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Stock assessment of Atlantic Surfclam, *Spisula solidissima*, of the Îles-de-la-Madeleine in 2018 – Methodology and Results

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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 studies.

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ABSTRACT

The Québec Atlantic Surfclam fishery is confined to the Îles-de-la-Madeleine. The commercial fishery is carried out both by hydraulic clam dredges from vessels in coastal waters and by hand harvest in lagoons or near the shore by shore harvesters and divers. Hand harvesting is well established in the Îles-de-la-Madeleine in both the recreational and commercial fisheries. However, the extent of recreational harvesting is not well known.

Three beds were delineated in sub-areas 5A1 and 5B1 based on the location of the commercial dredge fishery. The CGE and East beds are in 5A1, and the North bed straddles sub-areas 5A1 and 5B1. Since 2010, all fishing has been done on the North bed, whose known area is continually growing. Since 2012, the total allowable catch has been reached in 5A1 and 5B1. Fishing effort in 2018 was 21 and 23 days, respectively. Since 2012, the catch per unit effort (CPUE) calculated for the entire North bed has been above the 2004-2017 reference mean (223.0 kg per hour metre (kg/h·m)). Between 2009 and 2018, the exploitation rate index for the North bed ranged annually from 4.5% to 7.5%, with the average of the least three years being 6.4%. The size structures of clams landed in the last five years were fairly similar and the average size ranged from 132 to 137 mm.

Landings from the commercial hand harvest fishery vary with fishing effort. The averages for the last three years were 160 days and 42.3 t for divers and 113 days and 8.8 t for shore harvesters.

In one of the main areas harvested, A-12.1, the dive harvesting CPUE has been stable since 2016 and is at the 2005-2017 mean. The CPUE in A-09.5 has been fluctuating around its mean since 2014. Since 2008, the average size of landed clams has generally been around 131 mm in the sampled areas.

The shore harvesting CPUE varies from area to area. In A-09.5, it is rather stable and, in 2017 and 2018, it was near the 2005-2017 mean. The average size of landed clams is small compared with that of clams harvested by other methods. The average size in the last three years ranged from 111 to 120 mm, depending on the area.

INTRODUCTION

The Atlantic Surfclam (*Spisula solidissima*), also known as the surfclam or bar clam, is an endobenthic bivalve. In Québec, the Atlantic Surfclam fishery is confined to the Îles-de-la-Madeleine. Commercial dredging is carried out from vessels in coastal waters using a New England hydraulic dredge (Lambert and Goudreau 1996) and is restricted mainly to the eastern part of the Îles-de-la-Madeleine. Divers and shore harvesters use hand tools to gather surfclams in lagoons or near the shore. Hand tools are used in both the commercial and recreational fisheries.

Exploratory fisheries using hydraulic dredges were conducted in the Îles-de-la-Madeleine from 1948 to 1949, and in 1978, 1984 and 1985 (Medcof and MacPhail 1955, Bernier and Poirier 1979, Bio-Conseil Inc. 1986, Fréchette and Giguère 1986, Giguère et al. 2005) all at depths of less than 15 m. They located only two small surfclam beds: one at the entrance to Chenal du Havre aux Maisons (roughly in line with shellfish area A-16.1.2) and the other along Dune du Sud, shellfish area A-12.1 (Giguère et al. 2005). Two hydraulic dredge exploratory licences were issued in 1986; total landings were 46.5 t in 1986 and less than 1 t in 1987 (Gendron 1988). In 1986, yields declined sharply over the course of the fishing season, from 189 kg/h·m in July to 55 kg/h·m in December, and it was therefore concluded that these two beds could not support long-term commercial harvesting. Some harvesters nevertheless continued to explore the area, and a more intensive fishery began in the late 1990s, mainly at the entrance to Chenal de la Grande Entrée (northeastern end of shellfish area A-12.1). In the fall of 2001, an advisory committee was set up and, in March 2002, the first management plan was implemented to provide direction for the commercial dredge fishery. At that time, hand harvest by divers and shore harvesters was unregulated. It was not until the *Atlantic Fishery Regulations, 1985*, were amended in 2003 that a more effective framework for managing the recreational harvest of several mollusc species, including the Atlantic Surfclam, was created, setting out authorized gear, minimum legal size and daily catch limits. An initial management plan was established in the spring of 2005 to regulate commercial and recreational hand harvesting of Atlantic Surfclam in the Îles-de-la-Madeleine.

Fisheries and Oceans Canada (DFO) has conducted a review and assessment of the Atlantic Surfclam stock of the Îles-de-la-Madeleine every three years since 2009. The most recent review was on February 28, 2019. In support of that review (DFO 2019), this document presents the data, techniques, analyses and findings of the resource assessment following the 2018 fishing season. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada Science Advisory Schedule as they become available.

MANAGEMENT MEASURES

Commercial hydraulic dredging

Commercial hydraulic dredging was initially concentrated exclusively east of the Îles-de-la-Madeleine, in an area bounded by the current sub-area 5A1. To encourage exploration of all of Area 5, the area was divided into two sub-areas in 2005, into three sub-areas in 2008, and ultimately into four sub-areas in 2011, namely 5A1, 5A2, 5B1 and 5B2 (Appendices 1 and 2). Despite these incentives, the resource in sub-areas 5A2 and 5B2 remained relatively unfished. The boundaries of sub-areas 5A1 and 5B1 were slightly modified in the northern part of the Îles-de-la-Madeleine in 2013 (Brulotte 2013). The various monitoring indicators presented here have all been recalculated to take into account the new sub-area boundaries.

Most of the current management measures were in place for the dredge fishery in the Îles-de-la-Madeleine by 2002. These include the requirement to complete logbooks, the maximum dredge width of 2.13 m, and the minimum spacing of 3.175 cm between dredge bars. The fishing season varies slightly from year to year from late March to late December, and the fishery is closed during the spawning period, namely July and August, in sub-areas 5A1, 5A2 and 5B1 (Brulotte 2013 and Appendix 1). There are four commercial hydraulic dredge licences and, since 2016, they have included individual transferable quotas (ITQs). Since 2005, there has been a mandatory minimum 5% observer coverage under the At-Sea Observer Program and dredging in lagoons has been prohibited. In 2005, shellfish area A-08.4 was established as a refuge closed to all commercial and recreational fishing (Figure 1). In 2011, exclusion areas were added to protect lobster habitat, mainly north of the Îles-de-la-Madeleine (DFO 2011 and Figure 1). From 2002 to 2013, the minimum legal size was 76 mm; in 2014, it was increased to 90 mm.

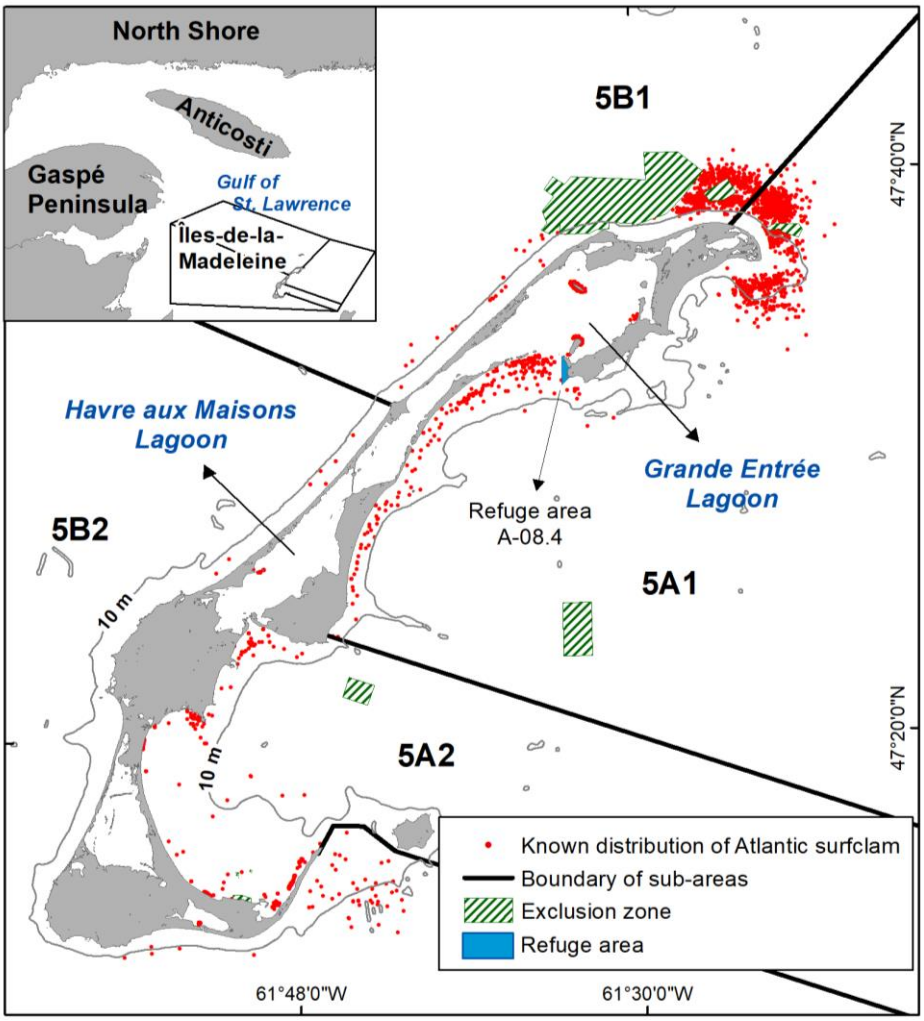


Figure 1. Boundaries of management sub-areas (5A1, 5A2, 5B1 and 5B2) in 2018, location of exclusion areas and refuge area, and known distribution of the Atlantic Surfclam in the Îles-de-la-Madeleine (information sources: logbooks (2002 to 2018), sea sampling (2005 to 2018), research surveys (2007 and 2012) and exploratory fisheries (1978, 1984 and 1985).

A TAC for the hydraulic clam dredge fishery was introduced in 2002 (Brulotte 2013). Since 2013, the TAC has been set at 125 t in 5A1, 55 t in 5A2 and 113 t in 5B1, while fishing effort has

been limited to 12 days in 5B2 (Appendix 1). Lastly, since 2015, dockside weighing has been mandatory for all surfclam landings caught using dredges.

Commercial and recreational hand harvesting

Hand harvesting of Atlantic Surfclam is carried out by shore harvesters and by divers. From 2005 to 2013, the minimum legal size in both the commercial and recreational fishery was 76 mm; in 2014, it was increased to 90 mm. The other management measures have remained unchanged since their implementation in 2005. The fishing season extends from mid-January to late December, and harvesting is authorized between sunrise and sunset. Hand harvesting may be commercial or recreational, but the harvesting or sale of more than 300 clams per day requires a commercial licence. There is currently no restriction on the number of licences that can be issued. Hand harvesters with a commercial licence are required to complete a logbook. There is no catch limit on commercial hand harvesting by shore harvesters, but commercial hand harvesting by divers has been subject to a maximum daily limit of 680 kg since 2016.

The Îles-de-la-Madeleine fishing area is divided into about 50 shellfish areas, nearly half of which are open (approved or conditionally approved) to shellfish harvesting (CSSP 2019). Hand harvesting of Atlantic Surfclam is concentrated mainly in about 10 areas (Figure 2). The Canadian Shellfish Sanitation Program (CSSP) regularly issues guidelines on the status of shellfish areas. Fishers and hand harvesters must ensure that shellfish areas are open before they begin harvesting.

BIOLOGY

The Atlantic Surfclam occurs along the east coast of North America. It ranges from the Gaspé Bay in the Gulf of St. Lawrence to Cape Hatteras in North Carolina (Bousfield 1964, FAO 2019). This endobenthic bivalve prefers soft medium sand and gravel substrates, or mixed sand, mud and gravel substrates (Medcof and MacPhail 1955, Yancey and Welch 1968, Fréchette and Giguère 1986). Surfclam habitat extends from the upper infralittoral zone to a depth of 60 m (Caddy et al. 1974, Jones et al. 1983). In the Îles-de-la-Madeleine, the Atlantic Surfclam is found primarily at depths of between 0 and 30 m (Figure 1). Adults occur at temperatures of 1°C to 25°C; temperatures above 28°C can be lethal (Merrill and Ropes 1969, Snelgrove et al. 1998, Cargnelli et al. 1999). It is a sedentary species that occurs in relatively large aggregations called “beds”. Surfclams are planktivorous feeders (Cargnelli et al. 1999).

On the Atlantic east coast, the main predators of the Atlantic Surfclam are the moon snail (*Euspira heros*), rock crab (*Cancer irroratus*), sand shrimp (*Crangon septemspinosa*), sea stars, various groundfish species, such as *Gadus morhua*, and seabirds (Yancey and Welch 1968, Caddy et al. 1974, Mackenzie et al. 1985, Stehlik 1993, Dietl and Alexander 1997, Cargnelli et al. 1999).

The length-age relationship assessed for all sites sampled in the Îles-de-la-Madeleine in 2012 and 2013 shows rapid growth during the first seven to eight years (Brulotte 2016 and Appendix 3) followed by a sharp decline in growth. Surfclam reaches a size of 76 mm in four or five years and the minimum legal size of 90 mm in five or six years. Based on the individuals harvested in 2012 and 2013, the oldest individuals harvested are 25 years old. These results are similar to those obtained in the Îles-de-la-Madeleine in 1986 by Gendron (1988), but Roberts (1981) reported a higher growth rate in the Northumberland Strait near Prince Edward Island (Appendix 3). According to the literature, it is estimated that the Atlantic Surfclam could have a lifespan of a little over 30 years and could reach a maximum size of 226 mm (Ropes and Ward 1977, Jones et al. 1978, Ropes 1980, Fay et al. 1983, Sephton and Bryan 1990,

Weinberg 1999, NOAA 2019). In several regions, the Atlantic Surfclam can typically live 15 to 25 years. The maximum size observed to date in the Îles-de-la-Madeleine is 184 mm.

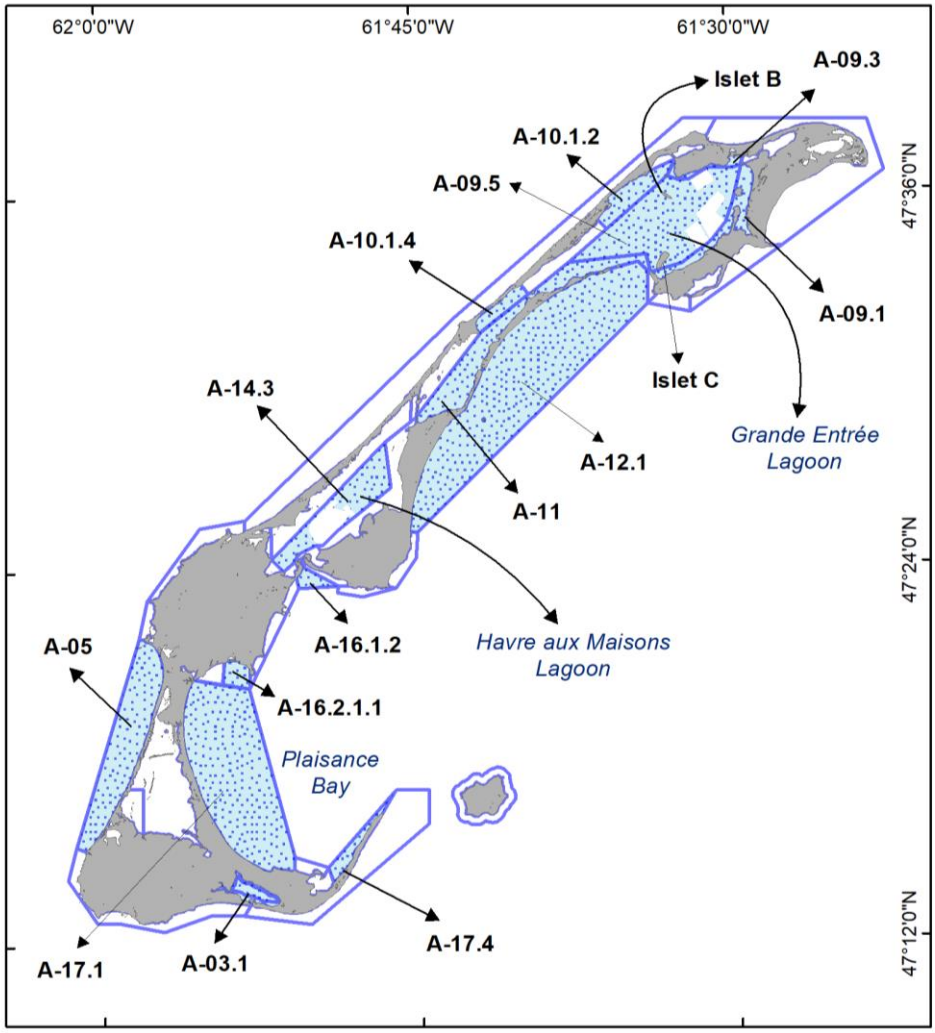


Figure 2. Location of main shellfish areas where Atlantic Surfclam is hand harvested in the Îles-de-la-Madeleine.

