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The 2017 assessment of the snow crab (Chionoecetes opilio) stock in the southern Gulf of St. Lawrence (Areas 12, 19, 12E and 12F)

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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 2017 assessment of the southern Gulf of St. Lawrence (sGSL) snow crab, *Chionoecetes opilio*, stock (Areas 12, 19, 12E and 12F) is presented. Snow crab in the southern Gulf of St. Lawrence is considered as a single stock unit for assessment purposes. The 2017 assessment was conducted as per the recommendations of the Snow Crab Assessment Methods Framework Science Review held in November 2011. The exploitation rate of the 2017 fishery in the sGSL was 44%. The 2017 post-fishery survey biomass of commercial-sized adult male crabs was estimated at 66,021 t (95% confidence intervals 57,456 to 75,495 t), a decrease of 33.4% from 2016. The available biomass for the 2018 fishery, derived from the 2017 survey, is within the healthy zone of the PA Framework. The residual biomass from the 2017 survey was estimated at 14,759 t, a decrease of 40.7% compared to the 2016 estimate. Seventy-eight percent (78%) of the 2017 survey biomass, available for the 2018 fishery, is composed of new recruitment (51,262 t). The recruitment to the commercial biomass from the 2017 survey decreased by 31.0% compared to 2016. The predicted recruitment of commercial-sized adult male crab for the 2019 fishery was estimated at 47,700 t (33,800 to 64,880 t). A risk analysis of catch options for the 2018 fishery is provided.

1.0. INTRODUCTION

Snow crab, *Chionoecetes opilio*, has been commercially exploited in the southern Gulf of St. Lawrence (sGSL) since the mid-1960s. Until 1994, the snow crab fishery in Area 12 (Fig. 1) was exploited by 130 mid-shore crab harvesters from New Brunswick, Québec and Nova Scotia. In 1997, the Prince Edward Island (PEI) coastal fishery (formerly called Areas 25/26) was integrated into Area 12. In 2003, a portion of the coastal fishery off Cape Breton (formerly called Area 18) was also integrated into Area 12, and a northern part of Area 18 was set as a buffer zone (non-snow crab fishing zone, label C in Fig. 1). For the purpose of this assessment, Area 12 refers to the new management unit (Fig. 1). In 1978, Area 19 (Fig. 1) was established for the exclusive use of Cape Breton inshore crab harvesters with vessels less than 13.7 m (45 ft) in length. Areas 12E and 12F were introduced in 1995 as exploratory fishery areas. A two nautical mile buffer zone was created between Area 12F and the adjacent Area 19 in 1996 (label B in Fig. 1). In 2002, the status of Areas 12E and 12F was changed from exploratory to commercial.

Currently, there are four individually managed fishing areas (Areas 12, 19, 12E and 12F) (Fig. 1), with Area 12 being the largest in area, number of participants, and landings. There is no biological basis for the delimitations of snow crab management areas in the sGSL (Chiasson and Hébert 1990; Hébert et al. 2008; DFO 2009). Crabs in the above four management areas are considered part of a single biological population and the sGSL is considered as a single unit for assessment purposes (Hébert et al. 2008).

Management of these fisheries is based on quotas (by management area and distributed among license holders) and effort controls (number of licenses, trap allocations, trap dimensions, and seasons).

In Areas 12, 12E and 12F, the fishing season generally starts as soon as the sGSL is clear of ice in late April to early May and lasts either until the closure of the fishing season in mid-July or when the quota is caught. In Area 19, the fishing season starts in July and ends in mid-September or when the quota is caught. The landing of females is prohibited and only hard-shelled males ≥ 95 mm carapace width (CW) are commercially exploited. Different limits on the number of traps apply to each license depending on the group of harvesters and fishing area.

New management measures were introduced in 1990 following the premature closure of the Area 12 fishery in 1989 due to a rapid decline in catch rates and high incidence of soft-shelled crabs in catches. One of the measures was to set the total allowable catch (TAC) or quota as some proportion of the biomass of adult male crab ≥ 95 mm CW, as estimated from a trawl survey. Another management strategy was to close portions of the fishery based on the percentage of soft- or white crabs to maximize yield and reproductive potential by limiting the capture of soft-shelled males.

This assessment follows recommendations from the Framework Science Peer Review of stock assessment methods for the sGSL snow crab stock held on November 21-25, 2011 (DFO 2012a).

The present report presents the assessment and commercial biomass estimates for the 2018 snow crab fishery in the sGSL (Areas 12, 19, 12E and 12F). Biomass estimates and population characteristics by life stage are derived from a trawl survey conducted after the fishery covering the sGSL snow crab habitat. Risk analysis of catch options for the 2018 fishery relative to the commercial biomass and removal reference points is also presented.

2.0. SYNOPSIS OF SNOW CRAB BIOLOGY

In the sGSL, molting of snow crab occurs from December to April, prior to the fishery (Watson 1972; Conan et al. 1988; Sainte-Marie et al. 1995; Benhalima et al. 1998; Hébert et al. 2002). Crab normally molt annually until they reach the adult phase via a final or “terminal” molt (Conan and Comeau 1986). Males reach adulthood at sizes ranging from 40 to 150 mm CW and females at 30 to 95 mm CW (Conan and Comeau 1986). Estimates of longevity of adult males are (after reaching the terminal molt) between 5 (Sainte-Marie et al. 1995) and 8 years (Fonseca et al. 2008).

In contrast to immature females, pubescent (adolescent) females have a wider abdomen and fully developed orange gonads in the fall. These females then undergo a terminal molt between December and April and become nulliparous females having a fully enlarged abdomen and ripe ovaries. Generally, they mate immediately after molting, while their carapace is still soft, and then extrude fertilized eggs for the first time, becoming primiparous females (Watson 1969; Moriyasu and Conan 1988). Multiparous refers to females which are repeat spawners (second brood or more). Their mating season occurs from late-May to early-June, after their eggs have hatched (Conan and Comeau 1986; Moriyasu and Conan 1988; Sainte-Marie and Hazel 1992; Moriyasu and Comeau 1996; Sainte-Marie et al. 1999). In the sGSL, mature females normally carry their eggs under the abdomen for two years (Mallet et al. 1993; Moriyasu and Lanteigne 1998), while a negligible portion of mature females follow a one-year cycle in Baie Sainte-Marguerite (Sainte-Marie et al. 1995). However, Khun and Choi (2011) reported that over 80% of mature females were estimated to follow a one-year reproductive cycle on the Scotian Shelf.

Mature females, both primiparous and multiparous, may produce more than one viable brood from sperm stored in their spermathecae from the first mating, without any subsequent mating (Sainte-Marie and Carrière 1995). However, the probability that a single mating was sufficient to fertilize a female’s lifetime production of eggs has been shown to be low (Rondeau and Sainte-Marie 2001). Mating after egg hatching seems to be a general rule for snow crab in the sGSL (Conan et al. 1988).

After molting, crabs have a soft shell engorged with water. It takes about 8-10 months for the carapace of an adult soft-shelled male to harden (Hébert et al. 2002) and one year to attain maximal meat yield (Dufour et al. 1997). Adult soft-shelled males are not able to mate during their postmolt period, but become active in reproductive activities with nulliparous females in February of the following year and in May-June with multiparous females (Conan et al. 1988; Moriyasu et al. 1988). Adult soft-shelled males of legal size represent the annual recruitment to the fishery, as they become commercially marketable in the following fishing season (Conan and Comeau 1986; Sainte-Marie et al. 1995; Comeau et al. 1998; Hébert et al. 2002).

Following Sainte-Marie et al. (1995), we use the term “adolescent” and “adult” to refer to what was formerly called morphometrically immature and mature, respectively (Conan and Comeau 1986).

3.0. METHODS

3.1. TRAWL SURVEY BIOMASS ESTIMATION

There have been progressive changes in the sampling design and protocols of the sGSL trawl survey since its inception in 1988. Originally, the survey area was sub-divided using a lattice of 10 by 10 minute latitude-longitude grids. One or two sampling locations were then randomly selected and used as fixed stations in subsequent survey years. Initially, the survey area only covered Area 12 but was expanded to Area 19 in 1990. Area 12 was sampled before its fishery

(July to October) for all years (except 1996 where there was no survey) and Area 19 was sampled before its fishery from 1990 to 1992 and then after its fishery from 1993 onward (Moriyasu et al. 2008).

In 1997, the survey area was again extended to include the new management Areas 12E and 12F. New stations were added randomly within grids as the survey polygon expanded or if areas were targeted for more intensive sampling to reduce the variance. Further details of these survey design changes are provided by Moriyasu et al. (2008).

The sampling design from 2006 to 2011 was modified in accordance with recommendations from the 2005 Assessment Framework Workshop on the sGSL snow crab (DFO 2006; Moriyasu et al. 2008). A new design was introduced to achieve spatial sampling homogeneity. While this survey design was spatially unbiased in the sense that the expected number of stations per 10 by 10 minute grid was proportional to its surface area, in practice the realized number of stations per grid was either one or two stations, and grids along the survey area margins often had zero stations. Past survey stations were retained as much as possible, but others were removed or added to the grid as prescribed by the sampling method (Hébert et al. 2007; Moriyasu et al. 2008).

In 2012, the sampling design was again modified following recommendations from the 2011 Snow Crab Assessment Methods Framework Science Review (DFO 2012a). The boundaries of the survey area were extended to the 20 and 200 fathom isobaths, encompassing the vast majority of favorable snow crab habitat (i.e. bottom temperatures less than 5°C) and thus the sGSL biological unit. To further improve spatial homogeneity, grids were set to be square rather than rectangular with dimensions defined as a function of the number of total samples, so that each grid included only a single sampling station (DFO 2012a). This protocol resulted in an entirely new set of sampling stations. The revised survey sampling design in 2012 is presented in Wade et al. (2014). For 2013, the number of stations increased from 325 to 355 following recommendations from the snow crab advisory committee to increase the precision of the biomass estimates in smaller fishing zones. The survey area was partitioned into square grids of 12.7 km x 12.7 km and a new set of sampling stations was generated. Since 2014, the number of sampling stations has remained at 355 and the successfully sampled stations from the previous year survey were used as fixed stations. In 2015, the 348 successfully sampled stations were used as fixed stations and a new set of seven sampling stations (the two sampling stations that were abandoned and five sampling stations that were conducted outside their assigned square grid areas in 2014) was generated randomly. In 2016, the 347 successful sampling stations from the 2015 trawl survey were used as fixed stations and a new set of eight sampling stations (the two sampling stations that were abandoned and six sampling stations that were conducted outside their assigned square grid areas in 2015) was generated randomly.

3.1.1. Trawl survey in 2017

In 2017, the number of sampling stations remained at 355. The 346 successful sampling stations from the 2016 trawl survey were used as fixed stations in 2017 and a new set of nine sampling stations (the one sampling station that was abandoned and eight sampling stations that were conducted outside their assigned square grid areas in 2016) was generated randomly (Fig. 2).

The trawl survey was conducted between July 9 and September 21 and covered Areas 12, 19, 12E and 12F (Fig. 2). The "*Jean-Mathieu*", a 65 foot stern-trawling (720 HP) steel boat, was used to conduct the trawl survey in 2017. A total of 353 stations were successfully trawled in 2017; two sampling squares had to be abandoned due to failures to successfully trawl the area.

A Bigouden Nephrops bottom trawl net, originally developed for Norway lobster (*Nephrops norvegicus*) fisheries in France, was used (20 m opening with a 28.2 m foot rope). The net is made of 2.5 mm diameter braided nylon twine and the mesh sizes are 80 mm in the wings, 60 mm in the belly and 40 mm in the cod-end (see Moriyasu et al. 2008 for more details on the description of the trawl).

All stations were trawled during the interval between morning and evening civil twilight hours. A predetermined amount of warp was let out (three times the distance of the depth) before the winch drums were locked. The start time of a standard tow was based on the information reported by the eSonar® depth and height sensors, later revised using data from a Minilog® temperature-depth probe attached to the trawl. The target duration of each tow was five minutes at a target speed of two knots. The horizontal opening of the trawl was recorded every four seconds with the eSonar® distance sensors. The swept distance of the trawl was estimated from the position (latitude/longitude) measured every second with a Differential Global Positioning System. The swept area for each tow was calculated by multiplying the swept distance and the horizontal opening of the trawl over the duration of the tow.

Tows were rejected if the net was damaged, the eSonar® system generated no usable data to determine the beginning of the tow, or the duration of the tow was less than five minutes. A replacement tow was conducted near the original start point or at the alternate sampling stations within the assigned grid (Fig. 2).

If the tow satisfied trawl survey protocols but the data signal quality from the eSonar® sensors was deemed to be inadequate to calculate the swept area, the swept area of the tow was set to the average of the values of the 10 nearest stations.

3.1.2. Biological sampling

The trawl catches were sorted on the vessel deck. Snow crabs were put aside for detailed sampling. All other organisms were sorted by species or species group and counted. Since 2010, individual length measurements for all fish species were made at 100 randomly selected stations. Fish length sampling was based on sub-samples of up to 100 individuals of each fish species in a selected tow. Starting in 2013, all species or species group were weighed.

The following information was recorded for all snow crabs: carapace width (CW), chela height (CH) for males only to the nearest 0.1 mm and carapace condition (Hébert et al. 1997). For females, the color (orange, dark orange, brown or black) and quantity (in percentages) of external eggs on ovigerous females, as well as the color (white, beige or orange) of the gonads of immature females were also noted.

