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# Assessment of northern shrimp stocks in the Estuary and Gulf of St. Lawrence in 2017: data from the research survey

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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 Estuary and Gulf of St. Lawrence northern shrimp (*Pandalus borealis*) stock status is determined every year by examining a main indicator from the commercial fishery and the research survey. This document presents the data and methods that were used to produce the 2017 survey indicators. The estimates of northern shrimp biomass and abundance are presented for each of the four fishing areas and for each sex. In addition, this document describes how some of the environmental and ecosystem characteristics of the Gulf of St. Lawrence potentially impact the northern shrimp stock dynamic through their effects on such factors as spatial distribution, growth, reproduction and trophic relationships.

# INTRODUCTION

Every year since 1990, a trawl research survey is conducted in the Estuary and northern Gulf of St. Lawrence from a Department of Fisheries and Oceans (DFO) vessel to assess the abundance of several species, including shrimp. This multidisciplinary survey aims to describe the biodiversity of Gulf species and the physical and biological oceanographic conditions.

It is the main source of fishery-independent data for the stock assessment of northern shrimp (*Pandalus borealis*) in the Estuary and Gulf of St. Lawrence. It also describes northern shrimp distribution, estimates its stock abundance and biomass, and reveals its population dynamics. The survey is deemed to effectively cover the entire distribution range of *P. borealis* in the Estuary and northern Gulf of St. Lawrence. Northern shrimp is typically confined to bottoms lying below the cold intermediate water layer at depths greater than 150 m.

The stock status is evaluated by examining a number of indicators from the commercial fishery and the DFO research survey for each of the 4 shrimp fishing areas (SFAs): the Estuary (SFA 12), Sept-Iles (SFA 10), Anticosti (SFA 9) and Esquiman (SFA 8) (Figure 1). This document updates the data and methods that are used to produce the survey indicators and that are described in Bourdages and Marquis (2014). The estimates of male and female shrimp abundance are used as such: to calculate the main indicator of stock status; and, to project harvests based on the precautionary approach guidelines (Savard, 2012). What's more, this document describes how some of the environment and ecosystem characteristics of the Gulf of St. Lawrence potentially impact the northern shrimp stock dynamic through such factors as spatial distribution, growth, reproduction and trophic relationships.

# BIOLOGY

Out of the 27 shrimp species listed in the Estuary and northern Gulf of St. Lawrence, the northern shrimp is by far the most abundant (Savard and Nozères 2012).

## LIFE CYCLE

The northern shrimp, *Pandalus borealis*, is a protandrous hermaphrodite species. In other words, individuals first reach sexual maturity as males, then change sex and become females (Figure 2). This feature of the life cycle is very important for the development of harvest strategies since larger individuals targeted by the fishery are almost exclusively female.

In the Estuary and Gulf of St. Lawrence, shrimp larvae hatch in the spring, in April or May and remain pelagic for several months. At the end of the summer, larvae increasingly resemble adults and adopt suprabenthic (bottom-based) behaviour. These postlarvae and juveniles are too small to be caught by commercial fishing trawls. Juveniles reach male sexual maturity during their second year. Spawning occurs in the fall and males may spawn 2 or 3 years prior to changing sex, which occurs in winter at age 4 or 5, at around 21 mm carapace length. Newly transformed females are easily recognized in spring and summer commercial catches as they have retained some male sexual traits. These females are called primiparous females and spawn the very next fall (September or October) after the sex change. Females carry their fertilized eggs under their abdomen during the incubation period which lasts about 8 months. The larvae hatch the following spring. Spawning females that survive reproduction are recognizable to those who have never spawned and are called multiparous females. In fact, primiparous and multiparous females can be distinguished by morphological characteristics (sternal spines) that disappear in the prenuptial moult. Females can spawn at least twice and the estimated longevity of Estuary and Gulf shrimp is about 7 years.

# METHOD

## DESCRIPTION OF THE SURVEY

A multidisciplinary research survey has been conducted annually in the Estuary and the northern Gulf of St. Lawrence since 1990 to estimate the abundance of northern shrimp and groundfish species. The survey is conducted with a shrimp trawl following a stratified random sampling plan. Fishing operations take place 24 hours a day. A description of the 2017 survey and sampling protocols is presented in Bourdages et al. (2018).

The stratification used for the allocation of fishing stations is presented in figure 3. In the Gulf, the grounds located at depths greater than 37 m (20 fathoms) are covered by the survey. In the Estuary, the survey covered the grounds at depths greater than 183 m (100 fathoms) from 1990 to 2007. In 2008, it was decided to add strata to cover depths from 37 to 183 m in this sector to obtain a better coverage of the northern shrimp spatial distribution. The surface of the study area has increased from 116,115 $km^2$ to 118,391 $km^2$.

In 2017, 170 fishing stations were successful, 47 in 4R, 83 in 4S and 40 in 4T (Figure 4). Coverage of the study area was very good; only two strata were not covered with a minimum of two stations. On average, 187 fishing stations are sampled per year (Table 1).

## PROCESSING OF SHRIMP CATCHES

For each fishing tow, the trawl catch is sorted by species or by taxon. The total catch of shrimp is weighted and a sample of about 2 kg is collected to determine the proportion of *Pandalus borealis* compared to other shrimp species and its biological characteristics as well. The maturity stage (male, primiparous or mutiparous female with or without gonads in maturation and egg bearing female) is identified for each individual. The cephalothorax length is measured with an electronic calliper with a precision of 0.1 mm. The individual weight is recorded with a precision of 0.1 g following a stratified sampling design (about ten individuals per sex per 1 mm length class) for each fishing area.

The area swept by the trawl is estimated from the duration of the tow, the speed of the vessel and the wingspread of the trawl. The *P. borealis* catch for each tow is estimated from its proportion in the sample and is standardized to an area of 1 $km^2$ taking into account the swept surface (Table 2 and Figure 5).

## DISTRIBUTION

### Geographic distribution of catches

The geographical distribution of catches by weight per tow (kg/15 minutes tow) was made for periods of four or five years. The interpolation of catches was performed on a grid covering the study area using a ponderation inversely proportional to the distance (R version 2.13.0, Rgeos library; R Development Core Team 2011). The isoline contours were then plotted for four biomass levels which approximate the $20^{th}$, $40^{th}$, $60^{th}$ and $80^{th}$ percentiles of the non-zero values. The catch rates distribution of males and females for 2014 to is also presented in a bubbles type map.

### Distribution of catches by depth and temperature

The relative cumulative frequency of catches (in weight) was compiled according to depth and temperature, all years combined. This relationship was depicted in graph form, in combination with the relative cumulative frequency of the number of stations sampled by depth in the study area. This figure illustrates the depth windows in which the shrimp is likely to be caught in August in the study area. The 5$^{th}$, 25$^{th}$, 50$^{th}$, 75$^{th}$, and 95$^{th}$ percentiles of this distribution are also presented in an adjacent table.

The distributions of biomass in terms of depth and temperature are presented by year and fishing area for males and females with a box-plot.

## Area of occupancy

Three spatial indices were selected: the design-weighted area of occupancy, the D95 and the Gini index.

### Design-weighted area of occupancy

The design-weighted area of occupancy (DWAO) (Smedbol et al. 2002) is the area of the study zone in which the shrimp is found.

### D95

The D95 index describes geographic concentration. This descriptor corresponds to the minimum area containing 95% of the shrimp biomass. Calculation details are described in Swain and Sinclair (1994).

### Gini index

The Gini index quantifies the homogeneity of shrimp distribution. This index is calculated using the Lorenz curve (Myers and Cadigan 1995). The index goes from 0 to 1, where 0 corresponds to a perfectly homogenous distribution and 1 corresponds to a very concentrated distribution.

## BIOMASS ESTIMATION BY GEOSTATISTICS

The biomass (kg/km²) calculated at all stations of the study area is kriged separately for males and females. First, the positions of sampling stations, expressed in latitude and longitude, are transformed into a Cartesian coordinate system according to the Lambert Conformal Conic projection using parallels 48$^0$N and 50$^0$N as a reference and 46.5$^0$N and 70$^0$O as point of origin. This conversion is carried out using libraries "sp" and "rgdal" (2013a Pebesma, Bivand 2013) of R (R Development Core Team 2011).

As a first step, a variogram is calculated for each survey. To highlight the spatial structure of the data, it is sometimes necessary to remove outliers. The values of cuts are shown in the table below. Likewise, values lower than 5 kg/km$^2$ are not used for estimating the variogram. From 1990 to 2012, annual variograms were estimated with the procedure "VARIO" of SAS software (SAS 1996). From 2013, the variograms were performed with the library "gstat" of R (Pebesma 2013b). The semivariances were calculated between all pairs of stations. The distance (h) between them was discrete and semivariances were averaged for different distance classes with intervals of 15 km and a maximum distance of 225 km.

Catches (kg/km$^2$) above which the data were removed from the variogram estimation.

| | 2015 | 2016 | 2017 |
|---|---|---|---|
| Male | 4,000 | 2,500 | 8,000 |
| Female | 4,000 | 3,000 | 5,000 |
| Total | 8,000 | 5,000 | - |

In a second step, the annual variogram is standardized, that is to say that semivariances are divided by the observed variance of the data used to construct the variogram. Subsequently, a pluriannual variogram is constructed from the average of the last three variograms, that of the current year and the two preceding years. The pluriannual variogram corresponds to the mean of the semivariances for each distance *h* of the annual variograms, weighted by the number of pairs associated with these distances. The use of a pluriannual variogram reduces the variability of the spatial structure which is observed in some years, allowing a better fit of the model.

From 1990 to 2012, the parameters of pluriannual variograms (nugget, sill and range) were fitted manually to obtain the best possible adjustment (Table 3). Although other variogram models were examined but the exponential model was selected because it produced the best fit. Since 2013, the parameters of the exponential variogram were fitted with the function "fit.variogram" from the library "gstat" of R (Pebesma 2013a). To minimize the least squares, the adjustment was performed by weighting the data by $N_j/h_j^2$ order to give more weight to the adjustment of the first points of the variogram (Figure 6).

Thereafter, the values of catches were spatially interpolated in the study area using kriging. To do this, all survey observations were used including low and extreme values. The pluriannual variogram was adjusted to represent the variance of the observations of the study area. The nugget ($C_0$) and sill parameters (C) were multiplied by the variance of all observations in the study area. The interpolation was performed on a regular grid with nodes separated by distances of 5 km in both directions (Figure 7). The local estimations were made using the catches of the eight nearest stations that are present within a maximum search radius of 200 km.

From 1990 to 2012, the kriging, the estimates of the mean and variance estimation were performed using the toolbox "Kriging" of MATLAB (Lafleur and Gratton 1998). Since 2013, the kriging was performed with the function "krige" of the library "gstat" of R (Pebesma 2013a) and the estimates of the kriging mean and variance estimation were calculated using a function developed by Sébastien Durand (DFO, Mont-Joli, pers. comm.).

The mean biomass (kg/km²) of each fishing area is then calculated by doing the mean of the local estimations in the area. The total biomass of a given fishing area is obtained by multiplying the mean biomass by the surface of the area. The surfaces of the fishing areas are as followed: Estuary, 4,000 km² from 1990 to 2007 and 6,325 km² from 2008 to 2017; Sept-Iles, 29,775 km² from 1990 to 2007 and 29,975 km² from 2008 to 2017; Anticosti, 46,400 km²; Esquiman, 32,350 km².

## ABUNDANCE ESTIMATION

Biomasses estimated by kriging are converted into abundance from the weight-length relationships and from the length frequency distributions. Length frequencies of each sample are first bumped to the total catch of the station and then, standardized to a 1 km² swept area. The frequencies (n/km²) are regrouped into 0.5 mm size class.

The mean distribution of frequencies (in n/km²) per size class is estimated for each fishing area, for males and females. The mean distribution is estimated from all stations that were sampled in the fishing area. The mean distribution is then converted into weight by applying a weight-length relationship that is estimated for each area (Table 4, Figure 8). The weight-length relationship estimated in 1993 is used for the 1990-2004 period. Since 2005, the relationship estimated annually is used for the current year. The same relationship is used for both sexes.

The stock biomass estimated by kriging is distributed among the size classes following the proportions in weight of the mean distribution of the stock. The abundance of each size class is obtained by dividing the biomass by the mean weight of the class. The total stock abundance is then obtained by adding the abundance of all size classes. The exercise is done separately for males and females. Given that the numbers are not kriged, it is not possible to obtain an estimate of the variance of the abundance by kriging. Therefore, the coefficient of variation of the biomass is used to estimate the 95% confidence interval of the abundance.

The female abundance could be separated into maturity stages for the years when the identification of the stage was done for each individual. The abundance of primiparous and multiparous females was calculated from 1990 to 2000 and then from 2009 to 2017.

It is possible to obtain an index of recruitment by estimating the abundance of juveniles for which the cephalothorax length is smaller than 12.5 mm. The individuals of these sizes are aged of about fifteen months (Daoud et al. 2010). The estimation of abundance of the juveniles is obtained by adding the abundance of the size classes that are included in the first mode.

## PREDATOR DIETS

Depending on the year, allocated resources and research objectives, the stomachs of redfish and Greenland halibut were collected during various missions aboard DFO vessels. Each time, the stomachs were brought back to the laboratory and dissected according to a protocol. In summary, each prey detected in a stomach was identified to the highest taxonomic level possible and its mass, recorded based on its state of digestion. Given dissection protocols, which have greatly evolved since the early 1990s, and procedures for validating and importing new data, data first had to be standardized. Subsequently, prey considered overly digested (e.g., digested fish, shellfish, etc.) was eliminated from the analysis: only prey allowing a better interpretation of predator diets was kept. Although this decision did not affect the number of stomachs selected, it changed some stomachs' empty or non-empty status. For example, a stomach filled only with digested fish was considered empty since its content precluded any inference as to the specific diet of redfish. A similar approach was taken to eliminate prey that was waste (e.g., rocks, sand, liquid) or parasites. Stomachs that were unexamined, evaginated, lacking a length value or collected in months other than August and September were eliminated from the analysis.

The remaining prey were subsequently classified according to their level of importance with regard to mass percentage and the partial fullness index (PFI) that they represented in predator diets. It is vital to use PFI as a standardization variable when classifying prey groups: doing so reduces the effect of predator length and better represents important prey rather than simply prey mass. As a result, the prey of small redfish are not underrepresented as compared with large redfish prey, which could be larger in relation to their predator's capacity. Following the creation of these different taxonomic groups, various redfish diets were compared.

Data on the redfish diet were then attributed either to an area where northern shrimp is actively fished, or to the rest of the Estuary and northern Gulf of St. Lawrence (eNGSL). Areas where shrimp is commercially fished were defined using the Vessel Monitoring System (VMS). This allowed for a spatial comparison of the redfish diet.

These various comparisons also helped quantify northern shrimp proportions (P) in different situations (e.g., redfish length class, spatial and temporal distributions, etc.). These proportions were used with estimated redfish biomasses (B) to provide an annual northern shrimp consumption estimate (Q) for redfish. Consumption was calculated with the following equation:

$$Q = B * P * \frac{Q}{B}$$

where the ratio Q/B is a theoretical value. The ratio values Q/B stem from ecosystem models for the northern Gulf of St. Lawrence at different periods (Savenkoff et al. 2004, Savenkoff and Rioual (DFO, unpublished data)). Redfish biomass estimates were based on the results of groundfish and shrimp multidisciplinary surveys conducted annually in August. Finally, consumption estimates were divided according to the various length classes for redfish and grouped under the periods 1995 to 1997 and 2015 to 2017, by using all the stomachs collected during both periods, respectively.

# RESULTS

## SPATIAL DISTRIBUTION

The survey is deemed to effectively cover the entire distribution range of northern shrimp in the Estuary and northern Gulf of St. Lawrence. The spatial distribution of northern shrimp shows that the best catch rates were observed along the Esquiman, Anticosti, and Laurentian channels, as well as west of Anticosti Island through the Estuary (Figure 9). Typically, young shrimp are found in shallower areas, often at the heads of channels, whereas older individuals, females, are found in deeper waters (Figure 10). Northern shrimp occurs only rarely in the southern Gulf.

In 2017, northern shrimp was distributed over more than 98 000 km$^2$ in the Estuary and northern Gulf of St. Lawrence: the study area was 116 115 km$^2$ (Figure 11). While there was a slight uptrend in the area of occupancy, there was a decrease in the highest shrimp concentration areas, where more than 95% of the biomass is distributed. Since 2000, the minimum area went from 54,000 km$^2$ to 33,000 km$^2$.

The research survey data shows that more than 80% of the cumulative northern shrimp biomass is found at depths between 193 and 331 m (Figure 12) with a bottom temperature from 3.7 to 5.8ºC (Figure 13). The median depth of northern shrimp distribution is 259 m and the median temperature is 5.3ºC. Generally, the northern shrimp is associated with deep water mass and found mainly in channels at depths of 200 to 300 m, where sediment is fine and consolidated.

Galbraith et al. (2017) have observed that since the beginning of the 1990s, there has been an uptrend in the Gulf’s deep water temperatures at 150, 200 and 300 m. These intrusions of warm waters from the Atlantic Ocean calmly flow upstream in the deep channels of the Gulf of St. Lawrence from Cabot Strait. In 2017, male and female shrimp were found in temperatures that were 1°C warmer as compared with the historical average (Figure 14). The most notable temperature changes in bottom water where shrimp occurs was observed 5 years ago in Esquiman and Anticosti, and 3 years ago in Sept-Iles and the Estuary. Despite this water temperature increase in shrimp habitat, no depth-related shrimp movement was observed (Figure 15).

## ABUNDANCE INDEX

The variations in shrimp sizes follow an east-west gradient, the smallest being observed in the Esquiman Channel and the largest, in the Estuary. The average size of male shrimp in 2017 was comparable to the historical average for the 4 fishing areas whereas the size of females decreased below the average in the Estuary, Sept-Iles and Anticosti. It remained stable and comparable to the average in Esquiman) (Figure 16). The survey has collected individual weight data since 2006. Shrimp weight estimates for males of 14 and 20 mm and females of 22 and 26 mm seem to increase over the years (Figure 17). Shrimp are heavier than average since 2010 in Esquiman and Anticosti, since 2012 in Sept-Iles, and since 2015 in the Estuary, based on a gradient that began earlier in the east.

The mean biomass and the variance estimation are presented for males and females and, for each fishing area, in tables 5 and 6. In general, the coefficient of variation is about 20 to 25% for males and 10 to 20% for females for the fishing areas Sept-Iles, Anticosti and Esquiman (Table 7). The coefficient of variation id higher in the Estuary area.

The total biomass distribution is presented by year (Figure 18) for males and females (figures 19 and 20). The total biomass estimate for each fishing area is shown in Figure 21, and for males and females, in Table 8 and Figure 22. The DFO survey biomass index indicates a downtrend for several years in all areas. The biomasses observed in 2017 are close to the values of the early 1990s.

Abundance indices for males and females have shown a downtrend for more than 10 years in the 4 fishing areas (Table 9 and Figure 23). Since 2015, this decline has been very marked in the Estuary and Sept-Îles, where decreases of more than 55% have been observed in 2 years. The Estuary and Sept-Îles indices are close to the values observed in the early 1990s. In Anticosti, the abundances of recent years show a slight downtrend, although the abundances since 2011 are lower than the values observed in the early 2000s. There has been a 25% decline since 2015. The downtrend in Esquiman has continued since 2003 and the decrease in the last 2 years was 29% for males and 8% for females.

The demographic structures by area obtained in 2017 from the DFO survey show that male and female abundances are decreasing and are below the series average (1990 to 2016) (Figures 24 and 25). In addition, juvenile abundance (carapace length between 8 and 12 mm) was low in 2016 and 2017 (Table 10).

The allocation of additional stations in the shallow area of the St. Lawrence Estuary since 2008 has had a very significant impact on the number of males and females surveyed in the Estuary fishing area and to a lesser extent in the Sept-Îles area. After 8 surveys with this increased coverage, the inter-annual coherence between the shrimp abundance measured according to the original area and the extended survey area indicates that the biomass was largely underestimated and the exploitation rate index significantly overestimated for the Estuary area. In the short term, shallow strata should be integrated into estimates of the main indicator of stock status.

## ECOSYSTEM

The ecosystem dominated by groundfish in the early 1990s has progressed to an ecosystem dominated by forage species. Shrimp population increased following the period during which the population of large groundfish species declined. There is a current increase in the abundance of redfish, Atlantic halibut and cod in the northern Gulf, whereas a recent decrease of Greenland halibut has been observed (Figure 26). Trophic changes may be observed in the coming years because shrimp is a part of numerous species' diets.

## PREDATOR DIETS

Of the 5,563 redfish stomachs available in the database, 4,640 were selected for analysis. Approximately 60 scarcely-digested or undigested prey were identified and classified into 13 taxonomic groups. The proportion of empty stomachs was higher in the 1990s data than in the 2015 to 2017 data, but still significant for both compared periods (Figure 27). Large redfish (>35 cm) had a higher fullness index from 2015 to 2017 than in the 1990s. The invertebrate/fish proportion is comparable for both periods.

The arrival of fish as prey is observed when redfish reaches approximately 25 cm in length, redfish and capelin being the main species (Figure 28). Prior to this size, virtually all of the identified prey is zooplankton. Northern shrimp and white shrimp are prey found in the entire length range of redfish whose stomachs were collected.

A global analysis (i.e., including all digestion stages and length classes) of the contents of stomachs collected during the multidisciplinary surveys conducted each August from 2015 to 2017, shows that northern shrimp is present in 5.05% of the stomachs of Greenland halibut compared with 2.59% for redfish. The mass contributed by northern shrimp in the stomachs of Greenland halibut ≥20 cm and <20 cm was 11.46% and 0.08% respectively; it was 13.51% and 2.18% for these same length ranges among redfish (Appendix 1).

Boundary surveys of the 6 areas of commercially-fished northern shrimp (Figure 29) made it possible to attribute the redfish stomachs collected from 1993 to 2017 (Figure 30) either to one of these 6 areas or to the rest of the eNGSL. Hence, northern shrimp represents more than 50% of the stomach content mass of redfish from the fishing areas and measuring 25 to 35 cm; in the rest of the eNGSL, this value is less than 25%, regardless of the period. In the rest of the eNGSL, northern shrimp is the prey of fewer redfish length classes and represents lower percentages of stomach content mass from 2015 to 2017 compared with the 1990s. White shrimp, which was not very important to the redfish diet during the 1990s, is now confirmed in almost all of the length classes of redfish captured from 2015 to 2017. In addition, it is still more important in the diet of redfish in fishing areas than in the rest of the eNGSL. What's more, from 2015 to 2017, capelin disappeared from the diet of redfish >30 cm and, in recent years, redfish has appeared as prey for capelin outside of the shrimp fishing areas (Figure 31).

Dividing the 2015 to 2017 stomach contents by area where northern shrimp is commercially fished and by redfish size class (Figure 32) shows that the 25 to 35 cm length range has a greater proportion of northern shrimp in most of the areas of commercially-fished shrimp. This is not observed in the rest of the eNGSL. This interpretation must remain cautious, however, given the low number of stomach contents by area and length class.

Based on the very high redfish biomasses observed in recent years (Figure 33), the estimated consumption values for northern shrimp are beginning to increase strongly as juveniles lengthen (Figure 34). Indeed, based on the calculated values for biomass and the proportion of northern shrimp in redfish's annual consumption, it has been estimated that about 28 000 t of shrimp were consumed annually from 1995 to 1997 compared with 86 000 t from 2015 to 2017—which is 3 times more. A review of the last few years reveals that this consumption doubled each year between 2015 and 2017: this seems to reflect the lengthening of strong redfish cohorts and the increased use of northern shrimp as important prey.

Abundance and biomass estimates of redfish in areas where northern shrimp is commercially fished show an increased presence of redfish in the DFO multidisciplinary survey since 2013 (figures 35 and 36). Anticosti, Esquiman and Sept-Iles are the areas where abundance seems to be highest. However, the estimated biomass for the Sept-Iles area is lower, but could increase in the coming years as the redfish stock grows. This suggests that this area will see a much higher shrimp consumption in the future than at present (Figure 37).

## CONCLUSION

Northern shrimp is typically widespread in the Estuary and northern Gulf of St. Lawrence at depths of 150 to 350 metres. Since the beginning of the 2000s, however, the distribution range with the highest shrimp abundances has been shrinking.

The DFO survey biomass index indicates a downtrend for several years in all areas. The biomasses observed in 2017 are close to the values of the early 1990s.

The demographic structures by area obtained in 2017 from the DFO survey show that male and female abundances are decreasing and are below the series average (1990 to 2016). In addition, juvenile abundance was low in 2016 and 2017.

Changes in environmental and ecosystem conditions were observed in the Gulf of St. Lawrence. The bottom temperature of channels and redfish abundance are increasing. The water temperature in shrimp habitat has risen by 1°C in recent years. Predation by redfish on northern shrimp has increased significantly over the last 3 years and may contribute to the decreased abundance of this shrimp species. These changes may have an impact on the northern Shrimp population dynamic through their effects on such factors as spatial distribution, growth, reproduction and trophic relationships.

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## TABLES

*Table 1. Mean catch (kg/km²) and standard error by year, for males and females for the whole studied area (n: number of stations).*

| Year | n | Males | | Females | |
|---|---|---|---|---|---|
| | | Mean | Standard error | Mean | Standard error |
| 1990 | 219 | 349.17 | 54.36 | 482.36 | 52.28 |
| 1991 | 250 | 265.82 | 50.53 | 412.06 | 50.09 |
| 1992 | 239 | 155.81 | 26.40 | 243.78 | 29.20 |
| 1993 | 214 | 203.54 | 32.87 | 184.91 | 22.54 |
| 1994 | 176 | 201.97 | 33.29 | 302.52 | 38.02 |
| 1995 | 182 | 339.35 | 47.62 | 408.28 | 44.58 |
| 1996 | 217 | 439.20 | 61.95 | 680.02 | 57.96 |
| 1997 | 185 | 602.86 | 92.43 | 715.33 | 82.08 |
| 1998 | 206 | 352.77 | 40.84 | 722.97 | 73.51 |
| 1999 | 224 | 472.82 | 64.43 | 659.18 | 62.95 |
| 2000 | 209 | 527.95 | 64.46 | 971.07 | 82.90 |
| 2001 | 183 | 572.65 | 100.28 | 631.87 | 67.30 |
| 2002 | 171 | 470.10 | 88.08 | 797.65 | 88.41 |
| 2003 | 164 | 1429.82 | 303.30 | 1339.34 | 135.13 |
| 2004 | 133 | 726.31 | 136.25 | 1177.82 | 144.64 |
| 2005 | 354 | 536.26 | 72.52 | 931.05 | 68.46 |
| 2006 | 192 | 477.51 | 73.83 | 942.67 | 111.71 |
| 2007 | 183 | 610.36 | 101.27 | 1141.59 | 158.19 |
| 2008 | 189 | 489.42 | 84.41 | 762.88 | 82.69 |
| 2009 | 164 | 586.99 | 89.54 | 686.90 | 78.53 |
| 2010 | 154 | 484.47 | 70.62 | 750.55 | 88.77 |
| 2011 | 156 | 357.29 | 54.43 | 637.67 | 74.19 |
| 2012 | 178 | 506.20 | 114.22 | 533.69 | 75.38 |
| 2013 | 141 | 390.40 | 80.87 | 661.56 | 99.84 |
| 2014 | 177 | 475.57 | 86.94 | 688.79 | 88.40 |
| 2015 | 182 | 415.61 | 66.81 | 611.87 | 77.04 |
| 2016 | 159 | 305.16 | 65.30 | 456.09 | 75.91 |
| 2017 | 163 | 198.28 | 36.84 | 297.75 | 51.08 |
| 2008+ | 201 | 488.34 | 80.51 | 842.41 | 90.62 |
| 2009+ | 177 | 594.42 | 83.94 | 758.18 | 83.23 |
| 2010+ | 166 | 518.46 | 79.86 | 778.54 | 89.04 |
| 2011+ | 166 | 408.66 | 59.41 | 669.28 | 77.29 |
| 2012+ | 188 | 517.62 | 109.33 | 550.83 | 74.19 |
| 2013+ | 152 | 384.16 | 75.31 | 722.18 | 103.66 |
| 2014+ | 185 | 490.24 | 84.08 | 706.65 | 87.51 |
| 2015+ | 190 | 414.4 | 65.07 | 604.02 | 74.68 |
| 2016+ | 167 | 351.33 | 68.84 | 517.99 | 82.87 |
| 2017+ | 170 | 203.19 | 35.72 | 301.18 | 49.65 |

*+: From 2008, the sampling was increased with the addition of strata in shallow waters (37 to 183 m) in the Estuary.*

