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An Assessment of Sea Scallop (*Placopecten magellanicus*) on St. Pierre Bank in 2019

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Foreword

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

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ABSTRACT

Populations of Sea Scallop (*Placopecten magellanicus)* on St. Pierre Bank are mainly found in three beds (North, Middle, and South beds) at depths of 40–100 m. They are usually found on hard bottom with variable substrate composition, consisting largely of sand, gravel, shell fragments, and stones. The Sea and Iceland Scallop distributions overlap to varying degrees with complete overlap in the Middle bed, and a high degree of overlap in the North bed. A large area in the southern portion of the South bed, with a sandy substrate, is inhabited by only Sea Scallop.

The directed fishery for Sea Scallop started on the St. Pierre Bank in the late 1970s. Prior to 2006, the fishery was managed by total allowable catch (TAC), and meat count regulations were applied to the offshore fleet, but not to the inshore fleet. In 2006, following the recommendations of the Hooley Report, specific fishing areas and TACs were applied to each fleet. From 2006 to 2015, the offshore fleet did not fish on the St. Pierre Bank but began fishing again in 2016. In contrast, fishing has been consistently prosecuted in the North bed by the Newfoundland and Labrador (NL) inshore fleet since 2006. From 2016 to 2019 landings averaged 720 t, round weight in the North bed, and 90 t, meat weight in the Middle and South beds.

A Fisheries and Oceans Canada (DFO) survey in September 2019 resulted in a minimum dredgeable biomass (MDB) estimate of 12,725 t, round weight. This point estimate is associated with high variability and a subsequent high level of uncertainty. The stock in the North bed is currently dominated by a modal group of scallop 75 mm, while in the Middle and South beds the modal group is 120 mm and 130 mm, respectively. The natural mortality index for Sea Scallop has decreased from 0.13 in 2015 to 0.02 in 2019, similar to levels observed from 2003 to 2006. The abundance of small scallop in the North bed indicate favourable prospects for the fishery in the near future.

INTRODUCTION

SPECIES BIOLOGY

Sea Scallop (*Placopecten magellenicus*) is confined to the Northwest Atlantic, and ranges from the Northern Gulf of St. Lawrence to Cape Hatteras, North Carolina. It is normally found in waters of depths 10–100 m. Fishable aggregations are found from the Virginia Capes to Port au Port Bay, Newfoundland and Labrador (NL), with Georges Bank off Nova Scotia being the world's largest producer of Sea Scallop. Populations on St. Pierre Bank, NL are mainly found at depths from 40 to 100 m in three beds: North, Middle, and South (Figure 1). The Sea Scallop fishery on the St. Pierre Bank is a pulse fishery, largely dependent on sporadic settlement and subsequent recruitment (DFO, 2007). Sea Scallop begin to recruit to the fishery at approximately age 4 (~ 90 mm). Sea Scallop are found on highly variable substrates, and on St. Pierre Bank, they are generally found on fine and coarse sand, gravel, cobble, and shell fragments. Sea Scallop is a filter-feeder, consuming plankton and detritus, and is associated with areas of strong currents. Unlike many species of scallops, this species is gonochoric, having one of two distinct sexes for its lifetime (Stokesbury et al., 2016). Sea Scallop can become sexually mature as early as age 1, but their first spawning does not occur until their second year at a shell height ranging from 23 to 75 mm. Spawning in Newfoundland waters begins in July and may be initiated by changes in temperature, food supply, and current speed (DFO, 2011). Eggs are externally fertilized, and larvae are planktonic for 35–45 days before settling to the bottom, possibly at considerable distances from the spawning adults, depending on currents (Stokesbury et al., 2016). Sea Scallop have been known to live up to 21 years. Adults commonly reach shell heights between 100 and 150 mm, but have been found at sizes greater than 200 mm (DFO, 2007).

THE FISHERY

Annual landings of Sea Scallop from the St. Pierre Bank have been highly variable (Figure 2, Table 1), as is typical of 'pulse'-type fisheries. Directed fishing started in the late-1970s and landings peaked twice in the 1980s, at 6,000 t, round weight in 1982 and 10,000 t in 1988. Landings declined through the early-1990s and removals were less than 500 t until 2003. Landings peaked again in 2004 and 2005 at approximately 4,500 t and 2,400 t, respectively (DFO, 2007). Prior to 2006 the fishery was managed by a TAC, and meat count regulations applied to the offshore fleet, but not the inshore fleet. Following the release of the Hooley report (Hooley, 2005) in 2006, the Minister assigned fishing areas based on three known fishing beds on the St. Pierre Bank (Figure 1) (DFO, 2011). Since 2006, the TAC and landings for the inshore fleet (North bed) have been recorded as round weight tonnes, whereas the offshore fleet (Middle and South beds) TAC and landings are recorded in meat weight tonnes. The conversion factor for Sea Scallop from round weight (shell stock) to meat weight is 8.3 (Hennen and Hart, 2012).

Since 2016, the TAC for the inshore fleet has been 872 t, round weight while the offshore fleet TAC has been variable with 90 t (meat weight) allocated in 2016 and 50 t, 100 t, and 125 t, (meat weight) respectively allocated in 2017, 2018, and 2019.

METHODOLOGY

FISHERY DATA

The fishery landings data are based on dockside monitoring reports, harvesters logbooks, and purchase slips from buyers. The harvesters report the daily catch for each week of the fishery.

The mean CPUE (catch per unit effort - round weight [tonnes] per tow) was calculated based on the harvester logbooks in the North bed. The CPUE was not standardized as the logbook data do not record tow length, number of tows, tow speed, or gear type.

CPUE for the South and Middle beds (offshore fleet) was calculated from 1982 to 2019 from harvester logbooks based on kilograms per hour meters (kg/hm), where hour-meters is calculated as:

$$hm = number\ of\ dredges\ \times width\ of\ dredges\ (m) \times tow\ duration\ (hours)$$

RESEARCH VESSEL SURVEYS

Survey Design

A Fisheries and Oceans Canada (DFO) resource assessment survey was conducted in September 2019 onboard the 50-m research vessel *CCGS Alfred Needler*. Resource assessment surveys have always taken place in late August or early September, however, have varied by vessel and with 4 to 5 year gaps in between surveys since 2010. Resource assessment surveys were conducted by DFO in 2003 using *CCGS Wilfred Templeman* and in 2010 and 2015 using *CCGS Alfred Needler*. From 2004 to 2006, the offshore fleet used the vessel *Cape Keltic* to conduct surveys.

Surveys followed a stratified random sampling scheme (DFO, 2011) based on beds (North, Middle and South) (Figure 3). Sets were optimally allocated in proportion to stratum-specific area and variance of the catch rates from the previous survey. Sets were optimally allocated to minimize the variance of the mean for a fixed sample size in a stratified random sampling scheme according to Cochran (1977):

$$n_h = \frac{n \times A_h \times S_h}{\sum(A_i \times S_i)}$$

where n_h=number of sets in stratum ‘h’, n=total number of sets available, A_h=area of stratum ‘h’, and S_h=Variance in stratum ‘h’, A_i = area of each stratum, and S_i = variance in each stratum.

The distribution of survey sets and number of sets completed by strata in the 2019 survey are shown in Table 2.

The coverage of the 2019 Sea Scallop survey area was reduced due to an error in the allocation of sets throughout the scallop strata and a reduction in survey time from ten survey days to four, whereby limited allocated sets were completed throughout the survey area (Figure 4).

Fishing Methods

An 8 ft. New Bedford scallop dredge equipped with 3” rings and interconnected with a 2-top and 3-bottom link configuration was used in all surveys. Standard tow length for the DFO surveys was 0.5 nm, whereas the Cape Keltic surveys used 0.5 standard mile tow length. All survey data were standardized to a 0.5-nm tow distance. Towing speed was approximately 3 knots with a warp (wire length) to depth ratio of 3:1. All tows passed through the allocated position, with tow direction being random except if the position was too close to the stratum border or the path was obstructed. In these situations, the direction was identified so that the tow could be completed within the stratum and/or to avoid the obstruction.

Sampling

The total catch was sorted by species, numerated, and weighed. Live scallops were bushelled into baskets and weighed whole. Depending on the volume of the catch and anticipated steam time to the next fishing station, either the whole catch or a randomly-selected weighed subsample was set aside for individual shell-height measurements to the nearest mm. Individual shell height and meat weight information was also collected in each bed in 2010, 2015, and 2019. Cluckers (persistent paired valves still attached at the hinge line) were separately sorted, weighed, counted, and measured. Cluckers were also counted to give an estimate of natural mortality. Clucker weights were subtracted from sampled and total catch weights, as was the weight of residual debris (e.g., sand, broken shell fragments, and pebbles).

Predatory sea stars were sorted by species and sampled for individual weight and length. The length of each sea star was measured from the mouth to the end of an arm to the nearest mm. Commercial finfish such as Atlantic Cod (*Gadus morhua*) and American Plaice (*Hippoglossoides platessoides*) were also sampled for length, sex, and stomach contents.

Each station was not occupied until the sampling from the previous set was completed. This guards against water loss in the scallops which can affect the weights recorded, subsequently affecting biomass estimates.

Biomass

The minimum dredgeable biomass (MDB) index for Sea Scallop was calculated for each survey within each of the three beds and for all beds combined using STRAP (Stratified Analysis Programs) (Smith and Somerton, 1981) from swept area estimates within survey strata. All surveys were standardized to 0.5-nm tows.

To investigate whether the reduction in the area covered within each strata had an effect on the biomass and abundance estimates for 2019, the biomass estimates from past surveys (2003–06, 2010, and 2015) were calculated with all sets included and then calculated with a reduction in sets from the areas that were excluded within each stratum for past surveys to compare trends.

Biomass estimates were inflated by inclusion of epibionts in the catch weight. However, this bias would not affect trends in biomass because epibionts abundance would be considered consistent from year to year.

Recruitment and Size Structure

The shell height data from all resource assessment surveys were used to determine the abundance at length in 5-mm groups determined with STRAP analysis for the North, South and Middle beds and all the beds combined. Length frequency distributions were generated to display these results.

Individual Shell Height and Meat Weights

Individual shell height - meat weight information was collected on the resource assessment surveys in 2010, 2015, and 2019. Based on these data a comparative linear model analysis was performed. The shell height and meat weight data were log transformed and the significance in the difference in slopes for the North, Middle and South beds were compared within each year.

Meat Counts and Yields

During the 2003, 2010, 2015, and 2019 resource assessment surveys, Sea Scallop were collected in most of the strata to determine biological meat yields (%), average meat weight (g), and meat counts (number of meats / 500 g).

Meat count is given by the formula:

$$x = \frac{500\ (g)}{meat\ weight\ (g)}\ X\ sample\ (n)$$

Biological meat yield is given by the formula:

$$x = \frac{meat\ weight\ (g)}{round\ weight\ (g)}\ X\ 100$$

Natural Mortality

Sea Scallop natural mortality was computed directly from percent occurrence of cluckers (Dickie, 1955) according to the following equation:

$$M = 1 - e\left(\frac{c}{t}\right)\left(\frac{1}{L}\right) * 365$$

where, *M* is annual mortality rate, c is the number of cluckers in a sample adjusted to account for tow-induced disarticulation (number of cluckers*1.211) (Naidu, 1988), *L* is the number of live scallops in a sample, and *t* is the average time in days (210.8) required for natural clucker disarticulation (Mercer, 1974).

Predation

The MDB index for predatory sea stars was calculated for each survey within each of the three beds and for all beds combined using STRAP (Smith and Somerton, 1981) from swept area estimates within survey strata. All surveys were standardized to 0.5-nm tows. Predatory sea star biomass estimates were compared to Sea scallop biomass estimates to investigate the contribution of sea stars to Sea Scallop natural mortality.

RESULTS

FISHERY DATA

Between 2005 and 2010, inshore landings (North bed) ranged from 300 t to 770 t then increased to 1,190 t in 2012, and since then have averaged 1,125 t round weight (136 t meat weight) (Figure 2). The offshore fleet (Middle and South beds) did not fish on the St. Pierre Bank from 2007 to 2015. Since resumption of fishing in 2016, landings have averaged 90 t meat weight (Figure 5).