The size frequency distributions for the population were derived from the samples weighted by the swept area (km^2) of each corresponding tow.

3.1.3. Estimation of snow crab abundance

The assessment follows the recommendations from the November 2011 Framework Science Peer Review of stock assessment methods for the sGSL snow crab stock (DFO 2012a).

The kriging polygon (and the survey area) has a total area of 57,840 km^2 (Fig. 3) and is partitioned into the four management areas for our analyses: 48,028 km^2 for Area 12, 3,833 km^2 for Area 19, 2,443 km^2 for Area 12E and 2,438 km^2 for Area 12F (Fig. 3). An additional unassigned zone A (above Areas 12E and 12F, Fig. 3) is included in the expanded polygon and located where no fishing activities were observed. This zone has an area of 674 km^2, while the buffer zones B and C (Fig. 3) cover an area of 112 and 310 km^2, respectively.

The sGSL biomass estimates includes the unassigned zone A and the buffer zones B and C (no fishing zones) (Fig. 3). Commercial biomass estimates in each management zone 12, 19, 12E and 12F were calculated excluding the buffer zones. Commercial biomass estimates were also calculated for each of the buffer zones (B and C) and for the unassigned zone (A).

The current model, kriging with external drift (KED) using depth as a secondary variable, used for the snow crab assessment is considered suitable for biomass estimates (DFO 2012a). A three-year average for the global variogram was calculated as this has been considered a more stable method for modeling the autocorrelation between the samples (Wade et al. 2014).

The 1997 to 2017 time series of estimated biomasses for the sGSL, using the expanded polygon of 57,840 km^2, was considered as a standardized time series for the purpose of stock assessment, development of reference points and provision of catch advice.

The data were analyzed using an integrated MATLAB toolbox (MPOGEOS), developed at the Ecole Polytechnique de Montréal, which incorporates all the functions required to perform a complete geostatistical analysis (Wade et al. 2014).

Biomass was estimated using KED on commercial-sized adult catch weights (Wade et al. 2014), with the weight estimated using a size-weight relationship:

$$W = (2.665 \times 10^{-4})\ CW^{3.098}$$

where W is the weight in grams and CW is the carapace width in mm (Hébert et al. 1992).

Total biomasses were estimated for the following categories of male crab:

- commercial-sized adult male ≥ 95 mm CW all carapace conditions,
- commercial-sized adult male crab ≥ 95 mm CW with carapace conditions 1 and 2 at the time of the survey, which represents the annual recruitment to the fishery (called R-1), and
- adult male crab ≥ 95 mm CW with carapace conditions 3, 4 and 5 (hard-shelled) at the time of the survey, which represent the residual or remaining biomass post- fishery.

The abundance indices of prerecruits at the time of the survey (R-4, R-3 and R-2) were used to forecast the recruitment to the fishery over the next four years. Stages R-4, R-3 and R-2 represent adolescent males with a CW range of 56-68 mm, 69-83 mm and larger than 83 mm, respectively, and they are expected to recruit (CW ≥ 95 mm) to the fishery in four, three and two years, respectively. The size increments from molting of pre-recruits R-4, R-3 and R-2 were set using a growth model for adolescent male snow crab (Hébert et al. 2002). The abundance of adolescent males of instar VIII, defined as those with a CW between 34 and 44 mm, was also estimated as an index of longer term recruitment. It takes at least six years for an adolescent male of instar VIII to reach the commercial size of 95 mm CW. In addition, the abundance indices of pubescent, primiparous and multiparous females were estimated.

3.2. ESTIMATION OF THE ANNUAL MORTALITY (Z) AND EXPLOITATION RATES

Annual mortality rates (*Z*) of commercial-sized adult male crab were calculated from trawl survey abundance estimates:

$$Z = -Ln\left(N_t^{3,4,5} / N_{t-1}^{1,2,3,4,5}\right)$$

where $N_{t-1}^{1,2,3,4,5}$ is abundance of commercial-sized adult crab with carapace conditions 1 to 5 after the fishery in year *t -1* and $N_t^{3,4,5}$ is the abundance of commercial-sized adult crab with carapace conditions 3, 4 and 5 after the fishery in year *t*. The corresponding proportion of annual loss is given by $1 - exp^{-Z}$.

The exploitation rate (*ER*) was calculated as the ratio of the catch (*t*) in the fishery of year *t* ($C_t^{3,4,5}$) and the commercial biomass ($B_{t-1}^{1,2,3,4,5}$) from the previous year.

$$ER = C_t^{3,4,5} / B_{t-1}^{1,2,3,4,5}$$

This exploitation rate does not consider natural mortality before or during the fishery.

3.3. RISK ANALYSIS AND CATCH OPTIONS

The Bayesian model described by Surette and Wade (2006) and Wade et al. (2014) was used to forecast the biomass of recruitment to the fishery (R-1) based on survey abundances of pre-recruits R-4, R-3 and R-2 from the sGSL, to project three, two and one year(s) into the future, respectively. The model incorporated uncertainties associated with observation errors.

3.4. SEPTEMBER MULTI-SPECIES BOTTOM TRAWL SURVEY INDEX

A second fishery independent index was calculated using 2001 to 2017 data from the September multi-species bottom trawl survey, a stratified random design, following the method presented in Benoît and Cadigan (2013). In areal extent, this survey covers that of the snow crab survey. While the catchability of the Western IIA trawl used in the September survey is much lower for snow crab than that used in the snow crab survey, it was shown that the index derived from the September survey broadly followed the same trends for commercial crab, though the uncertainty associated with the estimates was larger owing to the lower sampling intensity.

There were some minor analytical differences brought into the present update with respect to the previous analysis. Among them was a minor correction in the length-weight relationship coefficients with the exponent of the allometric equation passing from 3.089 to 3.098, as reported in the source article (Hébert et al. 2002). In addition, the length-weight relationship specific to immature male snow crab, also reported in Hébert et al. (2002), was applied to the immature component rather than the mature relationship which was previously applied. These changes resulted in a minor change in scale from the analysis presented in 2016, but as it is an index of biomass, changes in scale do not change the interpretation of the results, which rests on observed trends.

4.0. RESULTS AND DISCUSSION

4.1. ESTIMATES OF BIOMASS AND EXPLOITATION IN 2017

4.1.1. Southern Gulf

4.1.1.1. Variogram

The three-year averaged variogram model for commercial-sized adult males in 2017 had a nugget value of 2.08 x 10^6, a sill at 2.7 x 10^6 and a range of 63.6 km (Fig. 4). The annual variogram model for 2017 had a nugget value of 2.36 x 10^6, a sill at 2.36 x10^6 and a range of 0 km (Fig. 5).

4.1.1.2. Biomass estimates

The 2017 southern Gulf commercial biomass estimate was 66,021 t (95% confidence interval (C.I.) range of 57,456 to 75,495 t), a decrease of 33.4% from the 2016 estimate of 99,145 t

(87,749 to 111,600 t) (Table 1). The recruitment to the fishery at the time of the 2017 survey was estimated at 51,262 t (44,154 to 59,352 t), a decrease of 31.0% from the 2016 estimate of 74,269 t (66,381 to 82,807 t) and represents 77.6% of the commercial biomass (Table 1). The 2017 residual biomass (adult commercial-sized males with carapace conditions 3, 4 and 5) was estimated at 14,759 t (12,209 to 17,683 t), a decrease of 40.7% compared to the 2016 estimate of 24,876 t (21,369 to 28,793 t) (Table 1).

In 2017, local concentrations of commercial crab were mainly observed in Bradelle Bank, Chaleur Bay, in the southern part of the Magdalen channel and in the southeastern part of the sGSL (Fig. 6).

By carapace condition in 2017, commercial crabs were comprised of 76.2% fishery recruitment (carapace conditions 1 and 2) and 23.8% residual biomass (carapace conditions 3, 4 and 5) (Table 2). Further split by carapace condition, the residual biomass is composed of 18.3% of commercial crab with carapace condition 3, 5.1% of crabs with carapace condition 4 and 0.4% of crabs with carapace condition 5 (Table 2). This suggests that the composition of the commercial male population observed in the 2017 trawl survey is young and there is no sign of an ageing population at this time. Close monitoring of catch composition from the at-sea observer sampling and survey data is necessary to monitor the ageing of the commercial male population in the coming years.

A comparison between fishery recruitment predicted by the Bayesian model for the fishery of 2018 (46,200 t; 95% C.I. 31,400 to 64,230 t) and the recruitment biomass from the 2017 survey (51,262 t; 44,154 to 59,352 t) indicated that the estimated recruitment for the 2018 fishery is within the limits of the 95% credibility interval of the predicted value (Table 3; Fig. 7). The relationship between the abundance of R-2 prerecruits in year t and the recruitment to the fishery in year $t + 1$ is shown in Figure 8. A number of factors can account for the variability in this relationship, including variations in bycatch mortality, natural mortality, the molting schedule of precreruits (skip molting, molting to adolescent phase or molting to adult phase), and sampling error. Since 1997, the proportion of skip molters larger than 83 mm CW varied from 3.9% in 1997 to 61.0% in 2004, corresponding to its abundance (Fig. 9). In 2017, the proportion of the skip molters larger than 83 mm CW was at 33.7% while it was at 53.0% in 2015 (Fig. 9). More study is needed to better predict the arrival and growth of skip molters crabs into the population.

4.1.2. Estimation of the portion of total biomass in each management fishing zone and buffer zone

4.1.2.1. Area 12

The 2017 trawl survey estimate of commercial biomass for Area 12 was 54,739 t (47,253 to 63,068 t) (Table 4). This estimate corresponds to 83.7% of the sum of the independently estimated commercial biomasses in the four management zones.

4.1.2.2. Area 19

The 2017 post-fishery trawl survey estimate of the commercial biomass was 5,340 t (3,838 to 7,238 t) (Table 4). This estimate corresponds to 8.2% of the sum of the independently estimated commercial biomasses in the four management zones.

4.1.2.3. Areas 12E and 12F

Areas 12E and 12F lie at the margins of snow crab habitat in the sGSL and contain few sampling stations and have correspondingly uncertain biomass estimates with very large confidence intervals.

The Area 12E commercial biomass from the 2017 trawl survey was estimated at 637 t (101 to 2,173 t) (Table 4). This estimate corresponds to 1.0% of the sum of the independently estimated commercial biomasses in the four management zones.

In Area 12F, the commercial biomass from the 2017 trawl survey was estimated at 4,657 t (3,449 to 6,152 t) (Table 4). This estimate corresponds to 7.1% of the sum of the independently estimated commercial biomasses in the four management zones.

4.1.2.4. Buffer zones and unassigned zone

Commercial biomass estimates in the buffer zones and in the unassigned zone have very large confidence intervals given the low number of stations within these small zones.

The commercial biomass in the unassigned zone A above Areas 12E and 12F (Fig. 3) was 142 t (7 to 714 t) (Table 4). The commercial biomass in buffer zone B (2 nautical mile wide buffer zone) adjacent to Area 19 and 12F (Fig. 3) was estimated at 142 t (74 to 246 t) (Table 4). The commercial biomass in buffer zone C (5-miles buffer zone) located south of Area 19 (Fig. 3) was 395 t (186 to 740 t) (Table 4).

The sum of the commercial biomass estimates in the management, buffer, and unassigned zones in 2017 was 66,052 t, very close to the sGSL biomass estimate, 66,021 t (Table 4).

4.1.3. Exploitation rate

The exploitation rate in 2017 was 44.0% (Table 5; Fig. 10). The exploitation rates have varied between 20.8% and 45% from 1998 to 2017.

4.1.4. Annual mortality (Z) and difference in commercial-sized adult males

The annual mortality rate (Z), expressed as a proportion of commercial-sized adult male snow crab in the sGSL was estimated at 85.1% in 2017 and has varied between 45.8% and 82.5% from 1997 to 2016 except for 2011 where it was estimated at 5.6% (Fig. 10).

Over the time series (1997-2017), the sum of commercial biomasses from the survey was 29.4% higher than the sum of the residual biomasses and landings of the following year (Fig. 11). The difference between the commercial from the 2016 survey and the sum of the landings and the residual biomass in 2017 was 41.1% (Fig. 11). This difference (termed non-fishing directed mortality) could be attributed to a number of factors including misattribution of recruitment and residual groups, variability in survey estimates, natural mortality, by-catch mortality, unreported landings, as well as crab movement in and out of the sampling area.

4.1.5. Reproductive potential

The abundance of all adult males increased from 1997 to 1999, remained stable until 2004 and gradually decreased until 2009 (Fig. 12). From 2010 to 2017, the abundance of adult males increased to levels comparable to those observed during the 1999-2005 period (Fig. 12). The abundance of mature females (primiparous and multiparous) in 2017 remained high relative to the low values observed during 2006 to 2009 (Fig. 13). Over the time series, the annual mean size of mature females varied from 57.4 mm in 1999 to 61.7 mm CW in 2005 (Fig. 14). The mean size of mature females was 57.4 mm CW in 2017 (Fig. 14).

5.0. RISK ANALYSIS OF CATCH OPTIONS AND PROGNOSIS

Within the Precautionary Approach framework (DFO 2009), the limit reference point for biomass (B_{lim}) defines the critical / cautious zones and an upper stock reference point (B_{USR}) delimits the cautious and healthy zones on the stock status axis. A removal rate limit reference point (F_{lim}) defines the maximum removal rate in the healthy zone. Reference points which conform to the Precautionary Approach were developed in 2010 for the snow crab biological unit of the sGSL (DFO 2010). The change in methodology derived from the 2011 Snow Crab Assessment Methods Framework Science Review required the recalculation of the time series of biomass estimates and the Precautionary Approach reference points (DFO 2012b).

