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

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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

The directed fishery for Sea Scallop (*Placopecten magellanicus*) started on St. Pierre Bank (Northwest Atlantic Fisheries Organization (NAFO) Subdiv. 3Ps) in the late 1970s. This is a pulse fishery largely dependent on sporadic recruitment. Populations on St. Pierre Bank are mainly found at depths from 40 to 100 m in three beds: North, Middle and South. They are usually found on hard bottom, with variable substrate composition, consisting largely of sand, gravel, shell fragments, and cobble.

Prior to 2006, the fishery was managed by Total Allowable Catch (TAC) and meat count regulations 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. Since then, fishing has only been prosecuted in the North bed by the Newfoundland inshore fleet. Between 2005 and 2010, landings ranged from 300 t to 770 t then increased to 1,190 t in 2012, and since then have averaged 1,125 t shell stock (136 t meat weight).

A Fisheries and Oceans Canada research vessel survey in September 2015 resulted in a minimum dredgeable biomass (MDB) estimate of 5,912 t, the lowest since 2005. In addition, it was determined the abundance was dominated by a single modal group of scallops (110 mm) in the South and North beds. The natural mortality index for Sea Scallop increased from 0.09 in 2010 to 0.13 in 2015. Recruitment prospects are unknown.

# INTRODUCTION

## SPECIES BIOLOGY

The 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 Scallops. Populations on St. Pierre Bank are mainly found at depths from 40 to 100 m in three beds: North, Middle and South (Fig. 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 about 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. The 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.

## THE FISHERY

Annual landings of Sea Scallop from the St. Pierre Bank have been highly variable (Fig. 2, Table 1), as typical of 'pulse'-type fisheries. Directed fishing started in the late 1970s and landings peaked twice in the 1980s: 6,000 tonnes round weight (t) 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 ~ 4,500 t and 2,400 t, respectively (DFO, 2007). Between 2005 and 2010 landings 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). The conversion factor for Sea Scallop from round weight (shell stock) to meat weight is 8.3 (Hennen et al. 2012).

Prior to 2006 the fishery was managed by a Total Allowable Catch (TAC), and meat count regulations applied to the offshore fleet, but not to the inshore fleet. Following the release of the Hooley report (Hooley 2005) in 2006, fishing areas were assigned based on three known fishing beds on the St. Pierre Bank (Fig. 1). Since 2006, the offshore fleet has not fished on the St. Pierre Bank and fishing has only occurred on the North bed by NL inshore vessels.

In 2015, the TAC for the inshore fleet was 1,121 t (round weight) (135 t meat weight) and the offshore fleet was allocated 415 t (round weight) 50 t (meat weight).

# METHODOLOGY

## THE FISHERY

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.

# RESEARCH VESSEL SURVEYS

## Survey Design

A Fisheries and Oceans Canada (DFO) resource assessment survey was conducted in September 2015 onboard the 50 m research vessel Canadian Coast Guard Ship (CCGS) Alfred Needler. Previous surveys varied by time and vessel. Resource assessment surveys were conducted by DFO in 2003 using the CCGS Wilfred Templeman and in 2010 and 2015 using the 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) (Fig. 3). Sets were optimally allocated in proportion to stratum-specific area and variance of the catch rates from the 2003 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).

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

where $n_h$ = number of sets in stratum ‘h’, n = total number of sets available, $A_h$ = area of stratum ‘h’, and $S^2_h$ = Variance in stratum ‘h’

Allocation of fishing sets and number of sets completed by strata in the 2015 survey are shown in Tables 2 and 3.

## 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 nautical miles (nm), whereas the Cape Keltic surveys used 0.5 standard mi. tow length. All survey data were standardized to a 0.5 nm tow distance. Upon completion of each tow (i.e., set) empty scallop shells with non-disarticulated valves (“cluckers”) and live scallops were sorted by species (DFO, 2011). Towing speed was approximately 3 knots with a warp (wire length) to depth ratio of 3:1. Tow duration was determined on distance not time. All tows passed through the allocated position with tow direction being random except if the position was too close to the stratum border or an obstruction, then the direction was so that the tow could be completed within the stratum and/or to avoid the obstruction.

## Sampling

Upon completion of each tow, 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 and 2015. 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). Individual meat and shell samples were obtained for Sea Scallops.

In addition, 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 and predatory Sea Stars was calculated for each survey for each of the three beds: North, South, Middle, 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 tow.

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.

## NATURAL MORTALITY

Natural mortality of Sea Scallops was computed directly from percent occurrence of cluckers (Dickie 1955) according to the equation:

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

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

## MEAT YIELDS

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

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:

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

A length/weight regression was applied to abundance at length to estimate weight of meat in terms of biomass, instead of the whole shell stock or round weight. These results were presented for the North and South beds in 2010 and 2015 and for the Middle bed in 2010.

## SIZE STRUCTURE

The shell height data from the resource assessment surveys in 2003–2006, 2010, and 2015 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 DFO resource assessment surveys in 2010 and 2015. Based on these data a linear regression analysis of covariance (ANCOVA) was performed. The shell height and meat weight data were log transformed and the significance in the difference in slopes for the North and South beds within 2010 and 2015 were generated. The relationship and significance in the difference in the slopes was compared between years in 2010 and 2015 and within the North and South beds.

# RESULTS

## THE FISHERY

Between 2005 and 2010 landings ranged from 300 t to 770 t then increased to 1,190 t in 2012, and since then has averaged 1,125 t round weight (136 t meat weight).

## BIOMASS

The DFO resource assessment survey in 2015 resulted in an MDB estimate of 5,912 t (round weight) in all beds combined, the lowest since 2005 (Fig. 4, Table 2). The South bed constituted 60% of the MDB, with 31% of the MDB in the North bed and only 9% in the Middle bed. The reduction in overall biomass since 2010 was mainly a result of a 56% reduction in the North bed (4103 t in 2010 to 1821 t in 2015) (Figs. 4, 5). The biomass in the North bed started to show evidence of a decline in 2010 (Fig. 4). The biomass increased slightly from 329 t in 2010 to 516 t in 2015 in the Middle bed. In the South bed, the stock declined slightly from 2006 to 2010 then increased from 3,024 t in 2010, to 3,575 t in 2015 (Figs. 4, 5). The overall biomass in the three beds decreased from 7,500 t in 2010 to 5,912 t in 2015 (Fig 4. Table 2.).

## RECRUITMENT AND SIZE STRUCTURE

Recruitment potential was evaluated by examining the abundance of pre recruit size scallop < 90 mm, which has been low since 2004. Future recruitment prospects are unknown.

The length frequency distributions display the size structure for each bed (North, Middle, and South) and all beds combined (Figs. 6-9). The modal shell height (length) in the North bed slightly decreased since 2006, from approximately 120 mm to 105 mm in 2015 (Fig. 6). It is also evident from the length frequencies that the overall abundance across the broad range of lengths declined through the survey time series (Fig. 6).

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. There was a slight indication of pre-recruits in 2015, but again the overall abundance remains low (Fig. 7).

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. The modal group of shell height decreased from approximately 130 mm in 2010 to 110 mm in 2015 (Fig. 8).

For all the beds combined there were two modal groups in 2010 (93 mm and 130 mm), which then changed to a single modal group of 110 mm in 2015 (Fig. 9, Table 4).

## MEAT YIELDS AND MEAT BIOMASS

Biological meat yields were collected in most of the strata in the 2003, 2010, and 2015 resource assessment surveys (Fig. 10). Overall, the meat yields were approximately 25 meats/500g, expect for the middle bed which was 16 meats/500g in 2015. In the North bed and Middle bed, from 2010 to 2015, there was an increase in meat count. There was no change in the meat count in the South bed (Fig.10).

The abundance at length was used to estimate the meat biomass. The abundance (Fig. 11) and the meat biomass (Fig. 12) in the North bed decreased from 2010 to 2015 (Table 5). In the South bed, the abundance showed a slight increase (Fig. 11), but the meat biomass decreased (Fig. 12). In the Middle bed, the abundance and meat biomass estimates were only available for 2010, but both were relatively low compared to the other beds.

## INDIVIDUAL SHELL HEIGHT AND MEAT WEIGHTS

Individual shell height - meat weight information was collected on the resource assessment surveys in 2010 and 2015. Based on these data, a linear regression analysis of covariance (ANCOVA) was performed.

The relationship between the individual meat weight and lengths were compared for 2010 and 2015 and compared between beds (North and South). When the data were analysed using the meat weights and individual lengths for the years and beds, the trend was curvilinear and the variance increased with shell height (Fig. 13). Therefore, data were log-transformed to reduce these violations and investigate the relationship between the individual shell height and meat weights at a linear scale (Fig. 14). A clear linear relationship between logged meat height and logged meat weight was found ($p < 0.001$). Significant differences between the beds ($p < 0.001$) and years ($p < 0.001$) were also found, however, there were significant interactions between height and bed ($p < 0.0001$) and height, year and bed ($p < 0.0001$) with no significant interaction between height and year.

In the North bed there was inter-annual variation (Fig. 15), while in the South bed for the same shell height in 2010 the meat weight was lower in 2015 (Fig. 16). However, the pattern is not consistently parallel as there is more overlap in the larger shell height ranges, which could possibly explain the lack of change in the meat count in the South bed. In 2010, the meat weight was heavier for any given shell height in the South bed compared to the North bed (Fig. 17). However, in 2015 the parallel pattern and distinction between the beds was not clear (Fig. 18). Smaller scallop in the North bed are heavier than those in the South bed and larger scallop in the South bed are heavier than those in the North bed.

## NATURAL MORTALITY

The natural mortality index for all beds combined increased from 0.09 in 2010 to 0.13 in 2015 (Fig. 19). The highest natural mortality was in the South bed in 2015 at 0.15 and the lowest was in the Middle bed at 0.02 in 2015 (Fig. 19, Table 6). Overall the natural mortality is still considered low and is likely associated with low biomass of predatory Sea Stars.

## PREDATION

The abundance estimates for the key Sea Star species including *Leptasterias polaris*, *Crossaster papposus.*, *Solaster endeca*, and *Asterias rubens*. all show that the overall abundance has declined since 2003 (Fig. 20). However, Sea Stars in the North bed and Middle bed showed little to no change in biomass (Fig. 21). The most obvious change was in the South bed, where Sea Star biomass has substantially declined (Fig. 21). This may be an indication that predatory Sea Stars have not been a large contributor to the natural mortality of Sea Scallop.

