has not been exploited in the past four years. From 2018 to 2020, the North Shore accounted for 99% of landings and the Magdalen Islands for 1%. Figure 73 shows the proportion of the TAC that was reached by year and area. Two areas remain unexploited, namely areas 4C and 5A. The annual TAC for the 2018–2020 period averaged over 80% in areas 3A and 3B. For areas 1A, 2, 4A, 4B and 5B, the TAC for the same period averaged 5% to 76%.

The mean catches per unit effort (CPUE) for the 2018–2020 period were above the time series medians for Area 3A, but below them for Areas 1A, 2, 3B, 4A, 4B and 5B (Table 9). Figure 74 shows the difference between the annual CPUE and the time series mean for each fishing area. Until now, throughout each area, fishers were able to maintain good yields by moving over the same bed or from one bed to another. On a small scale, the fishery could still bring about a decrease in density and mean size and, consequently, in CPUE.

The mean size at landing is high in all areas compared with the legal size of 80 mm (Table 12). The mean sizes for the 2018–2020 period are above the time series median for areas 2, 3A, 4B and 5B, but below it for areas 1A, 3B and 4A (Table 12). For most areas, fishers were able to maintain high sizes by moving their fishing effort. The number of individuals measuring less than 80 mm in landings is minimal (about 0.6%) because of the dredge’s selectivity.

The mean exploitation rate in each area for the 2018–2020 period is below the recommended rate of 3% in all fishing areas (Table 11). The exploitation rates are below the recommended limit except in two beds, where it is exceeded: Baie de Moisie west of Area 3A (3.4%) and Rivière-au-Tonnerre east of Area 3B (4.0%). Such exploitation rates may not be sustainable in the long term.

Decision rules

Quota increases must be conservative, as the Arctic surfclam’s low growth rate and sedentariness make certain beds vulnerable to overexploitation. According to the guidelines established to recommend quota adjustments in each fishing area, increases should not exceed 6% per three-year period. A quota cannot be increased unless over 80% of it, on average, has been reached consistently during the assessment period and the CPUE and mean size indicators are above the time series median. In addition, the exploitation rate in the area should be below 3%.

According to the existing decision rule (Bourdages and Goudreau 2012), only Area 3A meets all the conditions for a 6% quota increase. The status quo is recommended for all other areas (Table 13).

1. We should also start thinking now about adding conditions to this decision rule for situations where the indicators would show a negative signal because of exploitation. In this respect, Bourdages and Goudreau (2012) proposed three types of reference points that could be used to develop a precautionary approach. In short, reference points based on indicators of CPUE and of mean size at landing.
2. The exploitation rate calculated from the dredged areas.
3. Knowledge of exploitable biomass through research surveys could be explored.

Finally, the application of this rule is only reviewed at the time of the stock assessment every three years or if a negative signal of the exploitation of the resource is perceptible at the time of the annual indicator update.

ECOSYSTEM CONSIDERATIONS

A science advisory report on the potential effects of mobile gear on benthic habitats and communities was published by DFO’s Canadian Science Advisory Secretariat in 2006 (DFO 2006). The effects of mobile gear are not uniform, but are at least a function of these considerations: (1) the particular characteristics of the benthic habitats, including the natural disturbance regime, (2) the species present, (3) the type of gear used, and (4) previous human activities. In applying the precautionary principle to the management of ecosystem effects from human activity, it is important to consider the ability of ecosystem components to recover from disturbances.

Habitat

Use of the hydraulic dredge has an immediate impact on substrate and benthic organisms. Dredge water jets liquefy the sediment up to 20 cm deep to collect most of the larger organisms and cause sedimentation adjacent to the dredge's path (Lambert and Goudreau 1995a, Gilkinson et al. 2003). The greatest impact of this fishery is to remove the largest surfclams from a bed, either through fishing or incidental mortality. Sedentariness, irregular recruitment and low growth rate mean that, after a stock is depleted, it could take many years for surfclams in a bed to recover to commercial sizes.

The impact of this fishery was studied on Banquereau Bank at a depth of 70 m (Gilkinson et al. 2003, 2005). At this depth, the study showed an impact on habitat and non-target organisms within the first two years after dredging. Juvenile surfclams were low in number throughout the study and no impact could be detected on them. In this time frame, there was considerable recovery of the composition of non-target benthic species, such as echinoderms, with a shift in relative abundance of the species present. Visual assessment with a camera did not reveal any dredge marks after one year. However, with side-scan sonar, it was still possible to see the marks after 10 years. At another shallower site, on Sable Island Bank at a 40-m depth, half of the marks could no longer be seen with side-scan sonar after one year (Ned King, Atlantic Geoscience Centre, pers. comm. in DFO 2012).

Recovery speed varies depending on the site's depth, sediment type and degree of hydrodynamics. Shallower sites with higher hydrodynamics produced by currents seem to recover their initial state of sediment and meiofaunal/macrofaunal composition between a few days to a few months (Hall et al. 1990, Constantino et al. 2009, Tuck et al. 2000). The rapid recovery could be caused by the high hydrodynamics and the more mobile nature of the sandy bottoms, favouring communities that are more resilient to disturbances (Zajac and Whitlatch 2003).

In Quebec, the fishery is carried out mainly along the coast on sandy bottoms, at depths of 10 to 25 m on the North Shore and about 30 m in the Magdalen Islands. Therefore, a more rapid recovery could be assumed on these fishing grounds than what was observed on Banquereau Bank. The overall effect of dredging on some elements of the benthic community could be mitigated by the fact that the fishery occurs on fairly mobile and well-stratified sand (Northeast Region Essential Fish Habitat Steering Committee 2002). At these depths, sandy sediments are disturbed and resuspended naturally by storms, waves and, in some places, strong currents. However, there are some uncertainties about the effect of dredging on benthic productivity in general.

The mean annual surface areas dredged from 2018 to 2020 totalled 0.656 km^2 on the North Shore and 0.015 km^2 in the Magdalen Islands. The total area dredged since the beginning of the fishery in 1993 is about 14.9 km^2 on the North Shore and 2.0 km^2 in the Magdalen Islands (Table 11). The footprint of this fishery on this habitat is relatively small compared with the surface areas of known beds—197 km^2 on the North Shore and 464 km^2 in the Magdalen Islands—and represents about 7.6% and 0.4% of the known surfclam habitat on the North Shore and in the Magdalen Islands, respectively.

Species present

Bourdages and Goudreau (2012) identified 15 research projects on the Upper and Middle North Shore from 1993 to 2010 that provided information on the species composition of the Arctic surfclam beds. These projects were conducted using a hydraulic dredge with a 20-mm liner (research component) inside the bucket and without a liner (commercial fishing component). In summary, the proportion in number of different species caught at the fishing sites varies spatially. On the Upper and Middle North Shore, the dominant species in research survey situations were Arctic wedge clam (*Mesodesma arctatum*, 33.7%), sand dollar (*Echinarachnius parma*, 31.5%), Arctic surfclam (*Mactromeris polynyma*, 22.9%), Northern propeller clam (*Cyrtodaria siliqua*, 3.5%), Greenland cockle (*Serripes groenlandicus*, 2.4%), and truncate softshell (*Mya truncata,* 1.6%). These six species account for more than 95% of the individuals caught in number by the lined dredge and represent potentially catchable species on the beds. For the stations sampled, the densities of these species are independent of the density of the Arctic surfclam; moreover, these species may occur outside the surfclam beds.

This same work has proven that in a commercial fishing situation, the dredge is very selective. Arctic surfclams account for 91.7% of the catch in numbers. Other species more frequently observed are the sand dollar, Northern propeller clam, waved whelk (*Buccinum undatum*), Greenland cockle, truncate softshell, green sea urchin (*Strongylocentrotus droebachiensis*), Arctic wedge clam, Iceland cockle (*Ciliatocardium ciliatum*), brittle star, Atlantic razor (*Siliqua costata*), quahog (*Arctica islandica*), hermit crab (*Pagurus* sp.), marine worm and razor clam (*Ensis directus*). Along with the Arctic surfclam, these species account for over 99.8% of individuals caught in commercial fishing situations. The only fish likely to be caught is the American sand lance (*Ammodytes americanus*, 0.02%). The same observation was made on Banquereau Bank: the proportion of non-bivalve bycatch is low (DFO 2012).

In studies of hydraulic dredge selectivity performance, Lambert and Goudreau (1995a) observed an efficiency rate greater than 90% for harvesting surfclams ≥ 80 mm. Nearly two thirds of the surfclams ≥ 66 mm left on the bottom were damaged when the dredge passed. For the smallest ones, mortality associated with dredge passes could be about 15% (Dale Roddick, DFO, pers. comm.). Also, Lambert and Goudreau (1995a) observed that for other species not harvested by the dredge, the percentage of damaged individuals was low.

CONCLUSION

The Arctic surfclam fishery has been relatively stable in recent years with the vast majority of landings coming from the North Shore. Until now, throughout each area, fishers were able to maintain good yields by moving over the same bed or from one bed to another. The exploitation rate in each area (based on the dredged surface area) was below the recommended rate of 3% in all fishing areas. However, some beds are exploited at more than 3% in two fishing areas.

Climate change and various environmental phenomena (for example, storm surges, shoreline erosion, reduced ice cover) could negatively affect Arctic surfclam populations, sandy sediments and recruitment to the population. We do not currently have accurate information on recruitment to the population from the different beds. Given the variable recruitment from year to year and the slow growth of this mollusc, it is important to enhance our knowledge of recruitment dynamics and to review some of the data used, including those used to determine the effort deployed and fishers' catches per unit effort, which date back to the 1990s. The resumption of scientific surveys in the different fishing areas would allow the determination of more precise reference points and a proper precautionary approach to ensure sustainable exploitation of this mollusc.

REFERENCES CITED

Bourassa, L., Giguère, M., Brulotte, S., Cyr, C., and Perreault, L. 2008. Évaluation de la croissance, du taux d'exploitation et du recrutement à la pêche de la mactre de Stimpson (*Mactromeris polynyma*) de la Moyenne-Côte-Nord, Québec. Rapp. tech. can. sci. halieut. aquat. 2799. x + 39 p.

Bourdages, H., and Goudreau, P. 2012. Évaluation de la pêche à la mactre de Stimpson (*Mactromeris polynyma*) des eaux côtières du Québec en 2011. Secr. can. de consult. sci. du MPO. Doc. de rech. 2012/008. vii + 94 p.

Bourdages, H., Goudreau, P., Lambert, J., Landry, L., and Nozères, C. 2012. Distribution des bivalves et gastéropodes benthiques dans les zones infralittorale et circalittorale des côtes de l'estuaire et du nord du golfe du Saint-Laurent. Rapp. tech. can. sci. halieut. aquat. 3004. iv + 103 p.

Brulotte, S. 1995. Distribution et abondance relative de la mactre de Stimpson en Haute-Côte-Nord et en Gaspésie. Programme d'adaptation des pêches de l'Atlantique (Canada). No 57. 25 p.

Cassista, M.C., and Hart, M.W. 2007. Spatial and temporal genetic homogeneity in the Arctic surfclam (*Mactromeris polynyma*). Mar. Biol. 152 : 569–579.

Constantino, R., Gaspar, M.B., Tata-Regala, J., Carvalho, S., Cúrdia, J., Drago, T., Taborda, R., and Monteiro, C.C. 2009. Clam dredging effects and subsequent recovery of benthic communities at different depth ranges. Mar. Env. Res. 67: 89-99.

Cyr, C. 1994. Pêche exploratoire de la mactre de Stimpson en Moyenne et Basse Côte-Nord du Québec. Programme d'adaptation des pêches de l'Atlantique (Canada). No 54. 21 p.

Davis, C.V., and Shumway, S.E. 1996. Larval and juvenile growth of stimpson's surfclam -- a new candidate species for aquaculture development? J. Shellfish Res. 15(2): 479-480.

DFO. 2006. Impacts of Trawl Gears and Scallop Dredges on Benthic Habitats, Populations and Communities. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2006/025.

DFO. 2007. Assessment of the Ocean Quahog (*Arctica islandica*) Stocks on Sable Bank and St. Mary's Bay, and the Arctic Surfclam (*Mactromeris polynyma*) Stock on Banquereau. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2007/034.

DFO. 2012. Assessment of the Arctic Surfclam (*Mactromeris polynyma*) Stock on Banquereau in 2010. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2011/068.

DFO. 2021. Assessment of Stimpson's surfclam stocks in Quebec coastal waters in 2020. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2021/040.

Gilkinson, K.D., Fader, G.B.J., Gordon Jr., D.C., Charron, R., McKeown, D., Roddick, D., Kenchington, E.L.R., MacIsaac, K., Bourbonnais, C., Vass, P., and Liu, Q. 2003. Immediate and long-term impacts of hydraulic clam dredging on an offshore sandy seabed: effects on physical habitat and processes of recovery. Cont. Shelf Res. 23: 1315-1336.

Gilkinson, K.D., Gordon Jr., D.C., MacIsaac, K.G., McKeown, D.L., Kenchington, E.L.R., Bourbonnais, C., and Vass, P. 2005. Immediate impacts and recovery trajectories of macrofaunal communities following hydraulic clam dredging on Banquereau, eastern Canada. ICES J. Mar. Sci. 62: 925-947.

Hall, S.J., Basford, D.J., and Robertson, M.R. 1990. The impact of hydraulic dredging for razor clams *Ensis sp.* on an infaunal community. Neth. J. Sea Res. 27(1): 119-125.

Hugues, S.E., and Bourne N. 1981. Stock assessment and life history of a newly discovered Alaska surf clam (*Spisula polynyma*) resource in th southeastern Bering Sea. Can. J. Fish. Aquat. Sci. 38(10):1173-1181.

Lambert, J., and Giguère, M. 1994. Développement de la pêche à la mactre de Stimpson (*Mactromeris polynyma*) au Québec et efficacité de la drague hydraulique de type Nouvelle-Angleterre. In The development of underutilized invertebrate fisheries in eastern Canada. Édité par L. Gendron et S. Robinson. Can. Manus. Rep. Fish. Aquat. Sci. 2247. pp. 73-81.

Lambert, J., and Goudreau, P. 1995a. Performance de la drague hydraulique de type Nouvelle-Angleterre pour la récolte de la mactre de Stimpson (*Mactromeris polynyma*). Rapp. can. ind. sci. halieut. aquat. 235. vii + 28 pages.

Lambert, J., and Goudreau, P. 1995b. Mactre de Stimpson et couteau des côtes du Québec. In Rapport sur l'état des invertébrés en 1994 : crustacés et mollusques des côtes du Québec, crevette nordique et zooplancton de l'estuaire et du golfe du Saint-Laurent. Édité par L. Savard. Rapp. manus. can. sci. halieut. aquat. 2323. 93-103.

Lambert, J., and Goudreau, P. 1997. Biologie et exploitation de la mactre de Stimpson (*Mactromeris polynyma*) sur les côtes du Québec. MPO Sec. can. éval. stock, Doc. rech. 97/101. 44 p.

Lambert, J., and Goudreau, P. 1999. Indices de croissance de la mactre de Stimpson (*Mactromeris polynyma*). Rapp. tech. can. sci. halieut. aquat. 2269. vii + 39 p.

Landry, T.E., Wade, E., and Giguère, M. 1992. Évaluation des gisements de mactre de Stimpson, *Mactromeris polynyma*, dans le golfe du Saint-Laurent : résultats préliminaires. CSCPCA, Doc. rech. 92/86, 29 p.

Langton, R.W., Robinson, W.E. and Schick, D. 1987. Fecundity and reproductive effort of sea scallops *Placopecten magellanicus* from the Gulf of Maine. Mar. Ecol. Prog. Ser. 37 : 19-25.

Lepage, D. 1994. Distribution et abondance relative de différentes espèces de mollusques à potentiel commercial récoltés dans le secteur de Sept-Îles. Programme d'adaptation des pêches de l'Atlantique (Canada). No 59. 24 p.

Mercier, P.-H. 1992. Pêche exploratoire et estimation de l'abondance de mactres de Stimpson dans le secteur de Sept-Îles. Programme d'adaptation des pêches de l'Atlantique (Canada). No 42. 39 p.

Northeast Region Essential Fish Habitat Steering Committee. 2002. Workshop on the effects of fishing gear on marine habitats off the Northeastern United States, October 23-25, 2001, Boston Massachussetts. Northeast Fish. Sci. Cent. Ref. Doc. 02-01. 86 p.

Richard, L.J., and Maguire, J.-J. 1998. Recent international agreements and the precautionary approach: new directions for fisheries management science. Can. J. Fish. Aquat. Sci. 55: 1545-1552.

Roddick, D.L., and Kenchington, E. 1990. A review of the Banquereau Bank fishery for *Mactromeris polynyma* for the 1986 to 1989 period. CAFSAC, Res. Doc. 90/14. 27 p.

Roddick, D., Brading, L., Carrigan, L., Davignon-Burton, T., Graham, S., and McEwen, C. 2012. Assessment of the Arctic Surfclam (*Mactromeris polynyma*) stock on Banquereau in 2010. DFO Can. Sci. Advis. Sec. Res. Doc. 2012/050. iii + 60 p.

Rowell, T.W., and Amaratunga, T. 1986. Distribution, abundance, and preliminary estimates of production potential for the Ocean Quahaug (*Arctica islandica*) and Stimpson's surf clam (*Spisula polynyma*) on the Scotian Shelf. CAFSAC Res. Doc. 86/56. 21 p.

Smith, S. 1980. Comparison of 2 methods of estimating the variance of the estimate of catch per unit effort. Can. J. Fish. Aquat. Sci. 37(12): 2346-2351.

Smith, S.J. (ed.). 2003. Workshop on biological reference points for invertebrate fisheries held in Halifax, Nova Scotia, 2–5 December 2002: Abstracts and proceedings. Can. Tech. Rep. Fish. Aquat. Sci. 2448. ix+ 62 p.

Trottier, S., and Goudreau, P. 2015. Évaluation des stocks de mactre de Stimpson (*Mactromeris polynyma*) des eaux côtières du Québec en 2014. Secr. can. de consult. sci. du MPO. Doc. de rech. 2015/063. ix + 72 p.

Tuck, I.D., Bailey, N., Harding, M., Sangster, G., Howell, T., Graham, N., and Breen, M. 2000. The impact of water jets dredging for razor clams, *Ensis sp.*, in a shallow sandy subtidal environment. J. Sea Res. 43: 65-81.

Zajac, R.N., and Whitlatch, R.B. 2003. Community and population-level responses to disturbance in a sandflat community. J. Exp. Mar. Bio. Ecol. 294 : 101-125.

TABLES

Table 1. Parameters of the von Bertalanffy growth curve estimated from growth rings on the shells of Arctic surfclams from some eastern Canadian beds.

Bed	Year	L_∞	K	t_0	Reference
Rivière Moisie	1993	119.47	0.0825	0.1926	Lambert and Goudreau 1999
Rivière-au-Tonnerre	1994	110.63	0.0980	0.4870	Lambert and Goudreau 1999
Longue-Pointe-de-Mingan	2004	134.00	0.0686	0.2120	Bourassa et al. 2008
Magdalen Islands	1992	122.37	0.0490	-0.8990	Landry et al. 1992
Banquereau	2010	119.56	0.0830	0.0980	Roddick et al. 2012
Natashquan	2010	125.52	0.0777	0.5899	Trottier and Goudreau 2015

Table 2. Management measures for the Arctic surfclam commercial fishery in 2020.

Management measures	Fishing area									
	1A	1B	2	3A	3B	4A	4B	4C	5A	5B
Number of licences	1	1	4	2	2	2	5	3 [1]	4	4
TAC (t)	80.0	68.6	54.9	85.2	93.7	174.5	425.0	170.1	204.0	113.0
TAC Management [2]	ITQ	ITQ	Comp.	ITQ	ITQ	ITQ	Comp.	Comp.	Comp.	Comp.
Start of fishing season	14/06							21/07	23/03	23/03
End of fishing season	14/11							17/10	31/12	31/12
Hail in	100%							0%	100%	
Dredge: number	1									
Dredge: width	1.83 m								2.13 m	
Dredge: spacing between stems	3.2 cm								3.175 cm	
Minimum legal size	80 mm									

[1] Exploratory licence
[2] Comp. (competitive fishery), ITQ (individual transferable quota with restriction)

Table 3. Number of Arctic surfclam samples collected from 2018 to 2020 in the DFO commercial dockside sampling program and sampling protocol by fishing area.

Fishing area	Year			Protocol [1]
	2018	2019	2020	
1A	-	7	10	10 samples distributed throughout the season
1B	-	-	-	10 samples distributed throughout the season
2	7	-	-	8 samples distributed throughout the season
3A	9	10	10	10 samples distributed throughout the season
3B	11	10	9	10 samples distributed throughout the season
4A	6	8	17	10 samples distributed throughout the season
4B	10	12	-	10 samples distributed throughout the season
4C	-	-	-	no sample
5A	-	-	-	6 samples distributed throughout the season
5B	-	2	-	6 samples distributed throughout the season

[1] One sample corresponds to about 150 measured surfclams

Table 4. Arctic surfclam landings (t live weight) by region and year.

Year	Region		Quebec
	North Shore	Magdalen Islands	
1993	71	4	76
1994	221	153	375
1995	178	50	228
1996	164	46	210
1997	128	86	214
1998	194	106	300
1999	255	6	261
2000	346	99	445
2001	384	27	411
2002	476	46	522
2003	835	48	883
2004	813	21	834
2005	879	8	887
2006	879	9	888
2007	608	17	625
2008	646	8	653
2009	896	0	896
2010	905	8	913
2011	805	41	846
2012	656	90	746
2013	806	102	909
2014	731	56	787
2015	675	38	714
2016	631	20	651
2017	552	0	552
2018	608	0	608
2019	605	10	615
2020	533	6	539

Table 5. Arctic surfclam landings (t live weight) by fishing area group and year.

Year	Fishing area		
	1A, 1B, 2 et 3A	3B, 4A, 4B et 4C	5A et 5B
1993	8	64	4
1994	24	197	153
1995	30	148	45
1996	67	97	44
1997	44	84	84
1998	56	131	106
1999	166	88	6
2000	170	176	99
2001	149	228	27
2002	220	245	46
2003	177	652	48
2004	134	675	21
2005	180	694	8
2006	179	700	9
2007	180	428	17
2008	155	489	8
2009	233	661	0
2010	237	666	8
2011	141	662	41
2012	186	470	88
2013	194	612	100
2014	112	619	54
2015	171	503	38
2016	173	457	20
2017	101	449	0
2018	107	494	0
2019	166	439	10
2020	158	374	6

Table 6. Total Allowable Catch (TAC, t live weight) of Arctic surfclams since the beginning of the fishery in 1993 by fishing area and year.

Year	Fishing area									
	1A	1B	2	3A	3B	4A	4B	4C	5A	5B
1993	-	-	-	-	-	-	-	-	-	-
1994	57	57	23	60	60	-	465	-	204	-
1995	57	57	23	60	60	102	249	-	204	91
1996	57	57	23	60	60	136	215	-	204	91
1997	57	57	23	60	60	136	442	-	204	91
1998	57	57	23	60	60	102	476	57	204	113
1999	57	57	45	60	60	91	408	57	204	113
2000	62	62	59	70	70	145	408	57	204	113
2001	66	66	64	76	96	143	465	170	204	113
2002	69	69	55	76	76	150	425	170	204	113
2003	69	69	55	76	76	150	425	170	204	113
2004	69	69	55	76	94	177	425	170	204	113
2005	69	69	55	76	94	177	425	170	204	113
2006	75	69	55	76	102	192	425	170	204	113
2007	75	69	55	76	102	192	425	170	204	113
2008	75	69	55	76	83	165	425	170	204	113
2009	75	69	55	76	83	165	425	170	204	113
2010	75	69	55	76	83	165	425	170	204	113
2011	76	69	55	80	88	175	425	170	204	113
2012	80	69	55	80	88	175	425	170	204	113
2013	80	69	55	80	88	175	425	170	204	113
2014	80	69	55	80	88	175	425	170	204	113
2015	80	69	55	80	94	175	425	170	204	113
2016	80	69	55	80	94	175	425	170	204	113
2017	80	69	55	80	94	175	425	170	204	113
2018	80	69	55	80	94	175	425	170	204	113
2019	80	69	55	85	94	175	425	170	204	113
2020	80	69	55	85	94	175	425	170	204	113

Table 7. Arctic surfclam fishing effort (in days) by fishing area and year.

Year	Fishing area									
	1A	1B	2	3A	3B	4A	4B	4C	5A	5B
1993	0	0	0	3	17	16	0	0	0	3
1994	0	0	0	18	21	52	0	0	0	42
1995	0	3	0	15	25	49	0	0	0	12
1996	10	14	0	20	13	36	0	0	0	10
1997	0	9	0	4	14	17	0	0	0	10
1998	11	13	0	9	0	32	15	0	0	19
1999	16	22	20	23	16	7	0	0	0	2
2000	18	14	17	27	16	23	0	0	0	32
2001	19	12	9	24	22	29	0	0	0	11
2002	25	23	17	29	20	27	4	0	0	14
2003	18	18	10	31	21	26	71	0	1	13
2004	18	16	2	21	17	29	70	0	6	0
2005	16	25	2	21	12	30	89	0	0	3
2006	20	4	13	27	16	34	93	0	0	4
2007	23	1	13	17	11	15	56	0	0	6
2008	25	0	6	17	21	14	66	3	0	3
2009	19	14	5	23	14	24	65	0	0	0
2010	20	10	9	20	15	25	83	0	0	3
2011	18	7	0	12	16	26	60	0	0	15
2012	18	11	0	17	12	21	54	0	0	24
2013	18	0	12	17	14	25	76	0	0	20
2014	0	0	9	16	13	20	74	0	0	9
2015	22	4	0	14	15	7	69	0	0	6
2016	26	6	0	12	15	0	68	0	0	7
2017	9	0	0	16	14	0	69	0	0	0
2018	0	0	12	16	15	26	68	0	0	0
2019	23	0	0	17	11	26	45	0	0	2
2020	23	0	0	15	12	28	23	0	0	2

Table 8. Effort in area dredged (km²) in the Arctic surfclam commercial fishery by fishing area and year.

Year	Fishing area									
	1A	1B	2	3A	3B	4A	4B	4C	5A	5B
1993	-	-	-	-	0.040	0.045	-	-	-	-
1994	-	-	-	0.062	0.056	0.184	-	-	-	0.174
1995	-	0.004	-	0.054	0.054	0.125	-	-	-	0.055
1996	0.022	0.032	-	0.055	0.025	0.070	-	-	-	0.086
1997	-	0.028	-	-	0.032	0.083	-	-	-	0.126
1998	0.040	0.034	-	0.030	-	0.107	0.051	-	-	0.160
1999	0.026	0.068	0.056	0.065	0.041	0.033	-	-	-	0.026
2000	0.060	0.033	0.058	0.085	0.043	0.099	-	-	-	0.244
2001	0.053	0.026	0.030	0.090	0.066	0.096	-	-	-	0.069
2002	0.075	0.095	0.058	0.108	0.071	0.102	0.017	-	-	0.096
2003	0.060	0.069	0.038	0.113	0.076	0.104	0.366	-	0.015	0.078
2004	0.057	0.024	0.002	0.064	0.056	0.128	0.342	-	0.041	-
2005	0.050	0.078	0.007	0.064	0.045	0.122	0.413	-	-	0.017
2006	0.057	0.018	0.058	0.077	0.063	0.141	0.507	-	-	0.018
2007	0.065	0.003	0.058	0.061	0.042	0.077	0.371	-	-	0.034
2008	0.070	-	0.023	0.058	0.063	0.053	0.378	0.002	-	0.016
2009	0.055	0.055	0.018	0.083	0.052	0.109	0.382	-	-	-
2010	0.059	0.038	0.046	0.094	0.055	0.126	0.451	-	-	0.022
2011	0.059	0.028	-	0.056	0.058	0.131	0.390	-	-	0.081
2012	0.068	0.048	-	0.076	0.049	0.104	0.304	-	-	0.209
2013	0.075	-	0.104	0.142	0.124	0.132	0.441	-	-	0.197
2014	-	-	0.076	0.126	0.088	0.089	0.437	-	-	0.107
2015	0.090	0.015	-	0.122	0.106	0.025	0.442	-	-	0.076
2016	0.105	0.024	-	0.104	0.107	-	0.431	-	-	0.048
2017	0.032	-	-	0.126	0.111	-	0.383	-	-	-
2018	-	-	0.97	0.102	0.088	0.094	0.392	-	-	-
2019	0.070	-	-	0.136	0.091	0.090	0.244	-	-	0.021
2020	0.077	-	-	0.133	0.093	0.123	0.135	-	-	0.025

Table 9. Catches per unit of effort (kg per tow for a 1-m-wide dredge) estimated using logbook data, by fishing area of the Arctic surfclam commercial fishery by fishing area and year.