Width, thickness and live weight values for various shell lengths are shown in Table 1. They were obtained from the morphometric relationships calculated from 2012 to 2013 for the Atlantic Surfclam in the Îles-de-la-Madeleine (Brulotte 2016 and Appendices 3 and 4). For example, a 130 mm clam is about 12 to 13 years old and weighs 375 g.

In the Atlantic Surfclam, the sexes are separate and there is no sexual dimorphism. Sephton and Bryan (1990) have shown that clams reach sexual maturity at four years. In the Îles-de-la-Madeleine, a four-year-old clam measures between 55 and 85 mm (Appendix 3 and Brulotte 2016). According to Giguère et al. (2005), surfclams harvested in the Îles-de-la-Madeleine measuring between 75 and 92 mm were all sexually mature. These authors have also reported that the gonads are fully mature by mid-May and spawning takes place mainly in July and August. The gametes are released into the water, where the ovules are fertilized (Ropes 1978). The larvae are pelagic. The duration of the larval phase depends on water temperature: about 35 days at 14°C or 19 days at 22°C (Loosanoff and Davis 1963, Fay et al. 1983). After

metamorphosis, which occurs at a length of approximately 300 µm, juveniles settle to the bottom and begin their benthic life stage (Ropes 1980, Fay et al. 1983).

Table 1. Estimated shell width and thickness, wet live weight, age, weight of 300 clams and number of clams required for a 66 kg basket based on the length of Atlantic Surfclam from the Îles-de-la-Madeleine.

Length (mm)	Width (mm)	Thickness (mm)	Live weight (g)	Age (year)	300 clams[1] (kg)	66 kg[2] (number)
76	57	34	77	4-5	23	851
90	67	40	127	5-6	38	519
100	73	44	173	6-7	52	381
110	80	48	229	7-8	69	289
120	87	52	296	9-10	88	224
130	94	56	375	11-13	112	177
135	97	58	419	13-15	125	159

[1] Maximum daily limit allowed for recreational fishers.

[2] Estimated weight of a basket used mainly in diving.

Recommended conservation measures generally aim to ensure the sustainability of each bed by maintaining its reproductive potential.

ENVIRONMENTAL CONDITIONS

The Îles-de-la-Madeleine are at the northern limit of the species' range (FAO 2019). Any change in water temperature at depths of between 0 and 50 m could impact its distribution and abundance. In recent years, average surface water temperatures of the Magdalen Shallows in August and September have been similar to or higher than the 1985-2010 reference mean (Galbraith et al. 2019). In August and September 2018, the surface and bottom water temperatures (about 0 to 30 m) around the islands were 1°C to 2.5°C warmer than the reference mean. The Atlantic Surfclam is a warm-water species. This observed warming could result in the extending its range into somewhat deeper water (25 to 35 m) and increase its productivity in the Îles-de-la-Madeleine. However, it could also reduce its presence in lagoons, where temperatures could become too high at certain times of the year (Weinberg 2005). It is clear that climate change will certainly have an impact on the distribution of the Atlantic Surfclam in the short term (Munroe et al. 2016, Hofmann et al. 2018, Timbs 2018).

MATERIAL AND METHODS

In Québec, commercial dredging is limited to Area 5 of the Îles-de-la-Madeleine which, since 2011, has been subdivided into four sub-areas: 5A1, 5A2, 5B1 and 5B2 (Figure 1). Hand harvesting of Atlantic Surfclam has a long history in the Îles-de-la-Madeleine in lagoons or near the shore. Hand harvesting is very popular in summer and is carried out in about 10 shellfish areas (Figure 2).

COMMERCIAL HARVESTING

Data for the commercial fishery are taken from three different sources: purchase slips, logbooks and commercial catch sampling. Purchase slips are completed by the buyer and provide official surfclam landing figures when sold at a facility. For dredging, the fisher must complete the logbook daily, providing the following information: the Fisher Identification Number (FIN), Vessel Registration Number (VRN), landing date, catch date, fishing position (start and end of the day), fishing sub-area, number of dredging hours and landed weight.

For commercial hand harvesting, fishers must complete the logbook after each fishing day, indicating their name, FIN, harvesting date, shellfish area visited, total quantity fished, duration of harvesting (in hours), the type of fishing (shore harvesters or divers) and the number of hand harvesters present.

Data for the current year are generally considered preliminary because, at the time of analysis, there may be a proportion of logbooks that have not yet been entered. Data are validated annually to eliminate or correct outliers (effort, location, etc.).

Since 2005, the DFO commercial catch sampling program has measured the size structure of landed clams. Sampling is done dockside or at a facility. Under the At-Sea Observer Program, sampling covers 5% of dredging trips. The sampling provides data on the size structure of the population caught (at sea) by the gear and on the fishing position of each tow.

Three main fishing areas or beds—CGE, East and North (Figure 3)—were delineated based on the daily commercial dredging positions from logbooks (2002 to 2018), the tow positions provided by at-sea sampling (2005 to 2018) and comments from fishers. The CGE and East beds are in 5A1, and the North bed straddles sub-areas 5A1 and 5B1. The area of known beds available to the fishery was estimated using the Kernel Density tool (ArcGIS 10.0, available with the Spatial Analyst license), as described in Trottier and Goudreau (2015). The calculated area (± 0.5 km^2) corresponds to the minimum area in which 95% of the fishing positions are distributed. Exclusion areas (under lobster habitat protection) were subtracted from the final areas.

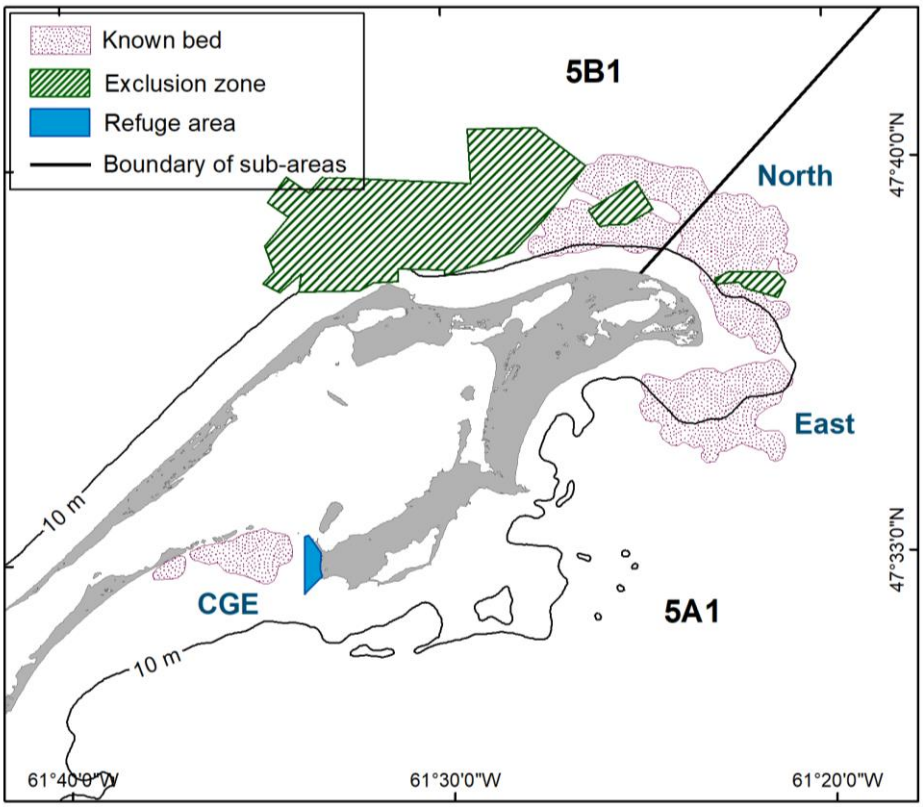


Figure 3. Location of the three known Atlantic Surfclam beds, exploited by the commercial dredge fishery in the Îles-de-la-Madeleine.

The commercial fishing indicators used to assess Atlantic Surfclam stock are annual landing, fishing effort, catch per unit effort (CPUE) and size structure at landing. For the commercial dredging fishery, the exploitation rate index and size structure at sea were also used.

Annual landing, expressed in tonnes (t) of live weight, is the total landing from all commercial fishing activities, by fishing type (dredging, hand harvesting by divers, and hand harvesting by shore harvesters) and by year. For dredging, official landings from 2002 to 2014 were estimated on the basis of the number of baskets multiplied by the mean weight of one basket: specifically, 54 kg/basket from 2002 to 2011 and 66 kg/basket from 2012 to 2014. The weight increase used for the conversion was necessary because, over the years, fishers had been filling their baskets a little more. Since 2015, dockside weighing has been mandatory for the surfclam dredge fishery. In the hand harvest, various types of pails or bins are used. The mean weight of clams was measured for each type and is used to estimate landings.

Fishing effort is expressed in days and is the sum of all fishing days of each harvester, regardless of the time spent fishing. Total effort is the sum of all fisher-days by fishing type.

The CPUE is calculated on the basis of the number of hours fished each day as recorded in logbooks and is expressed in kilograms of live weight per fishing hour and per gear metre (kg/h·m) for dredging, and in kilograms of live weight per fishing hour (kg/h) for hand harvest.

CPUEs were standardized (PROC MIXED, SAS version 9.3, values were first transformed to natural log) to take into consideration the effect of certain variables on catch rate (Gavaris 1980). For the dredge fishery, the CPUEs were standardized by bed, considering the following variables: year, fishing month and Fisher Identification Number (Appendices 5, 6 and 7). The calculation took into consideration only fishers who had been active for at least three years. For hand harvesting, CPUEs were standardized by type of hand harvesting—by divers or shore harvesters—for the main shellfish areas considering the year and FIN (Appendices 8 to 12). The selected hand harvesters must have made at least 30 trips. Non-standardized CPUEs were calculated using the same criteria as those used for the selected hand harvesters.

During the 2012 stock assessment, dredge CPUEs were analyzed to determine the effect of changing the conversion factor used to estimate basket weight and to ensure that CPUEs were comparable across the entire time series (Brulotte 2013). Ultimately, those adjustments had little effect on overall interannual trends of the standardized CPUEs.

Each year, the dredge fishery typically targets new portions of beds. To identify variations in the CPUE, monitoring was conducted at two small sites (quadrilateral) that had been fished for several years. Both sites are on the North bed, specifically in 5A1 and 5B1 (Appendix 13). Observations were selected from the daily positions (start and end) recorded by fishers in logbooks. Daily CPUEs per fisher were plotted by harvest date.

An exploitation rate index is estimated using the proportion of each bed that is dredged annually relative to the total known area of the bed. The area dredged annually was calculated by multiplying the dredging duration recorded in the logbooks by the dredge width and an average dredging speed of 1,519 m/h (0.82 knot). This average speed was calculated using at-sea sampling data from 2006 to 2018 that was verified by fishers., The exploitation rate index was calculated for each bed:

$$\text{Index (\%)} = \frac{\text{area dredged annually}}{\text{total known area}} \times 100$$

The number of samples collected annually under the landed commercial catch sampling program is typically 10 per fishing type. Since 2004, one sample has corresponded to about 150 measured clams. Dredge fishers make approximately two trips a year. Appendix 14

shows the number of clams measured and number of samples or trips by gear type, bed or shellfish area, and by year. The size of Atlantic Surfclam is based on the anteroposterior length of the shell (mm). Size structures are aggregated by fishing type, bed or shellfish area and by year, to obtain an annual size structure at landing or at sea. The figures are aggregated to ensure each sample has the same weighting (thereby eliminating the effect of the variation in the number of clams measured). Size structures are presented in the form of histograms by 3-mm size class.

The mean annual CPUE and size are presented with their 95% confidence interval. The reference mean of landings, fishing effort, CPUEs and mean sizes is calculated by fishing type and by sub-area, bed or shellfish area. The reference period varies depending on the data time series and never includes the last year, in this case, 2018. For sub-area 5A1 and the CGE and East beds, the reference period begins in 2002. For the North bed, fishers are considered to have actually started fishing in 2004; the few trips made before that date are considered to be exploratory in nature. For the same reason, the reference period for sub-area 5B1 begins in 2008. For mean sizes, the reference period starts in 2014, when the legal minimum size was increased. Lastly, the hand harvest reference period begins in 2005, when management measures were implemented.

The relative difference between the value of the 2018 indicator and the reference mean is calculated as follows:

$$\text{Relative difference} = \frac{\text{value of 2018 indicator} - \text{reference mean}}{\text{reference mean}} \times 100$$

The position of the annual value of an indicator may be categorized relative to its reference mean using the 95% confidence intervals. If the reference mean is included in the value's confidence interval, the value is said to be similar to the mean; otherwise, the value is either above or below the mean.

RECREATIONAL HAND HARVESTING

It is difficult to quantify the recreational hand harvest. Currently, the number of hand harvesters in Atlantic Surfclam sites is estimated using three sources of information. A survey of shore harvesting of Atlantic Surfclam has been conducted since 2005 by volunteers and DFO fishery officers to assess the level of activity at the various harvesting sites. The data collected are: date, time, shellfish area, total number of adults and total number of children on a site. In addition to this information, data is entered by commercial fishers in logbooks on the total number of harvesters (commercial and recreational) at the harvesting site for each trip. Lastly, DFO Fisheries Management in the Îles-de-la-Madeleine compiles a hail out file that includes information on several harvesting activities for which there are no logbooks.

After compilation and validation of the data, an estimate of the number of hand harvesting activities is calculated by shellfish area and year. This number is most likely underestimated since it depends on the number of visits or observations made. Each activity corresponds to one harvester in a shellfish area within a given day. The number of commercial activities, obtained from logbooks, is subtracted, providing an estimate of the number of recreational activities per shellfish area per year.

Recreational harvest catches can also be assessed on the basis of unreported fishing activities estimated annually by DFO fishery officers. These supplementary purchase slips, or SPSs, include estimates drawn from different sources: direct sales to the public, personal consumption (fish harvesters and their families, sport fishing), fish processed by fish harvesters, fish used as bait as well as estimates of recreational hand harvesting. Prior to the introduction of mandatory

dockside weighing, that is from 2002 to 2014, SPSs included unreported commercial dredging landings. However, since 2015, SPSs essentially provide an estimate of the recreational hand harvest. The 2017 and 2018 SPS values are preliminary. Landings presented in this document exclude SPSs.

RESULTS

GENERAL INFORMATION

From 2002 to 2004, commercial Atlantic Surfclam landings in the Îles-de-la-Madeleine fluctuated around 110 t and were exclusively from dredging (Figure 4 and Appendix 15). Subsequently, landings gradually increased, reaching nearly 290 t in 2009. This increase was primarily due to the commencement of harvesting in sub-area 5B1 of the North bed. Since then, total commercial landings have ranged from 242.9 to 304.0 t annually, with an average of 287.4 t over the last three years. Landings from the hydraulic dredge fishery account for more than 80%. Since 2008, the four dredge fishers have been active in sub-areas 5A1 and 5B1, and fishing effort has been sporadic and low in sub-areas 5A2 and 5B2.

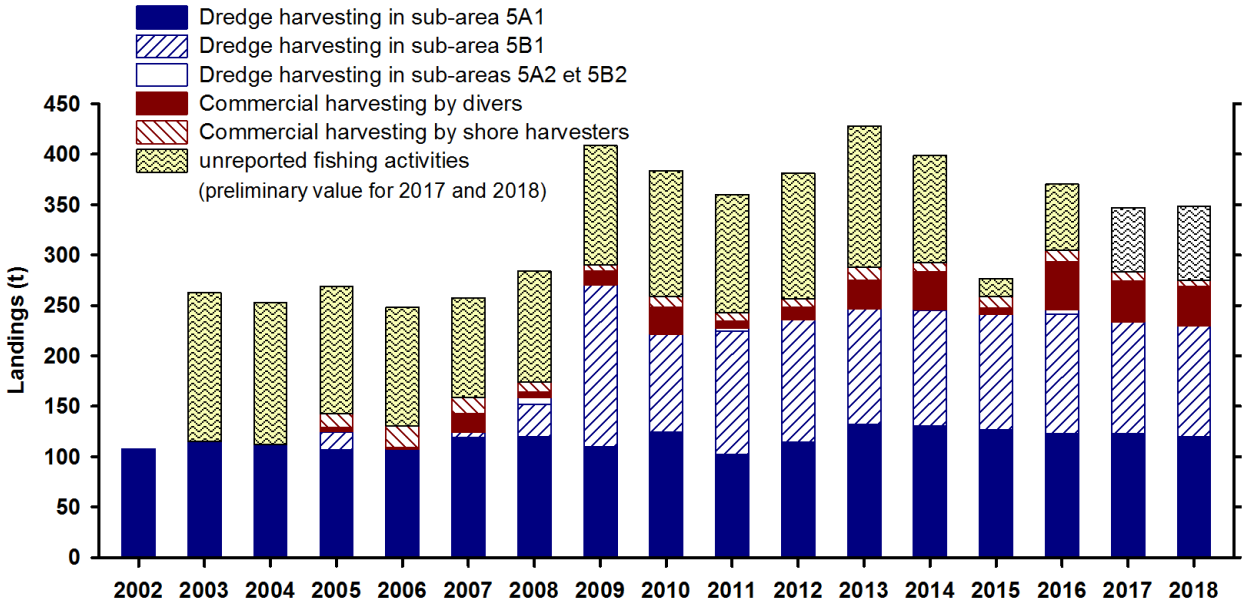


Figure 4. Annual landings by commercial fishing type and sub-area, and catch estimate for unreported Atlantic Surfclam fishing activities in the Îles-de-la-Madeleine.