The mean CPUE in the North bed declined from 2003 to 2006, where it remained stable until 2009 and peaked again in 2011 before declining until 2013, where it has remained stable (Figure 6). For the offshore fleet the CPUE (kg/hm*)* was highly variable in the last few years (Figure 7).

RESEARCH VESSEL SURVEYS

Biomass

The resource assessment survey in 2019 resulted in a MDB estimate of 12,725 t (round weight) in all beds combined (Table 3). This point estimate is associated with high variability and a subsequent high level of uncertainty. The biomass in the three beds combined decreased from 7,500 t in 2010 to 5,912 t in 2015, then increased by 53% to 12,725 t (round weight) in 2019, which is mainly due to the increase in the North bed where the biomass increased from 1,820 t in 2015 to 9,162 t in 2019 (Figure 8). The South bed, North bed, and Middle bed MDB estimates constituted 26%, 72%, and 2% of the overall biomass estimate, respectively (Figure 8). The biomass in the Middle bed increased slightly from 329 t in 2010 to 516 t in 2015 then decreased to 297 t in 2019. In the South bed, the biomass has been variable throughout the time series. It declined slightly between 2006 to 2010, then the biomass increased from 3,024 t in 2010 to 3,575 t in 2015, and then decreased to 3,265 t in 2019 (Figure 9).

The reduction in the survey area within each strata in 2019 was determined to have a negligible impact on biomass estimates. Biomass estimates from each respective group (including ‘all sets within the stratum’ and ‘a reduction in sets from the areas that were excluded within each stratum’) were compared and showed a clearly similar trend (Figure 10).

Recruitment and Size Structure

The modal shell height (length) in the North bed slightly decreased since 2006, from approximately 120 mm to 105 mm in 2010 and 2015, to an abundance dominated by a modal group of smaller size scallop (75 mm) in 2019 (Figure 11, Figure 12, Table 4, Table 5). It is also evident from the length frequencies for the North bed that the abundance across the broad range of lengths declined from 2004 to 2005 and remained stable through the survey time series until 2015 (Figure 11, Figure 12) before a large increase in abundance of smaller scallop in 2019.

The length frequency distributions in the Middle bed show a steep decline in abundance across all size categories from 2005 to 2006, with little signs of recovery in the 2010 and 2015 surveys (Figure 13, Figure 14). There was a slight indication of pre-recruits in 2015, but the overall abundance remained low (Figure 14). In 2019, the modal shell height in the Middle bed increased to 130 mm (Table 4, Table 5).

The length frequency distributions in the South bed show a slight sign of pre-recruits in 2010, but little to no sign of pre-recruits in 2015 (Figure 15, Figure 16). The modal group of shell height decreased from approximately 130 mm in 2010 to 110 mm in 2015, then increased in 2019 to 120 mm, with signs of pre-recruit size scallop (Figure 16, Table 5). The overall abundance in the South bed through the survey time series shows the abundance has remained relatively stable since 2006 (Figure 15, Figure 16).

Recruitment potential was evaluated by examining the abundance of pre-recruit size scallop, which has been low since 2004. Even though there are promising signs in the North bed with a high abundance of smaller size scallop in 2019, there is still uncertainty related to this point estimate with a reduction of survey time and coverage, and high variability associated with this estimate.

Individual Shell Height and Meat Weights

The relationship in slopes between the individual meat weight and shell heights within each bed in 2010, 2015, and 2019 was compared. In 2010, the meat weight was heavier for any given shell height in the South bed compared to the North and Middle beds (Figure 17). In 2015, individual meat weight and shell height data were only collected in the North bed and South bed, and smaller scallop (shell height) in the North bed were heavier than those in the South bed and larger scallop in the South bed were heavier than those in the North bed (Figure 17). In 2019, the analysis of meat weight at shell height show heavier meats for any given size in the South bed compared to the North and Middle beds. It was also evident that a high abundance of smaller size scallop were caught in the North bed.

Meat Counts and Yields

In the North bed, the biological meat counts increased from 22/500 g in 2003 and 2010, to 28/500 g in 2015, and 34/500 g in 2019 (Figure 18). This increase in the meat count is reflective of the high abundance of smaller scallop in the North bed. In the South bed, the meat count remained the same at 17/500 g in all four surveys, while in the Middle bed the meat count increased from 15/500 g in 2010, to 25/500 g in 2015, then decreased to 15/500 g in 2019 (Figure 18).

Natural Mortality

The natural mortality index for all beds combined increased from 0.09 in 2010 to 0.13 in 2015, then decreased to 0.02 in 2019 (Figure 19, Table 5). The natural mortality in the South bed decreased from 0.15 in 2015 to 0.03 in 2019, and in the North bed decreased from 0.12 in 2015 to 0.02 in 2019. The natural mortality increased in the Middle bed from 0.02 in 2015 to 0.05 in 2019. Overall, the natural mortality is still considered low and is likely associated with low biomass of predatory sea stars in 2019 (Figure 20).

Predation

The biomass estimates for the key sea star species, including *Leptasterias polaris*, *Crossaster papposus*, *Solaster endeca*, and *Asterias rubens* show that the overall abundance of predatory sea stars has declined since 2003 (Figure 20, Figure 21). However, when comparing the biomass estimates of sea stars and Sea Scallop in the North bed there was little to no change in the sea star biomass over the survey time series, but there was an increase in Sea Scallop from 2015 to 2019. The Middle bed showed very little change in biomass in both sea stars and Sea Scallop (Figure 21). The most obvious change in sea stars was in the South bed, where biomass substantially declined between 2003 and 2015 and the Sea Scallop biomass varied with little change (Figure 21). This may be an indication that predatory sea stars have not been a large contributor to the natural mortality of Sea Scallop.

CONCLUSIONS AND ADVICE

Between 2005 and 2010, landings from the inshore fleet (North bed) ranged from 300 t to 770 t, increased to 1,190 t in 2012, and averaged 900 t since. The offshore fleet (Middle and South beds) did not fish on the St. Pierre Bank from 2006 to 2015. Since resumption of fishing in 2016, landings have averaged 90 t, meat weight. Catch per unit effort (unstandardized) based on harvester logbook data from the North bed has remained stable without trend between 2013 and 2018.

The 2019 MDB index of 12,725 t, round weight is the highest estimate since 2004. The resource has increased since 2015 by 53% which is mainly due to the increase in biomass in the North bed. The abundance in the North bed was dominated by a modal group of 75 mm scallops, while in the South and Middle beds the modal group was 120 mm and 130 mm, respectively. The abundance of small scallop in the North bed indicate favourable prospects for the fishery in the near future. Overall, the natural mortality is considered low and is likely associated with low biomass of predatory sea stars.

There is currently no established reference points by which to determine stock status in relation to a Precautionary Approach (PA) Framework.

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APPENDIX I - TABLES

Table 1. Total allowable catch (TAC) and removals for Sea Scallop and Iceland Scallop on St. Pierre Bank.

Inshore			Offshore			
YEAR	**NL<65'**	**TAC (t, round)**	**NL + NS >65' (landings, round weight)**	**NS> 65' (t, meat weight)**	**Estimated TAC (t, round)**	**TAC (t, meat weight)**
1969	11	-	0	-	-	-
1970	23	-	0	-	-	-
1971	12	-	0	-	-	-
1972	9	-	0	-	-	-
1973	24	-	0	-	-	-
1974	3	-	0	-	-	-
1975	3	-	0	-	-	-
1976	18	-	0	-	-	-
1977	86	-	0	-	-	-
1978	41	-	191	-	-	-
1979	130	-	8	-	-	-
1980	67	-	291	-	-	-
1981	30	-	0	-	-	-
1982	169	-	5,951	-	-	-
1983	102	-	4,930	-	-	-
1984	340	-	3,428	-	-	-
1985	300	-	440	-	-	-
1986	328	-	1,270	-	-	-
1987	404	-	448	-	-	-
1988	1,591	-	8,176	-	-	-
1989	429	-	2,756	-	-	-
1990	289	-	1,270	152	1,245	150
1991	167	-	1,112	134	1,245	150
1992	0	-	556	67	1,245	150
1993	483	-	955	115	1,245	150
1994	534	-	407	49	1,245	150
1995	418	-	565	68	1,245	150
1996	8	-	150	18	415	50
1997	9	-	25	3	415	50
1998	268	-	0	0	415	50
1999	71	-	0	0	415	50
2000	79	-	34	4	415	50
2001	338	-	0	0	415	50
2002	51	-	0	0	415	50
2003	647	-	0	0	415	50
2004	2,465	-	2,081	251	2,075	250
2005	618	872	2,216	267	2,075	250
2006	523	872	43	5	1,619	195
2007	364	872	0	0	-	0
2008	303	872	0	0	-	0
2009	423	872	0	0	-	0
2010	770	872	0	0	-	0
2011	922	1,121	0	0	-	0

Inshore			Offshore			
YEAR	NL<65'	TAC (t, round)	NL + NS >65' (landings, round weight)	NS> 65' (t, meat weight)	Estimated TAC (t, round)	TAC (t, meat weight)
2012	1,190	1,121	0	0	-	0
2013	1,071	1,121	0	0	-	0
2014	1,169	1,121	0	0	208	25
2015	1,072	872	0	0	415	50
2016	794	872	655.7	79	747	90
2017	766	872	415	50	415	50
2018	427	872	821.7	99	830	100
2019	-	872	1,079	130	1,038	125

Table 2. Distribution of survey sets by strata, areas, and intensity of coverage in the 2019 resource assessment survey for Sea Scallop on St. Pierre Bank.

Stratum	Mean depth (m)	Area (2003 to 2015) (nm^2)	Area (2019) (nm^2)	No. of sets completed	No. of sets/nm^2
141	45	71.79	51.7	3	0.06
142	44.6	55.1	38.15	7	0.18
143	43.25	72.01	51.84	8	0.15
144	44.8	72.01	51.84	8	0.15
145	59.5	68.0	46.24	2	0.04
146	69.5	68.0	46.24	2	0.04
201	50	60.7	40.13	7	0.17
202	51	68.6	47.33	3	0.06
203	52	64.6	41.99	2	0.05
204	49.85	64.38	45.94	5	0.11
205	43	73.08	53.36	3	0.06
206	49.5	68.78	47.47	2	0.04
207	51.5	72.66	53.07	7	0.13
Totals =	-	879.55	615.3	59	0.1

Table 3. Estimates of minimum dredgeable biomass (t, round) for Sea Scallop on St. Pierre Bank, September 2019.

Stratum	sets	Area (nm^2)	mean	upper	lower	+/-
141	3	71.79	183.69	521.69	-154.30	338.00
142	7	55.10	516.41	968.71	64.11	452.30
143	8	72.01	7,416.52	16,594.59	-1,761.56	9,178.07
144	8	72.01	961.87	1,839.65	84.09	877.78
145	2	67.98	0.00	0.00	0.00	0.00
146	2	67.98	84.22	1,154.26	-985.83	1,070.04
North	30	406.87	9,162.70	21,078.89	-2,753.49	11,916.19
201	7	60.65	570.40	1,287.48	-146.68	717.08
202	3	68.58	857.24	3,595.14	-1,880.65	2,737.89
203	2	64.55	149.63	2,050.83	-1,751.57	1,901.20
204	5	64.38	171.45	356.89	-13.99	185.44
205	3	73.08	1286.37	4,320.12	-1,747.38	3,033.75
206	2	68.78	230.01	2,103.03	-1,643.02	1,873.03
South	22	400.02	3,265.10	4,552.37	2,597.70	977.27
Middle - 207	7	72.66	297.73	722.67	-127.20	424.94
All	59	879.55	12,725.54	22,039.11	3,411.96	9,313.57

Table 4. Stratum-specific means and Standard deviation (SD) for shell heights (mm) of Sea Scallops.