## CONCLUSIONS

In 2010, landings were 770 t then increased to 1,190 t in 2012 and decreased slightly to 1,089 t in 2015. Since 2006 the offshore fleet has not fished on the St. Pierre Bank and fishing has only been taking place on the North bed by NL inshore vessels. The MDB estimate from the 2015 survey was 5,912 t (round weight), the lowest since 2005. The resource has decreased by 56% since 2010 in the North bed. There was a slight increase in the biomass estimates in the Middle and South beds from 2010 to 2015.

The size structure in the North bed showed a decrease in the modal group from approximately 120 mm in 2010 to 105 mm in 2015. The Middle bed showed a steep decline in abundance from 2005 to 2006 with little signs of recovery in the 2010 and 2015 surveys and a decline in the modal group to less than 100 mm. The size structure in the South bed showed a decrease in the modal group from 130 mm to 110 mm with a slight sign of pre-recruits in 2010, but little or no sign of pre-recruits in 2015.

Even though there has been little fishing in recent years in the South bed there seems to be a deterioration in the meat quality in the existing shell stock and this bed had the highest natural mortality in 2015. The mode in shell height in all three beds combined on the St. Pierre Bank has decreased from 130 mm in 2010 to 110 mm in 2015.

Recruitment appears to have been relatively low since 2004. Recruitment prospects are unknown. Overall the natural mortality is still 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 Framework.

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## APPENDIX I- TABLES

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

| - | - | NL<65' | - | NL>65' | NS>65' | Total |
|---|---|---|---|---|---|---|
| **YEAR** | **TAC** | **Inshore** | **TAC** | **Offshore** | **Offshore** | **Offshore** |
| 1969 | - | 11 | - | 0 | 0 | 0 |
| 1970 | - | 23 | - | 0 | 0 | 0 |
| 1971 | - | 12 | - | 0 | 0 | 0 |
| 1972 | - | 9 | - | 0 | 0 | 0 |
| 1973 | - | 24 | - | 0 | 0 | 0 |
| 1974 | - | 3 | - | 0 | 0 | 0 |
| 1975 | - | 3 | - | 0 | 0 | 0 |
| 1976 | - | 18 | - | 0 | 0 | 0 |
| 1977 | - | 86 | - | 0 | 0 | 0 |
| 1978 | - | 41 | - | 0 | 191 | 191 |
| 1979 | - | 130 | - | 0 | 8 | 8 |
| 1980 | - | 67 | - | 0 | 291 | 291 |
| 1981 | - | 30 | - | 0 | 0 | 0 |
| 1982 | - | 169 | - | 0 | 5951 | 5951 |
| 1983 | - | 102 | - | 0 | 4930 | 4930 |
| 1984 | - | 340 | - | 0 | 3428 | 3428 |
| 1985 | - | 300 | - | 0 | 440 | 440 |
| 1986 | - | 328 | - | 0 | 1270 | 1270 |
| 1987 | - | 404 | - | 0 | 448 | 448 |
| 1988 | - | 1591 | - | 0 | 8176 | 8176 |
| 1989 | - | 429 | - | 0 | 2756 | 2756 |
| 1990 | - | 289 | - | 0 | 1270 | 1270 |
| 1991 | - | 167 | - | 0 | 1112 | 1112 |
| 1992 | - | 0 | - | 0 | 556 | 556 |
| 1993 | - | 483 | - | 0 | 882 | 882 |
| 1994 | - | 534 | - | 0 | 407 | 407 |
| 1995 | - | 418 | - | 0 | 565 | 565 |
| 1996 | - | 8 | - | 0 | 153 | 153 |
| 1997 | - | 9 | - | 0 | 25 | 25 |
| 1998 | - | 268 | - | 0 | 0 | 0 |
| 1999 | - | 71 | - | 0 | 0 | 0 |
| 2000 | - | 79 | - | 0 | 34 | 34 |
| 2001 | - | 338 | - | 0 | 0 | 0 |
| 2002 | - | 51 | - | 0 | 0 | 0 |
| 2003 | - | 647 | - | 0 | 0 | 0 |
| 2004 | - | 2465 | - | 1008 | 1073 | 2081 |
| 2005 | - | 618 | - | 1514 | 256 | 1770 |
| 2006 | 872 | 523 | 1619 | 0 | 43 | 43 |
| 2007 | 872 | 364 | 1619 | 0 | 0 | 0 |

| - | - | NL<65' | - | NL>65' | NS>65' | Total |
|---|---|---|---|---|---|---|
| **YEAR** | **TAC** | **Inshore** | **TAC** | **Offshore** | **Offshore** | **Offshore** |
| 2008 | 872 | 303 | 1619 | 0 | 0 | 0 |
| 2009 | 872 | 423 | 1619 | 0 | 0 | 0 |
| 2010 | 872 | 770 | 0 | 0 | 0 | 0 |
| 2011 | 872 | 922 | 0 | 0 | 0 | 0 |
| 2012 | 1121 | 1190 | 0 | 0 | 0 | 0 |
| 2013 | 1121 | 1071 | 0 | 0 | 0 | 0 |
| 2014 | 1121 | 1169 | 25 | 0 | 0 | 0 |
| 2015 | 1111 | 1089 | 0 | 0 | 0 | 0 |

*Table 2. Minimum dredgeable biomass estimates and number of sets per stratum in 2010 and 2015 DFO resource assessment surveys*

| | | **2010** | | | | | | **2015** | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Stratum** | **Sets** | **Mean** | **Upper** | **Lower** | **+/-** | **Sets** | **Mean** | **Upper** | **Lower** | **+/-** |
| 141 | 5 | 19.6 | 53.1 | 0.0 | 33.5 | 3 | 0 | 0 | 0 | 0 |
| 142 | 15 | 2,064.9 | 5,006.6, | 0.0 | 2,941.7 | 3 | 364.89 | 1,162.6 | -432 | 797.71 |
| 143 | 19 | 313.2 | 627.3 | 0.0 | 314.10 | 12 | 511.45 | 1,052.8 | 29.9 | 541.35 |
| 144 | 23 | 1,299.9 | 1,915.2 | 684.6 | 615.3 | 23 | 944.44 | 1352.2 | 536.7 | 407.6 |
| 145 | 2 | 0 | 0 | 0 | 0 | 6 | 0 | 0 | 0 | 0 |
| 146 | 22 | 405 | 631.6 | 178.4 | 226.6 | 6 | 0 | 0 | 0 | 0 |
| **North** | 86 | 4,102.6 | 7,118.7 | 1,086.5 | 3,016.10 | 53 | 1,820.78 | 3,567.60 | 134.6 | 1,746.66 |
| 201 | 18 | 495.6 | 899.10 | 92.10 | 403.5 | 7 | 942.19 | 1,497.9 | 386.5 | 555.7 |
| 202 | 29 | 448.4 | 719.6 | 177.2 | 271.2 | 10 | 524.87 | 937.6 | 112.2 | 412.7 |
| 203 | 3 | 112.7 | 597.4 | 0 | 484.7 | 7 | 85.5 | 222.9 | -51.9 | 137.4 |
| 204 | 9 | 1,034.1 | 2,296.3 | 0 | 1,262.2 | 14 | 811.5 | 1469 | 154.1 | 657.5 |
| 205 | 15 | 668.7 | 1,147.9 | 189.5 | 479.2 | 9 | 542.59 | 978.5 | 106.7 | 435.8 |
| 206 | 8 | 264.9 | 614.1 | 0 | 349.2 | 8 | 612.13 | 953.7 | 270.6 | 341.56 |
| **South** | 82 | 3,024.4 | 4,427.7 | 1,621.1 | 1,403.3 | 55 | 3,575.1 | 4,552.37 | 2,597.7 | 977.27 |
| **Middle - 207** | 82 | 329.5 | 713.3 | 0 | 383.8 | 6 | 515.8 | 1,211.5 | -180 | 695.8 |
| **Overall** | 181 | 7,457 | 10,710 | 4,203 | 3,253 | 114 | 5,911.6 | 7,241.14 | 4,582.1 | 1,392.6 |

*Table 3. Distribution of survey sets by strata, areas, and intensity of coverage in the 2015 resource assessment survey for Sea Scallop on St. Pierre Bank.*

| Stratum | Mean Depth (m) | Area (nmi$^2$) | No of sets completed | No of sets/nmi$^2$ |
|---|---|---|---|---|
| 141 | 44 | 71.79 | 3 | 0.04 |
| 142 | 44.7 | 55.1 | 3 | 0.05 |
| 143 | 42.75 | 72.01 | 12 | 0.17 |
| 144 | 44.8 | 72.01 | 23 | 0.32 |
| 145 | 54 | 68.0 | 6 | 0.09 |
| 146 | 59.8 | 68.0 | 6 | 0.09 |
| 201 | 50.1 | 60.7 | 7 | 0.12 |
| 202 | 50.4 | 68.6 | 10 | 0.15 |
| 203 | 54 | 64.6 | 7 | 0.11 |
| 204 | 47 | 64.38 | 14 | 0.22 |
| 205 | 47 | 73.08 | 9 | 0.12 |
| 206 | 48.1 | 68.78 | 8 | 0.12 |
| 207 | 52.1 | 72.66 | 6 | 0.08 |
| **Totals** | **-** | **879.55** | **114** | **0.13** |