*Table 2a. Mean catch (kg/km²) and standard error by year, for males and females for the Estuary fishing area (n: number of stations).*

| Year | n | Males | | Females | |
|---|---|---|---|---|---|
| | | Mean | Standard error | Mean | Standard error |
| 1990 | 12 | 156.25 | 77.65 | 233.61 | 82.82 |
| 1991 | 11 | 31.24 | 15.15 | 308.55 | 140.68 |
| 1992 | 11 | 83.54 | 64.96 | 187.46 | 120.92 |
| 1993 | 12 | 102.41 | 77.20 | 229.50 | 142.70 |
| 1994 | 8 | 119.91 | 83.71 | 398.97 | 271.60 |
| 1995 | 18 | 33.17 | 15.68 | 44.57 | 18.74 |
| 1996 | 17 | 134.76 | 53.69 | 663.28 | 244.99 |
| 1997 | 16 | 31.88 | 13.05 | 146.68 | 94.02 |
| 1998 | 16 | 34.63 | 18.54 | 158.71 | 62.10 |
| 1999 | 21 | 124.25 | 90.37 | 595.89 | 201.85 |
| 2000 | 17 | 54.87 | 20.71 | 440.12 | 129.51 |
| 2001 | 19 | 13.15 | 3.83 | 271.47 | 99.18 |
| 2002 | 12 | 10.37 | 6.37 | 125.36 | 81.22 |
| 2003 | 11 | 30.04 | 12.65 | 346.47 | 251.44 |
| 2004 | 9 | 140.28 | 109.56 | 722.38 | 367.21 |
| 2005 | 24 | 35.03 | 17.05 | 466.44 | 138.59 |
| 2006 | 12 | 5.88 | 2.02 | 208.70 | 76.78 |
| 2007 | 12 | 18.39 | 14.15 | 144.45 | 62.56 |
| 2008 | 10 | 17.15 | 6.47 | 379.29 | 159.29 |
| 2009 | 10 | 43.51 | 24.17 | 405.86 | 193.34 |
| 2010 | 12 | 77.14 | 42.62 | 240.66 | 137.05 |
| 2011 | 12 | 200.40 | 89.92 | 459.64 | 168.07 |
| 2012 | 11 | 168.99 | 104.58 | 541.06 | 296.08 |
| 2013 | 10 | 85.86 | 56.47 | 236.72 | 121.54 |
| 2014 | 8 | 119.40 | 54.11 | 890.30 | 385.24 |
| 2015 | 7 | 125.22 | 87.82 | 384.42 | 216.65 |
| 2016 | 8 | 36.36 | 15.19 | 172.74 | 70.07 |
| 2017 | 7 | 12.08 | 8.71 | 76.32 | 36.47 |
| 2008+ | 21 | 276.83 | 141.95 | 1377.73 | 446.43 |
| 2009+ | 23 | 407.83 | 121.58 | 1113.27 | 320.00 |
| 2010+ | 24 | 515.89 | 328.56 | 689.18 | 259.33 |
| 2011+ | 22 | 659.27 | 231.84 | 779.10 | 272.71 |
| 2012+ | 20 | 439.15 | 174.31 | 715.64 | 248.12 |
| 2013+ | 20 | 209.10 | 63.28 | 939.43 | 368.62 |
| 2014+ | 15 | 497.78 | 171.42 | 1057.50 | 334.67 |
| 2015+ | 14 | 283.77 | 174.33 | 435.04 | 185.95 |
| 2016+ | 15 | 696.15 | 329.79 | 1024.49 | 447.92 |
| 2017+ | 14 | 164.73 | 75.91 | 228.77 | 111.45 |

*+: From 2008, the sampling was increased with the addition of strata in shallow waters (37 to 183 m) in the Estuary.*

*Table 2b. Mean catch (kg/km²) and standard error by year, for males and females for the Sept-Iles fishing area (n: number of stations).*

| Year | n | Males | | Females | |
|---|---|---|---|---|---|
| | | Mean | Standard error | Mean | Standard error |
| 1990 | 73 | 368.74 | 93.59 | 651.33 | 98.58 |
| 1991 | 71 | 556.17 | 162.63 | 828.80 | 150.54 |
| 1992 | 60 | 205.76 | 56.56 | 366.15 | 78.75 |
| 1993 | 47 | 376.53 | 94.10 | 378.57 | 73.66 |
| 1994 | 49 | 360.66 | 97.71 | 605.40 | 103.66 |
| 1995 | 56 | 466.30 | 96.10 | 576.97 | 95.30 |
| 1996 | 74 | 580.37 | 108.36 | 998.29 | 93.68 |
| 1997 | 53 | 827.35 | 159.76 | 1096.30 | 125.72 |
| 1998 | 48 | 533.44 | 86.71 | 1478.68 | 219.66 |
| 1999 | 62 | 715.15 | 119.52 | 989.22 | 102.19 |
| 2000 | 51 | 1011.01 | 164.56 | 1854.23 | 159.49 |
| 2001 | 58 | 1148.13 | 272.57 | 1132.31 | 155.61 |
| 2002 | 56 | 871.07 | 228.82 | 1693.13 | 194.24 |
| 2003 | 48 | 3127.78 | 919.28 | 2586.03 | 228.81 |
| 2004 | 43 | 1248.81 | 289.40 | 2115.14 | 274.29 |
| 2005 | 65 | 1216.63 | 286.98 | 1907.67 | 135.04 |
| 2006 | 50 | 655.37 | 157.80 | 1878.57 | 259.06 |
| 2007 | 50 | 1063.62 | 313.79 | 2293.54 | 339.10 |
| 2008 | 44 | 1015.41 | 288.14 | 2035.73 | 203.68 |
| 2009 | 44 | 823.43 | 240.35 | 1186.57 | 194.23 |
| 2010 | 40 | 644.76 | 150.85 | 1410.73 | 191.62 |
| 2011 | 40 | 416.78 | 86.94 | 1003.53 | 145.39 |
| 2012 | 42 | 1156.22 | 382.07 | 936.69 | 113.12 |
| 2013 | 41 | 548.73 | 212.81 | 995.85 | 251.10 |
| 2014 | 40 | 815.56 | 259.68 | 1549.82 | 245.80 |
| 2015 | 41 | 780.17 | 175.09 | 1327.24 | 166.93 |
| 2016 | 45 | 502.34 | 163.93 | 884.77 | 207.47 |
| 2017 | 45 | 235.67 | 58.65 | 386.31 | 96.26 |
| 2008+ | 45 | 993.14 | 282.54 | 1990.49 | 204.18 |
| 2009+ | 44 | 823.43 | 240.35 | 1186.57 | 194.23 |
| 2010+ | 40 | 644.76 | 150.85 | 1410.73 | 191.62 |
| 2011+ | 40 | 416.78 | 86.94 | 1003.53 | 145.39 |
| 2012+ | 43 | 1135.94 | 373.63 | 919.52 | 111.79 |
| 2013+ | 42 | 536.20 | 208.06 | 973.82 | 246.03 |
| 2014+ | 41 | 795.84 | 254.03 | 1513.84 | 242.41 |
| 2015+ | 42 | 761.60 | 171.87 | 1295.72 | 165.93 |
| 2016+ | 46 | 491.44 | 160.70 | 865.56 | 203.82 |
| 2017+ | 45 | 235.67 | 58.65 | 386.31 | 96.26 |

*+: From 2008, the sampling was increased with the addition of strata in shallow waters (37 to 183 m) in the Estuary.*

*Table 2c. Mean catch (kg/km²) and standard error by year, for males and females for the Anticosti fishing area (n: number of stations).*

| Year | n | Males | | Females | |
|---|---|---|---|---|---|
| | | Mean | Standard error | Mean | Standard error |
| 1990 | 85 | 418.56 | 105.94 | 390.75 | 86.97 |
| 1991 | 82 | 185.46 | 37.18 | 257.11 | 41.09 |
| 1992 | 82 | 211.64 | 59.86 | 232.16 | 43.47 |
| 1993 | 76 | 207.97 | 64.32 | 141.47 | 25.94 |
| 1994 | 64 | 161.65 | 36.65 | 184.99 | 33.22 |
| 1995 | 57 | 378.61 | 87.89 | 470.25 | 71.13 |
| 1996 | 63 | 494.88 | 135.38 | 729.94 | 125.45 |
| 1997 | 60 | 489.24 | 105.34 | 608.32 | 86.48 |
| 1998 | 78 | 338.21 | 56.43 | 608.26 | 76.82 |
| 1999 | 78 | 381.33 | 67.30 | 566.39 | 68.19 |
| 2000 | 77 | 394.01 | 73.62 | 850.58 | 104.51 |
| 2001 | 36 | 203.38 | 60.44 | 373.76 | 59.71 |
| 2002 | 49 | 473.84 | 119.72 | 630.48 | 110.74 |
| 2003 | 46 | 802.28 | 297.96 | 852.30 | 205.04 |
| 2004 | 32 | 603.73 | 293.42 | 754.31 | 230.89 |
| 2005 | 134 | 515.13 | 96.85 | 972.22 | 112.60 |
| 2006 | 64 | 390.93 | 113.07 | 665.50 | 135.86 |
| 2007 | 66 | 581.38 | 106.72 | 1072.18 | 308.50 |
| 2008 | 66 | 287.94 | 59.28 | 392.16 | 72.02 |
| 2009 | 60 | 560.53 | 125.19 | 496.13 | 91.53 |
| 2010 | 54 | 522.60 | 121.99 | 564.85 | 114.99 |
| 2011 | 52 | 202.74 | 59.32 | 338.23 | 84.79 |
| 2012 | 59 | 190.57 | 45.90 | 338.13 | 62.69 |
| 2013 | 49 | 229.97 | 58.75 | 464.64 | 112.20 |
| 2014 | 62 | 341.98 | 101.97 | 398.96 | 94.07 |
| 2015 | 74 | 339.59 | 106.39 | 435.86 | 116.17 |
| 2016 | 56 | 139.59 | 57.20 | 253.35 | 71.04 |
| 2017 | 62 | 204.87 | 72.09 | 289.98 | 94.90 |

*Table 2d. Mean catch (kg/km²) and standard error by year, for males and females for the Esquiman fishing area (n: number of stations).*

| Year | n | Males | | Females | |
|---|---|---|---|---|---|
| | | Mean | Standard error | Mean | Standard error |
| 1990 | 49 | 246.89 | 73.44 | 450.48 | 94.34 |
| 1991 | 86 | 132.72 | 36.35 | 229.00 | 41.98 |
| 1992 | 86 | 76.95 | 20.47 | 176.71 | 38.87 |
| 1993 | 79 | 111.73 | 23.94 | 104.72 | 20.01 |
| 1994 | 55 | 119.45 | 37.17 | 155.42 | 36.81 |
| 1995 | 51 | 264.14 | 85.29 | 282.15 | 79.76 |
| 1996 | 63 | 299.84 | 100.71 | 260.78 | 58.81 |
| 1997 | 56 | 675.28 | 236.46 | 631.91 | 215.63 |
| 1998 | 64 | 314.53 | 87.65 | 437.06 | 104.71 |
| 1999 | 63 | 463.80 | 172.20 | 470.35 | 162.91 |
| 2000 | 64 | 429.80 | 124.03 | 553.29 | 164.08 |
| 2001 | 70 | 437.61 | 105.14 | 447.79 | 92.32 |
| 2002 | 54 | 153.06 | 68.92 | 170.08 | 53.91 |
| 2003 | 59 | 798.67 | 221.02 | 889.93 | 221.41 |
| 2004 | 49 | 455.49 | 171.87 | 715.51 | 219.18 |
| 2005 | 131 | 312.11 | 78.31 | 489.47 | 102.90 |
| 2006 | 66 | 512.48 | 138.68 | 635.87 | 191.06 |
| 2007 | 55 | 362.25 | 106.21 | 395.21 | 106.46 |
| 2008 | 69 | 415.18 | 116.38 | 361.40 | 100.03 |
| 2009 | 50 | 519.38 | 133.70 | 532.32 | 135.96 |
| 2010 | 48 | 409.84 | 126.00 | 536.80 | 167.72 |
| 2011 | 52 | 502.29 | 132.68 | 696.77 | 158.63 |
| 2012 | 66 | 430.91 | 171.38 | 450.81 | 170.26 |
| 2013 | 41 | 498.07 | 161.40 | 666.24 | 181.72 |
| 2014 | 67 | 438.73 | 137.78 | 418.88 | 123.42 |
| 2015 | 60 | 294.12 | 88.82 | 366.66 | 116.09 |
| 2016 | 50 | 356.13 | 127.48 | 342.68 | 114.00 |
| 2017 | 49 | 182.21 | 62.05 | 257.86 | 81.58 |

*Table 3a. Parameters of the variograms used for kriging the male biomass. An exponential model* was used each year.*

| Year | Period | Parameters | | |
|---|---|---|---|---|
| | | Nugget ($c_0$) | Sill ($c_0$ + c) | Range ($a_0$) |
| 1990 | 1990-1991-1992 | 0.50 | 1.05 | 35 |
| 1991 | 1990-1991-1992 | 0.50 | 1.05 | 35 |
| 1992 | 1990-1991-1992 | 0.50 | 1.05 | 35 |
| 1993 | 1991-1992-1993 | 0.20 | 1.05 | 30 |
| 1994 | 1992-1993-1994 | 0.20 | 1.05 | 30 |
| 1995 | 1993-1994-1995 | 0.20 | 1.00 | 20 |
| 1996 | 1994-1995-1996 | 0.20 | 1.00 | 20 |
| 1997 | 1995-1996-1997 | 0.20 | 0.95 | 18 |
| 1998 | 1996-1997-1998 | 0.20 | 0.90 | 20 |
| 1999 | 1997-1998-1999 | 0.40 | 0.90 | 20 |
| 2000 | 1998-1999-2000 | 0.40 | 0.90 | 20 |
| 2001 | 1999-2000-2001 | 0.40 | 0.90 | 17 |
| 2002 | 2000-2001-2002 | 0.30 | 1.00 | 25 |
| 2003 | 2001-2002-2003 | 0.20 | 1.00 | 25 |
| 2004 | 2002-2003-2004 | 0.20 | 1.00 | 25 |
| 2005 | 2003-2004-2005 | 0.30 | 1.00 | 30 |
| 2006 | 2004-2005-2006 | 0.30 | 1.00 | 25 |
| 2007 | 2005-2006-2007 | 0.30 | 1.00 | 25 |
| 2008 | 2006-2007-2008 | 0.30 | 1.00 | 20 |
| 2009 | 2007-2008-2009 | 0.25 | 1.00 | 25 |
| 2010 | 2008-2009-2010 | 0.30 | 1.00 | 25 |
| 2011 | 2009-2010-2011 | 0.40 | 1.00 | 30 |
| 2012 | 2010-2011-2012 | 0.30 | 1.00 | 22 |
| 2013 | 2011-2012-2013 | 0.00 | 0.96 | 15.68 |
| 2014 | 2012-2013-2014 | 0.00 | 0.96 | 15.65 |
| 2015 | 2013-2014-2015 | 0.00 | 0.92 | 15.09 |
| 2016 | 2014-2015-2016 | 0.00 | 0.92 | 12.25 |
| 2017 | 2015-2016-2017 | 0.00 | 0.92 | 11.21 |

* Exponential model : (where h = distance) $\gamma(h) = c_0 + c\left[1 - exp\left(-\frac{h}{a_0}\right)\right]$

*Table 3b. Parameters of the variograms used for kriging the female biomass. An exponential model* was used each year.*

| Year | Period | Parameters | | |
|---|---|---|---|---|
| | | Nugget ($c_0$) | Sill ($c_0$ + c) | Range ($a_0$) |
| 1990 | 1990-1991-1992 | 0.45 | 0.95 | 30 |
| 1991 | 1990-1991-1992 | 0.45 | 0.95 | 30 |
| 1992 | 1990-1991-1992 | 0.45 | 0.95 | 30 |
| 1993 | 1991-1992-1993 | 0.25 | 0.85 | 20 |
| 1994 | 1992-1993-1994 | 0.30 | 0.85 | 25 |
| 1995 | 1993-1994-1995 | 0.30 | 0.80 | 20 |
| 1996 | 1994-1995-1996 | 0.15 | 0.95 | 17 |
| 1997 | 1995-1996-1997 | 0.15 | 0.95 | 17 |
| 1998 | 1996-1997-1998 | 0.20 | 0.95 | 20 |
| 1999 | 1997-1998-1999 | 0.35 | 0.90 | 25 |
| 2000 | 1998-1999-2000 | 0.35 | 0.90 | 30 |
| 2001 | 1999-2000-2001 | 0.40 | 0.90 | 35 |
| 2002 | 2000-2001-2002 | 0.30 | 0.90 | 30 |
| 2003 | 2001-2002-2003 | 0.20 | 0.85 | 35 |
| 2004 | 2002-2003-2004 | 0.15 | 0.95 | 35 |
| 2005 | 2003-2004-2005 | 0.20 | 1.05 | 60 |
| 2006 | 2004-2005-2006 | 0.20 | 1.05 | 50 |
| 2007 | 2005-2006-2007 | 0.20 | 1.05 | 60 |
| 2008 | 2006-2007-2008 | 0.20 | 1.00 | 60 |
| 2009 | 2007-2008-2009 | 0.20 | 0.90 | 40 |
| 2010 | 2008-2009-2010 | 0.25 | 0.90 | 45 |
| 2011 | 2009-2010-2011 | 0.15 | 0.90 | 28 |
| 2012 | 2010-2011-2012 | 0.15 | 0.90 | 27 |
| 2013 | 2011-2012-2013 | 0.60 | 1.52 | 441.11 |
| 2014 | 2012-2013-2014 | 0.51 | 0.80 | 53.25 |
| 2015 | 2013-2014-2015 | 0.48 | 1.10 | 175.07 |
| 2016 | 2014-2015-2016 | 0.41 | 0.82 | 42.47 |
| 2017 | 2015-2016-2017 | 0.58 | 26.57 | 13249 |

* Exponential model : (where h = distance) $\gamma(h) = c_0 + c\left[1 - exp\left(-\frac{h}{a_0}\right)\right]$

*Table 3c. Parameters of the variograms used for kriging the total biomass. An exponential model* was used each year.*

| Year | Period | Parameters | | |
|---|---|---|---|---|
| | | Nugget ($c_0$) | Sill ($c_0$ + c) | Range ($a_0$) |
| 1990 | 1990-1991-1992 | 0.40 | 1.00 | 35 |
| 1991 | 1990-1991-1992 | 0.40 | 1.00 | 35 |
| 1992 | 1990-1991-1992 | 0.40 | 1.00 | 35 |
| 1993 | 1991-1992-1993 | 0.30 | 0.95 | 40 |
| 1994 | 1992-1993-1994 | 0.30 | 0.95 | 32 |
| 1995 | 1993-1994-1995 | 0.30 | 0.95 | 25 |
| 1996 | 1994-1995-1996 | 0.20 | 1.05 | 20 |
| 1997 | 1995-1996-1997 | 0.20 | 1.00 | 20 |
| 1998 | 1996-1997-1998 | 0.20 | 1.00 | 25 |
| 1999 | 1997-1998-1999 | 0.30 | 0.90 | 25 |
| 2000 | 1998-1999-2000 | 0.35 | 0.90 | 30 |
| 2001 | 1999-2000-2001 | 0.50 | 1.00 | 80 |
| 2002 | 2000-2001-2002 | 0.45 | 1.00 | 70 |
| 2003 | 2001-2002-2003 | 0.40 | 1.00 | 70 |
| 2004 | 2002-2003-2004 | 0.20 | 1.00 | 40 |
| 2005 | 2003-2004-2005 | 0.25 | 1.05 | 60 |
| 2006 | 2004-2005-2006 | 0.30 | 1.05 | 60 |
| 2007 | 2005-2006-2007 | 0.30 | 1.05 | 60 |
| 2008 | 2006-2007-2008 | 0.30 | 1.05 | 55 |
| 2009 | 2007-2008-2009 | 0.30 | 1.05 | 55 |
| 2010 | 2008-2009-2010 | 0.35 | 1.00 | 40 |
| 2011 | 2009-2010-2011 | 0.25 | 1.00 | 30 |
| 2012 | 2010-2011-2012 | 0.20 | 0.95 | 20 |
| 2013 | 2011-2012-2013 | 0.00 | 0.87 | 11.49 |
| 2014 | 2012-2013-2014 | 0.00 | 0.86 | 11.46 |
| 2015 | 2013-2014-2015 | 0.00 | 0.82 | 12.13 |
| 2016 | 2014-2015-2016 | 0.00 | 0.84 | 12.07 |
| 2017 | 2015-2016-2017 | 0.61 | 1.24 | 153.34 |

* Exponential model : (where h = distance) $\gamma(h) = c_0 + c\left[1 - exp\left(-\frac{h}{a_0}\right)\right]$

*Table 4. Parameters for the weight-length relationships* by fishing area and by year. Length in mm and weight in g.*

| Year | Estuary | | Sept-Iles | | Anticosti | | Esquiman | |
|---|---|---|---|---|---|---|---|---|
| | a | b | a | b | a | b | a | b |
| 1993 | 0.000713 | 2.945 | 0.000658 | 2.978 | 0.000593 | 3.018 | 0.000939 | 2.864 |
| 2005 | 0.001175 | 2.777 | 0.000654 | 2.960 | 0.000659 | 2.957 | 0.000754 | 2.904 |
| 2006 | 0.000682 | 2.945 | 0.000694 | 2.934 | 0.000527 | 3.040 | 0.000933 | 2.849 |
| 2007 | 0.001071 | 2.800 | 0.000724 | 2.930 | 0.000735 | 2.918 | 0.000767 | 2.904 |
| 2008 | 0.000561 | 3.016 | 0.000704 | 2.934 | 0.000769 | 2.908 | 0.000820 | 2.887 |
| 2009 | 0.000628 | 2.977 | 0.000897 | 2.864 | 0.000800 | 2.893 | 0.000767 | 2.911 |
| 2010 | 0.000759 | 2.920 | 0.000716 | 2.931 | 0.000585 | 3.011 | 0.000706 | 2.953 |
| 2011 | 0.000760 | 2.911 | 0.000685 | 2.942 | 0.000616 | 3.001 | 0.000544 | 3.036 |
| 2012 | 0.000733 | 2.931 | 0.000725 | 2.936 | 0.000771 | 2.923 | 0.000814 | 2.908 |
| 2013 | 0.000624 | 2.979 | 0.000643 | 2.976 | 0.000561 | 3.028 | 0.000672 | 2.967 |
| 2014 | 0.000657 | 2.962 | 0.000854 | 2.880 | 0.000741 | 2.933 | 0.000663 | 2.969 |
| 2015 | 0.000804 | 2.914 | 0.000894 | 2.870 | 0.000651 | 2.975 | 0.000763 | 2.924 |
| 2016 | 0.000699 | 2.963 | 0.001016 | 2.831 | 0.000750 | 2.945 | 0.000991 | 2.832 |
| 2017 | 0.000897 | 2.884 | 0.000951 | 2.862 | 0.000687 | 2.986 | 0.000614 | 2.985 |

** Model: Weight = a Length* $^{b}$

*Table 5. Mean biomass (kg/km²) estimated by kriging, by fishing area and by year, for males (M) and females (F).*

| Year | Estuary | | Sept-Iles | | Anticosti | | Esquiman | |
|---|---|---|---|---|---|---|---|---|
| | M | F | M | F | M | F | M | F |
| 1990 | 188.6 | 310.4 | 390.5 | 652.2 | 402.4 | 404.3 | 234.2 | 402.2 |
| 1991 | 44.3 | 514.4 | 566.7 | 774.9 | 207.0 | 300.6 | 185.5 | 285.3 |
| 1992 | 100.1 | 365.0 | 219.6 | 358.7 | 264.7 | 276.9 | 92.4 | 202.5 |
| 1993 | 88.9 | 274.7 | 336.2 | 442.0 | 207.7 | 150.0 | 114.3 | 107.1 |
| 1994 | 102.6 | 426.1 | 376.1 | 598.4 | 165.3 | 179.5 | 175.6 | 196.0 |
| 1995 | 33.1 | 52.9 | 426.2 | 559.7 | 392.7 | 509.3 | 334.5 | 327.7 |
| 1996 | 116.6 | 598.7 | 467.0 | 880.3 | 659.8 | 931.3 | 329.5 | 299.2 |
| 1997 | 69.7 | 375.4 | 777.1 | 999.6 | 456.7 | 552.9 | 747.2 | 693.7 |
| 1998 | 28.5 | 159.8 | 551.5 | 1547.1 | 269.5 | 566.0 | 366.8 | 481.2 |
| 1999 | 136.2 | 575.2 | 788.0 | 1098.1 | 345.9 | 551.8 | 455.2 | 457.9 |
| 2000 | 141.1 | 702.3 | 1005.3 | 1777.0 | 403.7 | 832.1 | 439.2 | 536.7 |
| 2001 | 22.2 | 439.9 | 1273.0 | 1141.8 | 331.2 | 508.2 | 452.4 | 452.5 |
| 2002 | 22.0 | 312.8 | 980.1 | 1713.4 | 594.6 | 739.3 | 197.3 | 217.5 |
| 2003 | 105.8 | 691.4 | 2952.5 | 2767.2 | 966.3 | 1232.6 | 873.0 | 998.5 |
| 2004 | 92.5 | 626.6 | 1444.4 | 2312.4 | 564.3 | 905.2 | 434.7 | 767.7 |
| 2005 | 44.5 | 554.1 | 925.6 | 1978.1 | 655.3 | 1141.8 | 596.3 | 853.3 |
| 2006 | 45.8 | 419.7 | 631.4 | 1872.6 | 385.9 | 685.5 | 713.6 | 847.1 |
| 2007 | 221.4 | 592.0 | 945.0 | 2363.8 | 623.5 | 1223.2 | 517.6 | 462.7 |
| 2008 | 23.6 | 617.7 | 835.7 | 2112.6 | 361.7 | 481.1 | 492.9 | 426.4 |
| 2009 | 49.0 | 356.0 | 1031.0 | 1336.2 | 593.7 | 532.2 | 547.0 | 536.9 |
| 2010 | 98.7 | 341.0 | 715.6 | 1527.8 | 534.5 | 570.9 | 447.7 | 568.0 |
| 2011 | 185.9 | 496.6 | 488.8 | 1024.7 | 218.0 | 432.3 | 624.7 | 831.8 |
| 2012 | 160.7 | 658.3 | 1223.6 | 1015.0 | 268.4 | 473.3 | 452.8 | 507.7 |
| 2013 | 110.2 | 367.9 | 669.0 | 1037.5 | 236.1 | 508.9 | 435.1 | 659.9 |
| 2014 | 149.8 | 1139.1 | 942.1 | 1709.5 | 380.6 | 478.7 | 482.0 | 479.9 |
| 2015 | 169.3 | 711.5 | 848.9 | 1382.2 | 333.2 | 483.5 | 298.7 | 395.5 |
| 2016 | 65.4 | 276.9 | 532.3 | 914.9 | 172.0 | 298.7 | 397.6 | 382.2 |
| 2017 | 15.2 | 89.3 | 267.8 | 444.3 | 239.9 | 347.2 | 247.4 | 349.7 |
| 2008+ | 284.6 | 1405.4 | 833.4 | 2103.8 | - | - | - | - |
| 2009+ | 421.3 | 1157.2 | 1028.8 | 1334.6 | - | - | - | - |
| 2010+ | 540.0 | 709.0 | 714.2 | 1526.1 | - | - | - | - |
| 2011+ | 557.9 | 588.7 | 490.2 | 1014.4 | - | - | - | - |
| 2012+ | 490.8 | 779.4 | 1220.6 | 1007.8 | - | - | - | - |
| 2013+ | 226.7 | 795.7 | 666.2 | 1029.1 | - | - | - | - |
| 2014+ | 534.4 | 1098.0 | 937.3 | 1693.6 | - | - | - | - |
| 2015+ | 261.6 | 589.7 | 843.7 | 1369.0 | - | - | - | - |
| 2016+ | 449.0 | 708.4 | 529.4 | 908.4 | - | - | - | - |
| 2017+ | 159.6 | 223.4 | 267.1 | 443.2 | - | - | - | - |

*+: From 2008, the sampling was increased with the addition of strata in shallow waters (37 to 183 m) in the Estuary.*

*Table 6. Variance of the estimation of the kriged biomass, by fishing area and by year, for males (M) and females (F).*

| Year | Estuary | | Sept-Iles | | Anticosti | | Esquiman | |
|---|---|---|---|---|---|---|---|---|
| | M | F | M | F | M | F | M | F |
| 1990 | 4593 | 4834 | 8401 | 8656 | 10171 | 6348 | 4803 | 7277 |
| 1991 | 190 | 15114 | 22197 | 17747 | 1265 | 1436 | 1228 | 1519 |
| 1992 | 3381 | 10859 | 2757 | 4974 | 3327 | 1636 | 343 | 1145 |
| 1993 | 3482 | 12624 | 5229 | 3335 | 3118 | 497 | 367 | 267 |
| 1994 | 4252 | 44887 | 6502 | 7158 | 1106 | 856 | 1031 | 987 |
| 1995 | 135 | 191 | 6029 | 5480 | 6483 | 3642 | 6979 | 5122 |
| 1996 | 1724 | 35077 | 9532 | 6893 | 17463 | 14585 | 7608 | 2547 |
| 1997 | 91 | 4508 | 18807 | 11438 | 12013 | 8093 | 44216 | 36384 |
| 1998 | 218 | 1728 | 5003 | 33605 | 2811 | 5478 | 4864 | 7254 |
| 1999 | 6043 | 27056 | 13218 | 9064 | 4150 | 4019 | 24527 | 20394 |
| 2000 | 292 | 9848 | 21632 | 17931 | 4676 | 8496 | 11177 | 16974 |
| 2001 | 11 | 6582 | 58555 | 16209 | 3886 | 4715 | 8744 | 5870 |
| 2002 | 28 | 4021 | 36174 | 22907 | 13616 | 10274 | 4047 | 2162 |
| 2003 | 126 | 39123 | 671578 | 32617 | 77033 | 28572 | 41275 | 32368 |
| 2004 | 7524 | 65553 | 72132 | 50945 | 93148 | 55313 | 21248 | 27467 |
| 2005 | 207 | 8972 | 84841 | 13234 | 11480 | 11319 | 6845 | 8114 |
| 2006 | 3 | 2762 | 16012 | 29251 | 12705 | 14893 | 15130 | 20125 |
| 2007 | 186 | 2686 | 72080 | 54547 | 8341 | 45769 | 9290 | 6329 |
| 2008 | 33 | 12784 | 69789 | 21424 | 2994 | 2624 | 12120 | 5643 |
| 2009 | 372 | 17218 | 42898 | 21100 | 15001 | 6168 | 14323 | 10689 |
| 2010 | 1352 | 10110 | 17455 | 20606 | 13020 | 8386 | 11540 | 14446 |
| 2011 | 5748 | 14016 | 6343 | 14156 | 2980 | 4768 | 14629 | 16123 |
| 2012 | 9148 | 55186 | 110879 | 7274 | 2112 | 3311 | 24943 | 18554 |
| 2013 | 2024 | 10692 | 34933 | 46665 | 3019 | 9645 | 20207 | 24445 |
| 2014 | 2597 | 103695 | 41220 | 37862 | 6935 | 6131 | 11651 | 10530 |
| 2015 | 4503 | 27811 | 18633 | 16393 | 6844 | 8083 | 4709 | 8565 |
| 2016 | 198 | 3195 | 17970 | 26068 | 2219 | 2993 | 11044 | 8236 |
| 2017 | 40 | 846 | 2180 | 6049 | 3598 | 6012 | 2818 | 4846 |
| 2008+ | 16392 | 102556 | 67828 | 21841 | - | - | - | - |
| 2009+ | 8170 | 40838 | 42864 | 21071 | - | - | - | - |
| 2010+ | 70574 | 31642 | 17444 | 20582 | - | - | - | - |
| 2011+ | 39732 | 39001 | 6354 | 14200 | - | - | - | - |
| 2012+ | 24374 | 36177 | 106422 | 7136 | - | - | - | - |
| 2013+ | 2488 | 103622 | 33892 | 45328 | - | - | - | - |
| 2014+ | 18242 | 72156 | 39639 | 37108 | - | - | - | - |
| 2015+ | 14305 | 19969 | 18156 | 16386 | - | - | - | - |
| 2016+ | 100643 | 153438 | 17312 | 25310 | - | - | - | - |
| 2017+ | 2915 | 7895 | 2182 | 6045 | - | - | - | - |