Stratum	**2003**		**2004**		**2005**		**2006**		**2010**		**2015**		**2019**	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
141	149.50	5.54	132.50	N/A	122.57	18.10	133.43	8.87	117.40	8.67	0.00	0.00	112.62	22.37
142	92.00	N/A	106.19	10.36	-	-	113.00	18.15	107.14	16.50	107.89	13.02	97.00	21.01
143	100.86	14.65	110.50	11.69	118.21	9.37	115.51	9.26	121.53	16.48	105.08	15.74	77.20	10.57
144	95.75	17.30	103.76	11.16	113.33	11.23	113.87	13.51	105.73	18.80	109.73	17.22	91.17	17.85
145	-	-	107.50	0.00	107.50	N/A	-	-	-	-	0.00	0.00	0.00	0.00
146	113.24	22.13	108.19	14.95	111.33	11.89	119.10	8.14	120.05	18.52	0.00	0.00	133.80	15.17
North	98.60	17.91	105.80	11.29	113.75	11.36	115.05	13.32	109.14	19.00	108.60	16.76	78.60	12.49
201	114.61	22.55	110.60	11.29	121.35	10.92	127.07	11.40	130.22	14.45	115.52	14.37	123.95	17.37
202	127.52	15.82	128.03	9.30	122.59	12.27	118.43	15.97	130.17	15.05	124.92	17.38	116.35	21.08
203	-	0.00	-	-	104.60	11.78	116.19	7.17	108.15	13.01	120.57	15.60	80.58	22.51
204	120.35	10.63	118.15	17.33	122.59	8.43	123.38	10.62	136.34	14.92	118.18	16.55	113.08	26.73
205	118.41	15.64	116.66	18.58	124.14	11.12	125.82	10.82	119.74	23.76	135.27	17.71	106.88	26.31
206	112.99	17.10	108.20	16.85	119.24	14.86	126.22	10.75	105.88	27.54	136.88	14.70	136.91	17.20
South	116.79	16.13	113.24	17.58	120.99	12.47	124.29	12.78	126.31	20.55	121.84	17.54	112.74	25.54
Middle - 2007	80.00	15.20	90.50	8.66	109.27	10.71	114.31	11.15	128.83	12.57	113.89	18.36	126.37	18.91

Stratum	2003		2004		2005		2006		2010		2015		2019	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Overall	101.70	20.32	103.60	14.18	114.00	12.38	119.19	13.80	115.86	21.13	114.79	18.22	80.49	15.67

Table 5. Stratum-specific means and modal shell heights (mm) of Sea Scallop in 2019 on St. Pierre Bank, September 2019.

Shell Height (mm)							
Stratum	**N Obs**	**Mean**	**SD**	**Min**	**Max**	**Mode**	**N**
141	21	112.62	22.38	74	150	98	21
142	283	97.00	21.01	50	150	85	283
143	9,820	77.20	10.57	17	140	75	9,820
144	597	91.17	17.85	60	147	88	597
145	0	0.00	0.00	0	0	0	0
146	5	133.80	15.17	112	150	–	5
North	**10,726**	**78.60**	**12.49**	**17**	**150**	**75**	**10,726**
201	142	123.95	17.37	75	160	130	142
202	96	116.35	21.08	60	150	127	96
203	38	80.58	22.51	41	141	90	38
204	63	113.08	26.73	46	161	90	63
205	171	106.88	26.31	36	196	140	171
206	11	136.91	17.20	87	152	143	11
South	**521**	**112.74**	**25.54**	**36**	**196**	**130**	**521**
207-Middle	**76**	**126.37**	**18.91**	**76**	**227**	**120**	**76**
Overall	**11,323**	**80.49**	**15.67**	**–**	**–**	**75**	**–**

Table 6. Stratum-specific natural mortality estimates for Sea Scallop on St. Pierre Bank, computed from ratio of cluckers to live scallops in September 2019. Clucker numbers are adjusted by a factor of 1.221 to allow for tow-induced disarticulation.

Stratum	Number of live scallop	Number of cluckers	Mortality (M)
141	21	0	0
142	283	1	-2
143	9878	84.6	0.02
144	620	0	0.00
145	36	1	0
146	5	0	0
Overall North	10,843	86.6	0.02
201	147	4	0.06
202	96	0	0.00
203	38	0	0
204	63	1.6	0.05
205	171	1	0.01
206	11	0	0
Overall South	526	6.6	0.03
Middle - 207	76	2	0.05
All	11,445	95.2	0.02

APPENDIX II - FIGURES

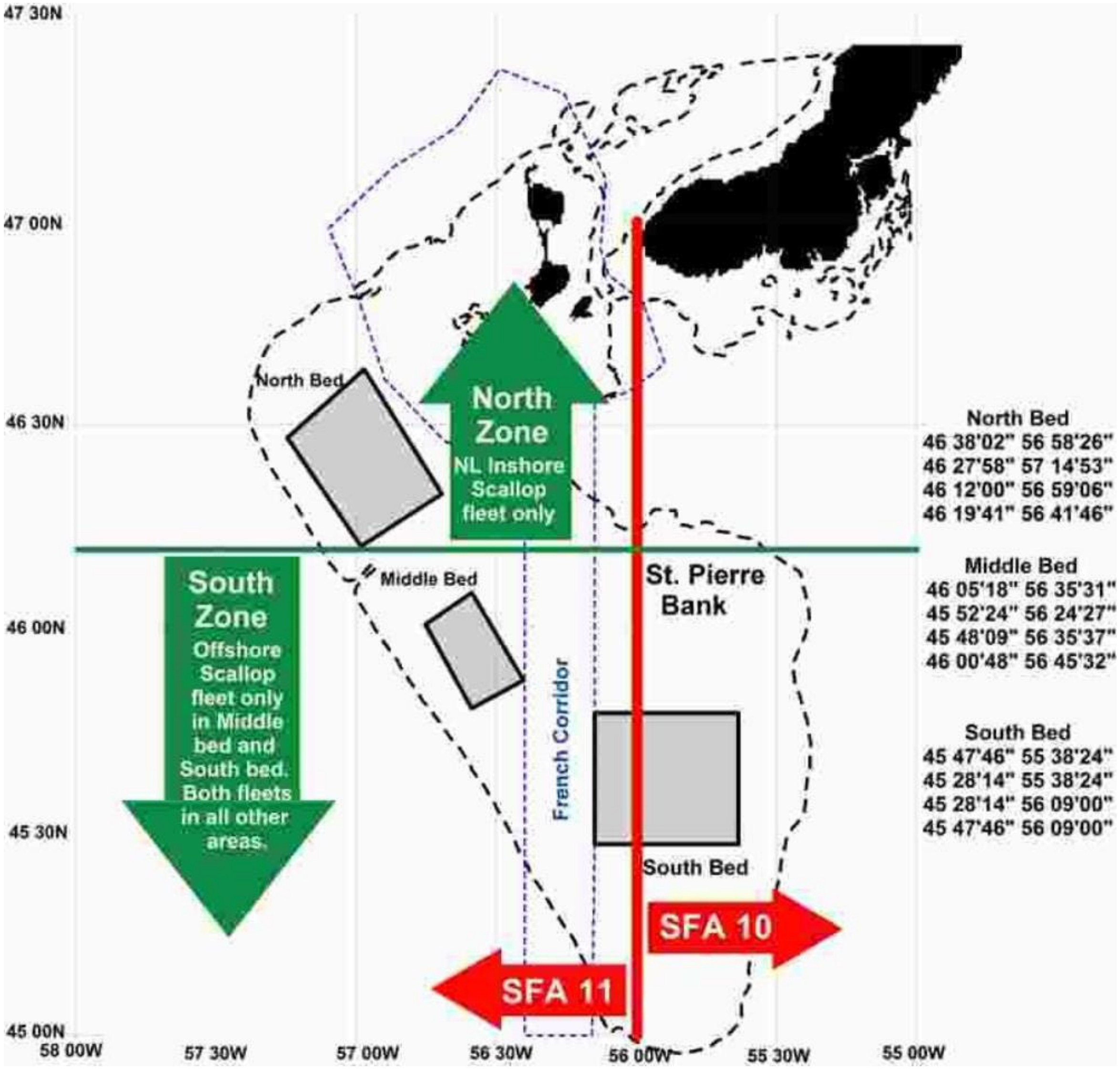

Figure 1. St. Pierre Bank showing the three Sea Scallop beds, the Hooley report recommended fleet separation zones, and Scallop Fishing Areas (SFA) 10 and 11.

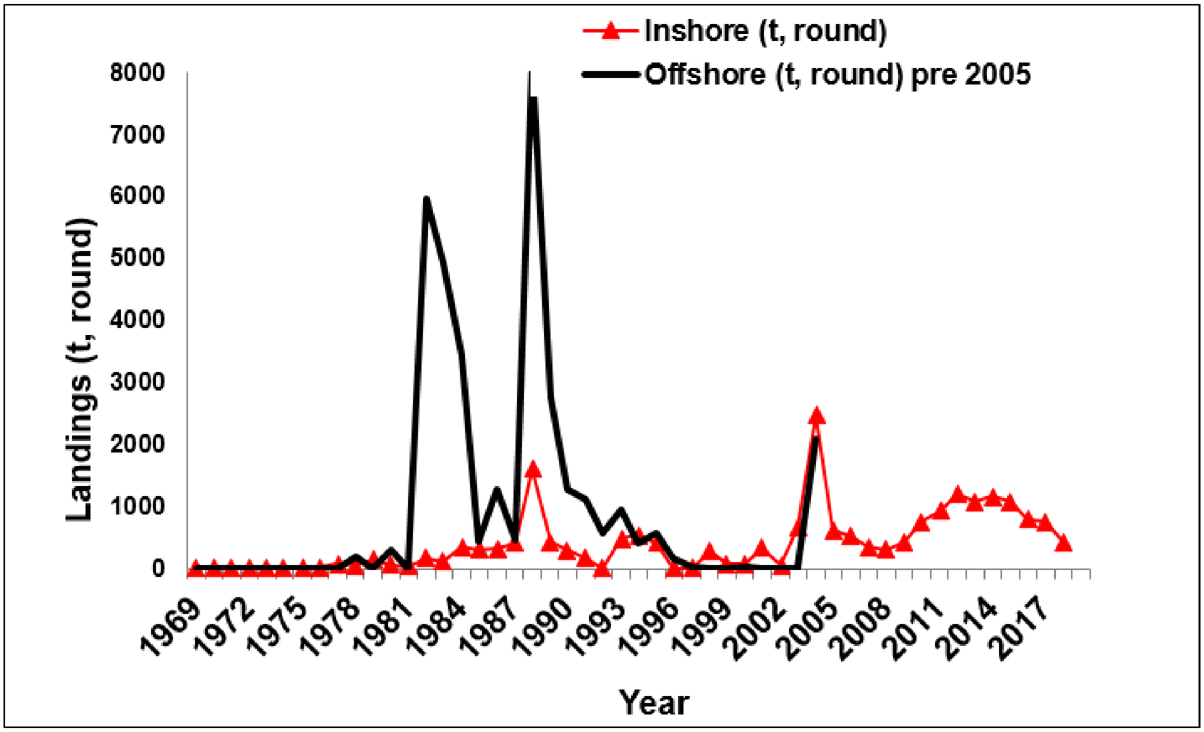

Figure 2. Sea Scallop landings (t, round weight) from the three beds combined on the St. Pierre Bank by inshore (1969–2018) and offshore fleets (pre-2005).