Year	Fishing area									
	1A	1B	2	3A	3B	4A	4B	4C	5A	5B
1993	-	-	-	-	87.6	84.8	-	-	-	-
1994	-	-	-	45.1	96.6	93.4	-	-	-	101.4
1995	-	62.6	-	57.9	97.4	94.1	-	-	-	94.8
1996	96.8	69.2	-	60.5	120.0	114.6	-	-	-	57.8
1997	-	83.2	-	-	138.7	62.8	-	-	-	75.7
1998	54.0	73.2	-	59.4	-	107.3	66.7	-	-	75.8
1999	136.9	78.5	96.4	74.0	122.4	154.0	-	-	-	23.0
2000	95.0	80.8	84.8	70.4	144.0	142.6	-	-	-	46.5
2001	97.8	81.7	102.8	73.6	142.4	172.4	-	-	-	39.7
2002	90.7	37.4	106.5	79.8	121.3	167.7	141.3	-	-	54.6
2003	104.5	32.1	76.7	77.0	113.4	160.4	135.3	-	41.7	62.9
2004	137.8	80.0	76.6	86.6	153.1	158.1	142.0	-	60.2	-
2005	158.1	93.0	110.1	73.0	156.9	153.3	130.3	-	-	53.3
2006	146.8	31.9	84.5	86.8	150.1	155.5	96.7	-	-	55.7
2007	134.3	50.2	97.8	100.6	111.7	179.0	82.7	-	-	55.5
2008	120.9	-	136.2	105.7	149.7	178.9	98.4	58.8	-	58.4
2009	157.5	132.3	128.0	103.4	182.9	172.4	124.6	-	-	-
2010	145.8	144.5	104.2	89.2	173.0	150.0	106.7	-	-	38.5
2011	147.5	113.5	-	75.7	169.1	150.9	119.2	-	-	58.4
2012	133.7	95.3	-	100.6	150.5	130.8	108.5	-	-	48.4
2013	122.3	-	43.5	60.0	78.3	134.7	96.8	-	-	58.0
2014	-	-	47.6	73.3	107.5	157.4	108.6	-	-	57.7
2015	100.0	94.2	-	75.8	99.6	167.3	96.9	-	-	57.3
2016	86.5	67.2	-	88.3	99.9	-	97.0	-	-	50.3
2017	73.3	-	-	73.2	97.0	-	106.6	-	-	-
2018	-	-	31.7	90.4	122.3	112.1	90.4	-	-	-
2019	132.2	-	-	72.5	118.5	165.9	100.5	-	-	53.9
2020	109.2	-	-	72.8	115.2	162.0	90.5	-	-	30.3
Average 2018-2020	120.7	-	31.7	78.6	118.7	146.6	93.8	-	-	42.1
Median 1993-2019	122.3	80.0	96.4	75.7	121.8	153.3	106.6	58.8	51.0	56.5

Table 10. Area of the beds, number of daily fishing positions available and retained for the beds, and areas estimated through the Kernel analysis corresponding to 100% and 95% of the fishing effort, by fishing area and bed.

Fishing area	Bed	Bed surface area (km²)	Positions on the bed (n)	Retained positions (n)	Exploited surface area 100 % (km^2)	Exploited surface area 95 % (km^2)
1A	Les Escoumins	0.881	39	24	0.352	0.282
	Forestville	14.828	300	287	7.034	4.355
	Colombier (1A)	1.306	75	54	1.013	0.715
2	Rivière-Pentecôte	6.797	15	13	0.778	0.502
	Baie-Trinité	3.338	91	89	1.997	1.313
3A	Moisie Ouest	7.326	215	197	3.422	2.281
	Ste-Marguerite	3.149	100	79	2.190	1.480
	Rivière à Bouleau	4.321	5	4	0.106	0.073
3B	Magpie	4.238	2	2	0.025	0.018
	Rivière-au-Tonnère Est	3.650	182	166	3.208	2.245
4A	Longue-Pointe	5.735	568	465	4.698	3.427
	Longue-Pointe Village	4.578	21	19	0.845	0.556
	Longue-Pointe Ouest	6.234	17	9	0.335	0.206
4B	Natashquan	36.565	1210	1097	23.123	15.225
5B	Rochers aux Oiseaux (south)	13.101	241	191	6.487	4.212

Table 11. Known area of the beds, area corresponding to 95% of the fishing intensity, total and mean fishing effort (area dredged) and mean exploitation rate by bed and fishing area.

Area	Bed	Bed surface area (km²)	Exploited surface area Kernel 95 % (km²)	Fishing effort (km²)		Exploitation rate 2018-2020 (%)
				Total 1993-2020	Annual average 2018-2020	
1A	Les Escoumins	0.881	0.282	0.133	0.003	0.99
	Forestville	14.828	4.355	0.910	0.029	0.66
	Cap Colombier (1A)	1.306	0.715	0.280	0.018	2.47
	TOTAL	17.015	5.351	1.323	0.049	0.92
1B	Cap Colombier (1B)	1.032	0.649	0.198	-	-
	Pointe à Michel	-	0.010	0.012	-	-
	Manicouagan	7.075	0.309	0.047	-	-
	Baie-Comeau	6.958	2.041	0.433	-	-
	TOTAL	15.065	3.009	0.690	-	-
2	Baie-Trinité Ouest	1.650	-	0.010	-	-
	Baie-Trinité Centre	3.338	1.313	0.378	0.031	2.38
	Baie-Trinité Est	9.235	-	0.012	-	-
	Rivière Pentecôte	6.797	0.502	0.061	0.001	0.01 [2]
	Caouis	3.257	0.249	0.028	-	-
	Îles de Mai	4.105	1.067	0.103	-	-
	TOTAL	28.382	3.131	0.591	0.032	1.03
3A	Ste-Marguerite	3.149	1.480	0.379	0.043	2.90
	Sept-Îles	1.174	0.631	0.403	-	-
	Caye de l'Est [1]	0.883	0.425	0.188	-	-
	Rivière Moisie Ouest	7.326	2.281	0.859	0.078	3.44
	Rivière Moisie Est	4.282	-	0.009	-	-
	Pointe St-Charles	0.787	-	0.003	-	-
	Pointe à la Perche	3.869	-	-	-	-
	Rivière au Bouleau	4.321	0.073	0.012	0.002	0.05 [2]
	Rivière Manitou	3.639	-	0.001	-	-
	TOTAL	28.547	4.464	1.664	0.124	2.77
3B	Sheldrake	1.390	0.763	0.134	-	-
	Rivière-au-Tonnerre Ouest	3.098		0.027	-	-
	Rivière-au-Tonnerre Centre	4.213	1.723	0.521	-	-
	Rivière-au-Tonnerre Est	3.650	2.245	0.676	0.089	3.96
	Magpie	4.238	0.018	0.006	0.002	0.04[2]
	TOTAL	16.589	4.749	1.365	0.091	1.91
4A	Longue-Pointe Ouest	6.234	0.206	0.067	0.013	0.21[2]
	Longue-Pointe	5.735	3.427	2.278	0.083	2.42
	Longue-Pointe Village	4.578	0.556	0.067	0.007	0.15[2]
	Mingan	-	-	0.005	-	-
	Havre-Saint-Pierre	0.801	-	0.008	-	-
	Île Saint-Charles	0.618	-	-	-	-
	TOTAL	17.966	4.190	2.424	0.103	2.46

Area	Bed	Bed surface area (km²)	Exploited surface area Kernel 95 % (km²)	Fishing effort (km²) Total 1993-2020	Fishing effort (km²) Annual average 2018-2020	Exploitation rate 2018-2020 (%)
4B	Aguanish	7.260	-	0.002	-	-
	Natashquan	36.565	15.225	6.840	0.257	1.69
	Natashquan Est	26.126	-	0.021	-	-
	TOTAL	69.951	15.225	6.863	0.257	1.69
4C	Blanc-Sablon	2.610	-	0.002	-	-
	Brador	0.607	-	-	-	-
	TOTAL	3.217	0.000	0.002	-	-
5A	5A	20.302	-	0.057	-	-
	TOTAL	20.302	0.000	0.057	-	-
5B	Rocher aux Oiseaux	13.101	4.212	1.811	0.015	0.36
	Rocher aux Oiseaux Nord	1.306	-	-	-	-
	5B N-E	0.083	-	-	-	-
	Est Havre-aux-Maisons	118.027	-	-	-	-
	Est Île d'Entrée	214.303	-	-	-	-
	N-O Grosse-Île	97.017	-	0.110	-	-
	TOTAL	443.838	4.212	1.921	0.015	0.36

[1] The Sept-Îles bed includes beds, such as Caye de l'Est.
[2] Average exploitation rate calculated with the total area of the bed.

Table 12. Annual mean size (mm) at landing of Arctic surfclams, by fishing area and year, estimated by a model that takes into account the year and bed.

Year	Fishing area									
	1A	1B	2	3A	3B	4A	4B	4C	5A	5B
1993	-	-	-	-	-	-	-	-	-	-
1994	-	-	-	109.4	110.7	115.2	-	-	-	95.5
1995	-	95.3	109.2	105.7	116.7	115.1	-	-	-	98.0
1996	-	93.9	-	104.4	113.5	111.9	-	-	-	94.9
1997	-	95.2	-	104.8	113.5	110.9	-	-	-	96.4
1998	-	102.2	-	116.2		112.4	-	-	-	98.9
1999	-	110.3	-	115.6	111.1	110.9	-	-	-	-
2000	115.6	107.2	-	119.1	109.2	111.6	-	-	-	101.6
2001	110.0	108.3	-	114.1	111.6	110.8	-	-	-	99.0
2002	111.6	108.5	114.6	104.2	106.8	113.0	-	-	-	-
2003	110.6	-	112.6	112.3	115.0	110.2	100.9	-	-	102.3
2004	114.6	104.1	113.0	114.6	110.1	108.5	105.5	-	-	101.1
2005	113.7	-	110.3	111.1	107.4	111.3	103.4	-	-	100.8
2006	113.7	-	115.4	108.1	104.5	106.1	104.1	-	-	-
2007	113.9	-	114.3	109.3	110.1	112.8	101.5	-	-	101.6
2008	112.7	-	113.1	109.2	107.6	113.4	102.3	-	-	-
2009	109.0	112.7	115.3	117.6	117.5	113.6	100.0	-	-	-
2010	118.5	110.1	115.5	112.9	115.2	116.2	107.2	-	-	-
2011	117.7	113.3	-	108.8	115.1	116.4	104.6	-	-	-
2012	117.6	114.3	-	108.9	112.7	113.8	104.0	-	-	97.0
2013	115.4	-	113.5	110.0	109.3	112.3	105.6	-	-	98.7
2014	-	-	112.9	110.9	112.5	107.8	108.5	-	-	94.3
2015	115.7	117.5	-	110.3	109.8	108.2	110.5	-	-	100.3
2016	117.7	112.6	-	110.4	109.9	-	109.4	-	-	98.6
2017	119.0	-	-	111.9	109.7	-	109.2	-	-	-
2018	-	-	114.6	108.7	111.9	113.4	110.2	-	-	-
2019	112.6	-	-	112.3	112.4	113.5	106.2	-	-	100.2
2020	114.6	-	-	110.2	107.6	107.3	107.4	-	-	-
Average 2018-2020	113.6	-	114.6	110.4	110.6	111.4	107.9	-	-	100.2
Median 1993-2019	114.3	108.5	113.5	110.3	111.1	112.3	105.5	-	-	98.9

Table 13. Indicators used in the decision rule to increase the TAC. Indicators in bold mean that they meet the conditions for a quota increase.

Fishing area	Average landing 2018-2020 (80 % of TAC, t)	Average CPUE 2018-2020 (median, kg/tow)	Average size 2018-2020 (median, mm)	Exploitation rate 2018-2020 (%)	Recommended quota increase
1A	51.5 (64.0)	120.7 (122.3)	113.6 (114.3)	**0.92**	No
1B	Not fished between 2018 and 2020				No
2	8.9 (43.9)	31.7 (96.4)	**114.6** (113.5)	**1.03**	No
3A	**83.4** (68.2)	**78.6** (75.7)	**110.4** (110.3)	**2.77**	**Yes**
3B	**93.9** (75.0)	118.7 (121.8)	110.6 (111.1)	**1.91**	No
4A	132.2 (139.6)	146.6 (153.3)	111.4 (112.3)	**2.46**	No
4B	209.5 (340.0)	93.8 (106.6)	**107.9** (105.5)	1.69	No
4C	Not fished between 2018 and 2020				No
5A	Not fished between 2018 and 2020				No
5B	5.4 (90.4)	42.1 (56.5)	**100.2** (98.9)	**0.36**	No

FIGURES

Figure 1. Mactromeris polynyma (English name: Arctic surfclam, Stimpson's surfclam; French name: mactre de Stimpson) (Bourdages and Goudreau 2012).

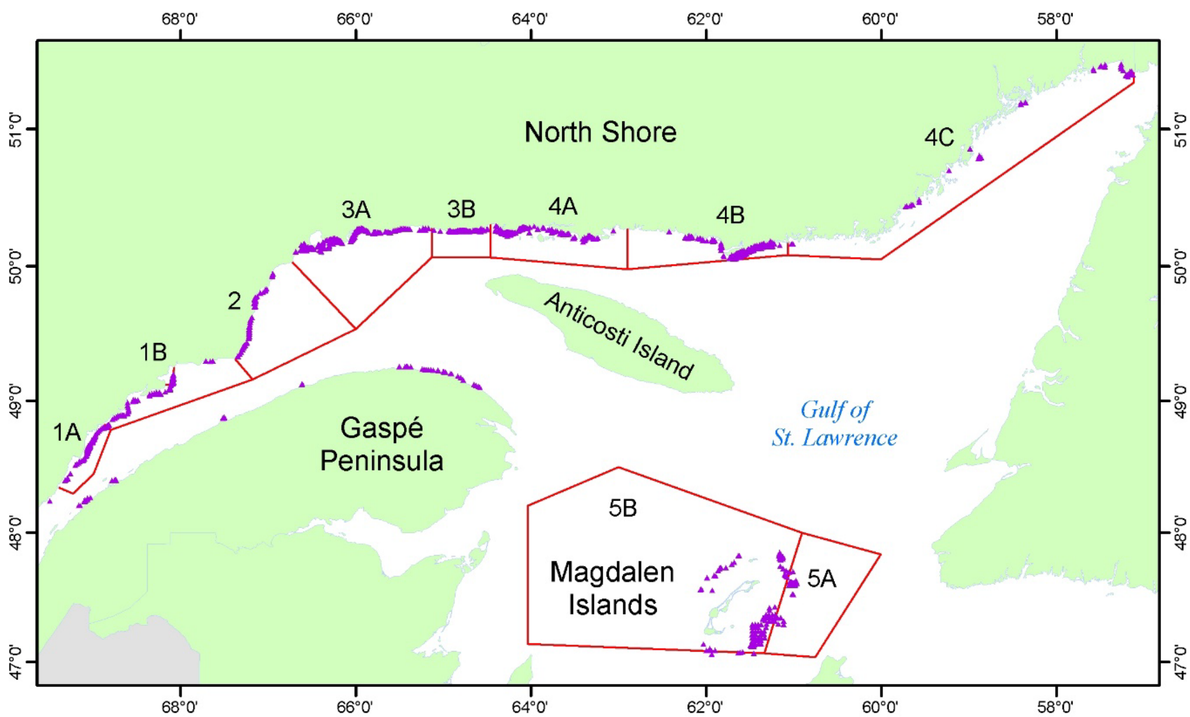


Figure 2. Known distribution of Arctic surfclams in Quebec inshore waters based on data collected from logbooks, research surveys and exploratory fisheries (Bourdages and Goudreau 2012).

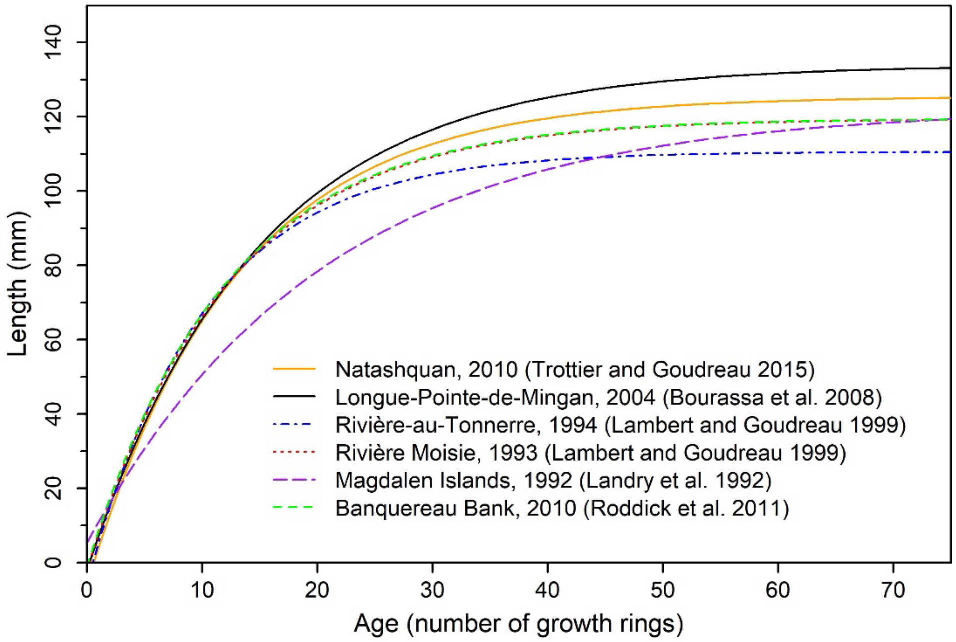


Figure 3. Von Bertalanffy growth curves estimated from growth rings on the shells of Arctic surfclams from some eastern Canadian beds.

Figure 4. New England hydraulic dredge (Bourdages and Goudreau 2012).

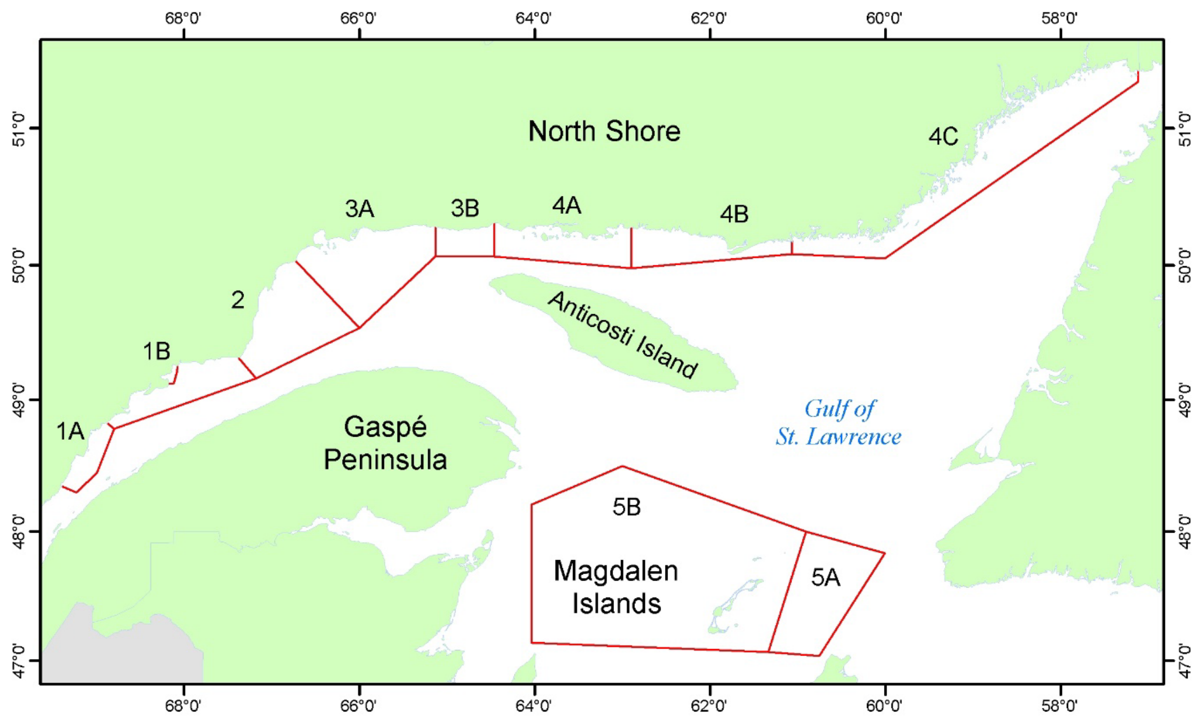


Figure 5. Management areas for the Arctic surfclam fishery in Quebec (Bourdages and Goudreau 2012).

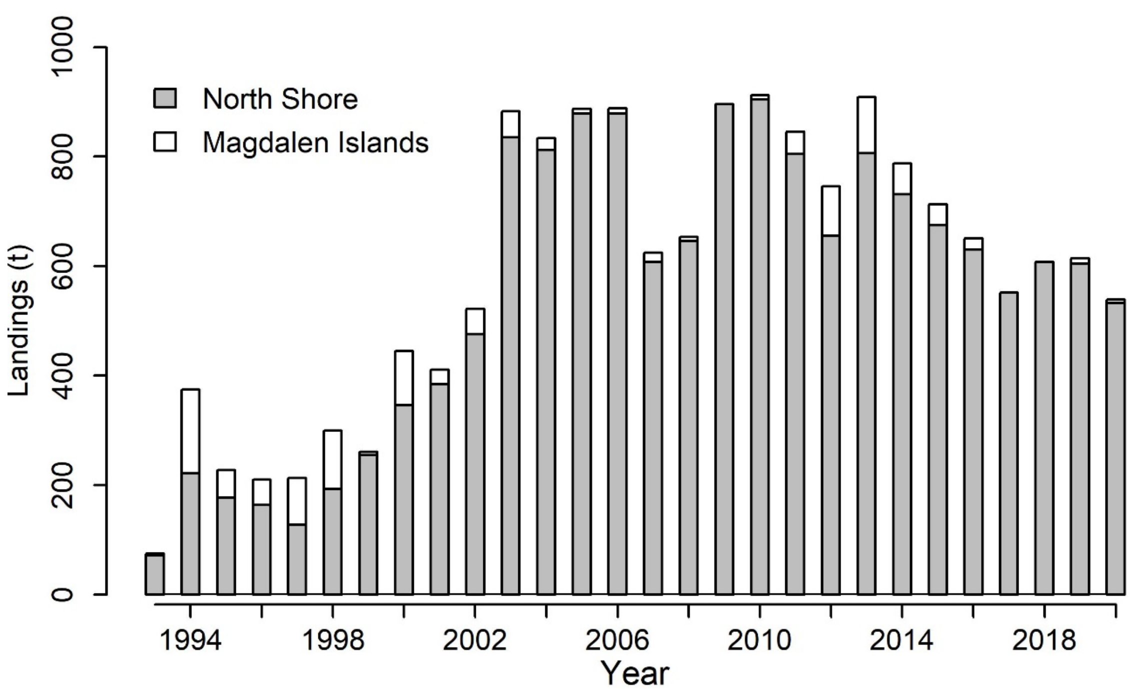


Figure 6. Annual Arctic surfclam landings in Quebec by marine region.

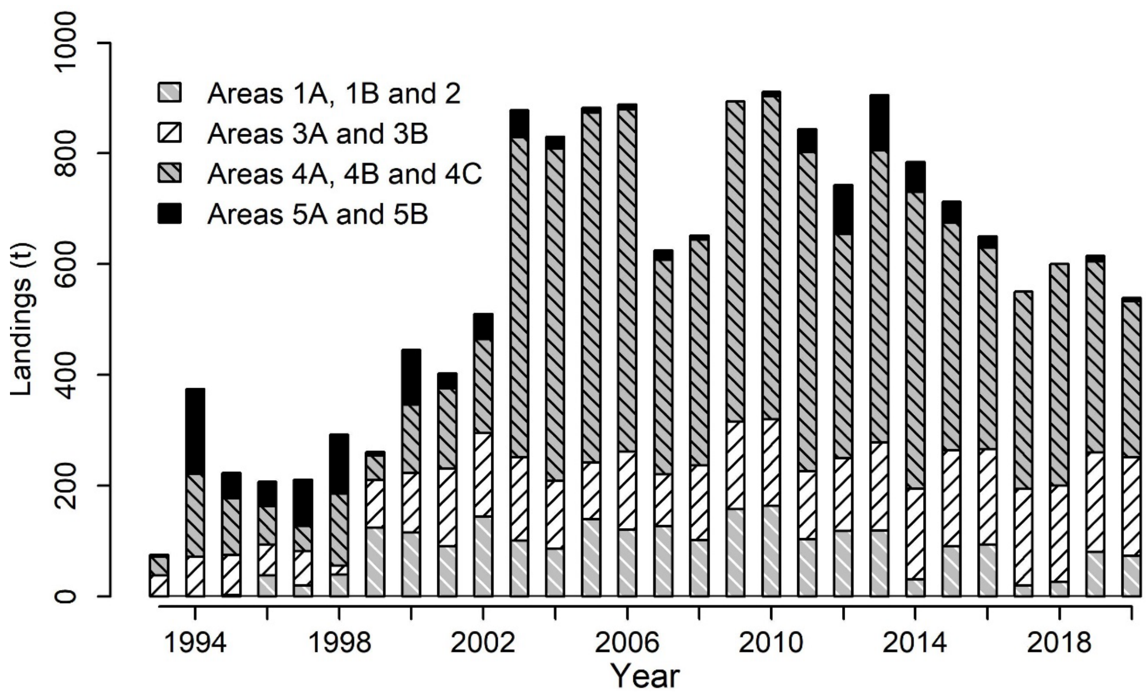


Figure 7. Annual Arctic surfclam landings in Quebec by fishing area group.

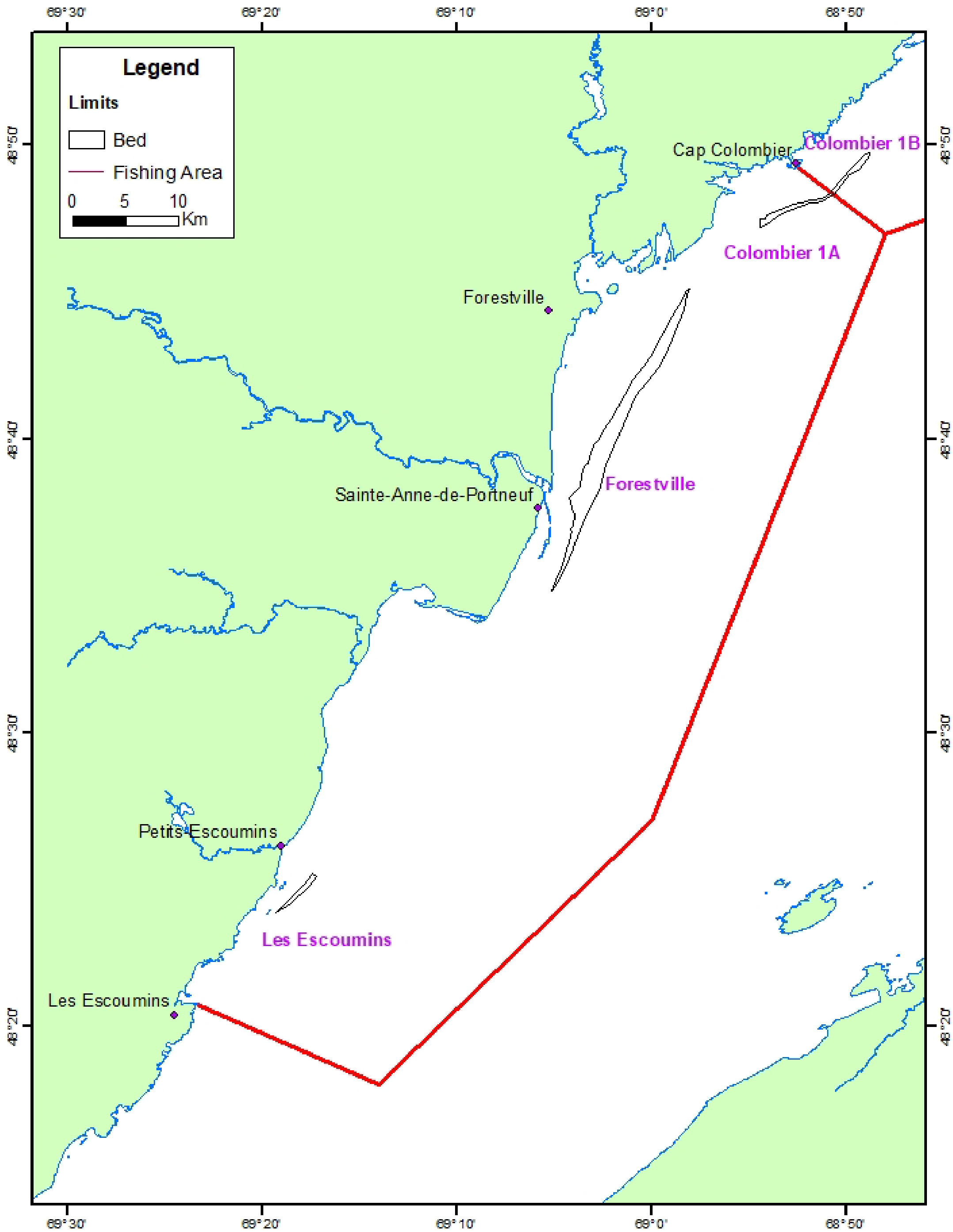


Figure 8. Location of known Arctic surfclam beds in Area 1A.