*+: From 2008, the sampling was increased with the addition of strata in shallow waters (37 to 183 m) in the Estuary.*

*Table 7. Coefficient of variation of the kriged biomass, by fishing area and by year, for males (M) and females (F).*

| Year | Estuary | | Sept-Iles | | Anticosti | | Esquiman | |
|---|---|---|---|---|---|---|---|---|
| | M | F | M | F | M | F | M | F |
| 1990 | 35.9 | 22.4 | 23.5 | 14.3 | 25.1 | 19.7 | 29.6 | 21.2 |
| 1991 | 31.1 | 23.9 | 26.3 | 17.2 | 17.2 | 12.6 | 18.9 | 13.7 |
| 1992 | 58.1 | 28.5 | 23.9 | 19.7 | 21.8 | 14.6 | 20.1 | 16.7 |
| 1993 | 66.4 | 40.9 | 21.5 | 13.1 | 26.9 | 14.9 | 16.8 | 15.2 |
| 1994 | 63.5 | 49.7 | 21.4 | 14.1 | 20.1 | 16.3 | 18.3 | 16.0 |
| 1995 | 35.1 | 26.1 | 18.2 | 13.2 | 20.5 | 11.9 | 25.0 | 21.8 |
| 1996 | 35.6 | 31.3 | 20.9 | 9.4 | 20.0 | 13.0 | 26.5 | 16.9 |
| 1997 | 13.7 | 17.9 | 17.6 | 10.7 | 24.0 | 16.3 | 28.1 | 27.5 |
| 1998 | 51.8 | 26.0 | 12.8 | 11.8 | 19.7 | 13.1 | 19.0 | 17.7 |
| 1999 | 57.1 | 28.6 | 14.6 | 8.7 | 18.6 | 11.5 | 34.4 | 31.2 |
| 2000 | 12.1 | 14.1 | 14.6 | 7.5 | 16.9 | 11.1 | 24.1 | 24.3 |
| 2001 | 15.1 | 18.4 | 19.0 | 11.2 | 18.8 | 13.5 | 20.7 | 16.9 |
| 2002 | 24.0 | 20.3 | 19.4 | 8.8 | 19.6 | 13.7 | 32.2 | 21.4 |
| 2003 | 10.6 | 28.6 | 27.8 | 6.5 | 28.7 | 13.7 | 23.3 | 18.0 |
| 2004 | 93.7 | 40.9 | 18.6 | 9.8 | 54.1 | 26.0 | 33.5 | 21.6 |
| 2005 | 32.3 | 17.1 | 31.5 | 5.8 | 16.4 | 9.3 | 13.9 | 10.6 |
| 2006 | 3.6 | 12.5 | 20.0 | 9.1 | 29.2 | 17.8 | 17.2 | 16.7 |
| 2007 | 6.2 | 8.8 | 28.4 | 9.9 | 14.6 | 17.5 | 18.6 | 17.2 |
| 2008 | 24.4 | 18.3 | 31.6 | 6.9 | 15.1 | 10.6 | 22.3 | 17.6 |
| 2009 | 39.4 | 36.9 | 20.1 | 10.9 | 20.6 | 14.8 | 21.9 | 19.3 |
| 2010 | 37.3 | 29.5 | 18.5 | 9.4 | 21.3 | 16.0 | 24.0 | 21.2 |
| 2011 | 40.8 | 23.8 | 16.3 | 11.6 | 25.0 | 16.0 | 19.4 | 15.3 |
| 2012 | 59.5 | 35.7 | 27.2 | 8.4 | 17.1 | 12.2 | 34.9 | 26.8 |
| 2013 | 40.8 | 28.1 | 27.9 | 20.8 | 23.3 | 19.3 | 32.7 | 23.7 |
| 2014 | 34.0 | 28.3 | 21.6 | 11.4 | 21.9 | 16.4 | 22.4 | 21.4 |
| 2015 | 39.6 | 23.4 | 16.1 | 9.3 | 24.8 | 18.6 | 23.0 | 23.4 |
| 2016 | 21.5 | 20.4 | 25.2 | 17.6 | 27.4 | 18.3 | 26.4 | 23.7 |
| 2017 | 41.7 | 32.6 | 17.4 | 17.5 | 25.0 | 22.3 | 21.5 | 19.9 |
| 2008+ | 45.0 | 22.8 | 31.2 | 7.0 | - | - | - | - |
| 2009+ | 21.5 | 17.5 | 20.1 | 10.9 | - | - | - | - |
| 2010+ | 49.2 | 25.1 | 18.5 | 9.4 | - | - | - | - |
| 2011+ | 35.7 | 33.5 | 16.3 | 11.7 | - | - | - | - |
| 2012+ | 31.8 | 24.4 | 26.7 | 8.4 | - | - | - | - |
| 2013+ | 22.0 | 40.5 | 27.6 | 20.7 | - | - | - | - |
| 2014+ | 25.3 | 24.5 | 21.2 | 11.4 | - | - | - | - |
| 2015+ | 45.7 | 24.0 | 16.0 | 9.4 | - | - | - | - |
| 2016+ | 70.7 | 55.3 | 24.9 | 17.5 | - | - | - | - |
| 2017+ | 33.8 | 39.8 | 17.5 | 17.5 | - | - | - | - |

*+: From 2008, the sampling was increased with the addition of strata in shallow waters (37 to 183 m) in the Estuary.*

*Table 8. Stock biomass (ton) estimated by kriging by fishing area and by year, for males (M) and females (F).*

| Year | Estuary | | Sept-Iles | | Anticosti | | Esquiman | |
|---|---|---|---|---|---|---|---|---|
| | M | F | M | F | M | F | M | F |
| 1990 | 755 | 1241 | 11627 | 19418 | 18670 | 18758 | 7577 | 13011 |
| 1991 | 177 | 2057 | 16874 | 23073 | 9606 | 13948 | 6000 | 9228 |
| 1992 | 400 | 1460 | 6538 | 10681 | 12284 | 12850 | 2989 | 6551 |
| 1993 | 356 | 1099 | 10011 | 13161 | 9636 | 6962 | 3698 | 3465 |
| 1994 | 410 | 1704 | 11198 | 17818 | 7670 | 8331 | 5681 | 6340 |
| 1995 | 133 | 212 | 12689 | 16667 | 18222 | 23630 | 10822 | 10602 |
| 1996 | 466 | 2395 | 13906 | 26212 | 30616 | 43214 | 10658 | 9680 |
| 1997 | 279 | 1501 | 23139 | 29763 | 21191 | 25653 | 24171 | 22443 |
| 1998 | 114 | 639 | 16421 | 46063 | 12503 | 26263 | 11867 | 15566 |
| 1999 | 545 | 2301 | 23464 | 32695 | 16051 | 25605 | 14724 | 14812 |
| 2000 | 564 | 2809 | 29934 | 52910 | 18732 | 38608 | 14207 | 17364 |
| 2001 | 89 | 1760 | 37905 | 33996 | 15366 | 23580 | 14635 | 14640 |
| 2002 | 88 | 1251 | 29184 | 51016 | 27590 | 34304 | 6382 | 7036 |
| 2003 | 423 | 2766 | 87909 | 82392 | 44836 | 57195 | 28242 | 32301 |
| 2004 | 370 | 2506 | 43008 | 68852 | 26182 | 42000 | 14062 | 24836 |
| 2005 | 178 | 2216 | 27558 | 58899 | 30406 | 52977 | 19292 | 27603 |
| 2006 | 183 | 1679 | 18800 | 55756 | 17905 | 31806 | 23086 | 27404 |
| 2007 | 885 | 2368 | 28137 | 70382 | 28931 | 56758 | 16745 | 14969 |
| 2008 | 94 | 2471 | 24883 | 62904 | 16781 | 22321 | 15944 | 13794 |
| 2009 | 196 | 1424 | 30697 | 39786 | 27549 | 24693 | 17697 | 17369 |
| 2010 | 395 | 1364 | 21308 | 45490 | 24802 | 26489 | 14483 | 18374 |
| 2011 | 744 | 1987 | 14555 | 30511 | 10115 | 20060 | 20209 | 26907 |
| 2012 | 643 | 2633 | 36433 | 30222 | 12456 | 21963 | 14648 | 16425 |
| 2013 | 441 | 1471 | 19919 | 30891 | 10956 | 23614 | 14077 | 21349 |
| 2014 | 599 | 4556 | 28050 | 50902 | 17662 | 22212 | 15592 | 15526 |
| 2015 | 677 | 2846 | 25277 | 41155 | 15461 | 22435 | 9662 | 12794 |
| 2016 | 262 | 1107 | 15849 | 27242 | 7981 | 13857 | 12863 | 12365 |
| 2017 | 61 | 357 | 7974 | 13230 | 11131 | 16108 | 8005 | 11313 |
| 2008+ | 1800 | 8889 | 24898 | 62852 | - | - | - | - |
| 2009+ | 2665 | 7319 | 30734 | 39873 | - | - | - | - |
| 2010+ | 3415 | 4484 | 21337 | 45591 | - | - | - | - |
| 2011+ | 3529 | 3724 | 14644 | 30305 | - | - | - | - |
| 2012+ | 3104 | 4930 | 36466 | 30108 | - | - | - | - |
| 2013+ | 1434 | 5033 | 19902 | 30745 | - | - | - | - |
| 2014+ | 3380 | 6945 | 28002 | 50595 | - | - | - | - |
| 2015+ | 1654 | 3730 | 25206 | 40899 | - | - | - | - |
| 2016+ | 2840 | 4481 | 15817 | 27137 | - | - | - | - |
| 2017+ | 1010 | 1413 | 7980 | 13239 | - | - | - | - |

+: From 2008, the sampling was increased with the addition of strata in shallow waters (37 to 183 m) in the Estuary.

*Table 9. Stock abundance (in million) by fishing area and by year, for males (M) and females (F).*

| Year | Estuary | | Sept-Iles | | Anticosti | | Esquiman | |
|---|---|---|---|---|---|---|---|---|
| | M | F | M | F | M | F | M | F |
| 1990 | 156 | 115 | 2266 | 1822 | 4686 | 2077 | 1661 | 1394 |
| 1991 | 26 | 196 | 3871 | 2278 | 1948 | 1458 | 1210 | 972 |
| 1992 | 87 | 128 | 2113 | 961 | 2928 | 1252 | 630 | 660 |
| 1993 | 85 | 92 | 2894 | 1264 | 2648 | 671 | 866 | 358 |
| 1994 | 87 | 163 | 3292 | 1918 | 1888 | 919 | 1471 | 716 |
| 1995 | 40 | 20 | 2920 | 1707 | 4854 | 2682 | 2681 | 1368 |
| 1996 | 86 | 226 | 3017 | 2667 | 7387 | 4769 | 3197 | 1207 |
| 1997 | 48 | 132 | 4939 | 2830 | 5852 | 2603 | 6497 | 2791 |
| 1998 | 30 | 54 | 3447 | 4212 | 2605 | 2563 | 3099 | 1808 |
| 1999 | 118 | 205 | 5797 | 3112 | 3910 | 2560 | 4112 | 1846 |
| 2000 | 114 | 257 | 6531 | 5329 | 4957 | 4008 | 4020 | 2137 |
| 2001 | 18 | 162 | 8559 | 3503 | 3604 | 2424 | 4610 | 1921 |
| 2002 | 20 | 125 | 6661 | 5543 | 7995 | 3898 | 1741 | 907 |
| 2003 | 219 | 271 | 17561 | 8982 | 12628 | 6741 | 8046 | 4298 |
| 2004 | 62 | 238 | 8521 | 7715 | 7070 | 5149 | 3740 | 3421 |
| 2005 | 29 | 222 | 6280 | 6498 | 6319 | 6441 | 4885 | 3913 |
| 2006 | 28 | 164 | 3806 | 6132 | 4322 | 3781 | 7165 | 3669 |
| 2007 | 141 | 226 | 6171 | 7251 | 8128 | 7224 | 5890 | 2243 |
| 2008 | 19 | 222 | 5613 | 6530 | 4809 | 2839 | 4938 | 2199 |
| 2009 | 43 | 133 | 7937 | 4311 | 9970 | 3258 | 5374 | 2529 |
| 2010 | 79 | 129 | 5942 | 5273 | 6481 | 3254 | 3634 | 2470 |
| 2011 | 178 | 231 | 3753 | 3639 | 2629 | 2421 | 5916 | 3404 |
| 2012 | 131 | 306 | 8345 | 3632 | 2961 | 2558 | 4310 | 2083 |
| 2013 | 143 | 158 | 4251 | 3513 | 2556 | 2787 | 3670 | 2741 |
| 2014 | 109 | 456 | 6422 | 5444 | 4907 | 2474 | 4067 | 1892 |
| 2015 | 138 | 274 | 5644 | 4362 | 4548 | 2799 | 2831 | 1619 |
| 2016 | 55 | 116 | 3698 | 3347 | 2277 | 1866 | 3245 | 1729 |
| 2017 | 12 | 40 | 1917 | 1650 | 3402 | 2074 | 1999 | 1488 |
| 2008+ | 456 | 831 | 5626 | 6525 | - | - | - | - |
| 2009+ | 1253 | 732 | 7946 | 4321 | - | - | - | - |
| 2010+ | 1073 | 467 | 5950 | 5284 | - | - | - | - |
| 2011+ | 1070 | 433 | 3776 | 3614 | - | - | - | - |
| 2012+ | 822 | 586 | 8355 | 3619 | - | - | - | - |
| 2013+ | 455 | 611 | 4249 | 3497 | - | - | - | - |
| 2014+ | 992 | 744 | 6413 | 5412 | - | - | - | - |
| 2015+ | 658 | 378 | 5628 | 4335 | - | - | - | - |
| 2016+ | 631 | 486 | 3690 | 3334 | - | - | - | - |
| 2017+ | 303 | 167 | 1918 | 1651 | - | - | - | - |

*+: From 2008, the sampling was increased with the addition of strata in shallow waters (37 to 183 m) in the Estuary.*

*Table 10. Abundance (in million) for juveniles (J), primiparous (Fp) and mutiparous (Fm) females, by fishing area and by year.*

| Year | Estuary | | | Sept-Iles | | | Anticosti | | | Esquiman | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | J | Fp | Fm | J | Fp | Fm | J | Fp | Fm | J | Fp | Fm |
| 1990 | 11 | 48 | 67 | 123 | 965 | 858 | 73 | 1486 | 590 | 4 | 1157 | 237 |
| 1991 | 0 | 57 | 138 | 349 | 773 | 1505 | 87 | 837 | 621 | 70 | 535 | 437 |
| 1992 | 0 | 43 | 85 | 342 | 556 | 404 | 394 | 843 | 408 | 50 | 554 | 106 |
| 1993 | 1 | 78 | 14 | 113 | 1031 | 234 | 29 | 580 | 92 | 23 | 234 | 124 |
| 1994 | 0 | 130 | 33 | 172 | 1600 | 318 | 19 | 802 | 118 | 98 | 627 | 90 |
| 1995 | 12 | 14 | 5 | 188 | 1496 | 211 | 493 | 2408 | 273 | 30 | 1182 | 185 |
| 1996 | 1 | 132 | 94 | 166 | 2011 | 656 | 1249 | 4048 | 721 | 637 | 881 | 327 |
| 1997 | 0 | 110 | 22 | 45 | 2294 | 535 | 609 | 2377 | 226 | 76 | 2063 | 728 |
| 1998 | 8 | 32 | 22 | 705 | 3498 | 714 | 204 | 2171 | 392 | 553 | 1567 | 241 |
| 1999 | 1 | 158 | 47 | 14 | 2707 | 405 | 26 | 2067 | 492 | 128 | 1284 | 563 |
| 2000 | 1 | 181 | 76 | 234 | 4544 | 785 | 688 | 3457 | 551 | 654 | 1612 | 525 |
| 2001 | 0 | - | - | 82 | - | - | 20 | - | - | 268 | - | - |
| 2002 | 0 | - | - | 77 | - | - | 444 | - | - | 25 | - | - |
| 2003 | 114 | - | - | 222 | - | - | 553 | - | - | 193 | - | - |
| 2004 | 0 | - | - | 84 | - | - | 64 | - | - | 17 | - | - |
| 2005 | 0 | - | - | 85 | - | - | 103 | - | - | 366 | - | - |
| 2006 | 0 | - | - | 54 | - | - | 248 | - | - | 101 | - | - |
| 2007 | 2 | - | - | 505 | - | - | 478 | - | - | 443 | - | - |
| 2008 | 2 | - | - | 127 | - | - | 349 | - | - | 58 | - | - |
| 2009 | 2 | 27 | 105 | 125 | 2022 | 2289 | 1258 | 2115 | 1144 | 127 | 1811 | 717 |
| 2010 | 0 | 60 | 69 | 64 | 3392 | 1880 | 83 | 1836 | 1418 | 146 | 1077 | 1393 |
| 2011 | 1 | 118 | 113 | 22 | 2058 | 1581 | 126 | 1709 | 712 | 533 | 2516 | 887 |
| 2012 | 2 | 258 | 48 | 203 | 2611 | 1022 | 35 | 1997 | 561 | 87 | 1591 | 492 |
| 2013 | 39 | 119 | 39 | 392 | 2735 | 779 | 138 | 2331 | 456 | 123 | 2331 | 410 |
| 2014 | 0 | 417 | 39 | 507 | 5141 | 303 | 444 | 2131 | 343 | 302 | 1613 | 279 |
| 2015 | 1 | 235 | 39 | 102 | 3996 | 366 | 172 | 2566 | 233 | 236 | 1172 | 447 |
| 2016 | 6 | 72 | 44 | 74 | 2274 | 1073 | 42 | 1463 | 403 | 11 | 1259 | 469 |
| 2017 | 0 | 26 | 13 | 39 | 1255 | 395 | 271 | 1550 | 524 | 65 | 922 | 566 |
| 2008+ | 136 | - | - | 136 | - | - | - | - | - | - | - | - |
| 2009+ | 519 | 347 | 385 | 125 | 2026 | 2294 | - | - | - | - | - | - |
| 2010+ | 17 | 321 | 146 | 64 | 3400 | 1884 | - | - | - | - | - | - |
| 2011+ | 82 | 237 | 196 | 22 | 2044 | 1571 | - | - | - | - | - | - |
| 2012+ | 78 | 442 | 144 | 206 | 2600 | 1019 | - | - | - | - | - | - |
| 2013+ | 94 | 504 | 107 | 392 | 2722 | 775 | - | - | - | - | - | - |
| 2014+ | 20 | 708 | 36 | 508 | 5109 | 303 | - | - | - | - | - | - |
| 2015+ | 39 | 345 | 33 | 102 | 3972 | 363 | - | - | - | - | - | - |
| 2016+ | 13 | 366 | 120 | 74 | 2265 | 1069 | - | - | - | - | - | - |
| 2017+ | 30 | 115 | 51 | 39 | 1256 | 395 | - | - | - | - | - | - |

+: From 2008, the sampling was increased with the addition of strata in shallow waters (37 to 183 m) in the Estuary.

# FIGURES

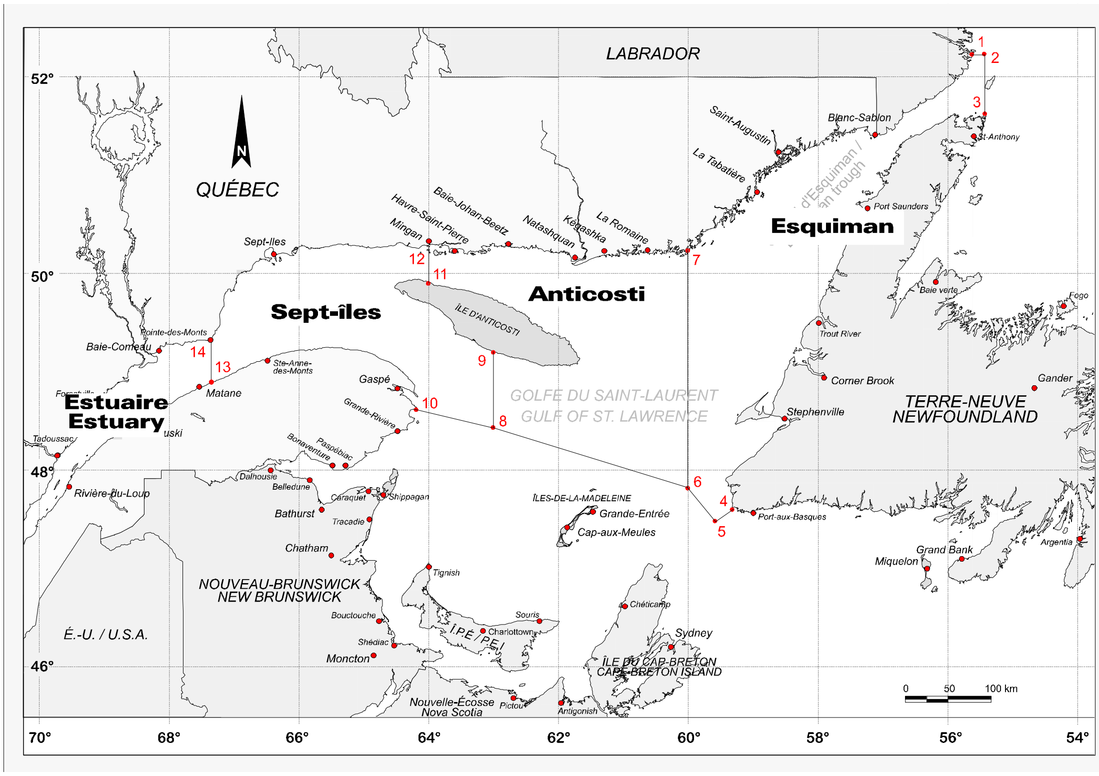



*Figure 1. Shrimp fishing areas (SFA) in the northern Gulf of St. Lawrence: Estuary (SFA 12); Sept-Iles (SFA 10); Anticosti (SFA 9); Esquiman (SFA 8).*

| | PRINTEMPS / SPRING | | ÉTÉ / SUMMER | | | AUTOMNE / FALL | | | HIVER / WINTER | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | M | J | J | A | S | O | N | D | J | F | M |
| **Age** | | | | | | | | | | | | |
| **0** | **ÉCLOSION / HATCHING** | | **Larves / Larvae** | | | **Post-larves / Post-larvae** | | | | | | |
| **1** | **Juvéniles / Juveniles** | | | | | | | | | | | |
| **2** | **Mâles / Males** | | | | | **REPRODUCTION** | | **Mâles / Males** | | | | |
| **3** | **Mâles / Males** | | | | | **REPRODUCTION** | | **Mâles / Males** | | | | |
| **4** | **Mâles / Males** | | | | | **REPRODUCTION** | | | **CHANGEMENT DE SEXE / SEX CHANGE** | | | |
| **5** | **Femelles primipares / Primiparous females** | | | | | **PONTE / SPAWNING** | | **Femelles oeuvées / Berried females** | | | | |
| **6** | **ÉCLOSION / HATCHING** | | **Femelles multipares / Multiparous females** | | | **PONTE / SPAWNING** | | **Femelles oeuvées / Berried females** | | | | |
| **7** | **ÉCLOSION / HATCHING** | | | | | | | | | | | |

*Figure 2. Life cycle of northern shrimp in the Gulf of St. Lawrence.*

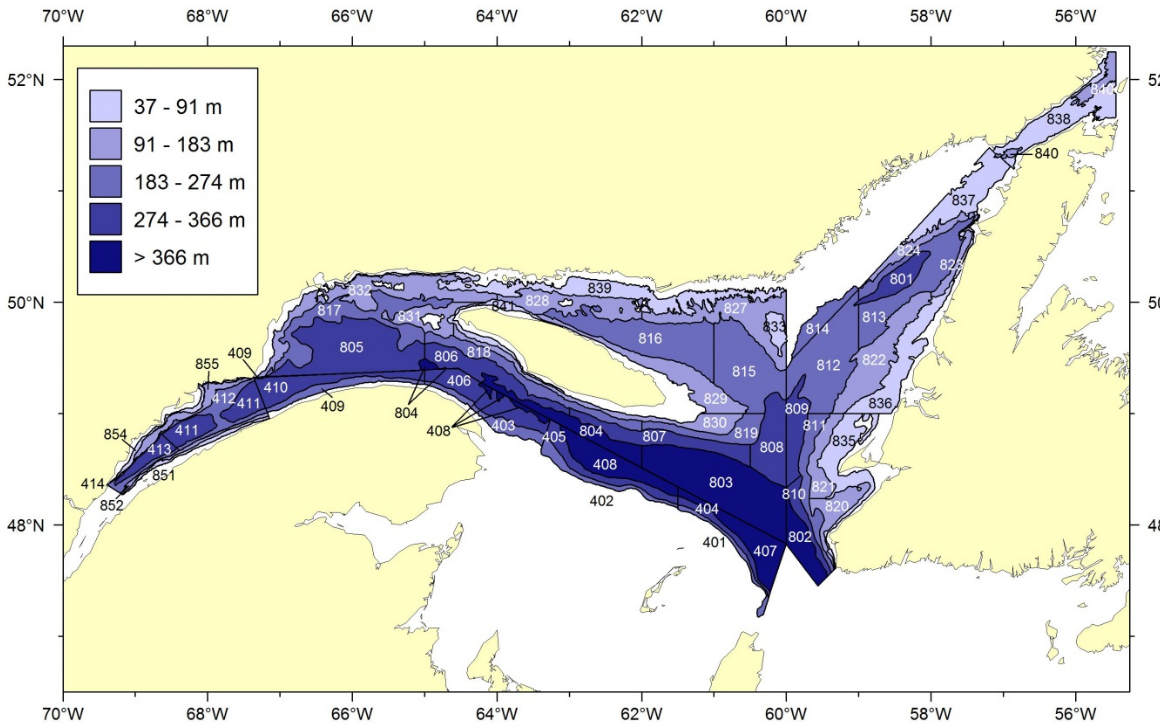



*Figure 3. Stratification used for the allocation of fishing stations of the survey in the northern Gulf of St. Lawrence. The strata 851, 852, 854 and 855 were added in 2008.*

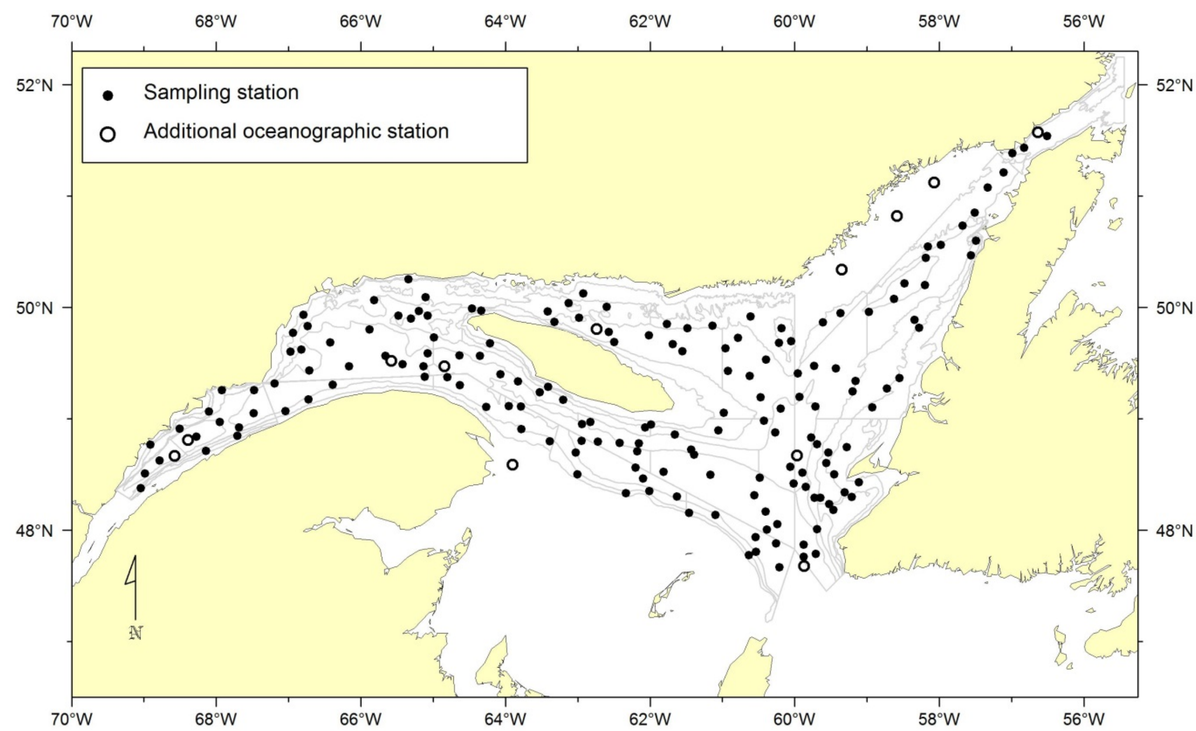



*Figure 4. Locations of successful sampling stations (trawl and oceanography) and additional oceanographic stations for the 2017 survey.*