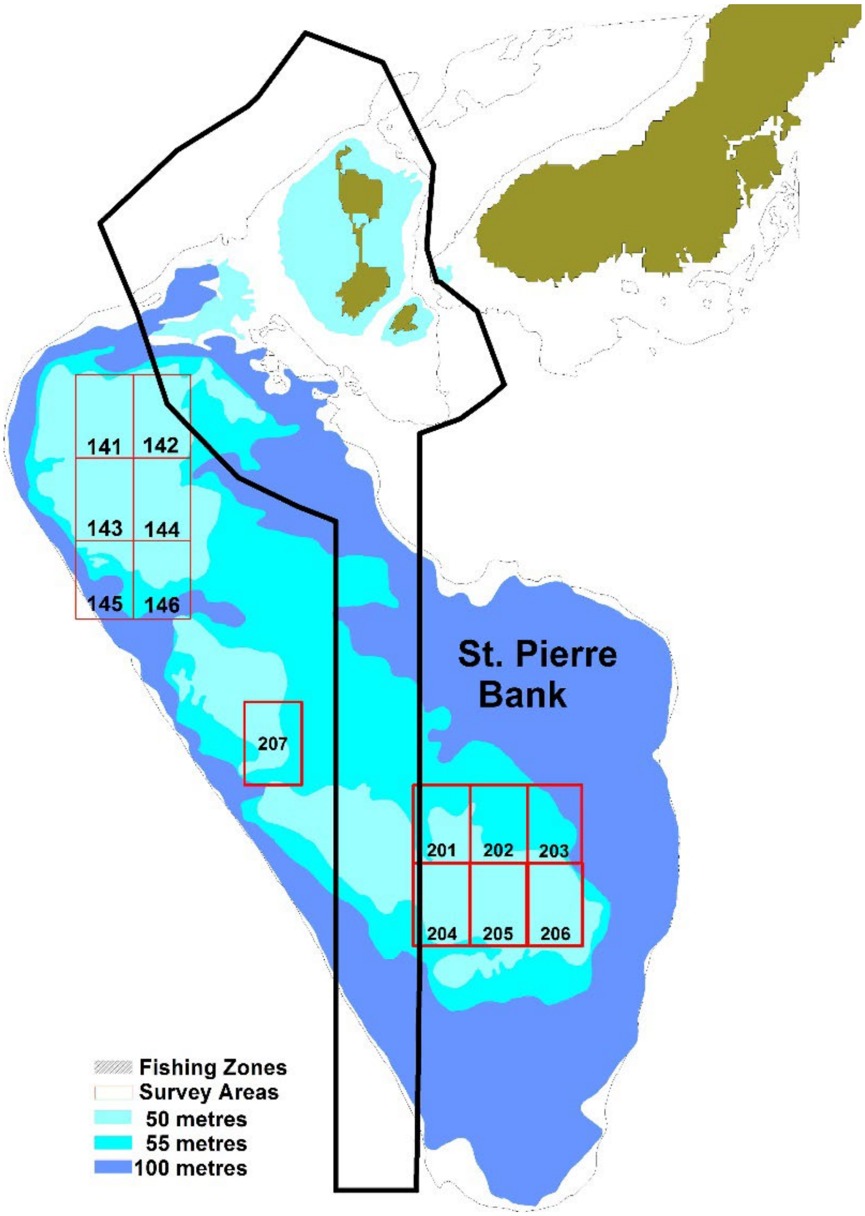

Figure 3. Stratification scheme used in the 2019 DFO resource assessment survey.

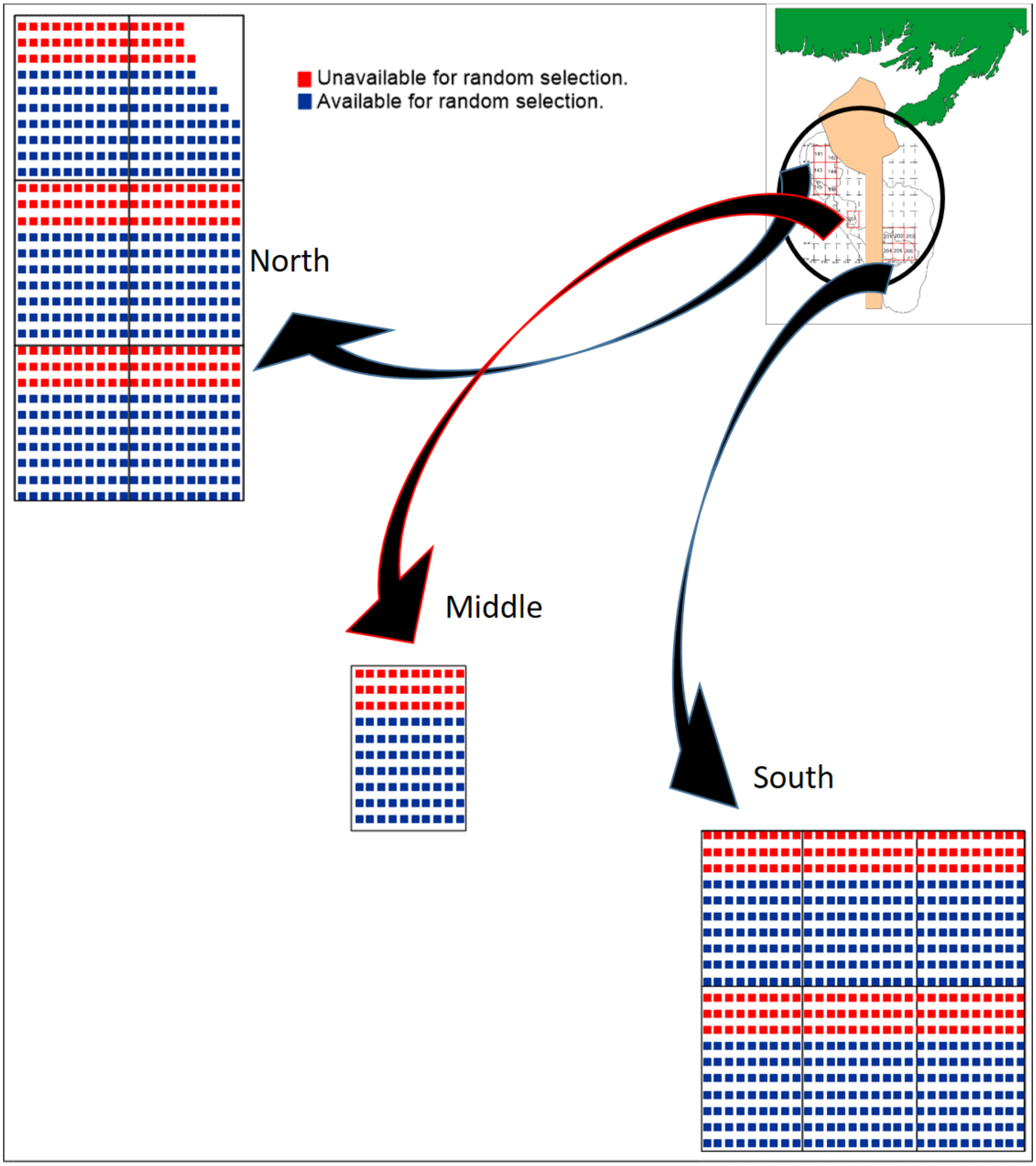

Figure 4. Map showing the strata with the blue area representing the area that was included in the set allocation in 2019, and the red area representing the area that was not used in the set allocation.

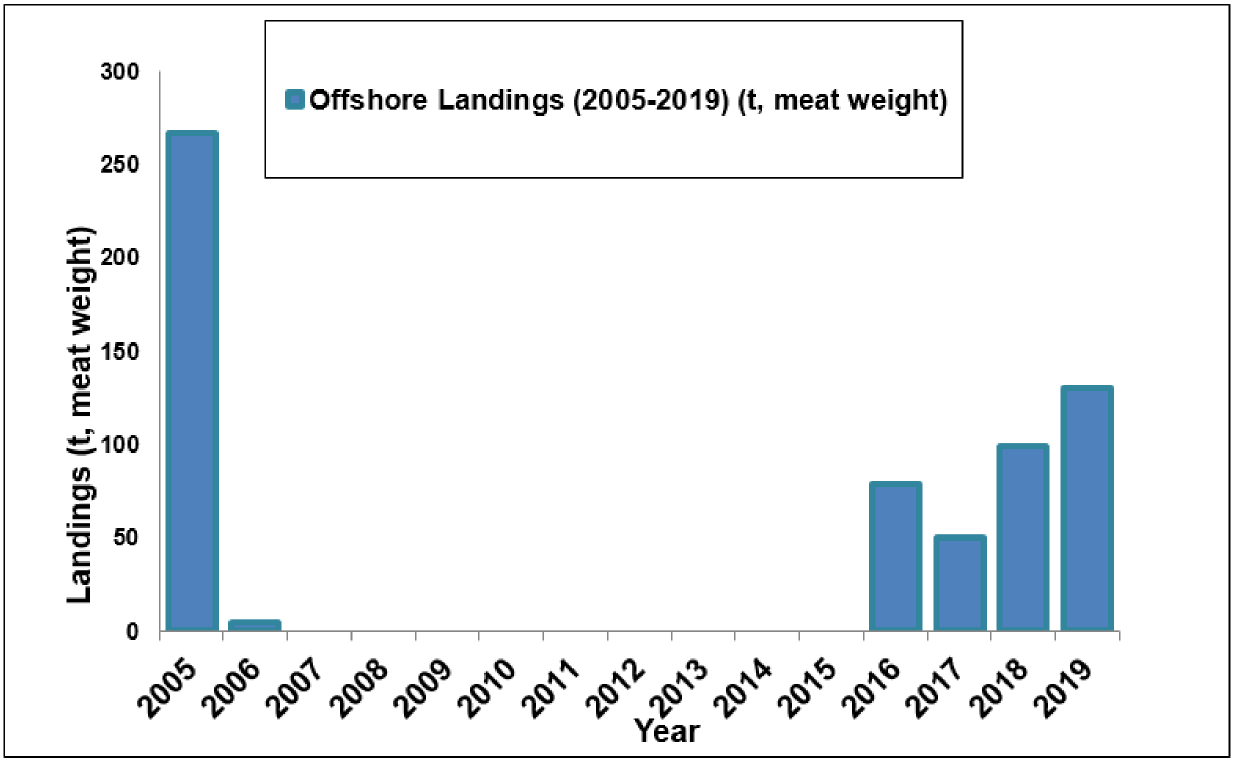

Figure 5. Sea Scallop landings (t, meat weight) from the Middle and South beds on the St. Pierre Bank from 2005 to 2019.

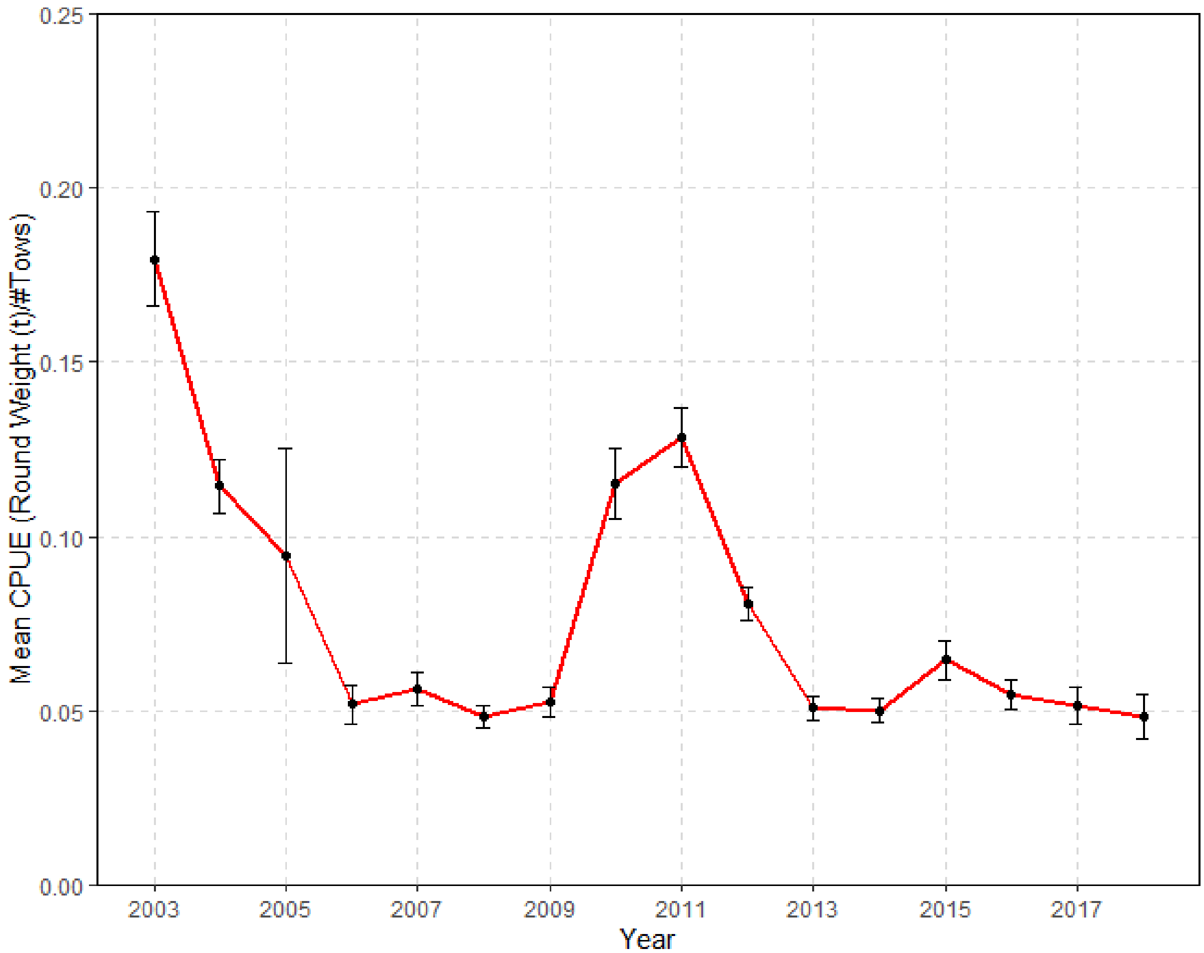

Figure 6: Unstandardized CPUE (t, round/ tow) for Sea Scallop in the North bed, 2003–18 (Confidence intervals- 95%).