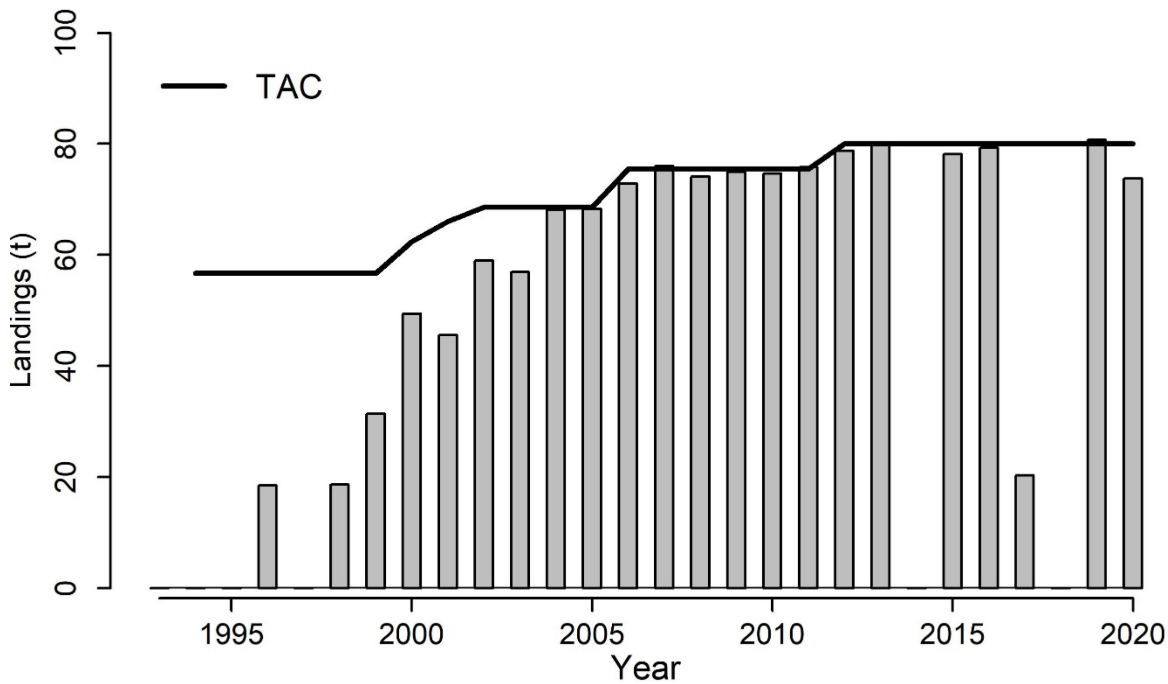


Figure 9. Annual Arctic surfclam landings in Area 1A.

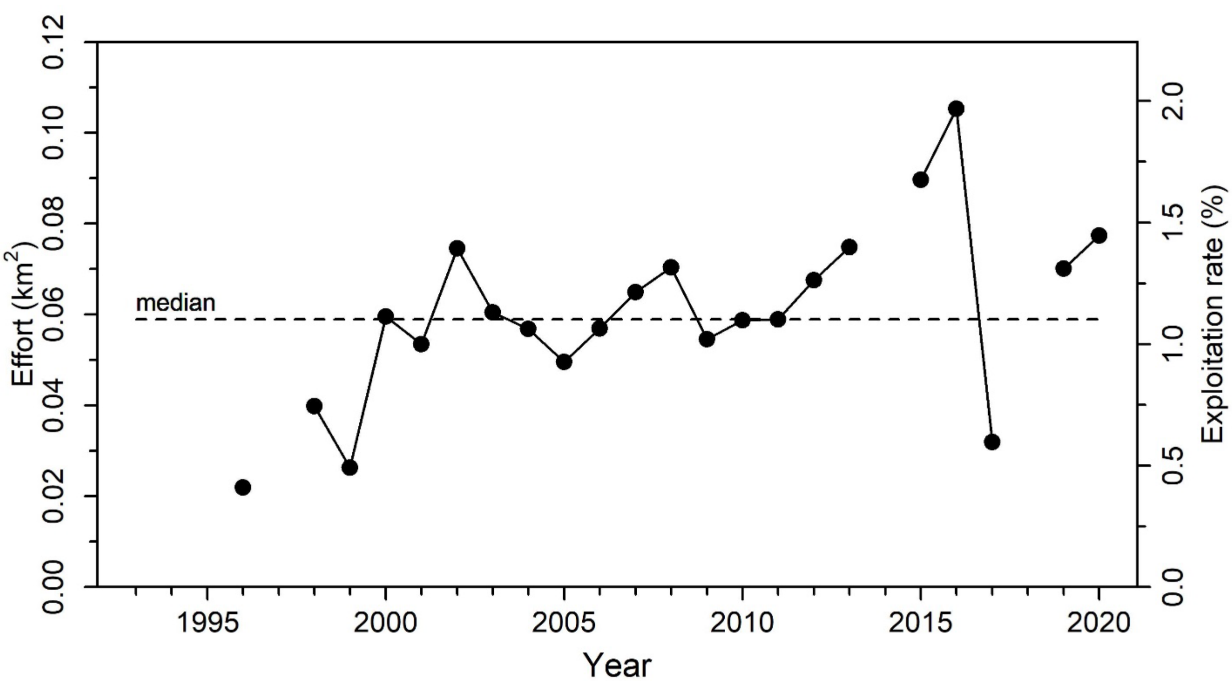


Figure 10. Fishing effort in area dredged (km^2) and annual exploitation rates in Area 1A.

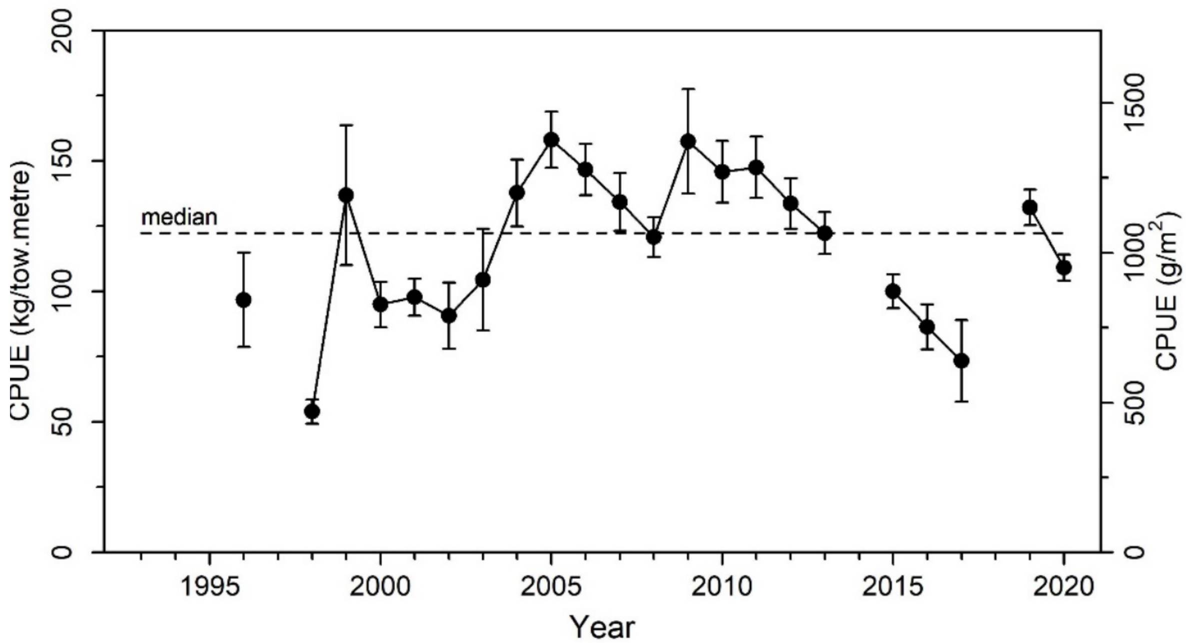


Figure 11. Annual catch per unit effort (± 95% confidence interval) in Area 1A.

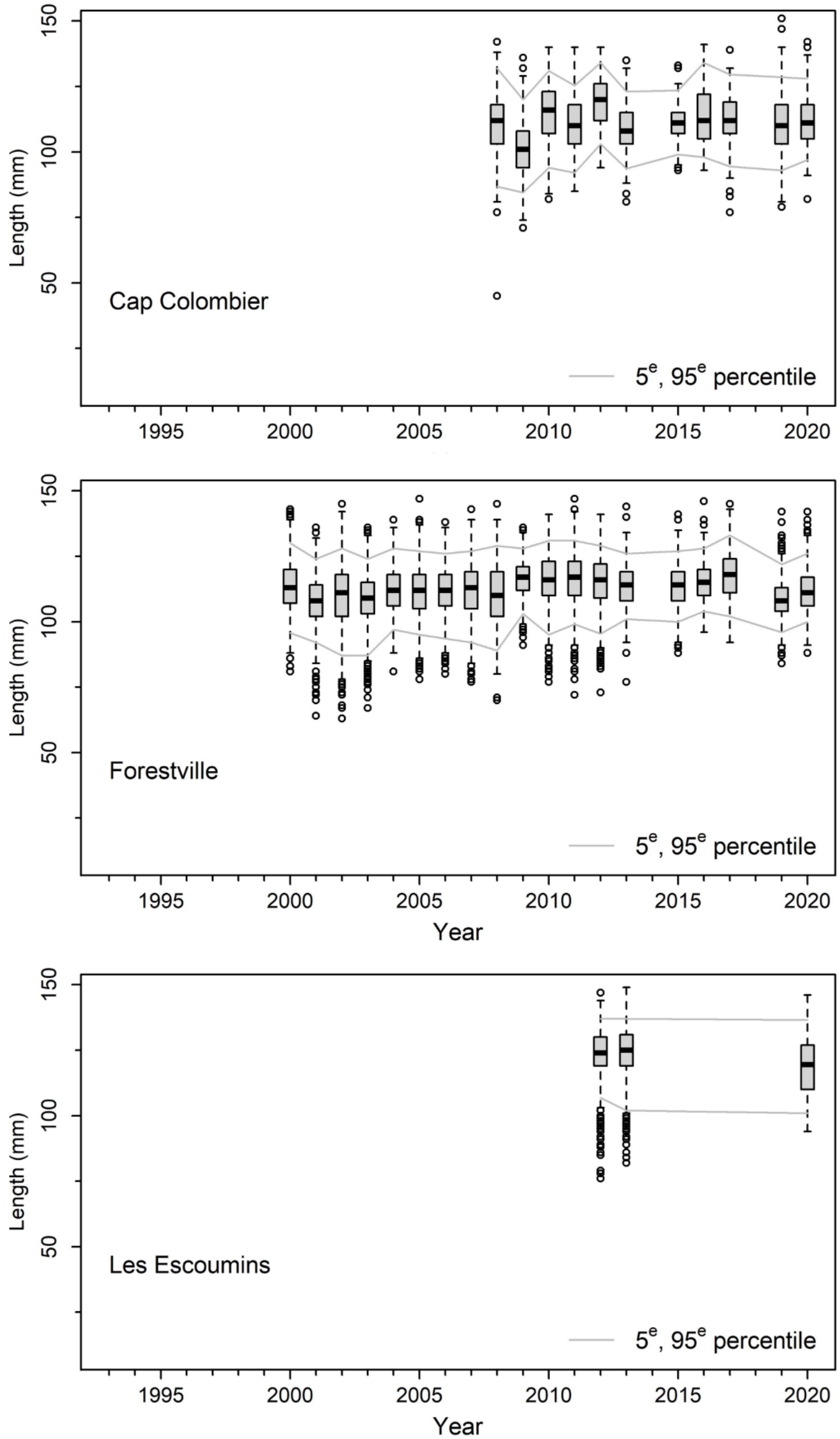


Figure 12. Annual distribution of the size at landing of Arctic surfclams measured by bed in Area 1A.

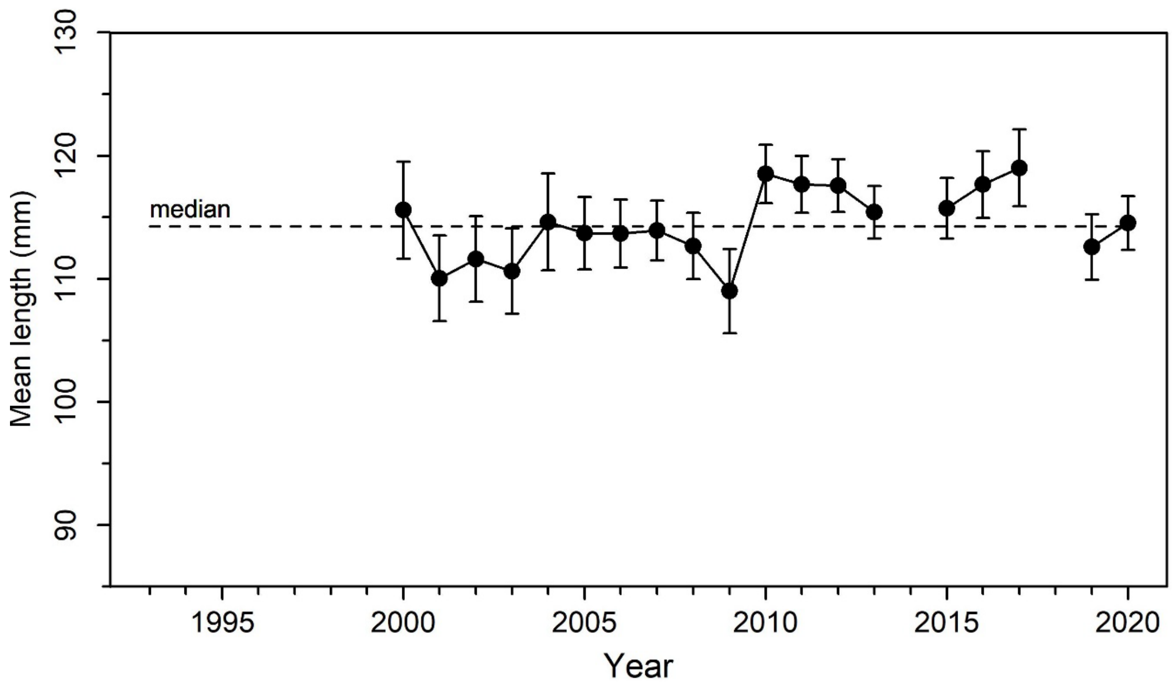


Figure 13. Estimated annual mean size (± 95% confidence interval) at landing of surfclams in Area 1A.

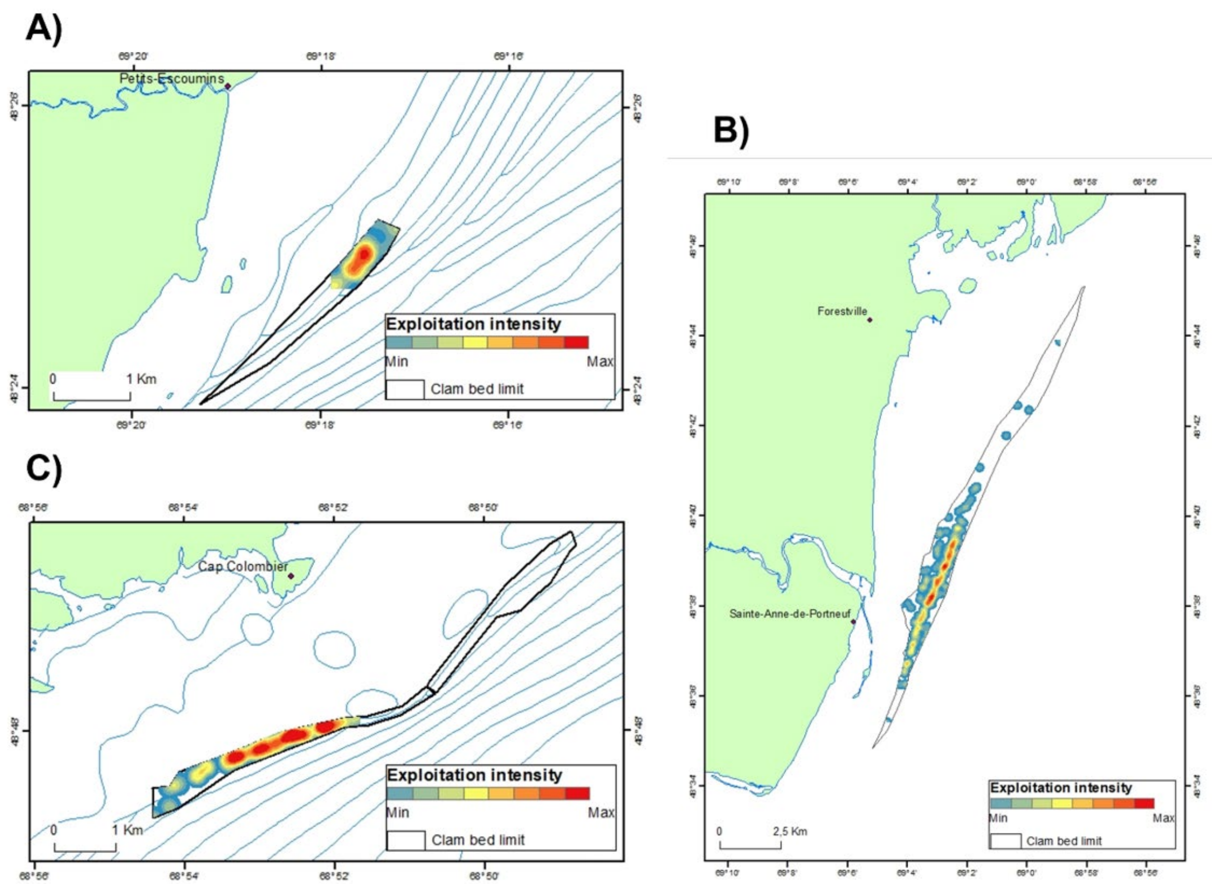


Figure 14. Intensity of exploitation from 1993 to 2020 in the Les Escoumins (A), Forestville (B) and Cap Colombier (C) beds in Area 1A.

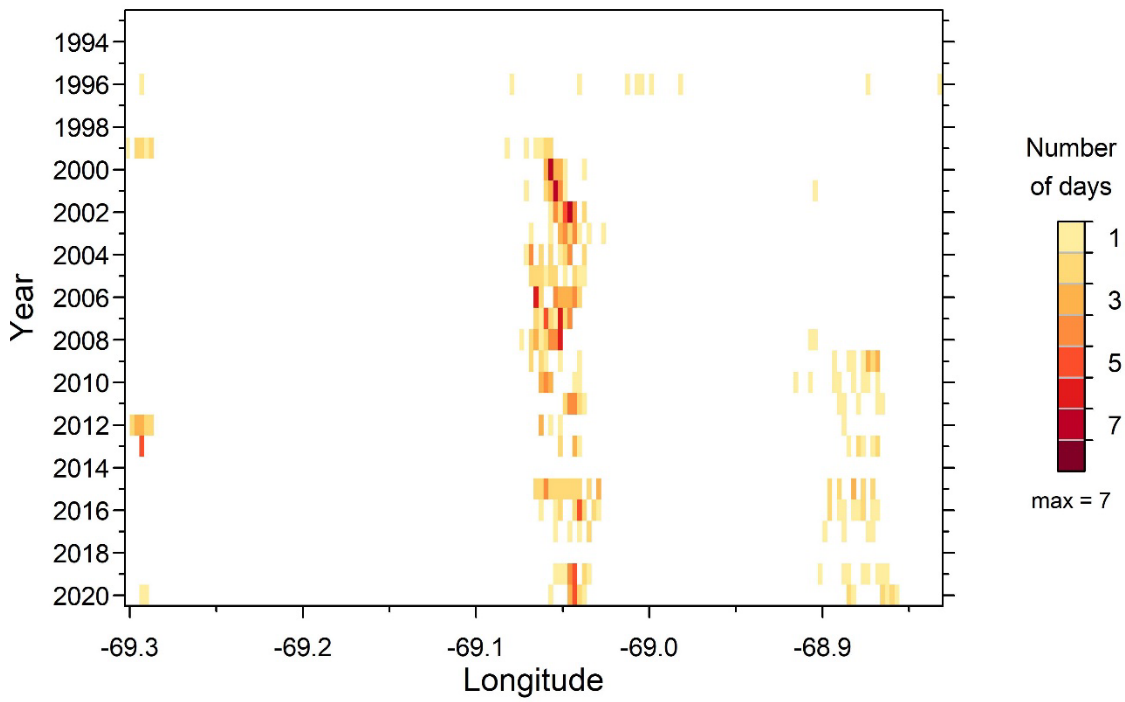


Figure 15. Annual distribution of fishing effort per 10 seconds of longitude in Area 1A.

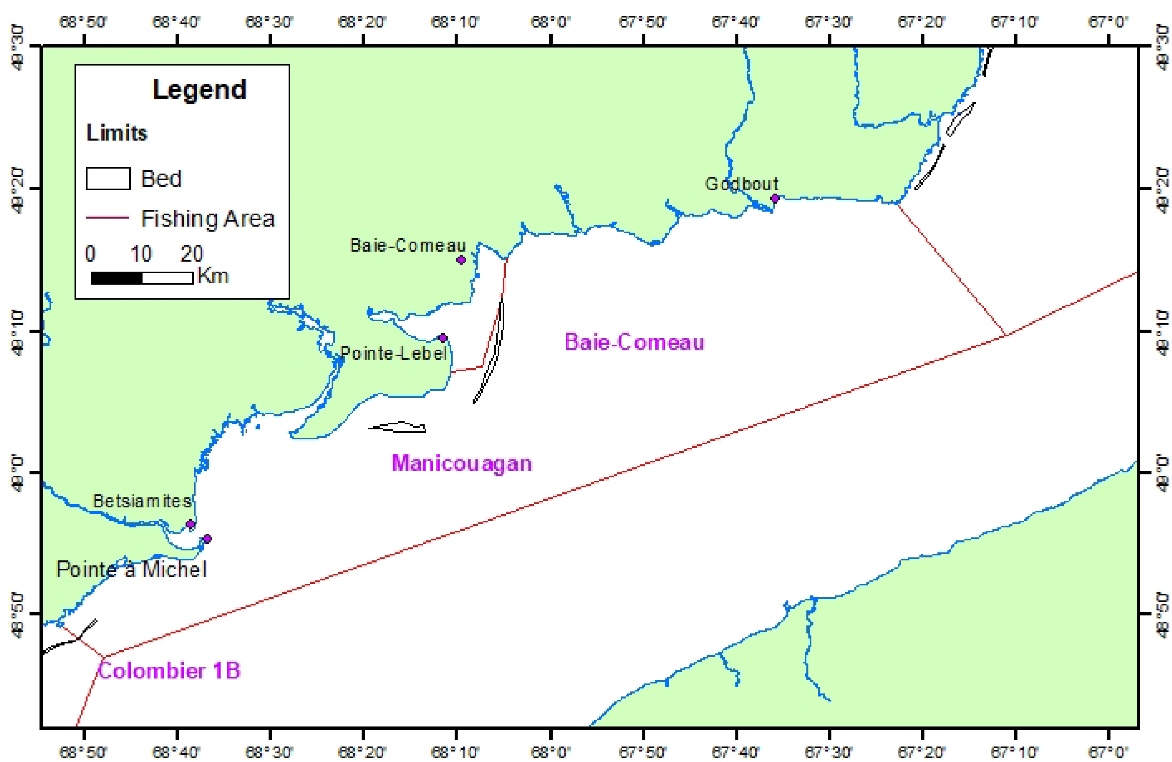


Figure 16. Location of known Arctic surfclam beds in Area 1B.

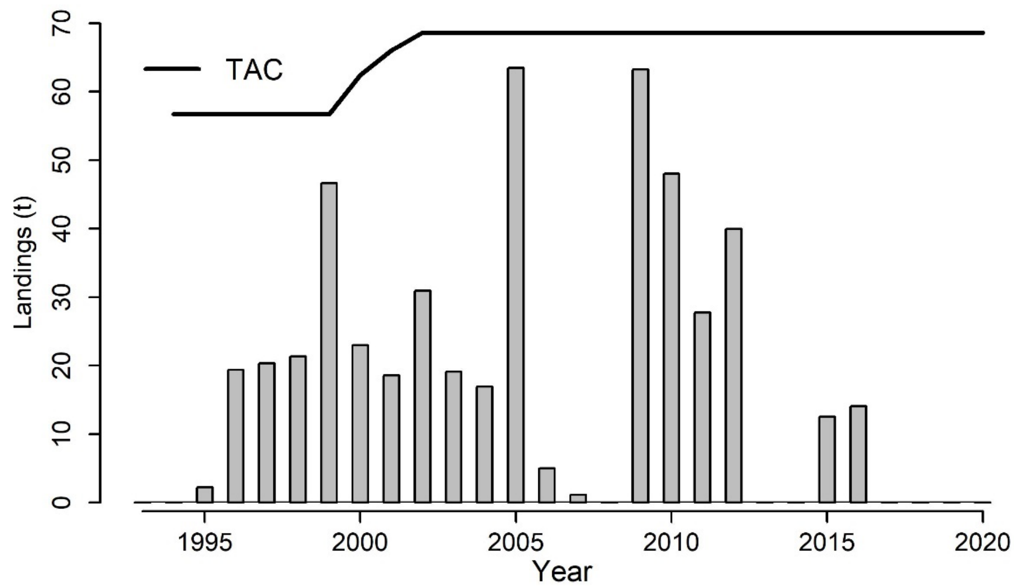


Figure 17. Annual Arctic surfclam landings in Area 1B.

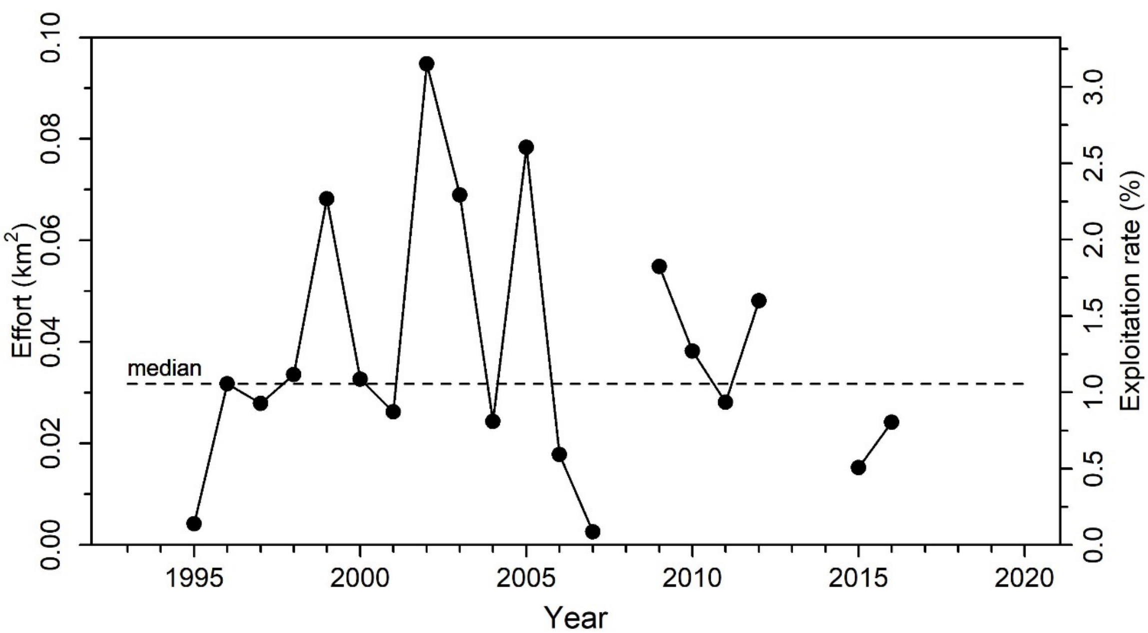


Figure 18. Fishing effort in area dredged (km²) and annual exploitation rates in Area 1B.

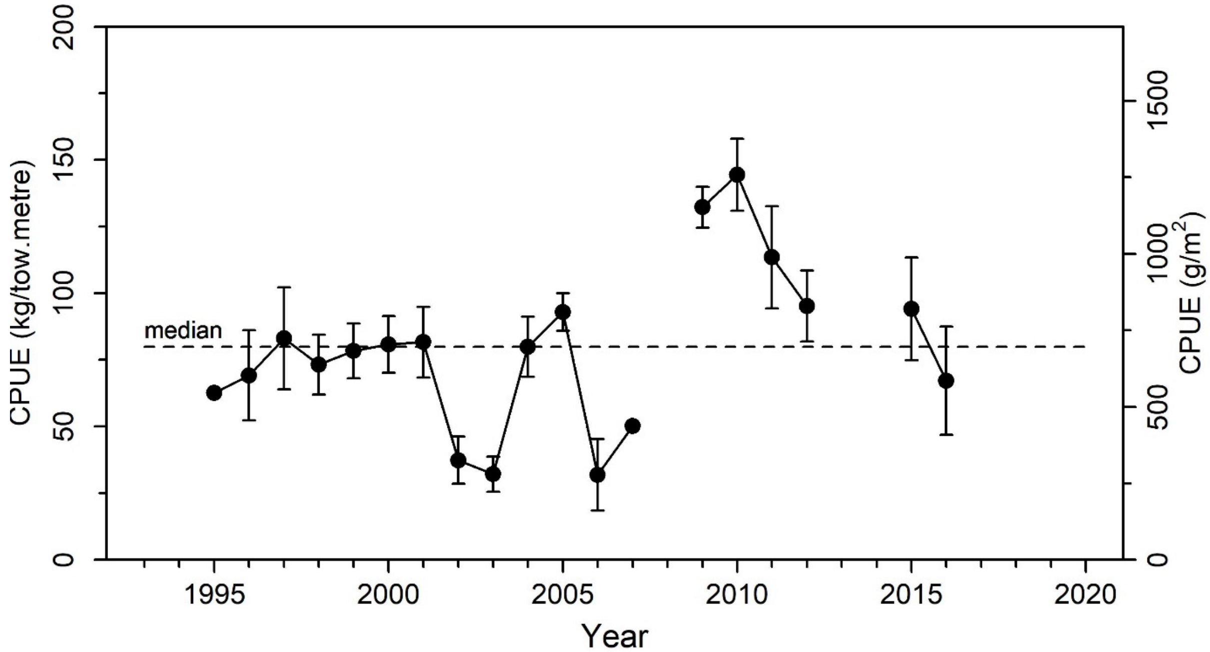


Figure 19. Annual catch per unit effort (± 95% confidence interval) in Area 1B.

