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Quebec Region

ASSESSMENT OF THE SEA CUCUMBER FISHERY IN QUEBEC'S INSHORE WATERS IN 2020

Photo: Jean-Paul Dallaire, DFO

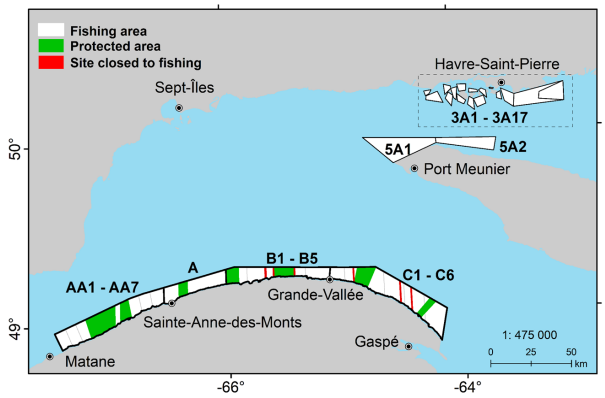


Figure 1. Sea cucumber management units (units AA, A, B, C, 3 and 5) in Quebec, with protected areas (in green) and fishery closure areas (in red).

Context:

*The sea cucumber (*Cucumaria frondosa*) fishery is a recent activity in the Estuary and northern Gulf of St. Lawrence. It began in 2008 on the Gaspé Peninsula's north shore and, in 2009, expanded to the Havre-Saint-Pierre area of the Middle North Shore. The fishery is carried out either by dive or with the use of a modified LGS-type dredge or a dredge designed specifically for fishing sea cucumbers on the North Shore. The catch is processed in Quebec and Maine, and products are exported mainly to Asian markets. There is currently no local market.*

In 2004, a study was conducted to determine the potential of this fishery on the Gaspé Peninsula's north shore. Initial exploratory licenses were issued in units A, B, C and 3 beginning in 2008-2009 and 2012-2013, and an experimental license, on the Lower North Shore in 2017.

Stock assessment indicators are derived from statistical data on the fishery, the sampling of commercial catches in units A, B, C and 3, the 2018 research survey in units A, B and C, and surveys along the Lower North Shore.

In general, the resource is assessed every three years to determine whether recent changes in its status justify altering the conservation approach and management plan. This assessment, originally planned for March 2020, was postponed due to the COVID-19 pandemic, and follows the one carried out in 2016 (DFO 2017) on the sea cucumber fishery in the Estuary and the northern Gulf of St. Lawrence.

SUMMARY

- The sea cucumber drag fishery in Quebec began in 2008 and is still in the exploratory stage in management units 3, B and C and in the experimental stage along the Lower North Shore. Average annual landings during the 2017-2020 period totalled 1,085.7 tonnes (t), 57.4% of which came from the Gaspé Peninsula's north shore and 42.6%, from the North Shore.
- The fishing effort seems to be generally well distributed in the various management units.
- Recent research confirms that the measurement of individual length and weight of sea cucumbers is strongly influenced by capture and handling conditions.

North Shore

Unit 3

- The authorized fishing effort increased from 100 to 120 fishing days in 2018. Average annual landings from 2017 to 2020 were 463 t, which is comparable to those in the period 2014-2016 (467 t). However, the fishing effort increased by 8.2% on average in 2017-2020 relative to 2014-2016, from 85 fishing days (2014-2016) to 94 fishing days (2017-2020).
- The mean CPUE in 2017-2020 (233 kg/h·m) is comparable to that in 2009-2016 (240.4 kg/h·m).
- The mean length of individuals measured at sea increased in 2018 (127 mm) relative to 2016 (108 mm) and has remained stable since then, but remains below the values recorded from 2009 to 2015 (137 mm on average).

Lower North Shore

- A total of four surveys were conducted from Kégaska to Blanc-Sablon in 2017 (two surveys), 2018 and 2020. The analysis of the survey data suggests that sea cucumbers along the Lower North Shore are low in density and small in size.

Gaspé Peninsula

- In 2015, management units B and C were divided into sub-units to improve the distribution of fishing effort. At the same time, the authorized range of depths that can be fished was modified from 22-40 m to 32-42 m, reducing the harvesting area, with TAC values lowered accordingly.
- In management units AA, A and B, a small-scale dive fishery was carried out on a trial basis in 2017 and 2018, to depths of around 18 m. This activity was not continued in 2019 and 2020 due to profitability problems and technical issues with dive harvesting.

Unit B

- The TAC was reduced from 350 t in 2016 to 325 t in 2017. Annual landings in 2017-2020 averaged 300.1 t. Fishing effort has been increasing since 2016.
- The CPUE declined from 2017 to 2018 but has been rising since then, reaching 581 kg/h·m in 2020, which is slightly under the 2017 value (641 kg/h·m).
- The mean length of individuals measured at sea in 2017-2019 was relatively stable (135 mm) and similar to that in 2016 (134 mm).

Unit C

- The TAC of 382 t in 2016 was reduced to 352 t in 2017 and to 271.8 t in 2020. Annual landings decreased from 421.6 t in 2017 to 259.3 t in 2020. The average fishing effort in 2017-2020 was 17.6% greater than in 2015-2016.
- The mean CPUE decreased between 2017 and 2020, and, at 183 kg/h·m, was 9.2% less than in 2015-2016 (201 kg/h·m).
- The mean length of individuals measured at sea was stable from 2017 to 2019 (average of 131 mm) and similar to that in 2015-2016 (137 mm).

Fishery independent surveys

- Research surveys were conducted by Fisheries and Oceans Canada (DFO) in 2018. From 2016 to 2020, the Mi'gmaq Maliseet Aboriginal Fisheries Management Association (MMAFMA) carried out post-season surveys along the north shore of the Gaspé Peninsula.
- According to the DFO survey, sea cucumbers are more abundant at depths of less than 20 m all along the Gaspé Peninsula, but are smaller in size.
- The DFO survey also shows that average weight and density decrease from west to east. At the depths fished in units B and C (32-42 m), the average density was 184 individuals/1,000 m^2 and 63 individuals/1,000 m^2, and the average weight was 780 g and 667 g in the two units respectively.
- Overall, the surveys showed that sea cucumber density is higher in protected areas than in fishing areas in a given survey year.

Perspectives for the 2021 to 2023 fishing seasons

- In Unit 3, an annual fishing effort similar to that of 2017-2020 could maintain the fishery's performance in the next three years. In addition, establishing one or more refuge areas is recommended.
- In units B and C, given the additional conservation measures implemented (protected areas and authorized range of depths for the fishery), maintaining landings near the average level for 2017-2020 should not have a major impact on sea cucumber abundance in these units in the next three years.

BACKGROUND

Species biology

The Sea Cucumber (*Cucumaria frondosa*) is an echinoderm found in the Arctic and North Atlantic oceans, ranging as far south as Cape Cod. It occurs in most inshore habitats in the Estuary and the Gulf of St. Lawrence. In their early years, sea cucumbers prefer depths of less than 10 m, but then migrate very slowly to depths of up to 60 m, although they sometimes can be found at depths of over 400 m. The species has five rows of tube feet which allow it to move and to attach to substrates. It prefers complex rocky bottoms or mixed substrates of gravels, stones, sand and shells. The sea cucumber feeds by spreading out its 10 tentacles to capture plankton suspended in the water column or organic matter on the substrate. Sea cucumbers are largely sedentary and aggregate in groups, which is critical to ensuring some degree of reproductive success, as the species reproduces by external fertilization. According to recent

research, the species can adjust its buoyancy, a strategy that allows it to be carried long distances by currents to avoid adverse environmental conditions (Hamel et al. 2019).

According to data from Les Escoumins, Quebec, spawning occurs in mid-June (Hamel and Mercier 1995) and is therefore believed to be later than in the Bay of Fundy (April–May), Newfoundland (February–May) and Maine (March–April). According to a recent study on the Gaspé Peninsula's north shore, spawning occurs there between late May and mid-June (Couillard et al. 2021). The sea cucumber has separate sexes but does not exhibit obvious sexual dimorphism, aside from a difference in gonopore shape (Hamel and Mercier 1996, Montgomery et al. 2018). Larval development takes roughly 6.5 weeks from the fertilization of the egg to larval settlement, when the undersides and sides of gravel as well as rock crevices are preferred (Hamel and Mercier 1996, So et al. 2010, Gianasi et al. 2020).