The introduction of logbooks in 2005 made it possible to monitor this fishery. Landings varied from year to year depending on fishing effort (Figure 4 and Appendix 15). Over the past three years, landings ranged from 45.4 to 58.5 t, with a 2005-2017 reference mean of 30.4 t.

COMMERCIAL HYDRAULIC DREDGING

Landings and fishing effort

Before 2009, the dredge fishery in sub-area 5A1 had targeted the CGE and East beds and the southeastern end of the North bed (Figure 5 and Appendices 15 and 16). In 2010, fishing effort shifted and is now focused exclusively on the North bed. However, there were a few days of fishing in the CGE and East beds from 2010 to 2014.

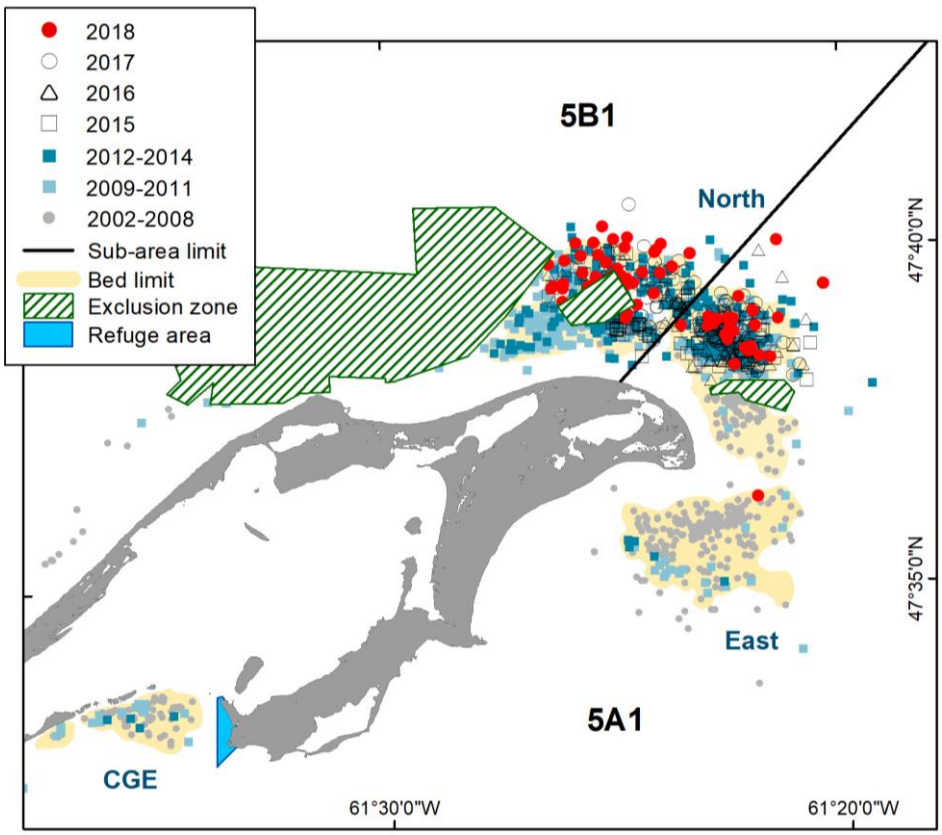


Figure 5. Location of commercial dredging of Atlantic Surfclam from 2002 to 2018 in sub-areas 5A1 and 5B1 in the Îles-de-la-Madeleine.

Over the years, total landings in sub-area 5A1 have ranged from 102.1 to 131.7 t (Figure 6 and Appendix 15). The TAC of 125 t has been reached or slightly exceeded since 2013. Average landings for the last three years were 121.7 t.

Prior to 2008, only occasional fishing was carried out in sub-area 5B1 (Figure 5 and Appendix 16). Harvesting in sub-area 5B1 of the North bed did not really begin until 2009, with landings of 160.3 t (Figure 7 and Appendix 15). Since 2009, landings from 5B1 have ranged from 97.2 to 160.3 t, with an average of 113.0 t over the last three years. Since 2013, the TAC of 113 t has been reached or slightly exceeded.

Fishing effort in 5A1 was higher (50 to 65 days) at the beginning of the fishery (Figure 6 and Appendix 17). Since 2011, fishing effort has remained at between 16 and 26 days. In 2018, fishing effort was 21 days, 46% less than the 2002-2017 reference mean of 39 days.

Prior to 2012, fishing effort in 5B1 varied (Figure 7 and Appendix 17). Subsequently, the annual fishing effort ranged from 18 to 26 days. The average for the last three years was 22 days, 10% lower than the 2008-2017 reference mean of 26 days.

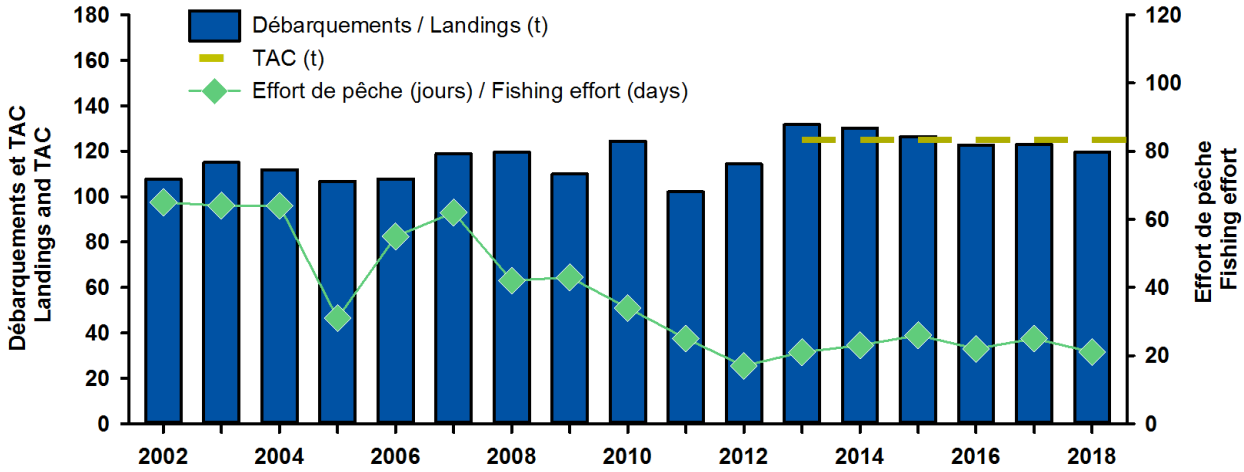


Figure 6. Annual landings, total allowable catch (TAC) and annual fishing effort in the commercial Atlantic Surfclam dredge fishery in sub-area 5A1 in the Îles-de-la-Madeleine.

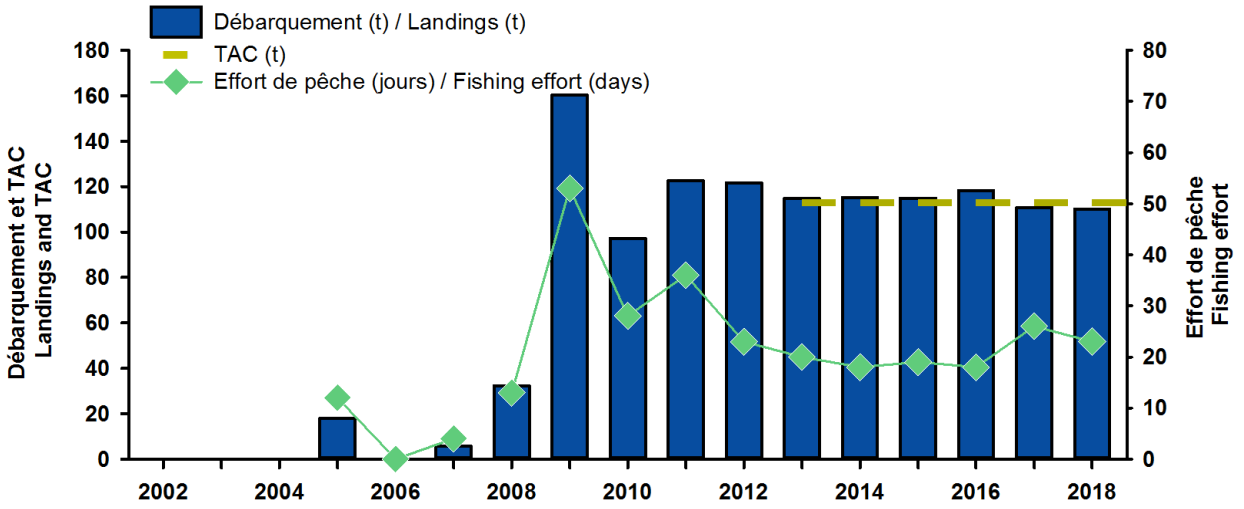


Figure 7. Annual landings, total allowable catch (TAC) and annual fishing effort in the commercial Atlantic Surfclam dredge fishery in sub-area 5B1 in the Îles-de-la-Madeleine.

Catch per unit effort

To provide a better understanding of the status of each of the beds, CPUE, size structure and average landed size indicators are shown for each bed.

The mean standardized CPUEs in the CGE and East beds for the period 2002-2009 were 108.6 and 143.7 kg/h·m, respectively (Appendix 18). Although there were a few days of fishing in these beds in subsequent years, the lack of observations made it impossible to calculate a CPUE.

In recent years, harvesting has been focused primarily in the North bed (Figure 5 and Appendix 16). From 2007 to 2012, CPUEs increased from 108.2 to 304.8 kg/h·m (Figure 8 and Appendix 18). Since 2012, standardized CPUEs have remained above the reference mean of 223.0 kg/h·m. The mean CPUE of the last three years is 264.1 kg/h·m, about twice that observed in the CGE and East beds.

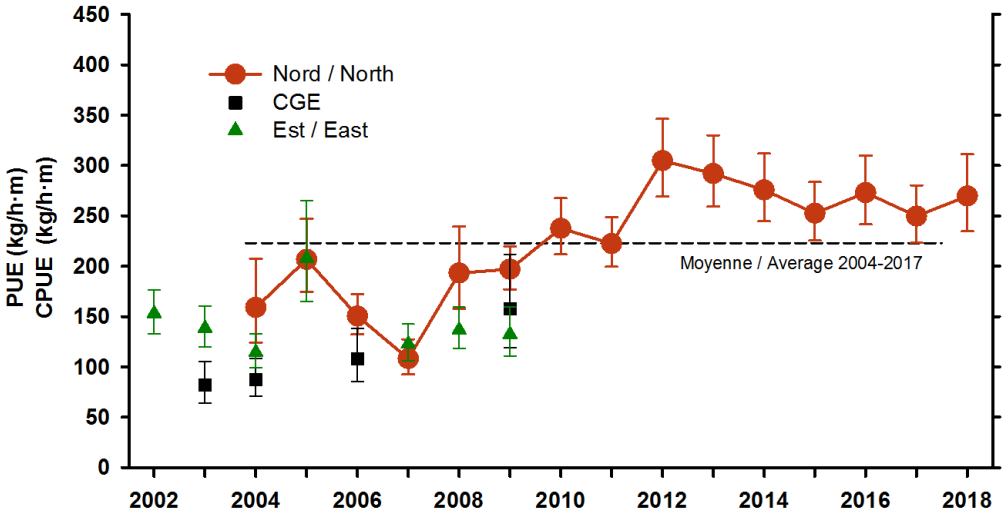


Figure 8. Annual mean catch per unit effort (CPUE ± 95% confidence interval) by bed and reference mean (2004-2017 mean) in the commercial Atlantic Surfclam dredge fishery in the North bed in the Îles-de-la-Madeleine.

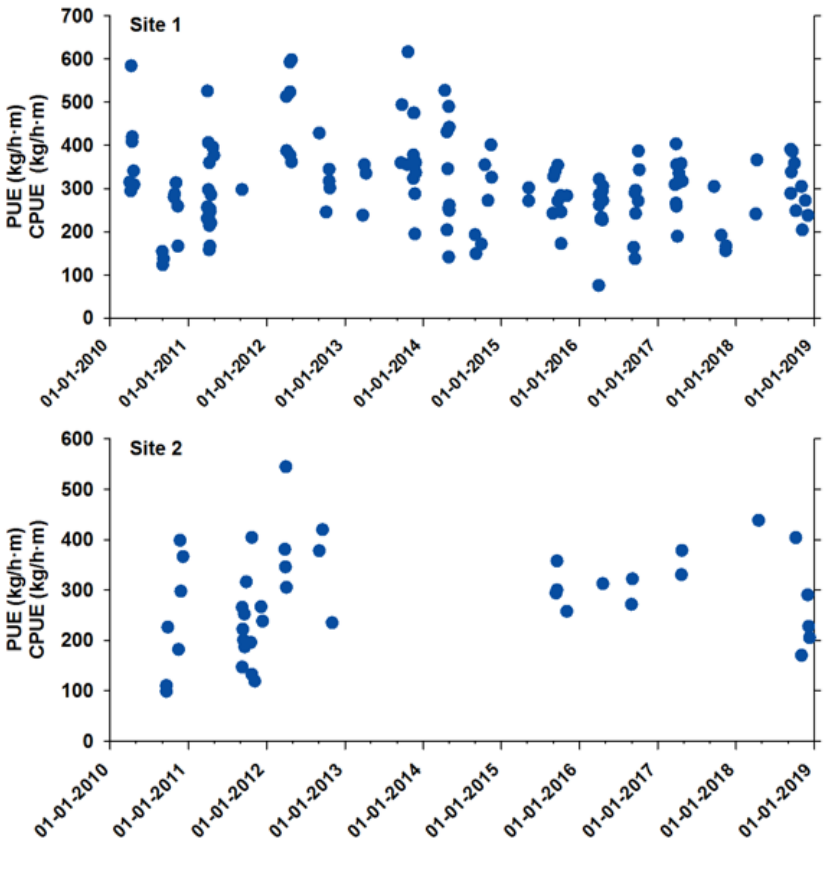
Given that the fishery is still targeting new sites, it is useful to monitor the change in daily CPUEs at sites that have been fished for several years. Two sites in the North bed were selected for monitoring: one in sub-area 5A1 and the other in 5B1 (Appendices 13 and 16). Harvesting at these sites covers the period 2010 to 2018; some values are missing for site 2 in 2013 and 2014 (Figure 9).

A total of 134 fishing days were recorded for site 1 (Figure 9). High values of between 400 and 617 kg/h·m were observed during the initial years of harvesting, from 2010 to 2014. Thereafter, the maximum CPUEs were 404 kg/h·m at most. The mean annual CPUEs remained between 258 and 372 kg/h·m, except in 2012, when it was 416 kg/h·m. There does not appear to have been any decrease in CPUEs during any fishing season or between seasons.

A total of 42 fishing days were recorded for site 2 (Figure 9). There was only one observation above 450 kg/h·m, in 2012. The mean annual CPUEs ranged from 227 to 373 kg/h·m, for an overall mean of 281 kg/h·m. As observed at site 1, CPUEs at site 2 appear to have remained unchanged year over year.

Exploitation rate index

In 2018, the total area of all beds in sub-areas 5A1 and 5B1 was estimated at 36.5 km^2 (Table 2). The area of the CGE and East beds has remained the same since 2008 at 4 km^2 and 11 km^2 respectively, whereas the area of the North bed is steadily increasing. In 2018, the total area of the North bed was estimated at 21.5 km^2 and was divided almost equally between sub-areas 5A1 and 5B1. The number of known beds and their area depend on fisher exploration. Currently, sub-areas 5A1 and 5A2 may be well known, but exploration continues in sub-areas 5B1 and 5B2.



Site 1

Year	N	Mean	Max.
2010	15	293	584
2011	19	286	526
2012	12	416	598
2013	15	372	617
2014	17	307	527
2015	11	281	354
2016	18	258	387
2017	15	283	404
2018	12	303	391
Total	**134**	**308**	**617**

Site 2

Year	N	Mean	Max.
2010	7	240	399
2011	13	227	404
2012	7	373	545
2013	0	-	-
2014	0	-	-
2015	4	302	358
2016	3	302	322
2017	2	354	379
2018	6	289	438
Total	**42**	**281**	**545**

Figure 9. Monitoring of daily CPUEs by harvest date, fisher and number of observations (N), mean annual CPUE and maximum CPUE in the commercial Atlantic Surfclam dredge fishery at sites 1 (sub-area 5A1) and 2 (sub-area 5B1) on the North bed in the Îles-de-la-Madeleine.