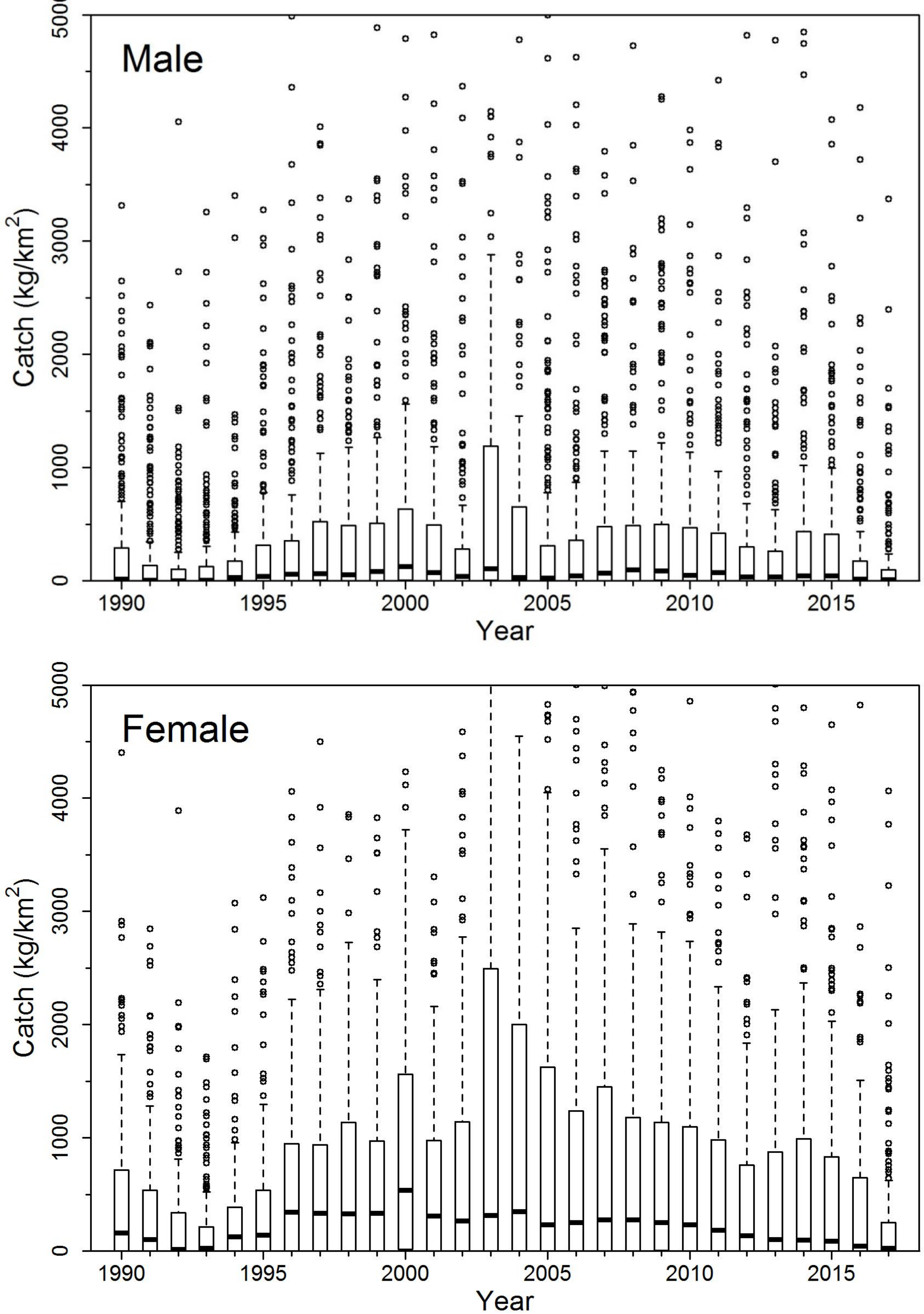



*Figure 5. Boxplot of male and female shrimp catches (kg/km²) obtained from the surveys conducted from 1990 to 2017.*

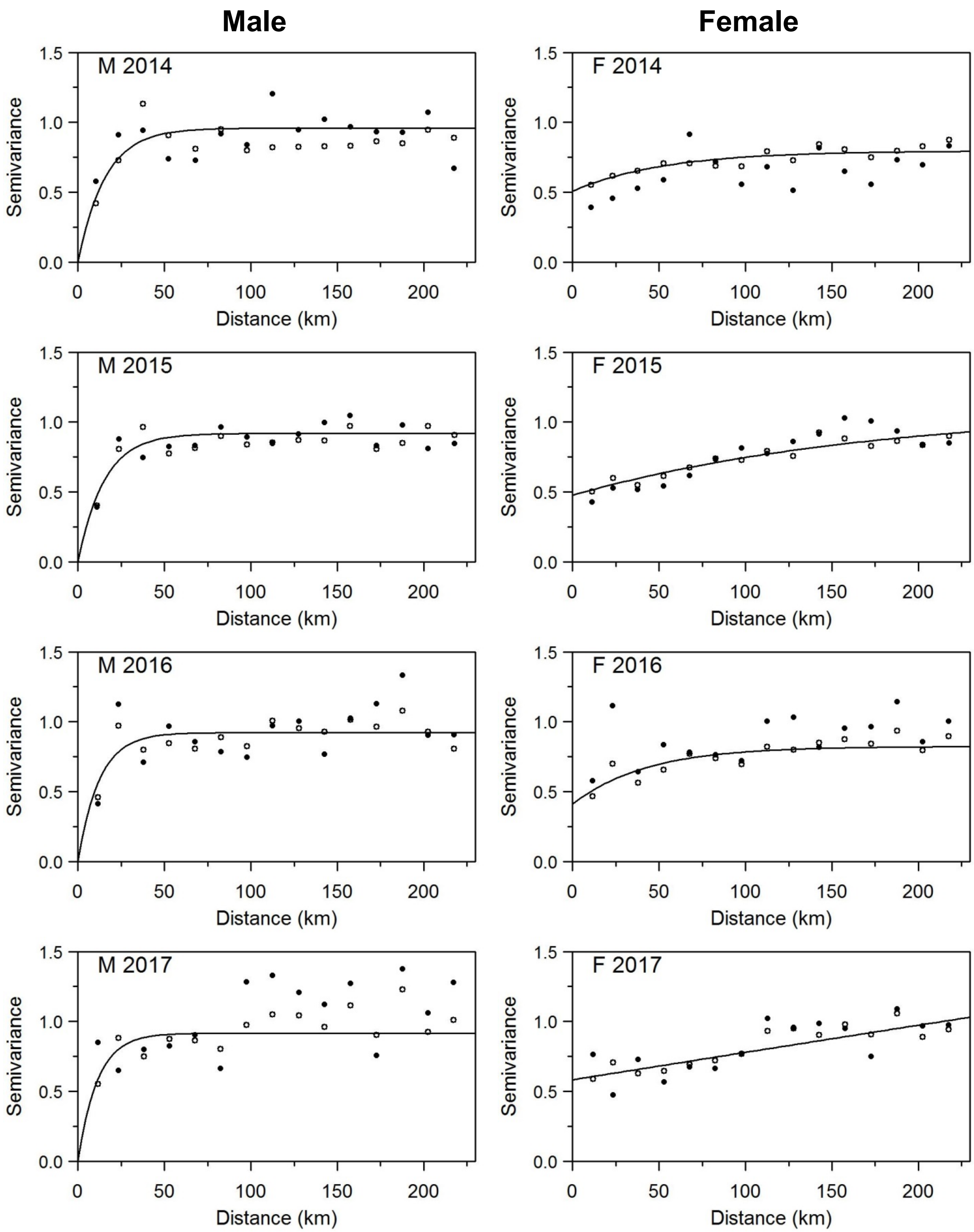



*Figure 6. Isotropic variograms of the biomasses (kg/km²) for the years 2014 to 2017. Filled circles: current year. Open circles: mean over three years. Curve: variogram adjusted on the 3 year mean.*

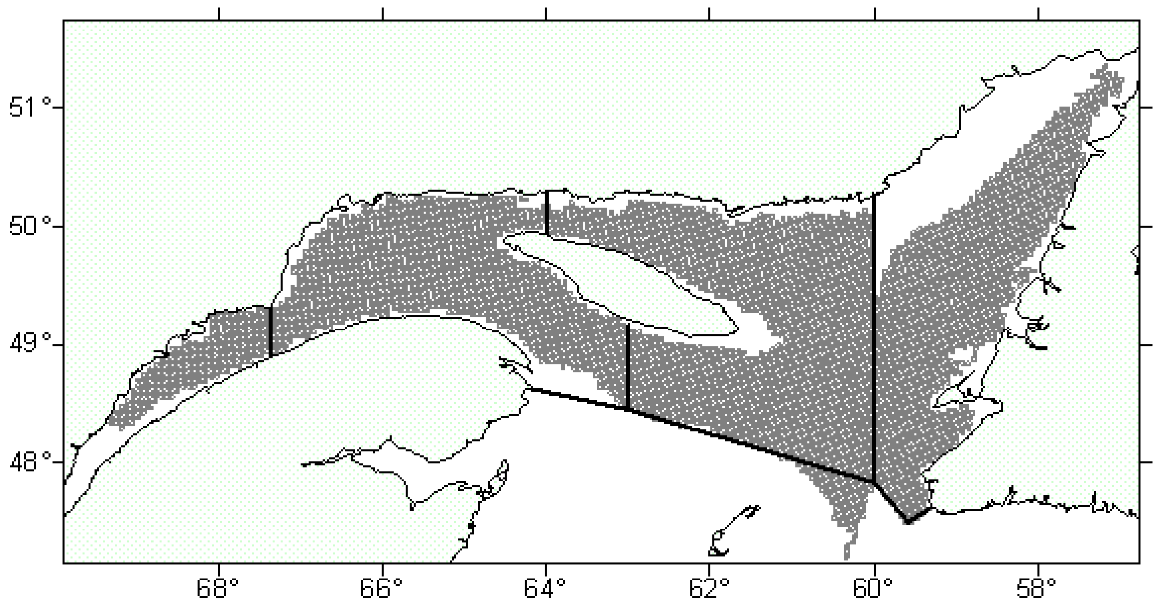



*Figure 7. Studied area for the kriging of the shrimp biomass in the northern Gulf of St. Lawrence. The limits of the fishing areas are indicated as well.*

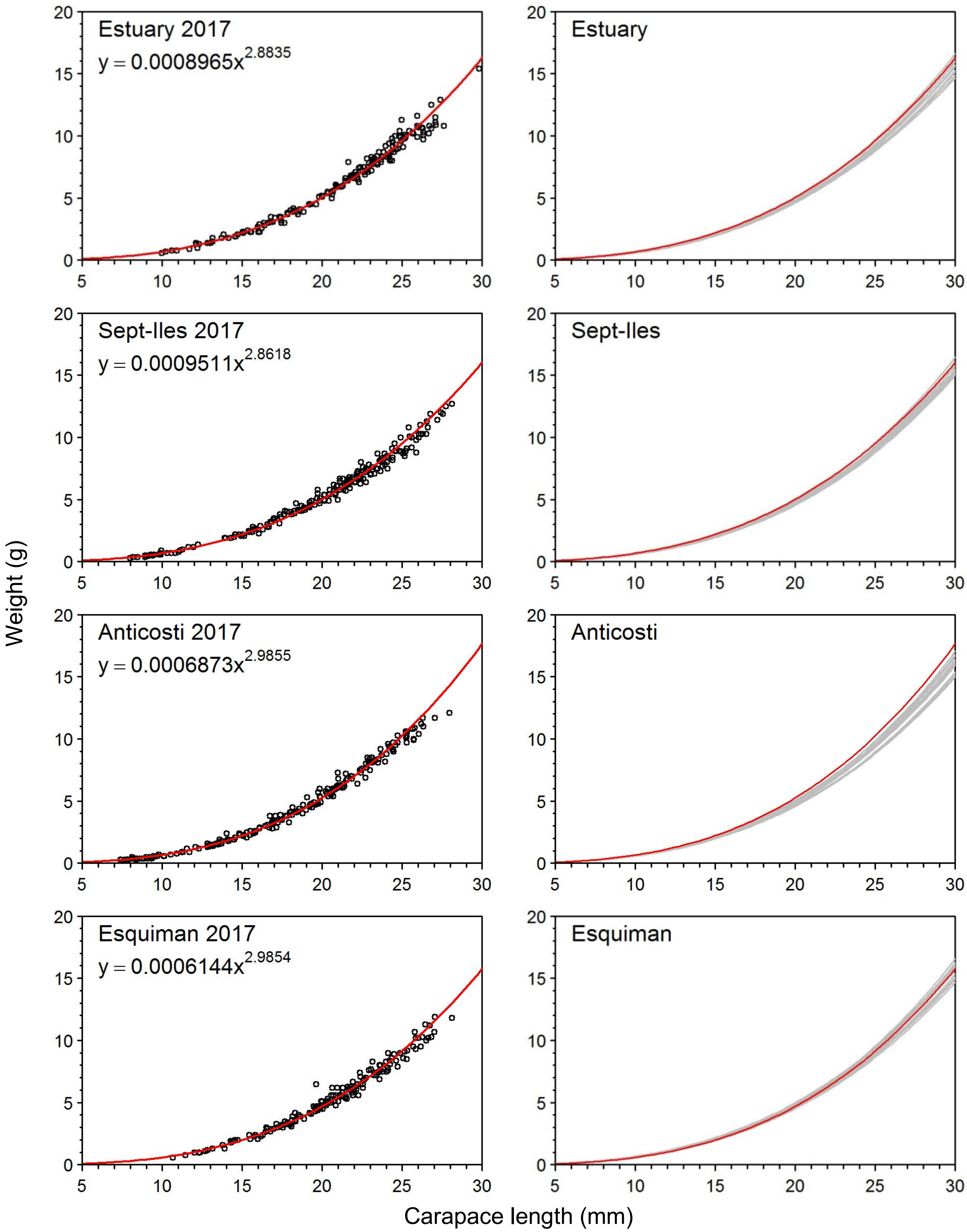



*Figure 8. Weight-length relationships by fishing area. The left panels represent the data for 2017 and in the right panels, the red line represents 2017 and the gray lines 1993 and 2005 to 2016.*

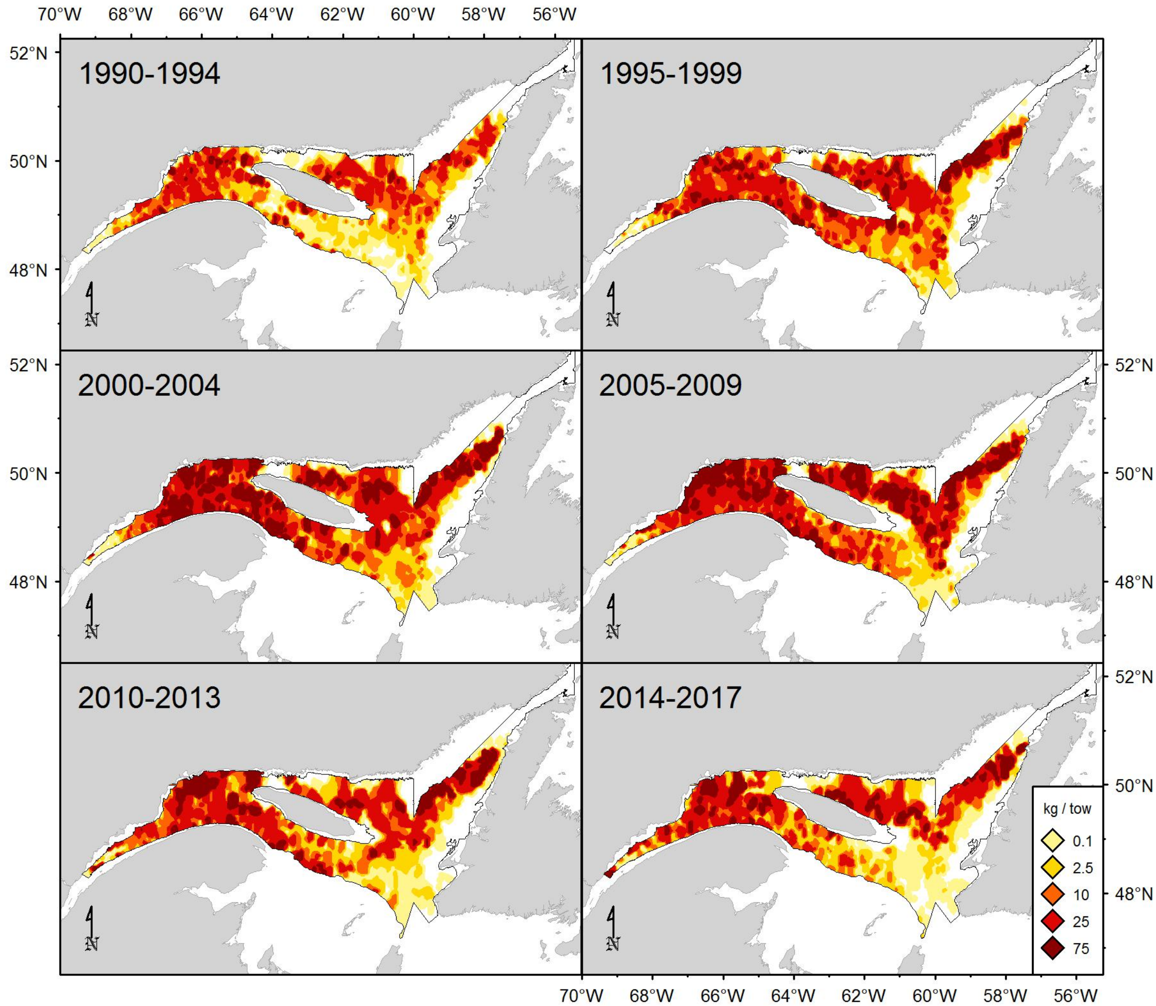



*Figure 9. Northern shrimp catch rates (kg/15 minutes tow) distribution.*

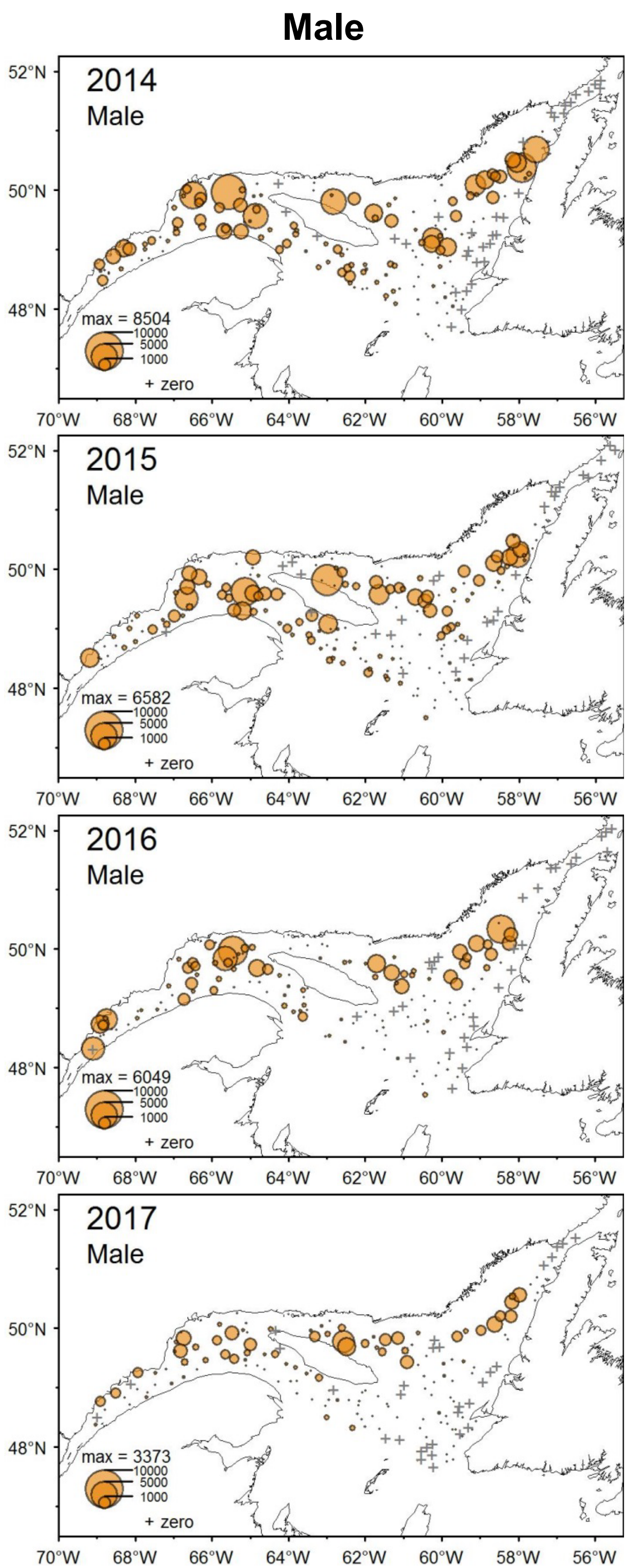



*Figure 10. Northern shrimp catch rates (kg/15 minutes tow) distribution for male and female from 2014 to 2017.*

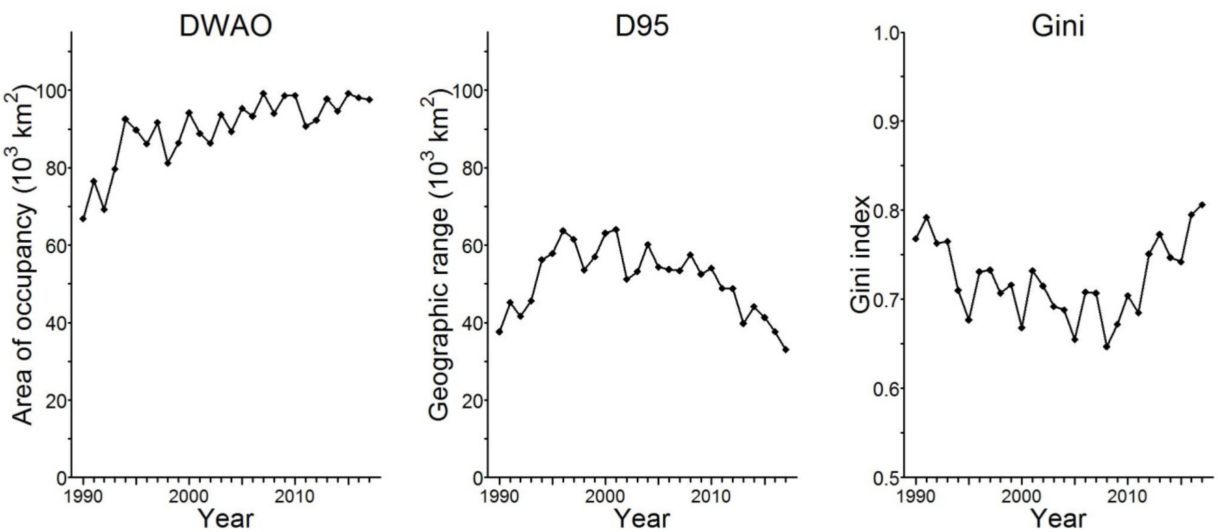
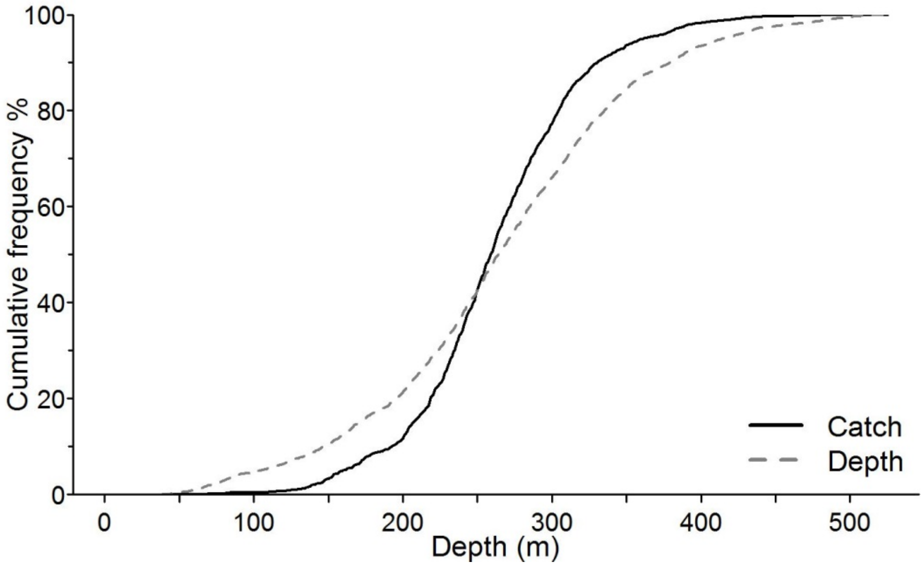
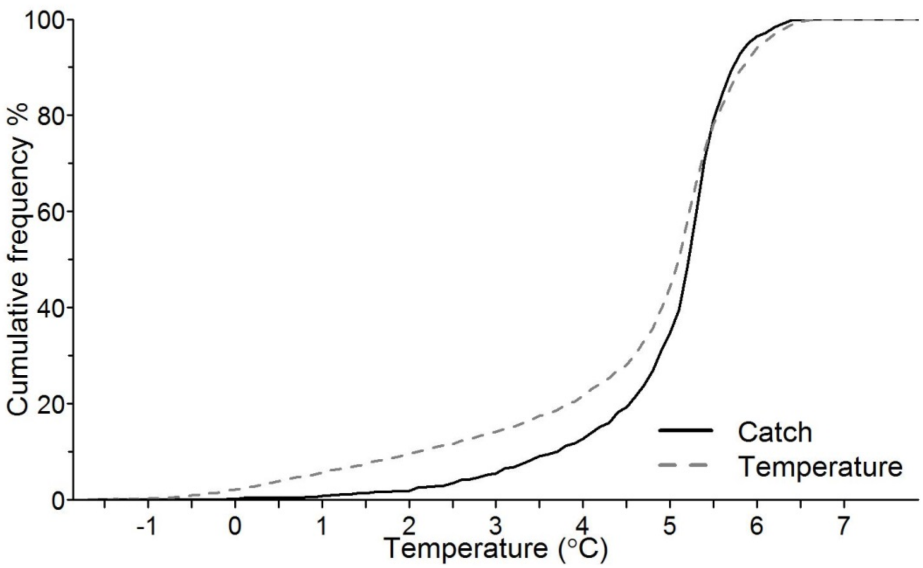



*Figure 11. Spatial distribution indices: 1) DWAO, design-weighted area of occupation; 2) D95, minimum area containing 95% of individuals; and 3) Gini's index. The total area of the study zone is of 116,115 km$^2$.*




| Centile | Depth (m) |
|---|---|
| 5 | 160 |
| 10 | 193 |
| 25 | 228 |
| 50 | 259 |
| 75 | 296 |
| 90 | 331 |
| 95 | 361 |

*Figure 12. Cumulative relative frequency distribution of catches (weight per tow) and number of sampled stations as a function of depth in the DFO survey from 1990 to 2017.*




| Centile | Temp. (°C) |
|---|---|
| 5 | 2.9 |
| 10 | 3.7 |
| 25 | 4.8 |
| 50 | 5.3 |
| 75 | 5.5 |
| 90 | 5.8 |
| 95 | 6.0 |

*Figure 13. Cumulative relative frequency distribution of catches (weight per tow) and number of sampled stations as a function of temperature in the DFO survey from 1990 to 2017.*

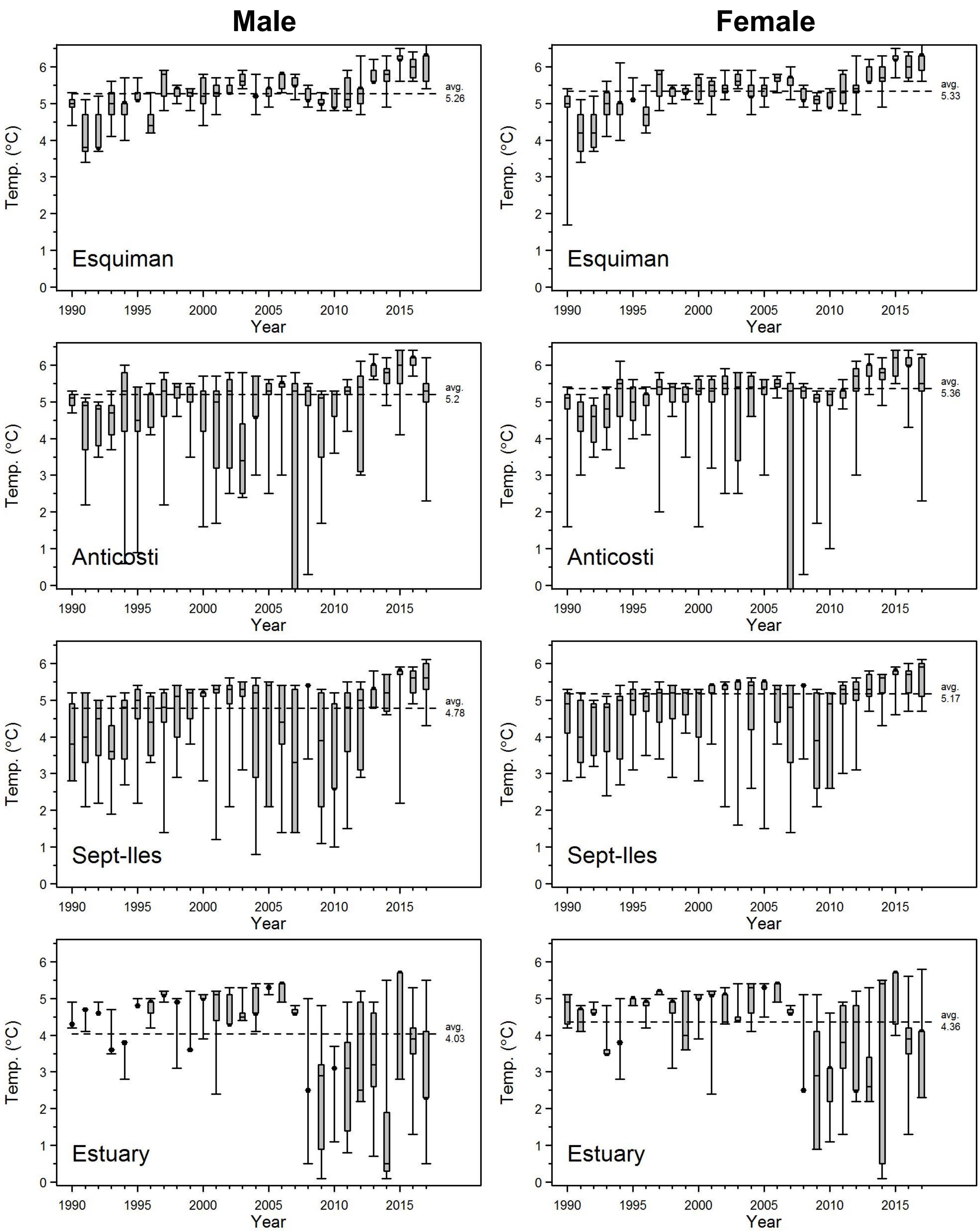



*Figure 14. Northern shrimp catch rates (kg/15 minutes tow) distribution for male and female as function of the bottom temperature per fishing area observed in the DFO survey.*