In Quebec, sea cucumbers are believed to begin to reach sexual maturity at between 80 and 102 mm, which is larger than in Newfoundland (Grant et al. 2006). According to another study done in Newfoundland (So et al. 2011), a minimum of 25 years is required to reach market size of 150 mm, while in the Gulf of St. Lawrence, this size is estimated to be reached at an minimum age of 10 years (Hamel and Mercier 1996).

Protecting at least one aggregation site in each management unit is often recommended as a conservation measure for this species to favour a certain level of reproductive success. It is important to note that reproductive success in the species is dependent on spawner density, since gametes are released in the water column, where fertilization takes place.

Fishery

Two different methods are used to harvest sea cucumbers. The first, dive fishing, consists of diving underwater and harvesting the animals, with or without the help of a siphon connected to a pump at the surface. This method is compulsory in units A, B and AA, taking place at depths of less than 18 m. It was used in 2009 and more recently in 2017 and 2018. The second method, drag fishing, consists of towing a dredge behind a fishing vessel. The dredges used in Quebec are a modified version of the LGS (light green sweep) dredge developed in the United States for harvesting green sea urchins. In recent years, a new, lighter and more compact wheeled model has been developed to potentially reduce the impact of dredging on the seabed. Sea cucumber dredges in Quebec range in width from no more than 2.45 m in Unit 3 to 3.65 m in units B and C.

The first trial of sea cucumber fishing in Quebec was carried out in 2008 in Unit C, along the Gaspé Peninsula's north shore (Figure 1). The following year, the fishery was expanded to nearby units A (dive fishing only) and B, and to Unit 3 in the Mingan region of the Middle North Shore. In 2010, protected areas were created all along the north shore of the Gaspé Peninsula, corresponding to about 15% of the authorized fishing area (Figure 1). In 2014, fishery closure areas were established in units B and C in order to conduct post-season surveys and assess the fishery's impacts on the habitat and benthic communities. From 2008 to 2014, the authorized range of depths varied depending on the management unit: below 18 m in units A and B for dive fishing, and between 22 m and 40 m in units B and C and greater than 20 m in Unit 3 for the drag fishery. Only one licence was issued per unit until 2012. Additional licences were issued in Unit 3 in 2012 and in units B and C in 2013. This fishery is still in the exploratory stage in all management units, except for the Lower North Shore, where an experimental fishing licence was granted in 2017, as well as in Unit AA where an experimental dive fishing licence was issued in 2018.

In 2015, units B and C were divided into sub-units to promote the better distribution of the fishing effort. At the same time, to avoid use conflicts with other fisheries, the harvestable area in units B and C was reduced by scaling down the authorized range of depths for the drag fishery from 22-40 m to 32-42 m. In addition, a legal minimum size of 114 mm has been in effect in all units along the Gaspé Peninsula's north shore since 2015 and along the North Shore since 2016. In 2018, Unit AA was created and is reserved solely for dive fishing.

TACs are used to manage the fishery in units A, B and C. The TAC values were determined based on information obtained in the preliminary survey in 2004 (Campagna et al. 2005). In Unit 3, the fishery is managed by effort control, i.e., by limiting the number of fishing days per season and the number of fishing hours per day.

ASSESSMENT

The data on landings, fishing effort and CPUE used in this assessment come from harvesters' logbooks and processors' sales slips. The size structures and mean size measurements of sea cucumbers were obtained from data from the DFO commercial catch sampling program (landings) and from at-sea sampling under the At-Sea Observer Program. Fishing positions were taken from logbooks.

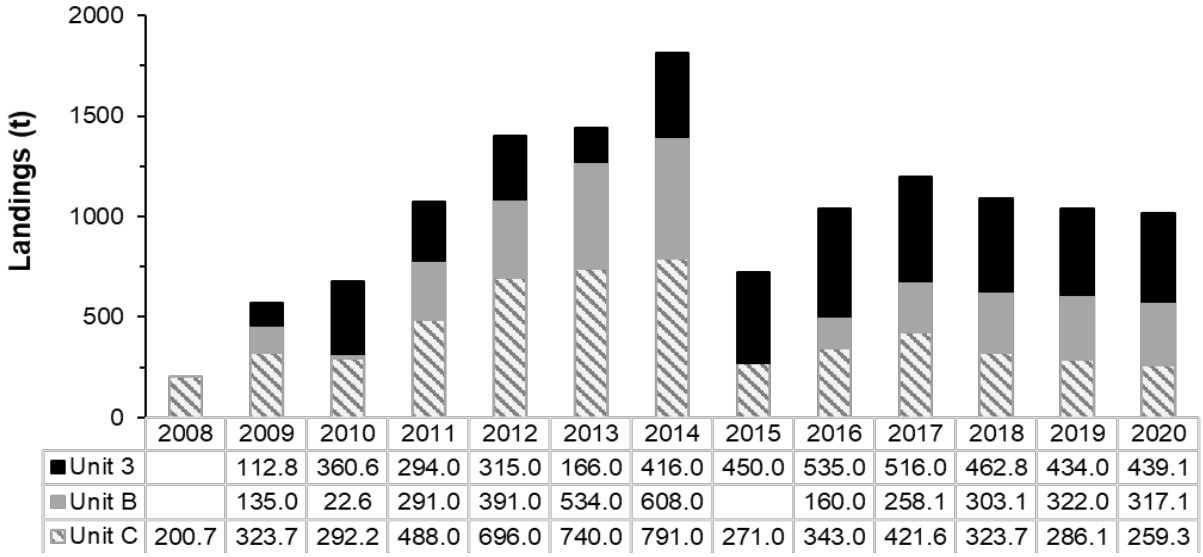
Drag fishery

From 2017 to 2020, average annual landings by the drag fishery were 1,085.7 t (Figure 2), with the most landings coming from, in decreasing order, the Gaspé Peninsula's north shore (57.4%, Unit B = 27.7%, Unit C = 29.7%), followed by the North Shore (42.6%, Unit 3). Average annual effort in these three units during the 2017-2020 period was 4,366.5 h·m (211.3 fishing days) (Figure 3).

In Unit 3 on the North Shore, the authorized fishing effort of 70 days established in 2010 was increased to 100 days with the addition of a new licence in 2014, then to 120 days in 2018. Landings remained below 400 t until 2013 and then rose to a peak of 535 t in 2016 owing to fishing in the newly exploited western portion of the unit (sub-units 3A6 and 3A15). Subsequently, from 2017, a gradual decline in landings was observed, with values reaching 434 t in 2019. In 2020, landings stabilized at 439 t (Figure 2). Fishing effort rose from an average of 1,834.7 h·m (84.7 fishing days) during the 2014-2016 period to 1,957.3 h·m (93.5 fishing days) during the 2017-2020 period, or an 8.2% increase (Figure 3). In 2016, CPUE values were the highest of the series (277 kg/h·m), declined to a low of 212.4 kg/h·m in 2019, and then rose again to 240.9 kg/h·m in 2020 (Figure 4). The mean CPUE during the 2017-2020 period (233 kg/h·m) is comparable to that in 2009-2016 (240.4 kg/h·m).