Table 2. Estimated area (km^2) of the various known Atlantic Surfclam beds in the Îles-de-la-Madeleine

Period[1]	CGE	East	North			Total
			5A1	5B1	Total	
2002–2009	4.0	11.0	6.5	3.5	10.0	25.0
2002–2012	4.0	11.0	8.0	5.5	13.5	28.5
2002–2015	4.0	11.0	9.0	8.0	17.0	32.0
2002–2018	4.0	11.0	11.5	10.0	21.5	36.5

[1] Since the period refers to the years used to calculate the area, the 2002 to 2018 period includes all available data from 2002 to 2018.

From 2002 to 2014, the area dredged annually on the CGE and East beds was equal to or less than 1.1 km^2 (Table 3). The average exploitation rate index was 4.7 ± 4.4%[1] for the CGE bed and 6.2 ± 4.5% for the East bed. However, the annual exploitation rate index for these beds was 9% to 12.7% on several occasions.

[1] ± standard deviation

Since 2009, the area dredged on the entire North bed has ranged from 1.0 to 1.6 km^2 (Table 3). The exploitation rate index for that period ranged from 4.5% to 7.5%. The average index for the last three years was 6.2%. This index was slightly higher in the part of the bed located in 5B1 (6.4%) than in the 5A1 part (6.0%).

Table 3. Area dredged (km^2) and exploitation rate index (%) from 2002 to 2018 by bed, for the commercial Atlantic Surfclam dredge fishery in the Îles-de-la-Madeleine

Year	CGE		East		North-5A1		North-5B1		North-Total	
	km^2	%	km^2	%	km^2	%	km^2	%	km^2	%
2002	0.1	3.3	1.1	10.4	-	-	-	-	-	-
2003	0.5	12.7	1.1	9.6	-	-	-	-	-	-
2004	0.4	11.2	1.1	10.3	-	-	-	-	-	-
2005	0.05	1.2	0.4	3.3	0.5	4.4	-	-	0.5	2.4
2006	0.4	9.0	0.1	0.8	0.9	7.7	-	-	0.9	4.1
2007	0.1	1.9	1.1	10.1	0.6	5.2	-	-	0.6	2.8
2008	0.1	2.9	1.1	10.1	0.2	1.9	0.3	2.8	0.5	2.4
2009	0.3	6.3	0.7	6.3	0.3	3.0	1.3	12.6	1.6	7.5
2010	0.04	0.9	0.03	0.3	0.8	6.6	0.6	5.9	1.3	6.3
2011	0.04	1.1	-	-	0.5	4.5	0.8	7.9	1.3	6.1
2012	0.03	0.9	-	-	0.4	3.7	0.5	5.4	1.0	4.5
2013	-	-	-	-	0.5	4.7	0.6	6.2	1.2	5.4
2014	-	-	0.04	0.4	0.7	6.0	0.6	5.6	1.2	5.8
2015	-	-	-	-	0.8	6.9	0.6	6.5	1.4	6.7
2016	-	-	-	-	0.7	5.9	0.6	5.6	1.2	5.8
2017	-	-	-	-	0.7	6.0	0.7	6.8	1.4	6.4
2018	-	-	-	-	0.7	5.9	0.7	6.7	1.4	6.3
Ref.[1]	0.2	4.7	0.7	6.2	0.6	5.1	0.7	6.5	1.1	5.1
Diff.[2]	-	-	-	-	-	+16 %	-	+3 %	-	24 %
Mean[3]	-	-	-	-	-	6.0	-	6.4	-	6.2

[1] Reference mean from 2002 to 2017, 2005 to 2017 or 2008 to 2017 depending on available data.
[2] Difference between the 2018 value and the reference mean.
[3] Mean for the last three years (2016 to 2018).

Size structure

The size structures of clams from the various beds are shown in these three appendices: Appendix 19 shows clam landed at dockside and sampled at sea, Appendix 20, their landed mean sizes and Appendix 21, their at-sea mean sizes. The size structures of landed clam and clam harvested at sea differ only slightly. Few clam smaller than 90 mm are harvested or landed. In addition, fishers report that they seldom sort their catch. The size structures of clams landed in the last five years are fairly similar.

The 2014 increase in the legal minimum size to 90 mm has scarcely impacted mean sizes; this is because, since 2007, landed clams have typically been greater than 100 mm (Figure 10 and Appendices 19 and 20). As well, the average size of clam landings caught on the North bed has been gradually increasing since 2009. From 2010 to 2012, 2013 to 2015 and 2016 to 2018, the mean sizes were 127 mm, 132 mm and 136 mm, respectively. The mean sizes of clams caught at sea were similar to those of landed clams (Appendices 20 and 21).

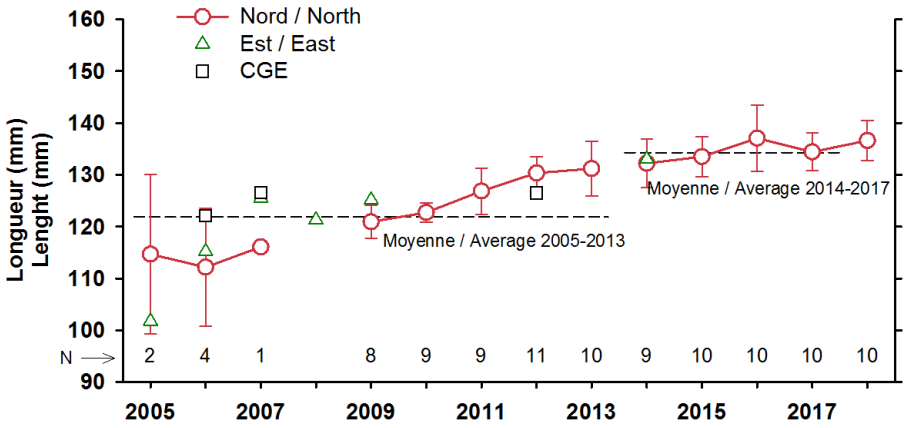


Figure 10. Annual mean size (± 95% confidence interval) of landed Atlantic Surfclams, by bed and reference mean (mean for 2005-2013 and 2014-2017), and number of samples (N) on the North bed in the commercial dredge fishery in the Îles-de-la-Madeleine.

COMMERCIAL HAND HARVESTING

Hand harvesting of Atlantic Surfclam is carried out in about 10 shellfish areas, but more typically in areas A-09.5 (mainly islets B and C) and A-09.1, in the Grande Entrée lagoon, along the beach of the Dune du Sud (A-12.1), in the Havre aux Maisons channel (A-16.1.2), at the Gros-Cap campsite (A-16.2.1.1) and along the beaches of La Martinique (A-17.1) and the Dune Sandy Hook (A-17.4) in Plaisance Bay (Figure 2).

Since 2005, between 121 and 155 commercial licences have been issued annually for harvesting Atlantic Surfclam by hand (Appendix 22). However, the annual number of officially active fishers (those who have completed at least one logbook) has been lower, ranging from 19 to 46. Although the fishing season runs from mid-January to late December, the actual fishing season is shorter, typically from mid-March to early October (Appendix 22).

Since 2005, annual landings from the commercial hand harvest fishery have ranged from 15.4 to 58.5 t (Appendix 15) and fishing effort has ranged from 105 to 298 days (Appendix 17). In 2018, fishing effort was 239 days for landings of 45.4 t, an increase of 18% and 49%, respectively, from the 2005-2017 reference mean. The average fishing effort for the last three years was 273 days for average landings of 51.1 t.

In the case of hand harvesting, non-standardized CPUEs were used to monitor the status of the beds. Given the type of standardization carried out, very high-performing and less-active fishers were favoured in 2018, which led to estimates of a high 2018 standardized CPUE of 92.2 kg/h for clam divers in Area A-12.1 (Appendix 18). However, the trends have remained unchanged regardless of the type of CPUE used (Appendices 18 and 23).

Dive harvesting

Since 2005, landings from commercial dive harvesting have varied considerably from year to year, from 1.5 to 47.3 t, depending on divers' fishing effort (Figure 11 and Appendices 15 and 17). Landings saw the same variations as fishing effort. Landings and fishing effort were low in 2015, largely due to unfavourable weather conditions. Average landings for the last three years (2016 to 2018) were 42.3 t for 160 days of hand harvesting. For the same period, landings were mainly from shellfish area A-12.1 and, to a lesser extent, areas A-09.5, A-16.2.1.1 and A-17.1 (Appendix 24).

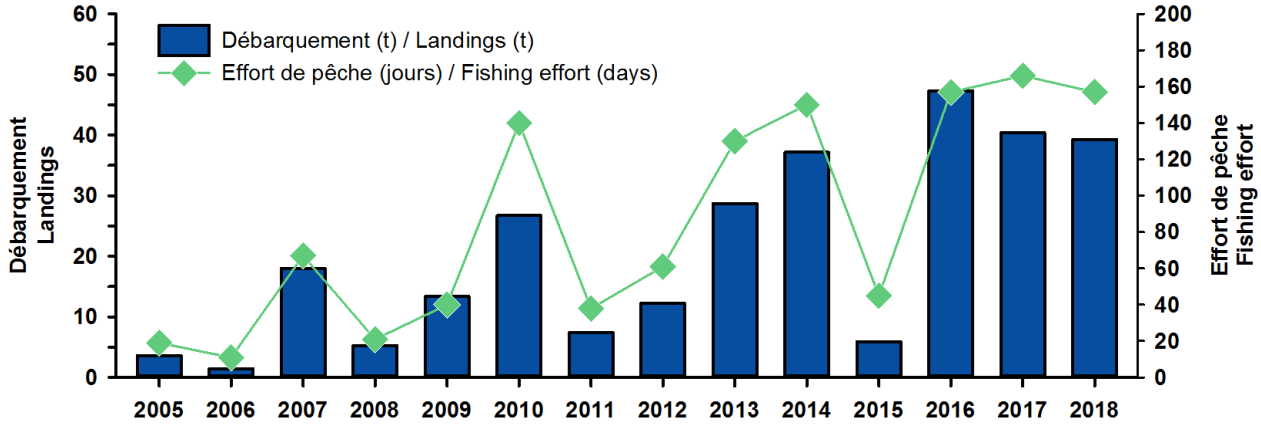


Figure 11. Annual landings and fishing effort for commercial dive harvesting of Atlantic Surfclam in the Îles-de-la-Madeleine.

From 2007 to 2009, CPUEs for commercial dive harvesting in A-12.1 remained above 80 kg/h (Figure 12 and Appendix 23). From 2010 to 2014, CPUEs decreased and stabilized at around 50 to 65 kg/h. The 2015 CPUE of 37.8 kg/h was the lowest value in the series. In the last three years, the mean CPUE was 67.8 kg/h, similar to the 2005-2017 reference mean.

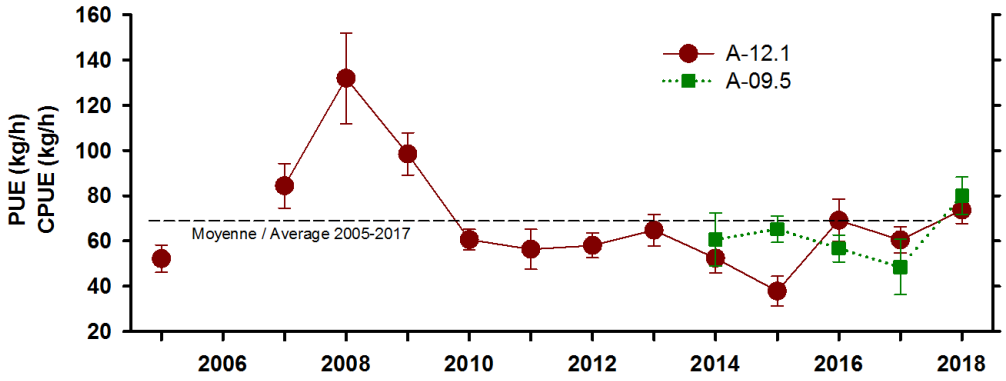


Figure 12. Mean annual non-standardized CPUE (± 95% confidence interval) by shellfish area and reference mean for commercial dive harvesting of Atlantic Surfclam in Area A-12.1 in the Îles-de-la-Madeleine.

CPUEs for Area A-09.5 were similar to those in A-12.1. However, the reference mean was lower, at 54.9 kg/h, but the mean CPUE in the last three years was 61.8 kg/h (Figure 12 and Appendix 23).

Dive-harvested clams measured at landing were large (Figure 13 and Appendix 25). Since 2010, there were few landed clams that were smaller than 100 mm. From 2005 to 2013, the average size of clams landed from A-12.1 ranged from 127 to 136 mm and remained close to the 2005-2017 reference mean (Figure 13 and Appendix 20). The average sizes in the following two years, 2014 and 2016, were high, at 144 and 146 mm respectively; they increased the 2014-2017 reference mean to 140 mm. In the last two years, the average size of landed clams returned to levels similar to those observed before 2014, specifically 131 to 132 mm.

The information from A-09.5 and A-16.2.1.1 is partial (Figure 13 and Appendices 20 and 25). However, the average sizes of clams landed from these areas were similar to those of A-12.1, except in 2005 and 2006 when average sizes were much smaller in A-09.5. However, it is worth

noting that for these areas, the number of samples collected and the number of clams measured were sometimes low (Appendix 10).

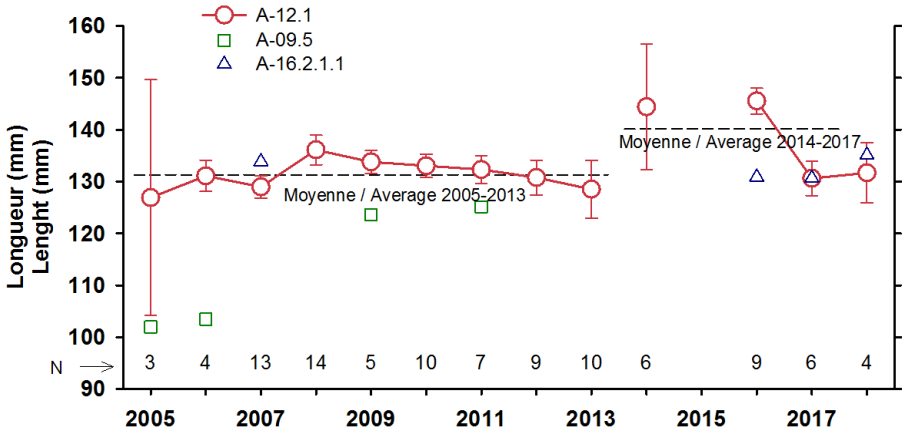


Figure 13. Annual mean size (± 95% confidence interval) of landed Atlantic Surfclams, by shellfish area and reference mean (mean for 2005 to 2013 and 2014 to 2017), and number of samples (N) collected for Area A-12.1 of the commercial dive fishery in the Îles-de-la-Madeleine.

Shore harvesters

Hand harvest landings from commercial shore harvesters ranged from 6.1 to 21.1 t annually and were 6.1 t in 2018 (Figure 14 and Appendix 15). The mean for the last three years was 8.8 t. From the time monitoring began, commercial landings have come mainly from shellfish area A-09.5 (Appendix 26). However, the share of landings from areas A-12.1, A-16.2.1.1, A-17.1 and A-17.4 has increased since 2013, and reached nearly 50% in 2018.

Landings varied with fishing effort. The fishing effort for commercial hand harvesting by shore harvesters for all areas was between 65 and 189 days per year (Figure 14 and Appendix 17). The average for the last three years was 113 days.

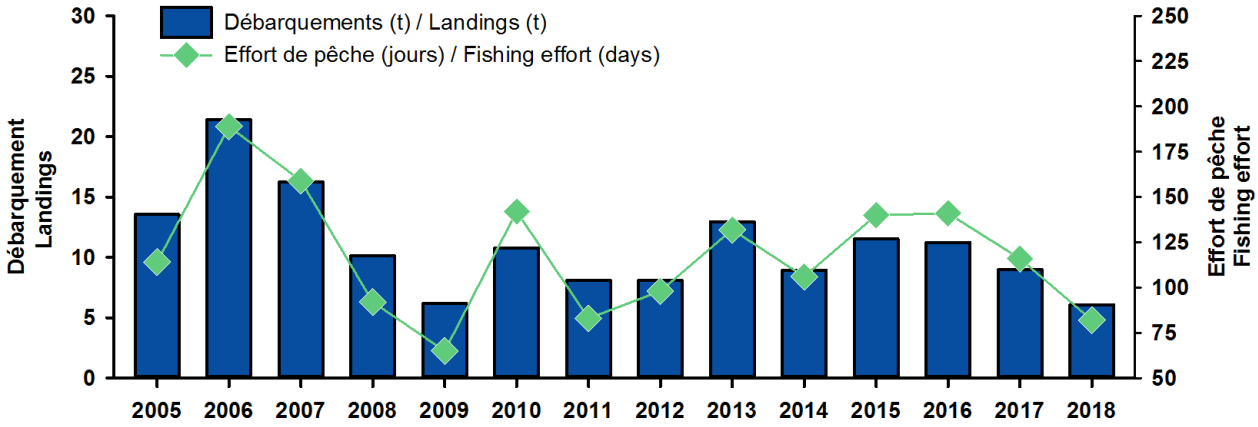


Figure 14. Annual landings and fishing effort for the commercial shore harvesting of Atlantic Surfclam in the Îles-de-la-Madeleine.