The rescaled B_{USR} is set at 41,400 t of commercial-sized adult males of all carapace conditions, which is 80% of the biomass of maximum sustainable yield (B_{MSY}) with the proxy for B_{MSY} chosen as 50% of the maximum estimated commercial biomass for the 1997 to 2008 time period (Table 5; Fig. 15). The rescaled B_{lim} value is 10,000 t (Table 5; Fig. 15). The B_{lim} was chosen as the lowest biomass of hard shelled commercial-sized adult males, which was observed in 2000 (residual biomass estimated from the trawl survey) (DFO 2010). The rescaled F_{lim} has been set at 34.6% (Table 5; Fig. 15), which is the average annual exploitation rate calculated as catch (weight) in year *t+1* divided by the estimated biomass of commercial-sized adult male crab from the post-fishery trawl survey in year *t* for the 1997 to 2009 time period (DFO 2010).

5.1. RISK ANALYSIS OF CATCH OPTIONS FOR 2018

The estimated commercial biomass available for the 2018 fishery in the sGSL is 66,021 t (57,456 to 75,495 t; Table 1), which is in the healthy zone of the precautionary approach framework (Fig. 15).

The predicted recruitment of commercial crab for the 2019 fishery based on the Bayesian prerecruit model (Surette and Wade, 2006; Wade et al., 2014), using the 2017 survey data, is 47,700 t (33,800 to 64,880 t) (Table 3; Fig. 16).

Harvest decision rules that conform to the precautionary approach have been developed (DFO 2014. These precautionary approach compliant harvest decision rules include rules for which the exploitation rate exceeds F_{lim} when the stock is in the healthy zone (DFO 2014). The Snow Crab Advisory Committee agreed on the proportional harvest decision rule (variant 4 in DFO 2014, Fig. 17) to derive the exploitation rate and the TAC based on the estimated biomass from the southern Gulf of St. Lawrence snow crab survey. This decision rule and the corresponding estimated commercial biomass from the 2017 survey of 66,021 t, results in a selected exploitation rate of 38.3%, corresponding to a TAC of 25,286 t for the 2018 fishery (Fig. 17).

A risk analysis was developed for the decision rule TAC and relative to other catch levels in 2018 (Table 6, Fig. 18). The risk analysis indicates that the TAC derived from the harvest decision rule will result in a near 100% chance of the biomass for the next year’s fishery being above B_{USR} and in the healthy zone of the PA (Table 6, Fig. 18). The risk analysis also provides predictions of the commercial biomass in the 2018 survey, assuming the corresponding catch level is taken in 2018. At the decision rule TAC value of 25,286 t for the 2018 fishery, the commercial biomass predicted for the 2018 post-fishery survey and for the 2019 fishery, is 69,780 t, with a 95% confidence interval range of 55,110 to 84,030 t (Table 6), an increase compared to the 2017 survey. The commercial biomass projections for 2019 according to different catch options for the 2018 fishery are presented in Table 6.

A number of factors can account for the variation in the recruitment rate of the prerecruits to the commercial-sized adult stage including unaccounted bycatch mortality, sampling uncertainties, natural mortality and variations in the molting schedule of precreruits (skip molting, molting to adolescent phase or molting to adult phase), especially if density-dependent phenomena occur. In addition, in these two-year commercial biomass projections, we used a forecast survivorship rate of 0.71, which is a five-year moving average. In the past, the survivorship rate has varied considerably from one year to the next which affects directly the commercial biomass projections.

5.2. PROGNOSIS

The fishery recruitment and the commercial biomass (by taking into account the application of the decision rule of 38.3% exploitation rate for the 2018 fishery) are expected to be 47,700 t (33,800 to 64,880 t; Table 3) and 69,780 t (55,110 to 84,030 t; Table 6**)**, respectively for the 2019 fishery. A small pulse of adolescent males, between 15 and 32 mm carapace width was observed in the 2017 survey (Fig. 19). The abundance of males with a CW between 34 and 44 mm in 2017, which will reach the commercial size in 6 years**,** remained at the same level as in 2016 (Fig. 20). The abundance of prerecruits ≥ 56 mm CW (R-4, R-3, R-2) remained high in 2017 (Table 3). The area occupied by these crabs in the 2017 survey was mostly in Chaleur Bay, on Bradelle Bank and in the southeastern part of sGSL (Fig. 21).

The estimated abundances of immature and pubescent females in the population increased from 2001 to 2012, decreased in 2013 and 2014 and increased since 2014 (Figs. 13 and 22). The increase in pubescent females observed in the 2017 trawl survey suggests that the abundance of mature females may increase in the coming years. The abundance of mature females remained high in 2017 relative to the low values observed during 2006 to 2009 (Figs. 13 and 22).

5.3. SEPTEMBER MULTI-SPECIES BOTTOM TRAWL SURVEY

The September multi-species research bottom trawl survey index shows generally similar trends (within the estimation precisions of the surveys) for commercial-sized adult male snow crab biomass between 2001 and 2017 (Fig. 23) as do the estimates from the dedicated snow crab trawl survey (Fig. 11). The September multi-species bottom trawl survey index indicated a decrease in the biomass of commercial-sized male crabs in 2017 (Fig. 23) similar to what was estimated from the dedicated snow crab survey data (Fig. 11).

6.0. UNCERTAINTIES

6.1. CHANGE IN THE SURVEY PROTOCOL AND VARIABILITY IN THE COMPOSITION OF COMMERCIAL BIOMASS

A number of survey protocol changes have weakened the assumption of homogeneity of the biomass time series.

Four different boats have been used to conduct the trawl survey: the “Emy-Serge” (1988-1998), a 65-foot side-trawling (375 HP) wooden boat, the “Den C. Martin” (1999-2002), a 65-foot stern-trawling (402 HP) steel boat, the “Marco-Michel’’ (2003-2012), a 65 feet stern-trawling (660 HP) fiberglass boat and the “Jean-Mathieu” in 2013, a 65-foot stern trawling (720 HP). Individual tows were standardized by trawl swept area using data from trawl acoustic monitoring sensors (Moriyasu et al. 2008). However, other factors may contribute to varying catchability among boats, but no comparative fishing studies were performed. A preliminary statistical comparison between snow crab survey and September multispecies survey data suggests that the boats did have different catchabilities, which can alter our perception of stock dynamics (Benoît and Cadigan 2013). Work is ongoing to refine the estimates of relative catchability of the vessels.

The kriging polygon or the area over which the abundance or biomass is estimated has increased over the years. The difference between the survey area, i.e. over which trawl samples are extracted, and the latest kriging polygon is more pronounced farther back in time. Thus there is more extrapolation and potential for bias during earlier years.

A Snow Crab Assessment Methods Framework Science Review conducted in November 2011 addressed these concerns as well as changes in survey design. Following this review, it was agreed that the time series from 1997 to the present was sufficiently coherent to be used in assessing stock status and providing catch advice (DFO 2012a). Further work is required to determine if the time series between 1989 and 1996, for which survey coverage was much less than the coverage from 1997 to the present, could also be used for assessment purposes.

6.2. GROWTH

Recruitment to the fishery for snow crab is highly variable from year to year (Comeau and Conan 1992; Sainte-Marie et al. 1995; Comeau et al. 1998; Moriyasu et al. 1998) depending on environmental conditions, predation and population levels. In sGSL snow crab stocks, the biomass of commercial-sized adult male crab appears to fluctuate from periods of three to four years of high recruitment followed by three to four years of low recruitment (Sainte-Marie et al. 1995; Comeau et al. 1998; Moriyasu et al. 1998). Since molting activity peaks in January for adolescent skip-molters and in March for normal molters, most postmolt males are potentially catchable as soon as the fishery starts (generally at the end of April). Soft-shelled males in the commercial catches are found from late April to August in the sGSL (Hébert et al. 2002).

The mechanism of molting to terminal phase is complex. Conan et al. (1988), and Comeau et al. (1998) hypothesized that the molt to terminal phase for a given size group may be density-dependent rather than genetically determined. Waiwood and Elner (1982) hypothesized that the removal of large old crab would release the snow crab population from a “stagnant” to a “dynamic” high-growth phase. Comeau et al. (1998) suggested that a high abundance of large mature (adult) males in the population may trigger molting to another larger juvenile (adolescent) instar stage instead of molting to the terminal phase. Alternatively growth could be inhibited resulting in an increased abundance of skip-molters. The annual trawl survey showed a very high (up to 50–60% in peak years) skip-molting rate in adolescent males larger than 50 mm CW. Such a high percentage of skip-molters may reflect a density-dependent effect on the molting schedule of larger adolescent males. Dawe et al. (2012) showed that the frequency of skip-molting is strongly and directly related to body size (i.e. larger than 50mm CW), and it is also inversely related to water temperature. Prediction of a given size of male crab belonging to the near-future recruitment population (R-1, R-2 and R-3) is difficult, which increases uncertainty of predicted and measured abundance of recruitment to the fishery. This may be a driving factor affecting the strength and timing of recruitment to the fishery.

6.3. ENVIRONMENTAL CONSIDERATIONS

Environmental factors, such as water temperature, can affect molting, reproductive dynamics and the movement of snow crab. Chassé and Pettipas (2009) reported that bottom temperatures over most of the sGSL are typically between -1 and 3ºC, a temperature range suitable for snow crab habitat. Data collected during research surveys indicate that the bottom temperatures in deeper waters of Areas 12E and 12F are higher (1 to 5ºC) than on the crab grounds (-1 to 2ºC) in Area 12. Bottom temperatures in Area 19 are usually 1 to 2 ºC warmer than on the traditional crab grounds in Area 12 (Chassé and Pettipas 2009).

In September 2017, near-bottom temperatures were near the mean value of the period 1981 to 2010 in most of the central portion of Area 12 as well as in Area 19 (Fig. 24). However, the bottom waters in Area 12E, Area 12F and the northwestern portion of the southern Gulf of St. Lawrence (channels connecting the slope of the Laurentian Channel to the Magdalen Shallows) were warmer than normal. Bottom waters in the western part of Chaleur Bay also were warmer than average (Fig. 24). There was a band of cooler-than-normal bottom waters in the southwestern part of Area 12 that stretched down from Miscou Island to both the west and east entrances of Northumberland Strait including St. George's Bay (Fig. 24).

Most of the snow crab fishing grounds had similar temperatures in 2017 compared to 2016 except for the area around PEI, the mouth of Chaleur Bay and in Area 19 where cooler bottom waters were present. The head of Chaleur Bay and a small area south of Shediac Valley had bottom waters that were warmer in 2017 than in 2016 (Fig. 24).

The snow crab habitat index (bottom area with temperatures from -1 to 3°C) was above the 1981-2010 average (4% above) in 2017 and increased by 5% from 2016 and 10% from 2015 (Fig. 25). In 2017, the mean temperature (0.9°C) within the defined snow crab habitat area index (-1 to 3°C) decreased by about 0.1°C compared to 2016 (1.0ºC). The mean temperature was at the highest of the 45 year time series in 2012, decreased in 2013 and 2014, and remained slightly above the normal since then (Fig. 25).

Snow crab is a stenothermic species with a preference for colder water temperatures. A temperature regime shift from cold to warm may have impacts on population dynamics of snow crab such as shortened reproductive cycles, increased per capita fecundity, and increased size at maturity, greater natural mortality, spatial contraction of habitat, and skewed sex ratio for reproduction. The outcome of climate change on snow crab population dynamics can be relatively abrupt and even detrimental, and the direction of the effect may be difficult to predict (Sainte-Marie et al. 2008).

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8.0. REFERENCES CITED

Benhalima, K., Moriyasu, M., and Hébert, M. 1998. A technique for identifying the early-premolt stage in the male snow crab, *Chionoecetes opilio*, (Brachyura: Majidae) in Baie des Chaleurs, southern Gulf of St. Lawrence. Can. J. Zool. 76: 609-617.

Benoît, H.P., and Cadigan, N. 2013. Model-based estimation of commercial- sized snow crab (*Chionoecetes opilio*) abundance in the southern Gulf of St. Lawrence, 1980-2012, using data from two bottom trawl surveys. DFO Can. Sci. Advis. Sec. Res. Doc. 2013/114.

Chassé, J., and Pettipas, R.G. 2009. Temperature Conditions in the southern Gulf of St. Lawrence during 2008 relevant to snow crab. DFO Can. Sci. Advis. Sec. Res. Doc. 2009/087.

Chiasson, Y., and Hébert, M. 1990. Literature review on stock delimitation pertaining to the Western Cape Breton Island snow crab (*Chionoecetes opilio*) and advice on a spring fishery in Area 18. DFO Can. Atl. Fish. Stock Assess. Sec. Res. Doc. 90/65.

Comeau, M., and Conan, G.Y. 1992. Morphometry and gonad maturity of male snow crab, *Chionoecetes opilio*. Can. J. Fish. Aquat. Sci. 49: 2460-2468.

Comeau, M., Conan, G.Y., Maynou, F., Robichaud, G., Therriault, J.-C., and Starr, M. 1998. Growth, spatial distribution, and abundance of benthic stages of the snow crab (*Chionoecetes opilio*) in Bonne Bay, Newfoundland, Canada. Can. J. Fish. Aquat. Sci. 55: 262-279.

Conan, G.Y., and Comeau, M. 1986. Functional maturity of male snow crab, (*Chionoecetes opilio*). Can. J. Fish. Aquat. Sci. 43: 1710-1719.