In Unit B in the Gaspé region, commercial landings increased between 2009 and 2014, when they peaked at 608 t, exceeding the TAC of 600 t (Figure 2). As a result of the reduction of the harvestable area in 2015, the TAC was also reduced to 350 t and divided among the five newly created sub-units. There was no fishery in 2015 and, in 2016, landings were only 160 t, from a single licence. In 2017, the TAC was lowered to 325 t and landings increased gradually to reach 322 t in 2019 and 317 t in 2020. The average fishing effort in Unit B during the 2017-2020 period was 586.3 h·m (41.3 fishing days), compared with 478 h·m (23 fishing days) in 2016, representing an increase of 22.7% (Figure 3). In 2020, the TACs allocated to the various sub-units were almost reached in B2 (89.6%) and B5 (92.2%), but were exceeded in B1, B3 and B4 (103.8%,120.1% and 107.7% respectively). Mean CPUE values increased between 2009 and 2014, peaking at 787 kg/h·m in 2014, and then plunging by more than 50% to 336 kg/h·m in 2016 (Figure 4). This decrease is partly attributable to changes in management measures,

including a substantial reduction in the harvestable area. Since the available fishing area is now smaller and the quota is divided up among the five sub-units, harvesters are forced to fish their entire area. As a result, few unexploited sites are left that, if fished, would improve the CPUE. After a significant increase in 2017, the CPUE declined from 2017 to 2018 but has been rising ever since, reaching 581 kg/h·m in 2020, slightly under the 2017 value (641 kg/h·m).



	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Unit 3		112.8	360.6	294.0	315.0	166.0	416.0	450.0	535.0	516.0	462.8	434.0	439.1
Unit B		135.0	22.6	291.0	391.0	534.0	608.0		160.0	258.1	303.1	322.0	317.1
Unit C	200.7	323.7	292.2	488.0	696.0	740.0	791.0	271.0	343.0	421.6	323.7	286.1	259.3

Figure 2. Landings (tonnes) by the commercial sea cucumber drag fishery in management units in Quebec from 2008 to 2020.

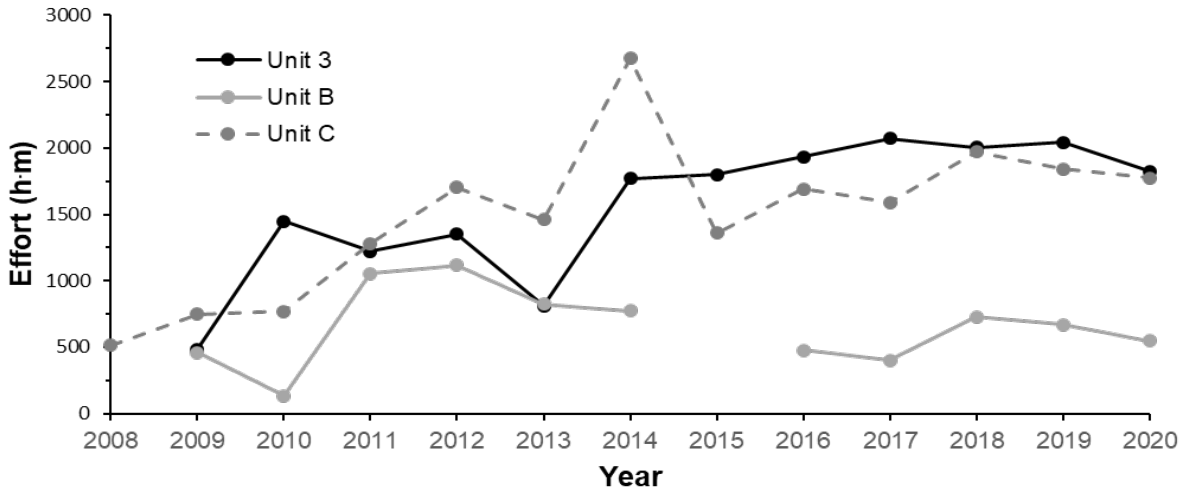


Figure 3. Fishing effort by the commercial sea cucumber drag fishery in management units in Quebec from 2008 to 2020.

In Unit C, the TAC of 800 t set in 2009 was almost reached from 2012 to 2014 (87.0%-98.9%). With the division of the unit into six sub-units in 2015 because of the reduction in harvestable area, the TAC was successively reduced to 382 t, 352 t and 271.8 t in 2015, 2017 and 2020 respectively. Even though two licences have been active since 2013, only 271 t were landed in

2015 and 343 t in 2016. Landings then declined further, from 422 t in 2017 to 256 t in 2020 (Figure 2). The average fishing effort during the 2017-2020 period was 17.6% greater (1,794.7 h·m, 76.5 fishing days a year) than that in 2015-2016 (1,525.5 h·m, 44.5 fishing days a year) (Figure 3). In 2020, the TACs for sub-units C3, C2, C1, and C6 were almost reached, by proportions of 77.1%, 91.9%, 96.2% and 99.3% respectively, while they were reached or exceeded in sub-units C5 and C4 at 100.3% and 109.8% respectively. The mean CPUE was 432 kg/h·m from 2011 to 2013, but then dropped sharply in 2014 (295.9 kg/h·m) when fishing effort was at its peak. As a result of the previously mentioned modifications to management measures, the CPUE stabilized at around 200 kg/h·m in 2015 and 2016 (Figure 4). After a slight increase in 2017 (265 kg/h·m), the CPUE continued to decline, falling to its lowest level of 146.1 kg/h·m in 2020. The mean CPUE during the 2017-2020 period (182.7 kg/h·m) was 9.2% lower than that in 2015-2016 (201.2 kg/h·m).

The size structures for sea cucumbers, based on the results of at-sea sampling in 2017-2019, show maximum sizes ranging from 210 mm to 260 mm depending on the unit and year (Figure 5). Data from at-sea sampling in 2020 were not available for this assessment. In Unit 3, the mean commercial size of individuals measured at sea in 2018 and 2019 (127 mm) was relatively stable and greater than in 2016 (108 mm) but lower than the values for the 2009-2015 period (137 mm on average; DFO 2014, 2017). In Unit B, the mean size of sea cucumbers measured at sea was relatively stable from 2017 to 2019 (135 mm) and was similar to that recorded in 2016 (134 mm; DFO 2017). In Unit C, the mean size of individuals measured at sea in recent years (2017-2019) (131 mm) has remained stable compared to 2016 (2015-2016 average: 137 mm; DFO 2017).

Dive fishery

The first sea cucumber dive fishery took place in 2009 in Unit A, on the Gaspé Peninsula's north shore, at a depth of roughly 18 m. An effort of nine fishing days resulted in landings of 23 t. Since then, no fishing activity has occurred in this unit, which is only accessible to dive licence holders. More recently, other small-scale dive fisheries have taken place on a trial basis in units B and AA in 2017 and 2018.

In Unit B, the TAC of 323 t was not reached in 2017 or 2018, with landings and fishing effort averaging around 66 t and 13 fishing days respectively. In Unit AA, created in 2018, landings totalled 53 t, with a fishing effort of 19 fishing days. Owing to the lack of information on the number of divers involved in this activity, the estimated CPUE per diver could not be calculated in these units. The size structure of sea cucumbers taken in the dive fishery and measured at sea, based on a single sample obtained in Unit AA in 2018, shows a maximum length of 240 mm and a mean length of 125 mm. The percentage of individuals smaller than the legal minimum size of 114 mm in the same sample was 35.5%.

The dive fishery was not conducted in 2019 and 2020 due to profitability problems and technical issues with dive harvesting.