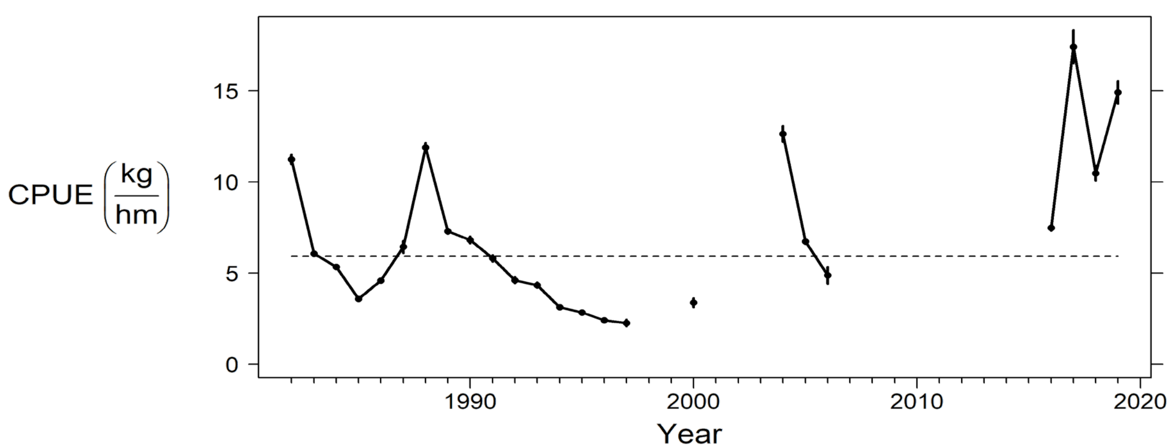

Figure 7. CPUE (kg/hm) for Sea Scallop in the offshore fleet (Middle and South beds), 1982–2019. Hm = Hour-meters.

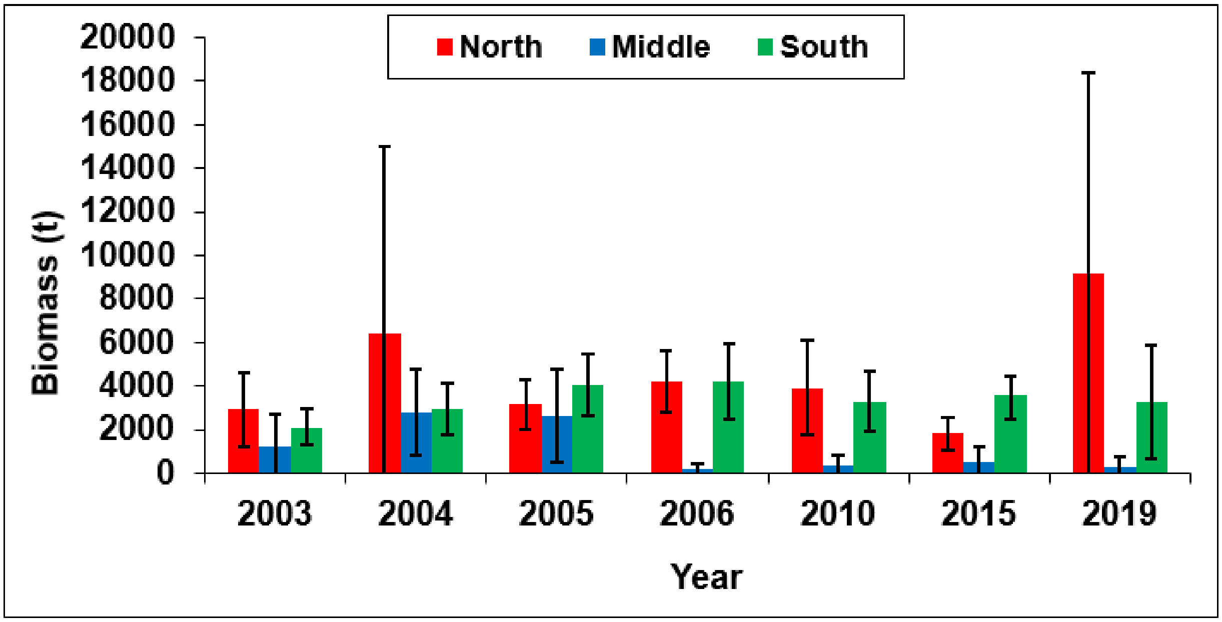

Figure 8. Minimum dredgeable biomass (MDB) estimates (with 95% confidence intervals) for the three beds on the St. Pierre Bank from 2003 to 2019.

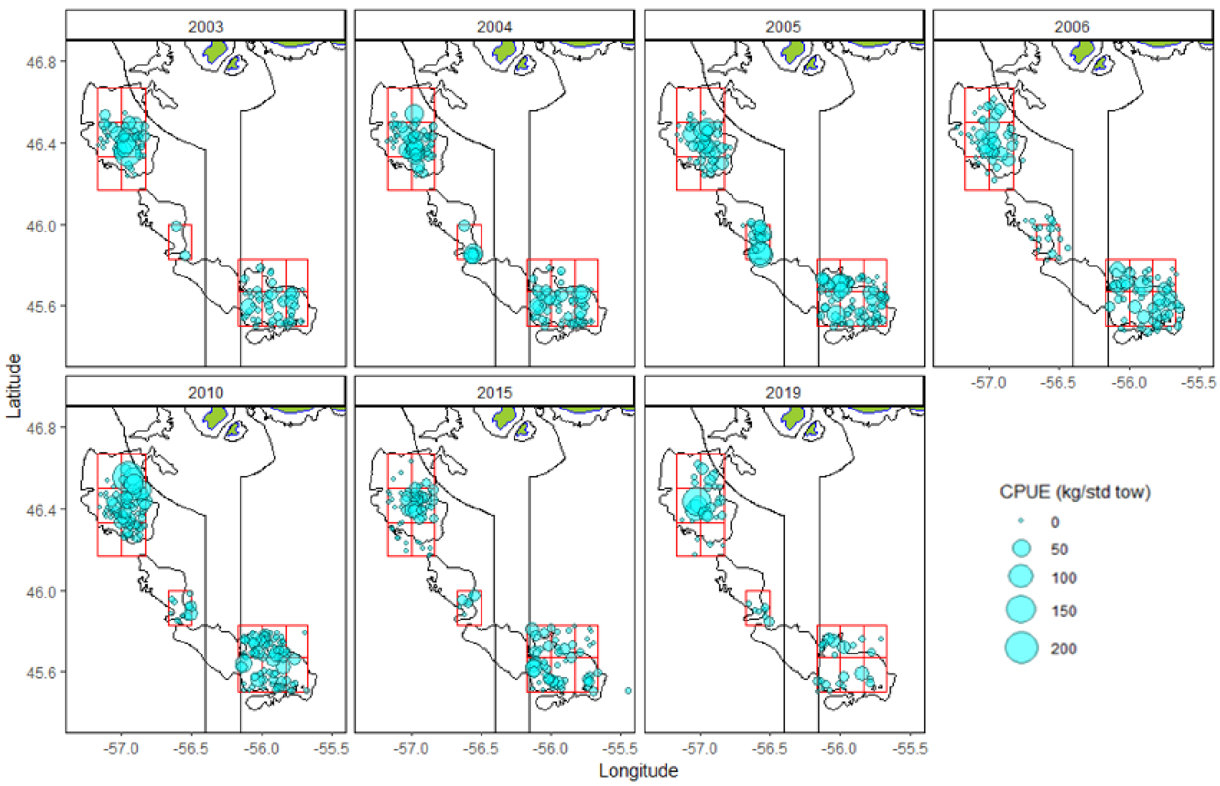

Figure 9. Scallop survey catches (kg/std tow) on St. Pierre Bank from 2003 to 2006, 2010, 2015, and 2019.

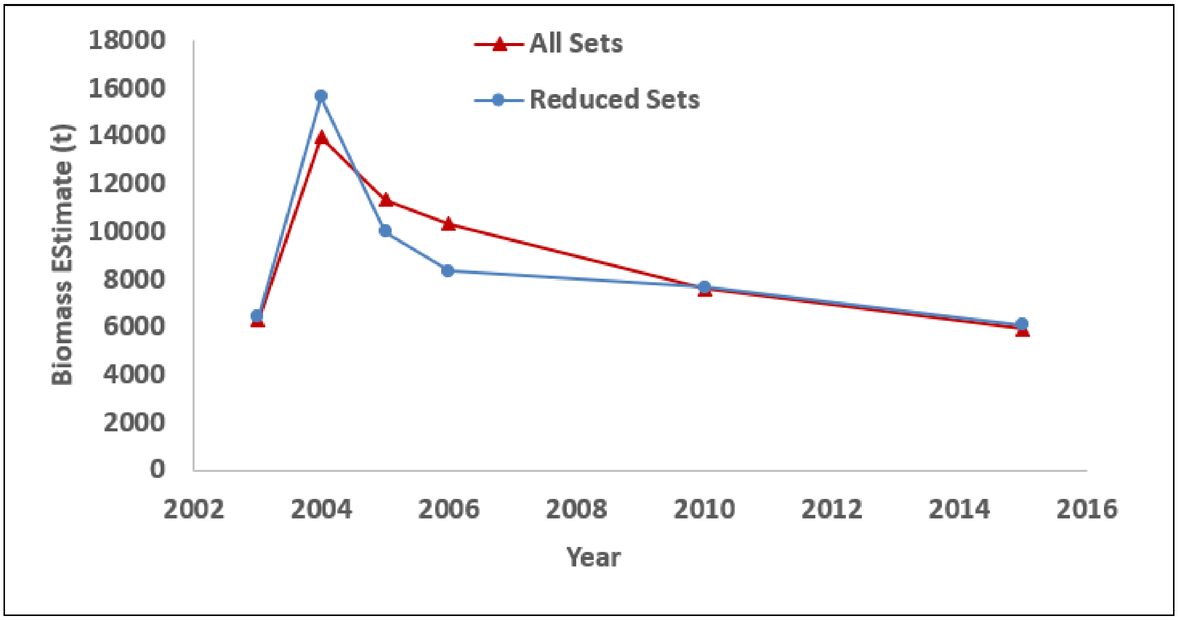

Figure 10. Biomass estimates over the survey time series for all allocated sets compared to the reduced sets based on the reduced allocated area in 2019.