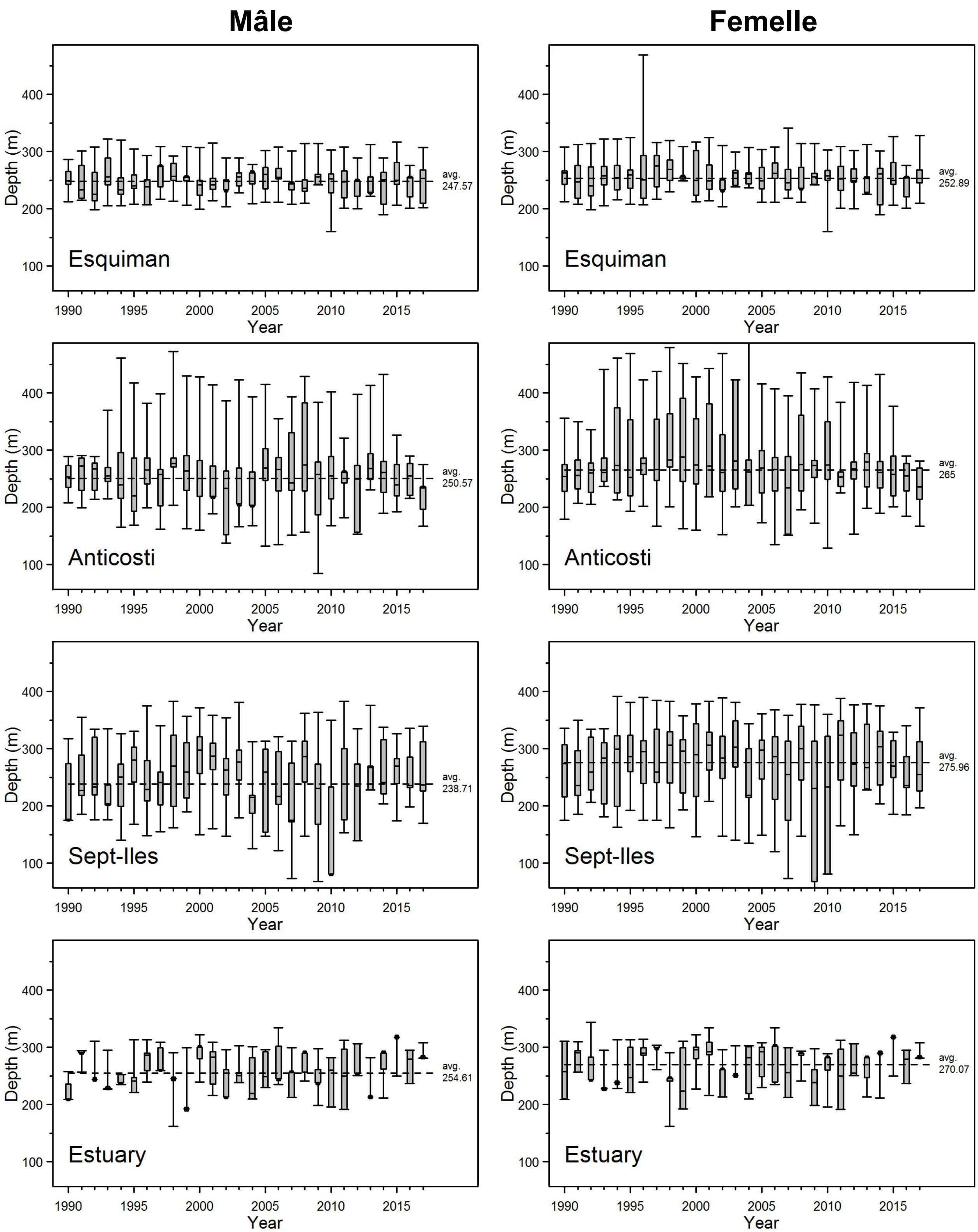



*Figure 15. Northern shrimp catch rates (kg/15 minutes tow) distribution for male and female as function of the depth per fishing area observed in the DFO survey*

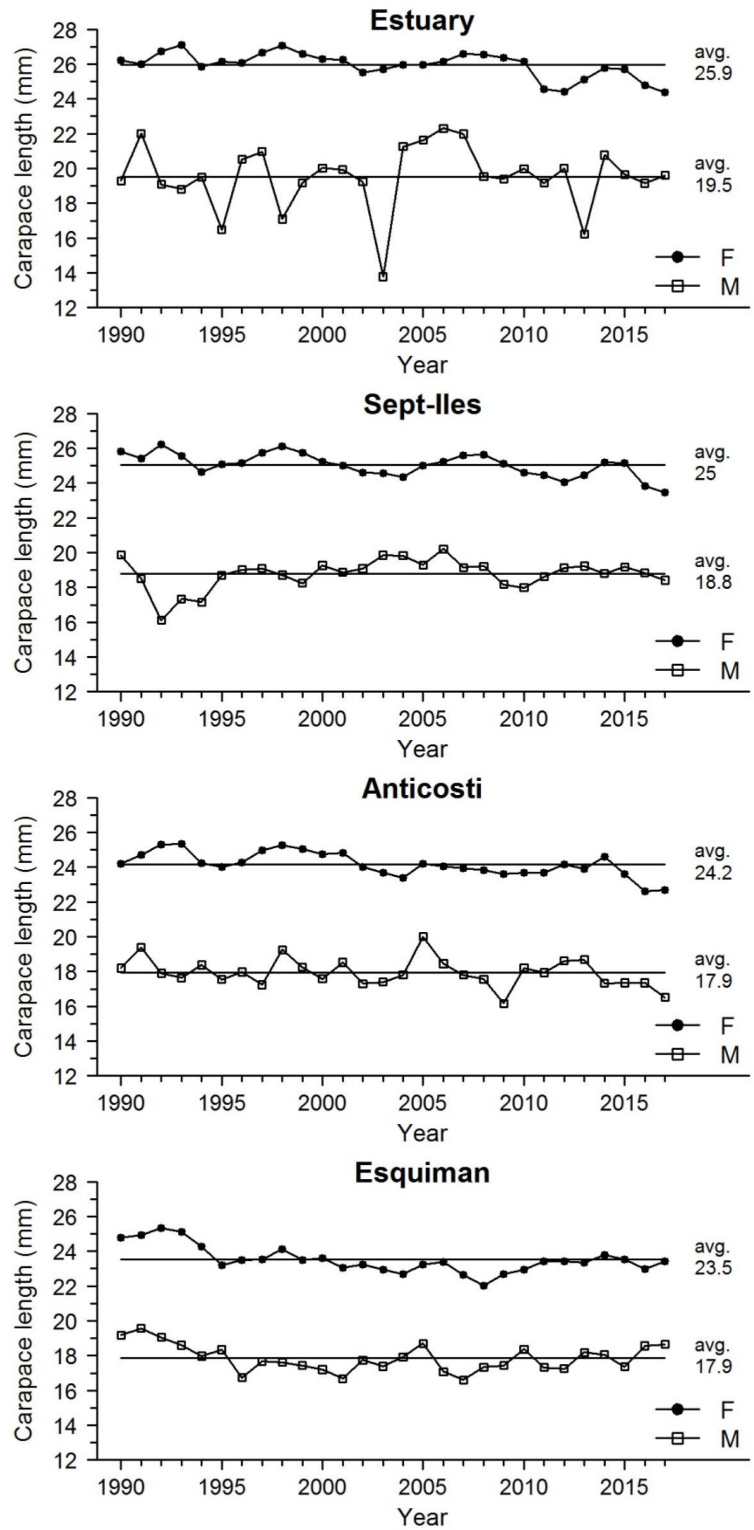



*Figure 16. Mean carapace length of male and female shrimp by fishing area in the DFO survey.*

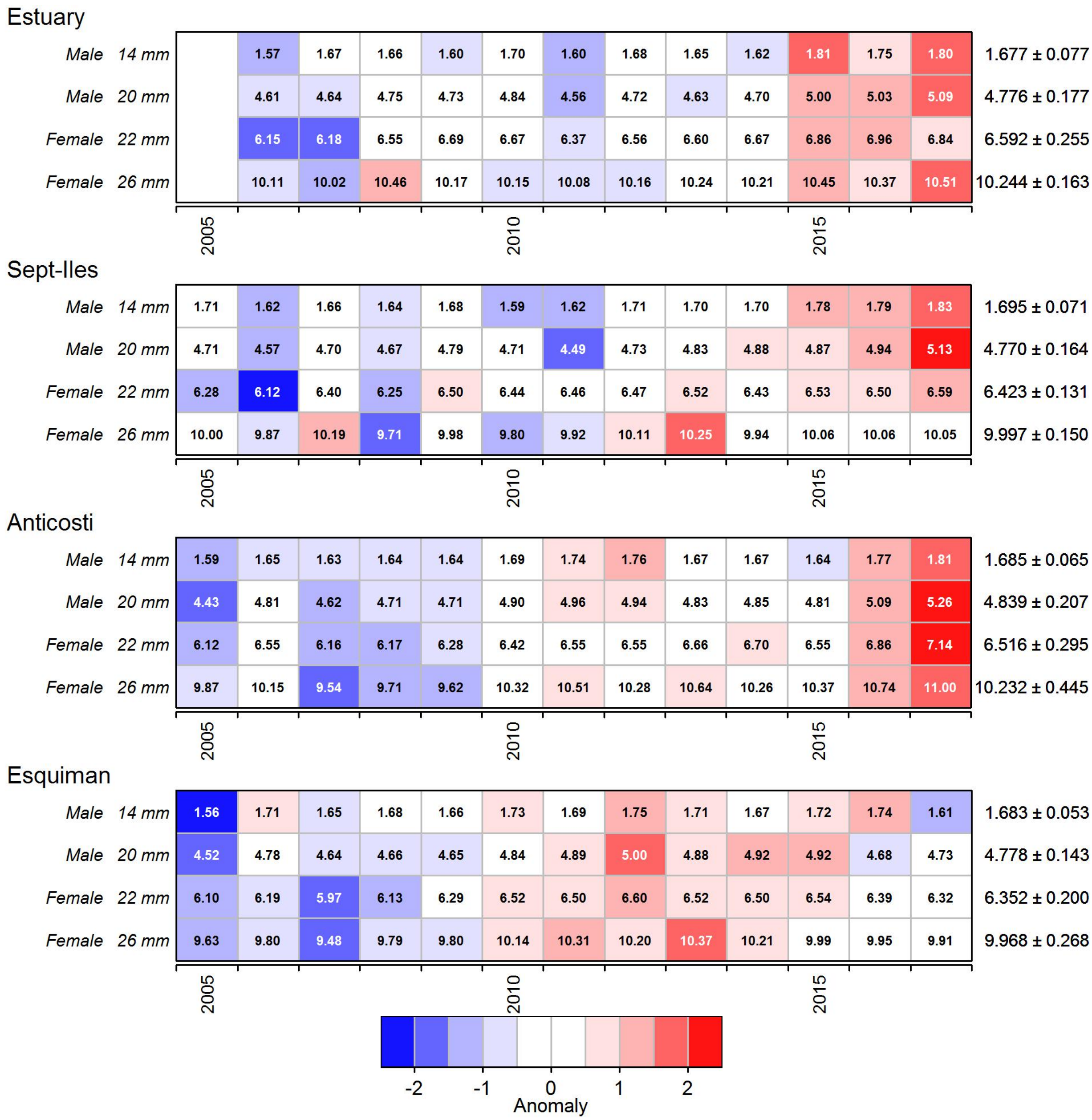



*Figure 17. Weights of male (14 and 22 mm) and female (22 and 26 mm) shrimp observed during the DFO survey in August. The color code represents the value of the anomaly, which is the difference between the weight of a shrimp and the average of the time series divided by the standard deviation of that average for each category.*

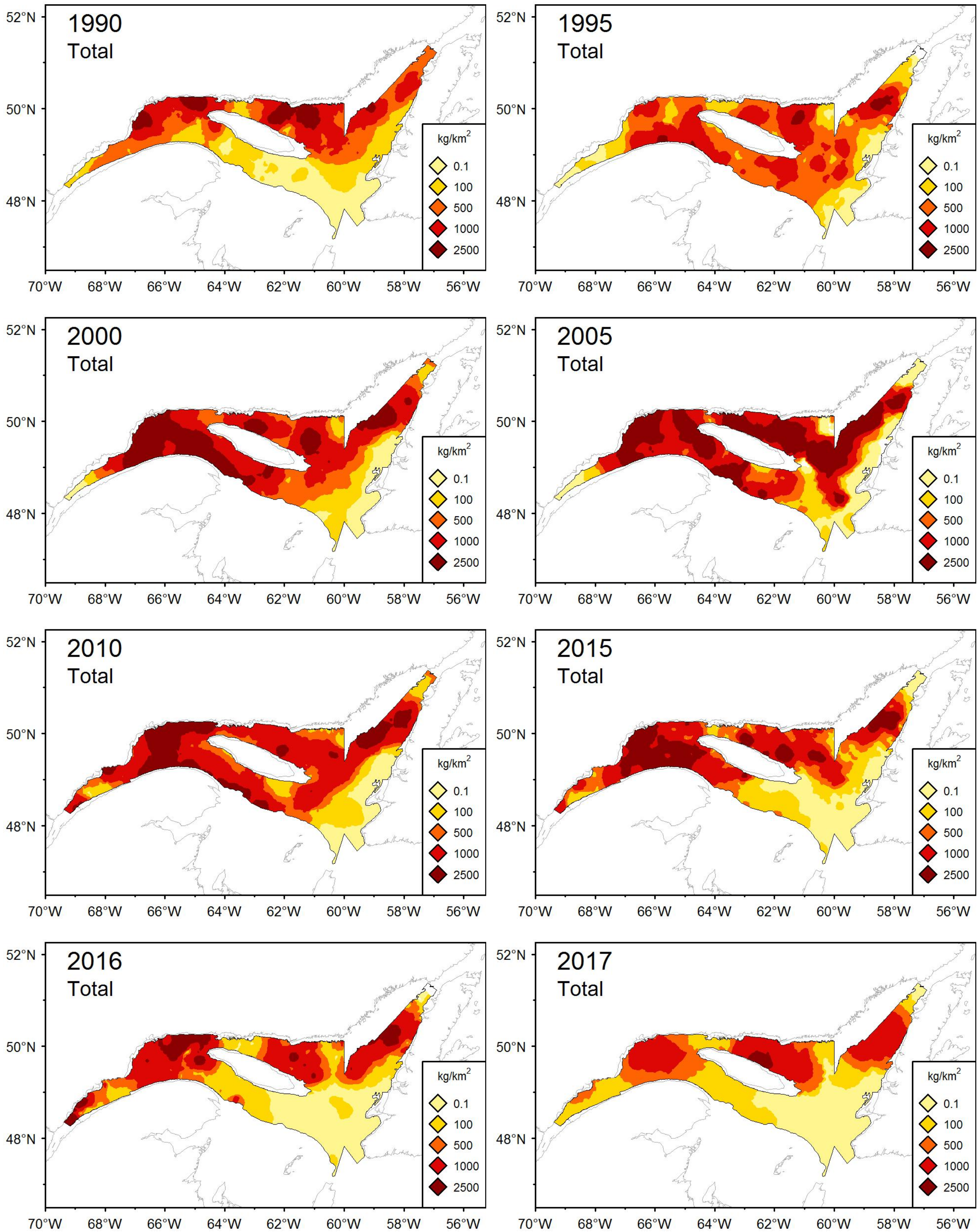



*Figure 18. Distribution of the biomass (kg/km²) obtained by kriging for years 1990, 1995, 2000, 2005, 2010 and from 2015 to 2017.*

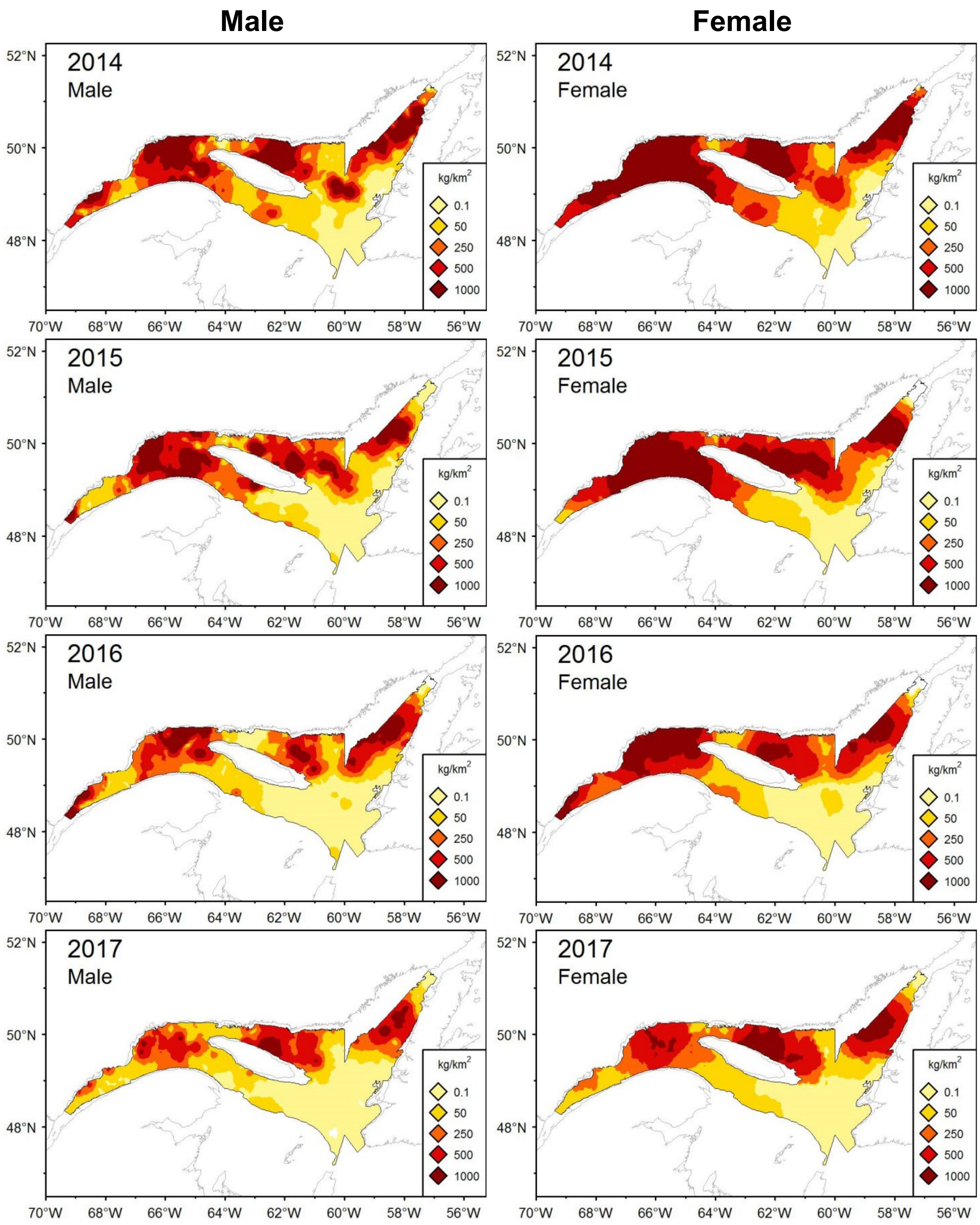



*Figure 19. Distribution of the biomass (kg/km²) obtained by kriging from 2014 to 2017 for males and females.*

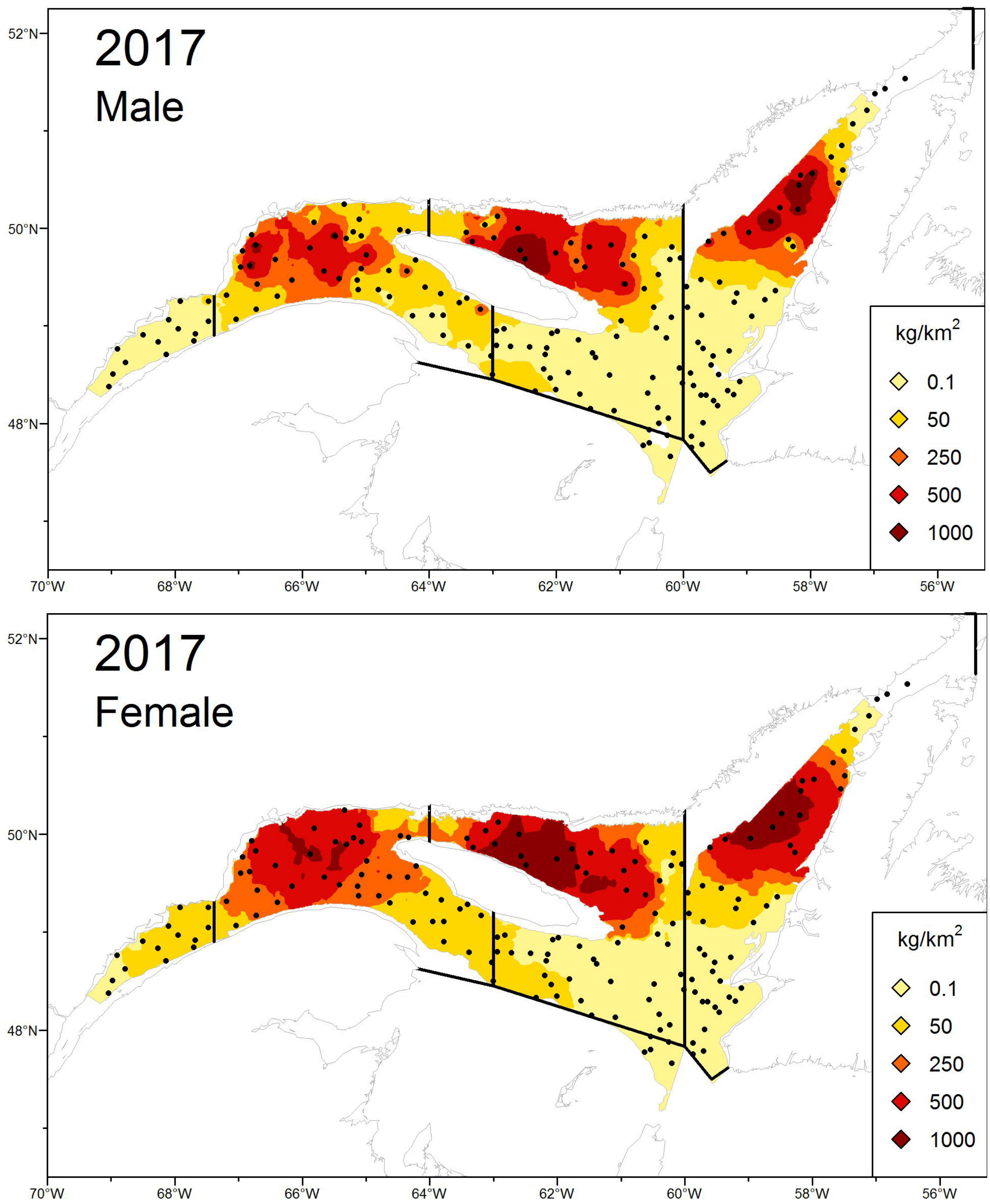



*Figure 20. Distribution of the biomass (kg/km²) obtained by kriging in 2017 for males and females. The dots represent the sampled tows.*

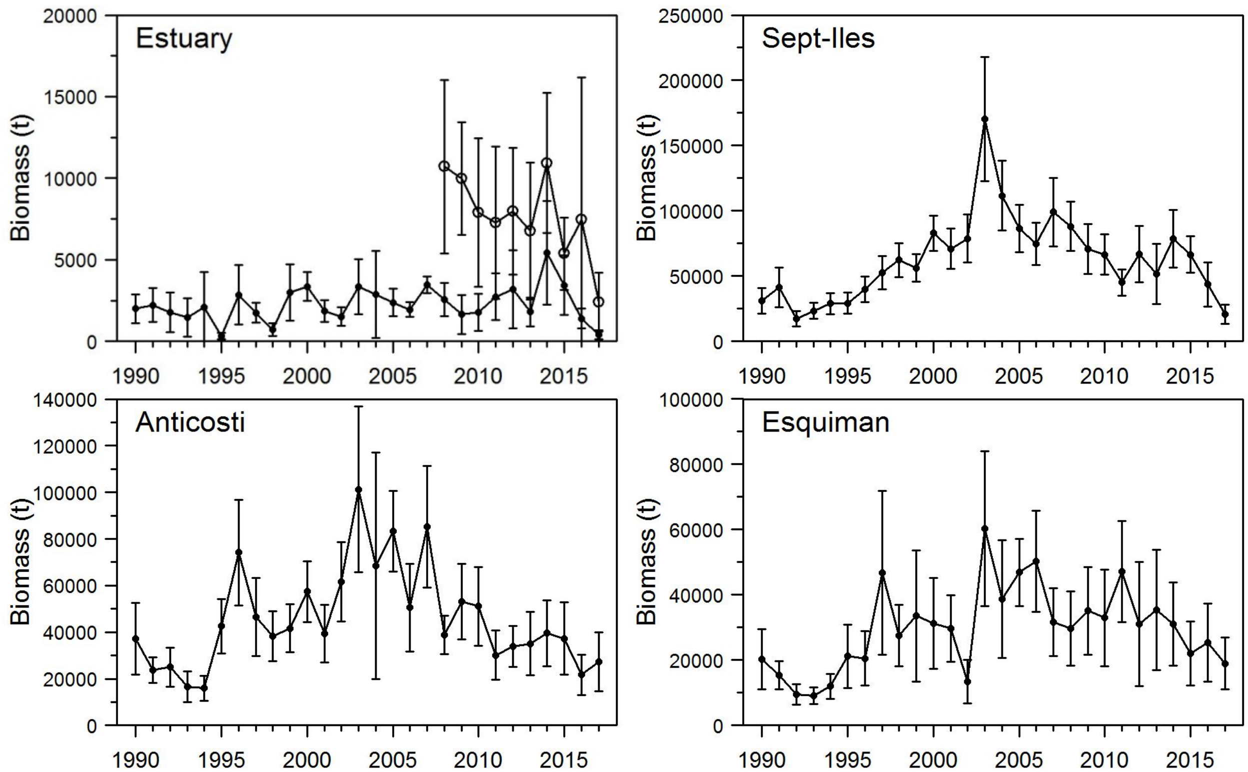



*Figure 21. Biomass (in ton) by fishing area and by year. The open circles from 2008 to 2017 show the results obtained when adding strata in shallow waters (37-183 m) of the estuary. Error bars indicate the 95% confidence interval.*

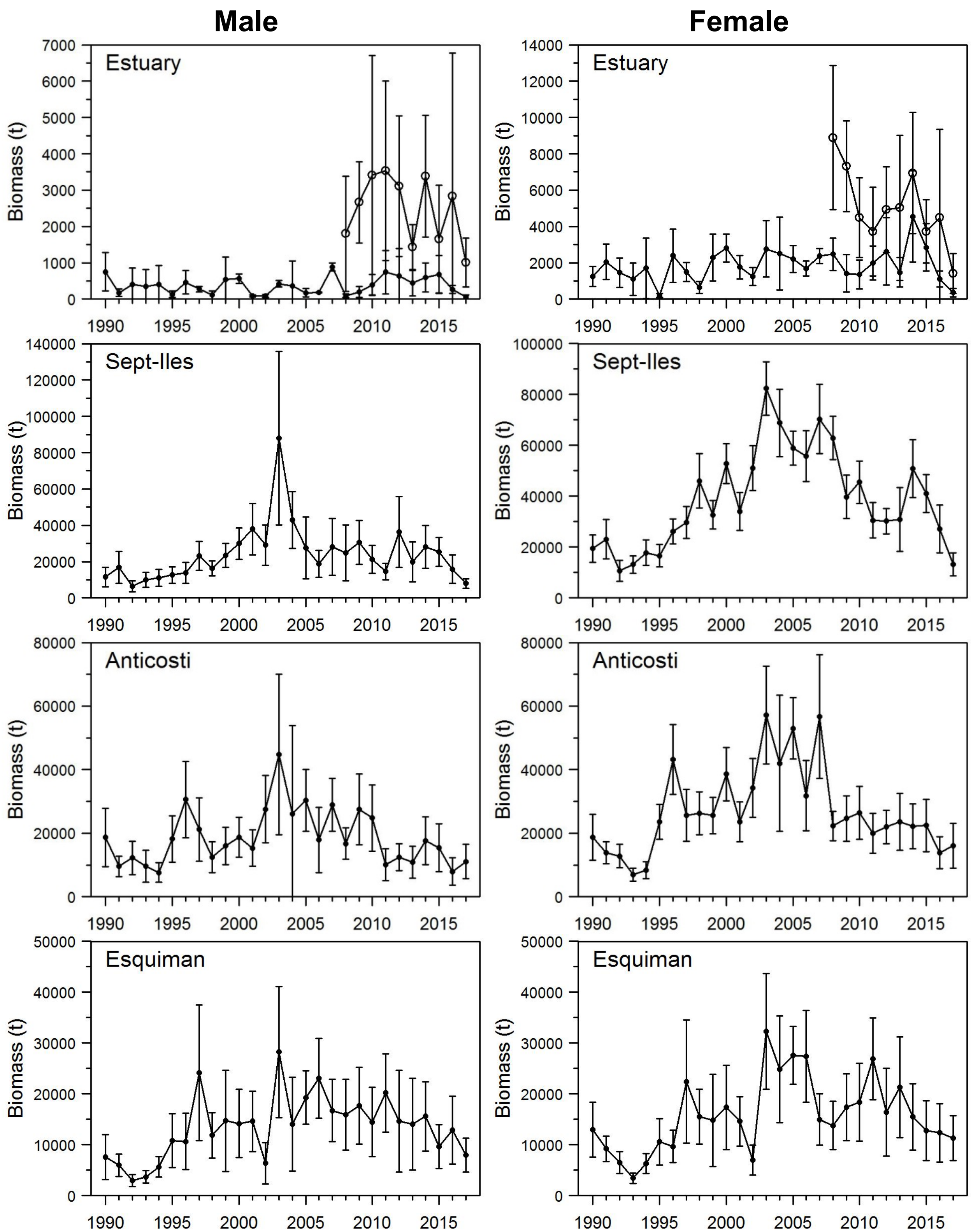



*Figure 22. Biomass (in ton) by fishing area and by year, for males and females. The open circles from 2008 to 2017 show the results obtained when adding strata in shallow waters (37-183 m) of the estuary. Error bars indicate the 95% confidence interval.*