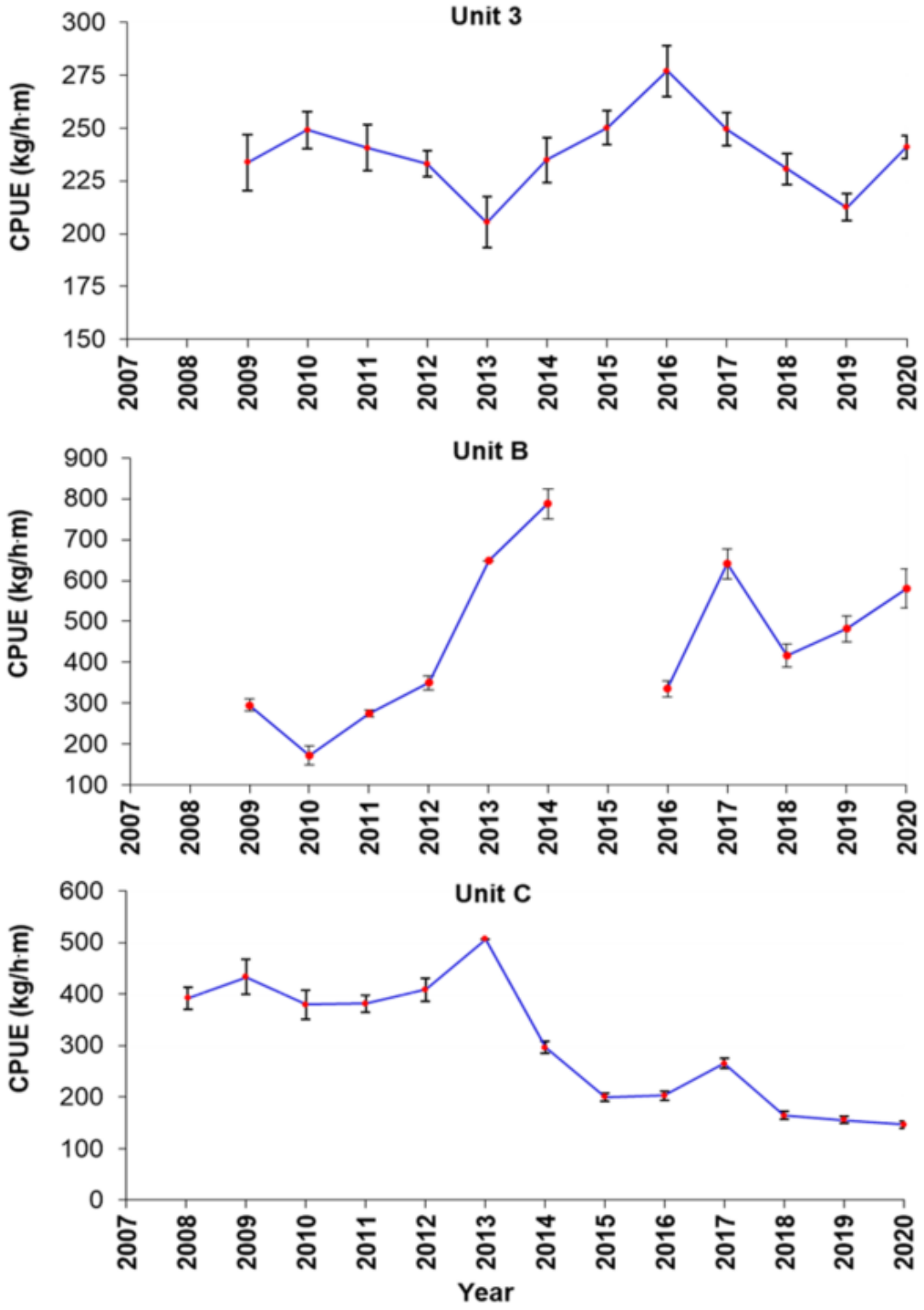


Figure 4. Annual CPUE (kg/h·m) in the commercial sea cucumber drag fishery in management units in Quebec.

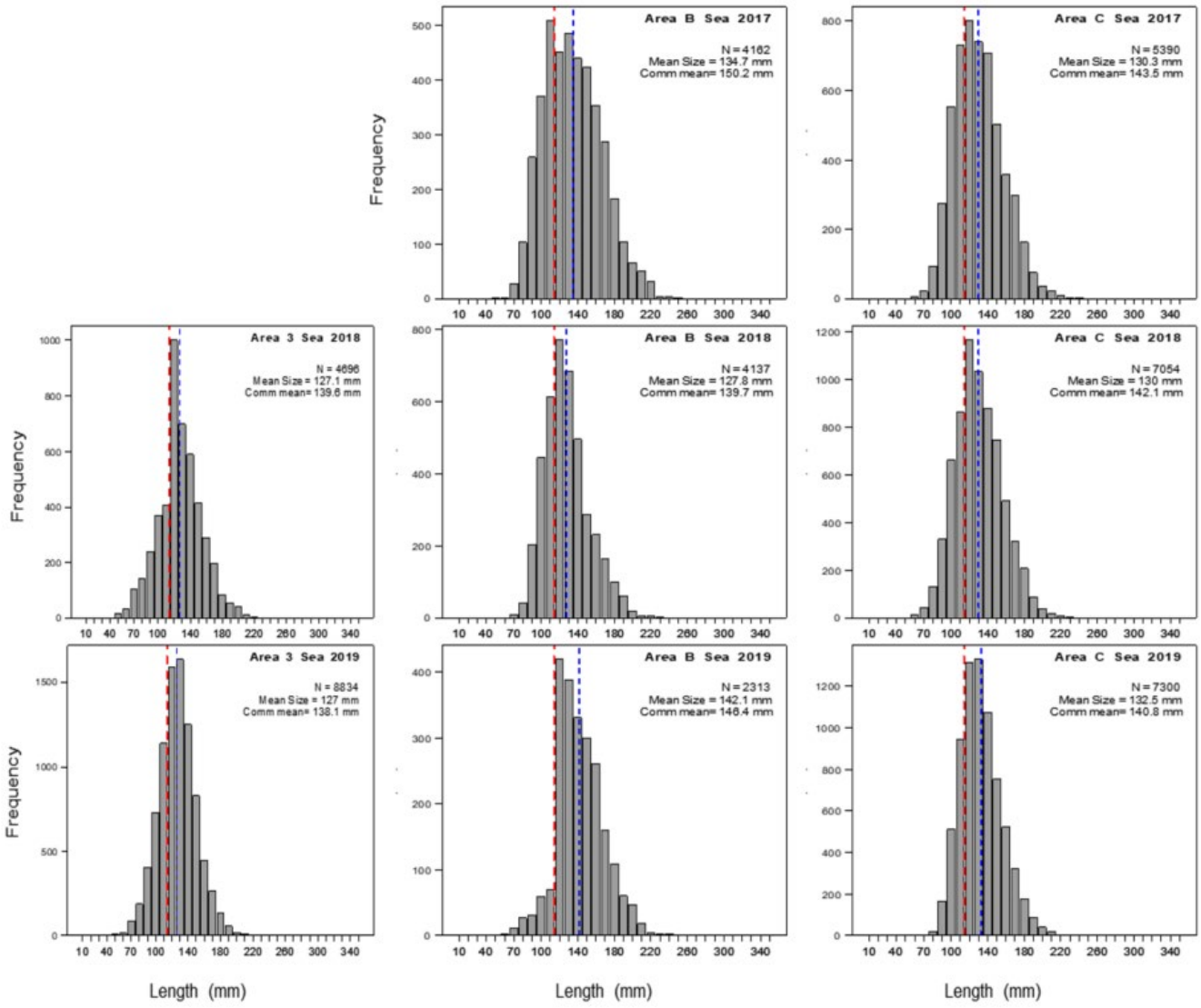


Figure 5. Size structure and number (N) of sea cucumbers caught in the drag fishery and measured at sea in units B, C and 3 from 2017 to 2019. The vertical dotted red line represents the legal minimum size of 114 mm, while the blue line indicates the mean size in the sample. The number (N), mean size of all individuals (Mean size) and the mean size of individuals ≥114 mm (Comm. mean, or commercial mean) are also shown.

Bycatch

From 2011 to 2019, the 10 main taxa in bycatches in units B, C and 3 represented from 3% to 25% of the total catch of all species (i.e., including sea cucumber) (Table 1). In Unit 3, bycatches appear to have increased since 2011, although ongoing monitoring was not carried out (paucity of data). In Unit B, bycatches have fallen since 2016 and are now at the same level observed in 2012-2014. In Unit C, the percentage is variable, with no clear trend observed since 2011. The composition of bycatch by taxa differs by management unit. In Unit 3, the bycatch was dominated by Green sea urchins, followed by starfish and *Hyas* spp., whereas the main bycatch species in units B and C were, in descending order, starfish, rock crab and *Hyas* spp. Lobster appeared in the bycatches in units B and C in 2018 and 2019 (Table 1).

Table 1. Number (N) and percentage (%) of sea cucumbers and percentage of the main bycatch taxa in the sea cucumber fishery in Quebec from 2011 to 2019, by management unit. The last column (Total Bycatch %) shows the total percentage represented by the main bycatch taxa in relation to the total catch of all species.