The 2005-2017 reference mean for CPUEs in A-09.5 was 25.8 kg/h (Figure 15 and Appendix 23). In the first four years of monitoring, namely 2005 to 2009, CPUEs were at or above the mean. Thereafter, CPUEs were stable, but slightly below the mean. In 2017 and 2018, CPUEs were similar to the mean, at 25.2 and 25.9 kg/h, respectively. For shellfish areas

A-16.2.1.1 and A-17.4, CPUEs since 2012 have been lower than those in A-09.5 and have ranged from 10.8 to 19.7 kg/h (Figure 15 and Appendix 23).

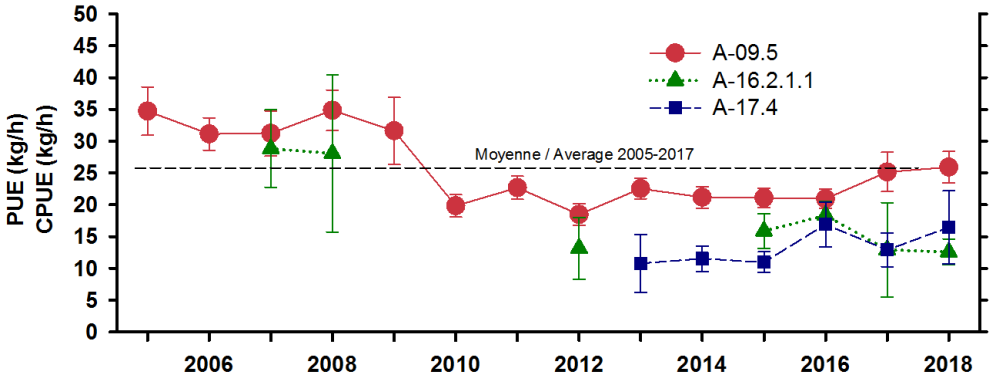


Figure 15. Annual mean non-standardized CPUE (± 95% confidence interval) by shellfish area and 2005-2017 reference mean for Area A-09.5 for the commercial shore harvesting of Atlantic Surfclam in the Îles-de-la-Madeleine.

The mean sizes of clams harvested by shore harvesters are smaller than those harvested by dredging and diving (Appendix 20). The 2014 increase in the legal minimum size to 90 mm has had a noticeable effect on size structures and mean size (Figure 16 and Appendix 27). Size structures and mean sizes vary significantly depending on the year and area. Across all shellfish areas, the mean size ranged from 104 to 122 mm from 2016 to 2018 (Figure 16 and Appendix 20). The number of clams measured in a year, for a same area, is sometimes low and can affect the size structures shown (Appendix 10).

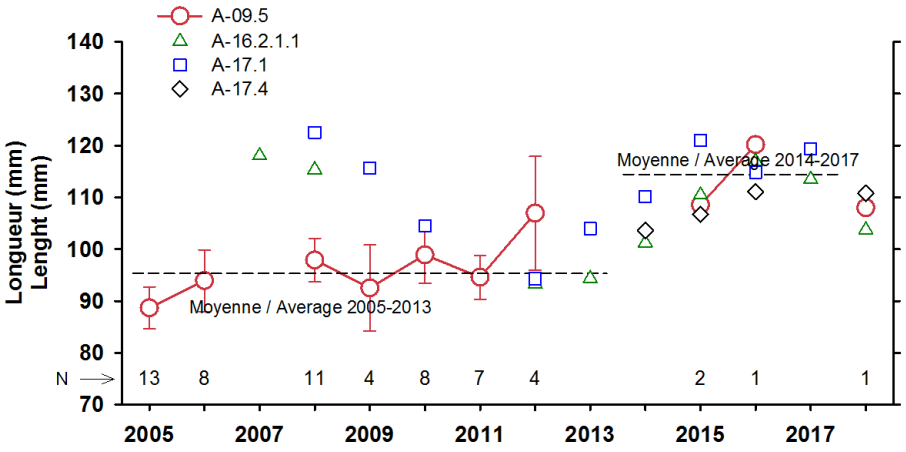


Figure 16. Annual average size (± 95% confidence interval) of landed Atlantic Surfclams, by shellfish area and reference mean (mean for 2005 to 2013 and 2014 to 2017) and number of samples (N) collected by commercial shore harvesters in Area A-09.5 of the Îles-de-la-Madeleine.

RECREATIONAL HAND HARVESTING

According to the information gathered, the minimum number of recreational hand harvesters observed in all shellfish areas could be very high, from 237 to 1,271 harvester-days per year (Appendix 28). This number is a minimum estimate, since it relies on the number of observations made and does not cover all areas every day. The annual fishing effort of the recreational hand harvest was much higher than that of the commercial hand harvest, which

ranged from 105 to 298 harvester-days per year (Appendices 17 and 28). On sunny summer days, there can be over 50 hand harvesters at a single shellfish bed.

The most visited shellfish areas are essentially the same as for the commercial hand harvest, namely A-09.5, A-12.1, A-16.2.1.1, A-17.1 and A-17.4. However, areas A-03.1, A-13 and A-14.2 were fished almost exclusively by recreational hand harvesters (Appendix 28). Of note, two of the areas visited between 2005 and 2018, namely A-16.2.1.2 and A-17.3, are closed to shellfish harvesting (CSSP 2019).

Despite its popularity, information on recreational hand harvesting, by either divers or shore harvesters, is limited. The maximum daily limit for recreational hand harvesting is 300 clams. The estimated weight of 300 clams having an average size of 110 mm (average size of landed clams harvested by shore harvesters) is 69 kg (Table 1). In 2018, the minimum fishing effort was 792 harvester-days, which represents about 55 t of harvested clams. These figures are of the same order of magnitude as those estimated for unreported fishing activities, which ranged from 64 to 73 t from 2016 to 2018 (Figure 4 and Appendix 15), and are similar to landings from commercial hand harvesting for the same years.

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REFERENCES

Bernier, L. and Poirier, L. 1979. Évaluation sommaire du stock de mactres de l'Atlantique, *Spisula solidissima* Dillwyn, des Îles-de-la-Madeleine (Golfe du Saint-Laurent). MICQ, D.G.P.M., Cahier d'Information No 92. 42 p.

Bio-Conseil, Inc. 1986. Pêche exploratoire à la palourde (*Spisula solidissima*) aux Îles-de-la-Madeleine, automne 1985. Final report, Quebec. 9 p.

Bousfield, E.L. 1964. Canadian Atlantic Sea Shells. National Museum of Canada, Ottawa, 89 p.

Brulotte, S. 2013. Assessment of Atlantic Surfclam, *Spisula solidissima*, in the coastal waters of the Îles-de-la-Madeleine, Québec – methodology and results. DFO Can. Sci. Advis. Sec. Res. Doc. 2013/082. x + 58 p.

Brulotte, S. 2016. Stock assessment of Atlantic Surfclam, *Spisula solidissima*, of the Îles-de-la-Madeleine, Québec in 2015 – methodology and results. DFO Can. Sci. Advis. Sec. Res. Doc. 2016/074. x + 51 p.

Caddy, J.F., Chandler, R.A. and Wilder, D.G. 1974. Biology and commercial potential of several underexploited molluscs and crustaceans on the Atlantic coast of Canada. Federal-Provincial Fisheries Committee Meeting on Utilization of Atlantic Resources, Montreal (QC), February 5–7, 1974. 111 p.

Cargnelli, L.M., Griesbach, S.J., Packer, D.B. and Weissberger, E. 1999. Essential fish habitat source document: Atlantic surfclam, *Spisula solidissima*, life history and habitat characteristics. NOAA Technical Memorandum NMFS-NE-142. 13 p.

CSSP. 2019. Canadian Shellfish Sanitation Program, Shellfish harvesting map. Government of Canada. (accessed 2019 May).

DFO. 2011. Identification of Atlantic surfclam fishing areas off Grosse-Île (Magdalen Islands, Quebec) to avoid impacting lobster habitat DFO Can. Sci. Advis. Sec. Sci. Resp. 2011/006 50 p.

DFO. 2019. Assessment of the Îles-de-la-Madeleine Atlantic Surfclam stock in 2018. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2019/031.

Dietl, G.P. and Alexander, R.R. 1997. Predator-prey interactions between the naticids *Euspira heros* Say and *Neverita duplicata* Say and the Atlantic surfclam *Spisula solidissima* Dillwyn from Long Island to Delaware. J. Shellfish Res. 16: 413–422.

FAO (Food and Agriculture Organization of the United Nations). 2019. Fisheries and Aquaculture Department.Species Fact Sheets, *Spisula solidissima* (Dillwyn, 1817). (accessed 2019 February 14).

Fay, C.W., Neves, R.J. and Pardue, G.B. 1983. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (mid Atlantic): surf clam. U.S. Fish and Wildlife Service, Division of Biological Services, FWS/OBS-82/11.13. U.S. Army Corps of Engineers, TR EL-82-4. 23 p.

Fréchette, M. and Giguère, M. 1986. Rapport sur une pêche exploratoire à la palourde aux Îles-de-la-Madeleine. DFO. Internal report. 12 p.

Gavaris, S. 1980. Use of a multiplicative model to estimate catch rate and effort from commercial data. Can. J. Fish. Aquat. Sci. 37 (12): 2272–2275.

Galbraith, P.S., Chassé, J., Caverhill, C., Nicot, P., Gilbert, D., Lefaivre, D. and Lafleur, C. 2019. Physical Oceanographic Conditions in the Gulf of St. Lawrence during 2018 DFO Can. Sci. Advis. Sec. Res. Doc. 2019/046. iv + 79 p.

Gendron, L. 1988. Exploitation et état du stock de mactres (*Spisula solidissima*) des Îles-de-la-Madeleine en 1986. Can. Manuscr. Rep. Fish. Aquat. Sci. 1993: v +17 p.

Giguère, M., Brulotte, S., Paille, N. and Fortin, J. 2005. Mise à jour des connaissances sur la biologie et l'exploitation de la mactre de l'Atlantique (*Spisula solidissima*) aux Îles-de-la-Madeleine. Can. Tech. Rep. Fish. Aquat. Sci. 2587: ix + 32 p.

Hofmann, E.E., Powell, E.N., Klinck, J.M., Munroe, D.M., Mann, R., Haidvogel, D.B., Narváez, D.A., Zhang, X. and Kuykendall, K.M. 2018. An overview of factors affecting distribution of the Atlantic Surfclam (*Spisula solidissima*), a continental shelf biomass dominant, during a period of climate change. J. Shellfish Res. 37(4): 821–831.

Jones, D.S., Thompson, I. and Ambrose, W. 1978. Age and growth rate determinations for the Atlantic surf clam *Spisula solidissima* (Bivalvia: Mactracea), based in internal growth lines in shell cross-sections. Mar. Biol. 47:63–70.

Jones, D.S., Williams, D.F. and Arthur, M.A. 1983. Growth history and ecology of the Atlantic surf clam, *Spisula solidissima* (Dillwyn), as revealed by stable isotopes and annual shell increments. J. Exp. Mar. Biol. Ecol. 73: 225–242.

Lambert, J. and Goudreau, P. 1996. Performance of the New England hydraulic dredge for the harvest of Stimpson's surf clams (*Mactromeris polynyma*). Can. Ind. Rep. Fish. Aquat. Sci. 235: vii + 28 p.

Loosanoff, V.L. and Davis, H.C. 1963. Rearing of bivalve mollusks. In: Advances in marine biology, Vol. 1. F.S. Russel (ed.) Acad. Press, London and New York. p. 1–136.

Mackenzie, C.L. Jr., Radosh, D.J. and Reid, R.N. 1985. Densities, growth, and mortalities of juveniles of the surf clam (*Spisula solidissima*) (Dillwyn) in the New York Bight. J. Shellfish Res. 5:81–84.

Medcof, J.C. and MacPhail, J.S. 1955. Survey of bar clam resources of the Maritimes provinces. Fish. Res. Board Can. Bull. 102, 6 p.

Merrill, A.S. and Ropes, J.W. 1969. The general distribution of the surf clam and ocean quahog. Proceedings of the National Shellfisheries Association 59:40–45.

Munroe, D.M., Narváez, D.A., Hennen, D., Jacobson, L., Mann, R., Hofmann, E.E., Powell, E.N. and Klinck, J.M. 2016. Fishing and bottom water temperature as drivers of change in maximum shell length in Atlantic surfclams (*Spisula solidissima*). Estuar. Coast. Shelf Sci. 170: 112–122.

NOAA Fishwatch. 2019. Atlantic Surfclam, *Spisula solidissima*. (accessed 2019 June 27).

Robert, G. 1981. Dynamics of an exploited population of bar clam, *Spisula solidissima*. Can. Manuscr. Rep. Fish. Aquat. Sci. Sci. 1607: iv + 12 p.

Ropes, J.W. 1978. Biology and distribution of surf clams (*Spisula solidissima*) and ocean quahogs (*Arctica islandica*) off the northeast coast of the United States. In: Proceedings of northeast clam industries: management for the future. April 27–28, 1978. Hyannis, MA. p. 47–66.

Ropes, J.W. 1980. Biological and fisheries data on the Atlantic surf clam, *Spisula solidissima* (Dillwyn). U.S. Natl Mar. Fish. Serv. Northeast Fish. Cent. Sandy Hook Lab. Tech. Ser. Rep. No. 24. 88 p.

Ropes, J.W. and G.E. Ward. Jr. 1977. The Atlantic coast surf clam fishery—1974. Mar. Fish. Rev. 39(5): 18–23.

Sephton T.W. and Bryan, C.F. 1990. Age and growth rate determinations for the Atlantic surf clam, *Spisula solidissima* (Dillwyn, 1817), in Prince Edward Island, Canada. J. Shellfish. Res. 9: 177–185.

Snelgrove, P.V.R., Grassle, J.P. and Butman, C.A. 1998. Sediment choice by settling larvae of the bivalve, *Spisula solidissima* (Dillwyn), in flow and still water. J. Exp. Mar. Biol. Ecol. 231: 171–190.

Stehlik, L.L. 1993. Diets of the brachyuran crabs *Cancer irroratus*, *C. borealis*, and *Ovalipes ocellatus* in the New York Bight. J. Crust. Biol. 13(4): 723–735.

Timbs, J. 2018. Spatial distribution and stock-recruitment analysis of the Atlantic surfclam, *Spisula solidissima*, in the Mid-Atlantic Bight and on Georges Bank. Thesis (M.Sc.), University of Southern Mississippi, The Aquila Digital Community.91 p.

Trottier, S. and Goudreau, P. 2015. Assessment of the Stimpson's surfclam stocks of Quebec coastal waters in 2014. DFO Can. Sci. Advis. Sec. Res. Doc. 2015/063. ix + 72 p.

Weinberg, J.R. 1999. Age-structure, recruitment, and adult mortality in populations of the Atlantic surfclam, *Spisula solidissima*, from 1978 to 1997. Mar. Biol. 134: 113–125.

Weinberg, J.R. 2005. Bathymetric shift in the distribution of Atlantic surfclams: response to warmer ocean temperature. ICES J. Mar. Sci. 62: 1444–1453.

Yancey, R.M. and Welch, W.R. 1968. The Atlantic coast surfclam—with a partial bibliography. U.S. Fish. Wildlife Serv. Circ. 228. 14 p.

APPENDICES

Appendix 1. Management measures from 2008 to 2018: A) for the sub-areas and fishing season shown; and, B) for the total allowable catch (t) and fishing effort limit (days) per sub-area of commercial dredging of Atlantic Surfclam in the Îles-de-la-Madeleine.