*Table 4. Stratum-specific means and modal shell heights (mm) of Sea Scallop in 2015. Shell Height (mm)*

| Stratum | N | Mean | SD | Mode | Min | Max |
|---|---|---|---|---|---|---|
| 141 | 0 | 0 | 0 | 0 | 0 | 0 |
| 142 | 85 | 107.89 | 13.02 | 105 | 80 | 138 |
| 143 | 287 | 105.08 | 15.74 | 105 | 75 | 152 |
| 144 | 946 | 109.73 | 17.22 | 105 | 21 | 198 |
| 145 | 0 | 0 | 0 | 0 | 0 | 0 |
| 146 | 0 | 0 | 0 | 0 | 0 | 0 |
| **North** | 1,318 | 108.6 | 16.76 | 105 | 21 | 198 |
| 201 | 297 | 115.52 | 14.37 | 109 | 63 | 155 |
| 202 | 171 | 124.92 | 17.38 | 110 | 72 | 158 |
| 203 | 23 | 120.57 | 15.6 | 114 | 90 | 159 |
| 204 | 418 | 118.18 | 16.55 | 111 | 56 | 170 |
| 205 | 110 | 135.27 | 17.71 | 134 | 97 | 162 |
| 206 | 111 | 136.88 | 14.7 | 130 | 106 | 164 |
| **South** | 1,173 | 121.84 | 17.54 | 110.0 | 56 | 170 |
| **Middle - 207** | 1,173 | 121.84 | 17.54 | 110 | 56 | 170 |
| **Overall** | 2,616 | 114.83 | 18.2 | 110 | 21 | 198 |

*Table 5. Abundance estimates from the 2010 and 2015 resource assessment surveys by bed and year; and biomass estimates (meat, t) calculated from abundance estimates and individual shell height and meat weight equations by bed and year.*

| Year | Bed | Abundance ($10^6$) | Upper | Lower | Biomass Meat (t) | Upper | Lower |
|---|---|---|---|---|---|---|---|
| 2010 | Middle | 2.00 | 2.6 | -0.6 | 63.6 | 61.59 | -17.83 |
| 2010 | North | 16.78 | 8.41 | 8.37 | 354.27 | 337.5 | 189.33 |
| 2010 | South | 12.15 | 9.18 | 2.97 | 451.51 | 439.36 | 160.22 |
| 2015 | North | 12.11 | 10.00 | 2.11 | 218.10 | 205.99 | 56.06 |
| 2015 | South | 13.71 | 7.93 | 5.78 | 355.77 | 342.06 | 175.05 |

*Table 6. Stratum-specific natural mortality estimates for Sea Scallop on St. Pierre Bank, computed from ratio of cluckers to live scallops in 2015. Clucker numbers are adjusted by a factor of 1.221 to allow for tow-induced disarticulation.*

| **Stratum** | **Live** | **Cluckers** | **M; $M=1-e^{(c/t)(1/L0*365}$** |
|---|---|---|---|
| 141 | 0 | 0 | 0 |
| 142 | 80 | 3 | 0.08 |
| 143 | 288 | 24 | 0.16 |
| 144 | 932 | 51 | 0.11 |
| 145 | 0 | 0 | 0 |
| 146 | 0 | 0 | 0 |
| **Overall North** | 1,300 | 78 | 0.12 |
| 201 | 304 | 18 | 0.12 |
| 202 | 157 | 12 | 0.15 |
| 203 | 17 | 0 | 0 |
| 204 | 451 | 45 | 0.19 |
| 205 | 103 | 3 | 0.06 |
| 206 | 111 | 9 | 0.16 |
| **Overall South** | 1,143 | 87 | 0.15 |
| **Middle- 207** | 122 | 1 | 0.02 |
| **All Beds** | 2,565 | 166 | 0.13 |

## APPENDIX II- FIGURES

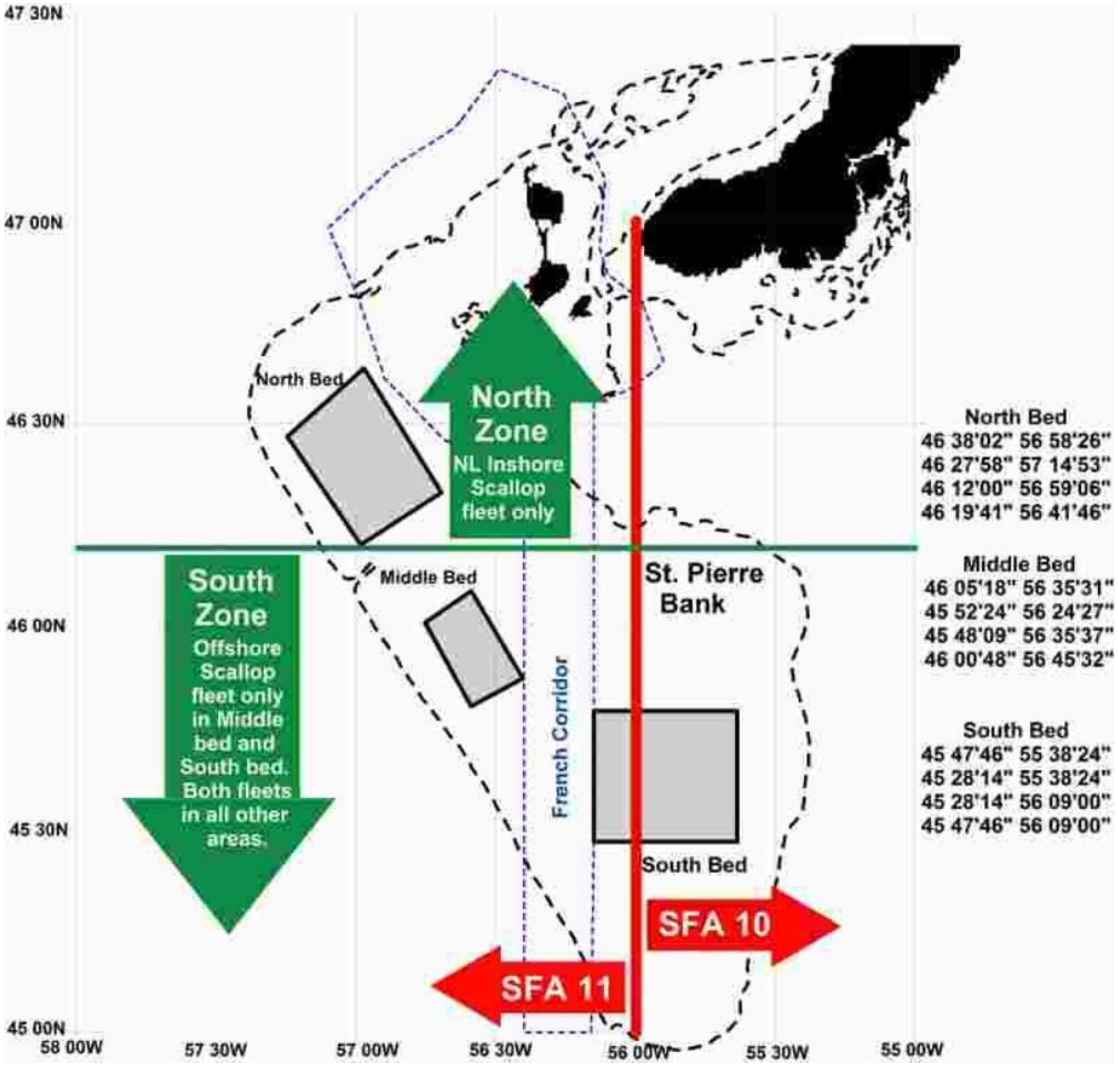


*Figure 1. St. Pierre Bank showing the three main Sea Scallop beds, the Hooley report recommended fleet separation zones and Scallop Fishing Areas (SFA) 10 and 11.*

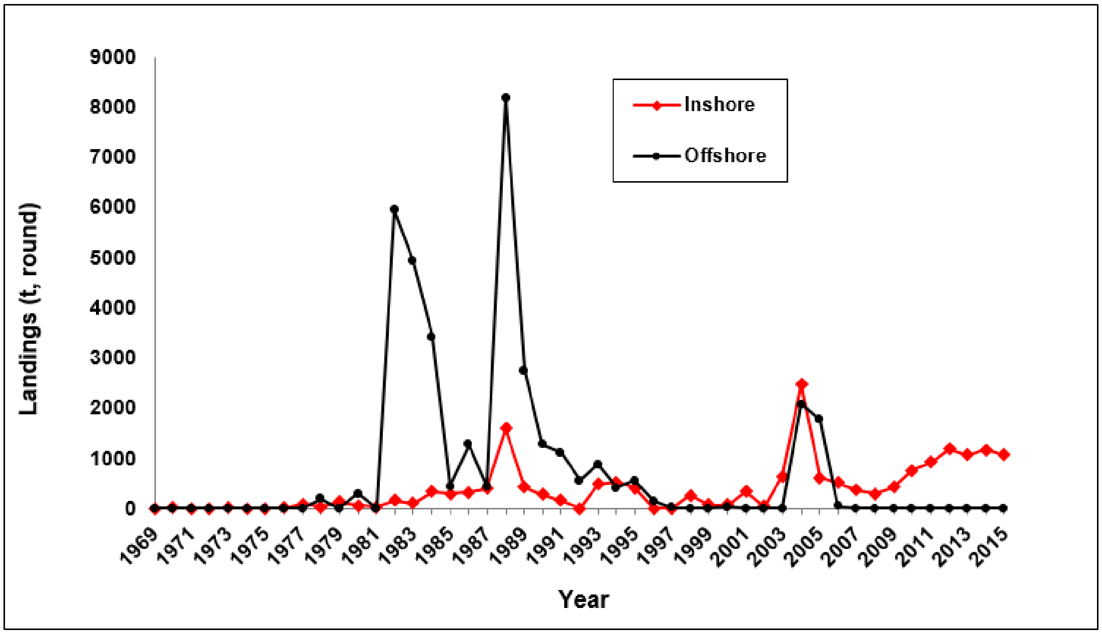


*Figure 2. Sea Scallop removals (t, round) from the three main beds on the St. Pierre Bank by inshore and offshore fleets.*