Year	Unit	Sea Cucumber		Main Bycatch Taxa (%)										Total Bycatch %
		N	%	Urchin	*Hyas* spp.	Rock Crab	Snow Crab	Scallops	Lobster	Whelk	Soft Corals	Anemone	Starfish	
2011	3	34,864	93.35	4.82	0.35	0.08	0.00	0.02	0.00	0.09	0.00	0.00	0.79	6.18
2015	3	16,891	79.47	6.02	7.81	1.52	0.00	0.03	0.00	0.07	0.00	0.00	2.35	18.30
2018	3	162,176	81.53	12.47	1.96	0.38	0.00	0.08	0.00	0.08	0.01	0.10	2.83	18.01
2019	3	202,839	73.89	19.18	2.09	0.24	0.01	0.12	0.00	0.16	0.00	0.12	3.10	25.30
2012	B	254,288	91.11	1.43	1.83	1.04	0.00	0.36	0.00	0.13	0.04	0.25	3.49	8.57
2013	B	413,966	93.54	0.18	1.03	1.27	0.00	0.18	0.00	0.01	0.00	0.36	3.43	6.45
2014	B	283,247	96.35	0.26	0.02	0.77	0.00	0.17	0.00	0.02	0.00	0.04	2.16	3.45
2016	B	120,400	79.12	0.64	0.09	5.17	0.00	0.81	0.00	0.17	0.00	0.87	12.32	20.07
2017	B	228,465	88.56	2.31	1.48	2.36	0.00	0.46	0.00	0.04	0.00	0.24	4.28	11.17
2018	B	56,241	89.55	0.10	2.66	2.61	0.00	0.19	0.00	0.07	0.01	0.09	3.55	9.28
2019	B	147,261	93.06	3.51	0.46	0.50	0.05	0.28	0.00	0.04	0.04	0.10	1.68	6.66
2011	C	310,634	95.60	0.00	1.06	0.95	0.00	0.06	0.00	0.00	0.00	0.00	2.28	4.35
2012	C	574,490	92.41	0.09	1.20	1.49	0.00	0.08	0.00	0.02	0.00	0.25	4.16	7.29
2013	C	434,479	88.84	0.31	0.98	2.27	0.00	0.70	0.00	0.17	0.13	0.28	6.21	11.07
2014	C	541,232	88.44	0.06	0.76	2.11	0.00	0.46	0.00	0.19	0.27	0.35	6.91	11.11
2015	C	177,324	92.60	0.01	0.13	1.70	0.00	0.04	0.00	0.06	0.00	0.30	4.06	6.31
2016	C	183,849	80.20	2.58	0.18	3.78	0.00	0.90	0.00	0.06	0.03	0.46	10.67	18.67
2017	C	200,964	90.84	0.56	1.27	3.12	0.01	0.45	0.00	0.02	0.00	0.15	2.99	8.58
2018	C	171,432	89.66	0.55	1.12	1.98	0.00	0.32	0.01	0.04	0.00	0.07	5.12	9.20
2019	C	157,337	84.02	0.20	3.22	4.99	0.01	0.87	0.02	0.06	0.05	0.54	5.42	15.39

Research surveys

In 2018, DFO conducted a post-season research survey from September 23 to October 13 along the Gaspé Peninsula's north shore (management units A, B and C), to assess the abundance and biological characteristics (size structure, average individual weight) of sea cucumbers. A stratified random sampling plan was used, covering all depth strata from 10 m to 80 m, defined a priori in the units and sub-units. A total of 206 drag tows were performed: 58 in Unit A, 73 in Unit B and 75 in Unit C. In addition to the drag tows, 10 video tows each were performed in units B and C, covering protected areas, fishery closure areas and authorized fishing areas.

Since 2013, post-season surveys have also been carried out by the Mi'gmaq Maliseet Aboriginal Fisheries Management Association (MMAFMA) in units B and C. The purpose of the surveys is to compare yields in the various fished and unfished (i.e., protected and fishery closure areas) sites, as well as to monitor the medium- and long-term impacts of dredging on benthic communities. Fixed stations targeting the 32-m isobath where sea cucumber fishing occurs have been sampled annually since 2016 (M.-H. Rondeau, MMAFMA, unpublished data).

Sea cucumber densities observed in the DFO survey vary by management unit (Figure 6). The average density in Unit C is lower than that in units A and B, regardless of whether all depths (Figure 6a) or only the stratum in which fishing occurs (32-42 m) (Figure 6c) are considered and whether protected areas and fishery closure areas are included (Figure 6). The average density observed in the depth stratum where fishing occurs (32-42 m) in units B and C was 184 individuals/1,000 m^2 and 63 individuals/1,000 m^2 respectively (Figure 6d).

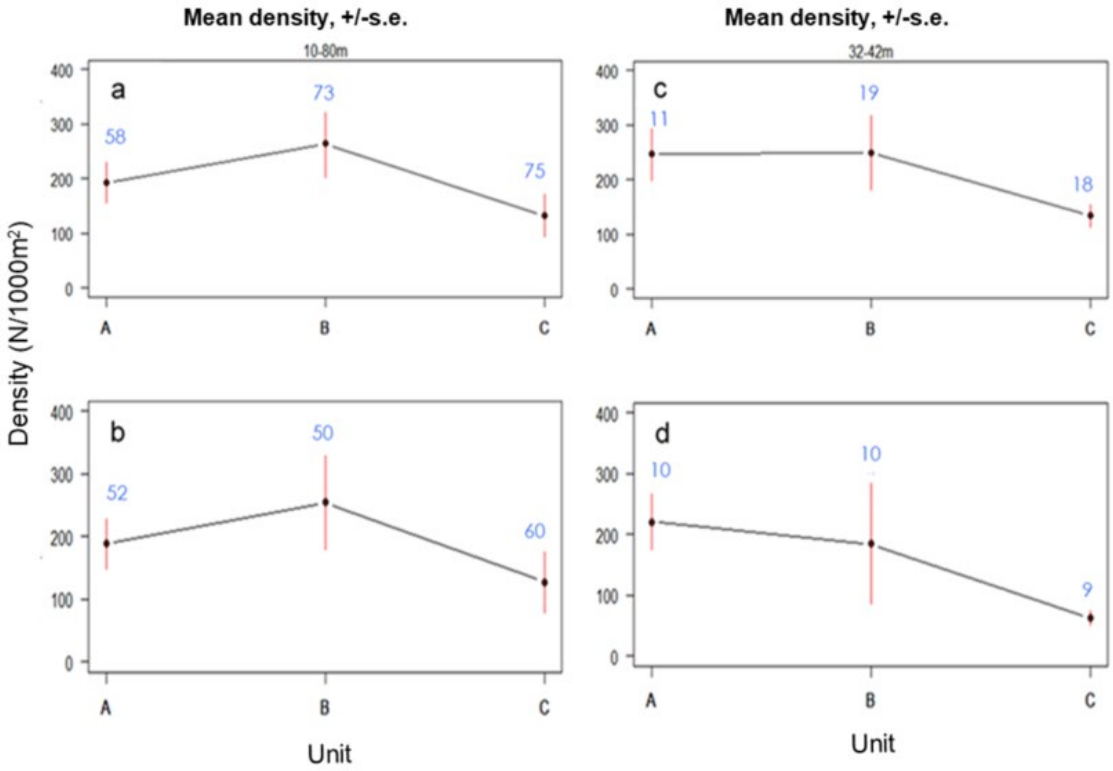


Figure 6. Density by abundance (N /1,000 m^2± standard error) obtained in the 2018 DFO survey of the Gaspé Peninsula's north shore, by management unit. Left: 10-80 m stratum: (a) entire unit (authorized fishing area, protected areas and fishery closure areas); (b) authorized fishing area only. Right: stratum exploited by the fishery (32-42 m); (c) entire unit (authorized fishing area, protected areas and fishery closure areas); (d) authorized fishing area only. The number in blue shows the number of tows performed.