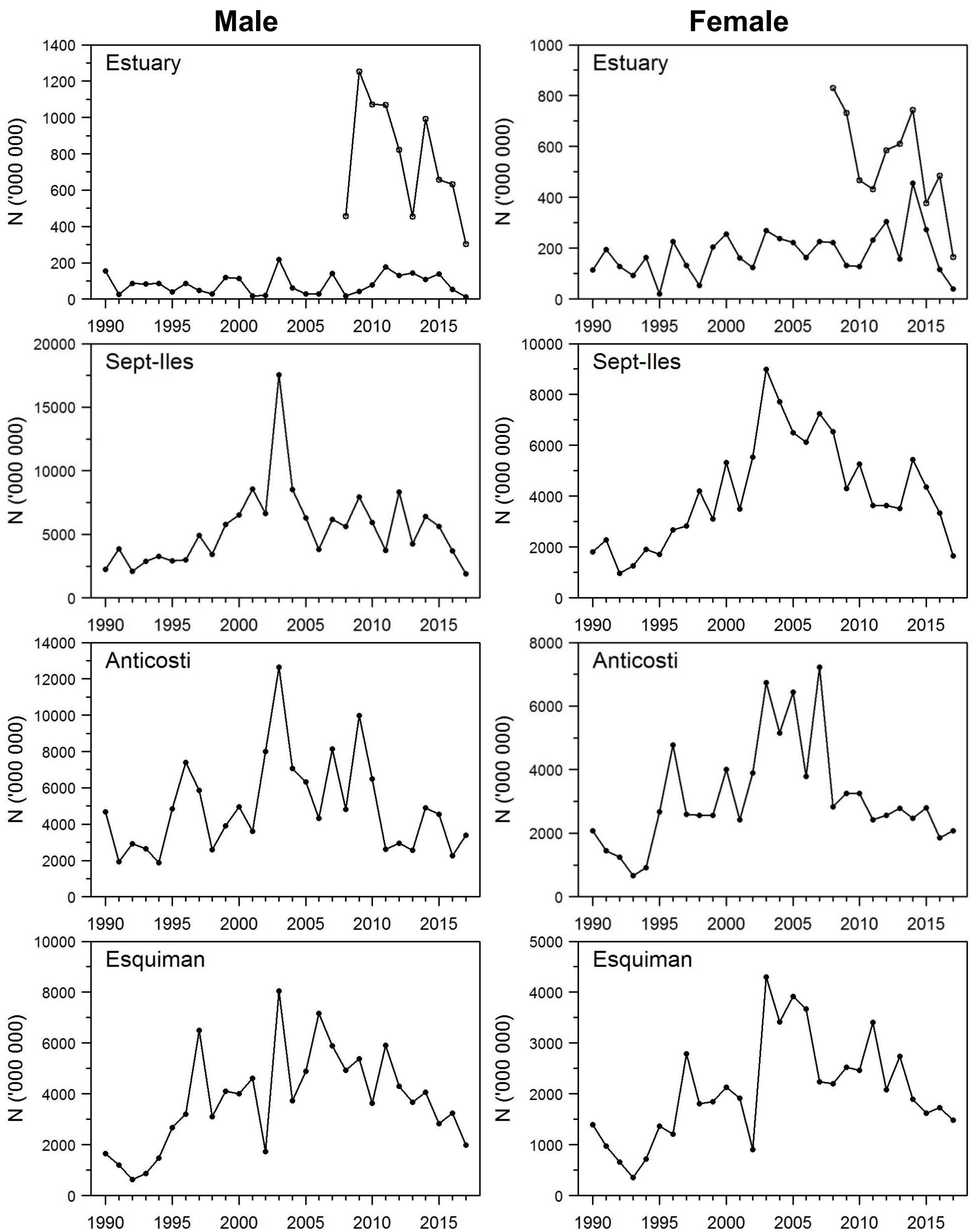



*Figure 23. Abundance (in million) by fishing area and by year, for males and females. The open circles from 2008 to 2017 show the results obtained when adding strata in shallow waters (37-183 m) of the estuary.*

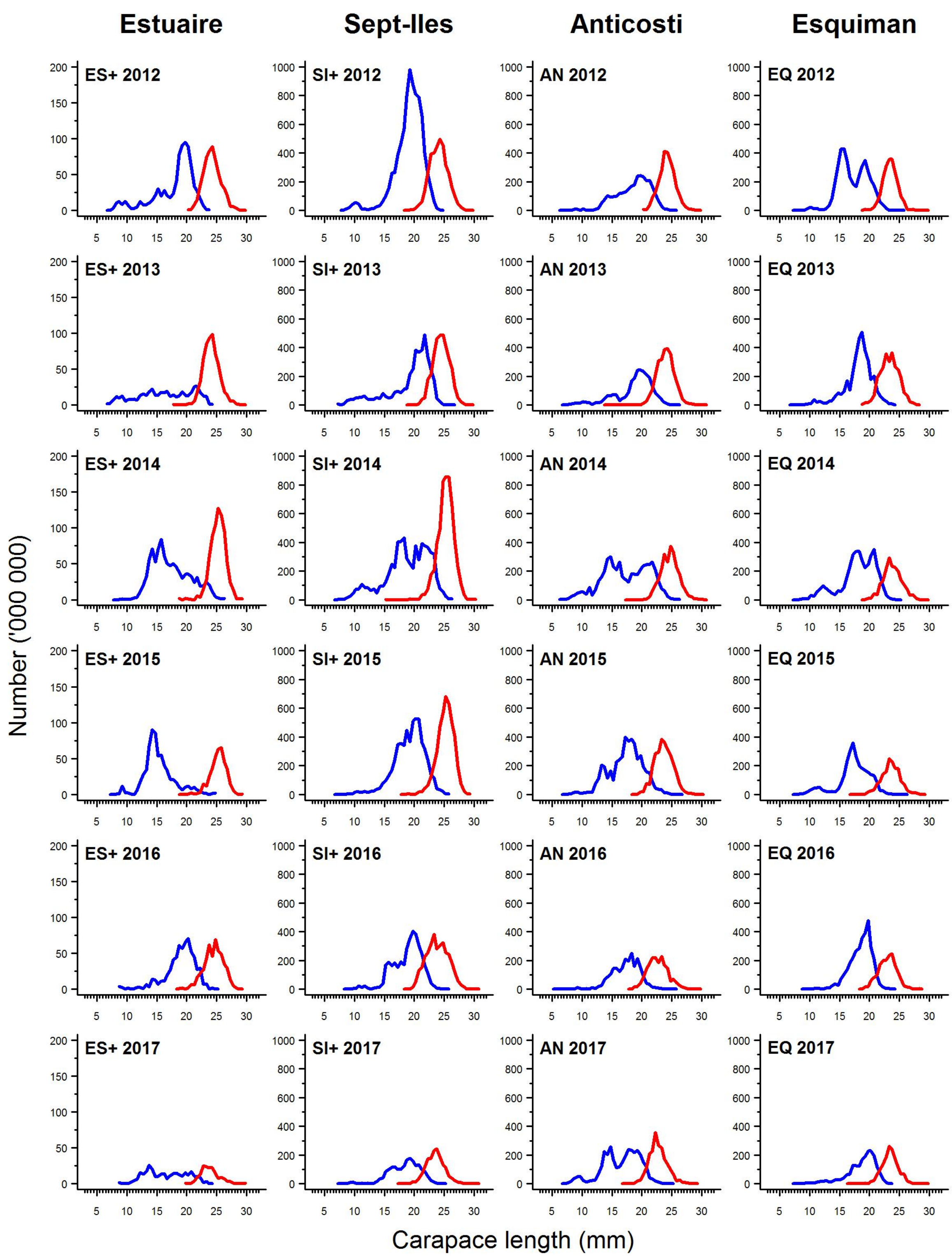



*Figure 24. Abundance (in million) by carapace length class (classes of 0.5 mm) by fishing area from 2012 to 2017 for males (in blue) and females (in red). The + placed beside the area shows the results obtained when adding strata in shallow waters (37-183 m) of the estuary.*

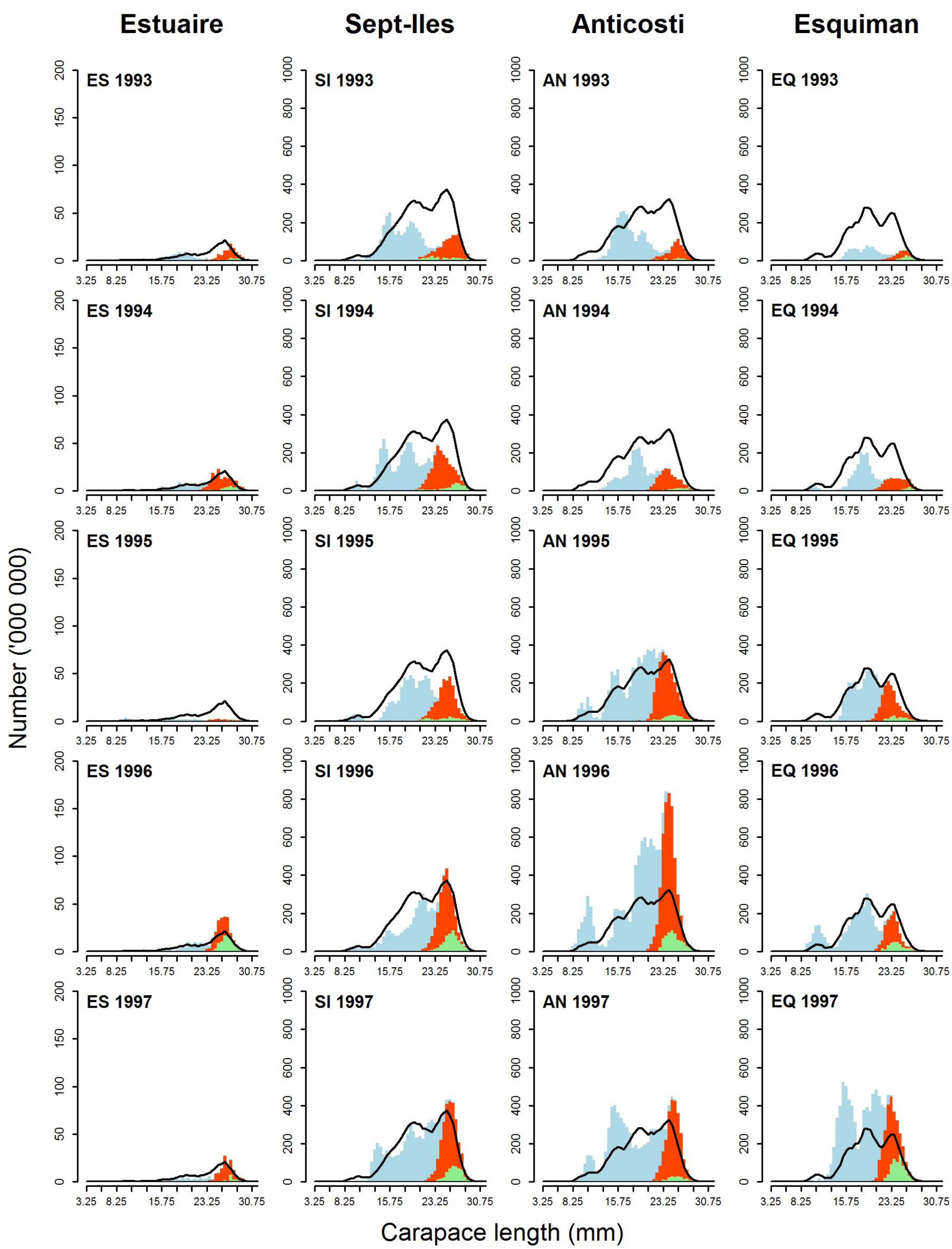



*Figure 25. Abundance (in million) by carapace length class (classes of 0.5 mm) by fishing area for males (in blue), primiparous females (in red), multiparous females (in green) and females (in pink, 2001 to 2008 period). The straight line indicates the average for 1990-2016 or 2008-2016 if a + is placed beside the area. The + placed beside the area shows the results obtained when adding strata in shallow waters (37-183 m) of the estuary.*

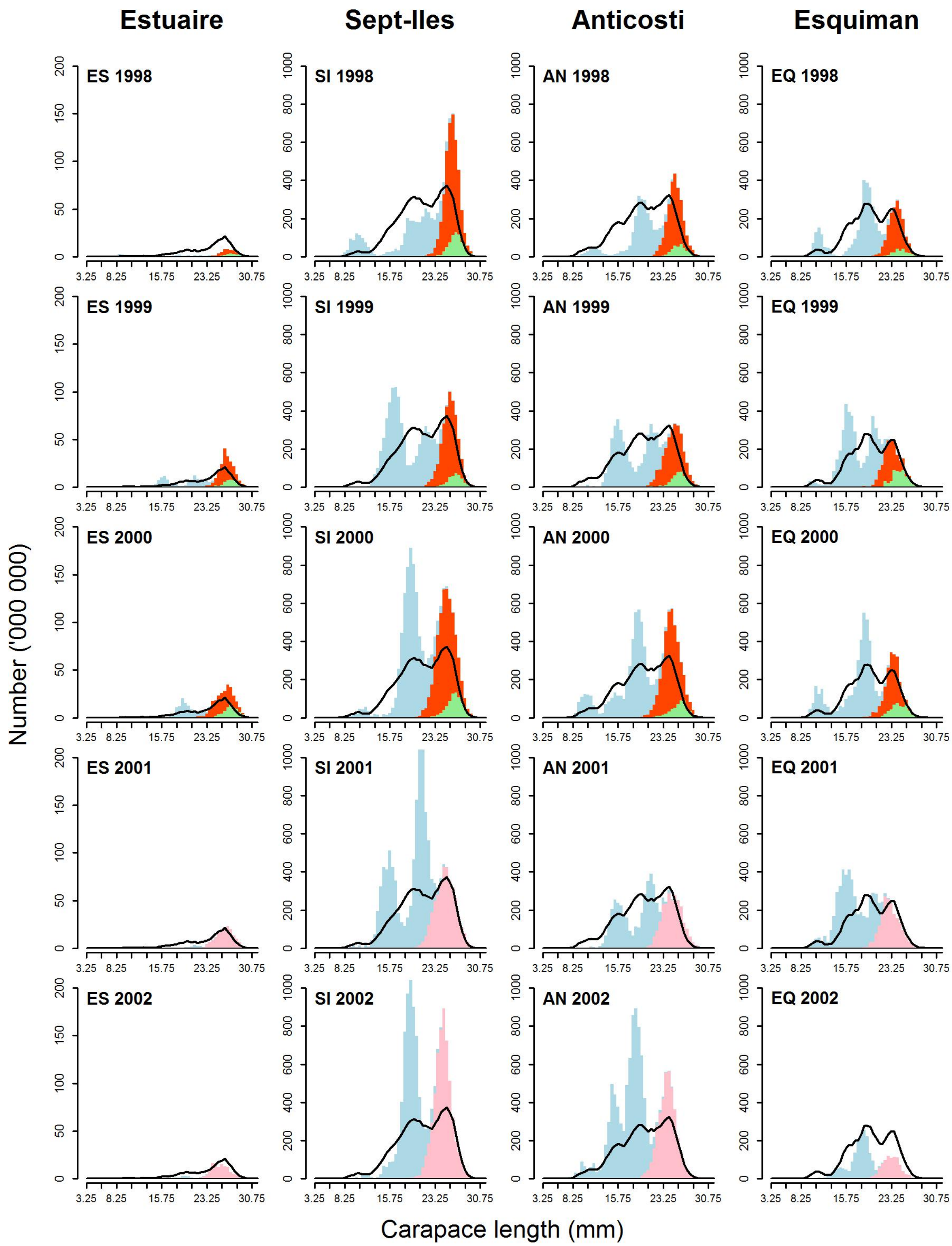



*Figure 25. Continued.*

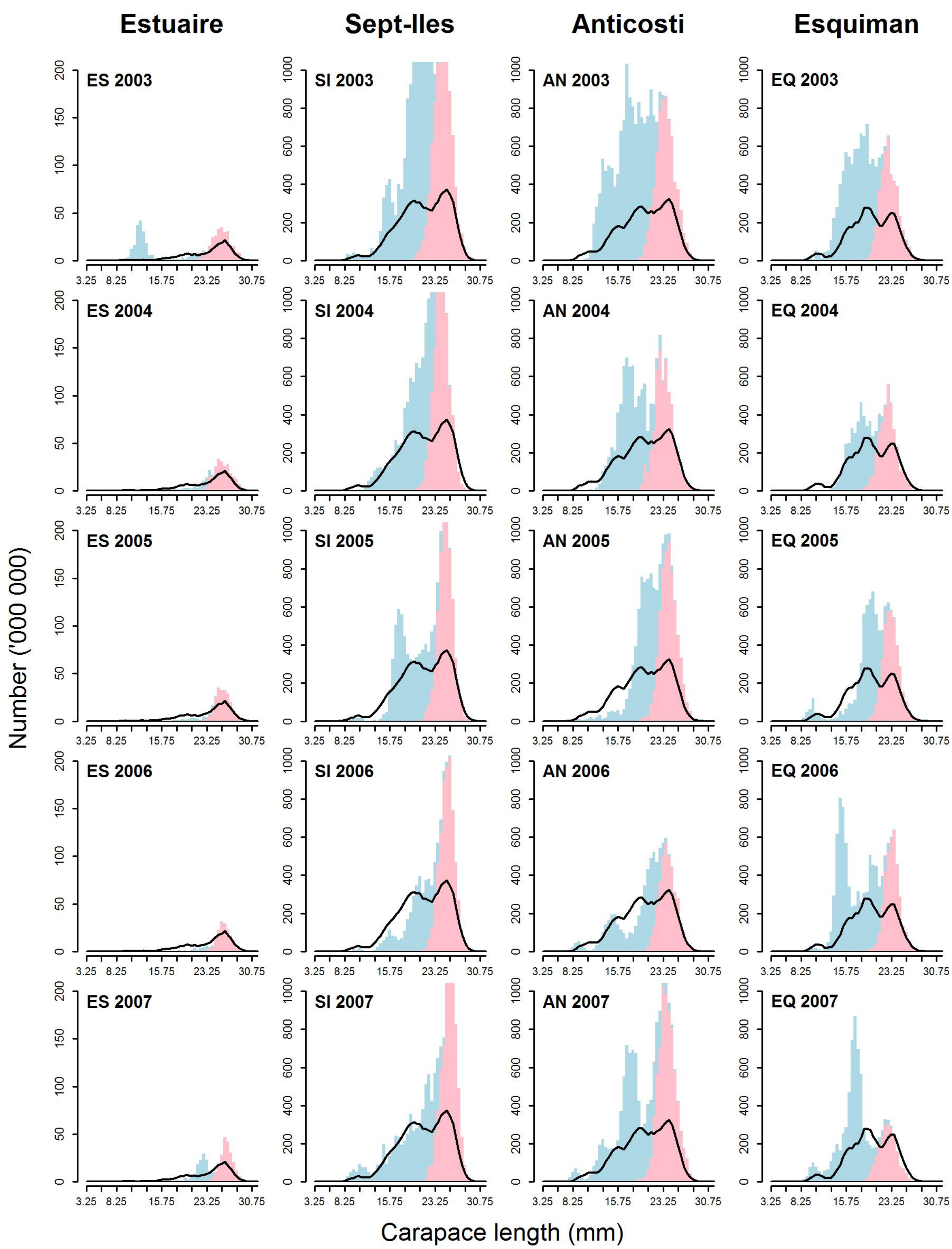



*Figure 25. Continued.*

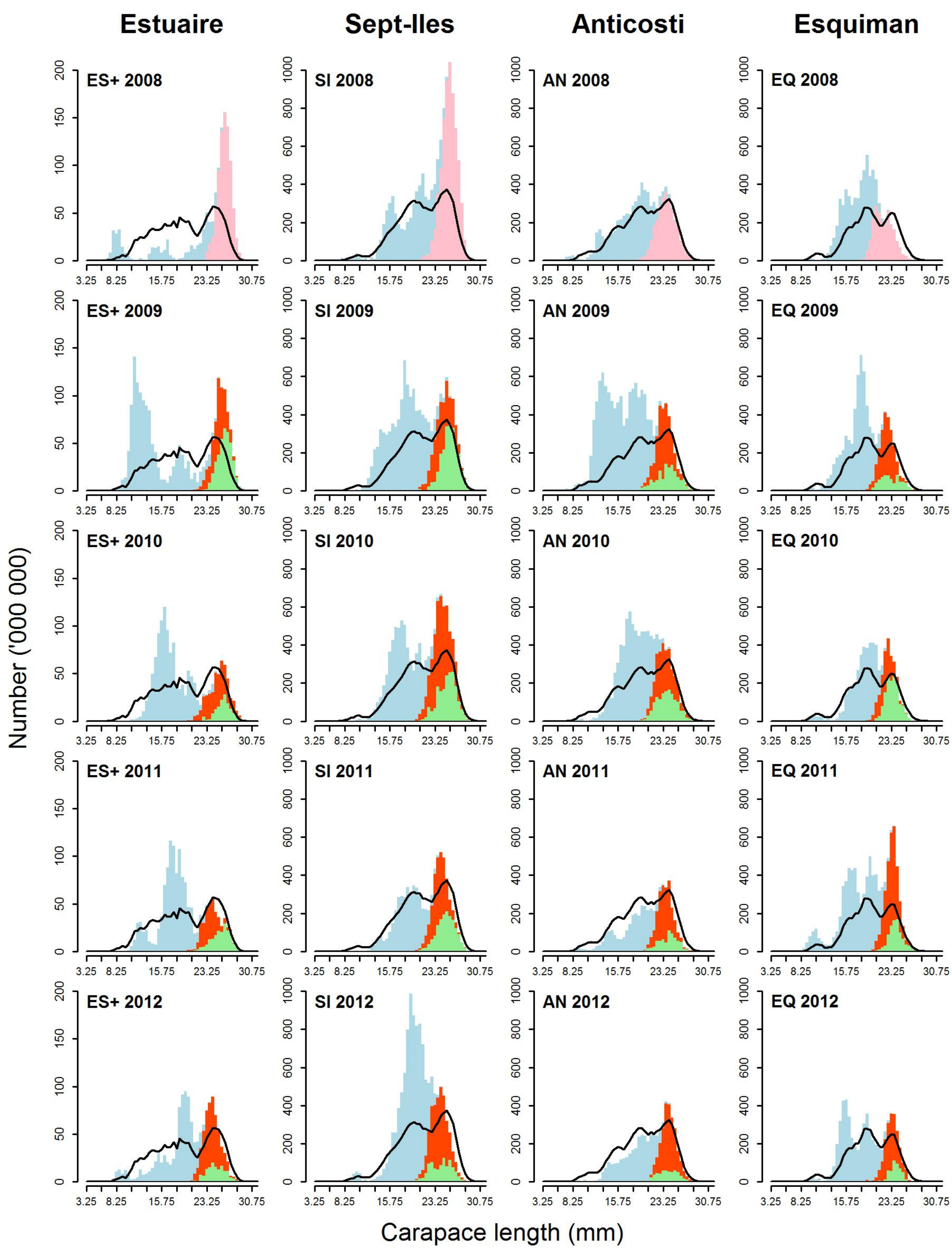



*Figure 25. Continued.*

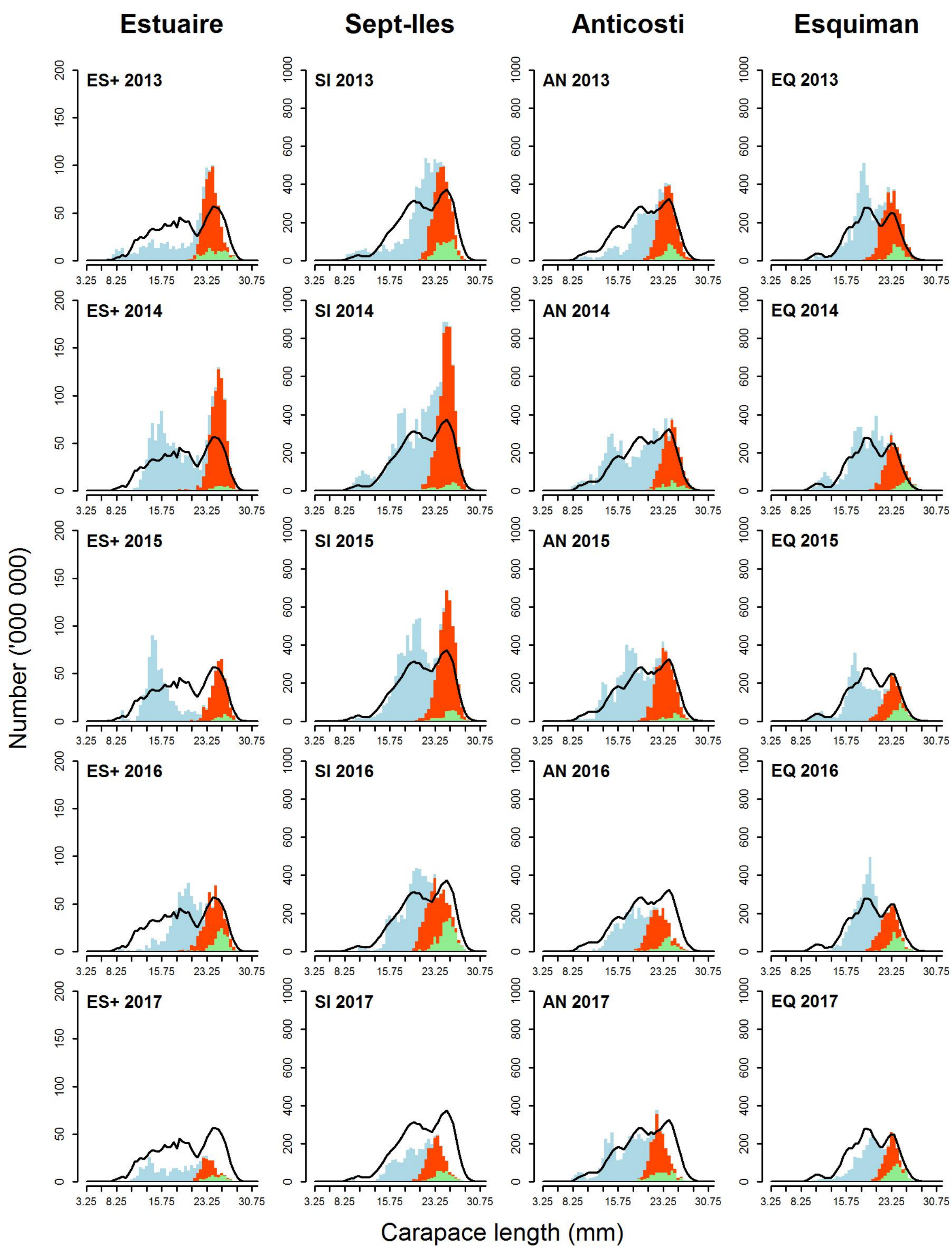
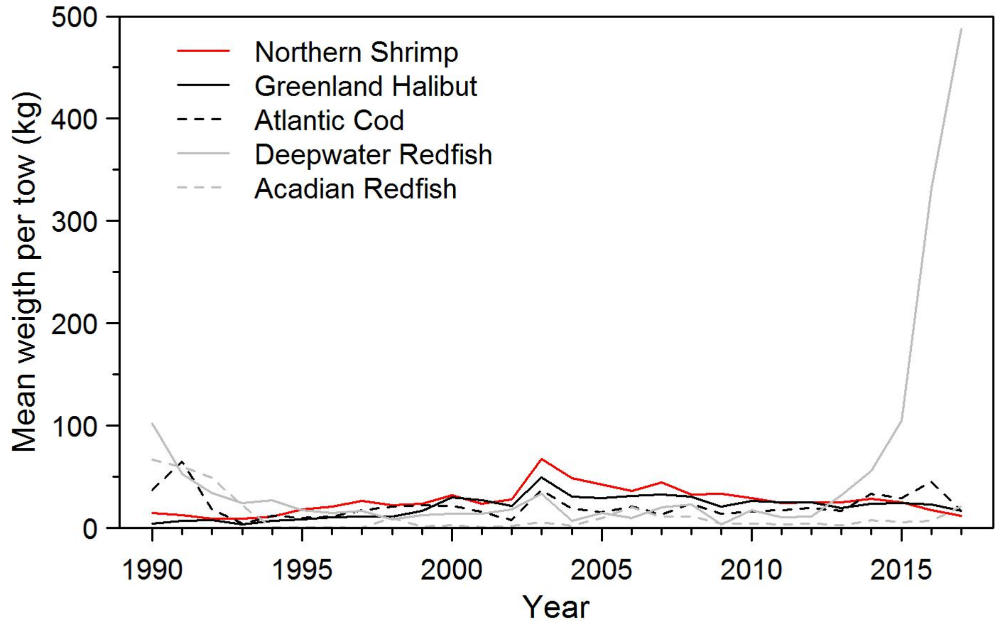