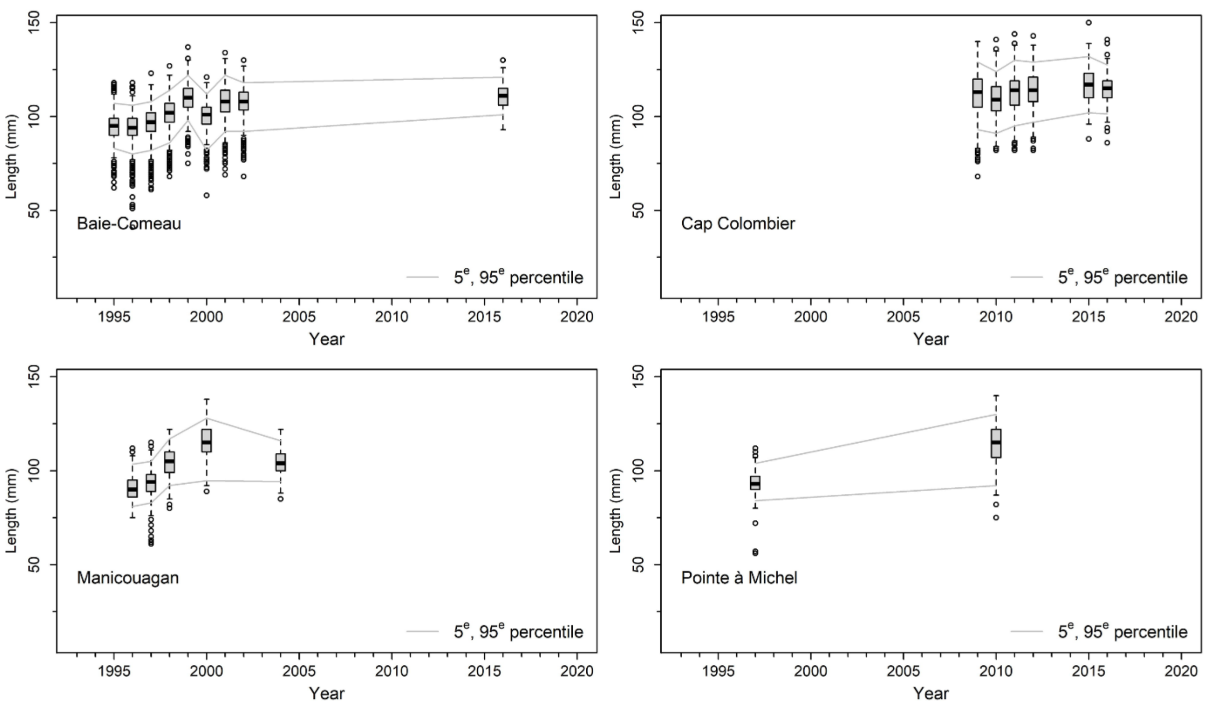


Figure 20. Annual distribution of the size at landing of Arctic surfclams measured by bed in Area 1B.

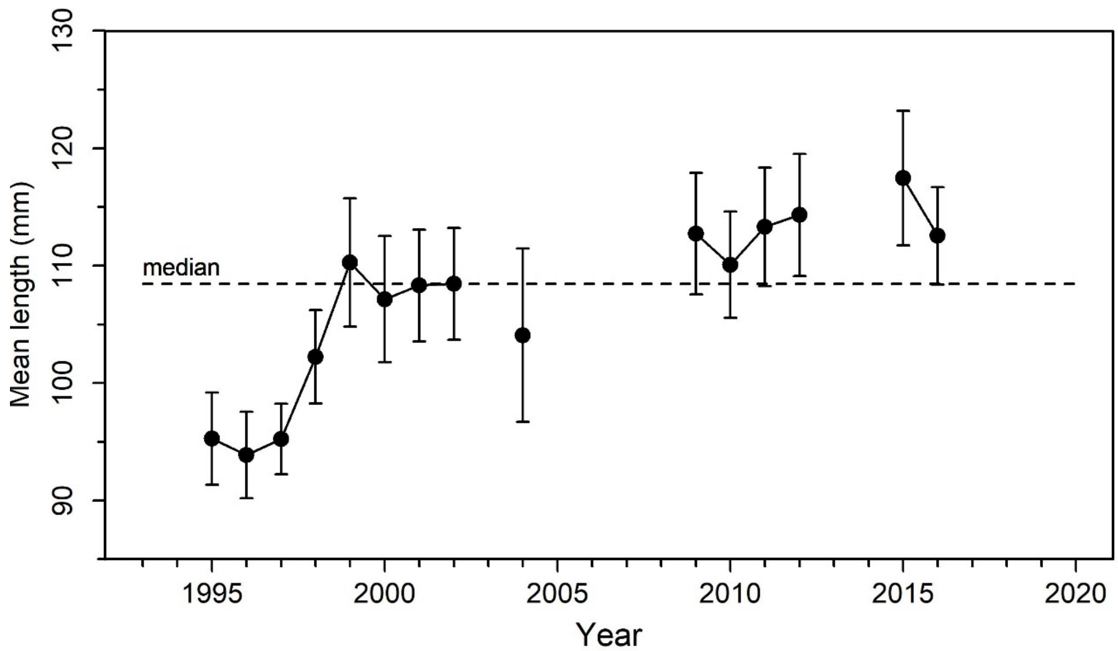


Figure 21. Estimated annual mean size (± 95% confidence interval) at landing of surfclams in Area 1B.

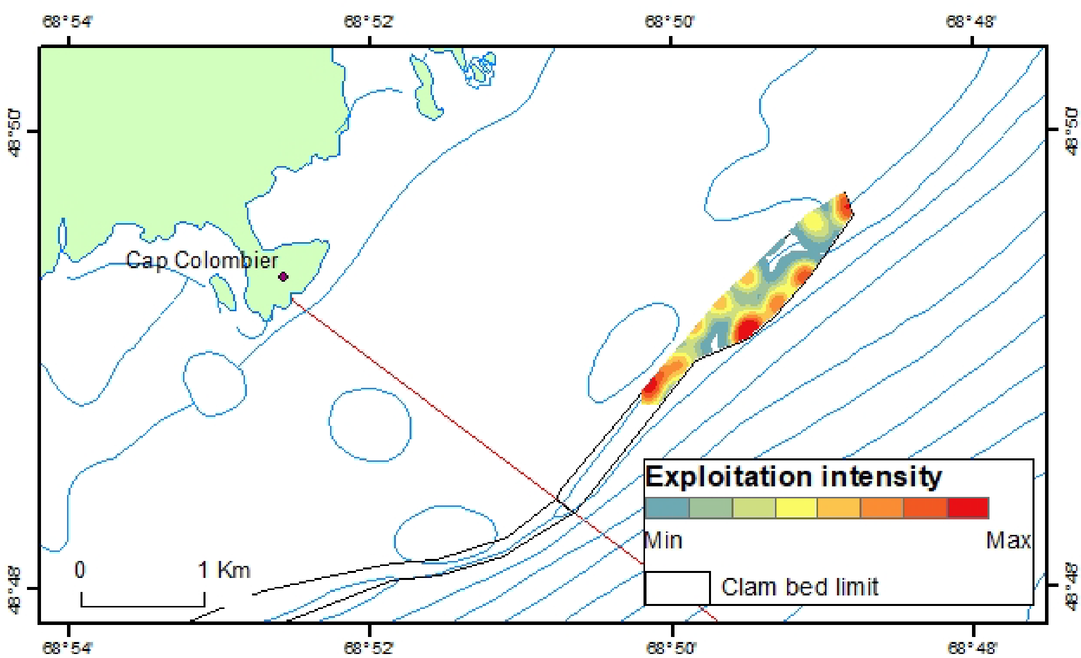


Figure 22. Intensity of exploitation from 1993 to 2020 in the Cap Colombier bed in Area 1B.

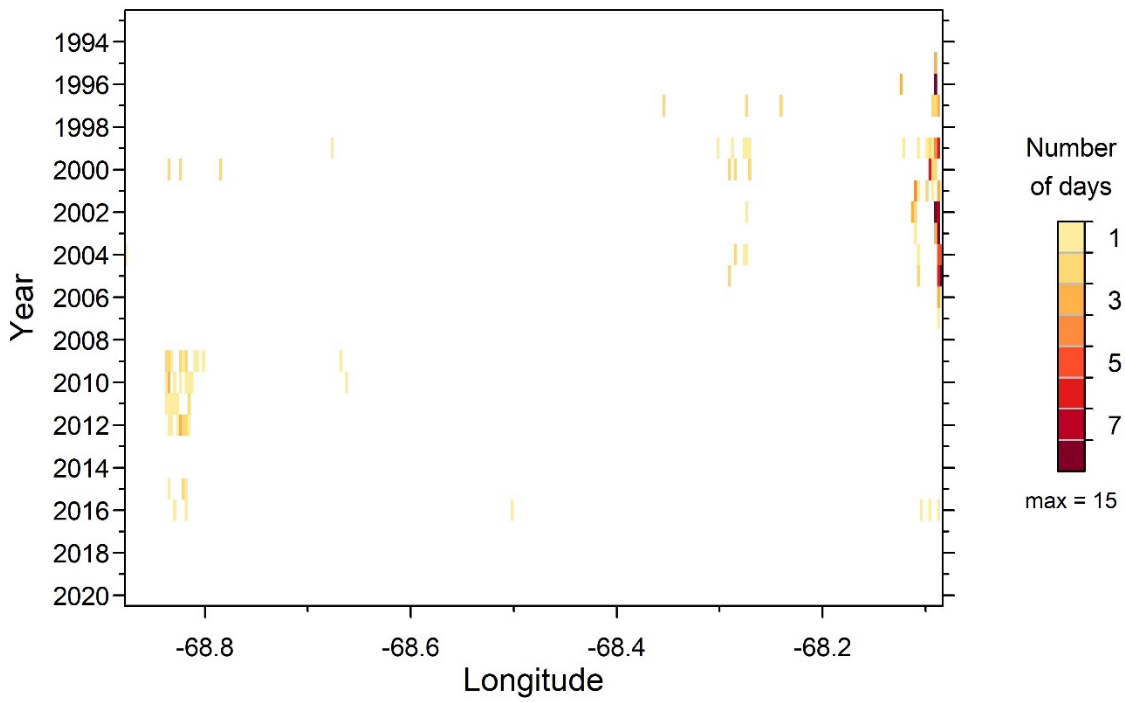


Figure 23. Annual distribution of fishing effort per 10 seconds of longitude in Area 1B.

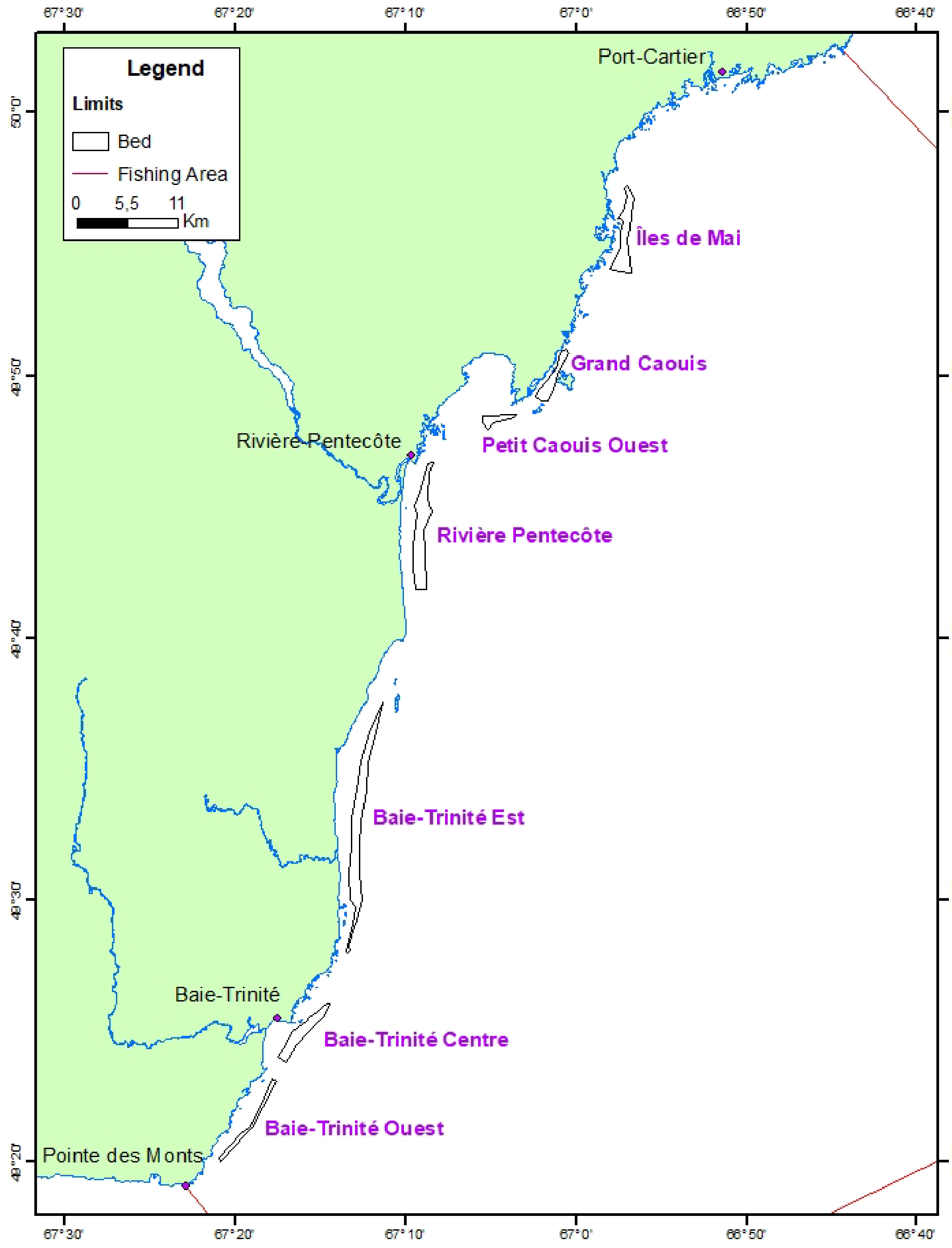


Figure 24. Location of known Arctic surfclam beds in Area 2.

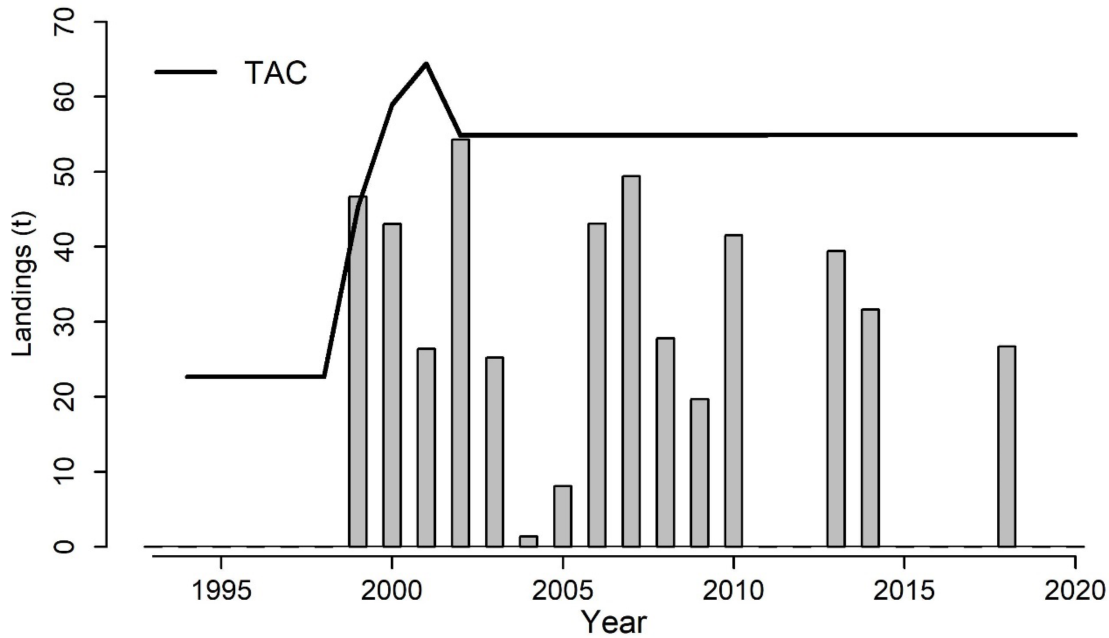


Figure 25. Annual Arctic surfclam landings in Area 2.

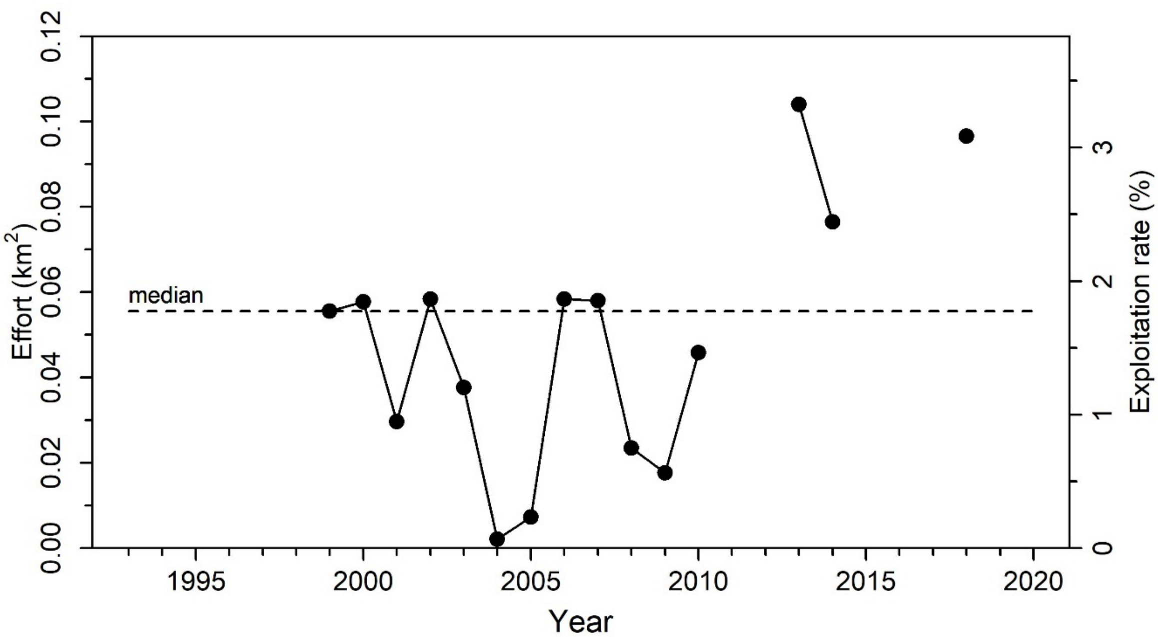


Figure 26. Fishing effort in area dredged (km^2) and annual exploitation rates in Area 2.

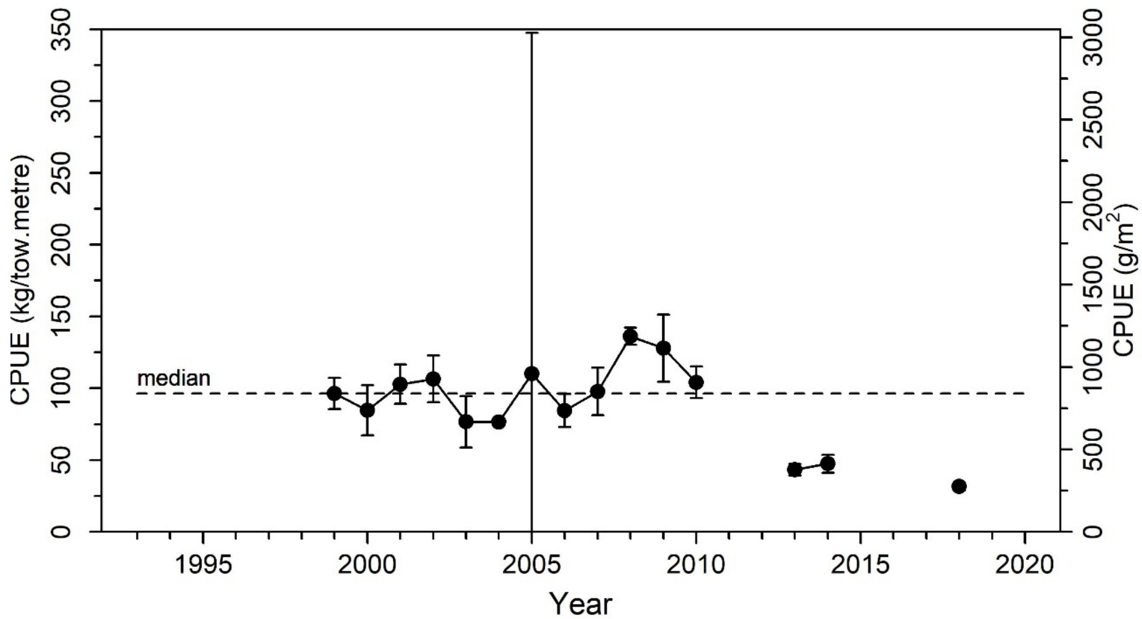


Figure 27. Annual catch per unit effort (± 95% confidence interval) in Area 2.

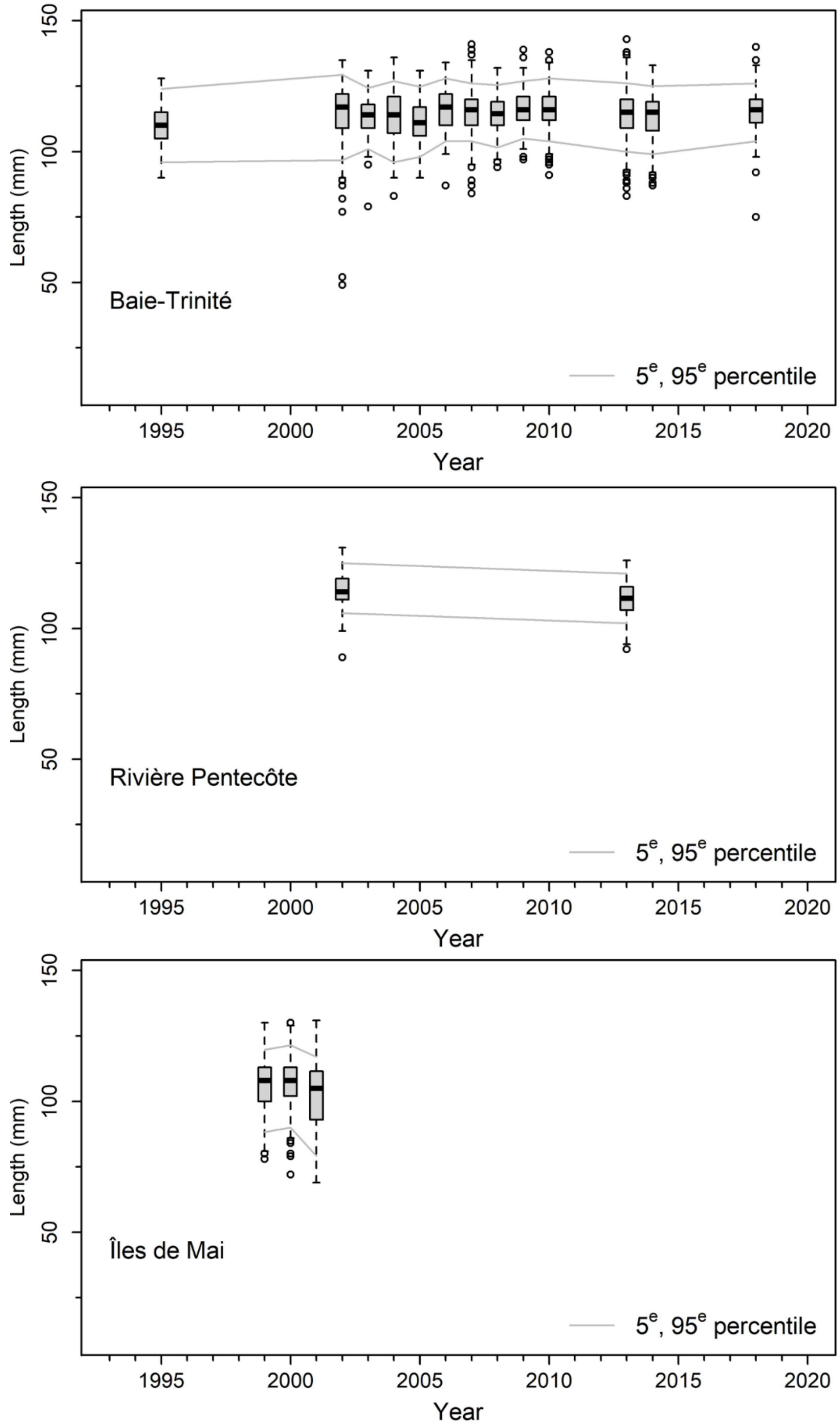


Figure 28. Annual distribution of size at landing of Arctic surfclams measured by bed in Area 2.

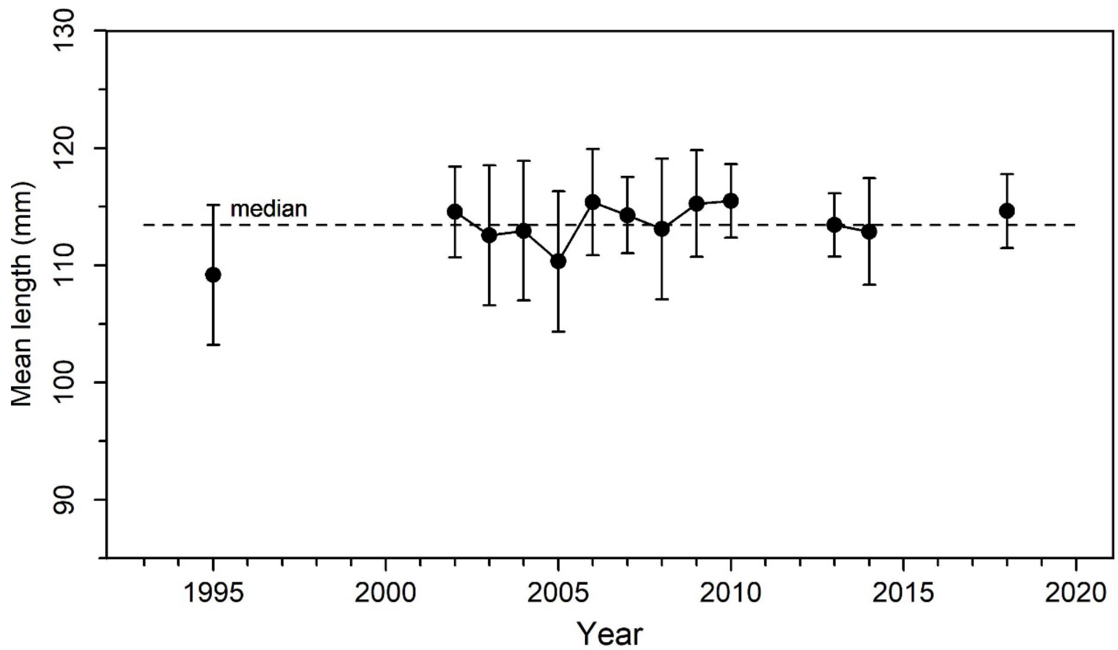


Figure 29. Estimated annual mean size (± 95% confidence interval) at landing of surfclams in Area 2.

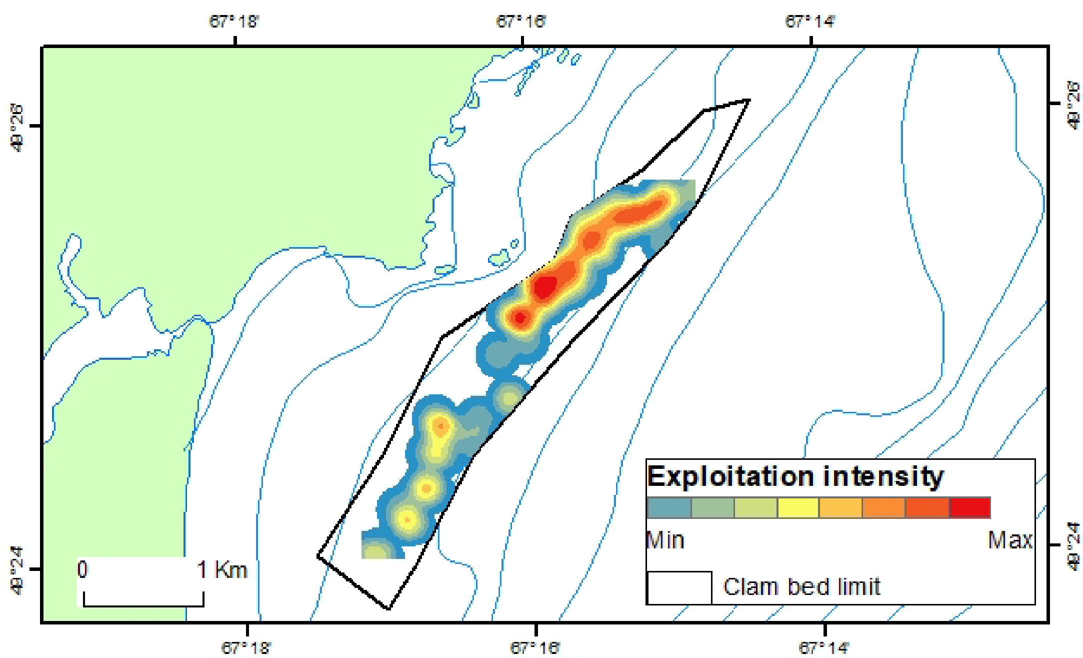


Figure 30. Intensity of exploitation from 1993 to 2020 in the Baie-Trinité Centre bed in Area 2.