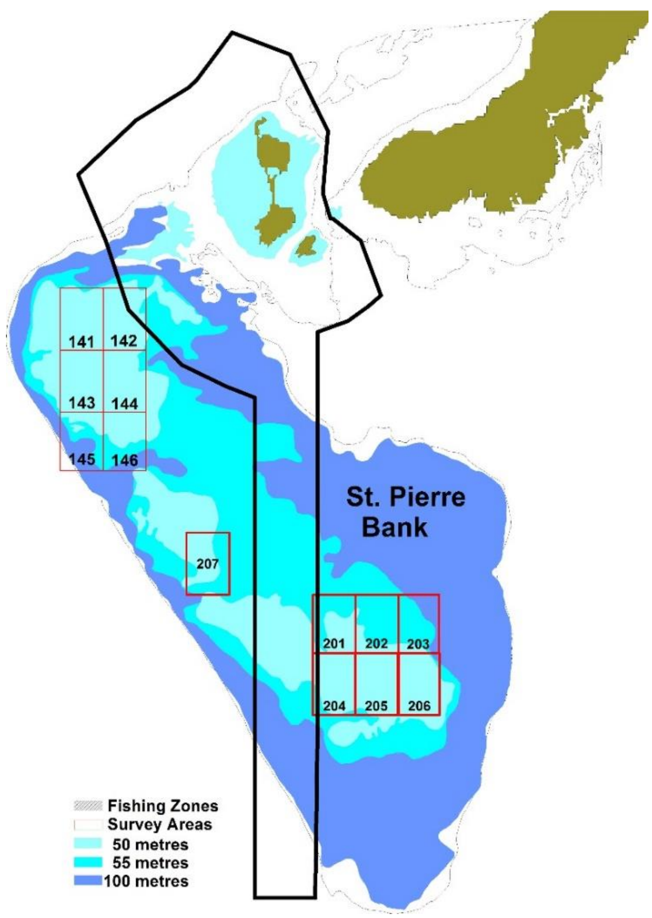


*Figure 3. Stratification scheme used in the 2015 DFO resource assessment survey.*

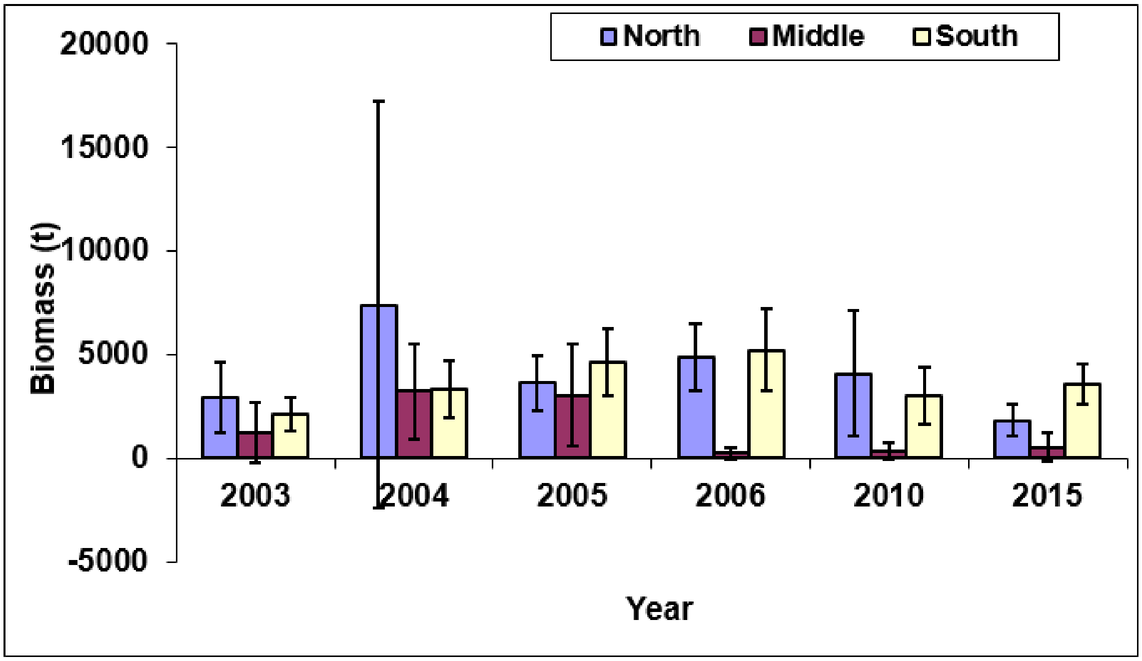


*Figure 4. Minimum dredgeable biomass estimates for the three main beds on the St. Pierre Bank from 2003 to 2015.*

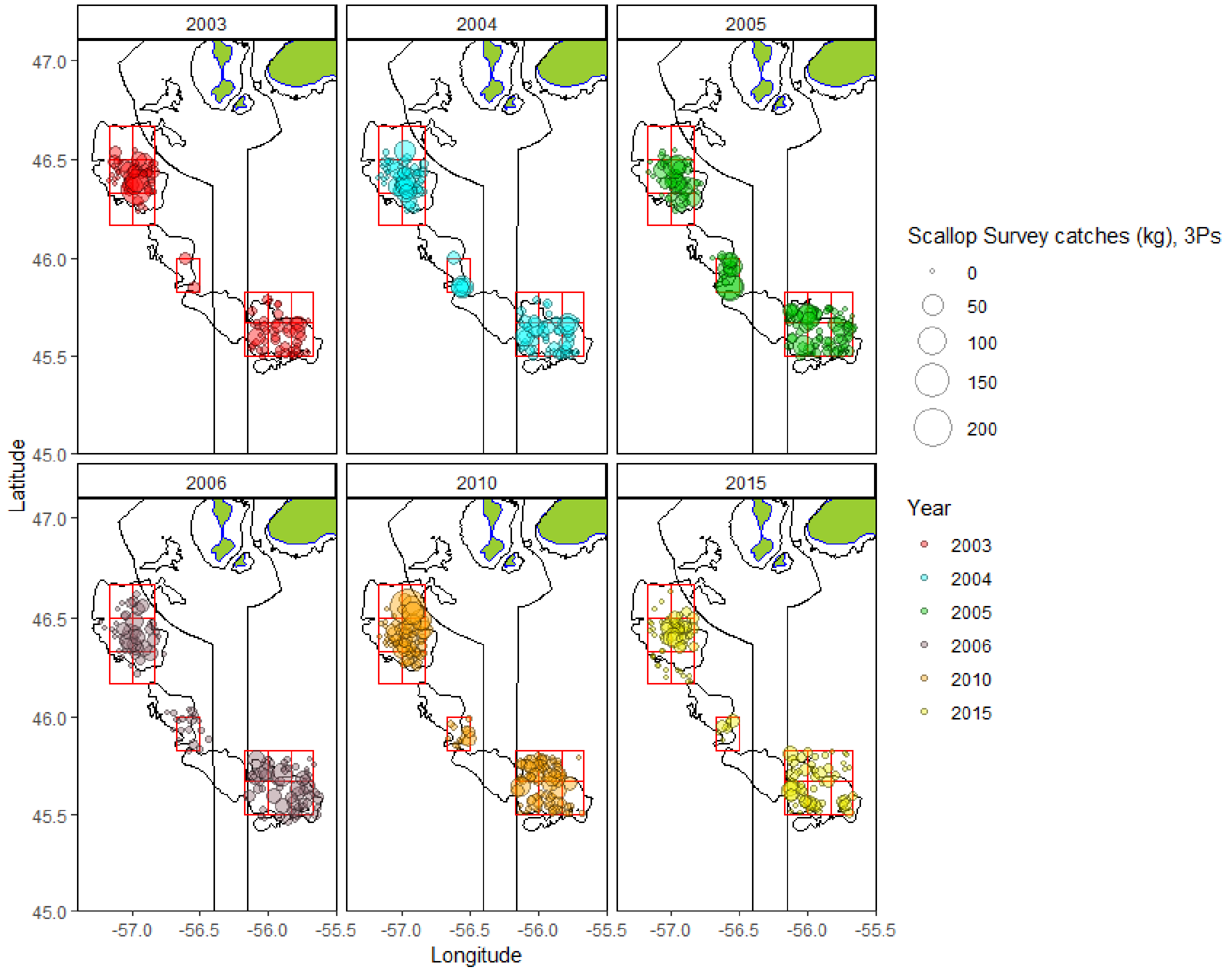


*Figure 5. Scallop survey catches (Kg) on St. Pierre Bank from 2003 to 2006, 2010 and 2015.*