Conan, G.Y., Moriyasu, M., Comeau, M., Mallet, P., Cormier, R., Chiasson, Y., and Chiasson, H. 1988. Growth and maturation of snow crab (*Chionoecetes opilio*), p. 45-66. In G.S. Jamieson and W.D. McKone (eds.). Proceedings of the international workshop on snow crab biology, December 8-10, 1987, Montréal Québec. Can. Mans. Rep. Fish. Aquat. Sci. 2005.

Dawe E., Mullowney D., Moriyasu M., and Wade E. 2012. Effects of temperature on size-at-terminal molt and molting frequency in snow crab *Chionoecetes opilio* from two Canadian Atlantic ecosystems. Mar. Ecol. Prog. Ser. 469:279-296.

DFO. 2006. Proceedings of the Assessment Framework Workshop on the southern Gulf of St. Lawrence snow crab (Areas 12, E, F and 19), Gulf Regional Advisory Process; 11-14 October 2005. DFO Can. Sci. Advis. Sec. Proc. Ser. 2006/042.

DFO. 2009. A fishery decision-making framework incorporating the Precautionary Approach.

DFO. 2010. Reference points consistent with the precautionary approach for snow crab in the southern Gulf of St. Lawrence. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2010/014.

DFO. 2011. Assessment of Nova Scotia (4VWX) snow crab. DFO. Can. Sci. Advis. Sec. Sci. Advis. Rep. 2011/045.

DFO. 2012a. Proceedings of the Gulf Region Science Peer Review Framework Meeting of Assessment Methods for the Snow Crab Stock of the southern Gulf of St. Lawrence; November 21 to 25, 2011. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2012/023.

DFO. 2012b. Revised reference points for snow crab to account for the change in estimation area of the southern Gulf of St. Lawrence biological unit. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2012/002.

DFO. 2014. Assessment of candidate harvest decision rules for compliance to the precautionary approach framework for the snow crab fishery in the southern Gulf of St. Lawrence. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2014/007.

Dufour, R., Bernier, D., and Brêthes, J.-C. 1997. Optimization of meat yield and mortality during snow crab (*Chionoecetes opilio*, O. Fabricius) fishing operations in Eastern Canada. Can. Tech. Rep. Fish. Aquat. Sci. 2152.

Fonseca, D.B., Sainte-Marie, B., and Hazel, F. 2008. Longevity and change in shell condition of adult male snow crab, *Chionoecetes opilio*, inferred from dactyl wear and mark-recapture data. Trans. Amer. Fish. Soc., 137:4, 1029-1043.

Hébert, M., Gallant, C., Chiasson, Y., Mallet, P., DeGrâce, P., et Moriyasu, M. 1992. Le suivi du pourcentage de crabes mous dans les prises commerciales de crabe des neiges (*Chionoecetes opilio*) dans le sud-ouest du golfe du Saint-Laurent (zone 12) en 1990 et 1991. Rapp. Tech. Can. Sci. Halieut. Aquat. 1886.

Hébert, M., Wade, E., DeGrâce, P., Biron, M., and Moriyasu, M. 1997. 1996 assessment of snow crab (*Chionoecetes opilio*) stock in the southern Gulf of St. Lawrence (Areas 12, 18, 19, 25/26 and zones E and F). DFO Can. Sci. Advis. Sec. Res. Doc. 1997/086.

Hébert, M., Benhalima, K., Miron, G., and Moriyasu, M. 2002. Molting and growth of male snow crab, *Chionoecetes opilio*, (O. Fabricius, 1788) (Crustacea: Majidae) in the southern Gulf of St. Lawrence. Crustaceana 75: 671-702.

Hébert, M., Wade, E., Surette, T., and Moriyasu, M. 2007. The 2006 assessment of snow crab (*Chionoecetes opilio*) stock in the southern Gulf of St. Lawrence (Areas 12, 19, E and F). DFO Can. Sci. Advis. Sec. Res. Doc. 2007/028.

Hébert, M., Wade, E., DeGrâce, P., Bélanger, P., and Moriyasu, M. 2008. The 2007 assessment of snow crab (*Chionoecetes opilio*) stock in the southern Gulf of St. Lawrence (Areas 12, 19, E and F). DFO Can. Sci. Advis. Sec. Res. Doc. 2008/040.

Hébert, M., Wade, E., Biron, M., DeGrâce, P., Landry, J.-F., and Moriyasu, M. 2012. The 2011 assessment of snow crab, *Chionoecetes opilio*, stocks in the southern Gulf of St. Lawrence (Areas 12, 19, E and F). DFO Can. Sci. Advis. Sec. Res. Doc. 2012/080.

Kuhn, P.S., and Choi, J.S. 2011. Influence of temperature on embryo developmental cycles and mortality of female *Chionoecetes opilio* (snow crab) on the Scotian Shelf, Canada. Fish. Res. 107: 245-252.

Mallet, P., Conan, G.Y., and Moriyasu, M. 1993. Periodicity of spawning and duration of incubation time for *Chionoecetes opilio*, in the Gulf of St. Lawrence. ICES CM/1993: K:26.

Moriyasu, M., and Conan, G.Y. 1988. Aquarium observation on mating behaviour of snow crab, *Chionoecetes opilio*. ICES C. M., 1988/K: 9.

Moriyasu, M., Conan, G.Y., Mallet, P., Chiasson, Y.J., and Chiasson, H. 1988. Growth at molt, molting season and mating of snow crab, *Chionoecetes opilio*, in relation to functional and morphometric maturity. ICES CM/1987 K:21.

Moriyasu, M., and Comeau, M. 1996. Grasping behavior of male snow crab, (*Chionoecetes opilio* O. Fabricius, 1788, Decapoda, Majidae). Crustaceana 69: 211-222.

Moriyasu, M., and Lanteigne, C. 1998. Embryo development and reproductive cycle in the snow crab, *Chionoecetes opilio* (Crustacea: Majidae), in the southern Gulf of St. Lawrence, Canada. Can. J. Zool. 76: 2040-2048.

Moriyasu, M., Wade, E., Sinclair, A., and Chiasson, Y. 1998. Snow crab, *Chionoecetes opilio*, stock assessment in the southwestern Gulf of St. Lawrence by bottom trawl survey. Can. Spec. Publ. Fish. Aquat. Sci. 125:29-40.

Moriyasu, M., Wade, E., Hébert, M., and Biron, M. 2008. Review of the survey and analytical protocols used for estimating abundance indices of southern Gulf of St. Lawrence snow crab from 1988 to 2006. DFO Can. Sci. Advis. Sec. Res. Doc. 2008/069.

Rondeau, A., and Sainte-Marie, B. 2001. Variable mate-guarding time and sperm allocation by male snow crab, *Chionoecetes opilio*, in response to sexual competition, and their impact on the mating success of females. Biol. Bull. 201: 204-217.

Sainte-Marie, B., and Hazel, F. 1992. Moulting and mating of snow crabs, *Chionoecetes opilio* (O. Fabricius), in shallow waters of the northwestern Gulf of Saint Lawrence. Can. J. Fish. Aquat. Sci. 49: 1282-1293.

Sainte-Marie, B., and Carrière, C. 1995. Fertilization of the second clutch of eggs of snow crab, *Chionoecetes opilio*, from females mated once or twice after their molt to maturity. Fish. Bull. 93: 759-764.

Sainte-Marie, B., Raymond, S., and Brêthes, J.-C. 1995. Growth and maturation of the benthic stages of male snow crab, *Chionoecetes opilio* (Brachyura: Majidae). Can. J. Fish. Aquat. Sci. 52: 903-924.

Sainte-Marie, B., Urbani, N., Sévigny, J.-M., Hazel, F., and Kuhnlein, U. 1999. Multiple choice criteria and the dynamics of assortative mating during the first breeding season of female snow crab *Chionoecetes opilio* (Brachyura, Majidae). Mar. Ecol. Prog. Ser. 181: 141-153.

Sainte-Marie, B., Gosselin, T., Sévigny, J.-M., and Urbani, N. 2008. The snow crab mating system: opportunity for natural and unnatural selection in a changing environment. Bull. Mar. Sci. 83: 131-161.

Surette, T., and Wade, E. 2006. Bayesian serial linear regression models for forecasting the short-term abundance of commercial snow crab (*Chionoecetes opilio*). Can. Tech. Rep. Fish. Aquat. Sci. 2672.

Wade, E., Moriyasu, M., and Hébert, M. 2014. Methods and models used in the 2012 assessment of the snow crab (*Chionoecetes opilio*), stock in the southern Gulf of St-Lawrence.DFO Can. Sci. Advis. Sec. Res. Doc. 2013/113.

Waiwood, K.G., and Elner, R.W. 1982. Cod predation of snow crab (*Chionoecetes opilio*) in the Gulf of St. Lawrence. In: Proceedings of the International Symposium on the genus Chionoecetes. p. 449-520. Lowell Wakefield Symposium Series, Alaska Sea Grant Report. 82:10. University of Alaska Fairbanks.

Watson, J. 1969. Biological investigation on the spider crab, *Chionoecetes opilio*, p. 23-47. In Proc. Meeting on Atlantic Crab Fishery Development. Can. Fish. Rep. 13.

Watson, J. 1972. Mating behavior in the Spider Crab, *Chionoecetes opilio*. J. Fish. Res. Board Can. 29: 447-449.

TABLES

Table 1. Estimated biomass (t, mean and 95% confidence interval in parentheses) of commercial-sized adult male snow crab, Chionoecetes opilio, in the southern Gulf of St. Lawrence (all zones) by kriging, based on trawl survey data from 1997 to 2017. Recruitment refers to snow crab with carapace conditions 1 and 2 whereas residual biomass refers to snow crab with carapace conditions 3 to 5.

Survey year	Commercial biomass	Recruitment biomass	Residual biomass
1997	65,310 (54,801-77,239)	37,619 (26,376-52,064)	27,690 (21,995-34,407)
1998	57,595 (45,630-71,735)	29,818 (17,580-47,435)	27,775 (21,022-36,013)
1999	57,051 (47,946-67,376)	25,874 (15,918-39,818)	31,177 (25,051-38,346)
2000	49,823 (40,473-60,682)	39,845 (30,543-51,093)	9,977 (6,649-14,401)
2001	59,150 (47,740-72,460)	42,243 (31,198-55,942)	16,905 (12,657-22,125)
2002	79,559 (66,688-94,181)	66,481 (53,434-81,746)	13,075 (10,451-16,157)
2003	84,423 (71,964-98,410)	57,503 (44,809-72,679)	26,919 (21,223-33,674)
2004	103,429 (91,029-117,036)	83,702 (70,955-98,069)	19,726 (15,836-24,280)
2005	82,537 (73,487-92,387)	58,398 (48,417-69,824)	24,140 (18,726-30,632)
2006	74,285 (66,192-83,087)	54,371 (46,124-63,660)	19,914 (16,161-24,275)
2007	66,660 (60,183-73,638)	39,635 (33,089-47,092)	27,025 (23,354-31,106)
2008	52,564 (46,658-59,006)	31,555 (25,181-39,048)	21,010 (17,960-24,426)
2009	30,920 (27,237-34,959)	20,520 (16,848-24,754)	10,399 (8,560-12,516)
2010	35,795 (31,681-40,291)	20,351 (15,360-26,450)	15,444 (12,859-18,394)
2011	63,162 (55,965-71,022)	29,394 (20,909-40,190)	33,768 (28,297-39,985)
2012	74,997 (65,822-85,086)	48,969 (38,667-61,173)	26,028 (21,950-30,641)
2013	65,868 (56,283-76,610)	38,981 (28,969-51,346)	26,886 (22,909-31,352)
2014	67,534 (60,994-74,579)	43,630 (36,774-51,388)	23,897 (20,927-27,168)
2015	58,808 (52,754-65,466)	34,929 (31,670-38,429)	24,022 (20,761-27,647)
2016	99,145 (87,749-111,600)	74,269 (66,381-82,807)	24,876 (21,369-28,793)
2017	66,021 (57,456-75,495)	51,262 (44,154-59,352)	14,759 (12,209-17,683)

Table 2. Abundance (number in million; mean and 95% confidence interval) of commercial-sized adult male crabs by carapace condition (CC 1+2, CC3, CC4 and CC5) in the southern Gulf of St. Lawrence based on trawl survey data from 1997 to 2017.