A)

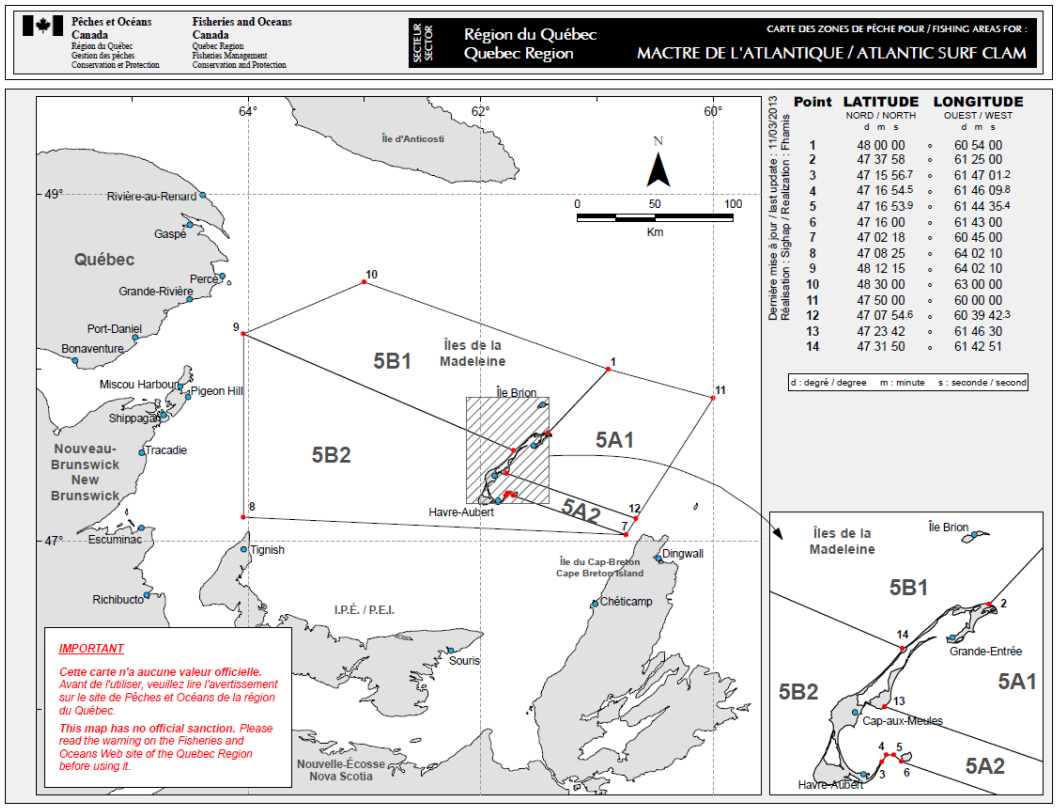
Year	Sub-area	Fishing season
2008	5A1 5A2 5B	5A1 and 5A2: 07/04 to 05/07 and 01/09 to 13/12 5B 07/04 to 13/12
2009	5A1 5A2 5B	5A1 and 5A2: 06/04 to 04/07 and 01/09 to 12/12 5B 06/04 to 12/12
2010	5A1 5A2 5B	5A1 and 5A2: 29/03 to 01/07 and 01/09 to 11/12 5B: 01/09 to 11/12
2011	5A1 5A2 5B1 5B2	5A1, 5A2 and 5B1: 28/03 to 02/07 and 01/09 to 31/12 5B2: 11/04 to 31/12
2012	5A1 5A2 5B1 5B2	5A1, 5A2 and 5B1: 26/03 to 30/06 and 01/09 to 31/12 5B2: 26/03 to 31/12
2013[1]	5A1 5A2 5B1 5B2	5A1, 5A2 and 5B1: 25/03 to 29/06 and 02/09 to 31/12 5B2: 25/03 to 31/12
2014	5A1 5A2 5B1 5B2	5A1, 5A2 and 5B1: 24/03 to 28/06 and 01/09 to 31/12 5B2: 24/03 to 31/12
2015	5A1 5A2 5B1 5B2	5A1, 5A2 and 5B1: 29/03 to 03/07 and 30/08 to 31/12 5B2: 29/03 to 31/12
2016	5A1 5A2 5B1 5B2	5A1, 5A2 and 5B1: 21/03 to 02/07 and 29/08 to 31/12 5B2: 21/03 to 31/12
2017	5A1 5A2 5B1 5B2	5A1, 5A2 and 5B1: 20/03 to 01/07 and 27/08 to 31/12 5B2: 20/03 to 31/12
2018	5A1 5A2 5B1 5B2	5A1, 5A2 and 5B1: 26/03 to 01/07 and 27/08 to 31/12 5B2: 26/03 to 31/12

[1] 5A1 and 5B1 boundary changed.

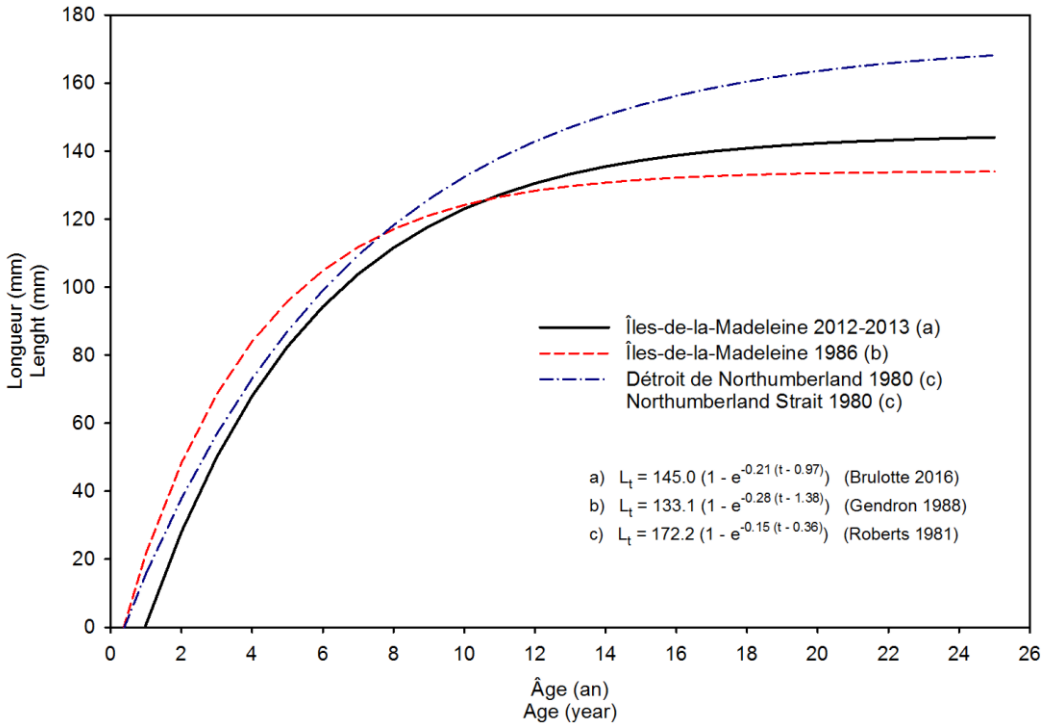
B)

Year	Area 5			
	5A		5B	
	5A1	5A2	5B1	5B2
2008	113 t	55 t	-	
2009	113 t	55 t	-	
2010	125 t	55 t	100 t or 36 days	
2011	125 t	55 t	100 t or 36 days	12 days
2012	125 t	55 t	100 t or 36 days	12 days
2013	125 t or 44 days	55 t	113 t or 36 days	12 days
2014	125 t or 44 days	55 t	113 t or 36 days	12 days
2015	125 t or 44 days	55 t	113 t or 36 days	12 days
2016	125 t	55 t	113 t	12 days
2017	125 t	55 t	113 t	12 days
2018	125 t	55 t	113 t	12 days

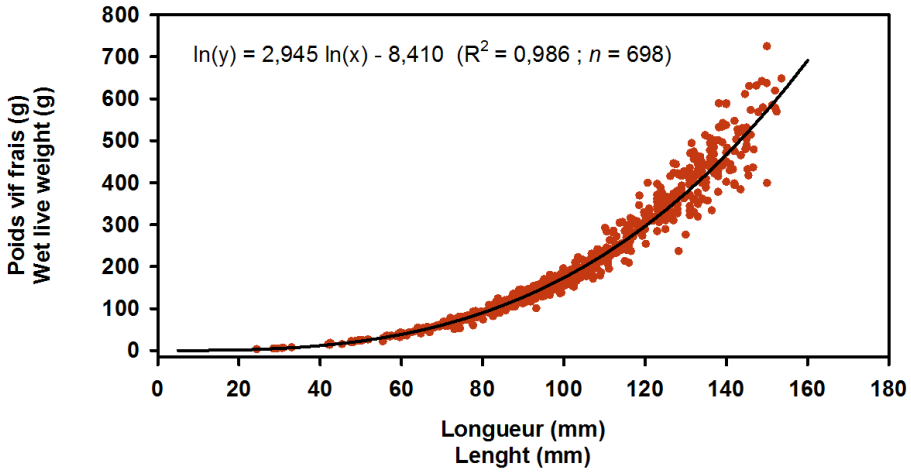
Appendix 2. Boundaries of sub-areas for commercial dredging of Atlantic Surfclam in the Îles-de-la-Madeleine, in 2018.



Appendix 3. Von Bertalanffy growth curve for Atlantic Surfclam harvested in Eastern Canada.



Appendix 4. Morphometric relationship between wet live weight and length of Atlantic Surfclam harvested in the Îles-de-la-Madeleine in 2013 and 2014.



Appendix 5. A) Frequency of the different variables used to standardize (PROC MIXED) catches per unit effort, and B) variance analysis results for commercial dredging of Atlantic Surfclam on the CGE bed (sub-area 5A1) in the Îles-de-la-Madeleine.

A)

Variable	Value	Frequency (number)	Percentage (%)
Year	2003	19	32.20
	2004	17	28.81
	2006	13	22.03
	2009	10	16.95
Month	9	28	47.46
	10	17	28.81
	11	14	23.73
Harvester	1	25	42.37
	2	10	16.95
	3	24	40.68

B)

Covariance

Factor	Estimated	Number of observations
Residual	0.1637	59

Type-III test, fixed effects

Factor	Degrees of freedom for the numerator	Degrees of freedom for the denominator	F-value	P > F
Year	3	51	4.99	0.0041
Month	2	51	0.97	0.3848
Harvester	2	51	17.79	< 0.0001

Appendix 6. A) Frequency of the different variables used to standardize (PROC MIXED) catches per unit effort and B) variance analysis results for commercial dredging of Atlantic Surfclam on the East bed (sub-area 5A1) in the Îles-de-la-Madeleine.

A)

Variable	Value	Frequency (number)	Percentage (%)
Year	2002	44	20.47
	2003	38	17.67
	2004	36	16.74
	2005	11	5.12
	2007	35	16.28
	2008	31	14.42
	2009	20	9.3
Month	4	7	3.26
	9	82	38.14
	10	68	31.63
	11	52	24.19
	12	6	2.79
Harvester	1	54	25.12
	2	77	35.81
	3	39	18.14
	4	45	20.93

B)

Covariance

Factor	Estimated	Number of observations
Residual	0.1323	215

Type-III test, fixed effects

Factor	Degrees of freedom for the numerator	Degrees of freedom for the denominator	F-value	P > F
Year	6	201	4.73	0.0002
Month	4	201	3.91	0.0044
Harvester	3	201	28.83	< 0.0001

Appendix 7. A) Frequency of the different variables used to standardize (PROC MIXED) catches per unit effort and B) variance analysis results for commercial dredging of Atlantic Surfclam on the North bed (sub-areas 5A1 and 5B1) in the Îles-de-la-Madeleine.

A)

Variable	Value	Frequency (number)	Percentage (%)
Year	2004	7	1.29
	2005	18	3.31
	2006	34	6.25
	2007	22	4.04
	2008	13	2.39
	2009	61	11.21
	2010	50	9.19
	2011	58	10.66
	2012	38	6.99
	2013	40	7.35
	2014	39	7.17
	2015	45	8.27
	2016	40	7.35
	2017	50	9.19
	2018	29	5.33
Month	4	129	23.71
	5	10	1.84
	9	195	35.85
	10	107	19.67
	11	81	14.89
	12	22	4.04
Harvester	1	30	5.51
	2	40	7.35
	3	23	4.23
	4	83	15.26
	5	30	5.51
	6	46	8.46
	7	20	3.68
	8	72	13.24
	9	54	9.93
	10	146	26.84

B)

Covariance

Factor	Estimated	Number of observations
Residual	0,1070	544

Type-III test, fixed effects

Factor	Degrees of freedom for the numerator	Degrees of freedom for the denominator	F-value	P > F
Year	14	515	12.34	< 0.0001
Month	5	515	6.59	< 0.0001
Harvester	9	515	36.33	< 0.0001

Appendix 8. A) Frequency of the different variables used to standardize (PROC MIXED) catches per unit effort and B) variance analysis results for dive harvesting of Atlantic Surfclam from Area A-09.5 in the Îles-de-la-Madeleine.

A)

Variable	Value	Frequency (number)	Percentage (%)
Year	2014	16	13.01
	2016	52	42.28
	2017	22	17.89
	2018	33	26.83
Harvester	1	67	54.47
	2	13	10.57
	3	31	25.20
	4	12	9.76

B)

Covariance

Factor	Estimated	Number of observations
Residual	0.1153	94

Type-III test. fixed effects

Factor	Degrees of freedom for the numerator	Degrees of freedom for the denominator	F-value	P > F
Year	2	89	21.23	< 0.0001
Harvester	2	89	17.09	< 0.0001

Appendix 9. A) Frequency of the different variables used to standardize (PROC MIXED) catches per unit effort and B) variance analysis results for dive harvesting of Atlantic Surfclam in Area A-12.1 in the Îles-de-la-Madeleine.

A)

Variable	Value	Frequency (number)	Percentage (%)
Year	2005	10	1.46
	2007	48	7.01
	2008	11	1.61
	2009	34	4.96
	2010	108	15.77
	2011	35	5.11
	2012	39	5.69
	2013	69	10.07
	2014	65	9.49
	2015	33	4.82
	2016	65	9.49
	2017	81	11.82
	2018	87	12.70
Harvester	1	28	4.09
	2	52	7.59
	3	85	12.41
	4	23	3.36
	5	37	5.40
	6	31	4.53
	7	69	10.07
	8	41	5.99
	9	41	5.99
	10	40	5.84
	11	64	9.34
	12	42	6.13
	13	35	5.11
	14	97	14.16

B)

Covariance

Factor	Estimated	Number of observations
Residual	0.1324	685

Type-III test. fixed effects

Factor	Degrees of freedom for the numerator	Degrees of freedom for the denominator	F-value	P > F
Year	12	659	13.23	< 0.0001
Harvester	13	659	30.99	< 0.0001

Appendix 10. A) Frequency of the different variables used to standardize (PROC MIXED) catches per unit effort and B) variance analysis results for shore harvesting of Atlantic Surfclam in Area A-09.5 in the Îles-de-la-Madeleine.

A)

Variable	Value	Frequency (number)	Percentage (%)
Year	2005	40	6.04
	2006	74	11.18
	2007	35	5.29
	2008	29	4.38
	2009	21	3.17
	2010	59	8.91
	2011	56	8.46
	2012	54	8.16
	2013	70	10.57
	2014	42	6.34
	2015	64	9.67
	2016	58	8.76
	2017	35	5.29
	2018	25	3.78
Harvester	1	24	3.63
	2	62	9.37
	3	43	6.5
	4	118	17.82
	5	12	1.81
	6	124	18.73
	7	6	0.91
	8	60	9.06
	9	213	32.18

B)

Covariance

Factor	Estimated	Number of observations
Residual	0.1064	662

Type-III test. fixed effects

Factor	Degrees of freedom for the numerator	Degrees of freedom for the denominator	F-value	P > F
Year	13	640	23.27	< 0.0001
Harvester	8	640	11.84	< 0.0001

Appendix 11. A) Frequency of the different variables used to standardize (PROC MIXED) catches per unit effort and B) variance analysis results for shore harvesting of Atlantic Surfclam in Area 16.2.1.1 in the Îles-de-la-Madeleine.

A)

Variable	Value	Frequency (number)	Percentage (%)
Year	2007	9	10.71
	2008	6	7.14
	2015	16	19.05
	2016	28	33.33
	2017	7	8.33
	2018	18	21.43
Harvester	1	7	8.33
	2	17	20.24
	3	41	48.81
	4	19	22.62

B)

Covariance

Factor	Estimated	Number of observations
Residual	0.1268	84

Type-III test. fixed effects

Factor	Degrees of freedom for the numerator	Degrees of freedom for the denominator	F-value	P > F
Year	5	75	1.81	0.1209
Harvester	3	75	6.53	0.0006

Appendix 12. A) Frequency of the different variables used to standardize (PROC MIXED) catches per unit effort and B) variance analysis results for shore harvesting of Atlantic Surfclam in Area A-17.4 in the Îles-de-la-Madeleine.

A)

Variable	Value	Frequency (number)	Percentage (%)
Year	2014	23	29.49
	2015	12	15.38
	2016	15	19.23
	2017	19	24.36
	2018	9	11.54
Harvester	1	50	64.10
	2	28	35.90

B)

Covariance

Factor	Estimated	Number of observations
Residual	0.1712	78

Type-III test. fixed effects

Factor	Degrees of freedom for the numerator	Degrees of freedom for the denominator	F-value	P > F
Year	4	72	1.97	0.1078
Harvester	1	72	0.09	0.7704

Appendix 13. Period covered and position (NAD83 latitude and longitude) of sites used to monitor catches per unit effort for commercial dredging of Atlantic Surfclam in the Îles-de-la-Madeleine (based on available data).

Site	Sub-area	Latitude (N)	Longitude (W)	Period
1	5A1	47°38.28' to 47°38.97'	61°22.01' à 61°23.05'	Nov. 2009 to Dec. 2018
2	5B1	47°39.35' to 47°39.89'	61°25.48' to 61°26.45'	Nov. 2010 to Nov. 2012 and Sept. 2015 to Oct. 2018

Appendix 14. Number of Atlantic Surfclams measured (number of samples or number of sea trips in parentheses) by fishing type, bed and year under the DFO landed commercial catch sampling program and At-Sea Observer Program.