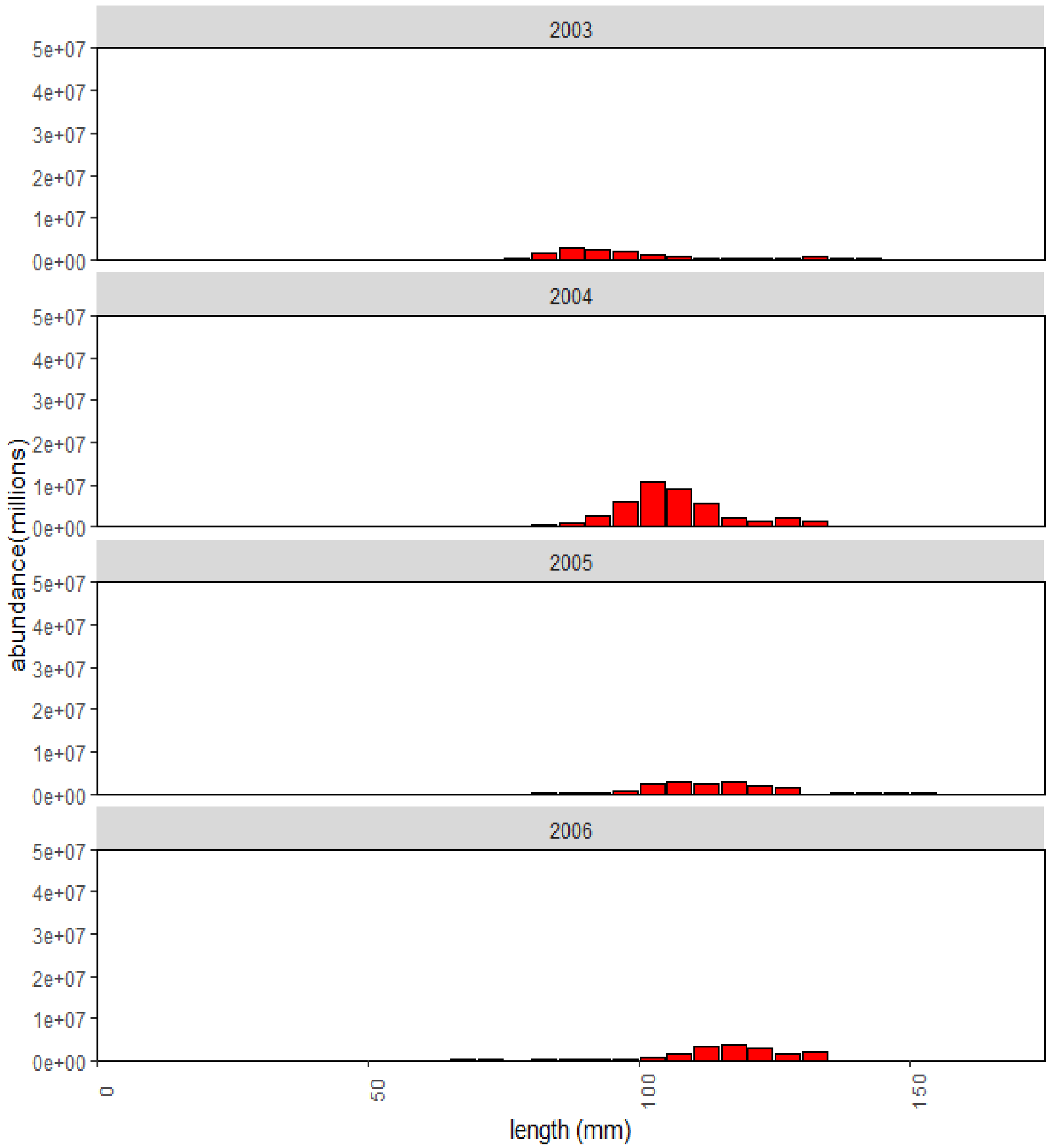

Figure 11. Size structure (length frequency [5 mm] groupings) of Sea Scallop sampled in research assessment surveys in the North bed on the St. Pierre Bank from 2003 to 2006.

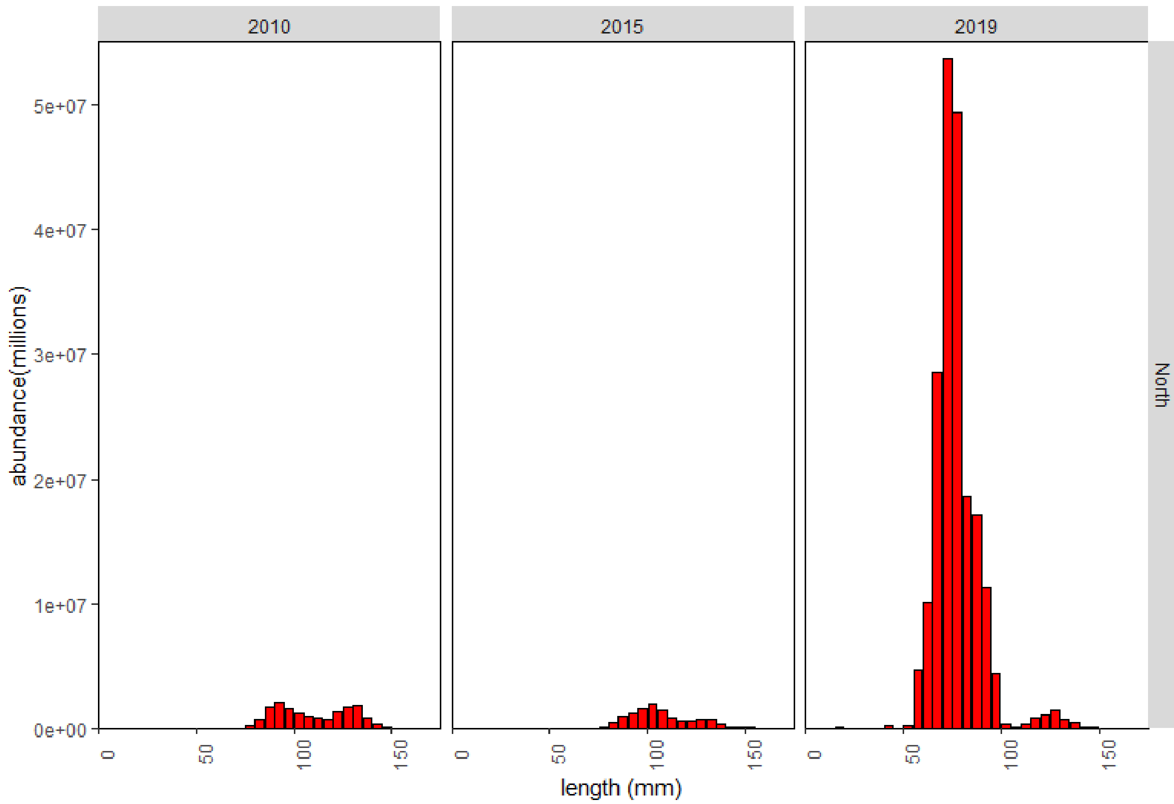

Figure 12. Size Structure (length frequency [5 mm] groupings) of Sea Scallop sampled in research assessment surveys in the North bed on the St. Pierre Bank in 2010, 2015, and 2019.

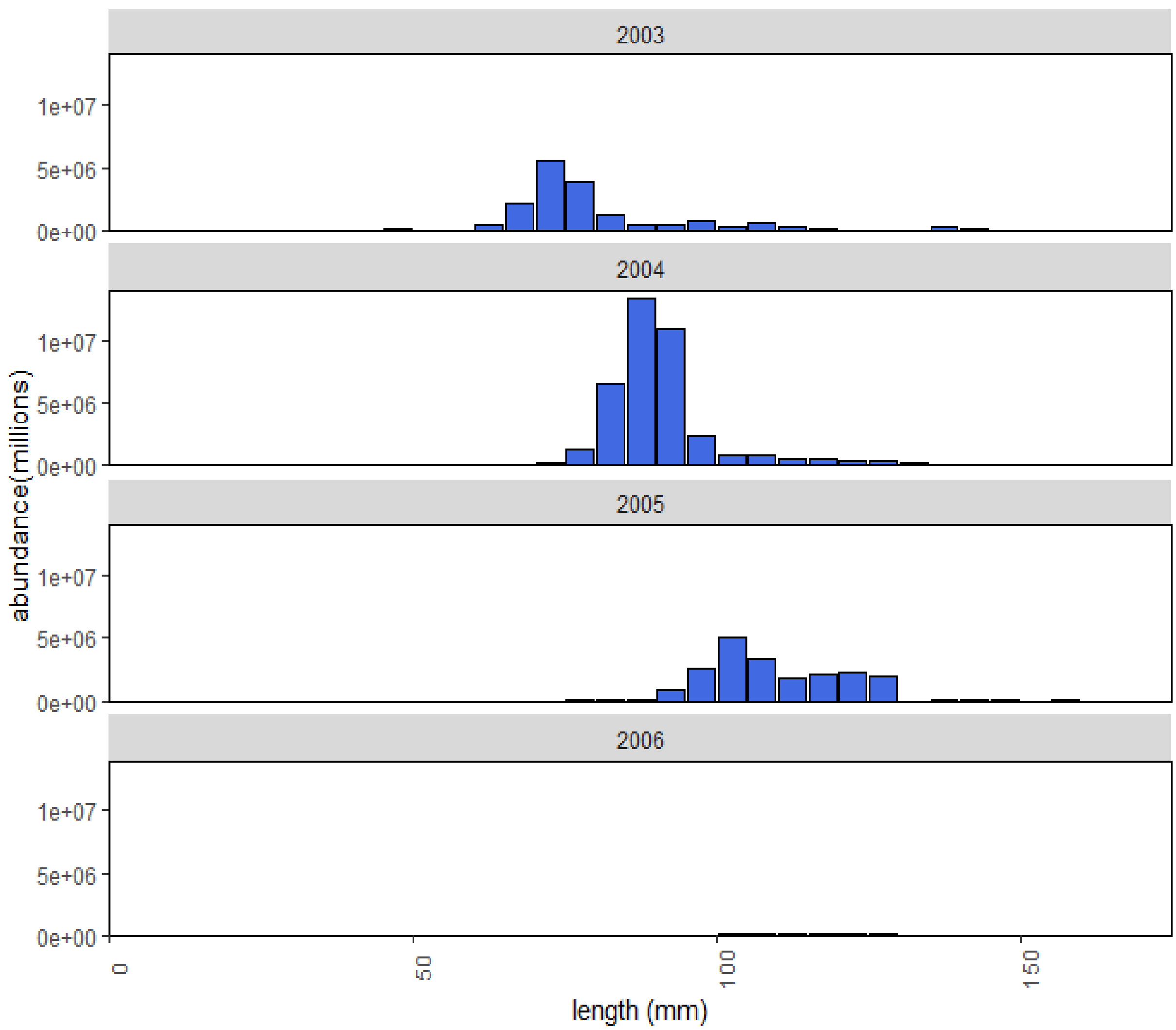

Figure 13. Size Structure (length frequency [5 mm] groupings) of Sea Scallop sampled in research assessment surveys in the Middle bed on the St. Pierre Bank from 2003 to 2006.