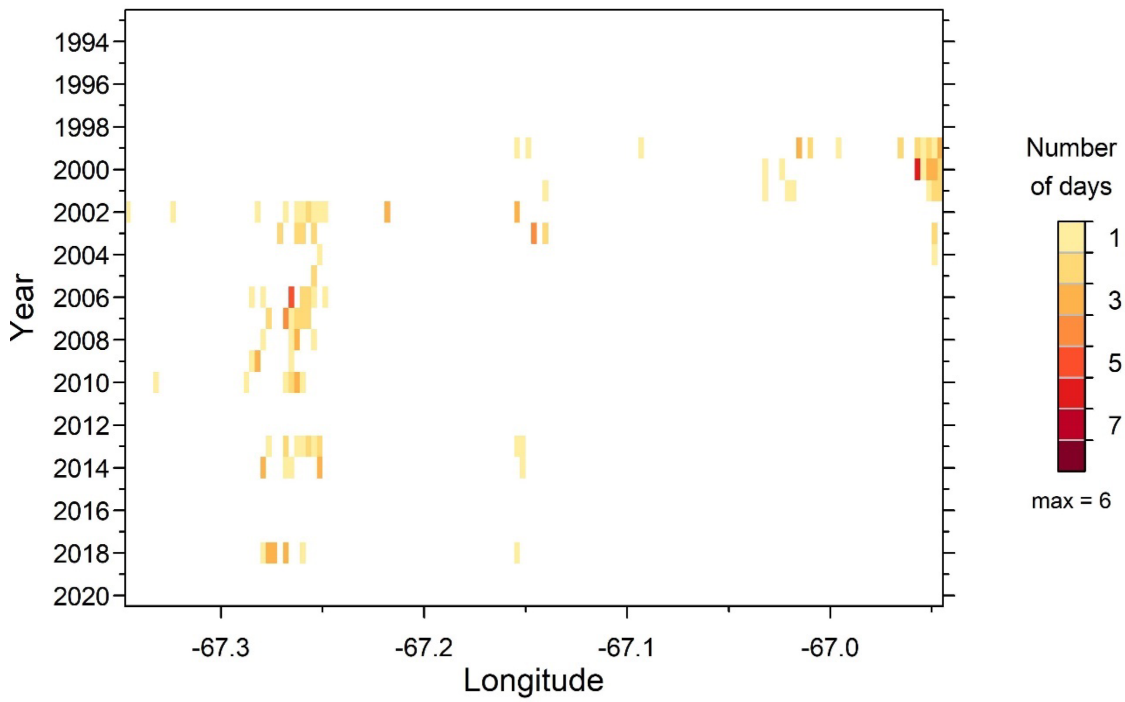


Figure 31. Annual distribution of fishing effort per 10 seconds of longitude in Area 2.

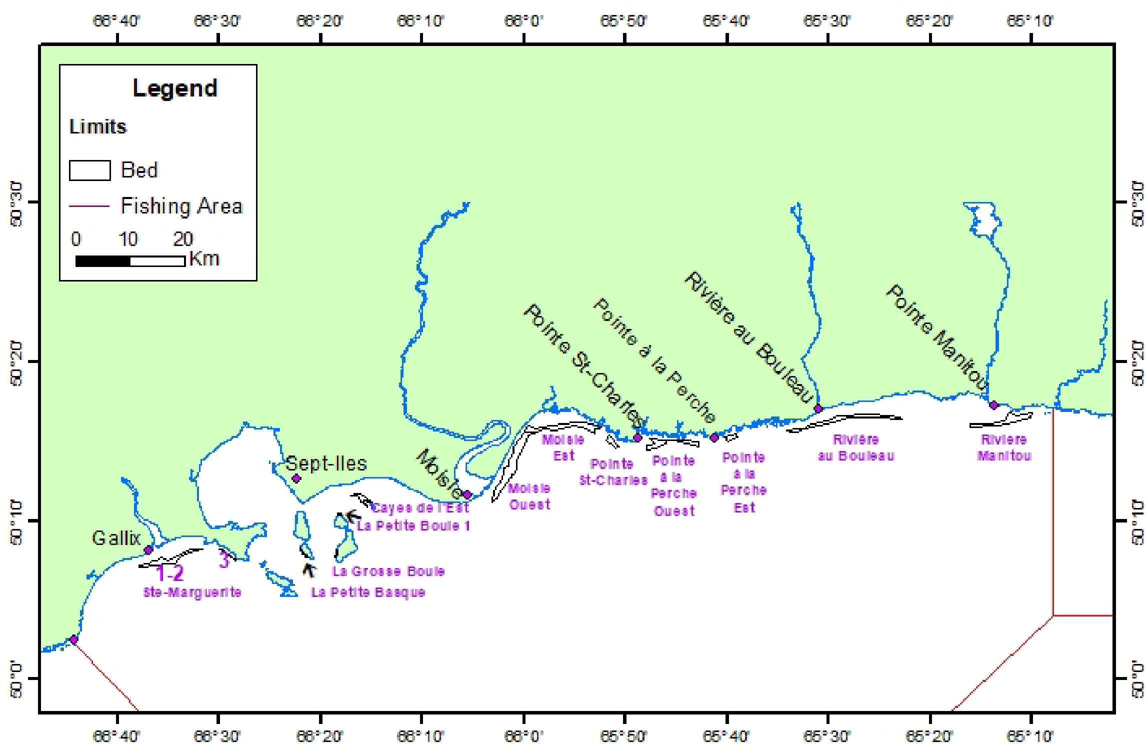


Figure 32. Location of known Arctic surfclam beds in Area 3A.

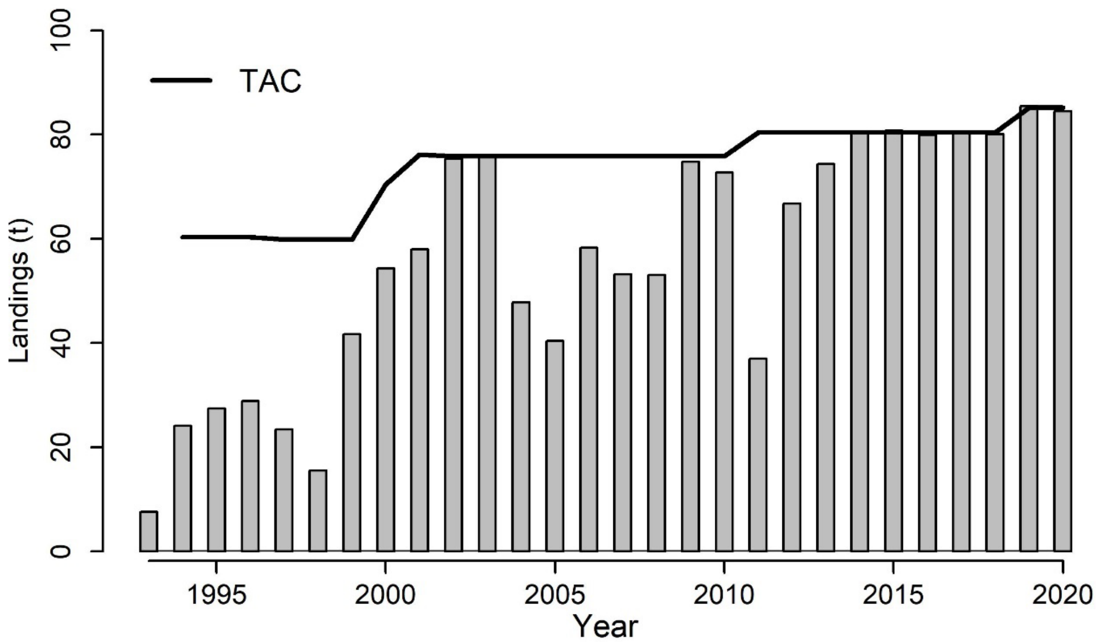


Figure 33. Annual Arctic surfclam landings in Area 3A.

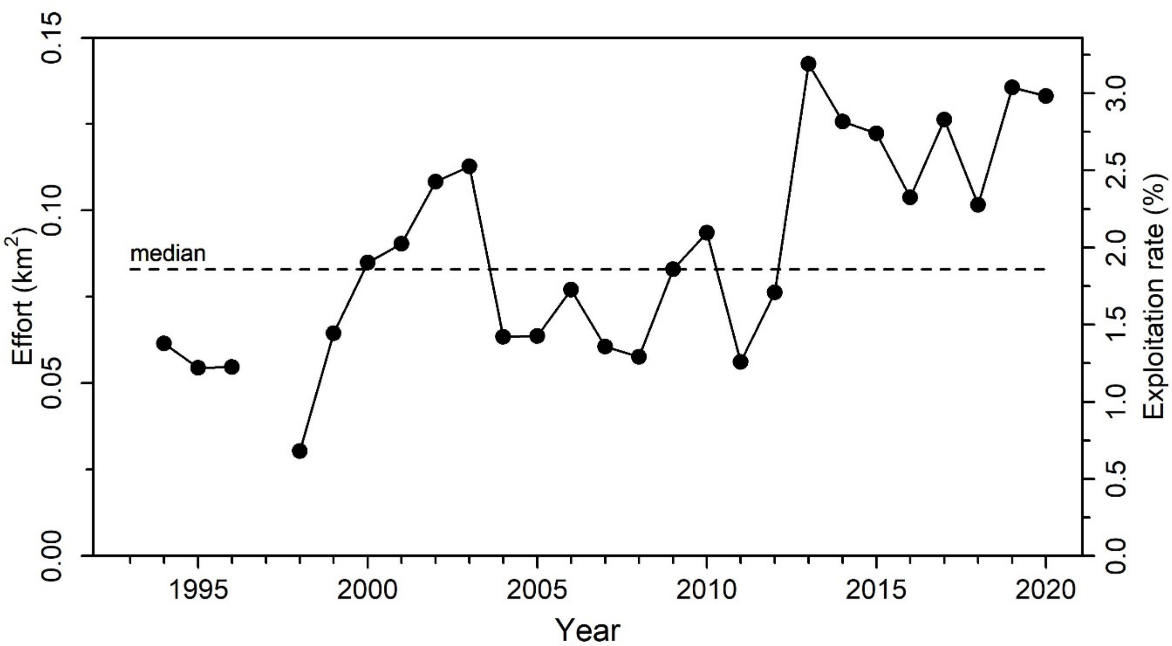


Figure 34. Fishing effort in area dredged (km^2) and annual exploitation rates in Area 3A.

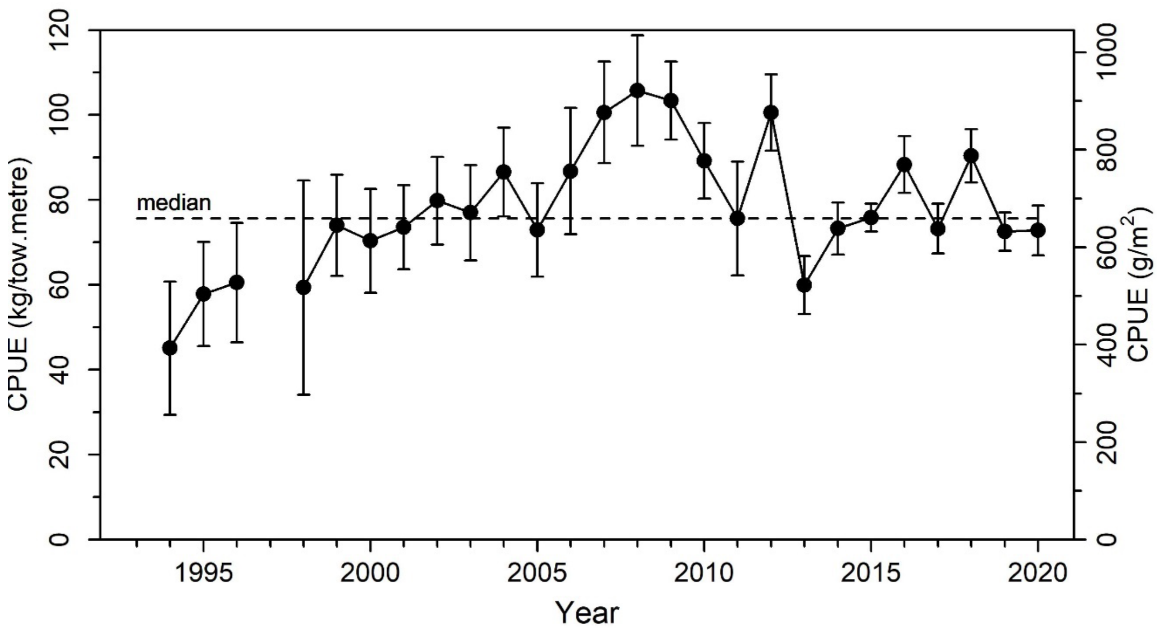


Figure 35. Annual catch per unit effort (± 95% confidence interval) in Area 3A.

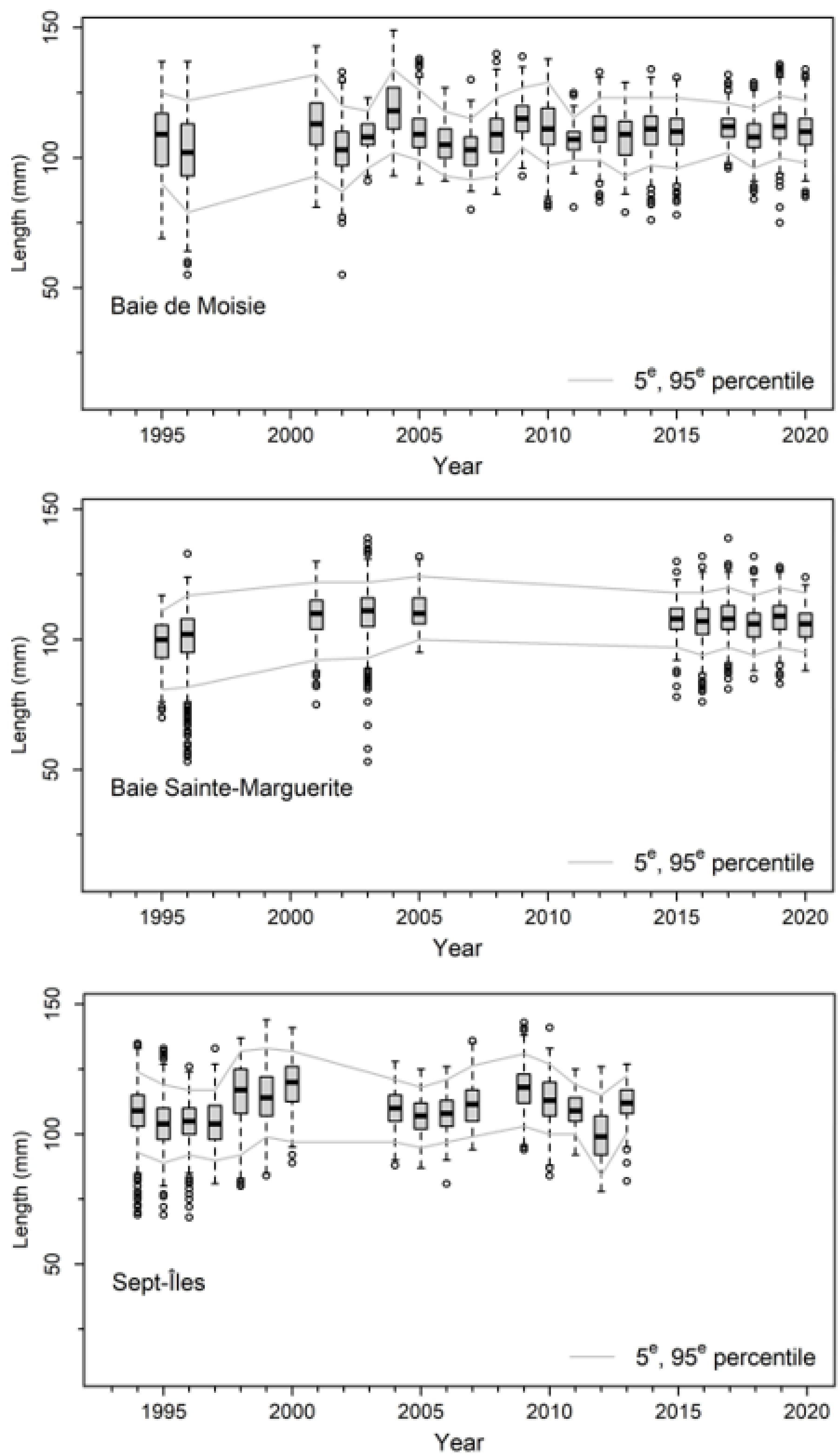


Figure 36. Annual distribution of the size at landing of Arctic surfclams measured by bed in Area 3A.

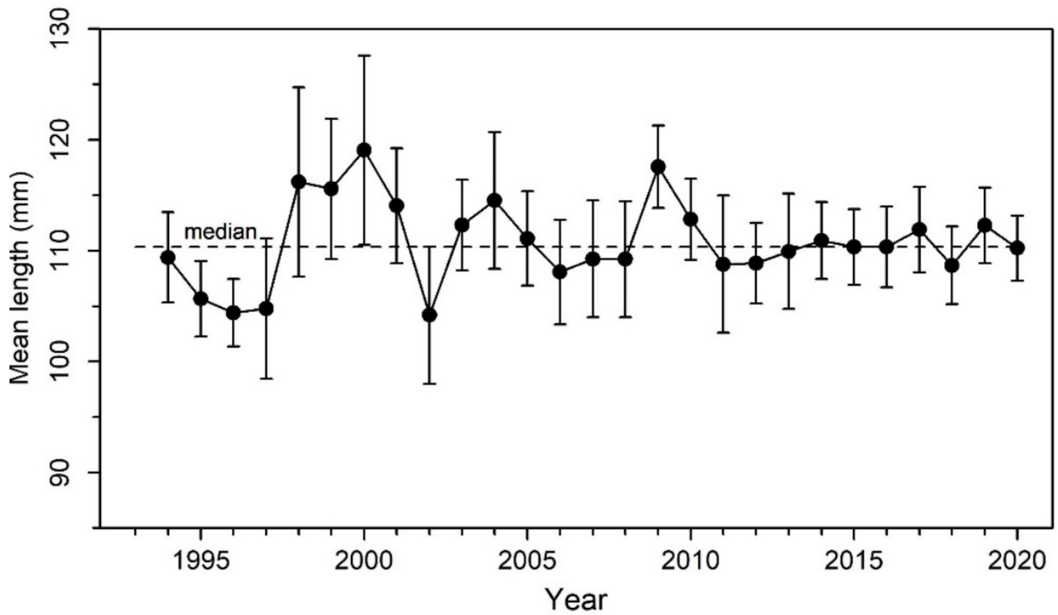
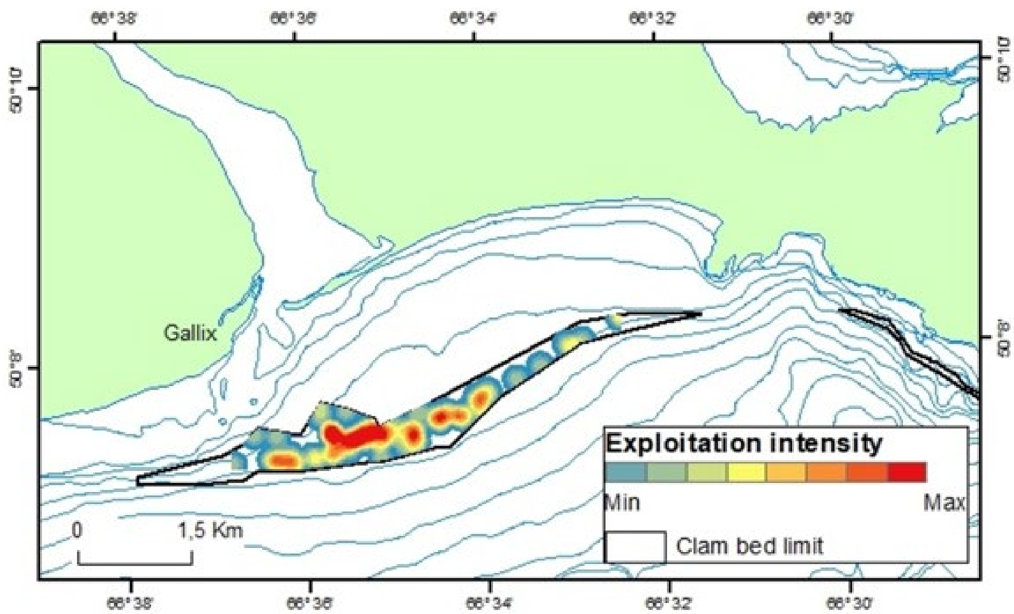


Figure 37. Estimated annual mean size (± 95% confidence interval) at landing of surfclams in Area 3A.

A)



B)

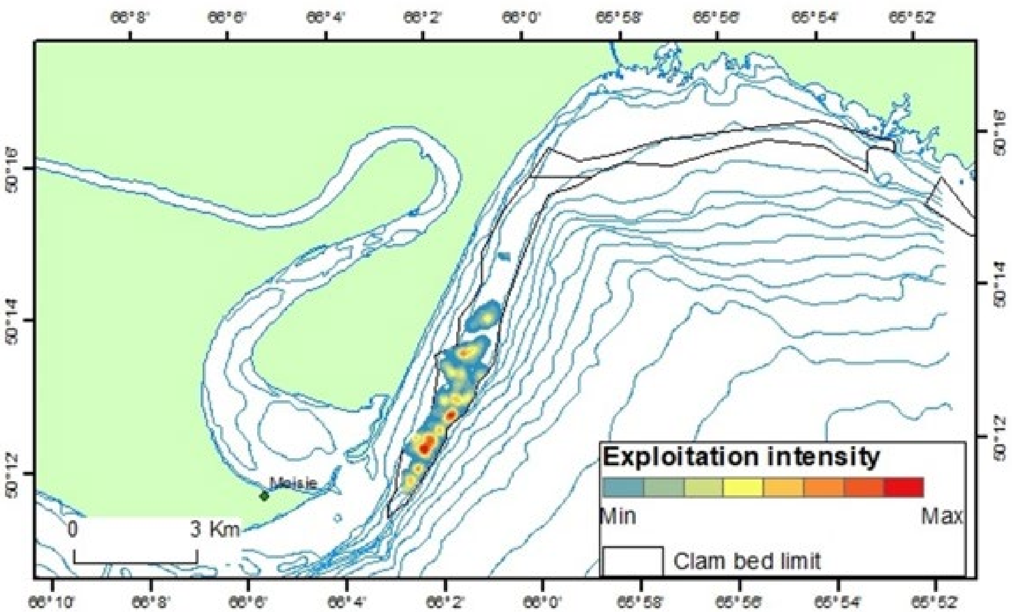


Figure 38. Intensity of exploitation from 1993 to 2020 in the Ste-Marguerite (A) and west Moisie River (B) beds in Area 3A.

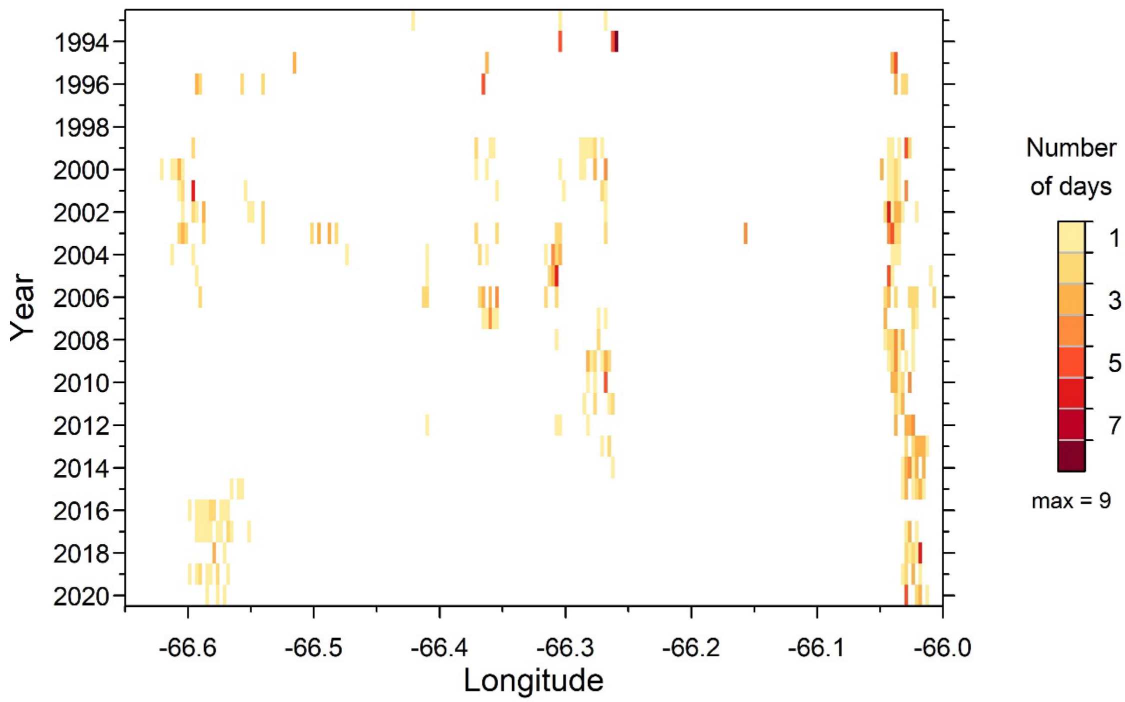


Figure 39. Annual distribution of fishing effort per 10 seconds of longitude in Area 3A.

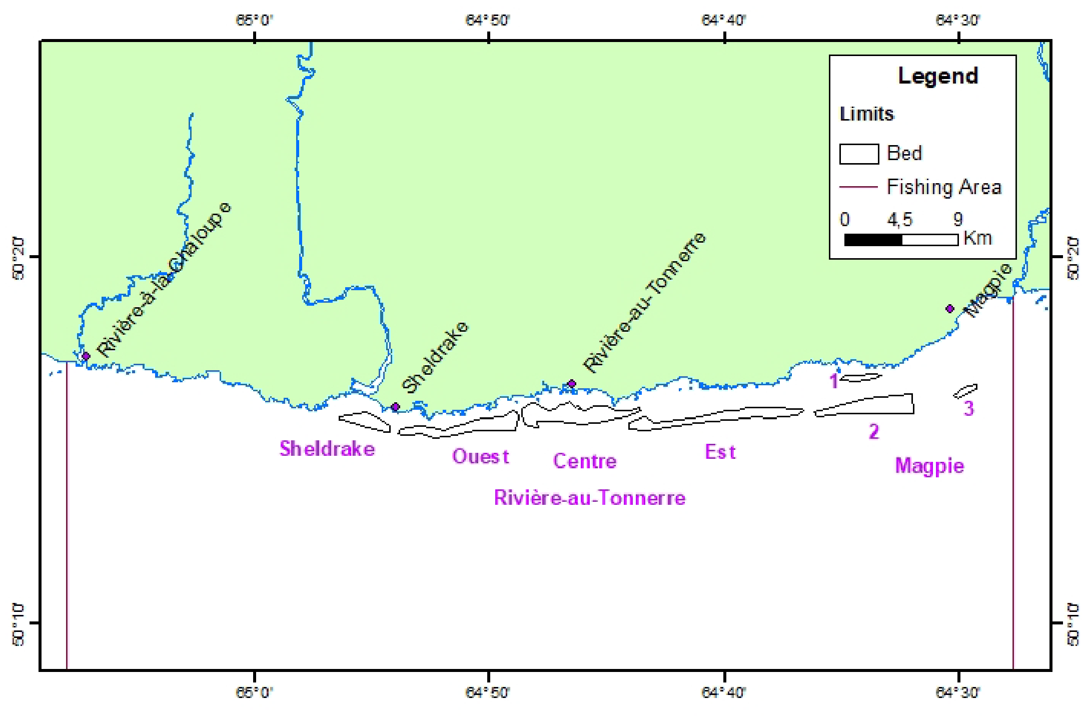


Figure 40. Location of known Arctic surfclam beds in Area 3B.