According to the data from the DFO post-season survey, sea cucumber abundance is greater in protected areas than in fished areas in units B and C (Figure 7). MMAFMA's post-season surveys in the same units yielded similar results (Figure 8, M.-H. Rondeau, MMAFMA, unpublished data). The DFO survey also found that density varies as a function of depth (Figure 9). The highest sea cucumber densities (> 2,500 individuals/1,000 m^2) were observed at depths of less than 20 m in units B (sub-units B1 and B3) and C (sub-unit C1) (Figure 9). These high densities of small individuals could be nursery areas and could contribute to the renewal of the commercial population.

At shallow depths (< 20 m), the average individual weight observed in the DFO survey in units A, B and C was 480 g, 467 g and 424 g respectively (Figure 9). In the 32-42 m stratum exploited by the fishery, the average individual weight was 780 g and 667 g in units B and C, respectively. Average individual weight varies by management unit and depth, as well as along a west to east gradient. In all units, the average individual weight generally increased from shallow depths to medium depths (~40 m), and then decreased at greater depths (Figure 9).

Although a larger size range was found in fished areas, the average length of the individuals measured was generally slightly greater in the protected areas and fishery closure areas (155 mm) than in the authorized fishing areas (148 mm) (Figure 10).

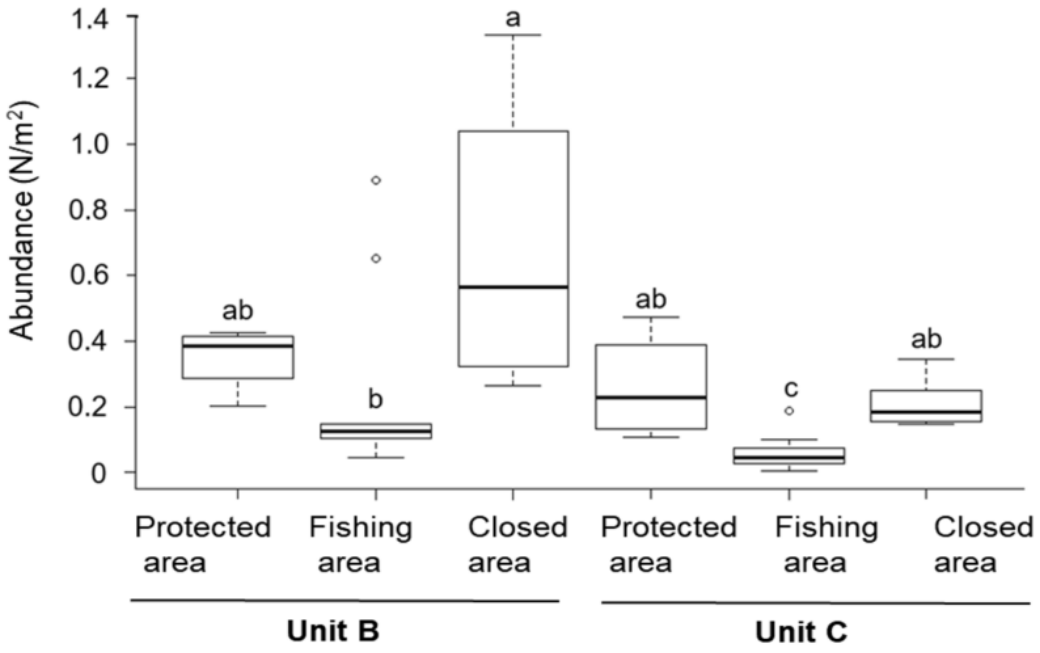


Figure 7. Sea cucumber abundance (N/m^2) observed on videos as a function of fishing status (protected area, authorized fishing area or fishery closure area) and management unit (unit B or C) during the 2018 DFO survey. In the box plot, the line inside the box represents the median value; the box, the 25 to 75 percentiles; the error bars, the 95% confidence interval; and the circles, extreme values. The letters indicate significant differences between areas and sites in the same management unit (figure taken from St-Pierre et al. 2021).

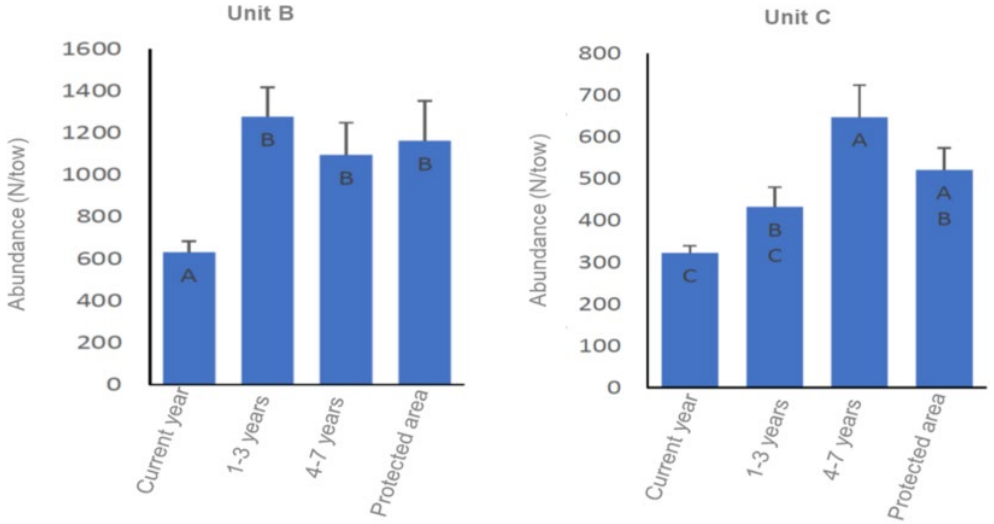


Figure 8. Abundance (number of individuals/tows ± standard error) obtained in post-season MMAFMA surveys from 2016 to 2019, based on sites fished in the current year (in progress), sites fished 1-3 years ago, sites fished 4-7 years ago, and control sites (protected areas) in units B and C. The different letters indicate significant differences between sites in the same management unit (with permission from M.-H. Rondeau, MMAFMA).

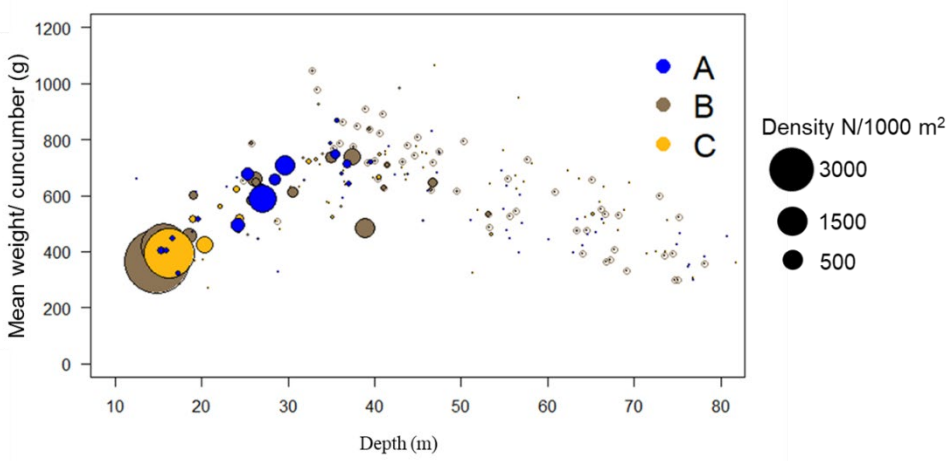


Figure 9. Average individual weight (grams) and density by abundance (N/1,000 m^2) of sea cucumbers by management unit and depth according to the 2018 DFO survey. The colour indicates the management unit, and the size of the circles is proportionate to density.