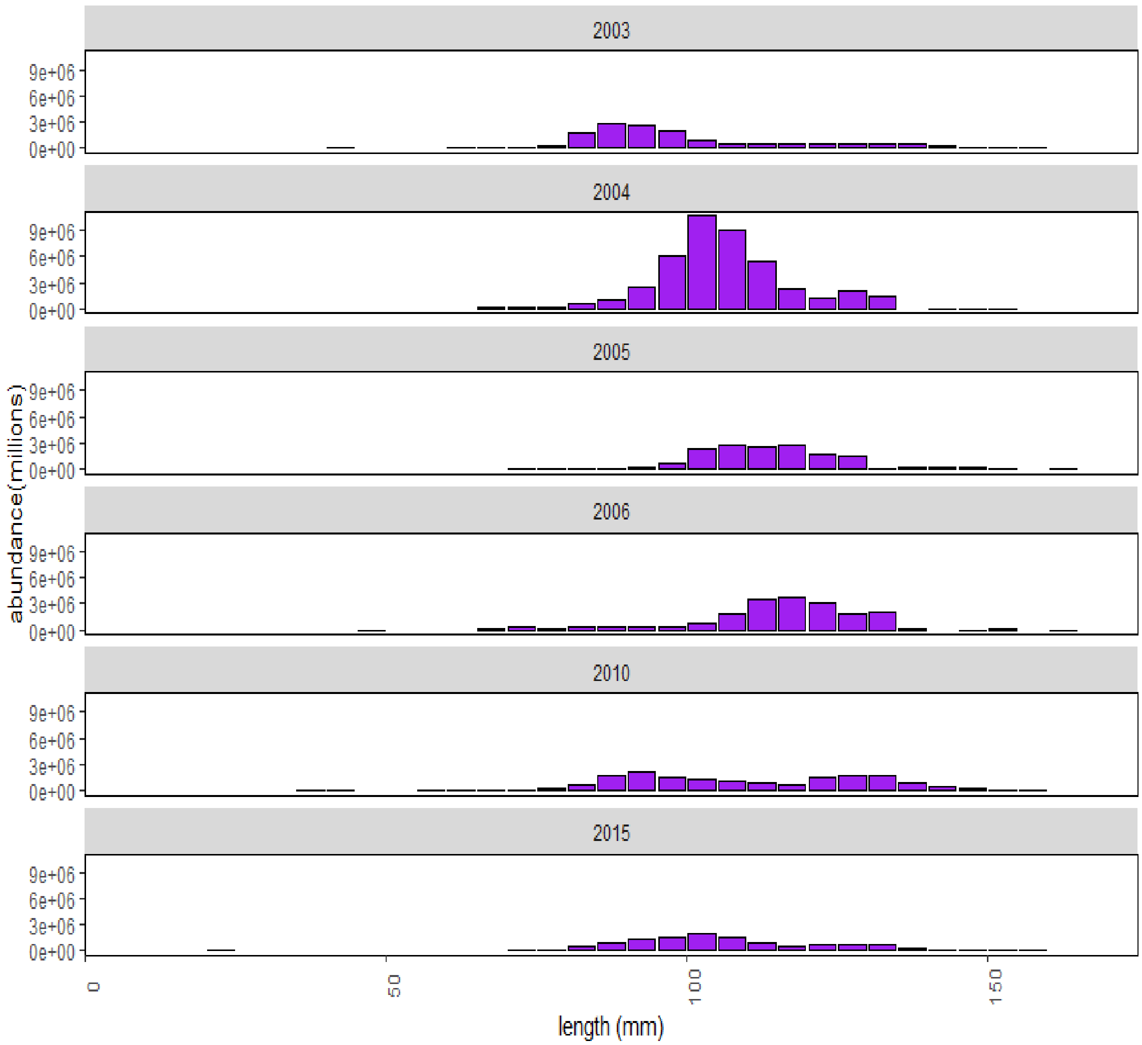


*Figure 6. Size Structure (length frequency (5 mm) groupings) of Sea Scallop sampled in research assessment surveys in the North bed on the St. Pierre Bank from 2003 to 2006, 2010, and 2015.*

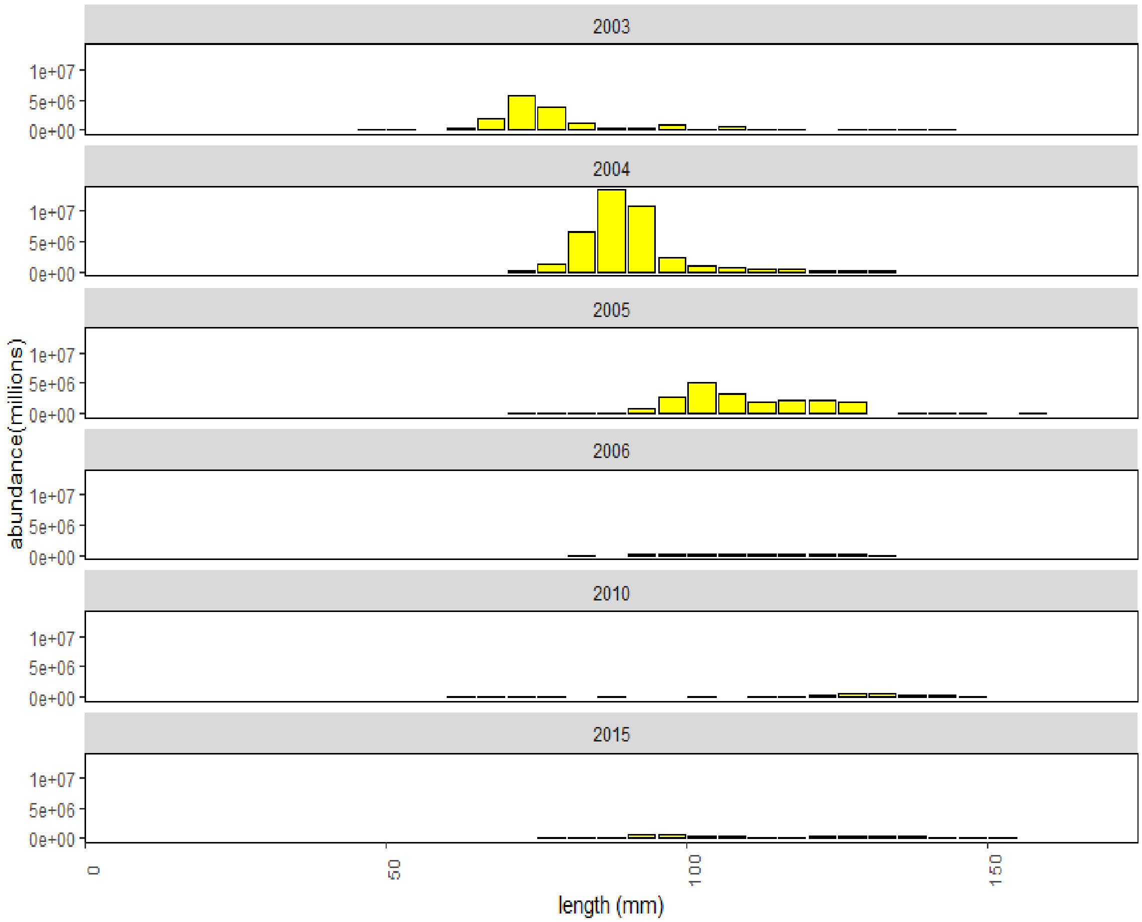


*Figure 7. Size Structure (length frequency (5 mm) groupings) of Sea Scallop sampled in research assessment surveys in the Middle bed on the St. Pierre Bank from 2003 to 2006, 2010, and 2015.*

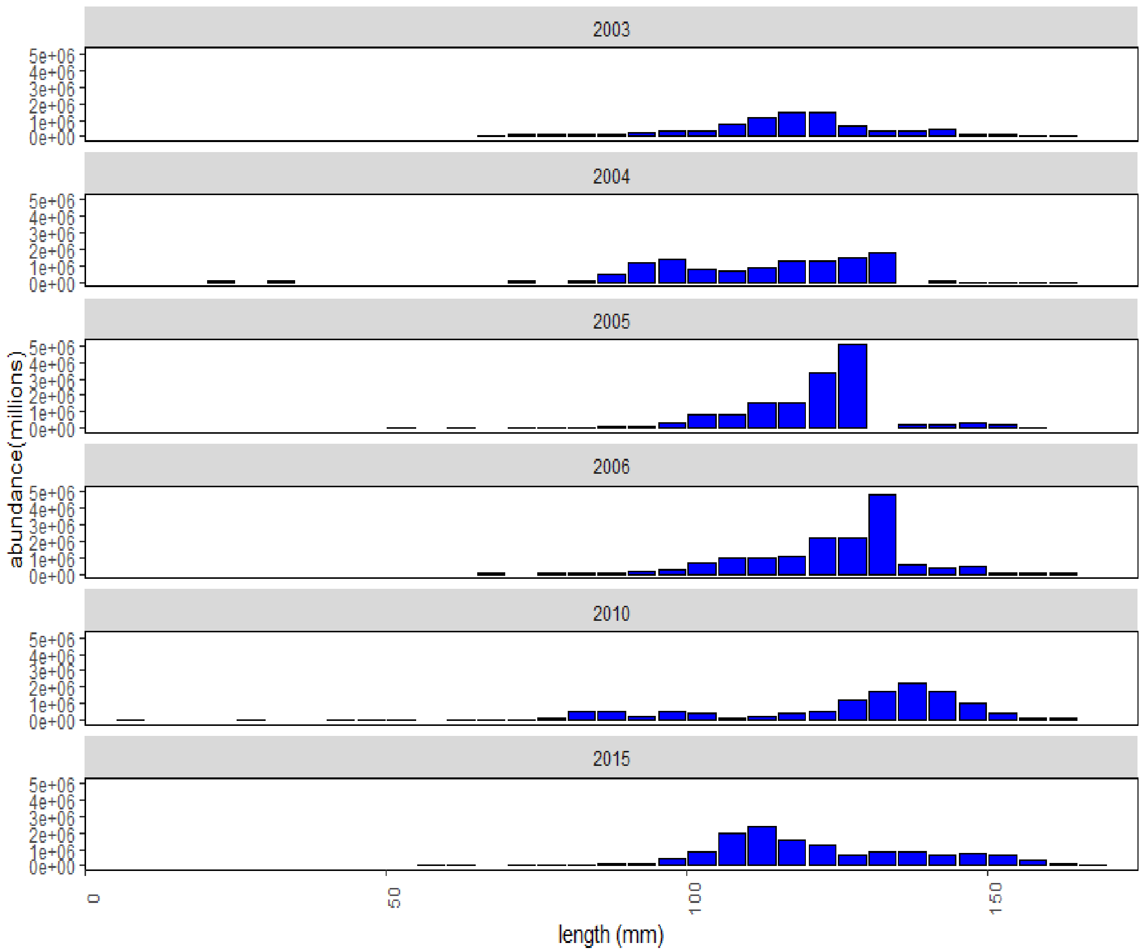


*Figure 8. Size Structure (length frequency (5 mm) groupings) of Sea Scallop sampled in research assessment surveys in the South bed on the St. Pierre Bank from 2003 to 2006, 2010, and 2015.*