Year	Dredger			Hand harvest by divers			Hand harvest by Shore harvesters			
	CGE	East	North	A-09.5	A-12.1	A-16.2[1]	A-09.5	A-16.2[1]	A-17.1	A-17.4
Dockside sampling										
2004	-	1 102 (4)	-	-	-	-	-	-	-	-
2005	-	165 (1)	333 (2)	139 (1)	575 (3)	-	2 121 (13)	-	-	-
2006	217 (1)	204 (1)	872 (4)	158 (1)	670 (4)	-	1 263 (8)	-	-	-
2007	175 (1)	661 (4)	200 (1)	-	2 022 (13)	159 (1)	1 082 (6)	947 (8)	-	-
2008	-	746 (4)	-	-	2 144 (14)	-	1 811 (11)	271 (2)	58 (1)	-
2009	-	799 (3)	1 512 (8)	185 (1)	786 (5)	-	694 (4)	-	105 (1)	-
2010	-	-	1 536 (9)	-	1 590 (10)	-	1 434 (8)	-	261 (2)	-
2011	-	-	1 650 (9)	508 (3)	1 115 (7)	-	1 183 (7)	-	-	-
2012	300 (2)	-	1 772 (11)	-	1 370 (9)	-	575 (3)	97 (1)	150 (1)	-
2013	-	-	1 632 (10)	-	1 568 (10)	-	-	951 (6)	337 (2)	-
2014	-	150 (1)	1 385 (9)	-	860 (6)	-	-	197 (1)	431 (3)	153 (1)
2015	-	-	1 550 (10)	-	-	-	300 (2)	150 (1)	753 (5)	300 (2)
2016	-	-	1 543 (10)	-	1 399 (9)	167 (1)	150 (1)	643 (4)	282 (2)	300 (2)
2017	-	-	1 505 (10)	-	943 (6)	509 (4)	-	1 445 (9)	150 (1)	-
2018	-	-	1 473 (10)	-	617 (4)	300 (2)	150 (1)	627 (4)	-	374 (2)
Sea sampling										
2005	-	301 (1)	-	-	-	-	-	-	-	-
2006	-	-	1 723 (2)	-	-	-	-	-	-	-
2007	-	1 747 (2)	1 120 (1)	-	-	-	-	-	-	-
2008	-	245 (1)	-	-	-	-	-	-	-	-
2009	-	-	2 725 (6)	-	-	-	-	-	-	-
2010	-	-	1 406 (3)	-	-	-	-	-	-	-
2011	-	-	2 221 (3)	-	-	-	-	-	-	-
2012	-	-	779 (2)	-	-	-	-	-	-	-
2013	-	-	534 (1)	-	-	-	-	-	-	-
2014	-	-	958 (2)	-	-	-	-	-	-	-
2015	-	-	1 196 (2)	-	-	-	-	-	-	-
2016	-	-	1 543 (2)	-	-	-	-	-	-	-
2017	-	-	952 (1)	-	-	-	-	-	-	-
2018	-	-	606 (1)	-	-	-	-	-	-	-

[1] Shellfish area A-16.2.1.1.

Appendix 15. Annual landings by sub-area or bed, total landings by type of commercial fishery and estimate of catches from unreported fishing activities (SPSs) for Atlantic Surfclam from the Îles-de-la-Madeleine.

Year	Dredging (t)				Hand harvesting (t)			Total (t)	
	5A1	5B1	North	Total	Divers	Shore harvesters	Total	Quebec	SPS
2002	107.6	-	(0.5)	107.6	-	-	-	107.6	-
2003	115.0	-	(3.4)	115.0	-	-	-	115.0	147.4
2004	111.9	-	16.1	111.9	-	-	-	111.9	140.6
2005	106.7	(17.8)	63.5	125.3	3.6	13.6	17.2	142.4	126.1
2006	107.8	-	77.9	107.8	1.5	21.1	22.6	130.4	117.5
2007	118.8	(5.6)	35.6	124.4	18.0	16.2	34.2	158.6	98.7
2008	119.5	32.4	41.8	158.6	5.3	10.1	15.4	174.1	109.9
2009	109.9	160.3	190.7	270.7	13.4	6.2	19.6	290.3	118.6
2010	124.3	97.2	188.2	221.6	26.7	10.7	37.4	259.0	124.8
2011	102.1	122.6	219.5	227.4	7.4	8.1	15.5	242.9	117.4
2012	107.3	128.7	230.1	236.1	12.2	8.1	20.3	256.4	124.5
2013	131.7	114.8	246.5	246.5	28.7	13.0	41.7	288.2	140.0
2014	130.2	115.2	240.1	246.2	37.2	8.9	46.1	292.3	106.6
2015	126.4	115.0	241.4	241.4	5.9	11.5	17.4	258.8	18.1
2016	122.8	118.2	241.0	245.4	47.3	11.2	58.5	304.0	65.8
2017	122.9	110.8	233.7	233.7	40.4	9.0	49.4	283.1	64.0[1]
2018	119.5	110.2	229.7	229.7	39.3	6.1	45.4	275.1	73.0[1]
Ref.[2]	116.6	111.5	161.9	188.7	17.9	11.4	30.4	213.4	108.0
Diff.[3]	+3 %	-1 %	+42%	+22 %	+120 %	-47 %	+49 %	+29 %	-
Mean[4]	121.7	113.0	234.8	236.3	42.3	8.8	51.1	287.4	67.6

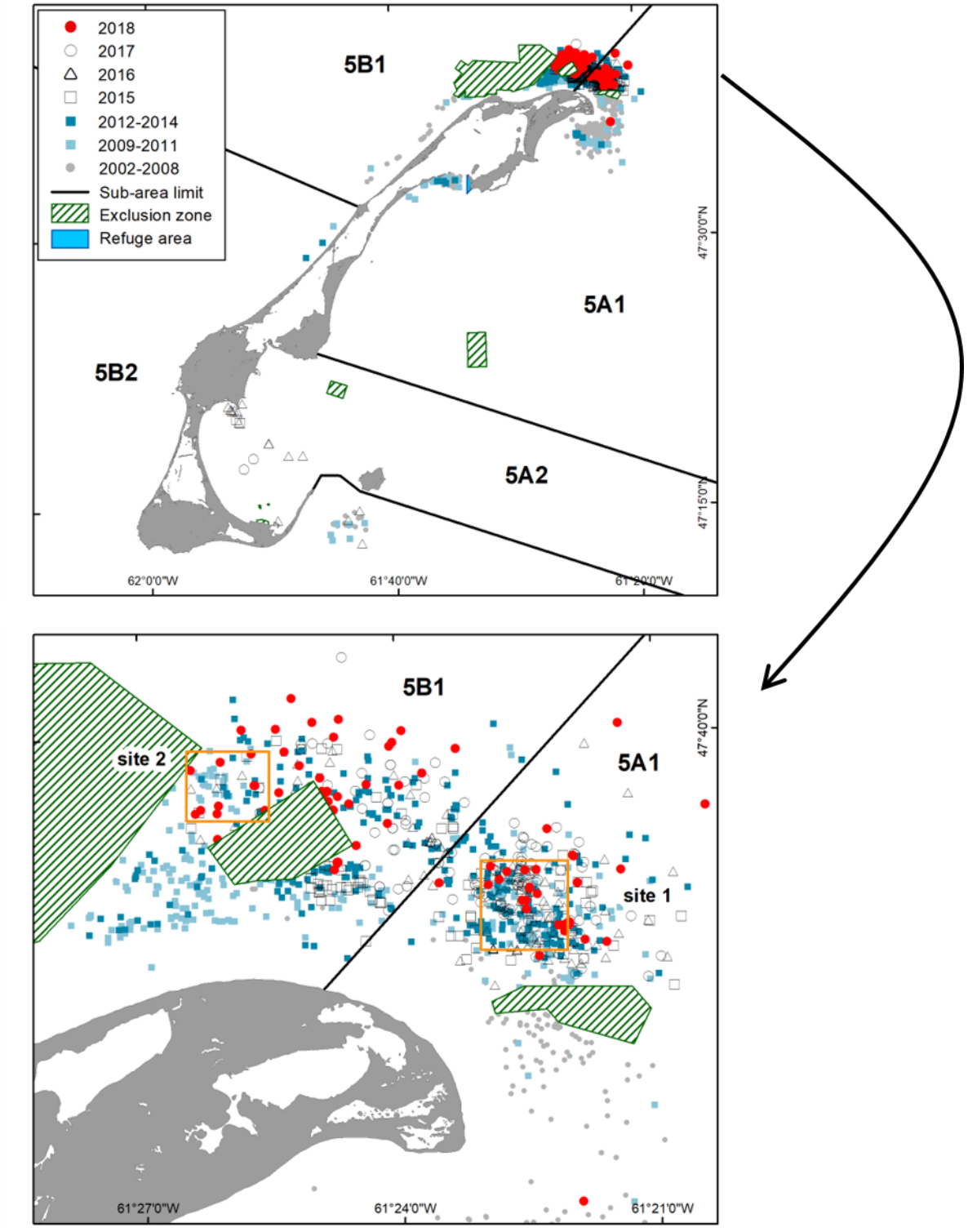
[1] Values for 2017 and 2018 are preliminary.

[2] Reference mean from 2002 to 2017 for 5A1, from 2008 to 2017 for 5B1, from 2004 to 2017 for the North bed, and from 2005 to 2017 for hand harvest (by divers and shore harvesters). The values in parentheses were excluded from the reference mean calculation.

[3] Difference between the 2018 value and the reference mean.

[4] Mean for the last three years (2016 to 2018).

Appendix 16. Fishing location, zoom-in of the North bed and location of sites (yellow boxes) used to monitor the CPUEs of the commercial Atlantic Surfclam dredge fishery from 2002 to 2018 in the Îles-de-la-Madeleine.



Appendix 17. Annual fishing effort by sub-area and total fishing effort by type of commercial Atlantic Surfclam fishery in the Îles-de-la-Madeleine.

Year	Dredging (days)				Hand harvesting (days)		
	5A1	5B1	North	Total	Divers	Shore harvesters	TOTAL
2002	65	-	(2)	65	-	-	-
2003	64	-	(1)	64	-	-	-
2004	64	-	7	64	-	-	-
2005	31	(12)	18	44	19	114	133
2006	55	-	35	55	11	189	200
2007	62	(4)	23	66	67	159	226
2008	42	13	14	62	21	92	113
2009	43	53	62	97	40	65	105
2010	34	28	52	63	140	142	282
2011	25	36	59	65	38	83	121
2012	16	24	38	40	61	98	159
2013	21	20	41	41	130	132	262
2014	23	18	39	42	150	106	256
2015	26	19	45	46	45	140	185
2016	22	18	40	48	157	141	298
2017	25	26	51	52	166	116	282
2018	21	23	44	44	157	82	239
Ref.[1]	39	26	37	57	80	121	202
Diff.[2]	-46 %	-10 %	+18 %	-23 %	+95 %	-32 %	+18 %
Mean[3]	23	22	45	48	160	113	273

[1] Reference mean from 2002 to 2017 for 5A1, from 2008 to 2017 for 5B1, from 2004 to 2017 for the North bed, and from 2005 to 2017 for hand harvest (by divers and shore harvesters). The values in parentheses were excluded from the reference mean calculation.

[2] Difference between the 2018 value and the reference mean.

[3] Mean for the last three years (2016 to 2018).

Appendix 18. Annual mean standardized catch per unit effort by fishing type and by bed or shellfish area for the commercial Atlantic Surfclam fishery in the Îles-de-la-Madeleine.

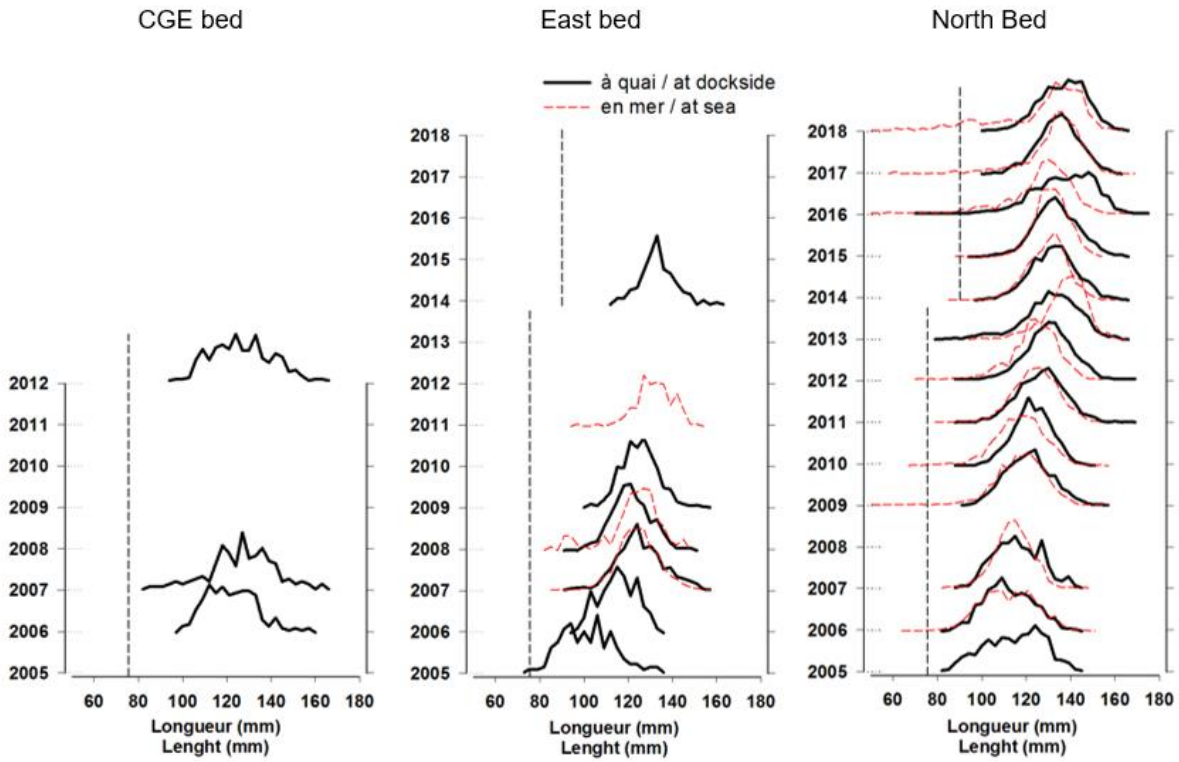
Year	Dredging (kg/h·m)			Hand harvesting (kg/h)				
	CGE	East	North	Divers		Shore harvesters		
				A-09.5	A-12.1	A-09.5	A-16.2.1.1	A-17.4
2002	81.7	153.1	-	-	-	-	-	-
2003	87.4	138.5	-	-	-	-	-	-
2004	-	114.4	159.1	-	-	-	-	-
2005	-	207.9	206.7	-	43.3	38.5	-	-
2006	107.9	-	150.5	-	-	33.2	-	-
2007	-	122.8	108.2	-	58.0	29.6	21.0	-
2008	-	136.8	193.3	-	81.3	33.5	20.4	-
2009	157.6	132.3	197.0	-	68.7	30.1	-	-
2010	-	-	237.5	-	52.0	17.6	-	-
2011	-	-	222.5	-	38.1	20.0	-	-
2012	-	-	304.8	-	50.3	16.8	-	-
2013	-	-	292.0	-	57.2	20.5	-	-
2014	-	-	275.7	-	61.9	19.3	-	11.5
2015	-	-	252.6	-	46.1	18.6	20.3	11.2
2016	-	-	273.0	50.7	60.8	19.1	21.4	17.7
2017	-	-	249.7	40.3	68.1	22.5	14.3	13.0
2018	-	-	269.7	78.4	92.2	25.3	16.6	16.4
Ref.[1]	108.6	143.7	223.0	45.5	57.1	24.6	19.5	13.3
Diff.[2]	-	-	+21 %	+72 %	+61 %	+3 %	-15 %	+23%
Mean[3]	-	-	264.1	56.5	73.7	22.3	17.4	15.7

[1] Reference mean from 2002 to 2017 for the CGE and East beds, from 2004 to 2017 for the North bed and from 2005 to 2017 for hand digging (by divers and shore harvesters).

[2] Difference between the 2018 value and the reference mean.

[3] Mean for the last three years (2016 to 2018).

Appendix 19. Size structure (%) of Atlantic Surfclams landed (at dockside) and caught at sea, by bed, in the commercial dredge fishery in the Îles-de-la-Madeleine (the vertical dashed line represents the minimum legal size).



Appendix 20. Annual mean size (mm) of Atlantic Surfclams landed (at dockside) by fishing type and by bed or shellfish area in the commercial fishery in the Îles-de-la-Madeleine.