*Figure 25. Continued.*




| | 1990 | | | | | 1995 | | | | | 2000 | | | | | 2005 | | | | | 2010 | | | | | 2015 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Northern Shrimp* | 15.1 | 12.9 | 9.3 | 9.3 | 11.8 | 18.3 | 21.3 | 26.5 | 22.2 | 24.0 | 32.5 | 23.8 | 28.5 | 67.6 | 48.9 | 43.0 | 36.1 | 44.5 | 33.0 | 33.7 | 29.8 | 24.7 | 25.2 | 25.0 | 28.6 | 25.0 | 17.5 | 12.0 | 26.783 ± 13.020 |
| *Greenland Halibut* | 4.3 | 7.6 | 7.9 | 4.0 | 7.2 | 8.6 | 10.8 | 11.8 | 11.3 | 17.0 | 30.0 | 27.4 | 21.6 | 49.8 | 30.9 | 29.3 | 31.8 | 33.0 | 31.2 | 21.3 | 26.7 | 25.5 | 25.3 | 20.0 | 24.2 | 24.7 | 23.1 | 17.1 | 20.837 ± 10.826 |
| *Atlantic Cod* | 37.2 | 65.2 | 18.2 | 4.8 | 12.1 | 10.1 | 11.6 | 17.7 | 21.5 | 22.7 | 22.2 | 16.4 | 7.9 | 37.1 | 18.8 | 15.6 | 21.4 | 13.6 | 24.0 | 14.4 | 16.3 | 17.7 | 19.6 | 16.9 | 33.7 | 29.4 | 45.4 | 17.1 | 21.732 ± 12.558 |
| *Deepwater Redfish* | 102.8 | 52.9 | 34.5 | 24.8 | 27.3 | 18.0 | 14.6 | 17.2 | 8.5 | 12.8 | 14.3 | 14.3 | 18.2 | 33.7 | 7.5 | 14.7 | 10.1 | 20.3 | 22.9 | 4.1 | 17.7 | 10.9 | 11.2 | 32.1 | 55.9 | 105.5 | 332.1 | 487.5 | 54.502 ± 105.552 |
| *Acadian Redfish* | 66.7 | 60.2 | 49.6 | 22.0 | 0.7 | 1.0 | 0.8 | 0.6 | 10.2 | 1.9 | 3.0 | 1.0 | 2.4 | 6.2 | 2.2 | 10.0 | 20.8 | 11.7 | 11.6 | 4.4 | 4.7 | 3.9 | 4.2 | 3.1 | 7.7 | 5.6 | 7.1 | 21.6 | 12.325 ± 17.675 |

Anomaly: -2, -1, 0, 1, 2

*Figure 26. Biomass (kg per tow) of the main predators of northern shrimp in the northern Gulf of St. Lawrence. The color code represents the value of the anomaly, which is the difference between the weight the CPUE and the average of the time series divided by the standard deviation of that average for each species.*

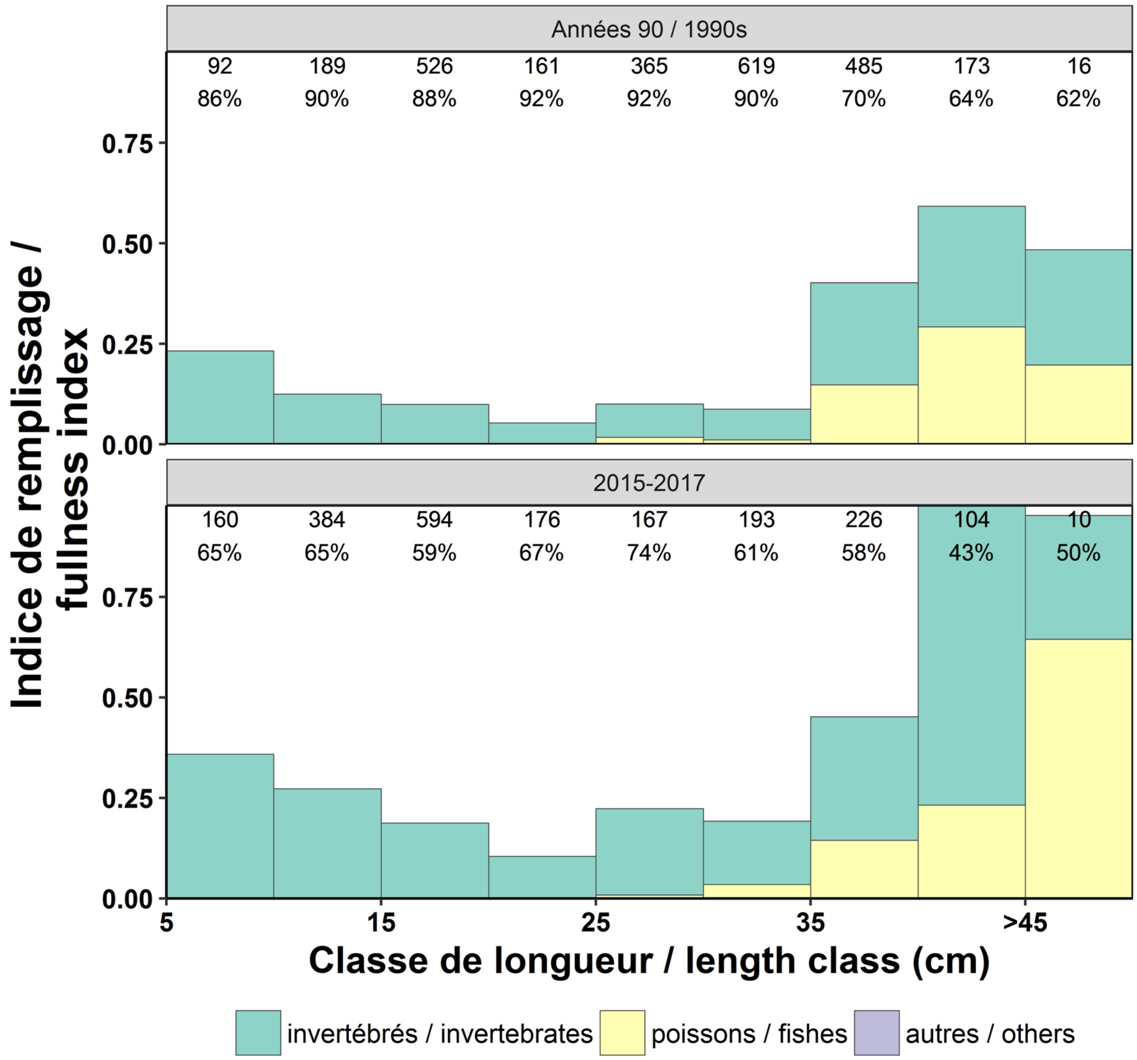



*Figure 27. Partial fullness index by length class and prey type, for the 1990s and 2015 to 2017. Bar height corresponds to the total fullness index. The numbers above the bars correspond to the number of stomachs selected for analysis and the percentage empty stomachs.*

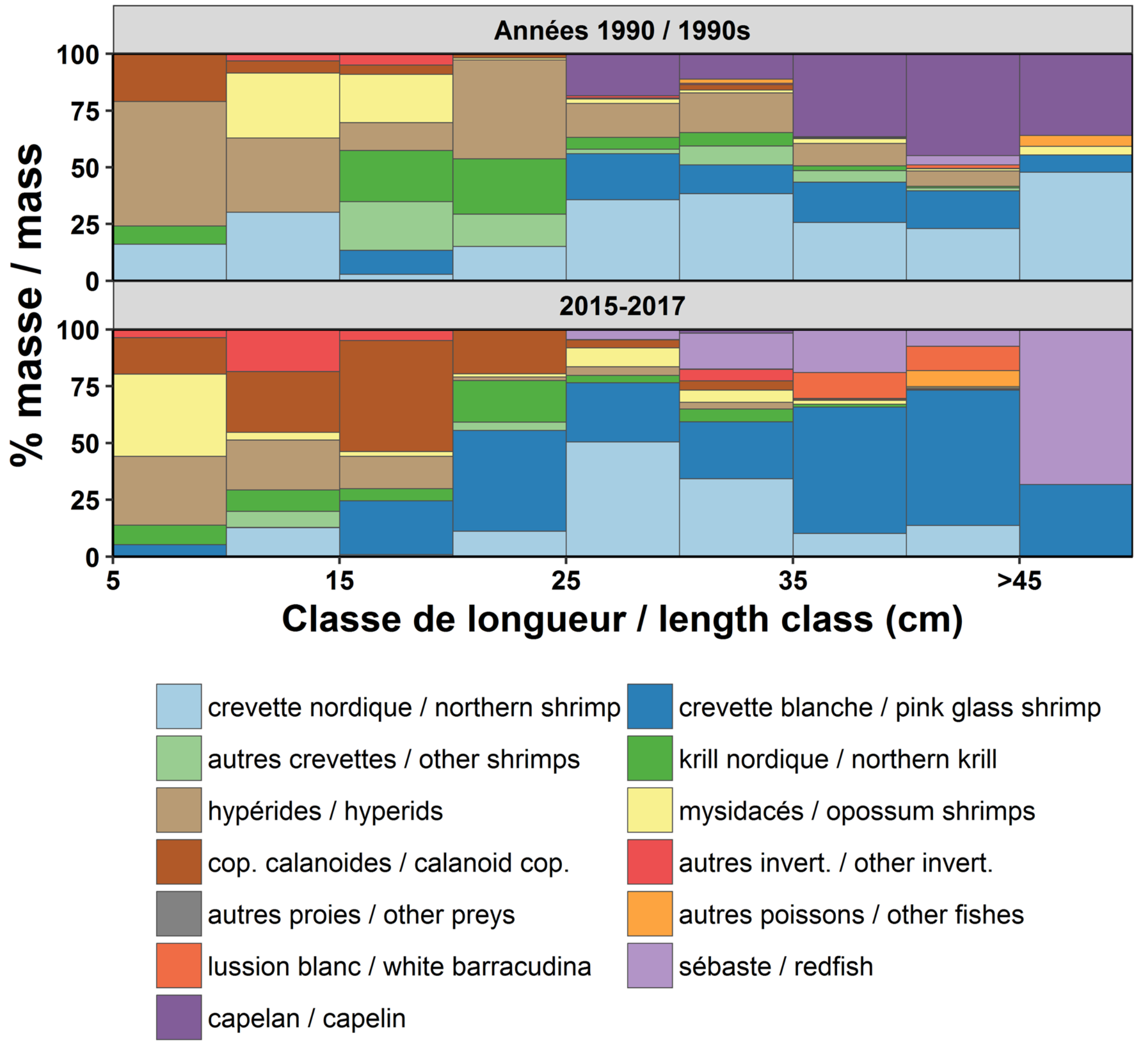



*Figure 28. Average percentage of various taxonomic groups in the redfish diet with regard to total stomach content mass, by period and length class.*

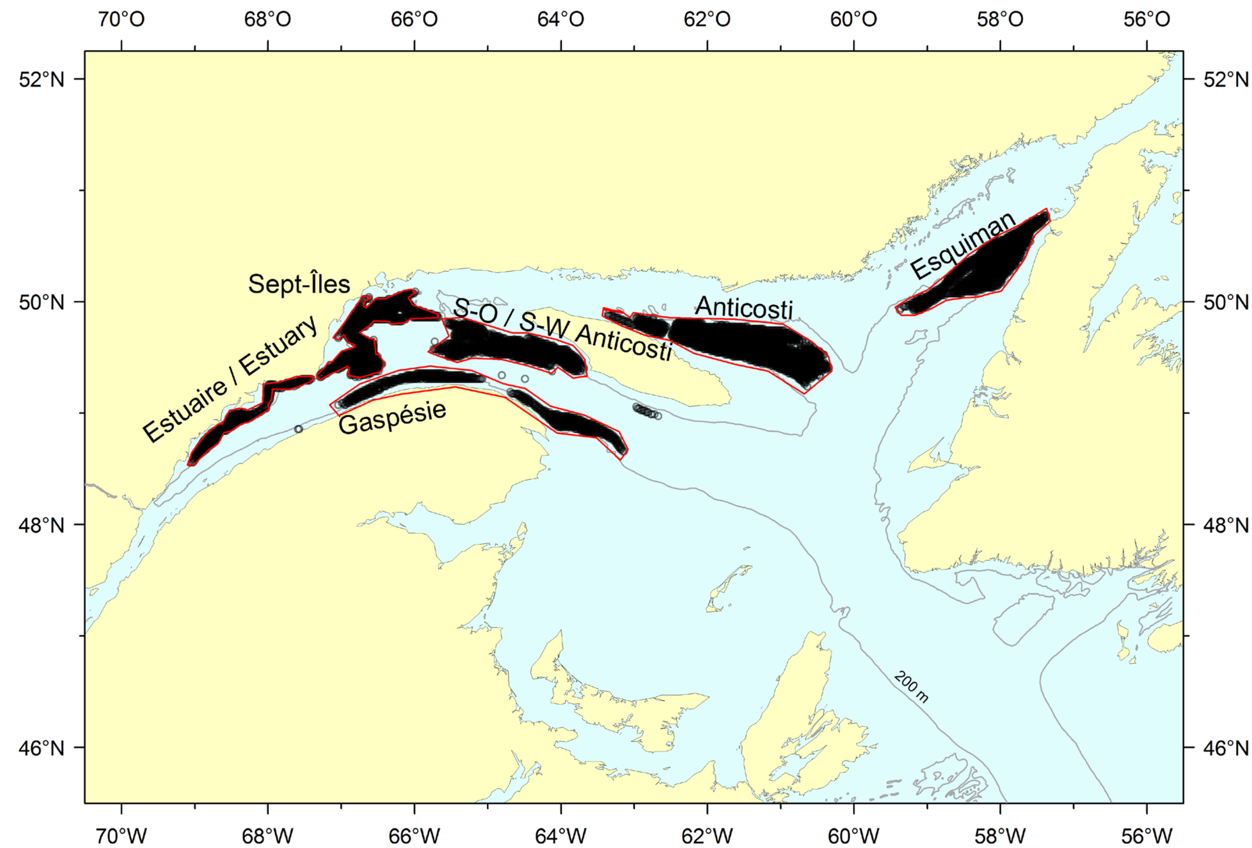



*Figure 29. Boundary surveys of the 6 areas of commercially-fished northern shrimp, based on Vessel Monitoring System (VMS) data. It includes the terminology of the areas used in the following figures.*

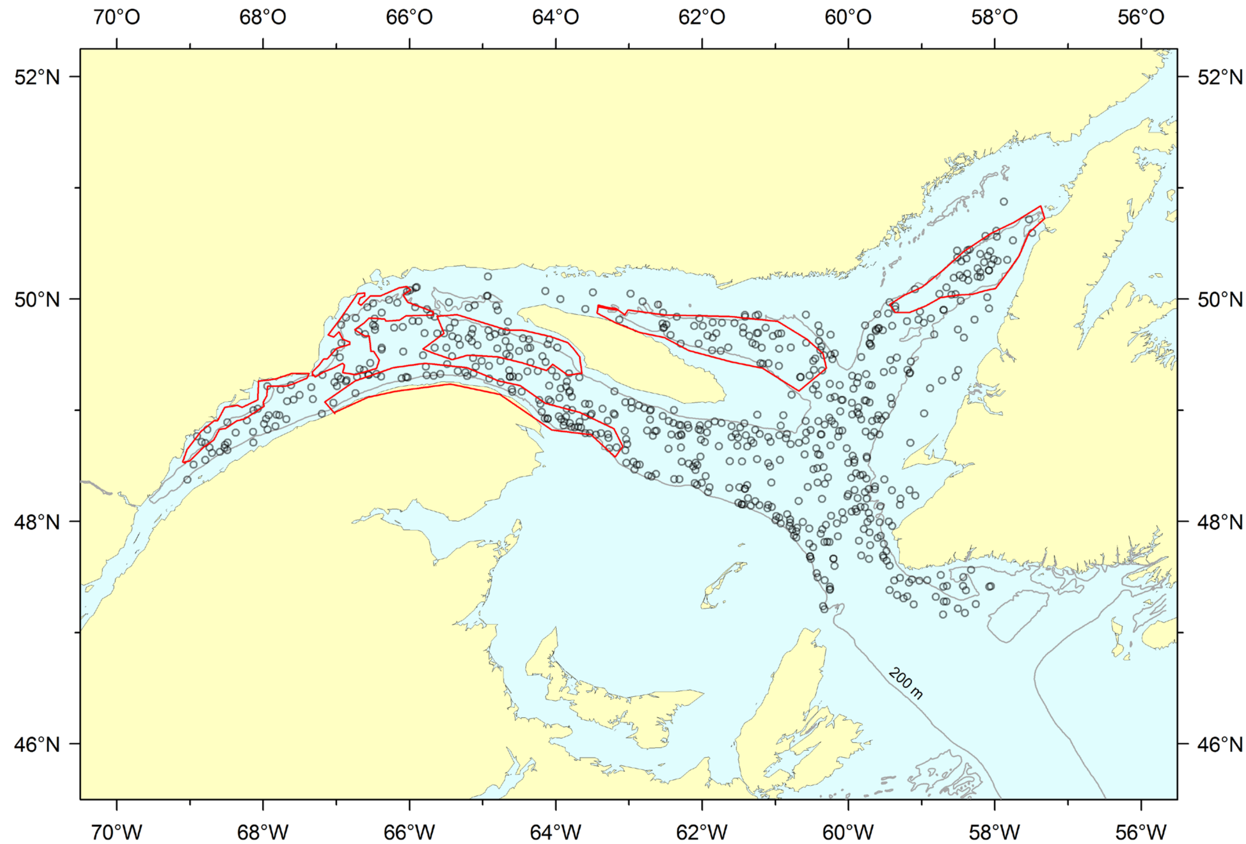



*Figure 30. Fishing tows from which redfish stomachs were collected from 1993 to 2017. A total of 4,640 stomachs were analyzed. The geographical location of each stomach–except 4 of them—allowed a spatial analysis of redfish diet trends. Red polygons represent the boundaries of areas of commercially-fished northern shrimp, calculated based on VMS data (see Figure 29).*

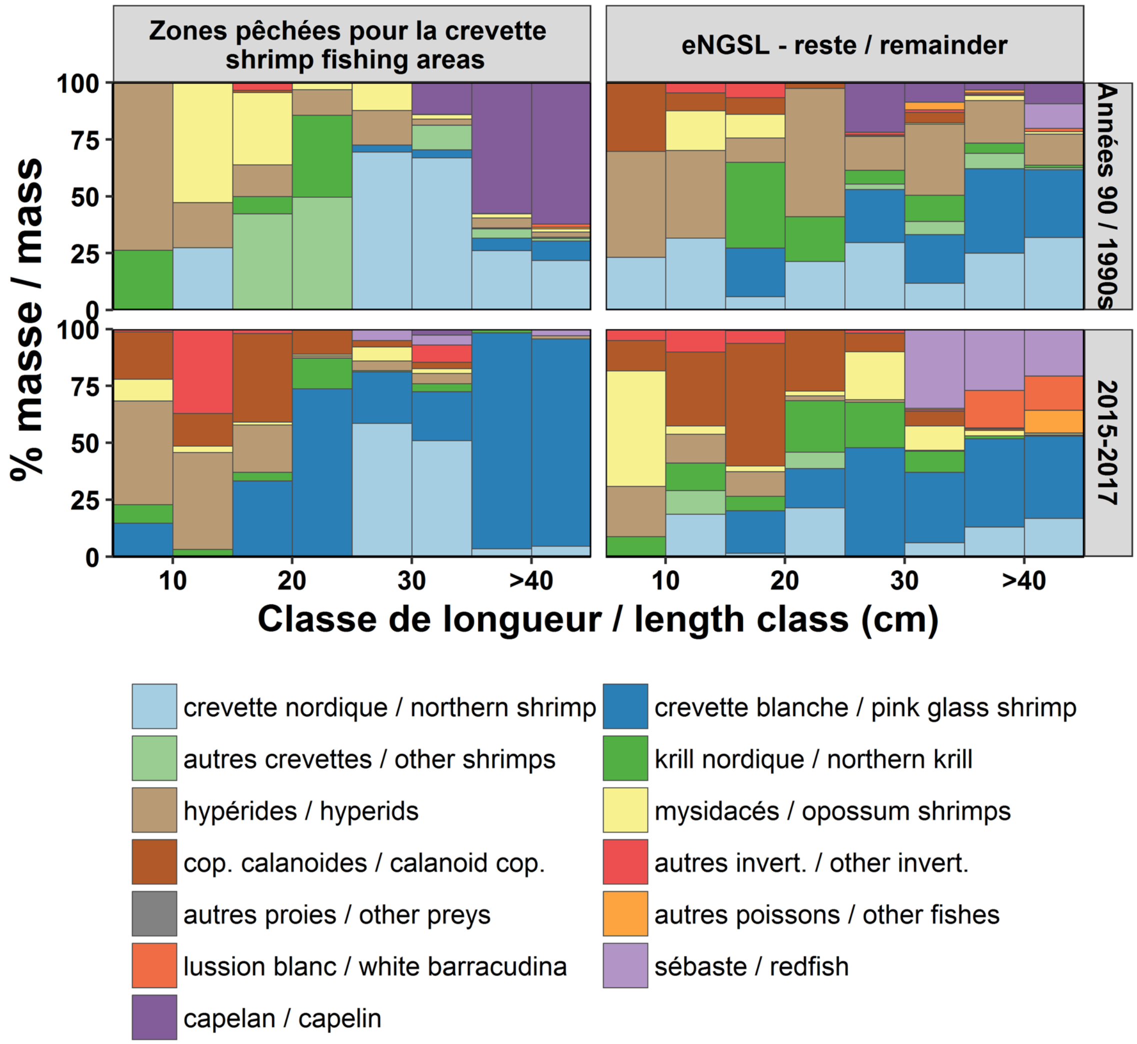



*Figure 31. Average percentage of various taxonomic groups in the redfish diet with regard to total stomach content mass, by period, area type (areas fished for northern shrimp compared with the rest of the Estuary and northern Gulf of St. Lawrence) and length class.*

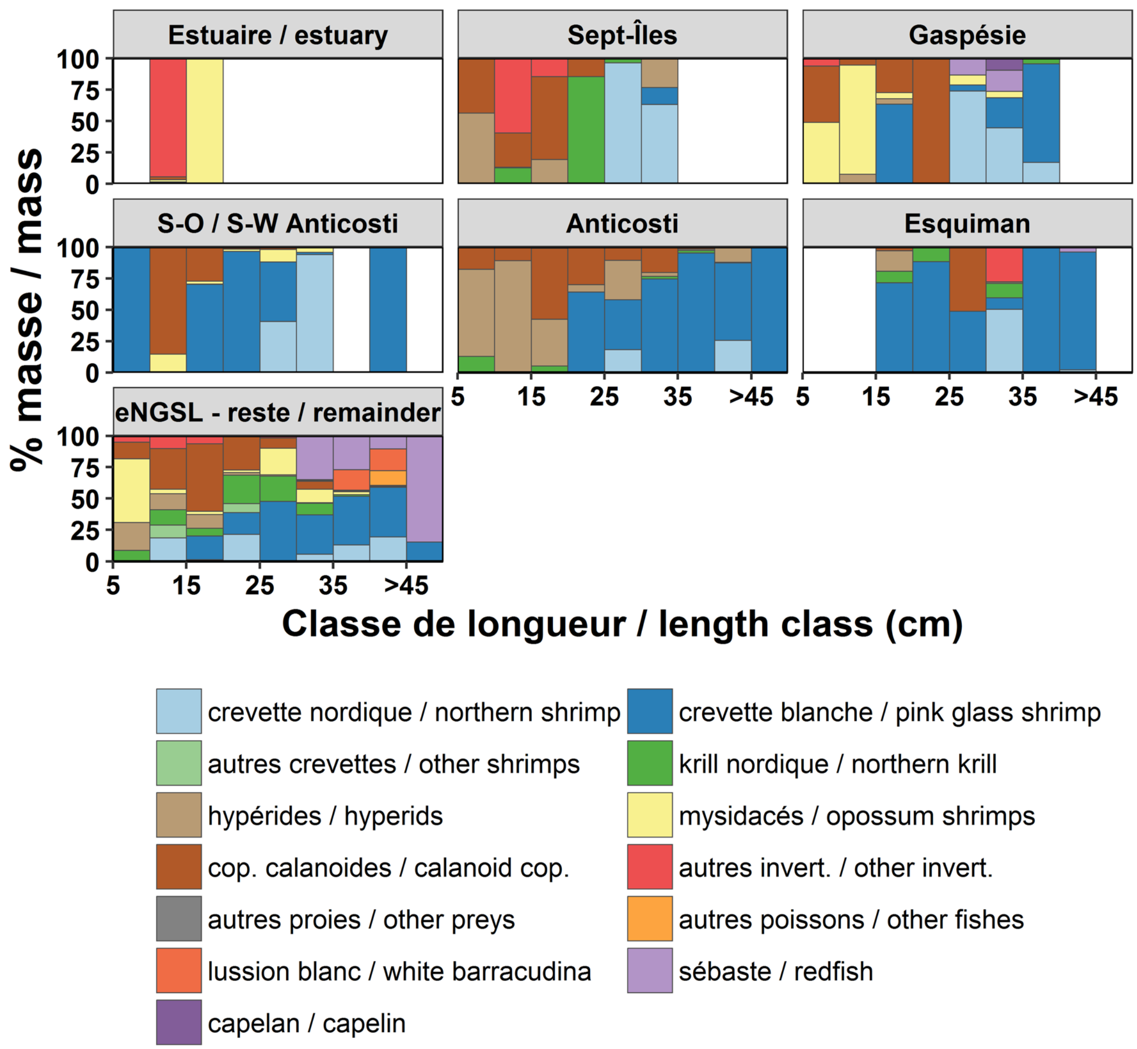



*Figure 32. Average percentage of various taxonomic groups in the redfish diet with regard to total stomach content mass, from 2015 to 2017, area (areas fished for northern shrimp compared with the rest of the eNGSL) and length class.*

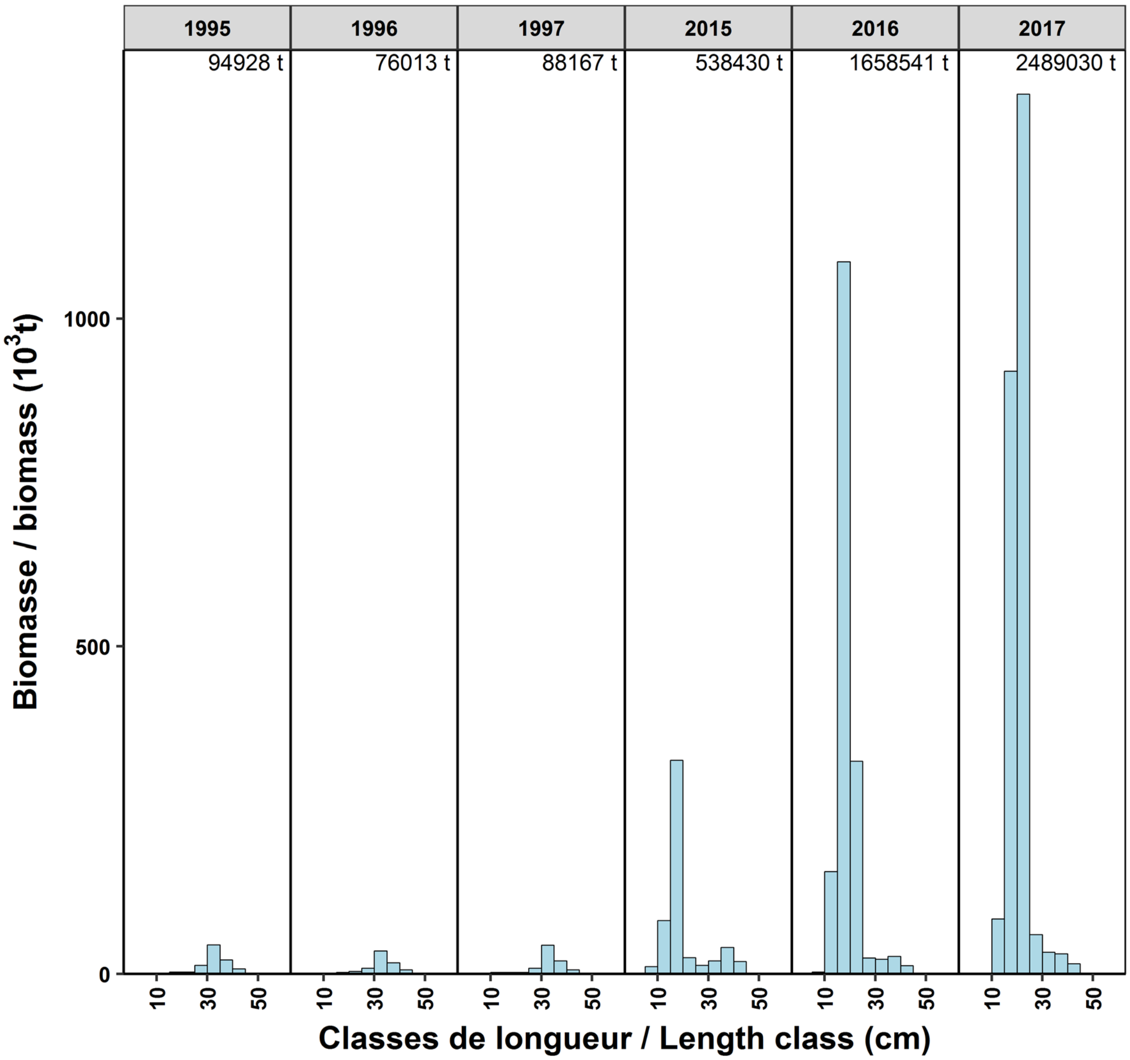



*Figure 33. Annual biomass estimate for redfish from 1995 to1997 and 2015 to 2017, by length class and for the entire eNGSL. The values in the upper part of the panels represent the total biomass estimated for a given year.*