Survey year	Carapace condition 1+2			Carapace condition 3			Carapace condition 4			Carapace condition 5		
	Mean	Confidence interval		Mean	Confidence interval		Mean	Confidence interval		Mean	Confidence interval	
1997	61.272	51.848	71.906	27.858	22.644	33.910	17.144	13.556	21.391	5.675	4.154	7.574
1998	51.738	41.550	63.665	23.956	18.874	29.986	15.711	12.041	20.150	8.891	6.220	12.327
1999	49.755	40.294	60.766	32.840	25.189	42.086	16.258	12.637	20.594	7.874	5.239	11.380
2000	67.530	51.847	86.473	10.242	5.622	17.199	7.384	4.455	11.538	2.527	1.147	4.860
2001	76.238	60.652	94.604	26.667	21.371	32.876	5.134	2.502	9.401	1.474	0.393	3.917
2002	112.785	95.089	132.807	21.605	17.356	26.578	4.318	2.646	6.664	0.893	0.411	1.701
2003	99.346	84.820	115.635	38.180	30.183	47.646	11.431	7.097	17.466	1.715	0.717	3.485
2004	138.152	120.945	157.106	28.964	23.320	35.559	9.867	7.684	12.479	1.072	0.671	1.629
2005	97.311	87.537	107.870	30.516	23.465	39.022	10.679	8.049	13.895	0.567	0.217	1.222
2006	84.216	75.183	94.027	29.830	24.513	35.955	5.725	3.991	7.961	1.030	0.552	1.762
2007	62.530	55.515	70.179	32.053	25.962	39.141	14.243	10.714	18.566	1.004	0.523	1.752
2008	51.110	44.873	57.967	23.028	18.600	28.191	11.440	8.614	14.900	3.081	1.951	4.635
2009	31.729	27.218	36.771	12.714	10.170	15.701	5.393	3.832	7.379	1.276	0.685	2.179
2010	32.854	28.548	37.624	20.628	16.819	25.040	4.223	3.236	5.417	1.567	0.925	2.490
2011	53.387	46.199	61.369	45.065	37.545	53.646	9.979	7.706	12.713	1.778	1.024	2.878
2012	86.900	72.956	102.723	38.900	32.850	45.736	5.570	4.238	7.676	1.150	0.601	2.002
2013	62.875	54.251	72.471	30.204	25.895	35.020	18.560	14.744	23.060	0.695	0.338	1.273
2014	73.141	63.594	82.687	29.788	25.261	34.315	13.134	10.268	16.000	0.658	0.180	1.136
2015	56.225	47.830	64.620	27.129	22.603	31.654	17.339	14.164	20.513	0.505	0.023	0.986
2016	126.470	110.200	144.450	31.145	25.096	38.211	15.162	12.228	18.563	0.071	0.007	0.280
2017	90.439	77.608	104.774	21.721	16.881	27.519	6.101	4.797	7.650	0.365	0.129	0.824

Table 3. Data used in the risk analysis of catch options: point estimates of abundance (number in million) of snow crab male prerecruits (R-4, R-3 and R-2), the estimated (with 95% confidence intervals) and forecast (from the Bayesian model with 95% credible intervals) values for recruitment biomass (t; R-1), estimated residual biomass (t) and estimated commercial biomass (t) in the southern Gulf of St. Lawrence based on trawl survey data, and survivorship rates (S) between years used for the forecast model of commercial biomass. S is calculated based on a 5-year moving average.

	Prerecruit number (million)							
Survey Year	R – 4	R - 3	R - 2	Recruitment to the fishery (R-1; t)	Forecast recruitment (R-1 ; t)	Residual biomass (t)	Commercial biomass (t)	Survivorship rates (S)
1997	114.2	92.7	57.9	37,619 (26,376-52,064)	na	27,690 (21,995-34,407)	65,310 (54,801-77,239)	na
1998	139.5	91.6	57.1	29,818 (17,580-47,435)	na	27,775 (21,022-36,013)	57,595 (45,630-71,735)	na
1999	199.7	150.9	115.0	25,874 (15,918-39,818)	na	31,177 (25,051-38,346)	57,051 (47,946-67,376)	na
2000	238.7	159.4	89.3	39,845 (30,543-51,093)	na	9,977 (6,649-14,401)	49,823 (40,473-60,682)	na
2001	313.2	229.2	135.7	42,243 (31,198-55,942)	na	16,905 (12,657-22,125)	59,150 (47,740-72,460)	na
2002	166.7	241.8	199.7	66,481 (53,434-81,746)	na	13,075 (10,451-16,157)	79,559 (66,688-94,181)	na
2003	137.8	207.1	181.4	57,503 (44,809-72,679)	na	26,919 (21,223-33,674)	84,423 (71,964-98,410)	na
2004	86.4	122.8	142.5	83,702 (70,955-98,069)	na	19,726 (15,836-24,280)	103,429 (91,029-117,036)	na
2005	63.3	79.4	117.1	58,398 (48,417-69,824)	60,500 (38,800-86,000)	24,140 (18,726-30,632)	82,537 (73,487-92,387)	na
2006	55.0	49.8	65.3	54,371 (46,124-63,660)	49,700 (33,200-73,000)	19,914 (16,161-24,275)	74,285 (66,192-83,087)	na
2007	57.2	47.9	56.0	39,635 (33,089-47,092)	35,200 (21,300-55,000)	27,025 (23,354-31,106)	66,660 (60,183-73,638)	na
2008	80.4	54.3	45.8	31,555 (25,181-39,048)	29,000 (18,500-42,000)	21,010 (17,960-24,426)	52,564 (46,658-59,006)	na
2009	89.4	69.5	43.6	20,520 (16,848-24,754)	27,700 (17,800-38,000)	10,399 (8,560-12,516)	30,920 (27,237-34,959)	na
2010	140.4	109.1	71.8	20,351 (15,360-26,450)	25,900 (17,100-37,000)	15,444 (12,859-18,394)	35,795 (31,681-40,291)	0.65
2011	91.5	98.7	87.6	29,394 (20,909-40,190)	33,700 (22,900-47,000)	33,768 (28,297-39,985)	63,162 (55,965-71,022)	0.69
2012	96.0	86.8	80.4	48,969 (38,667-61,173)	40,700 (31,300-52,400)	26,028 (21,950-30,641)	74,997 (65,822-85,086)	0.69
2013	103.8	87.5	78.4	38,981 (28,969-51,346)	40,380 (31,670-50,380)	26,886 (22,909-31,352)	65,868 (56,283-76,610)	0.73

Survey Year	Prerecruit number (million) R – 4	R - 3	R - 2	Recruitment to the fishery (R-1; t)	Forecast recruitment (R-1 ; t)	Residual biomass (t)	Commercial biomass (t)	Survivorship rates (S)
2014	107.1	96.1	118.5	43,630 (36,774-51,388)	37,893 (28,568-49,114)	23,897 (20,927-27,168)	67,534 (60,994-74,579)	0.72
2015	107.3	126.6	127.8	34,929 (31,670-38,429)	42,300 (32,760-51,840)	24,022 (20,761-27,647)	58,808 (52,570-65,578)	0.73
2016	112.1	125.2	101.8	74,269 (66,381-82,807)	50,000 (36,400-66,900)	24,876 (21,369-28,793)	99,145 (87,749-111,600)	0.76
2017	111.7	120.9	103.4	51,262 (44,154-59,352)	46,200 (31,400-64,230)	14,759 (12,209-17,683)	66,021 (57,456-75,495)	0.73
2018	na	na	na	na	47,700 (33,800-64,880)	na	na	0.71

Table 4. Estimated snow crab commercial biomass (t; mean and 95% confidence interval) in 2017 using kriging with external drift for the southern Gulf overall, by management areas 12, 19, 12E and 12F, and in buffer zones.

Areas	Surface area (km^2)	Commercial biomass (t) Mean	Commercial biomass (t) 95% confidence interval
Southern Gulf	57,840	66,021	57,456-75,495
Area 12	48,028	54,739	47,253-63,068
Area 19	3,833	5,340	3,838-7,238
Area 12E	2,443	637	101-2,173
Area 12F	2,438	4,657	3,449-6,152
Sum of management areas	56,742	65,373	na
Unassigned zone above 12E (A)	674	142	7-714
Buffer zone 19/12F (B)	112	142	74-246
Buffer zone 12/ 19 (C)	310	395	186-740
Sum of total areas and zones	57,838	66,052	na

Table 5. Data (from the trawl survey data, 1997 to 2008, using kriging in weights) used in the development of reference points for the snow crab fishery of the southern Gulf and exploitation rates for the fisheries in 1998 to 2017.

		Southern Gulf of St. Lawrence		
Year of the fishery	Landings (t)	Estimated commercial biomass (t) from survey in year t-1	Estimated residual biomass (t) from survey in year t-1	Exploitation rate (%) (landings fishery year t / commercial biomass year t-1)
1998	13,575	65,310 (54,801-77,239)	27,690 (21,995-34,407)	20.8
1999	15,110	57,595 (45,630-71,735)	27,775 (21,022-36,013)	26.2
2000	18,712	57,051 (47,946-67,376)	31,177 (25,051-38,346)	32.8
2001	18,262	49,823 (40,473-60,682)	9,977 (6,649-14,401)	36.7
2002	25,691	59,150 (47,740-72,460)	16,905 (12,657-22,125)	43.4
2003	21,163	79,559 (66,688-94,181)	13,075 (10,451-16,157)	26.6
2004	31,675	84,423 (71,964-98,410)	26,919 (21,223-33,674)	37.5
2005	36,118	103,429 (91,029-117,036)	19,726 (15,836-24,280)	34.9
2006	29,121	82,537 (73,487-92,387)	24,140 (18,726-30,632)	35.3
2007	26,867	74,285 (66,192-83,087)	19,914 (16,161-24,275)	36.2
2008	24,458	66,660 (60,183-73,638)	27,025 (23,354-31,106)	36.7
2009	23,642	52,564 (46,658-59,006)	21,010 (17,960-24,426)	45.0
2010	9,549	30,920 (27,237-34,959)	10,399 (8,560-12,516)	30.9
2011	10,708	35,795 (31,681-40,291)	15,444 (12,859-18,394)	29.9
2012	21,956	63,162 (55,965-71,022)	33,768 (28,297-39,985)	34.8
2013	26,049	74,997 (65,822-85,086)	26,028 (21,950-30,641)	34.7
2014	24,479	65,868 (56,283-76,610)	26,886 (22,909-31,352)	37.1
2015	25,911	67,534 (60,994-74,579)	23,897 (20,927-27,168)	38.4
2016	21,725	58,808 (52,570-65,578)	24,022 (20,761-27,647)	36.9
2017	43,656	99,145 (87,749-111,600)	24,876 (21,369-28,793)	44.0
2018	na	66,021 (57,456-75,495)	14,759 (12,209-17,683)	na

Table 6. Risk analyses for different catch options in 2018 for the southern Gulf of St. Lawrence snow crab fishery showing probabilities of the commercial-sized adult male biomass falling below the limit reference point for biomass (B_{lim}), and being over the upper stock reference point (B_{USR}) after the fishery in 2018. In bold is the catch option (exploitation rate of 38.3% corresponding to the commercial biomass of 66,021 t) according to the agreed decision rule of the Precautionary Approach (variant 4, DFO 2014).

Catch option (t) for 2018	Probability commercial-sized adult male biomass after the fishery		Predicted commercial biomass for 2019 (t)
	< B_{lim} (10,000 t)	≥ B_{usr} (41,400 t)	
20,000	0	1	74,770 (60,400-89,320)
21,000	0	1	73,770 (59,400-88,320)
22,000	0	1	72,770 (58,400-87,320)
23,000	0	1	71,770 (57,400-86,320)
24,000	0	1	70,770 (56,400-85,320)
25,286	0	1	69,780 (55,110-84,030)
26,000	0	1	68,770 (54,400-83,320)
27,000	0	1	67,770 (53,400-82,320)
28,000	0	1	66,770 (52,400-81,320)
29,000	0	1	65,770 (51,400-80,320)
30,000	0	1	64,770 (50,400-79,320)
31,000	0	1	63,770 (49,400-78,320)
32,000	0	1	62,770 (48,400-77,320)
33,000	0.1	1	61,770 (47,400-76,320)
34,000	0.2	1	60,770 (46,400-75,320)
35,000	0.3	1	59,770 (45,400-74,320)
36,000	0.4	1	58,770 (44,400-73,320)
37,190	0.5	1	57,580 (43,210-72,130)
53,420	1	0.5	41,350 (26,980-55,900)

FIGURES

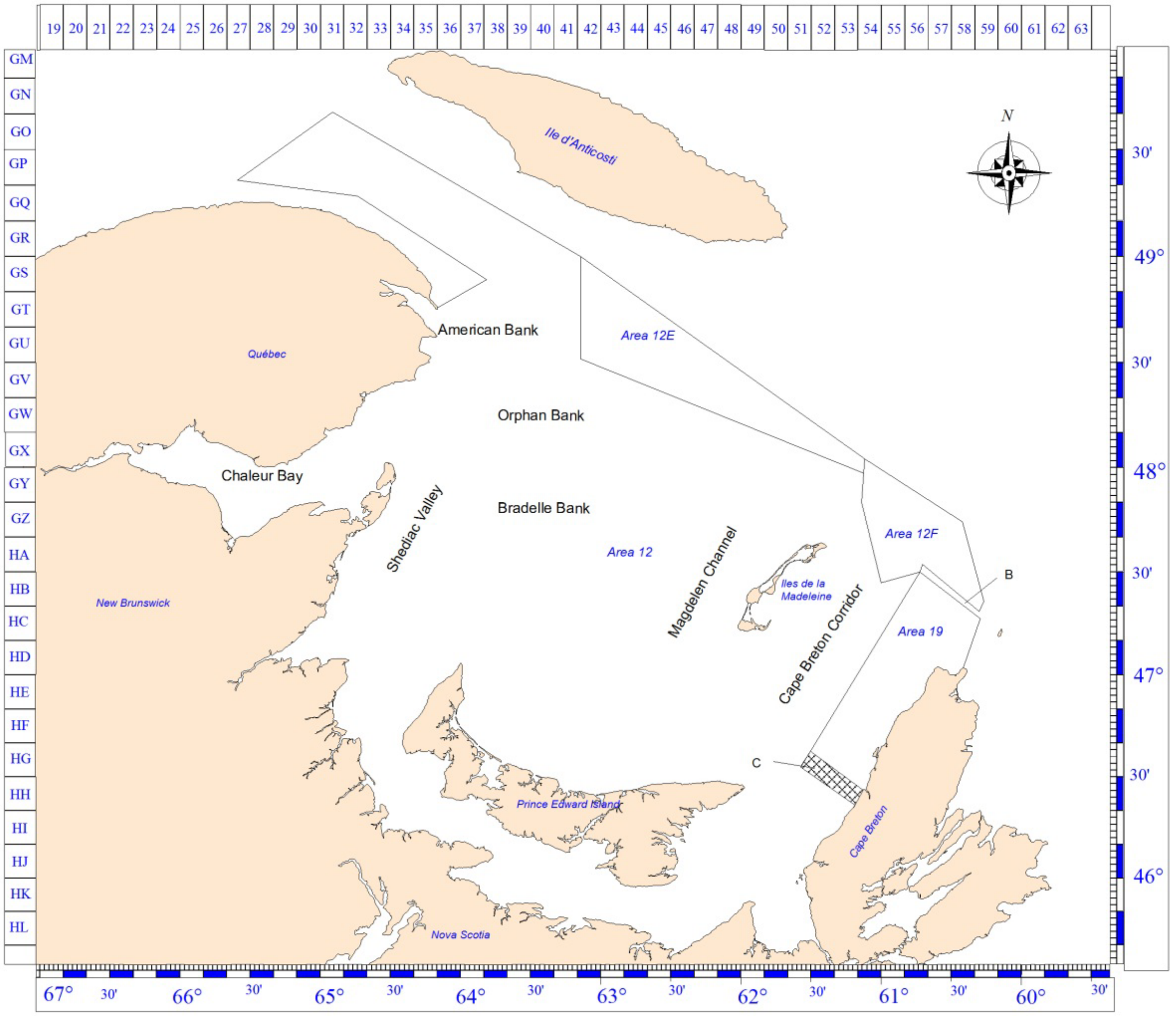


Figure 1. Map of the southern Gulf of St. Lawrence showing the snow crab (Chionoecetes opilio) fishing areas fishing grounds, and management buffer zones (labels B and C, shaded areas).