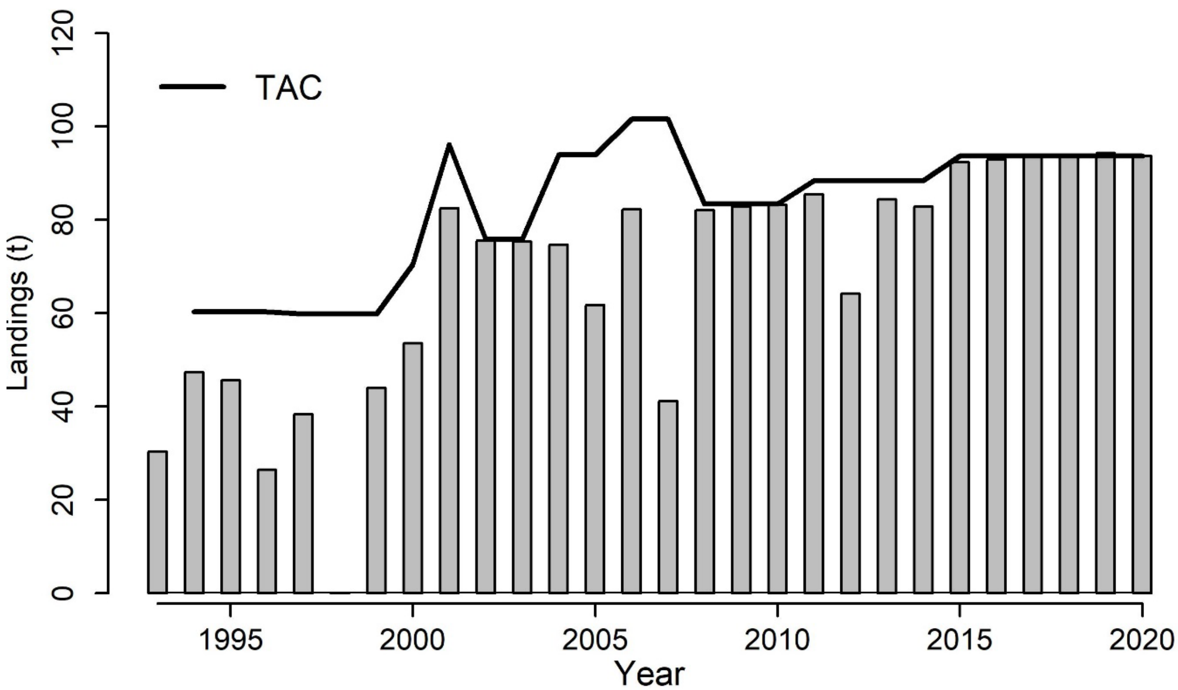


Figure 41. Annual Arctic surfclam landings in Area 3B.

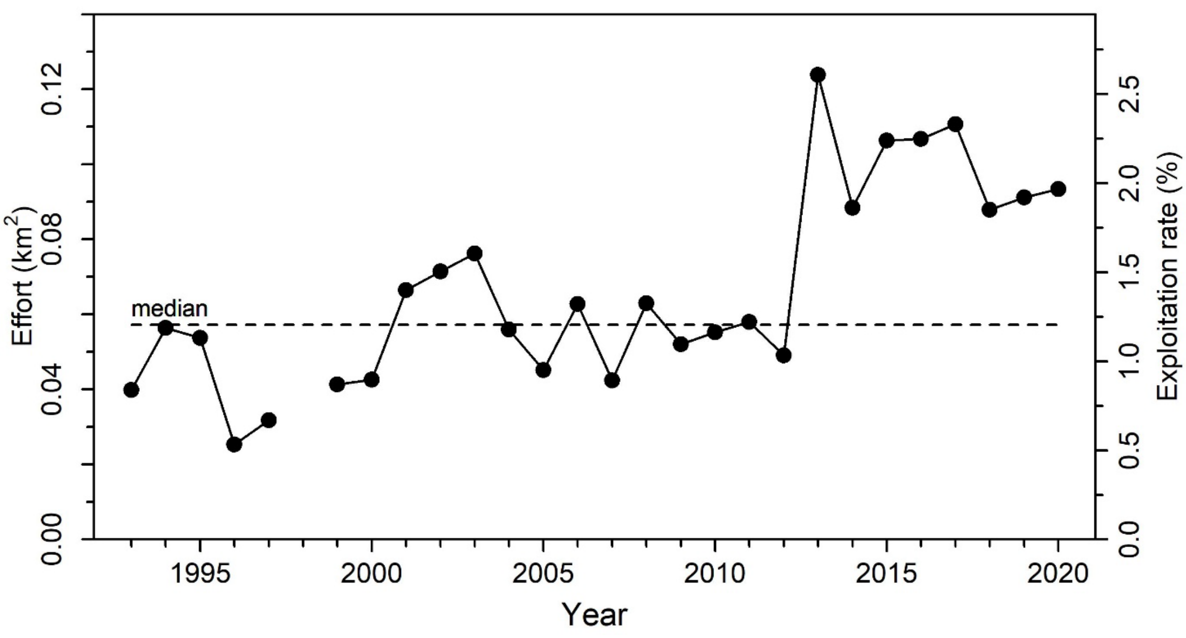


Figure 42. Fishing effort in area dredged (km^2) and annual exploitation rates in Area 3B.

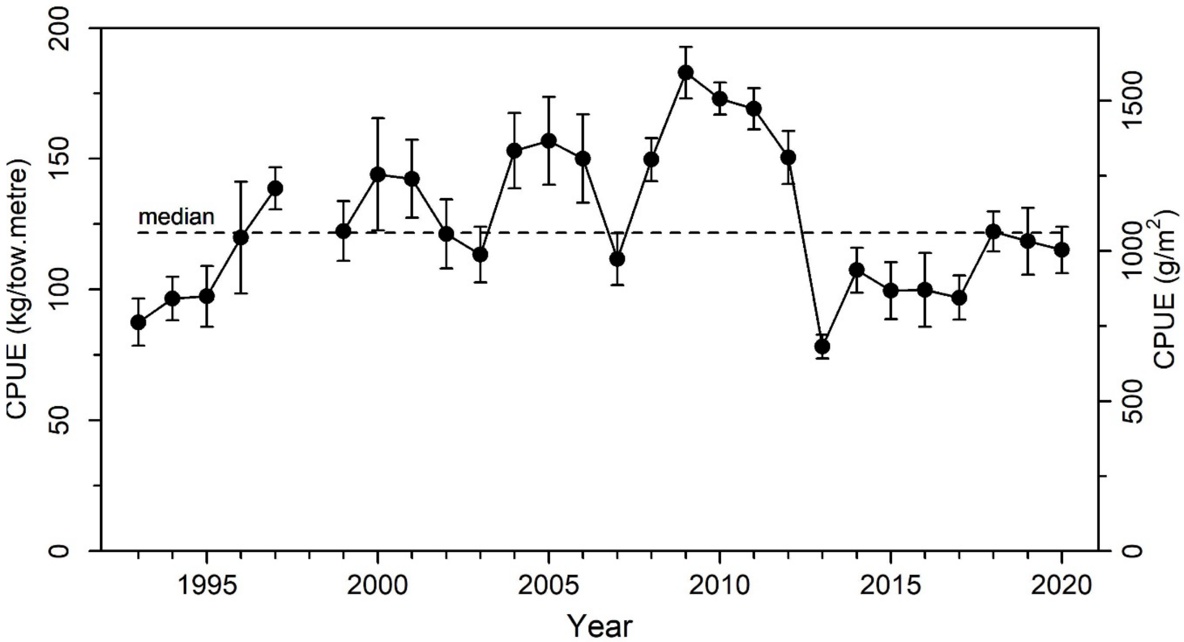


Figure 43. Annual catch per unit effort (± 95% confidence interval) in Area 3B.

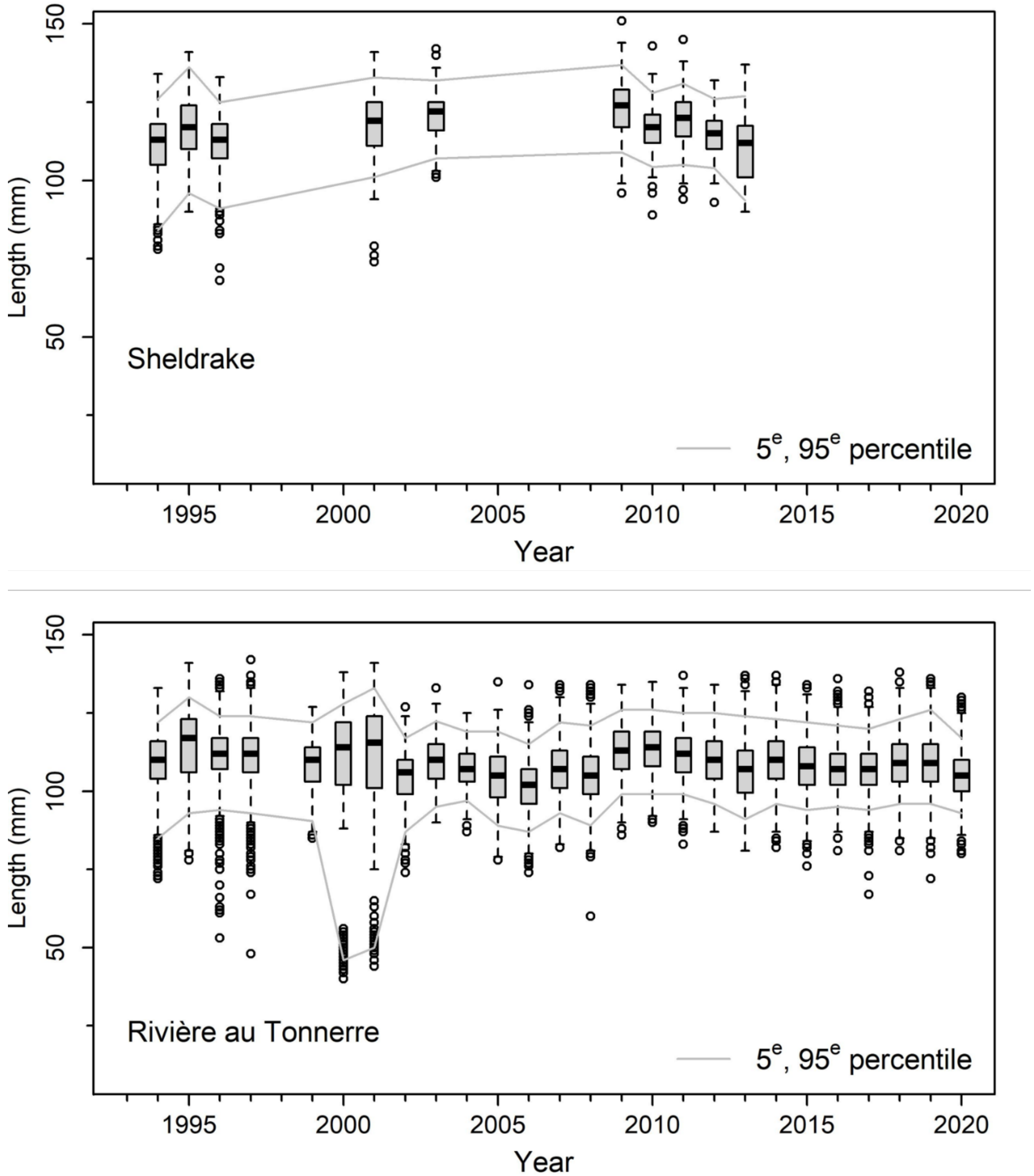


Figure 44. Annual distribution of the size at landing of Arctic surfclams measured by bed in Area 3B.

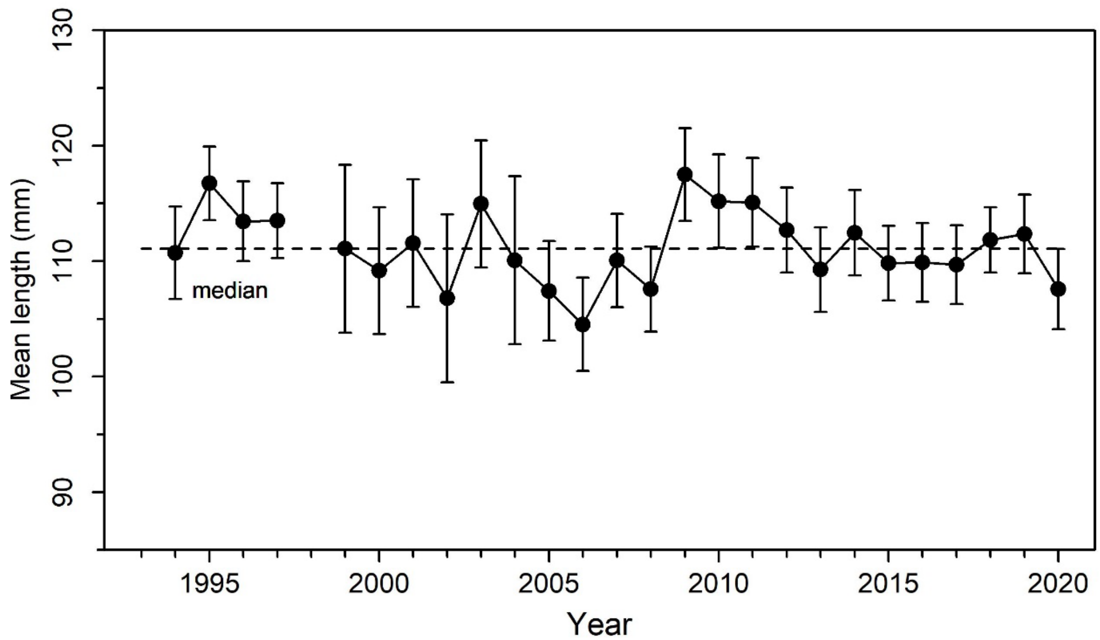


Figure 45. Estimated annual mean size (± 95% confidence interval) at landing of surfclams in Area 3B.

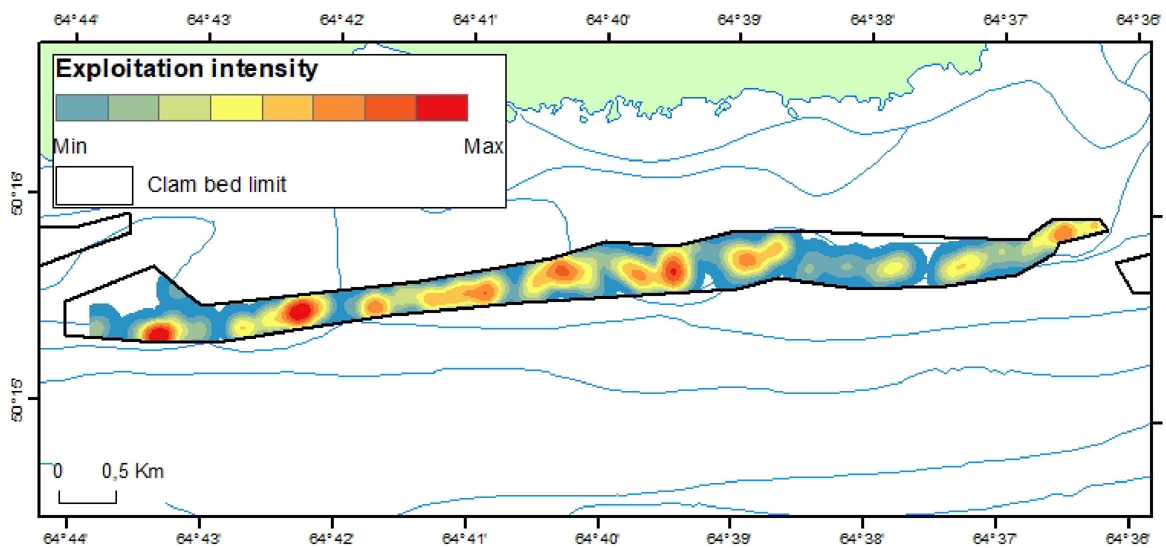


Figure 46. Intensity of exploitation from 1993 to 2020 in the Rivière-au-Tonnerre Est bed in Area 3B.

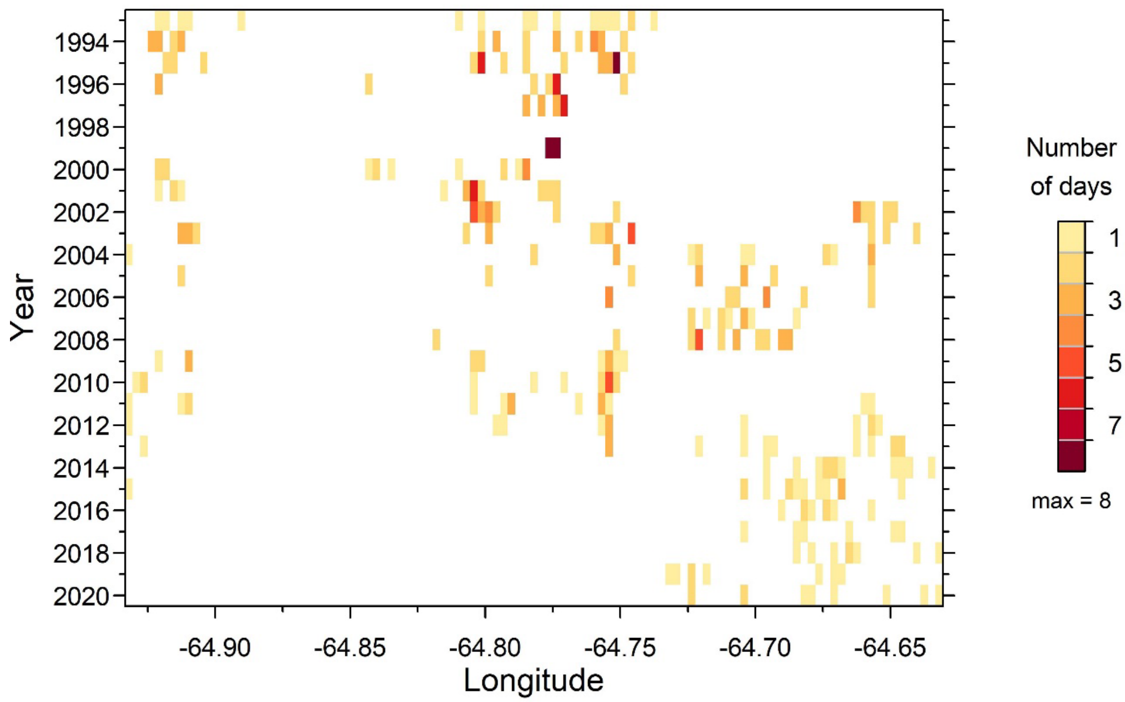


Figure 47. Annual distribution of fishing effort per 10 seconds of longitude in Area 3B.

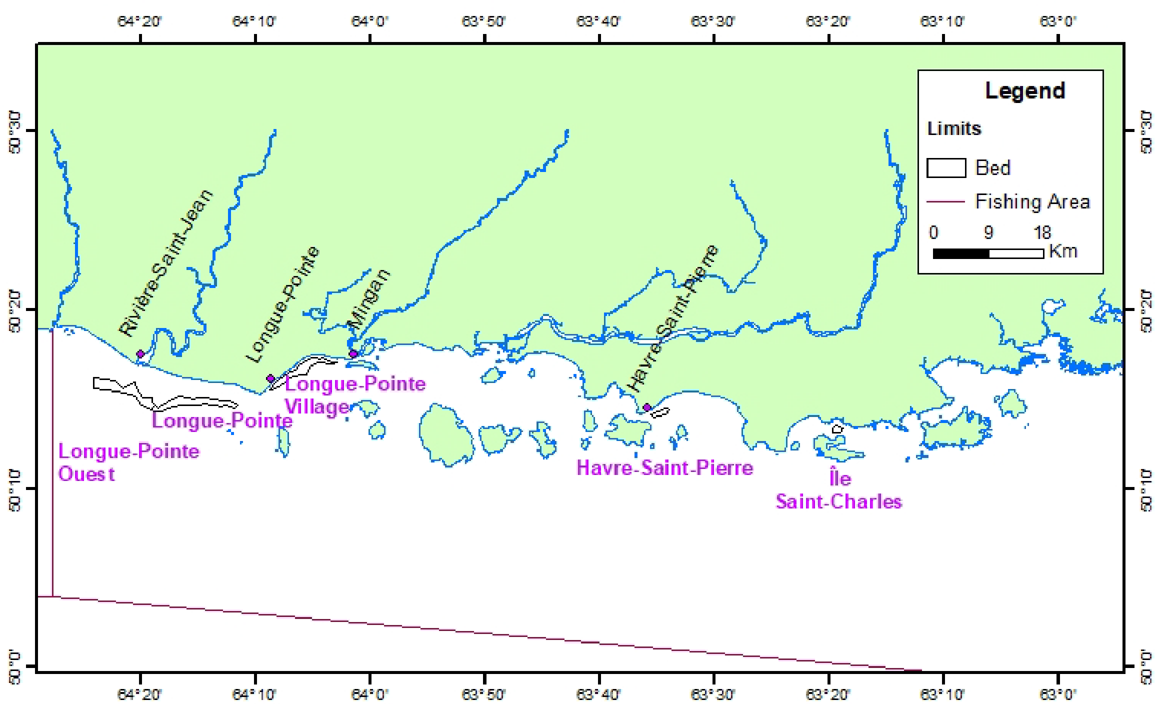


Figure 48. Location of known Arctic surfclam beds in Area 4A.

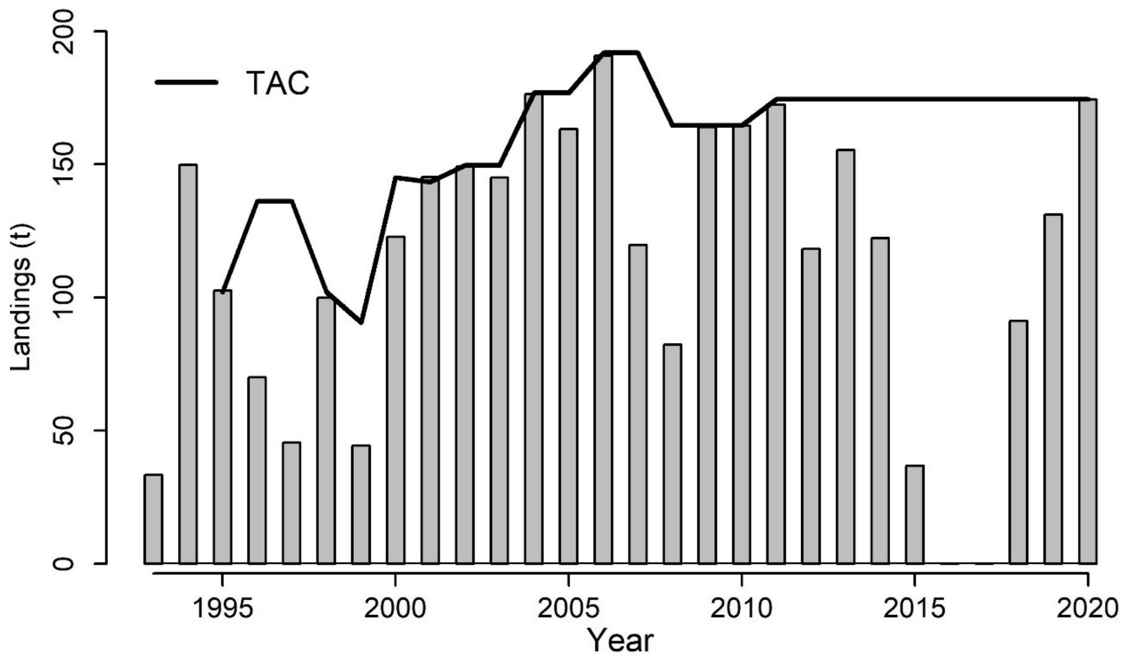


Figure 49. Annual Arctic surfclam landings in Area 4A.

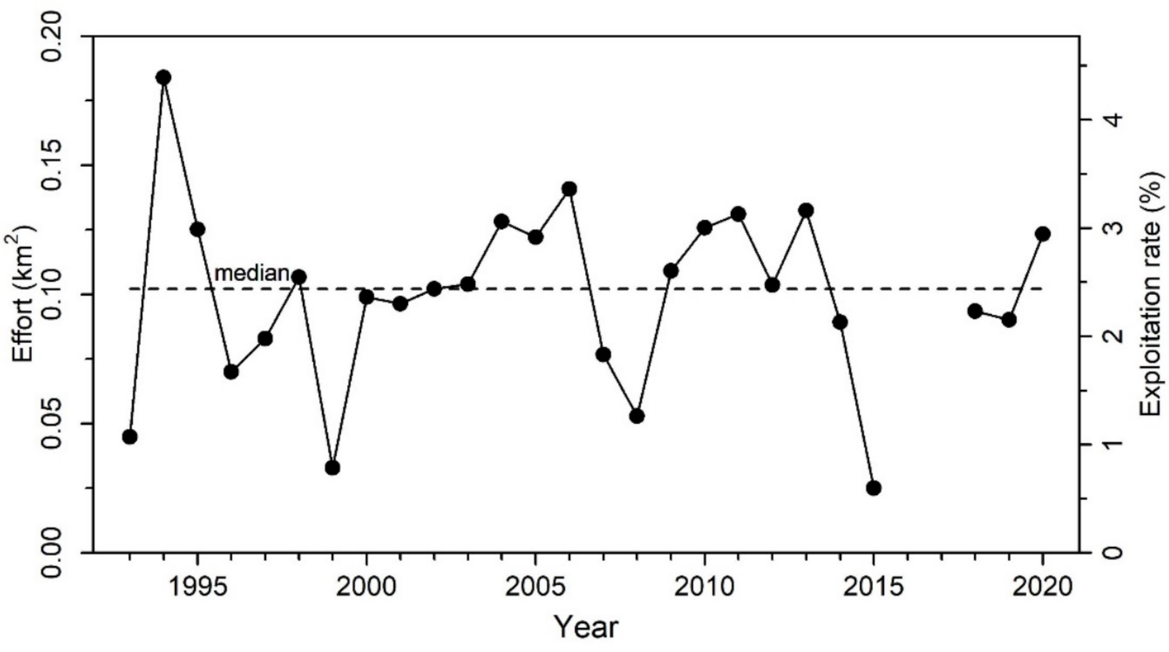


Figure 50. Fishing effort in area dredged (km^2) and annual exploitation rates in Area 4A.

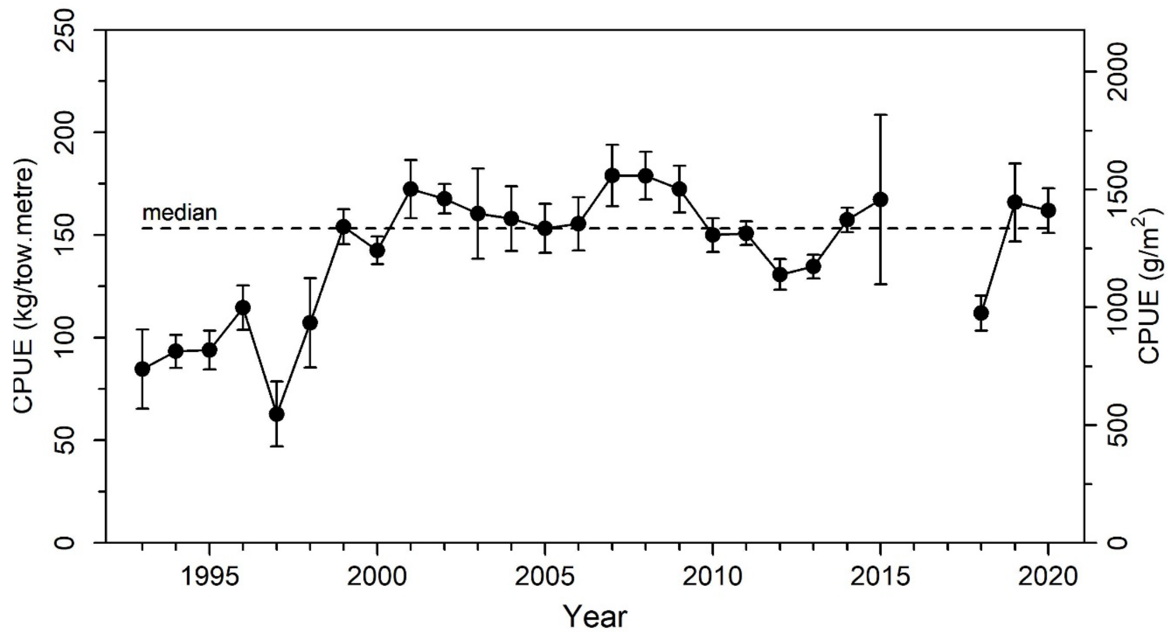


Figure 51. Annual catch per unit effort (± 95% confidence interval) in Area 4A.