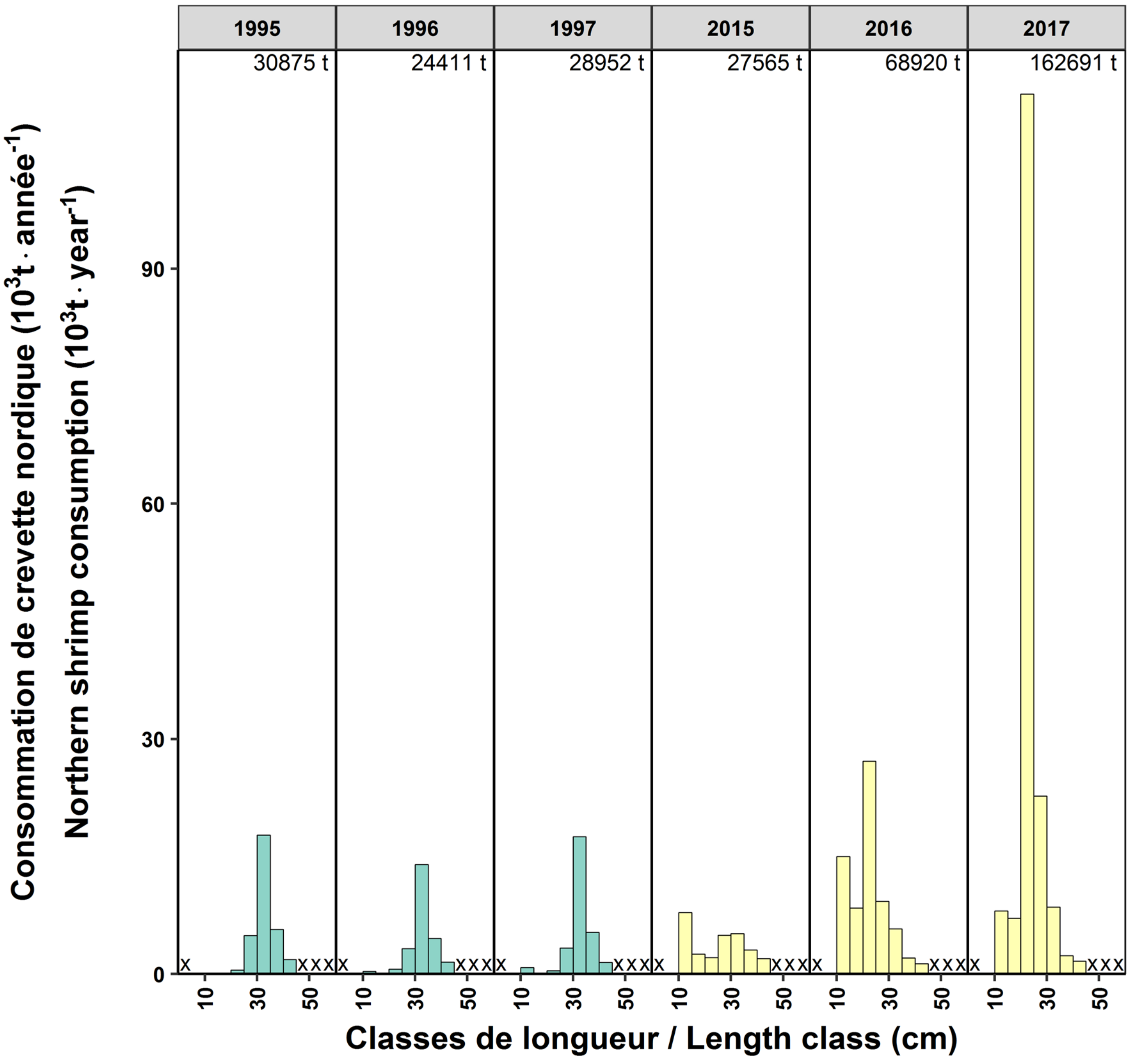



*Figure 34. Annual consumption estimate of northern shrimp by redfish, from 1995 to1997 and 2015 to 2017, by length class and for the entire eNGSL. The values in the upper part of the panels represent the total estimated consumption for a given year. An X symbol indicates that no stomachs were collected for a given length class or less than 20 stomachs. The annual consumption estimated for these length classes is therefore impossible or considered non-representative.*

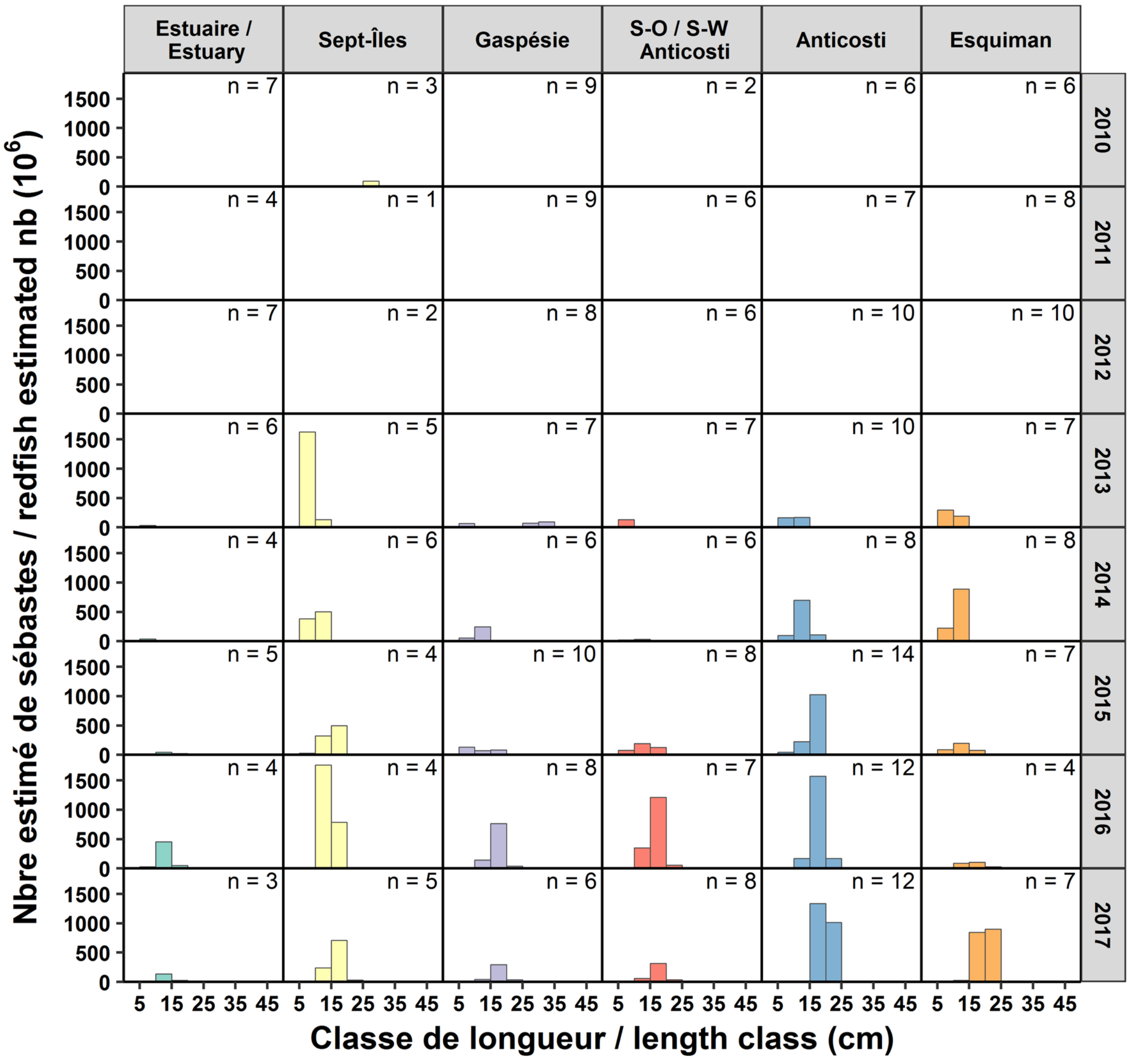



*Figure 35. Estimated number of redfish found in each of the 6 areas actively fished for northern shrimp, from 2010 to 2017. The n values represent the number of tows conducted in an area, for a given year. These estimates are based on the results of groundfish and shrimp multidisciplinary surveys conducted annually in August.*

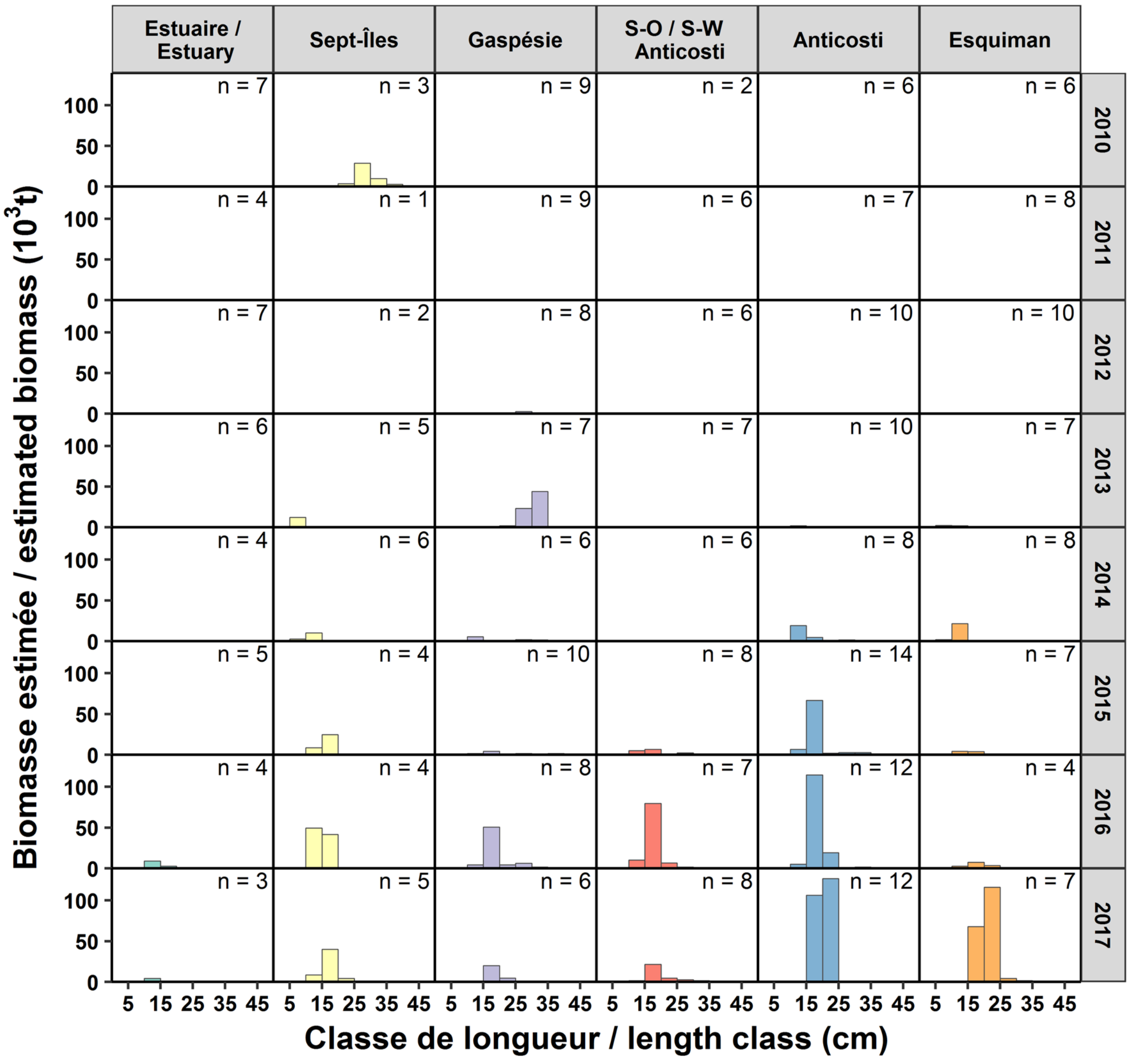



*Figure 36. Biomass estimate for redfish found in each of the 6 areas actively fished for northern shrimp, from 2010 to 2017. The n values represent the number of tows conducted in an area, for a given year. These estimates are based on the results of groundfish and shrimp multidisciplinary surveys conducted annually in August.*

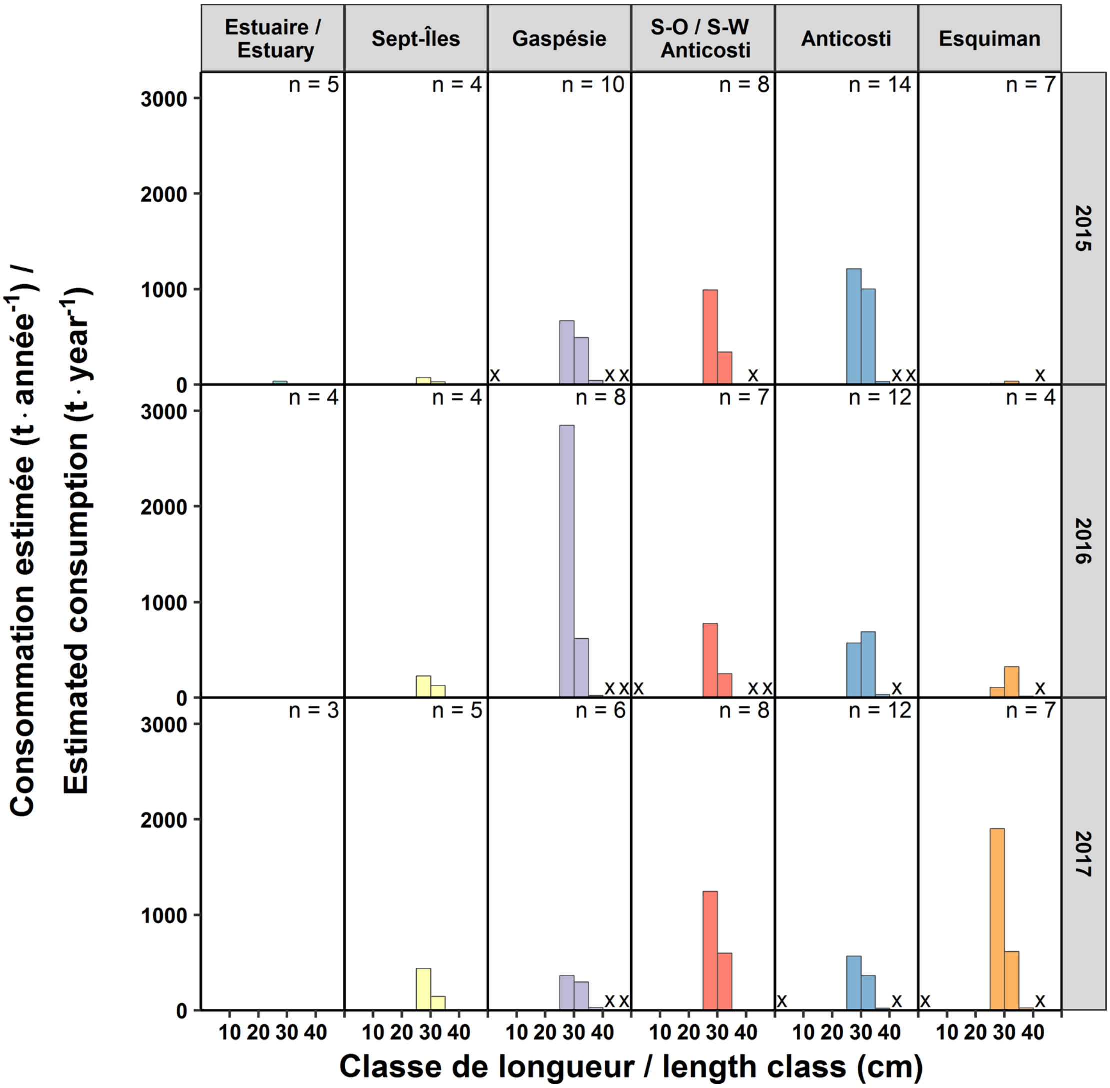



*Figure 37. Annual consumption estimate of northern shrimp by redfish, from 1995 to1997 and 2015 to 2017, by length class and areas actively fished for shrimp. The n values represent the number of tows conducted in an area, for a given year. An X symbol indicates that no stomachs were collected for a given length class or less than 20 stomachs. The annual consumption estimated for these length classes is therefore impossible or considered non-representative. Stomach data for the 3 years were combined to obtain the diet proportion attributed to northern shrimp, by length class.*

## APPENDIX

*Appendix 1. Diet of Greenland halibut and redfish in the Estuary and Gulf of St. Lawrence from the Teleost missions conducted each August from 2015 to 2017. For each prey, the frequency of occurrence (Focc), mass contribution (MC in terms of % of the mass of all prey) and the fullness index rank (PFI) are provided. The species of prey were identified when the digestion level allowed.*

Prey of Greenland halibut (length ≥ 20 cm)

| Latin name | English name | $F_{occ}$ (%) | MC (%) | Rank PFI |
|---|---|---|---|---|
| *Sebastes sp.* | Redfish | 8.84 | 55.32 | 1 |
| *Pandalus borealis* | Northern shrimp | 6.01 | 11.46 | 2 |
| *Mallotus villosus* | Capelin | 2 | 6.93 | 3 |
| - | Digested fish (except flat fish) | 2.67 | 5.6 | 4 |
| *Pasiphaea multidentata* | Pink glass shrimp | 2.92 | 2.67 | 5 |
| - | Unidentified digested material | 4.09 | 1.74 | 6 |
| *Enchelyopus cimbrius* | Fourbeard rockling | 0.75 | 4.33 | 7 |
| *Thysanoessa sp.* | Euphausid | 0.33 | 0.35 | 8 |
| *digested fish* | Digested fish | 3.25 | 1.88 | 9 |
| *Pandalus sp.* | Shrimp | 1.08 | 0.95 | 10 |
| *Clupea harengus* | Atlantic herring | 0.08 | 1.54 | 11 |
| *Arctozenus risso* | Spotted barracudina (sand eel) | 0.42 | 1.63 | 12 |
| *Dendrobranchiata / Caridea* | Shrimps (generic) | 2.42 | 0.99 | 13 |
| *Melanostigma atlanticum* | Atlantic soft pout | 2.09 | 1.02 | 14 |
| *Crustacea* | Crustacean | 1.75 | 0.31 | 15 |
| *Themisto sp.* | Hyperiid | 1.08 | 0.1 | 16 |
| *Euphausiidae* | Euphausid | 0.67 | 0.12 | 17 |
| *Myxine glutinosa* | Atlantic hagfish | 0.08 | 1 | 18 |
| *Ammodytes sp.* | Sand lance | 0.17 | 0.23 | 19 |
| *Pandalus montagui* | Striped shrimp | 0.25 | 0.16 | 20 |
| *Amblyraja radiata* | Thorny skate | 0.08 | 0.38 | 21 |
| *Gasterosteus aculeatus* | Threespine stickleback | 0.08 | 0.03 | 22 |
| *Sergia robusta* | Shrimp | 0.08 | 0.11 | 23 |
| *Rajidae* | Skates | 0.08 | 0.18 | 24 |
| *Brisaster fragilis* | Urchin | 0.08 | 0.37 | 25 |
| *Themisto libellula* | Hyperiid | 0.33 | 0.04 | 26 |
| *Nezumia bairdii* | Marlin-spike | 0.08 | 0.26 | 27 |
| *Boreomysis sp.* | Mysid | 1.17 | 0.06 | 28 |
| *Meganyctiphanes norvegica* | Nordic krill | 0.42 | 0.04 | 29 |
| *Chionoecetes opilio* | Snow crab | 0.08 | 0.06 | 30 |
| *Pontophilus norvegicus* | Shrimp | 0.25 | 0.09 | 31 |
| *Spirontocaris lilljeborgii* | Friendly blade shrimp | 0.08 | 0.01 | 32 |
| *Wimvadocus torelli* | gammaride | 0.08 | 0.01 | 33 |
| *Stegocephalus inflatus* | gammaride | 0.08 | 0 | 34 |
| *Themisto compressa* | Hyperid | 0.08 | 0 | 35 |
| *Tmetonyx cicada* | Gammarid | 0.08 | 0.01 | 36 |
| *Boreomysis arctica* | Mysid | 0.08 | 0 | 37 |
| - | Unidentified eggs | 0.17 | 0 | 38 |
| *Paraeuchaeta norvegica* | Calanoid copepod | 0.08 | 0 | 39 |
| *Scina borealis* | Hyperid | 0.08 | 0 | 40 |
| *Decapoda* | Decapod crustaceans | 0.08 | 0 | 41 |
| *Hyperiidae* | Hyperiidae | 0.08 | 0 | 42 |
| Percentage of empty stomachs | | 65.30 | - | - |
| Number of stomachs | | 1199 | - | - |

*Appendix 1. Continued.*

Prey of Greenland halibut (length < 20 cm)

| Latin name | English name | $F_{occ}$ (%) | MC (%) | Rank PFI |
|---|---|---|---|---|
| *Euphausiidae* | Euphausid | 22.45 | 19.2 | 1 |
| *Mallotus villosus* | Capelin | 3.27 | 29.41 | 2 |
| *Thysanoessa sp.* | Euphausid | 5.71 | 11.87 | 3 |
| *Pasiphaea multidentata* | Pink glass shrimp | 3.27 | 8.76 | 4 |
| *Themisto sp.* | Hyperiid | 16.73 | 4.85 | 5 |
| *Crustacea* | Crustacean | 7.76 | 4.9 | 6 |
| *Themisto compressa* | Hyperid | 7.35 | 3.26 | 7 |
| *Meganyctiphanes norvegica* | Nordic krill | 6.94 | 3.29 | 8 |
| - | Unidentified digested material | 6.12 | 3.7 | 9 |
| *poisson digéré* | Digested fish | 3.67 | 4.44 | 10 |
| | Digested fish (except flat fish) | 1.22 | 1.46 | 11 |
| *Themisto libellula* | Hyperiid | 2.04 | 1.47 | 12 |
| *Dendrobranchiata / Caridea* | Shrimps (generic) | 0.82 | 1.18 | 13 |
| *Reinhardtius hippoglossoides* | Greenland halibut | 0.41 | 0.66 | 14 |
| *Gammaridea* | Gammaridea | 0.41 | 0.37 | 15 |
| *Brachyura* | Crabs | 1.22 | 0.28 | 16 |
| *Melanostigma atlanticum* | Atlantic soft pout | 0.41 | 0.63 | 17 |
| *Pandalus borealis* | Northern shrimp | 0.41 | 0.08 | 18 |
| *Hyperiidae* | Hyperiidae | 0.82 | 0.09 | 19 |
| *Boreomysis sp.* | Mysid | 0.41 | 0.1 | 20 |
| *Themisto abyssorum* | Hyperid | 0.82 | 0.01 | 21 |
| Percentage of empty stomachs | | 35.92 | - | - |
| Number of stomachs | | 245 | - | - |

*Appendix 1. Continued.*

Redfish preys (length ≥ 20 cm)

| Latin name | English name | $F_{occ}$ (%) | MC (%) | Rank PFI |
|---|---|---|---|---|
| *Pasiphaea multidentata* | Pink glass shrimp | 26.58 | 45.18 | 1 |
| *Pandalus borealis* | Northern shrimp | 5.84 | 13.51 | 2 |
| *Sebastes sp.* | Redfish | 2.06 | 12.77 | 3 |
| *Arctozenus risso* | Spotted barracudina (sand eel) | 1.15 | 7.3 | 4 |
| - | Digested fish (except flat fish) | 1.83 | 3.22 | 5 |
| - | Digested fish | 2.75 | 3.3 | 6 |
| *Meganyctiphanes norvegica* | Nordic krill | 6.3 | 1.09 | 7 |
| *Dendrobranchiata / Caridea* | Shrimps (generic) | 6.19 | 1.97 | 8 |
| *Pandalus sp.* | Shrimp | 1.49 | 1.03 | 9 |
| *Crustacea* | Crustacean | 11.91 | 0.85 | 10 |
| *Boreomysis sp.* | Mysid | 9.97 | 1.1 | 11 |
| *Notoscopelus elongatus kroyeri* | Krøyer’s lanternfish | 0.23 | 2.3 | 12 |
| - | Unidentified digested material | 2.52 | 1.39 | 13 |
| *Euphausiidae* | Euphausid | 4.12 | 0.46 | 14 |
| *Calanus sp.* | Calanoid copepod | 6.3 | 0.3 | 15 |
| *Themisto sp.* | Hyperiid | 8.48 | 0.32 | 16 |
| *Myctophidae* | Lanternfishes | 0.11 | 0.92 | 17 |
| *Melanostigma atlanticum* | Atlantic soft pout | 1.49 | 0.43 | 18 |
| *Calanoida* | Calanoid copepod | 6.3 | 0.18 | 19 |
| *Calanus hyperboreus* | Calanoid copepod | 4.47 | 0.23 | 20 |
| *Themisto compressa* | Hyperid | 3.09 | 0.37 | 21 |
| *Pandalus montagui* | Striped shrimp | 0.46 | 0.19 | 22 |
| *Thysanoessa sp.* | Euphausid | 0.57 | 0.3 | 23 |
| *Boreomysis arctica* | Mysid | 1.15 | 0.26 | 24 |
| *Themisto libellula* | Hyperiid | 0.23 | 0.15 | 25 |
| - | Unidentified fish eggs | 0.11 | 0.29 | 26 |
| *Paraeuchaeta norvegica* | Calanoid copepod | 2.06 | 0.09 | 27 |
| Pleuronectiformes | Flat fish | 0.23 | 0.23 | 28 |
| *Mallotus villosus* | Capelin | 0.11 | 0.09 | 29 |
| *Rossia sp.* | Cuttle fish | 0.11 | 0.04 | 30 |
| *Copepoda* | Copepod | 1.03 | 0.03 | 31 |
| *Themisto abyssorum* | Hyperiid | 1.83 | 0.02 | 32 |
| - | Digested invertebrates | 0.69 | 0.05 | 33 |
| *Pasiphaea sp.* | Shrimp | 0.23 | 0.02 | 34 |
| *Mysidae* | Mysidae | 0.23 | 0.01 | 35 |
| *Gammaridea* | Gammaridea | 0.23 | 0 | 36 |
| *Hyperia galba* | Big-eye amphipod | 0.23 | 0 | 37 |
| *Polychaeta* | Polychaete | 0.11 | 0 | 38 |
| *Metridia sp.* | Calanoid copepod | 0.34 | 0 | 39 |
| *Cumacea* | Cumacean shrimp | 0.23 | 0 | 40 |
| *Scina borealis* | Hyperiid | 0.23 | 0 | 41 |
| *Hyperiidae* | Hyperiid | 0.11 | 0 | 42 |
| *Amphipoda* | Amphipods | 0.11 | 0 | 43 |
| *Erythrops erythrophthalma* | Mysid | 0.11 | 0 | 44 |
| Percentage of empty stomachs | | 39.86 | - | - |
| Number of stomachs | | 873 | - | - |

*Appendix 1. Continued.*

Redfish preys (length < 20 cm)

| Latin Name | English name | $F_{occ}$ (%) | MC (%) | Rank PFI |
|---|---|---|---|---|
| *Crustacea* | Crustacean | 21.88 | 12.75 | 1 |
| *Calanoida* | Calanoid copepod | 21.79 | 11.74 | 2 |
| *Themisto compressa* | Hyperid | 5.2 | 8.1 | 3 |
| *Calanus sp.* | Calanoid copepod | 13.95 | 12.84 | 4 |
| *Pasiphaea multidentata* | Pink glass shrimp) | 1.46 | 12.92 | 5 |
| *Meganyctiphanes norvegica* | Nordic krill | 4.01 | 6.43 | 6 |
| *Themisto sp.* | Hyperiid | 11.76 | 5.66 | 7 |
| *Euphausiidae* | Euphausid | 5.29 | 5.25 | 8 |
| *Thysanoessa sp.* | Euphausid | 1.19 | 3.97 | 9 |
| *Boreomysis arctica* | Mysid | 1.46 | 0.95 | 10 |
| *Boreomysis sp.* | Mysid | 4.47 | 2.33 | 11 |
| *Calanus hyperboreus* | Calanoid copepod | 10.12 | 5.64 | 12 |
| *Pandalus borealis* | Northern shrimp | 0.18 | 2.18 | 13 |
| | Unidentified digested material | 4.19 | 1.27 | 14 |
| *Dendrobranchiata / Caridea* | Shrimps (generic) | 1.64 | 1.94 | 15 |
| *Pandalus sp.* | Shrimp | 0.46 | 0.52 | 16 |
| *Copepoda* | Copepod | 1.82 | 0.63 | 17 |
| *Pandalus montagui* | Striped shrimp | 0.09 | 0.99 | 18 |
| *Metridia sp.* | Calanoid copepod | 4.1 | 0.52 | 19 |
| *Themisto libellula* | Hyperiid | 0.64 | 0.79 | 20 |
| *Aphroditella hastata* | Polychaete | 0.09 | 0.29 | 21 |
| *Scina borealis* | Hyperiid | 1.55 | 0.31 | 22 |
| *Aetideidae* | Calanoid copepod | 0.09 | 0.07 | 23 |
| *Themisto abyssorum* | Hyperiid | 1.28 | 0.42 | 24 |
| *Paraeuchaeta norvegica* | Calanoid copepod | 2.73 | 0.25 | 25 |
| *Pseudomma roseum* | Mysid | 0.27 | 0.12 | 26 |
| *Cumacea* | Cumacean shrimp | 1.46 | 0.06 | 27 |
| - | Digested invertebrates | 0.46 | 0.14 | 28 |
| *Calanus. finn. + glacialis* | Copepods | 0.46 | 0.05 | 29 |
| *Amphipoda* | Amphipods | 0.73 | 0.06 | 30 |
| - | Digested fish | 0.18 | 0.14 | 31 |
| *Hyperia sp.* | Hyperiid | 0.09 | 0.03 | 32 |
| *Neohela monstrosa* | Gammarid | 0.09 | 0.17 | 33 |
| *Gammaridea* | Gammarid | 0.36 | 0.02 | 34 |
| *Byblis sp.* | Gammarid | 0.18 | 0.06 | 35 |
| *Mallotus villosus* | Capelin | 0.09 | 0.14 | 36 |
| *Hyperiidae* | Hyperiid | 0.46 | 0.03 | 37 |
| *Hyperia galba* | Hyperiid | 0.09 | 0.07 | 38 |
| *Bradyidius similis* | Calanoid copepod | 0.64 | 0.01 | 39 |
| *Ostracoda* | Ostracods | 0.55 | 0.01 | 40 |
| *Metridia longa* | Calanoid copepod | 0.55 | 0.04 | 41 |
| - | Unidentified fish eggs | 0.09 | 0.03 | 42 |
| *Monoculodes sp.* | Gammarid | 0.09 | 0.01 | 43 |
| *Pseudomma sp.* | Mysid | 0.09 | 0.01 | 44 |
| *Calanus finmarchicus* | Calanoid copepod | 0.18 | 0.01 | 45 |
| *Limacina sp.* | Sea butterfly | 0.18 | 0.01 | 46 |
| *Mysida* | Mysid | 0.09 | 0.01 | 47 |
| *Brachyura* | Crabs | 0.09 | 0 | 48 |
| *Metridia lucens* | Calanoid copepod | 0.09 | 0 | 49 |
| *Chiridius gracilis* | Calanoid copepod | 0.18 | 0 | 50 |
| *Invertebrata* | Invertebrates | 0.09 | 0 | 51 |
| *Gastropoda* | Gastropods | 0.09 | 0 | 52 |
| *Mollusca* | Molluscs | 0.09 | 0 | 53 |
| *Mysidae* | Mysid | 0.09 | 0 | 54 |
| Percentage of empty stomachs | | 32.73 | - | - |
| Number of stomachs | | 1097 | - | - |