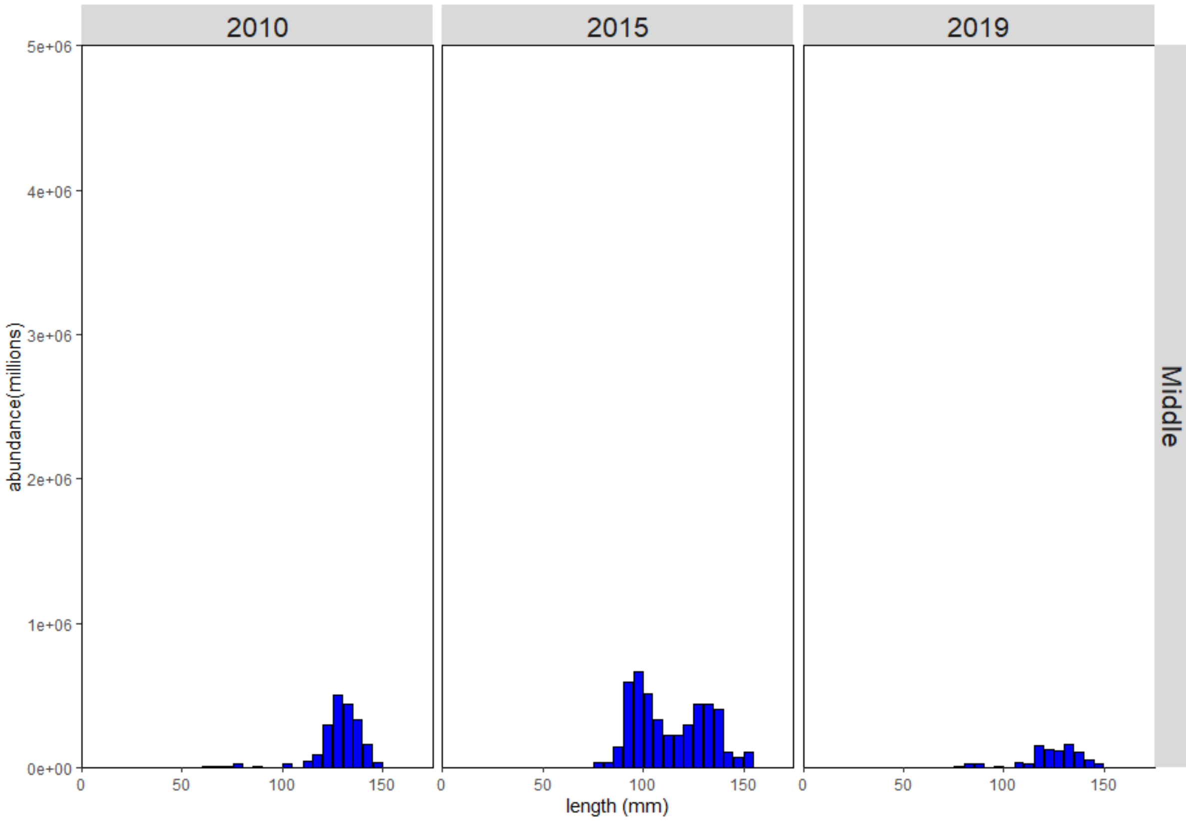

Figure 14. Size Structure (length frequency [5 mm] groupings) of Sea Scallop sampled in research assessment surveys in the Middle bed on the St. Pierre Bank in 2010, 2015, and 2019.

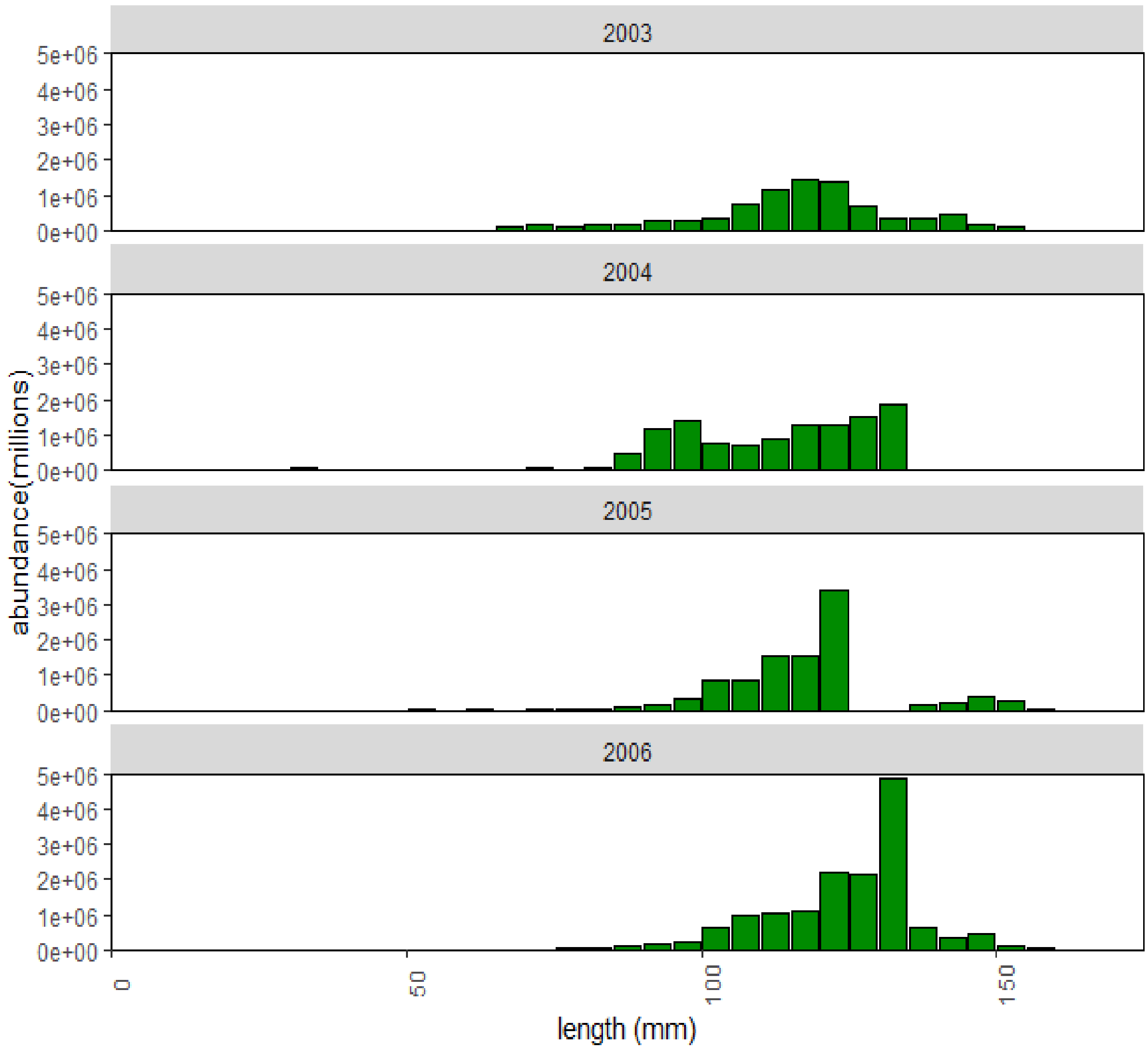

Figure 15. Size Structure (length frequency [5 mm] groupings) of Sea Scallop sampled in research assessment surveys in the South bed on the St. Pierre Bank from 2003 to 2006.

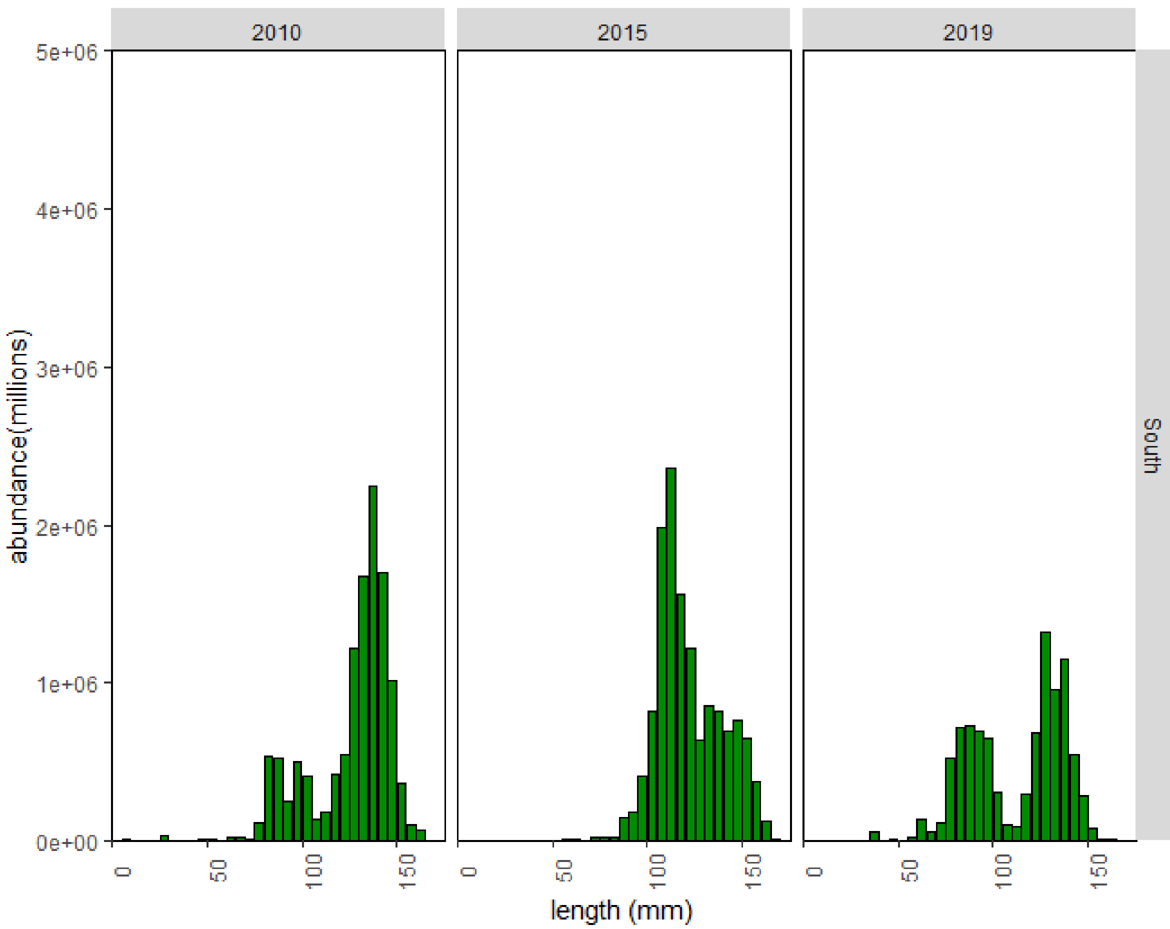

Figure 16. Size Structure (length frequency [5 mm] groupings) of Sea Scallop sampled in research assessment surveys in the South bed on the St. Pierre Bank in 2010, 2015, and 2019.

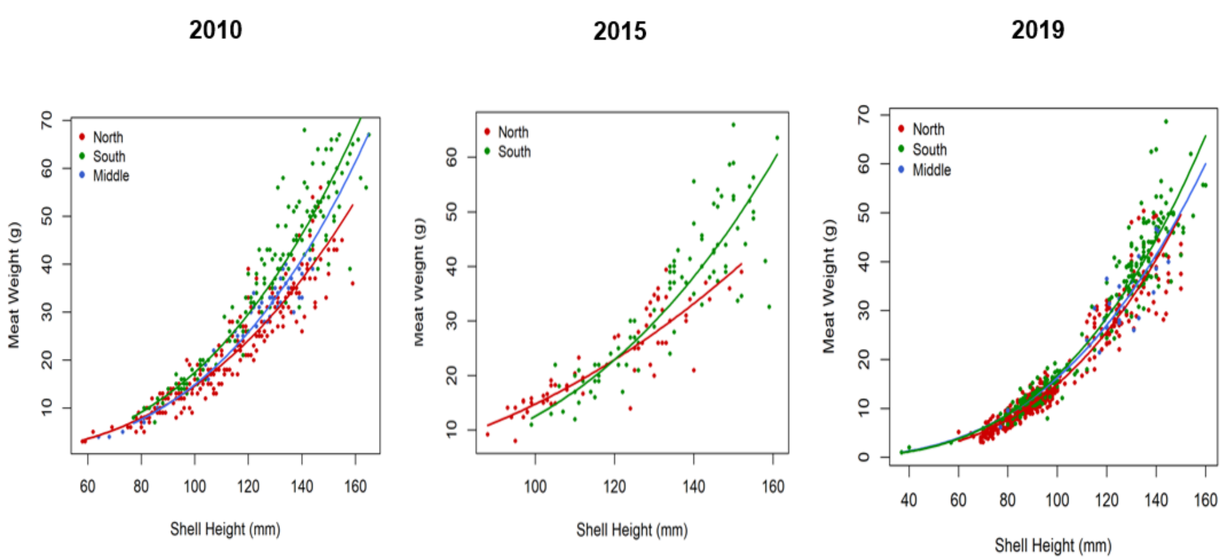

Figure 17. Shell height (mm) versus meat weight (g) from the 2010, 2015, and 2019 surveys in the North, South and Middle beds.