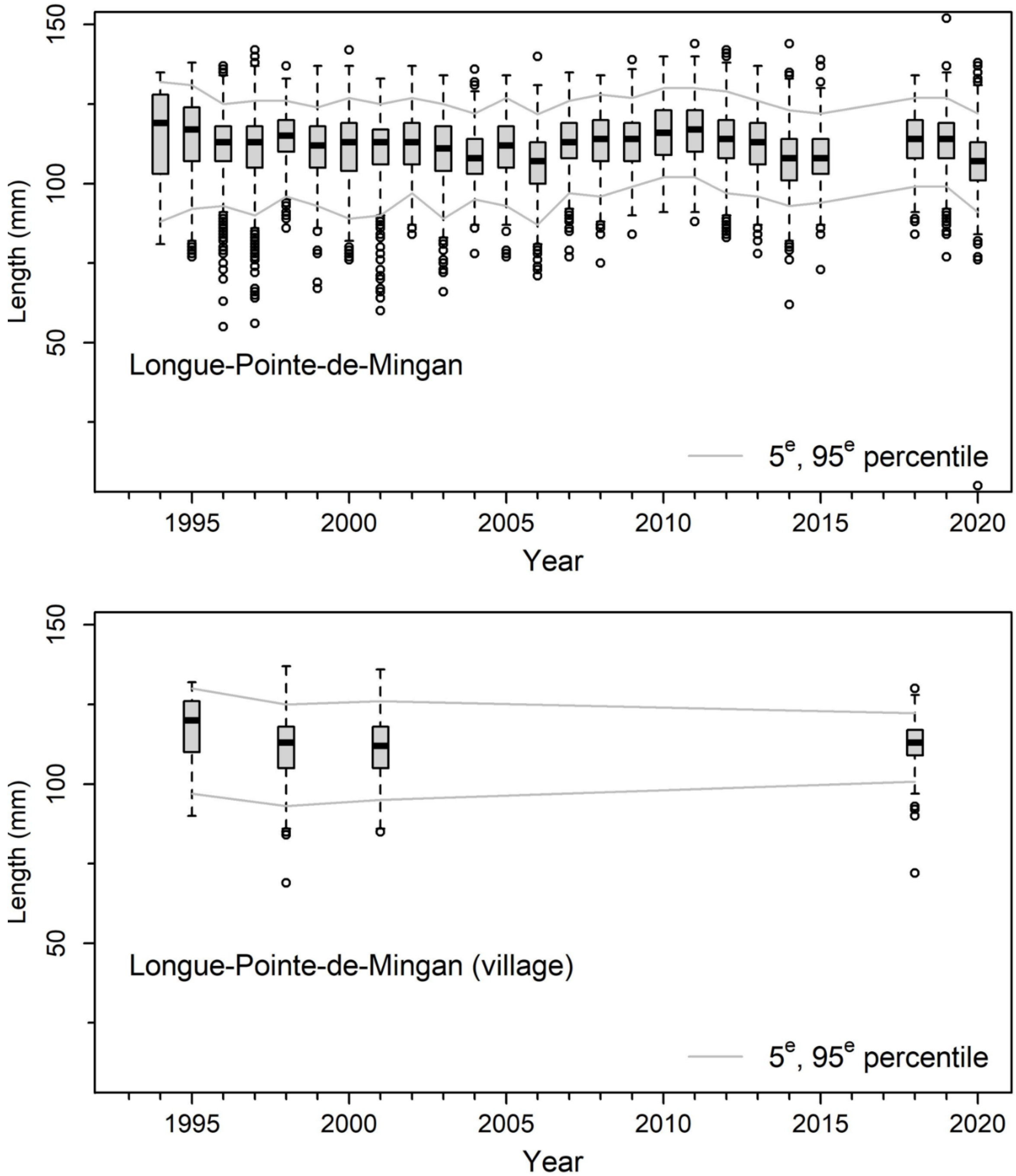


Figure 52. Annual distribution of the size at landing of Arctic surfclams measured by bed in Area 4A.

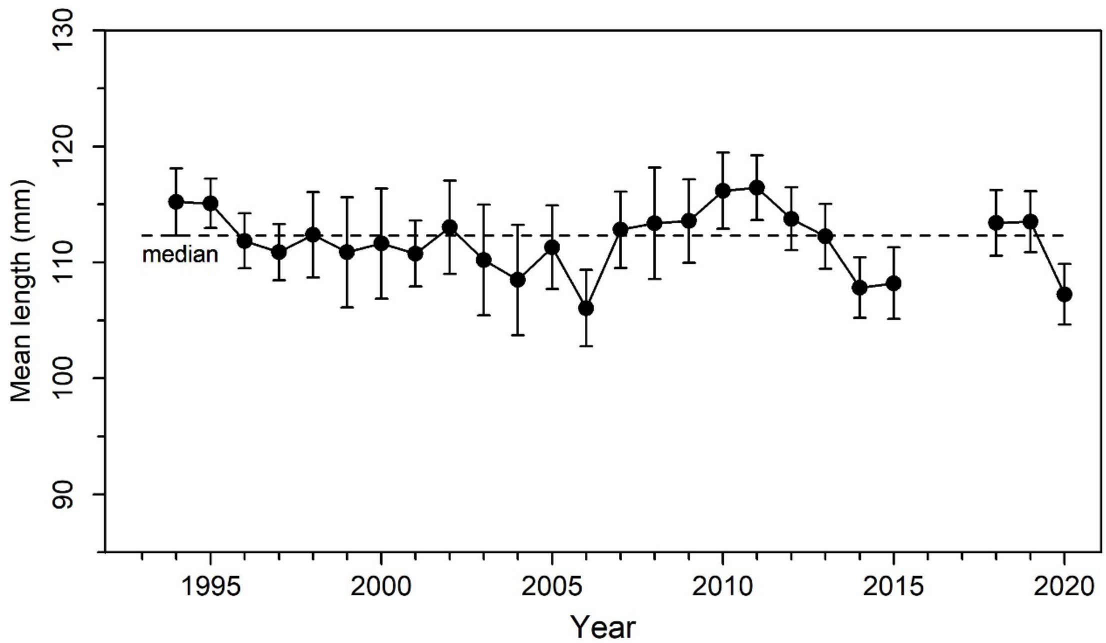


Figure 53. Estimated annual mean size (± 95% confidence interval) at landing of surfclams in Area 4A.

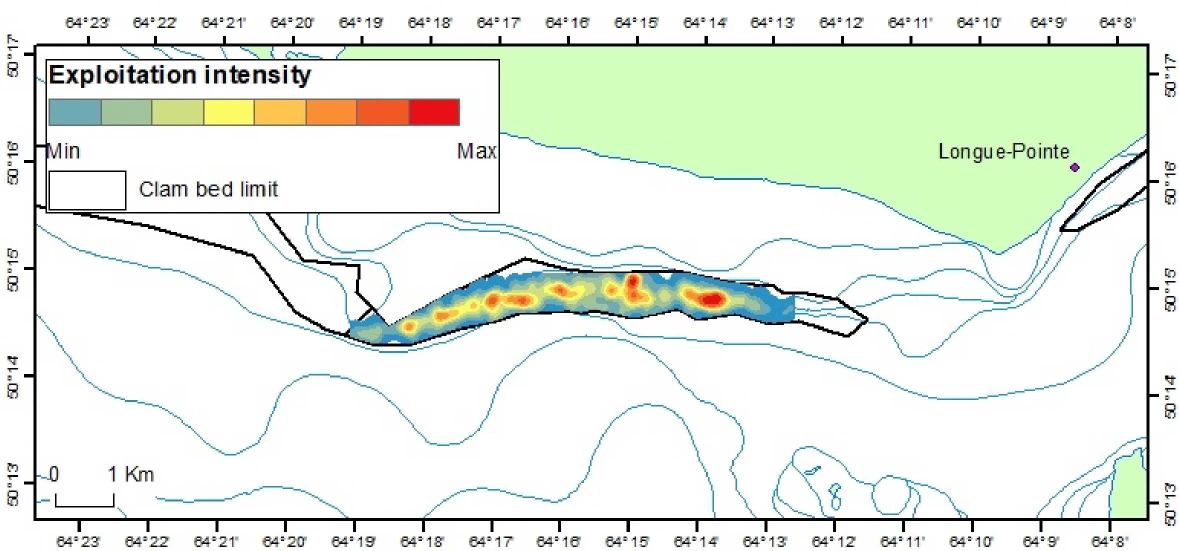


Figure 54. Intensity of exploitation from 1993 to 2020 in the Longue-Pointe-de-Mingan bed in Area 4A.

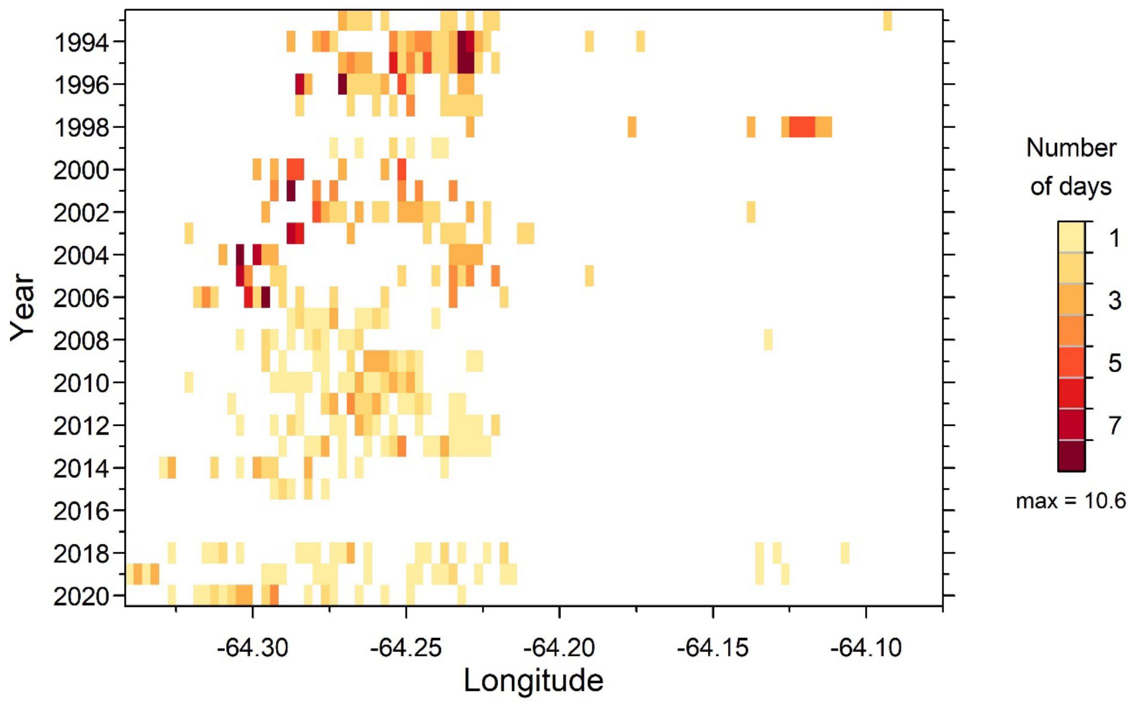


Figure 55. Annual distribution of fishing effort per 10 seconds of longitude in Area 4A.

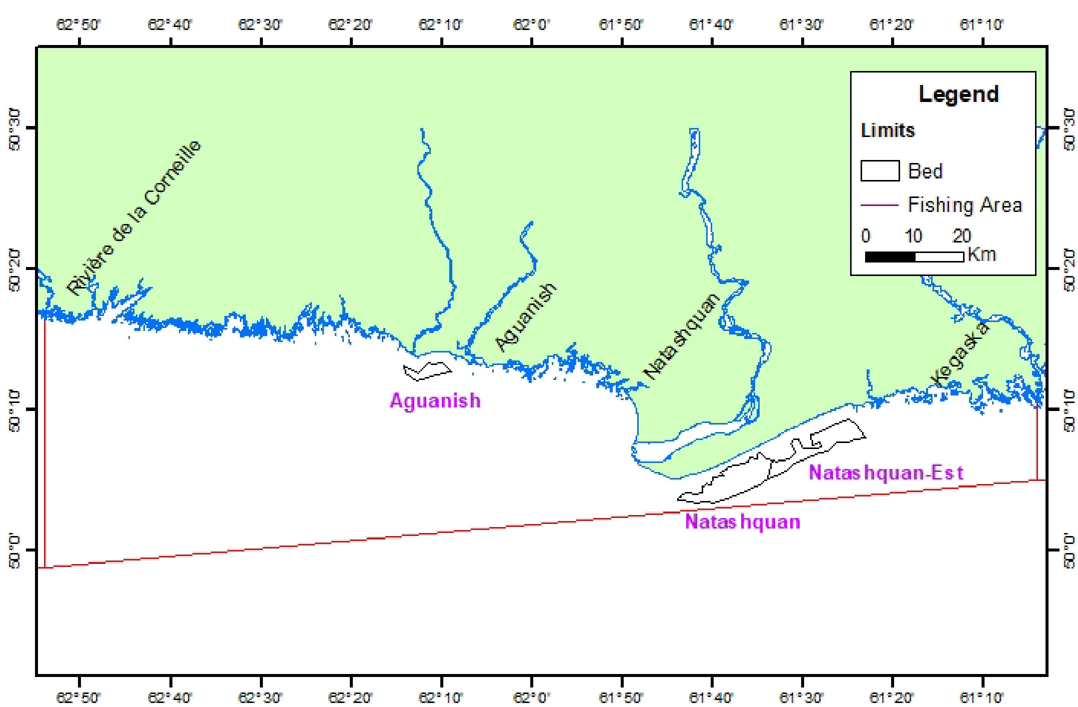


Figure 56. Location of known Arctic surfclam beds in Area 4B.

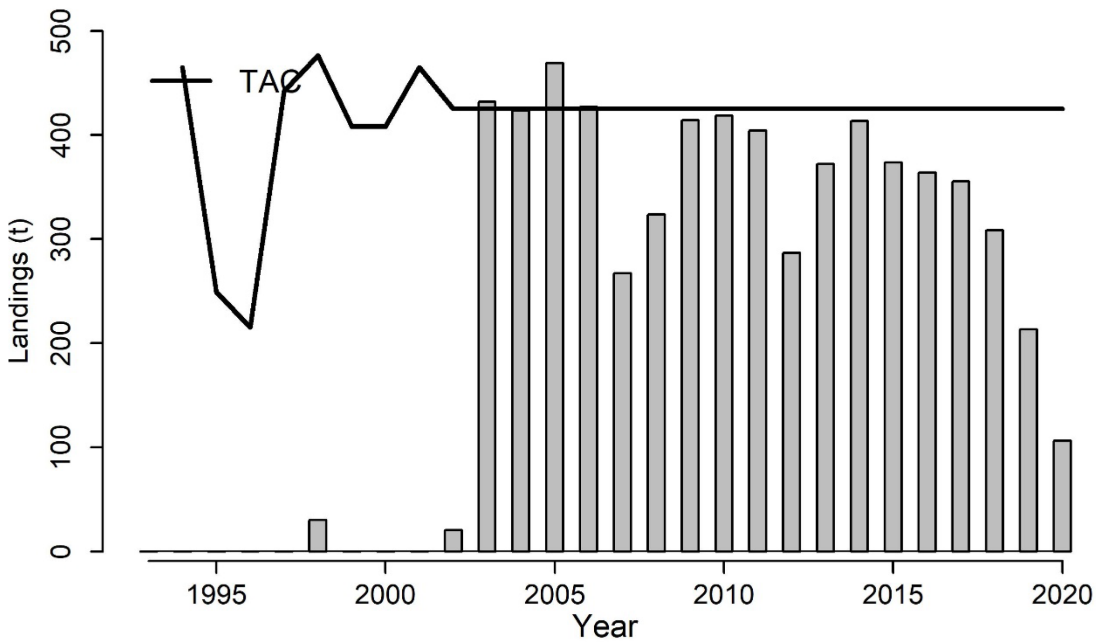


Figure 57. Annual Arctic surfclam landings in Area 4B.

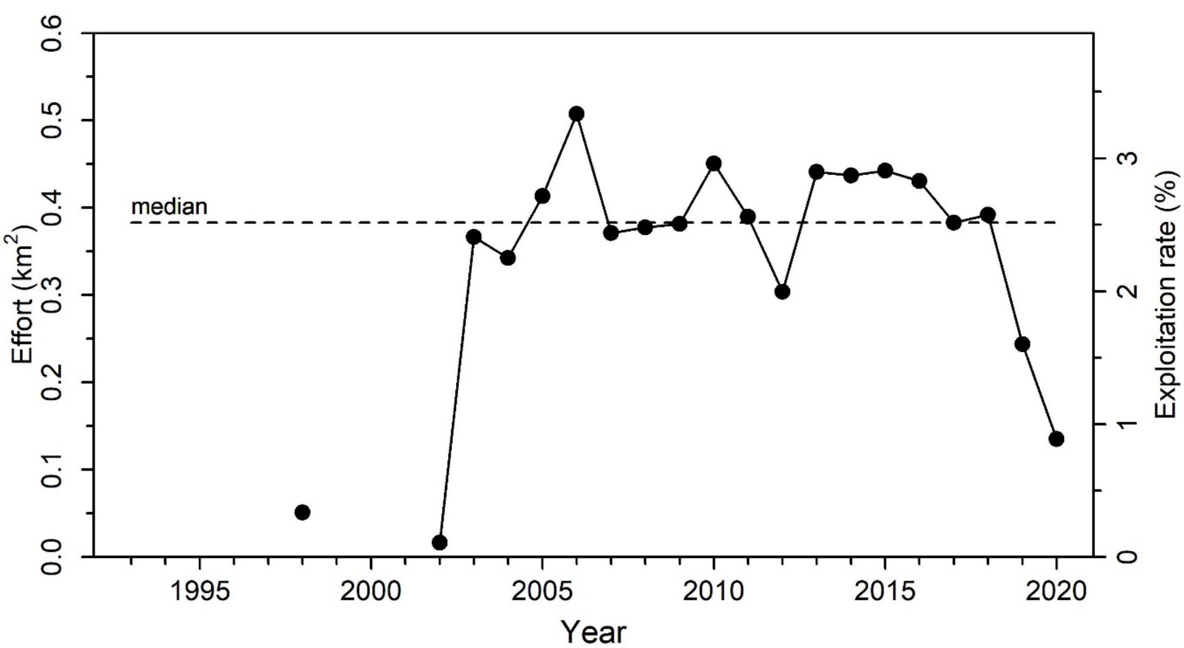


Figure 58. Fishing effort in area dredged (km²) and annual exploitation rates in Area 4B.

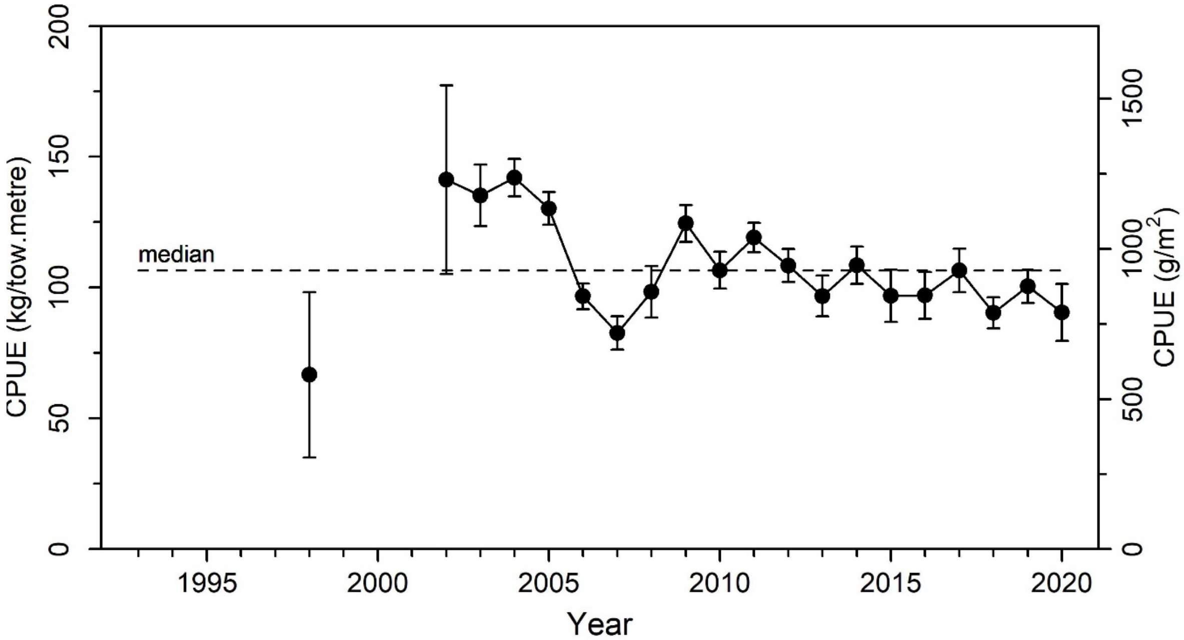


Figure 59. Annual catch per unit effort (± 95% confidence interval) in Area 4B.

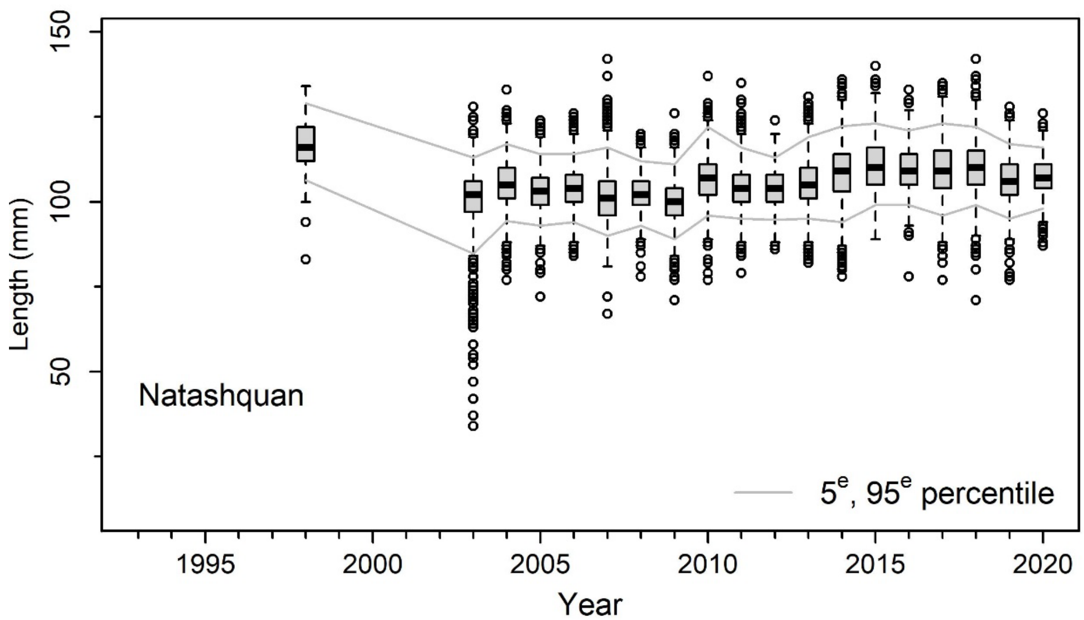


Figure 60. Annual distribution of the size at landing of Arctic surfclams measured by bed in Area 4B.

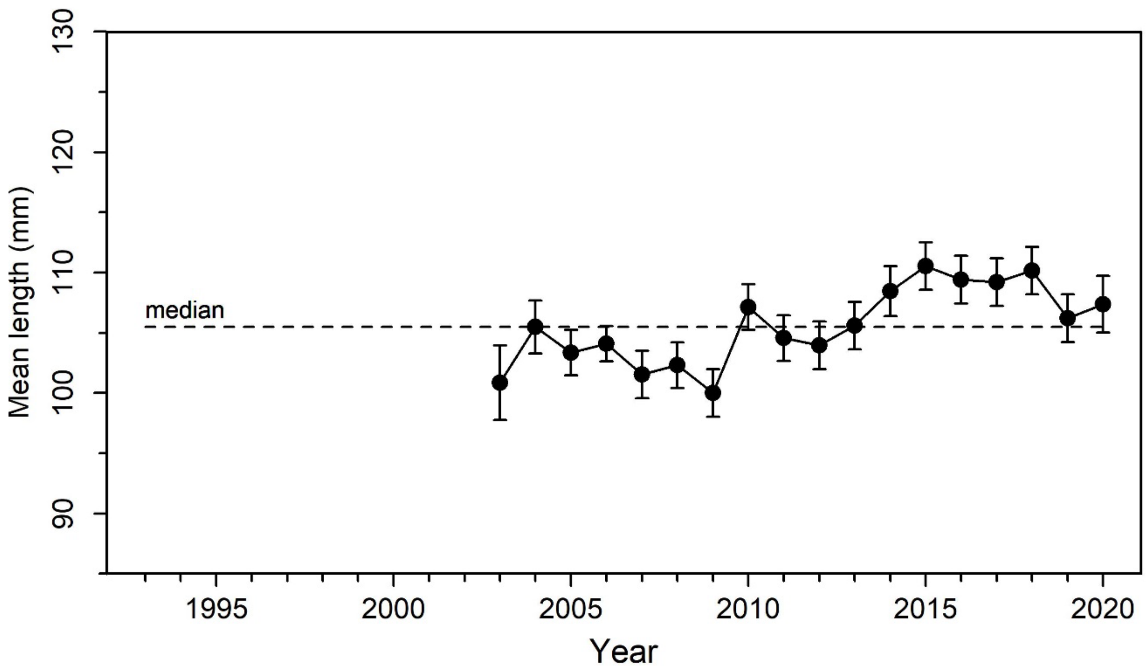


Figure 61. Estimated annual mean size (± 95% confidence interval) at landing of surfclams in Area 4B.

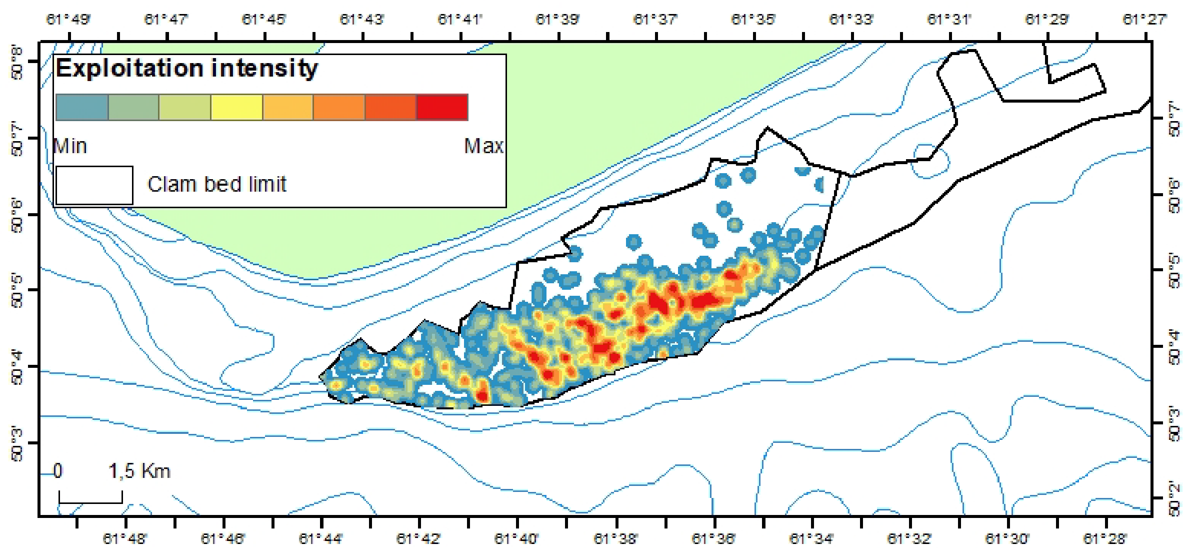


Figure 62. Intensity of exploitation from 1993 to 2020 in the Natashquan bed in Area 4B.

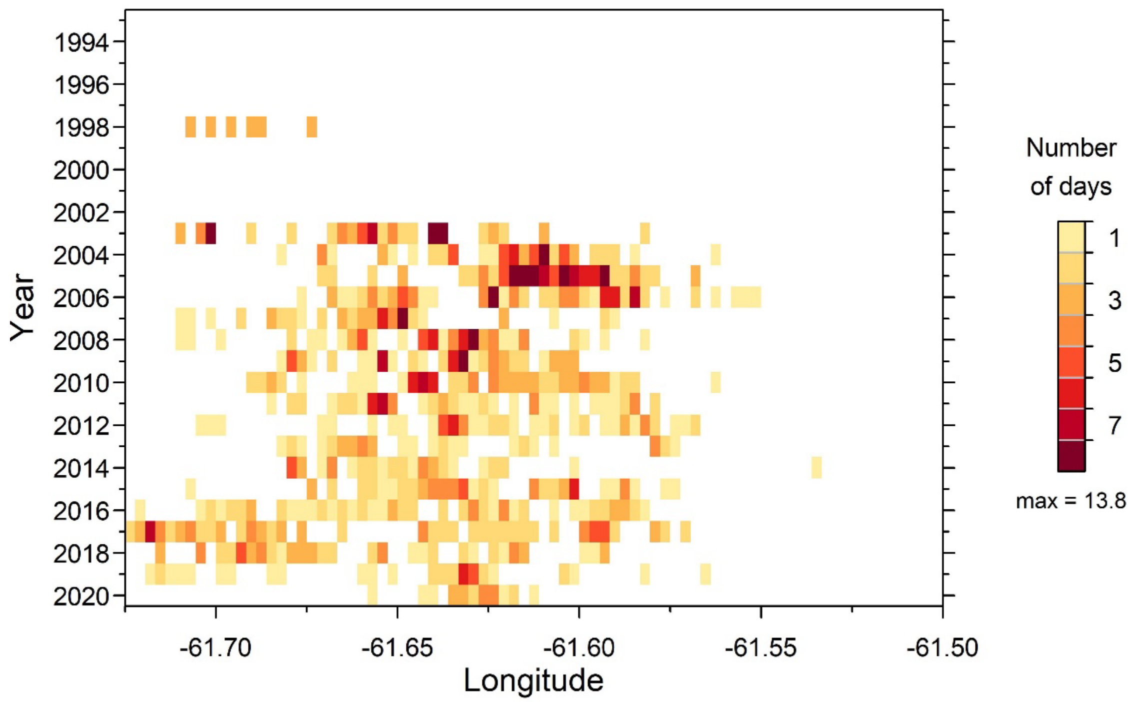


Figure 63. Annual distribution of fishing effort per 10 seconds of longitude in Area 4B.