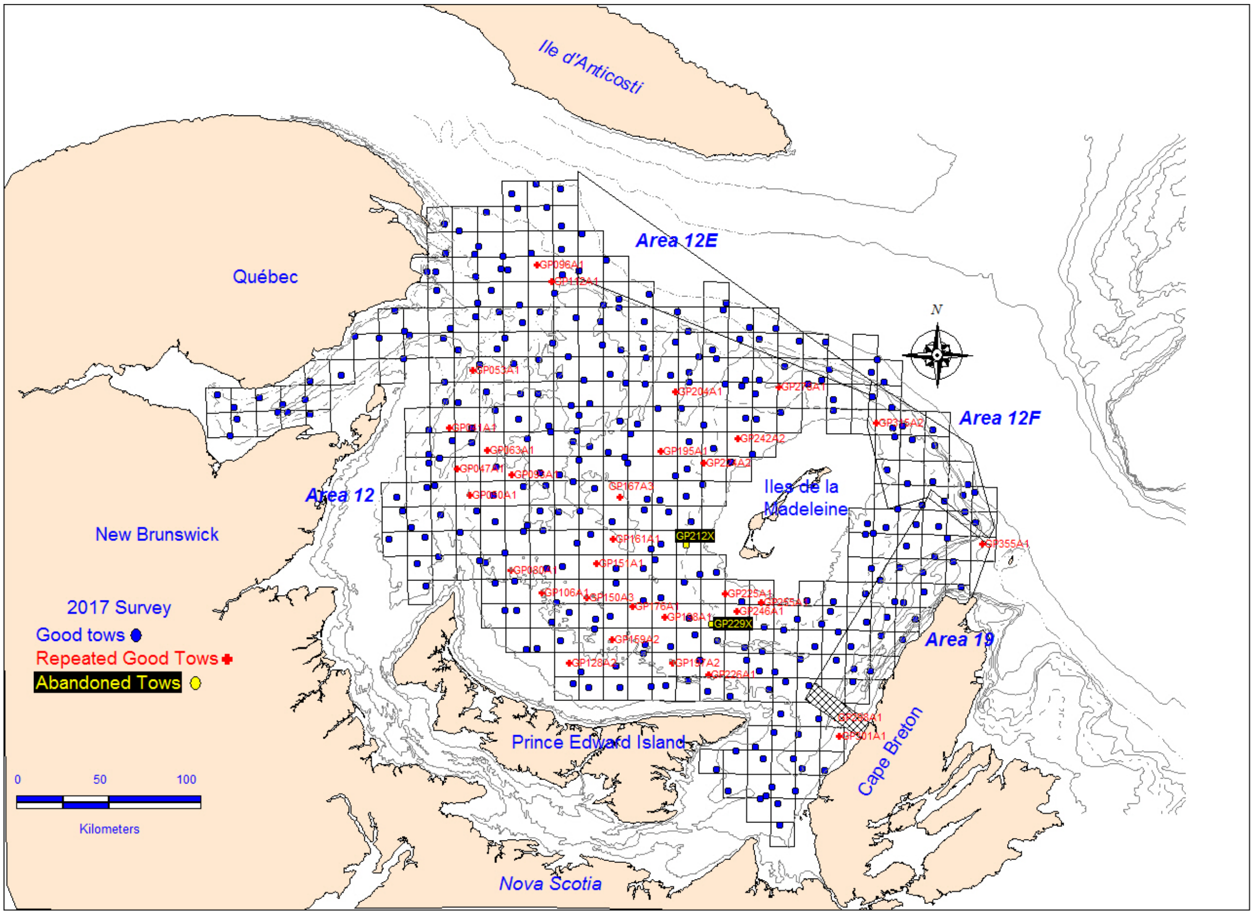


Figure 2. Locations of the 2017 snow crab (Chionoecetes opilio) trawl survey stations within the estimation polygon of 57,840 km^2 in the southern Gulf of St. Lawrence. The blue points are successful tows, red points are successful repeat tows and yellow points are abandoned tows.

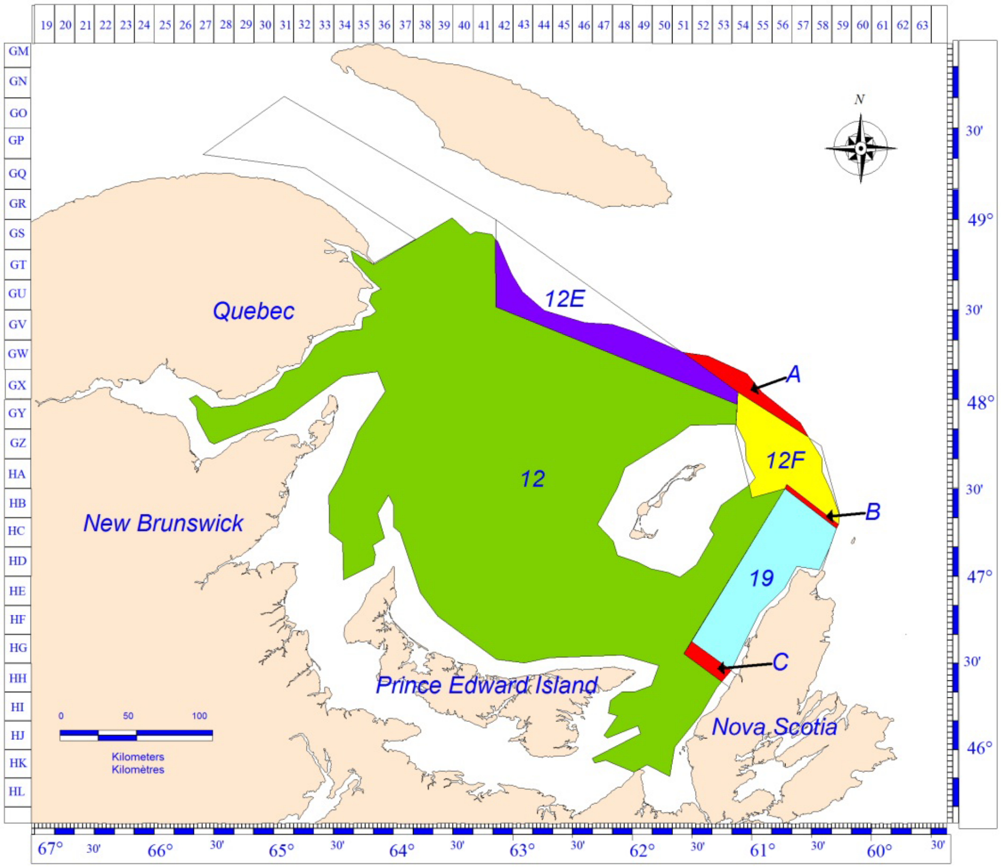


Figure 3. The estimation polygon of 57,840 km^2 used for the 2017 snow crab (Chionoecetes opilio) stock assessment in the southern Gulf of St. Lawrence (all coloured areas) and corresponding estimation polygons for the four crab fishing areas (12, 12E, 12F and 19). The unassigned zone north of areas 12E and 12F (label A) and buffer zones (labels B and C) are also shown.

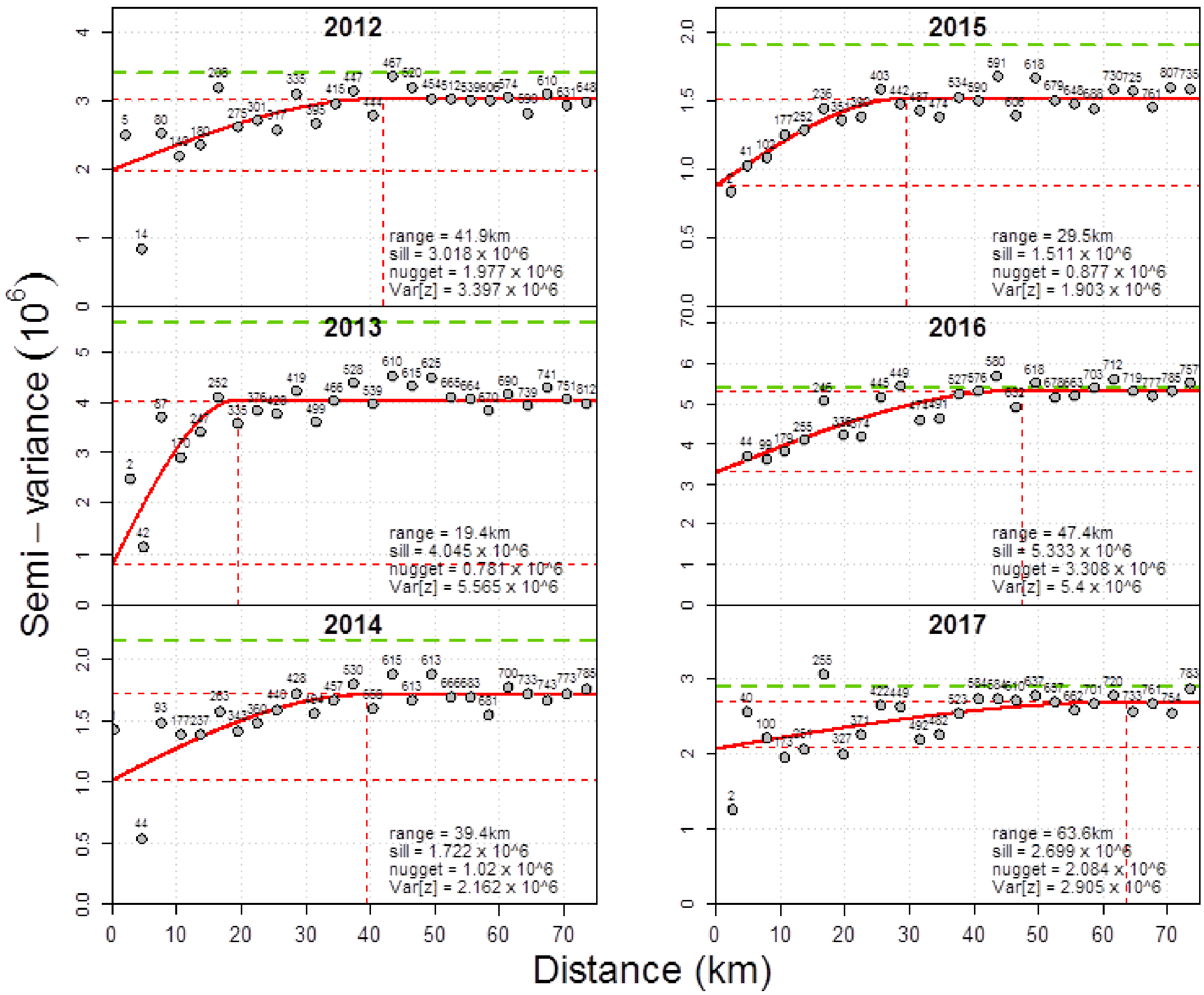


Figure 4. Three-year moving average variogram models for commercial-sized adult male snow crab (Chionoecetes opilio) in the southern Gulf of St. Lawrence, 2012 to 2017. Indicated is the number of paired observations used per distance lag semi-variance calculation. The red dashed lines indicate the range value on the abscise axis and the nugget and sill values on the y axis. The green dashed line indicates the variance on the y axis.