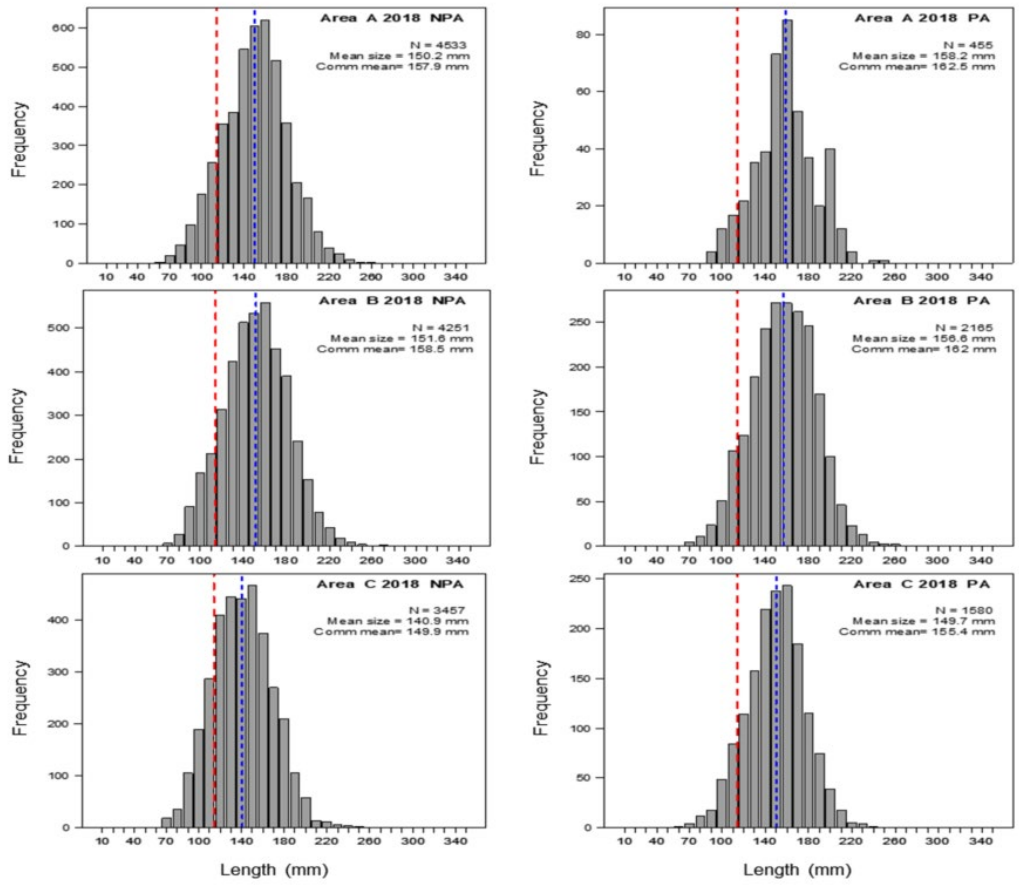


Figure 10. Size structure of sea cucumbers in the 10-80 m stratum by management unit obtained in the 2018 research survey. Left: unprotected areas (NPA). Right: protected areas and fishery closure areas (PA). The vertical dotted red line represents the legal minimum size of 114 mm, while the blue line indicates the mean size in the sample. The number (N), mean size of all individuals (Mean size) and the mean size of individuals ≥114 mm (Comm. mean, or commercial mean) are also shown.

Experimental fisheries on the Lower North Shore

Surveys were conducted along the Lower North Shore in 2017, 2018 and 2020 by one harvester and the *Agence Mamu Innu Kaikusseth* (*AMIK*), to obtain information on sea cucumber distribution, abundance and size structure. The surveys covered the area from Kégaska to Saint-Augustin between July 24 and August 2, 2017; from La Tabatière to Saint-Augustin between September 11 and 17, 2017; and from Vieux-Fort to Blanc-Sablon between September 4 and September 20, 2018 and between August 15 and October 3, 2020. Only 19.9% of the 341 drag tows (each 5 minutes long at 1.5 knots) yielded 10 or more sea cucumbers.

Sea cucumber densities in the Kégaska to Saint-Augustin sector ranged from zero to 776.1 individuals/1,000 m^2 but were low on average (average of 8.8 ± 4.5 individuals/1,000 m^2) (Figure 11a). In the Vieux-Fort to Blanc-Sablon sector, the average densities observed in 2018 (23.9 ± 8 individuals/1,000 m^2) and 2020 (21.8 ± 8.1 individuals/1,000 m^2) were also low (Figure 11b).

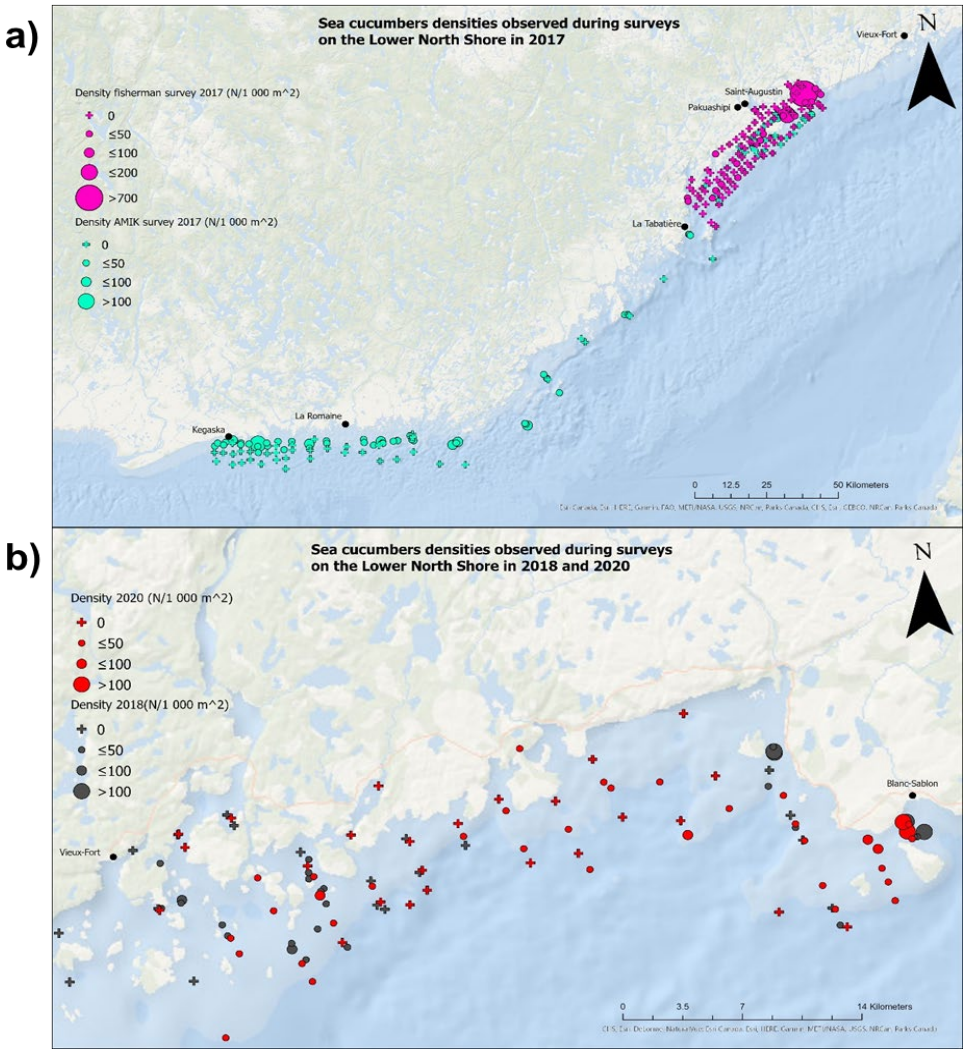


Figure 11. Estimated density (N/1,000 m^2) of sea cucumbers on the Lower North Shore: (a) from Kégaska to Saint-Augustin based on two surveys in 2017; and (b) from Vieux-Fort to Blanc-Sablon based on surveys from 2018 to 2020.

The greatest average densities were observed at depths of less than 20 m (Table 2). Average individual length ranged from 112 mm to 131 mm (Figure 12). The main bycatch taxa were, in decreasing order, green sea urchin, sand dollar, starfishes, *Hyas* spp. and scallops.