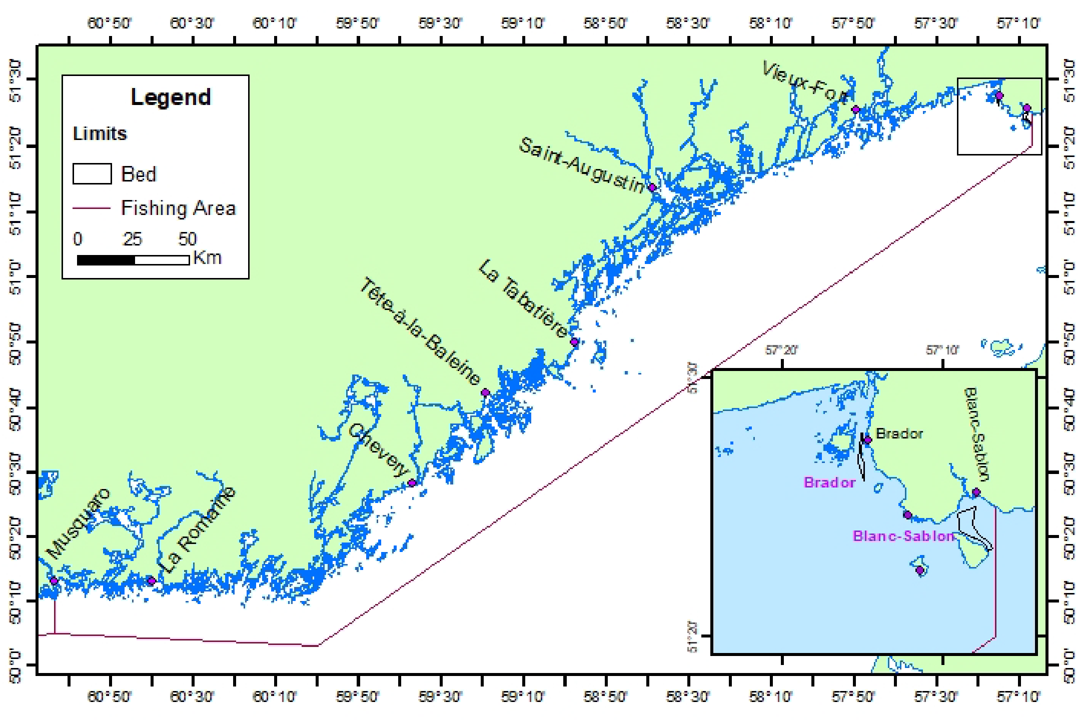


Figure 64. Location of known Arctic surfclam beds in Area 4C.

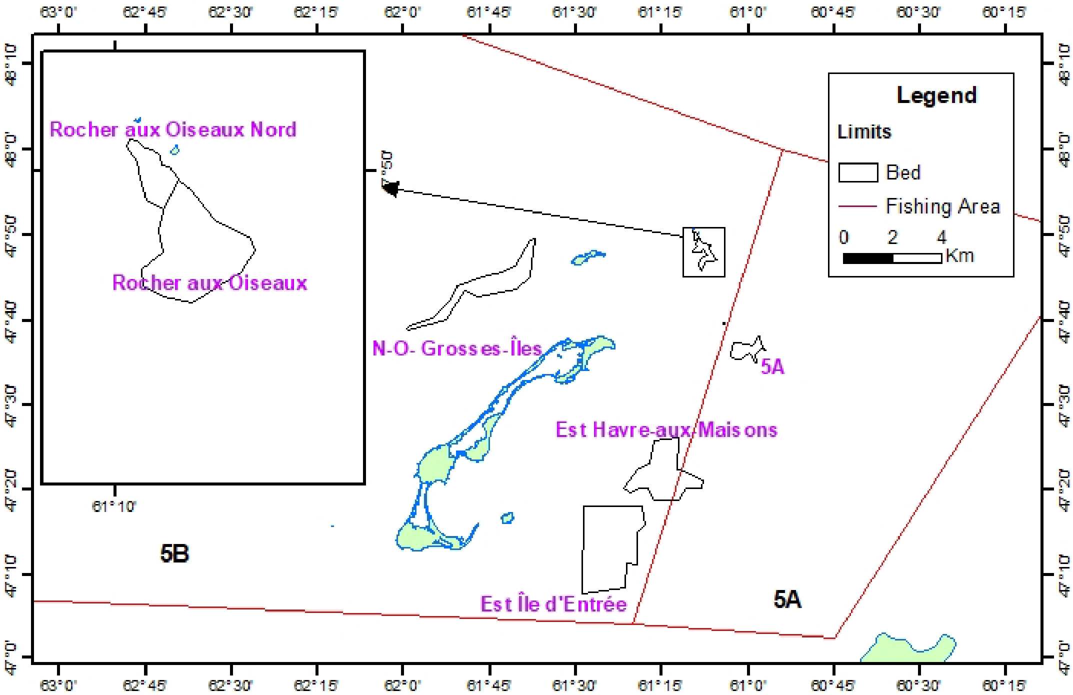


Figure 65. Location of known Arctic surfclam beds in areas 5A and 5B.

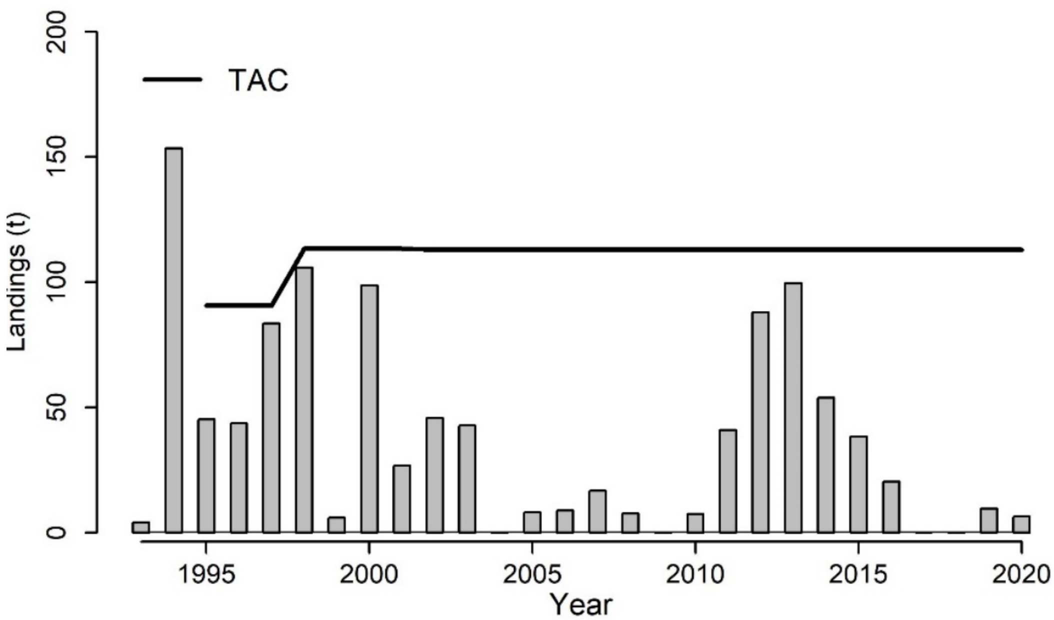


Figure 66. Annual Arctic surfclam landings in Area 5B.

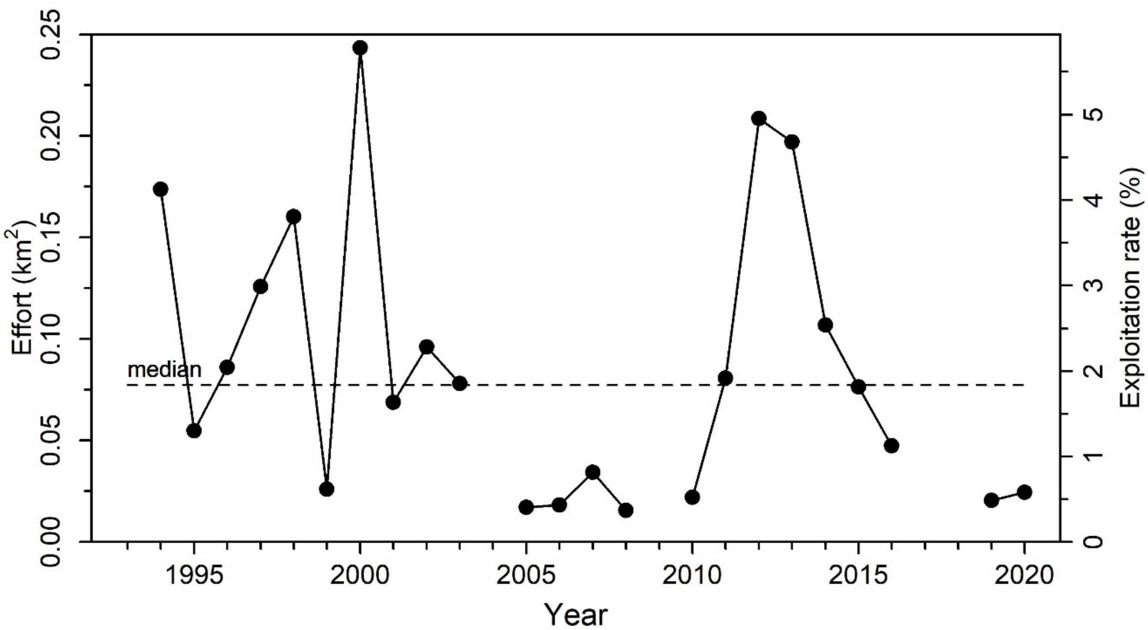


Figure 67. Fishing effort in area dredged (km^2) and annual exploitation rates in Area 5B.

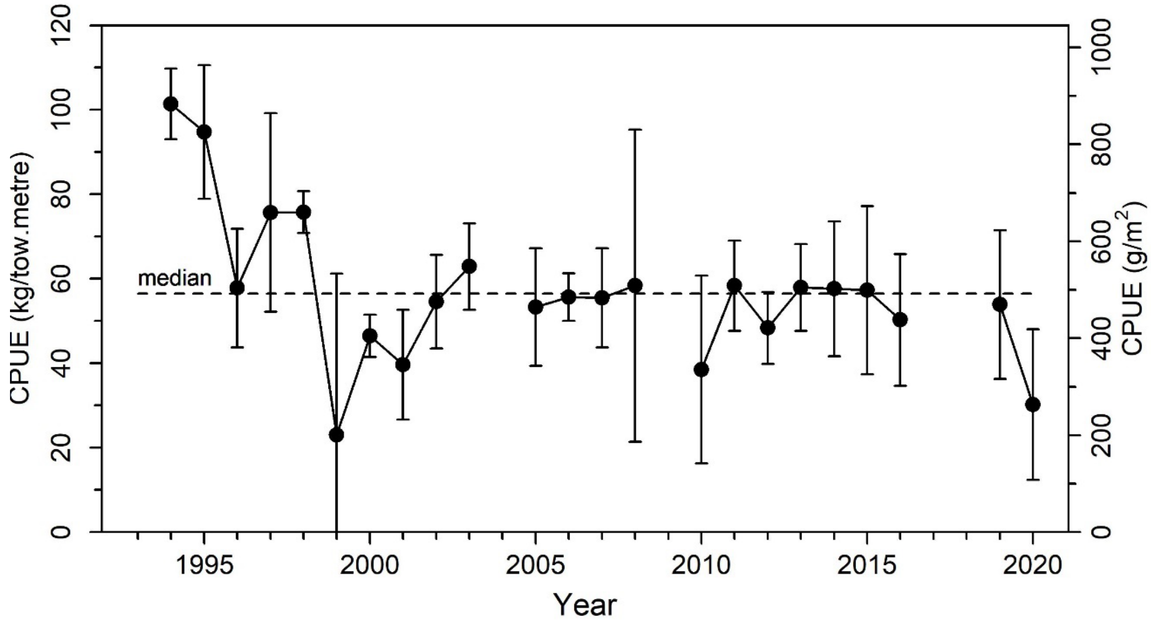


Figure 68. Annual catch per unit effort (± 95% confidence interval) in Area 5B.

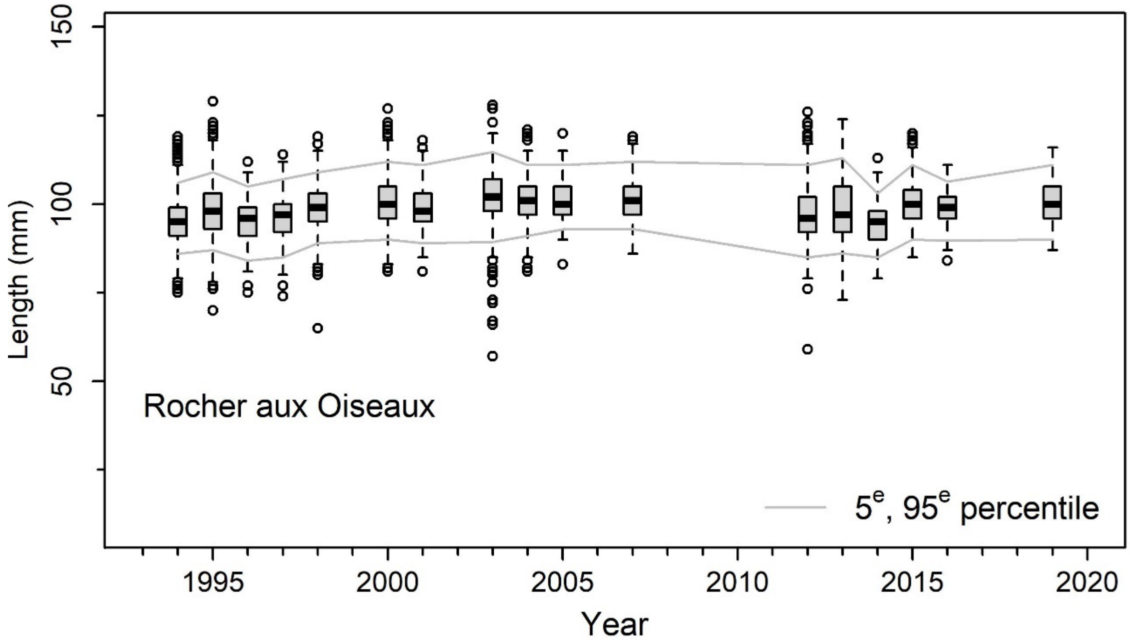


Figure 69. Annual distribution of the size at landing of Arctic surfclams measured by bed in Area 5B.

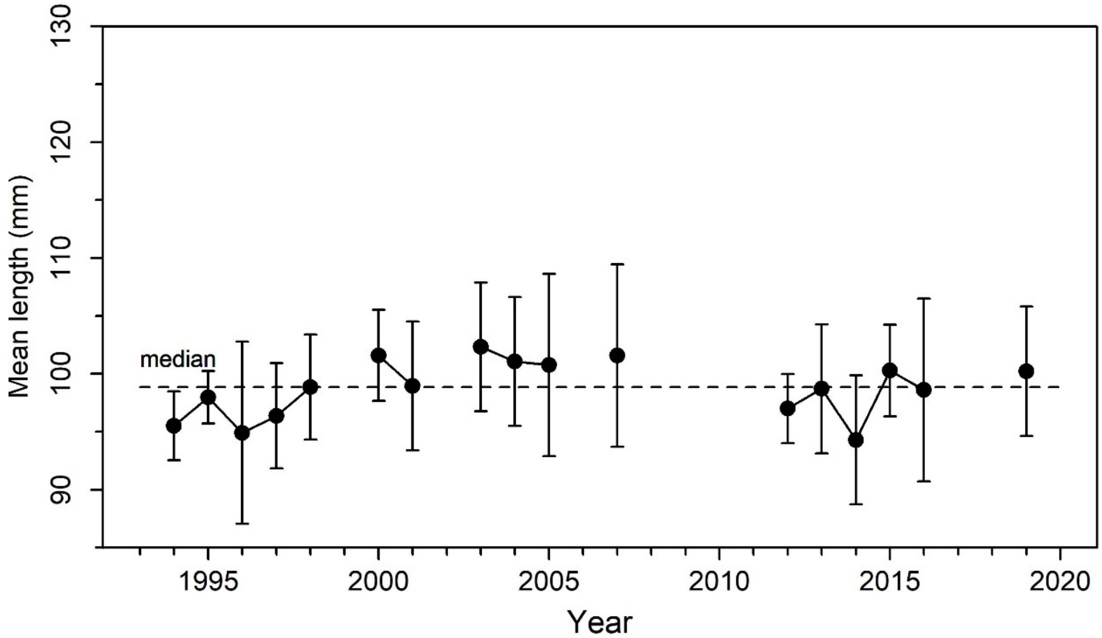


Figure 70. Estimated annual mean size (± 95% confidence interval) at landing of surfclams in Area 5B.

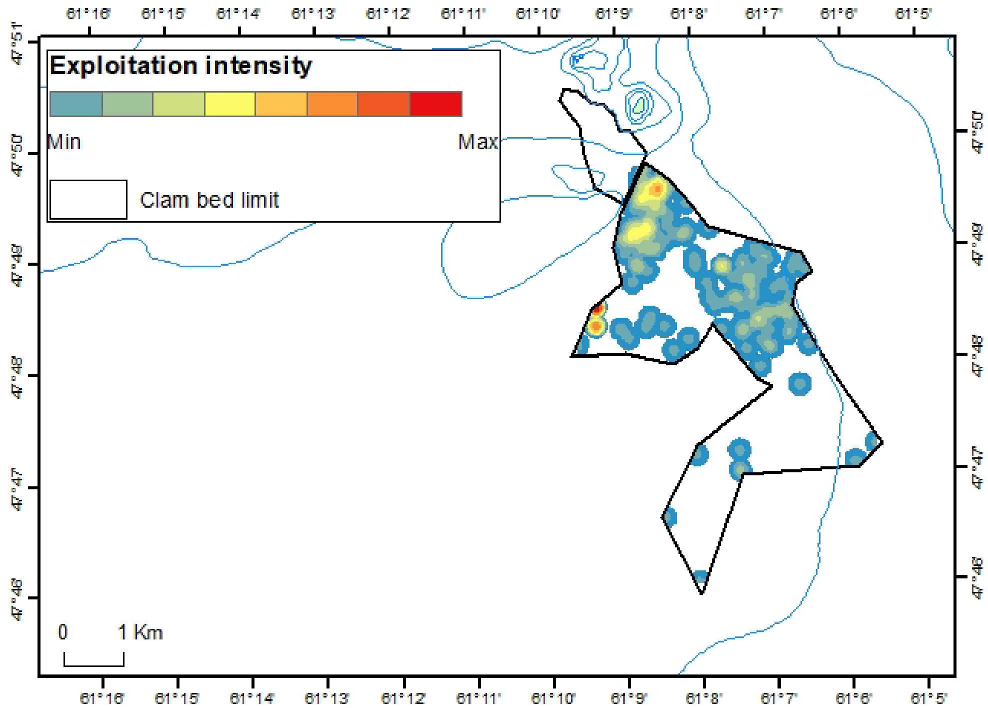


Figure 71. Intensity of exploitation from 1993 to 2020 in the Rocher aux Oiseaux bed in Area 5B.

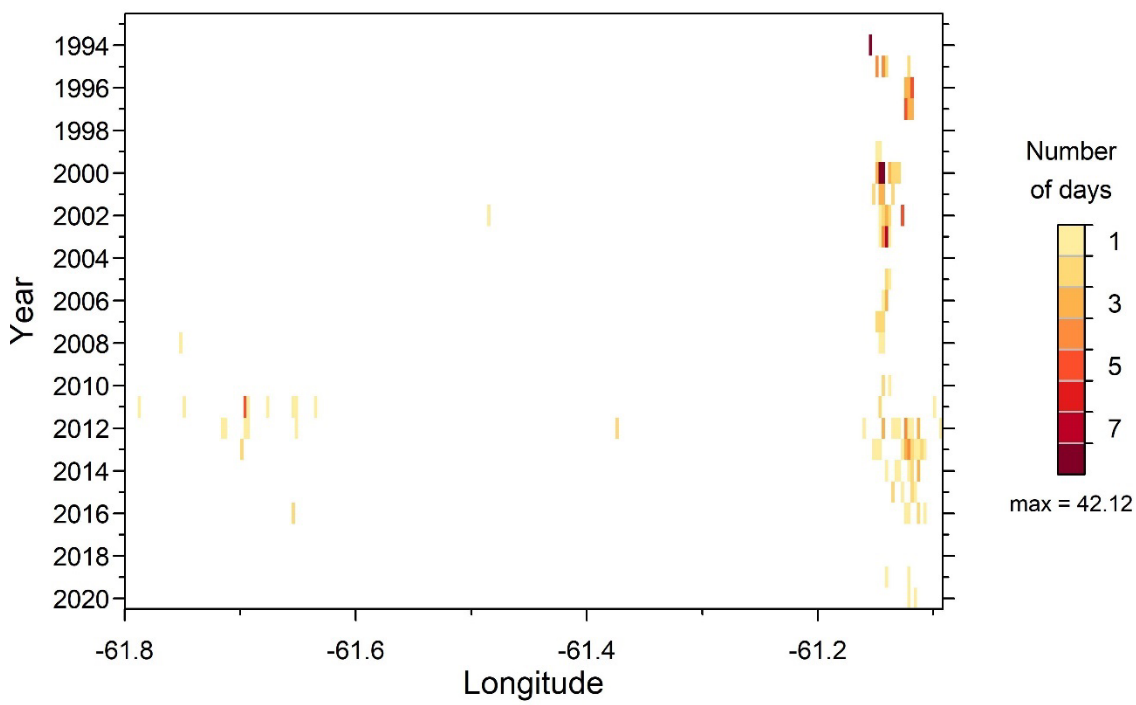


Figure 72. Annual distribution of fishing effort per 10 seconds of longitude in Area 5B.

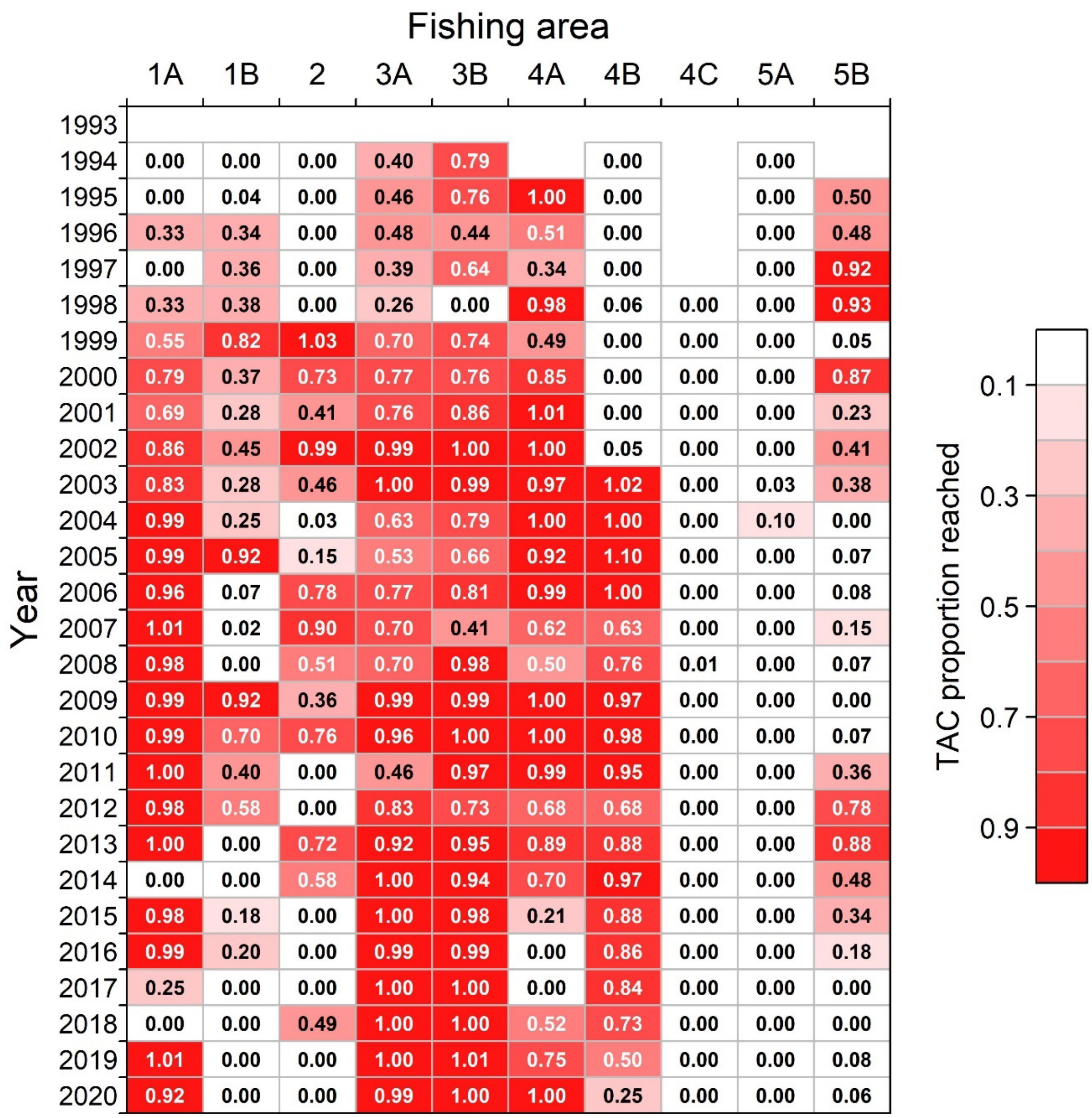


Figure 73. Landings and total allowable catch (TAC) by fishing area.

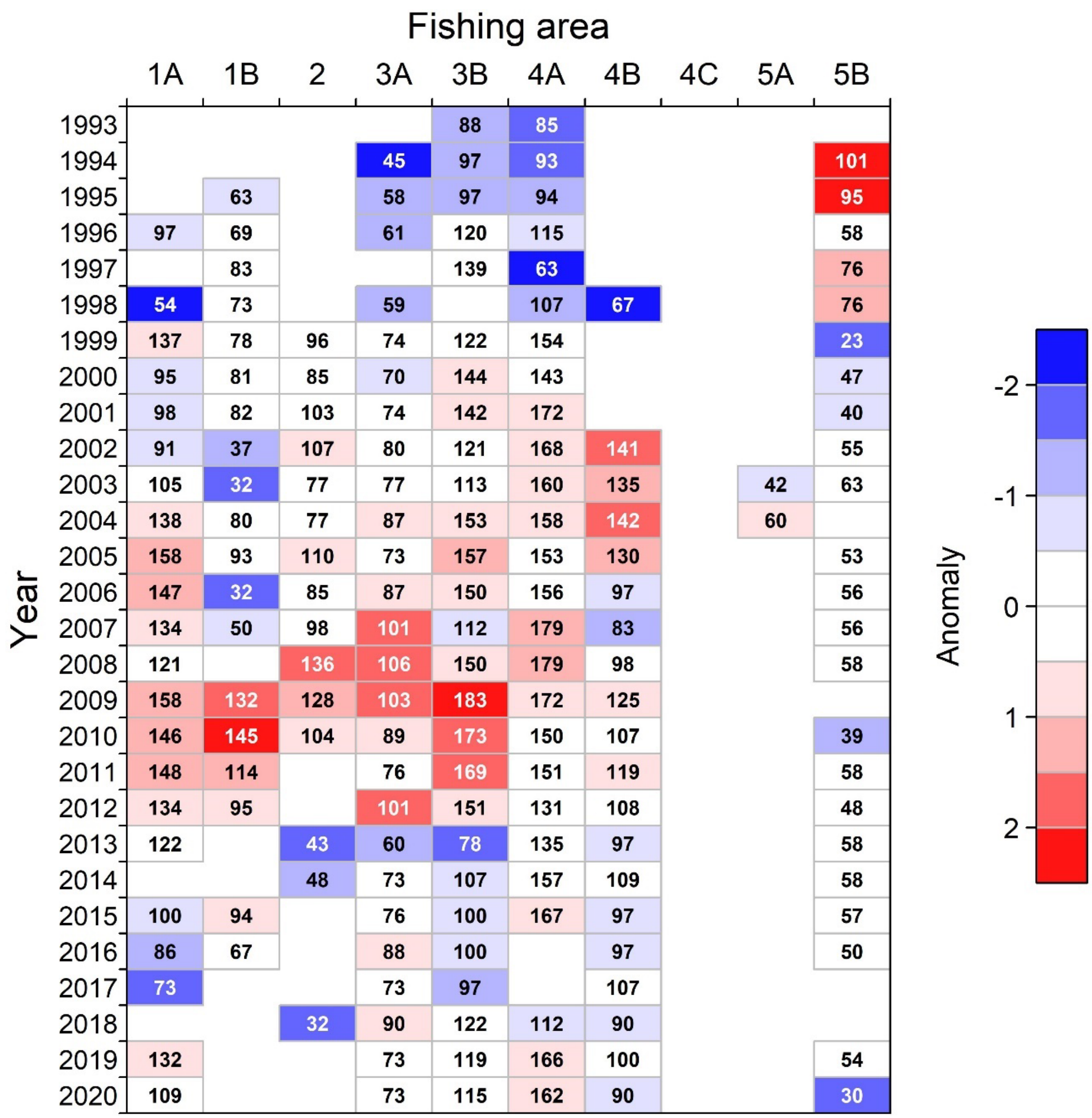


Figure 74. Catches per unit effort (kg per tow for a 1-m-wide dredge) estimated using logbook data of the commercial fishery, by fishing area and by year. The colour code represents the value of the anomaly that corresponds to the difference between the CPUE in a given year and the mean CPUE in the time series for each fishing area divided by the standard deviation of this mean.