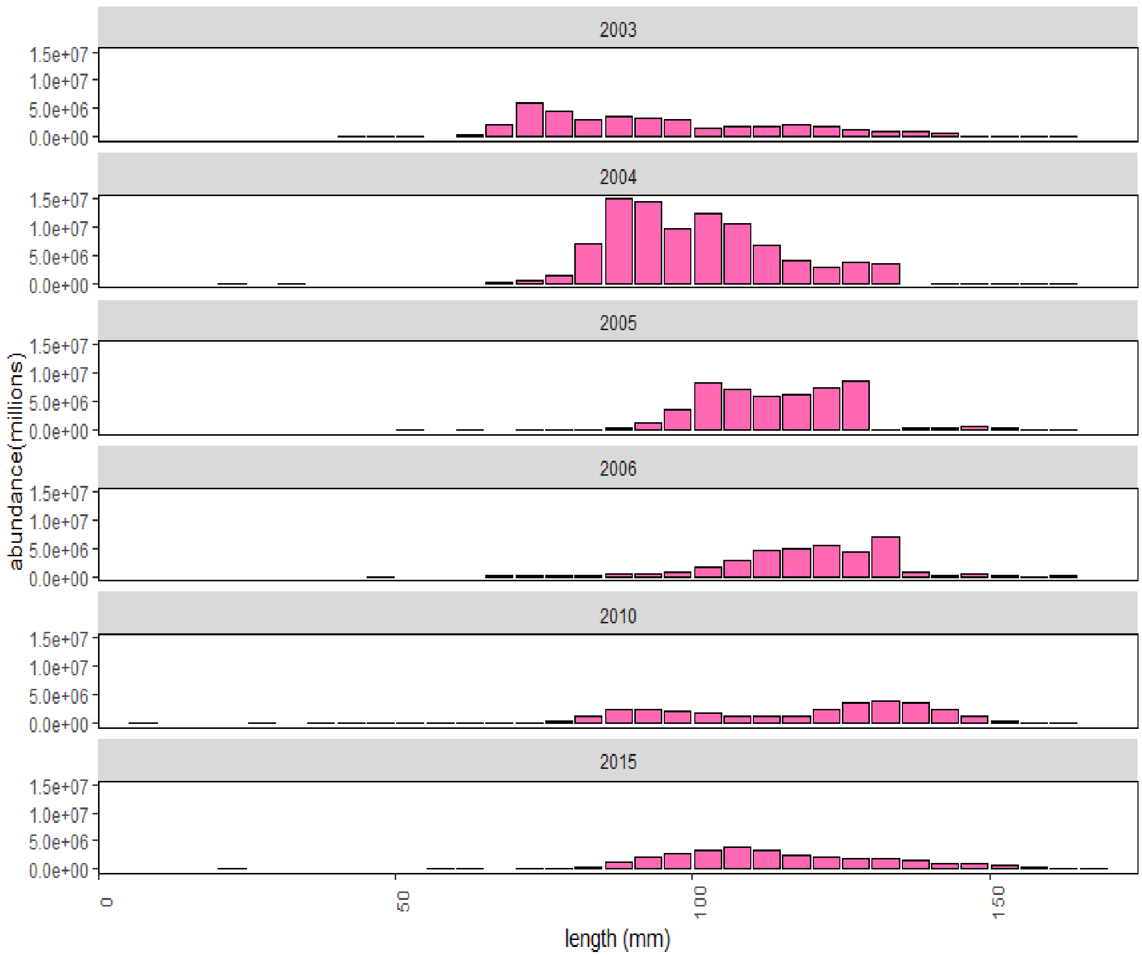


*Figure 9. Size Structure (length frequency (5 mm) groupings) of Sea Scallop sampled in research assessment surveys on all three beds on the St. Pierre Bank from 2003 to 2006, 2010, and 2015.*

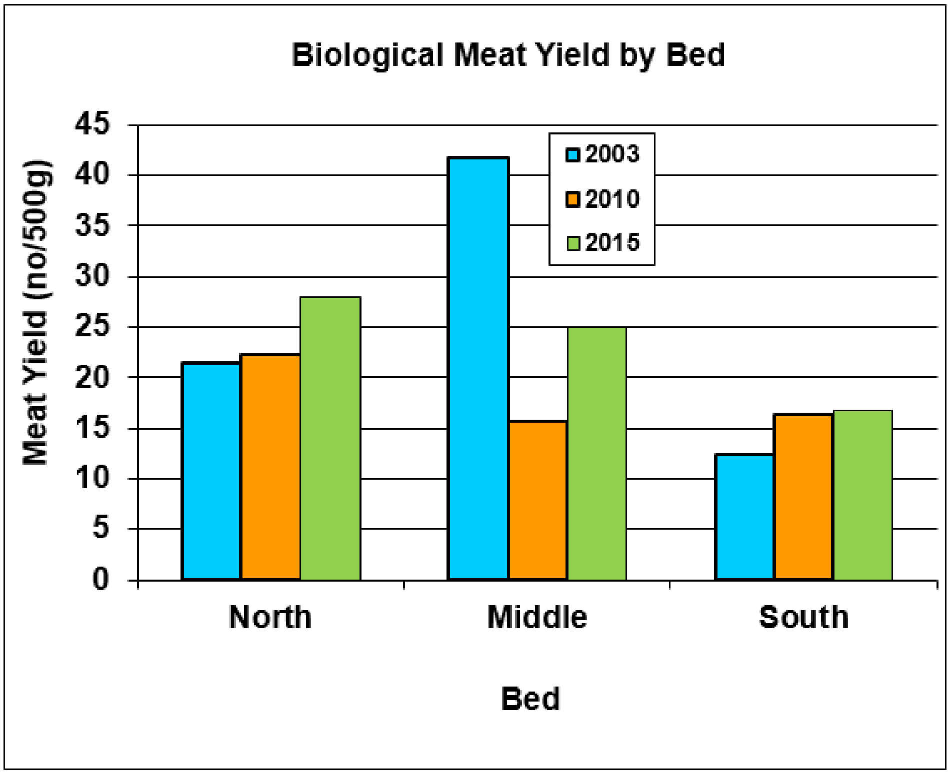


*Figure 10. Biological meat yields in the North, Middle, and South beds in 2003, 2010, and 2015.*

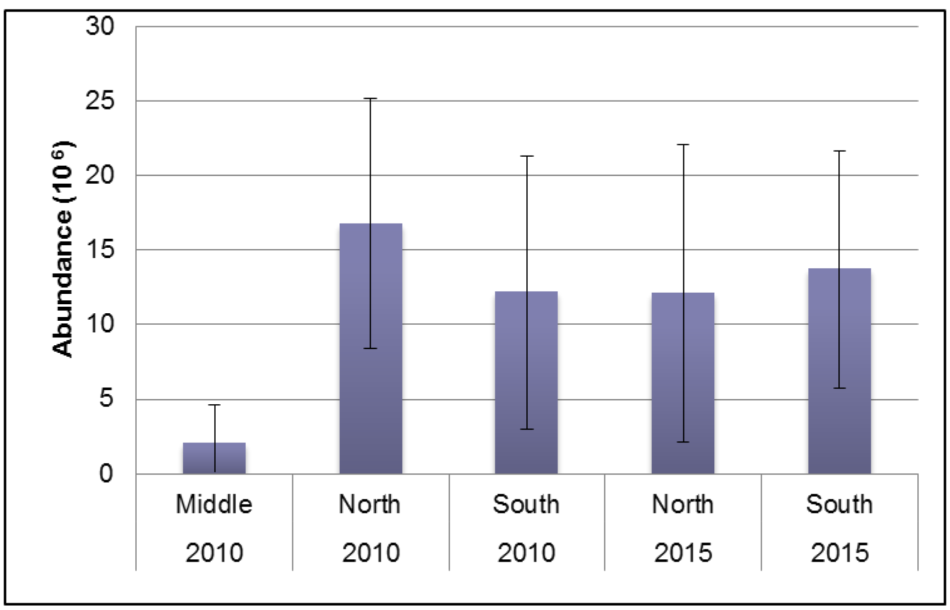


*Figure 11. Abundance estimates from the 2010 and 2015 survey by bed. No estimate for Middle bed was available in 2015.*

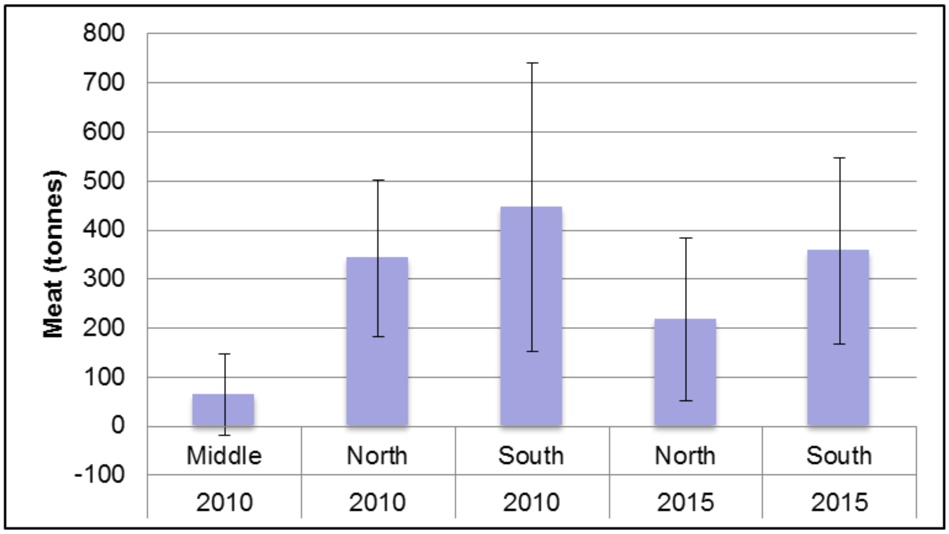


*Figure 12. Biomass estimates (meats, t) calculated from abundance estimates and individual shell height - meat weight by year and bed.*

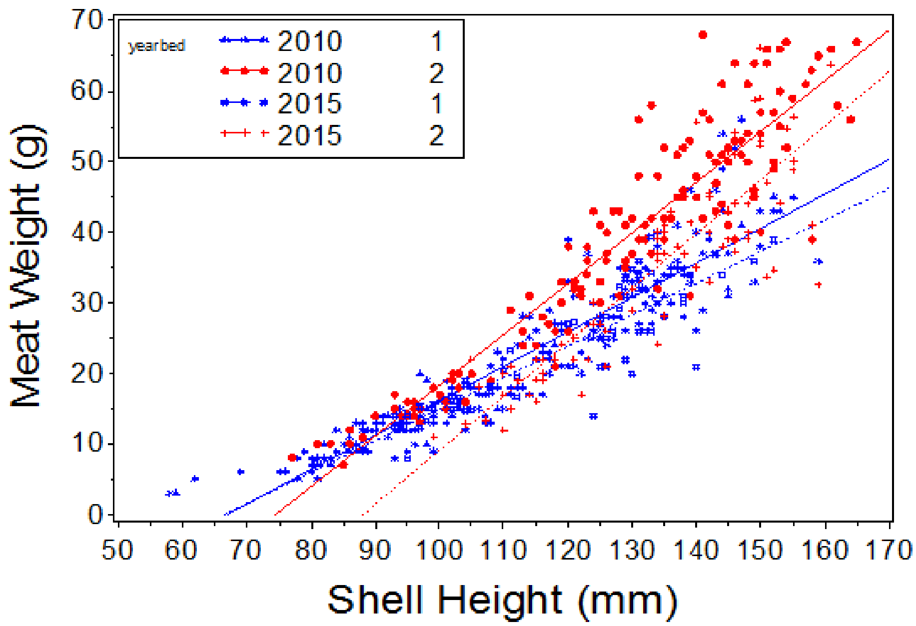


*Figure 13. Shell height versus meat weight from the 2010 and 2015 surveys for the North (1) and South (2) beds.*