Table 2. Average density (N/1,000 m^2 ± standard error) of sea cucumbers by depth stratum during 2017, 2018 and 2020 surveys along the Lower North Shore

	2017 AMIK survey (Kégaska to Saint-Augustin)		2017 harvester survey (La Tabatière to Saint-Augustin)		2018 harvester survey (Vieux-Fort to Blanc-Sablon)		2020 harvester survey (Vieux-Fort to Blanc-Sablon)	
Depth stratum (m)	No. of tows	Density N/1,000 m^2	No. of tows	Density N/1,000 m^2	No. of tows	Density N/1,000 m^2	No. of tows	Density N/1,000 m^2
<20	27	25.0 ± 7.0	15	52.7± 51.7	18	25.4 ±14.3	39	32.1 ±12.8
20-29	27	5.4 ± 2.0	41	1.1 ± 0.5	16	38.2 ±16.1	15	6.4 ±3.1
30-39	17	6.6 ± 4.1	16	9.3 ± 7.8	7	2.7 ± 2.1	9	2.4 ±1.3
40-49	26	3.2 ± 2.0	22	0.7 ± 0.7	1	8.9	-	-
50+	21	0.04 ± 0.0	20	0.7 ± 0.5	4	0.9 ± 0.5	-	-
Average	118	**8.6 ± 1.8**	114	**8.9 ± 6.9**	46	**23.9 ± 8.0**	63	**21.8 ± 8.1**

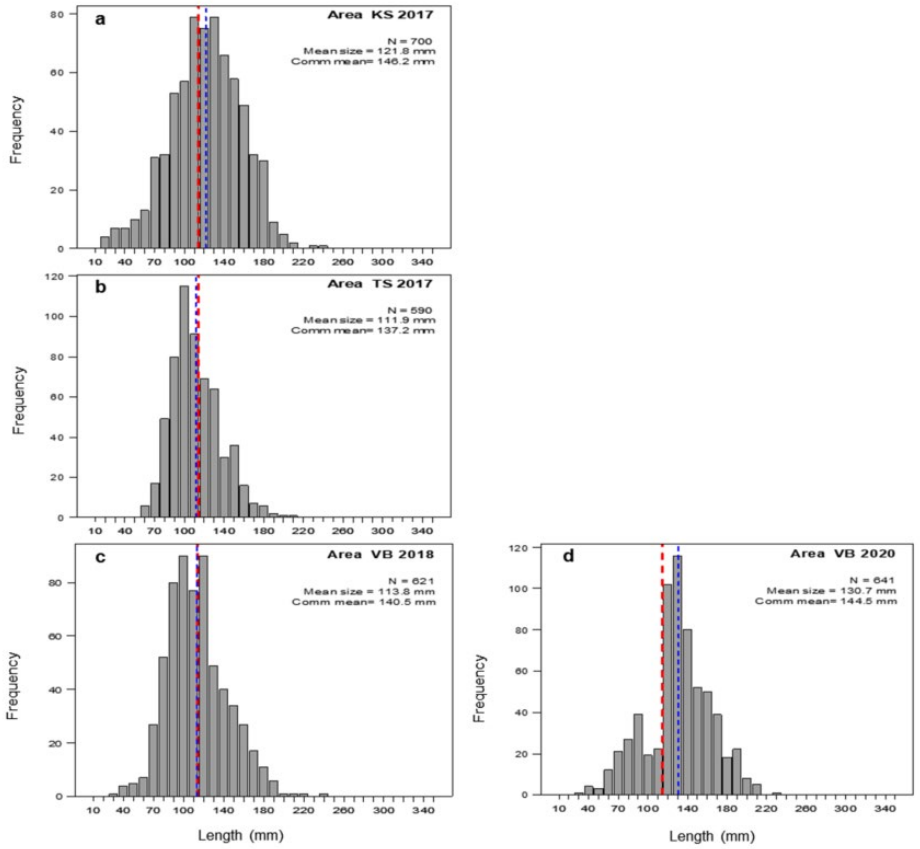


Figure 12. Size structure of sea cucumbers based on measurements at sea during surveys along the Lower North Shore: (a) Kégaska to Saint-Augustin, 2017; (b) La Tabatière to Saint-Augustin, 2017; (c) and (d) Vieux-Fort to Blanc-Sablon, 2018 and 2020. The vertical dotted red line represents the legal minimum size of 114 mm, while the blue line indicates the mean size in the sample. The number (N), mean size of all individuals (Mean size) and the mean size of individuals 114 mm or more (Comm. mean, or commercial mean) are also shown.

Sources of Uncertainty

This assessment relies largely on the quality of the indices obtained from logbooks, purchase slips collected at the dock and at-sea commercial catch sampling, as well as a single research survey along the Gaspé Peninsula's north shore in 2018. Unless the actual exploitation rate is known, it is difficult to adjust fishing quotas or management strategies other than by adopting a more cautious approach.

The sea cucumber fishery currently uses fishing gear that is still in development and that differs from one sector to another. Consequently, differences in estimated CPUE values between sectors and between years could be influenced by these gear differences. In addition, differences in harvesters' preferred fishing techniques, which include factors such as dredging speed, cable length, towing direction relative to the current, towing duration, time of day of dredging and a change in harvesters or vessels, may also affect the estimation of CPUE values. Consequently, interannual variations in CPUE values are possible if harvesters do not visit the same sites from year to year, if their dredging or fishing technique changes, or if their experience differs from that of other harvesters.

Furthermore, the mean lengths of sea cucumbers measured at sea or at the dock are directly influenced by the technique used by the sampler to ensure that all individuals sampled are sufficiently contracted, as well as by the time elapsed between fishing and measurement. Recent work shows that the measurement of length and weight in individual sea cucumbers is strongly influenced by capture and handling conditions (Couillard et al. 2021), which can affect CPUE and landing values.

These different sources of uncertainty limit the interpretation of the indicators and could therefore result in a poor fit between the conclusions in this advice and the actual status of sea cucumber stocks.

CONCLUSIONS AND ADVICE

Drag fishery

The sea cucumber drag fishery is still in the exploratory stage in management units 3, B and C, and in the experimental stage along the Lower North Shore. The fishery is fairly recent, and our knowledge is still too partial or insufficient to be able to determine an acceptable exploitation rate. Consequently, the recommended TACs in units A, B and C and the fishing effort in Unit 3 could be reassessed in light of new knowledge. In this type of fishery, effort control could be considered to manage each of the units. In this and all other emerging fisheries, any increase in fishing effort must be achieved slowly and in stages, and even then, only if catches and stock status indicators have been stable or improving for a number of years. Furthermore, the differences observed between fishing sites suggest that management regimes should be developed specifically for each management unit.

In Unit 3, an annual fishing effort near the level expended during the 2017-2020 period could help maintain the performance of the fishery in the next three years. In addition, establishing one or more refuge areas is recommended.

Given the additional conservation measures in place in units B and C (protected areas, fishery closure areas, and authorized fishing depths), maintaining landings near the average level for the 2017-2020 period should not have a major impact on sea cucumber abundance in these units in the next three years.

The analysis of surveys conducted along the Lower North Shore has revealed the low density and small size of the sea cucumbers in this area. Our current knowledge of several aspects such as the population dynamics in the sector is still insufficient and should be improved before a commercial fishery is envisaged.

Dive fishery

Several small-scale trial dive fisheries for sea cucumbers took place in Quebec in 2017 and 2018. This harvesting method seems to have the lowest impact on both the resource and benthic habitat. This method should continue to be prioritized for the commercial harvesting of the species. However, dive fishing did not continue in units A, B and AA due to profitability problems and technical issues.

OTHER CONSIDERATIONS

Most commercial sea cucumber fisheries around the world are dive fisheries. Despite the rudimentary methods available to commercial divers, a number of stocks have collapsed and show no significant signs of recovery, which suggests that sea cucumber species react poorly to high fishing pressure. Consequently, a more precautionary approach to the *Cucumaria frondosa* fishery in Quebec's waters is critical. We have no information on the resilience of this species at this latitude compared to stocks in more temperate regions.

Our knowledge of many aspects of the species, particularly its biology and ecology, is inadequate or insufficient and must be improved. Therefore, efforts must be focused on determining the spawning period in our waters, the minimum density required to ensure adequate reproductive success, growth rates, size at sexual maturity, exploitation rates, spatial and temporal dynamics and the impact of fishing gear on the benthic community, as well as on developing more reliable biometric indicators.

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