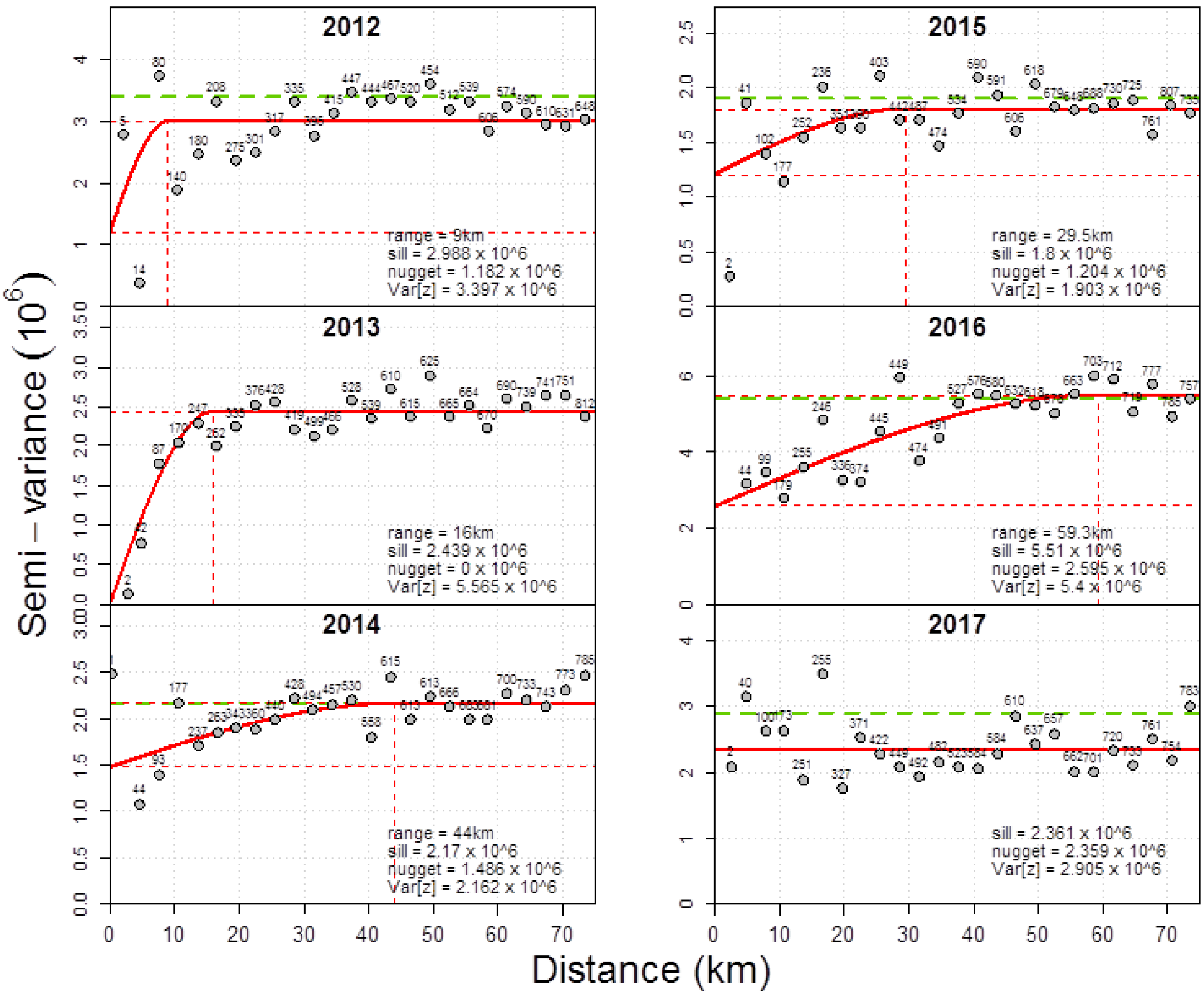


Figure 5. Annual variogram models for commercial-sized adult male snow crab (Chionoecetes opilio) in the southern Gulf of St. Lawrence, 2012 to 2017. Indicated is the number of paired observations used per distance lag semi-variance calculation. The red dashed lines indicate the range value on the abscise axis and the nugget and sill values on the y axis. The green dashed line indicates the variance on the y axis.

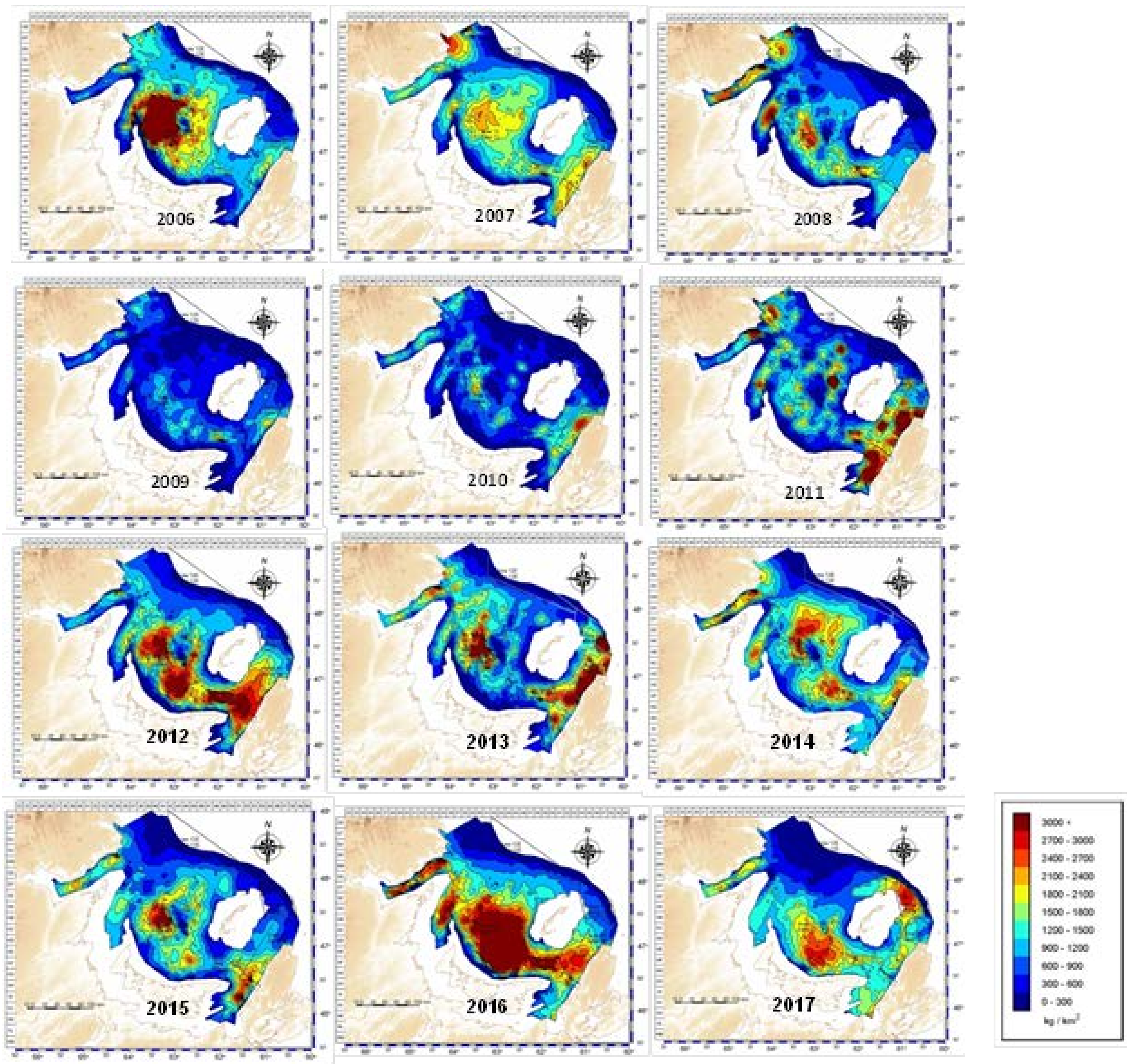


Figure 6. Density (kg per km²) contours of commercial-sized (≥ 95 mm of carapace width) adult male snow crab (Chionoecetes opilio) based on trawl survey data in the southern Gulf of St. Lawrence, 2006 to 2017.

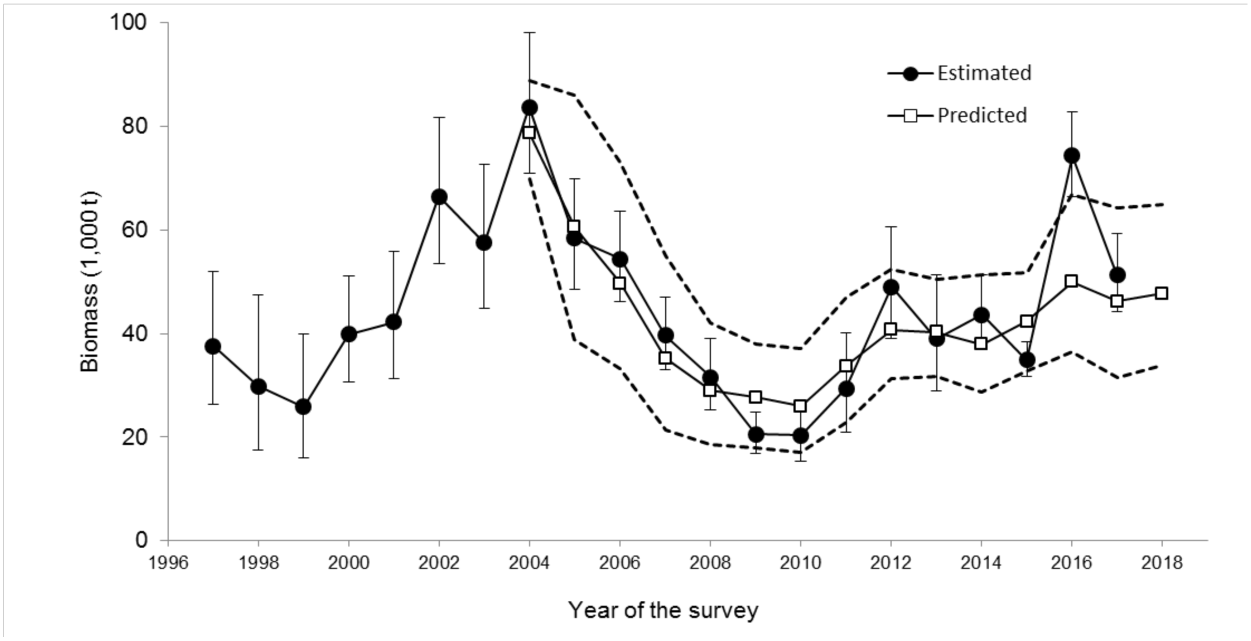


Figure 7. Comparison between the observed (mean with 95% confidence intervals) and forecasted (mean with 95% confidence intervals) recruitment (R-1) of male snow crab (Chionoecetes opilio) based on the Bayesian model on prerecruits (Surette and Wade 2006; Wade et al. 2014).

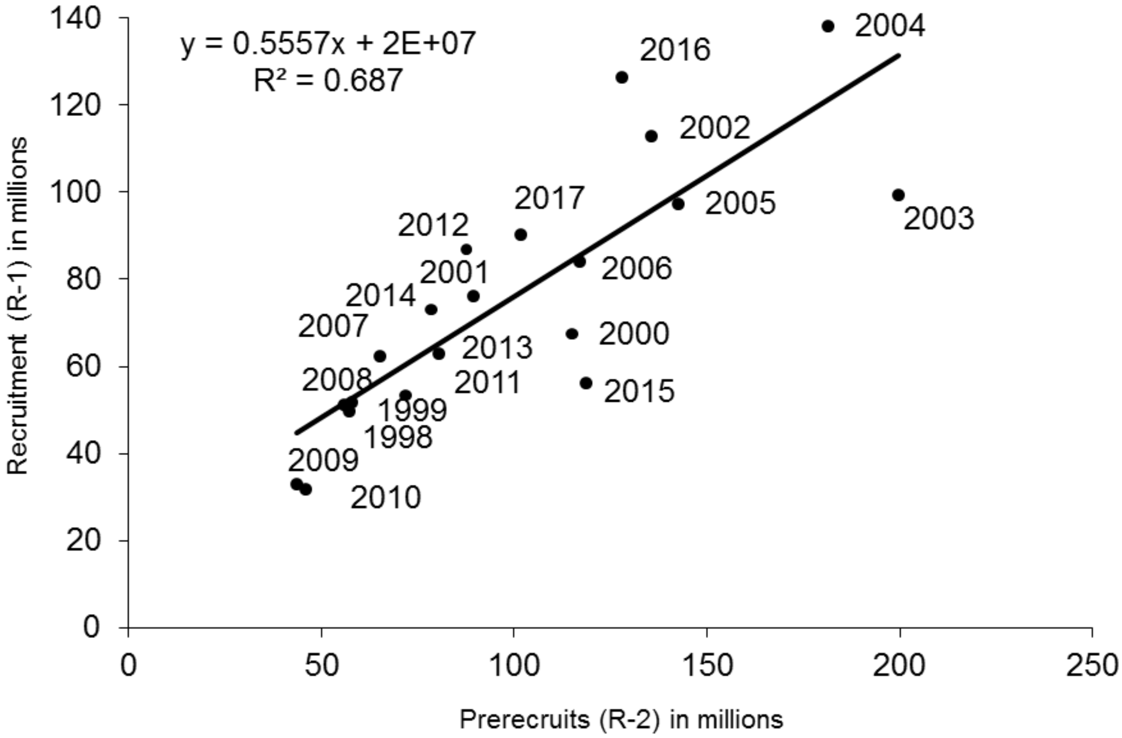


Figure 8. Relationship between the estimated abundance of prerecruits R-2 in year t and the estimated abundance of the recruitment to the fishery (R-1) in year t + 1 from the trawl survey data for the snow crab (Chionoecetes opilio) assessment in the southern Gulf of St. Lawrence.