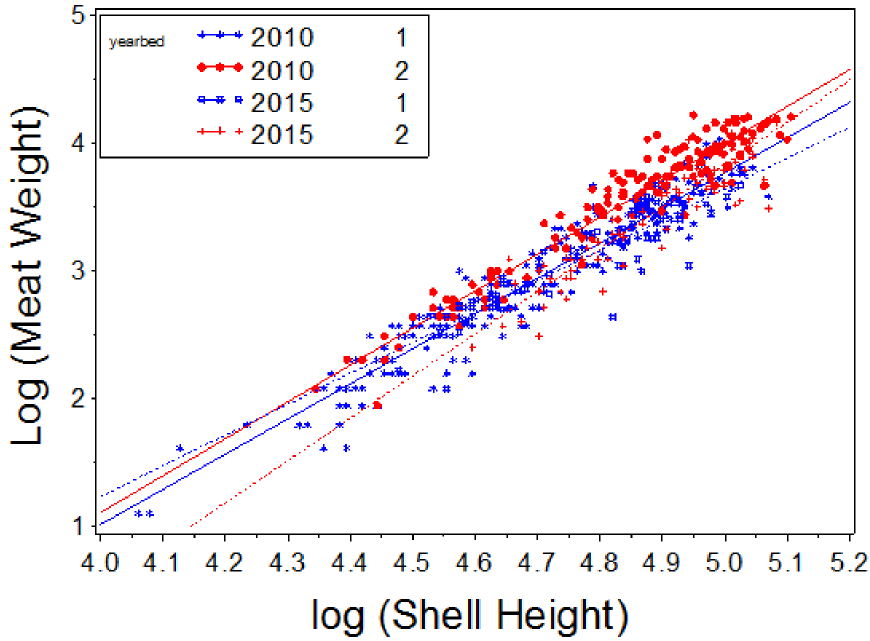


*Figure 14. Log (shell height) versus log (meat weight) from the 2010 and 2015 surveys for the North (1) and South (2) beds.*

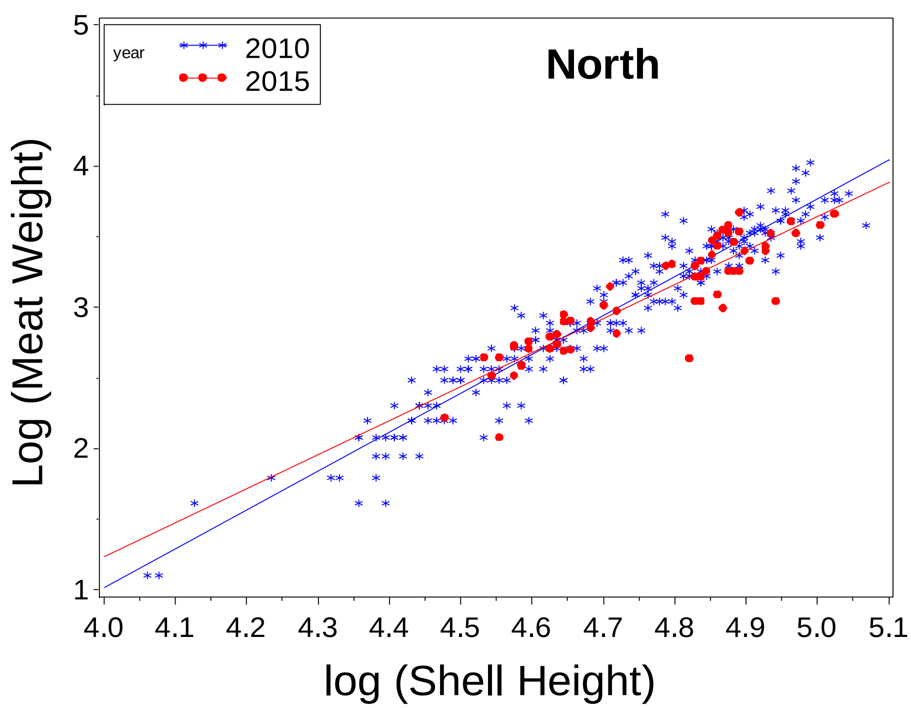


*Figure 15. Log (shell height) versus log (meat weight) from the North bed for 2010 and 2015.*

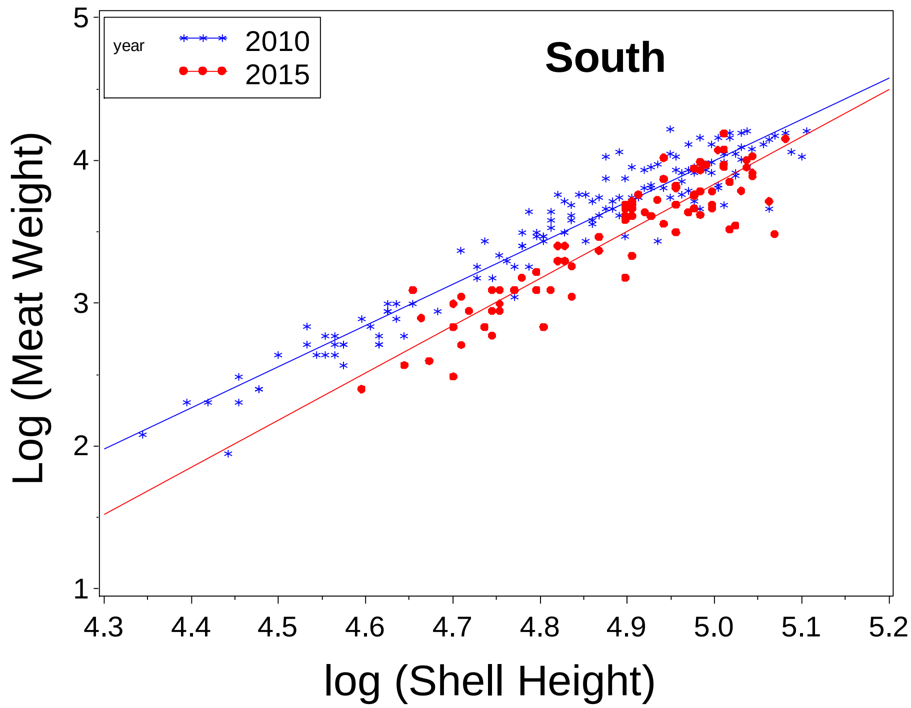


*Figure 16. Log (shell height) versus log (meat weight) from the South bed for 2010 and 2015.*

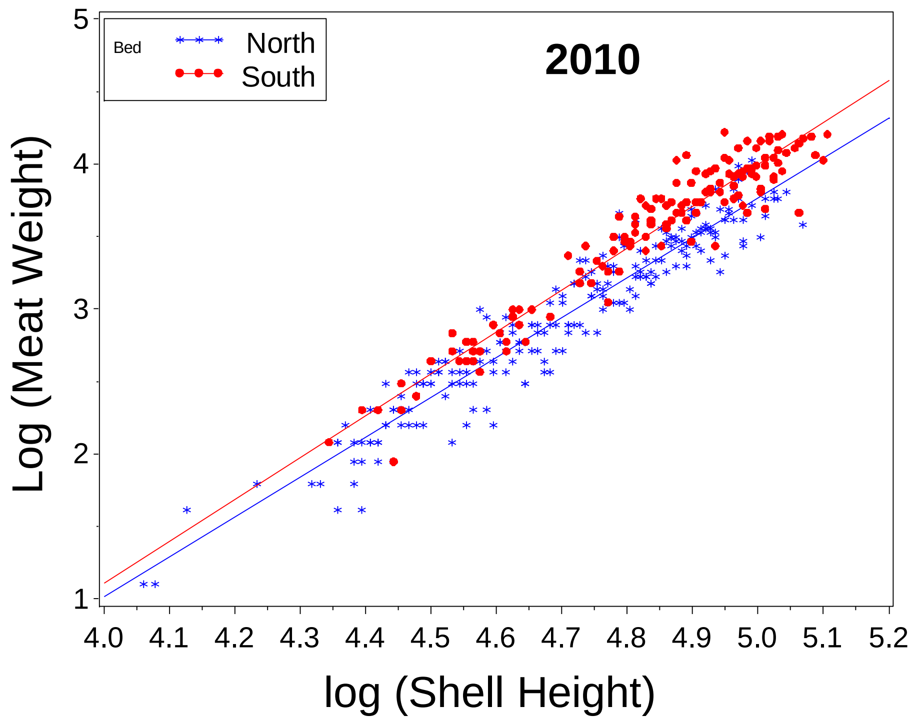


*Figure 17. Log (shell height) versus log (meat weight) in North and South beds for 2010.*

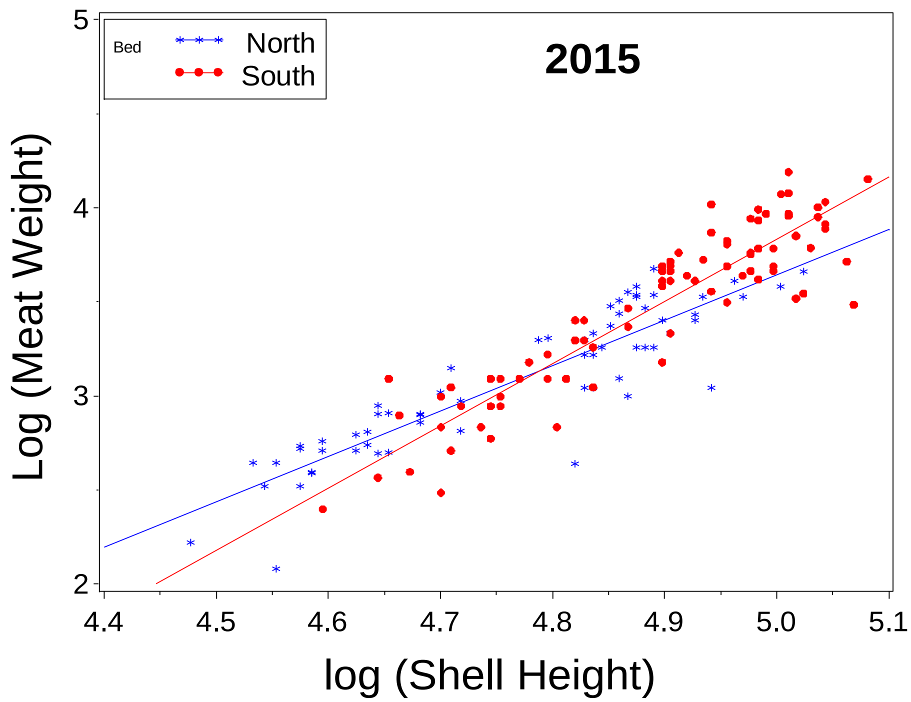


*Figure 18. Log (Shell Height) versus log (meat weight) in the North and South beds for 2015.*