Year	Dredging			Diver harvesting			Shore harvesting				
	CGE	East	North	A-09.5	A-12.1	A-16.2[1]	A-09.5	A-12.1	A-16.2[1]	A-17.1	A-17.4
2004	-	(110)	-	-	-	-	(86)	-	-	-	-
2005	-	(102)	(115)	(102)	(127)	-	(89)	-	-	-	-
2006	(122)	(115)	(112)	(103)	(131)	-	(94)	-	-	-	-
2007	(127)	(126)	(116)	-	(129)	(134)	(97)	-	(118)	-	-
2008	-	(121)	-	-	(136)	-	(98)	-	(115)	(123)	-
2009	-	(125)	(121)	(124)	(134)	-	(93)	-	-	(116)	-
2010	-	-	(123)	-	(133)	-	(99)	-	-	(105)	-
2011	-	-	(127)	(125)	(132)	-	(95)	-	-	-	-
2012	(127)	-	(130)	-	(131)	-	(107)	(107)	(93)	(94)	-
2013	-	-	(131)	-	(129)	-	-	(114)	(94)	(104)	-
2014	-	133	132	-	144	-	-	112	101	110	104
2015	-	-	134	-	-	-	109	-	110	121	107
2016	-	-	137	-	146	131	120	117	117	115	111
2017	-	-	134	-	131	131	-	-	114	119	-
2018	-	-	137	-	132	135	108	122	104	-	111
Ref.[2]			134		140	131	114	115	111	116	107
Diff.[3]			+2 %		-6 %	+3 %	-6 %	+6 %	-6 %		+3 %
Mean[4]			136		136	132	114	120	111	117	111

[1] Shellfish area A-16.2.1.1.

[2] Reference mean from 2014 to 2017. The values in parentheses were excluded from the reference mean calculation.

[3] Difference between the 2018 value and the reference mean.

[4] Mean for the last three years (2016 to 2018).

Appendix 21. Mean size (mm ± standard error) and size range (mm) of Atlantic Surfclams caught at sea on the North bed in the commercial dredge fishery in the Îles-de-la-Madeleine.

Year	Mean size	Range	Year	Mean size	Range
2006	112 ± 3.5	66-148	2013	137 ± 1.9	96-162
2007	114	85-146	2014	129 ± 1.7	88-158
2008	-	-	2015	131 ± 0.8	90-152
2009	116 ± 1.0	31-155	2016	125 ± 1.4	20-164
2010	117 ± 1.9	71-154	2017	132	61-166
2011	124 ± 2.4	81-152	2018	127	43-160
2012	124 ± 0.6	73-152	-	-	-

Appendix 22. Number of licences issued annually, number of active fishers and the actual fishing season for commercial hand harvesting of Atlantic Surfclam in the Îles-de-la-Madeleine.

Year	Licences issued	Active harvesters	Actual fishing season
2005	129	35	23/04 to 29/11
2006	134	41	17/03 to 24/10
2007	135	46	12/03 to 06/12
2008	135	30	10/03 to 29/08
2009	125	27	18/02 to 17/09
2010	132	43	14/03 to 15/11
2011	121	19	11/04 to 28/09
2012	128	31	22/04 to 25/09
2013	155	42	09/04 to 17/11
2014	140	37	19/03 to 09/10
2015	139	20	06/04 to 09/10
2016	141	37	07/05 to 31/10
2017	143	36	14/03 to 15/11
2018	126	24	28/02 to 02/10

Appendix 23. Annual mean non-standardized catch per unit effort (kg/h) by shellfish area for commercial dive and shore harvesting of Atlantic Surfclam in the Îles-de-la-Madeleine.

Year	Diver harvesting		Shore harvestings		
	A-09.5	A-12.1	A-09.5	A-16.2.1.1	A-17.4
2005	-	52.2	34.7	-	-
2006	-	-	31.1	-	-
2007	-	84.4	31.2	28.8	-
2008	-	131.9	34.9	28.1	-
2009	-	98.5	31.6	25.5	-
2010	39.6	60.6	19.8	-	-
2011	-	56.4	22.7	13.2	-
2012	-	58.0	18.5	19.7	-
2013	58.3	64.8	22.5	-	10.8
2014	60.7	52.4	21.2	-	11.5
2015	65.3	37.8	21.1	15.9	11.0
2016	56.8	69.2	20.9	18.4	16.9
2017	48.5	60.5	25.2	12.9	12.9
2018	80.0	73.7	25.9	12.6	16.5
Reference[1]	54.9	68.9	25.8	20.3	12.6
Difference[2]	+46 %	+7 %	0 %	-38 %	+30%
Mean[3]	61.8	67.8	24.0	14.6	15.4

[1] 2005-2017 reference mean.

[2] Difference between the 2018 value and the reference mean.

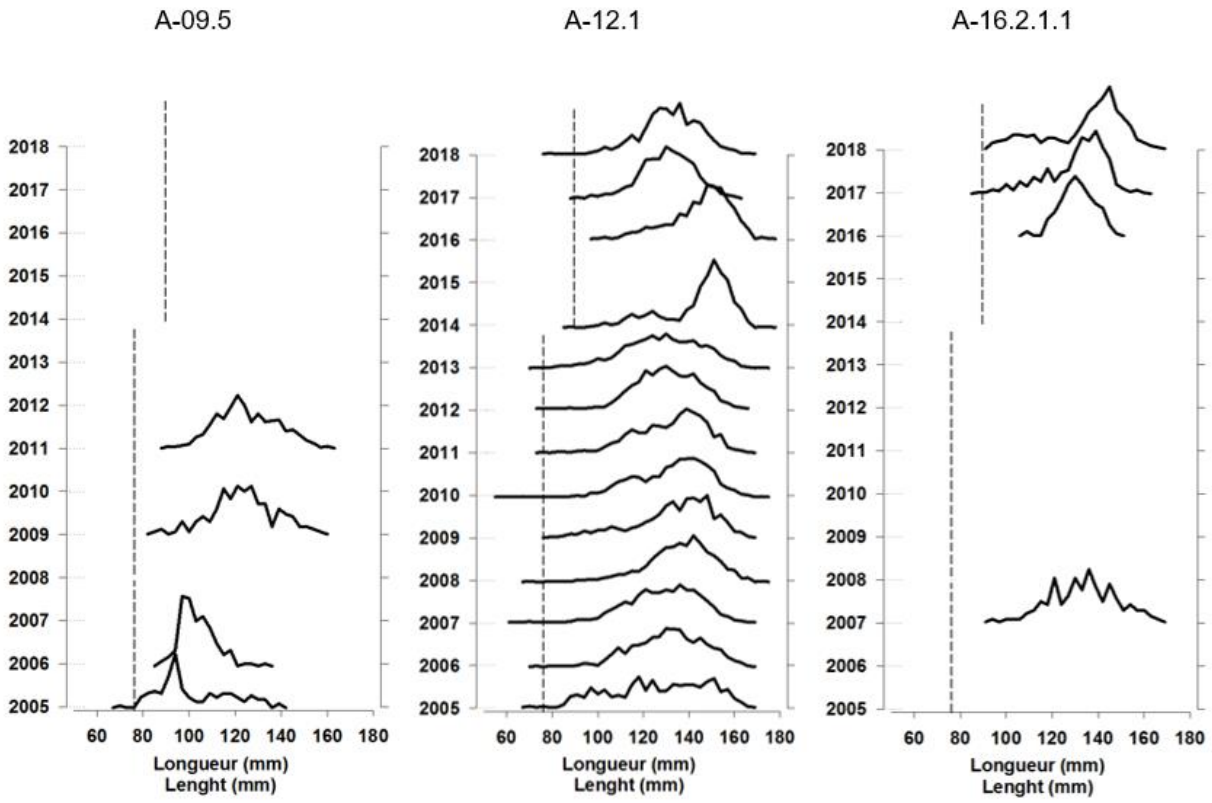
[3] Mean for the last three years (2016 to 2018).

Appendix 24. Annual landings (t) by shellfish area for commercial dive harvesting of Atlantic Surfclam in the Îles-de-la-Madeleine.

Year	A-05	A-09.1	A-09.5	A-10.1.4	A-11	A-12.1	A-16.2.1.1	A-17.1
2005	-	-	0.4	0.6	-	2.6	-	-
2006	-	0.6	0.1	-	-	0.3	-	0.4
2007	-	0.3	-	-	-	16.4	0.6	0.7
2008	-	-	0.7	-	-	4.6	-	-
2009	-	0.3	-	-	-	13.1	0.1	-
2010	-	-	5.0	-	-	21.7	-	-
2011	-	-	-	-	-	7.4	-	-
2012	2.0	-	1.0	-	0.2	9.0	-	-
2013	-	0.2	2.0	-	-	26.4	< 0.1	-
2014	-	4.7	4.2	-	-	27.9	-	-
2015	-	-	1.3	-	-	4.6	-	-
2016	-	0.3	10.9	-	0.3	34.1	1.3	< 0.1
2017	-	-	2.6	0.4	-	34.0	3.3	0.1
2018	-	-	10.7	-	-	27.3	0.5	0.8
Reference[1]	2.0	1.0	2.7	0.5	0.2	14.6	1.1	0.3
2016–2018 Mean		0.3	8.1	0.4	0.3	31.8	1.7	0.3

[1] Reference mean for 2005 to 2017.

Appendix 25. Size structure (%) of Atlantic Surfclams landings by shellfish area for commercial dive harvesting in the Îles-de-la-Madeleine (the vertical dashed line represents the minimum legal size).



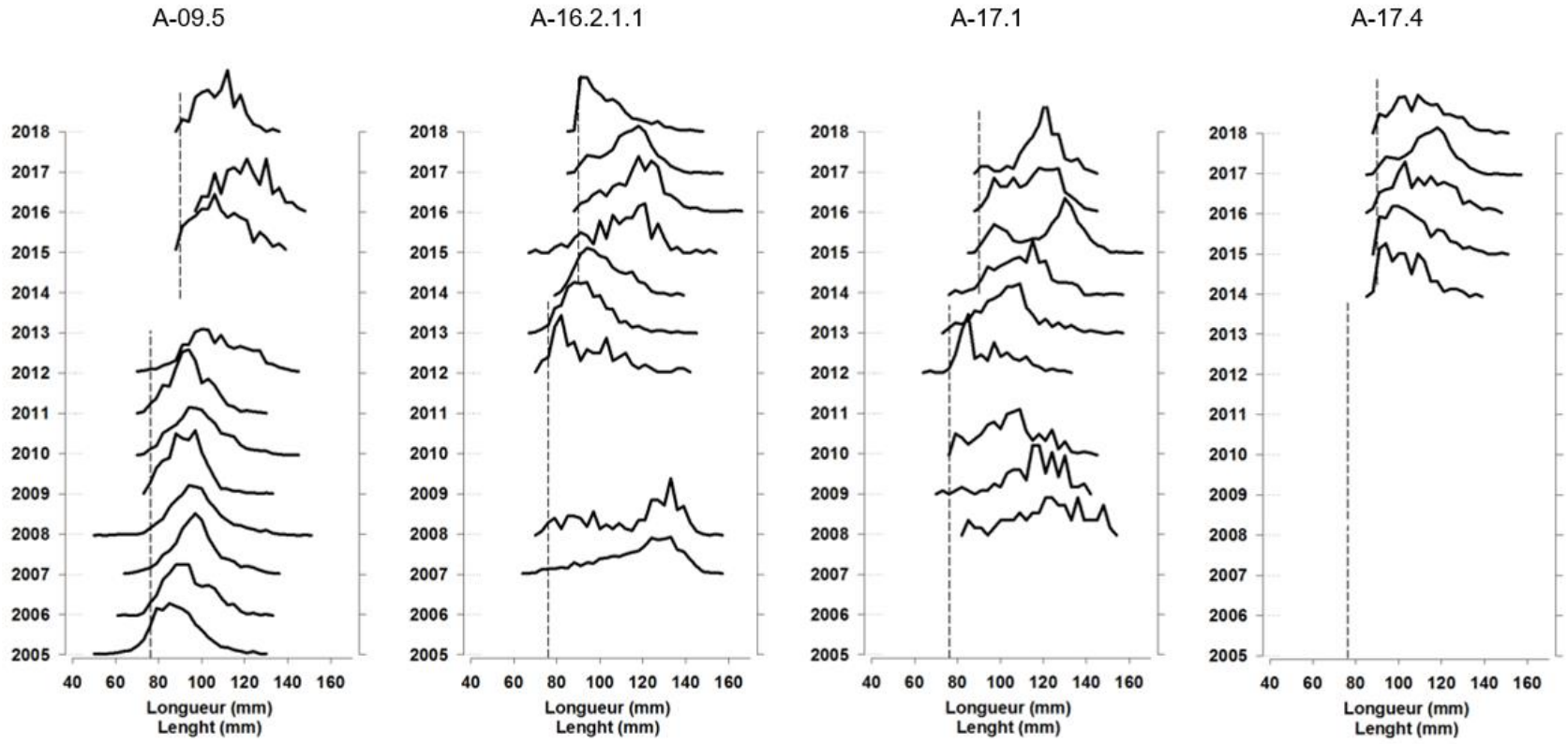
Appendix 26. Annual landings (t) by shellfish area for commercial shore harvesting of Atlantic Surfclam in the Îles-de-la-Madeleine.

Year	A-09.1	A-09.3	A-09.5	A-10.1.2	A-10.1.4	A-10.2	A-11	A-12.1	A-14.3	A-16.1.2	A-16.2.1.1	A-17.1	A-17.4
2005	0.5	0.5	12.3	-	-	-	-	0.1	-	0.1	-	< 0.1	< 0.1
2006	1.5	0.5	18.6	0.1	-	-	-	-	0.1	< 0.1	-	0.3	0.1
2007	0.7	-	13.5	-	-	-	-	-	0.2	0.1	1.4	0.3	-
2008	0.6	-	8.2	0.2	-	-	-	-	0.2	-	0.6	0.3	-
2009	0.7	-	4.7	-	-	-	-	0.2	-	< 0.1	0.1	0.4	-
2010	0.4	-	8.3	< 0.1	-	< 0.1	-	1.9	-	< 0.1	< 0.1	0.1	< 0.1
2011	-	-	7.2	-	-	-	-	0.8	-	< 0.1	-	0.1	-
2012	-	-	6.1	-	0.3	-	0.3	1.2	-	0.1	0.1	0.1	-
2013	0.2	-	9.4	-	0.1	-	-	1.9	-	0.1	0.2	0.2	0.9
2014	-	-	6.3	-	< 0.1	-	-	0.9	-	-	0.3	0.2	1.4
2015	-	-	8.0	-	-	-	-	0.9	-	-	1.6	0.5	0.5
2016	-	-	6.6	-	-	-	0.1	1.2	-	-	2.1	0.2	1.0
2017	0.4	-	4.8	-	-	-	-	1.3	-	-	1.3	0.4	0.8
2018	-	-	3.2	-	-	-	-	1.0	-	-	0.8	0.6	0.4
Reference[1]	0.6	0.5	8.8	0.1	0.1	< 0.1	0.2	1.0	0.2	0.1	0.8	0.2	0.6
Mean[2]	0.4	-	4.9	-	-	-	0.1	1.2	-	-	1.4	0.4	0.7

[1] Reference mean for 2005 to 2014.

[2] Mean for the last three years (2016 to 2018).

Appendix 27. Size structure (%) of Atlantic Surfclam landings by shellfish area from commercial shore harvesting in the Îles-de-la-Madeleine. The vertical dash line represents the minimum legal size.



Appendix 28. Minimum number of recreational shore Atlantic Surfclam harvesters (harvester-days), by shellfish area and by year, in the Îles-de-la-Madeleine based on volunteer surveys, logbooks and hail outs.

Area	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Max[1]
A-03.1	-	-	-	1	-	4	-	-	6	-	-	-	-	-	5
A-05[2]	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1
A-09.1	8	4	39	2	-	18	4	41	5	83	-	9	-	-	39
A-09.5	1 044	199	766	149	656	315	273	326	123	165	140	174	110	223	214
A-10.1.1	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1
A-10.1.2	-	-	-	-	-	5	-	-	-	-	-	1	-	-	5
A-10.1.4	-	-	-	1	-	-	1	-	-	-	-	-	-	-	1
A-11	4	1	-	-	3	2	3	-	7	-	-	16	-	-	14
A-12.1	10	4	82	-	13	198	18	65	143	76	177	101	182	136	49
A-13	-	-	-	-	-	-	-	-	-	-	3	-	-	-	3
A-14.2	-	-	1	-	-	-	1	-	-	-	-	1	-	-	1
A-14.3	-	2	7	3	28	9	-	3	-	-	-	2	-	2	7
A-15.1.2	2	7	62	-	20	8	5	-	3	-	-	-	-	20	50
A-16.1.2	21	9	10	13	2	2	6	3	3	1	-	-	-	-	11
A-16.2.1.1	-	-	244	56	25	27	9	29	14	27	106	280	102	84	74
A-16.2.1.2[3]	-	-	-	-	2	-	-	-	-	-	-	-	-	-	1
A-17.1	19	5	60	33	59	13	7	7	16	71	68	6	24	65	20
A-17.3[3]	-	2	-	-	-	-	-	-	-	-	-	-	-	-	1
A-17.4	36	4	-	2	4	4	7	3	100	39	35	99	137	262	49
Total[4]	1 144	237	1 271	260	812	605	334	478	421	462	529	689	555	792	-
Obs.[5]	67	37	187	34	74	162	76	131	204	285	118	216	258	244	-
Max.[1]	91	51	58	71	214	68	37	56	45	28	49	74	40	45	-

[1] Maximum number of recreational harvesters observed in an area on a given day by shellfish area (all years) or by year (all areas).

[2] Dive harvesters only.

[3] Closed shellfish area.

[4] Total number of recreational harvesters observed in all shellfish areas by year.

[5] Number of observations used to count recreational harvesters.