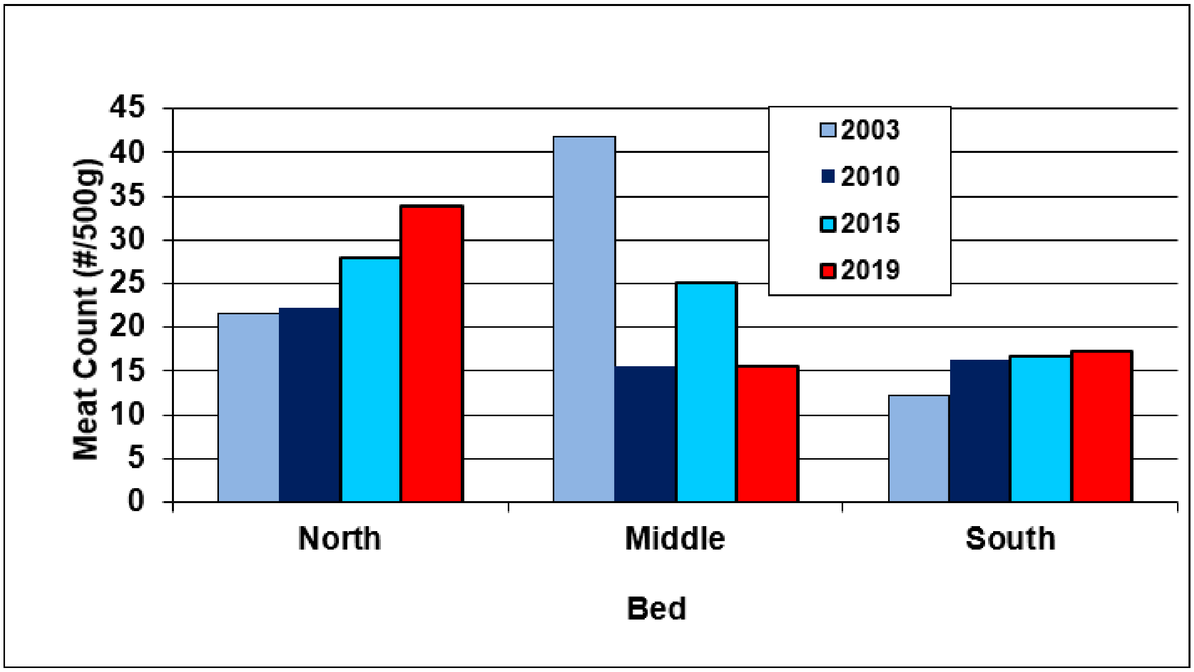

Figure 18. Biological meat count (#/500 g) for the North, Middle and South beds based on the 2003, 2010, 2015, and 2019 resource assessment surveys.

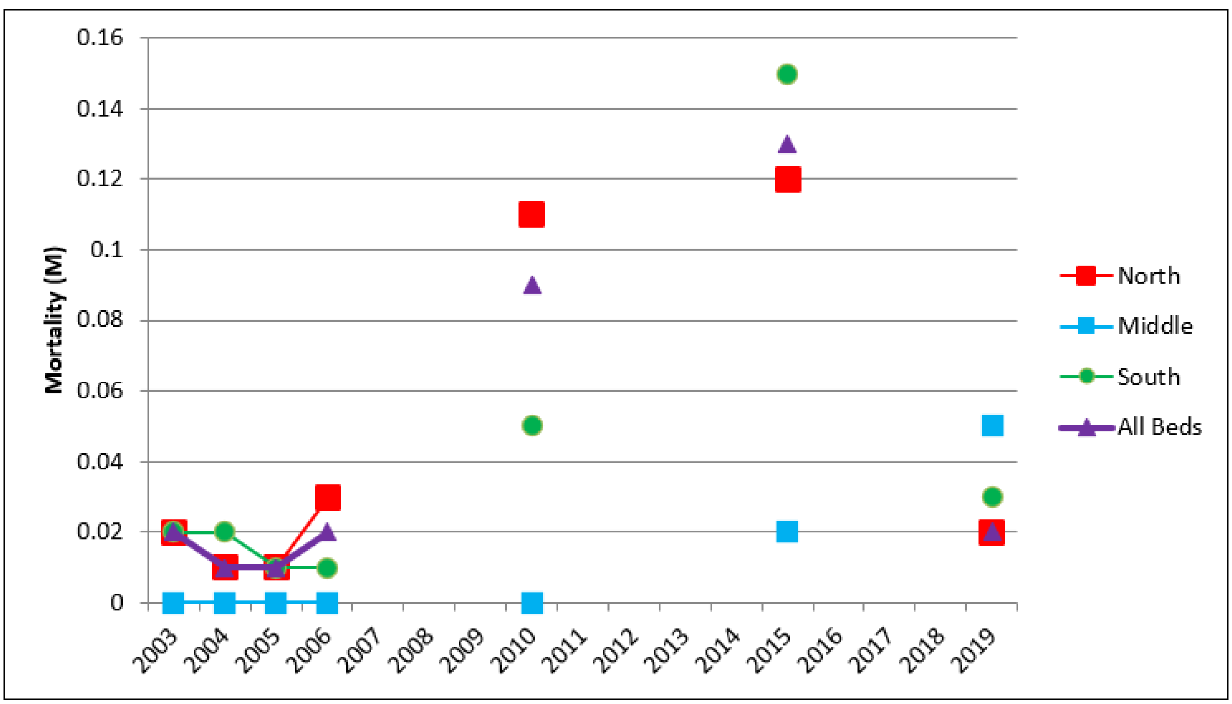

Figure 19. Mortality estimate trends for Sea Scallop in the North, Middle and South beds and all beds combined on St. Pierre Bank, for each year of the survey time series.

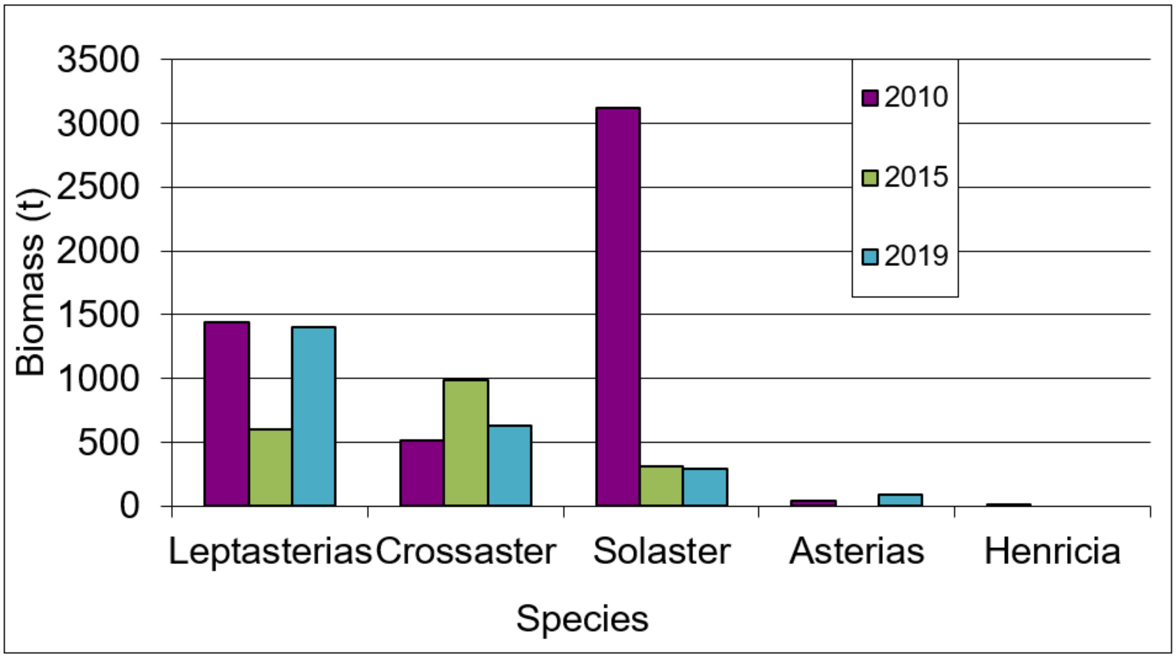

Figure 20. Abundance estimates of the five sea star species on St. Pierre Bank based on the scallop resource assessment surveys in 2003, 2010, 2015, and 2019.

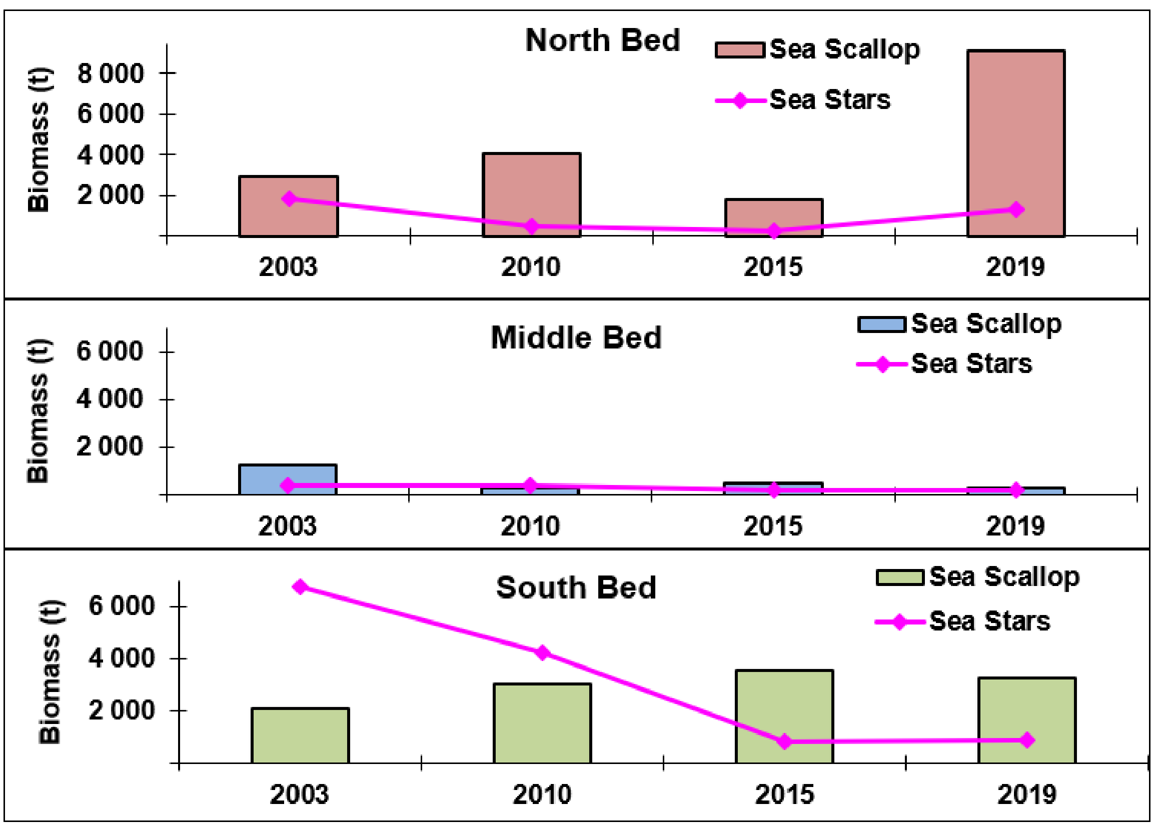

Figure 21. Biomass estimates of Sea Scallop (bars) and sea stars (lines) over the survey time series, in the North bed (top panel), Middle bed (middle panel), and South bed (bottom panel).