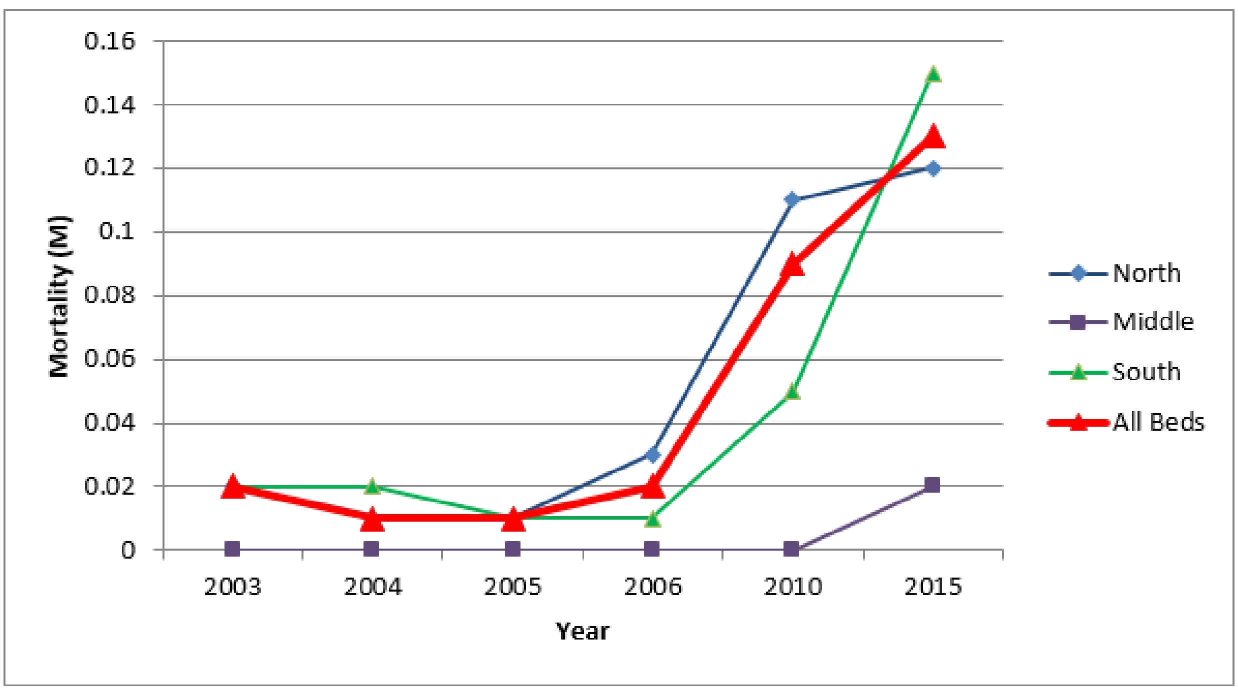


*Figure 19. Mortality estimate trends for Sea Scallop in the North, Middle and South beds and all beds combined on St. Pierre Bank, for each year of the survey time series.*

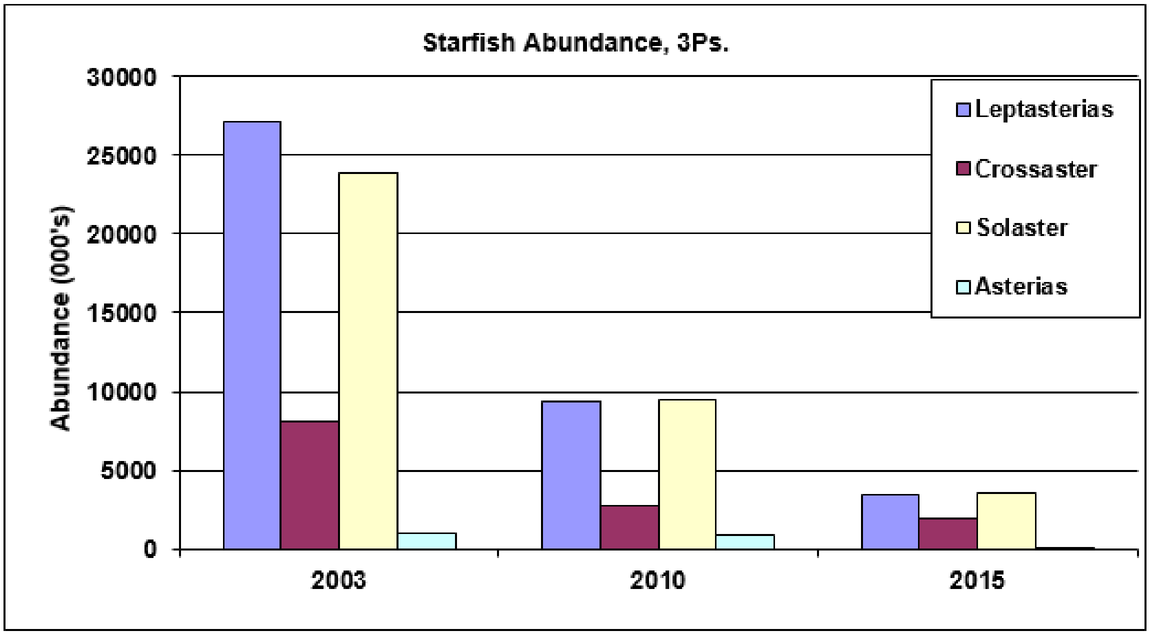


*Figure 20. Abundance estimates of the four key Sea Star species on St. Pierre Bank based on the scallop resource assessment surveys in 2003, 2010, and 2015.*

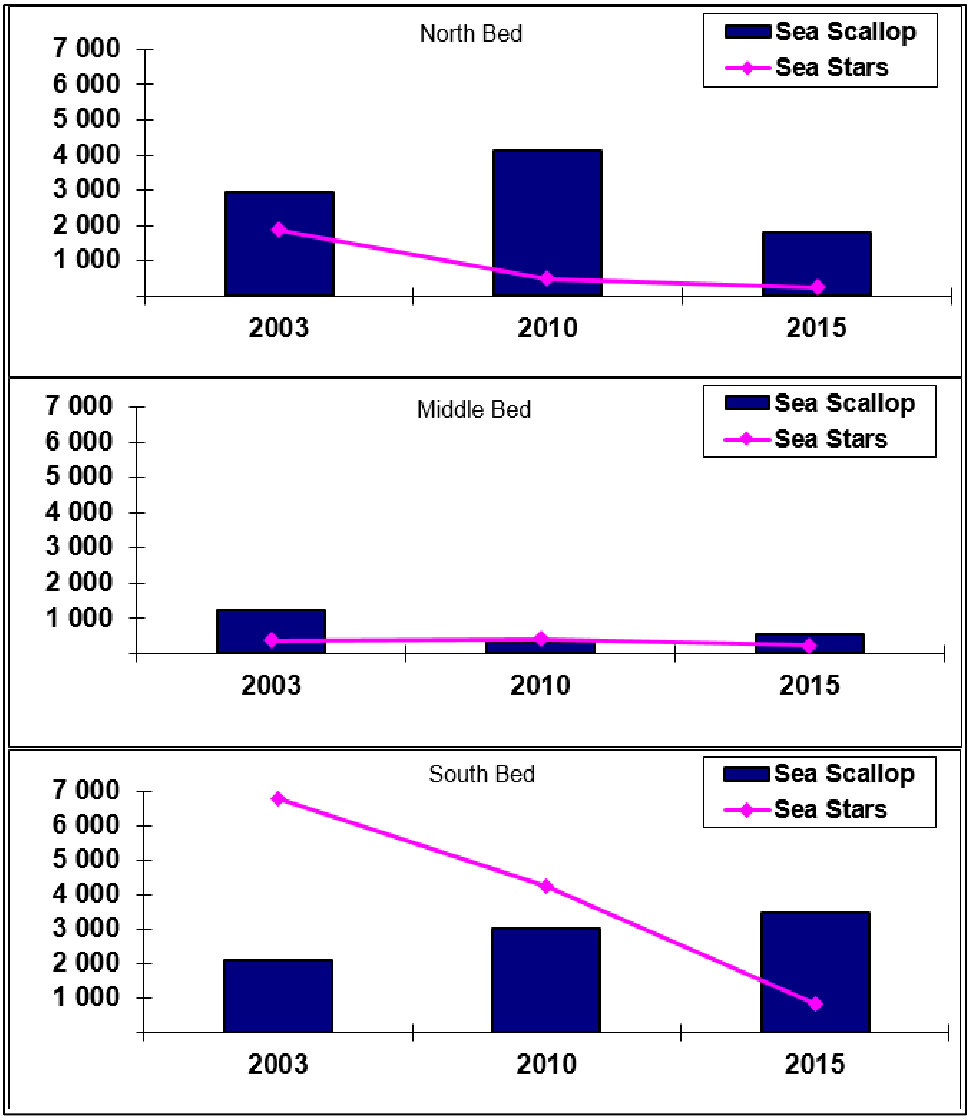


*Figure 21. Biomass estimates of Sea Scallop (bar graph) and Sea Stars over the survey time series, in the North bed (top panel), Middle bed (middle panel), and South bed (bottom panel).*