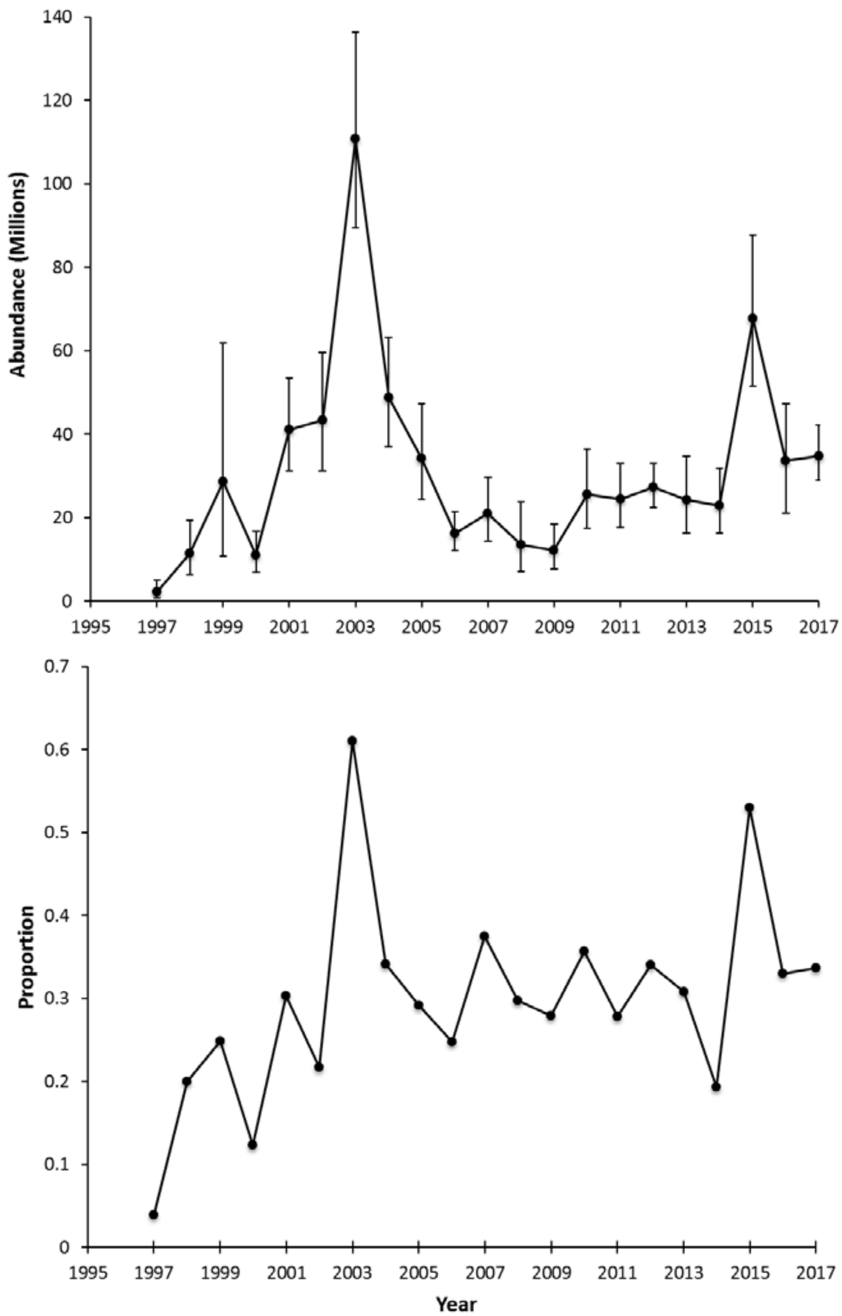


Figure 9. Abundance (in millions) (upper panel) and proportion (lower panel) of R-2 adolescent skip molters in the southern Gulf of St. Lawrence estimated from the trawl survey from 1997 to 2017.

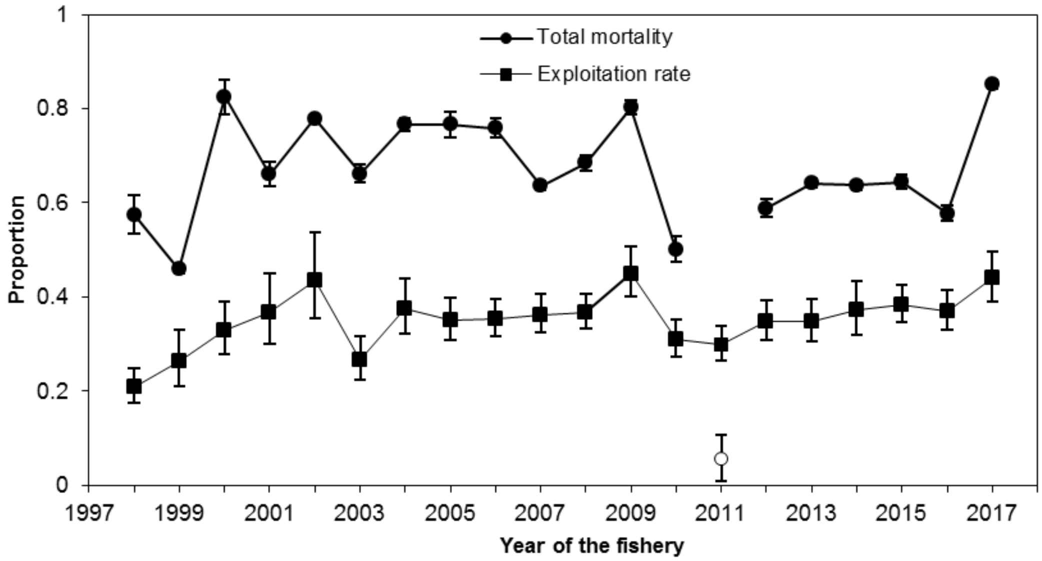


Figure 10. Estimated annual rates of exploitation and total loss of commercial-sized adult male snow crab (Chionoecetes opilio) in the southern Gulf of St. Lawrence, 1997 to 2017. The 2011 total mortality value is not consistent in the series (Hébert et al. 2012).

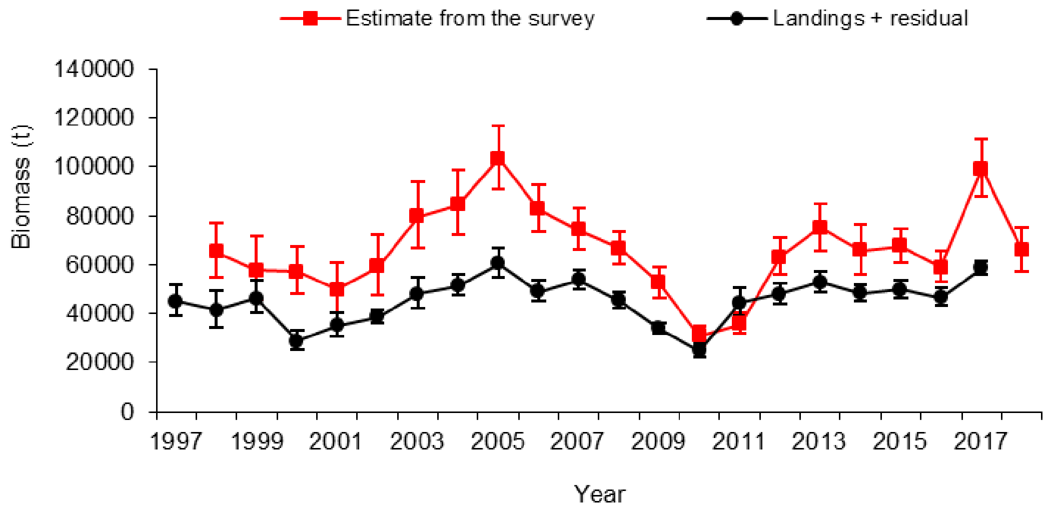


Figure 11. Comparison of the post-fishery calculated biomass (t; residual biomass plus the landings in year t+1) and the pre-fishery commercial-sized adult male snow crab (Chionoecetes opilio) biomass (t; recruitment plus residual biomass in year t) estimated from the trawl survey in the southern Gulf of St. Lawrence.

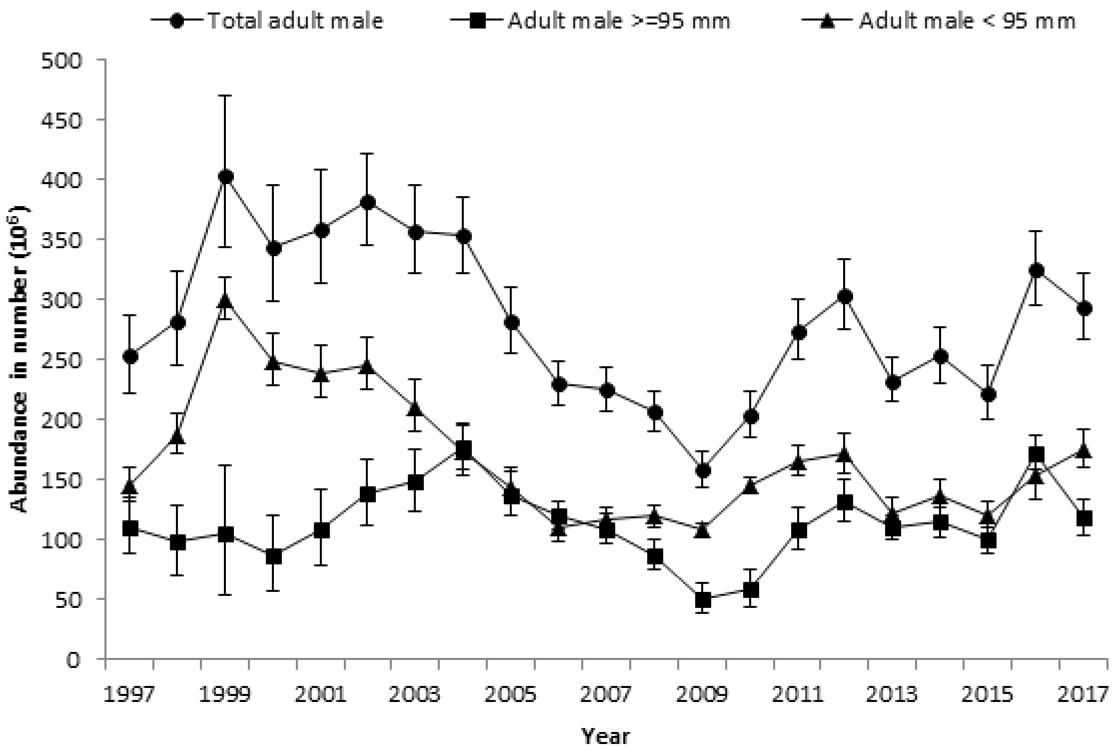
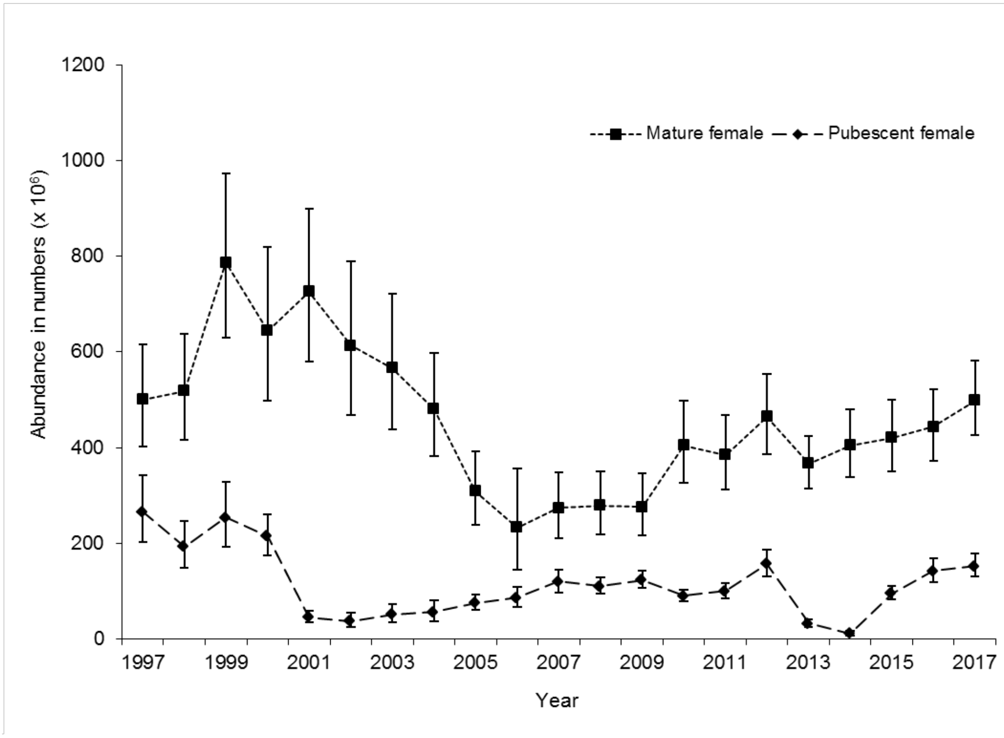


Figure 12. Estimated abundance (number in millions) of snow crab (Chionoecetes opilio) adult males, by carapace width category and overall, in the southern Gulf of St. Lawrence, 1997 to 2017.



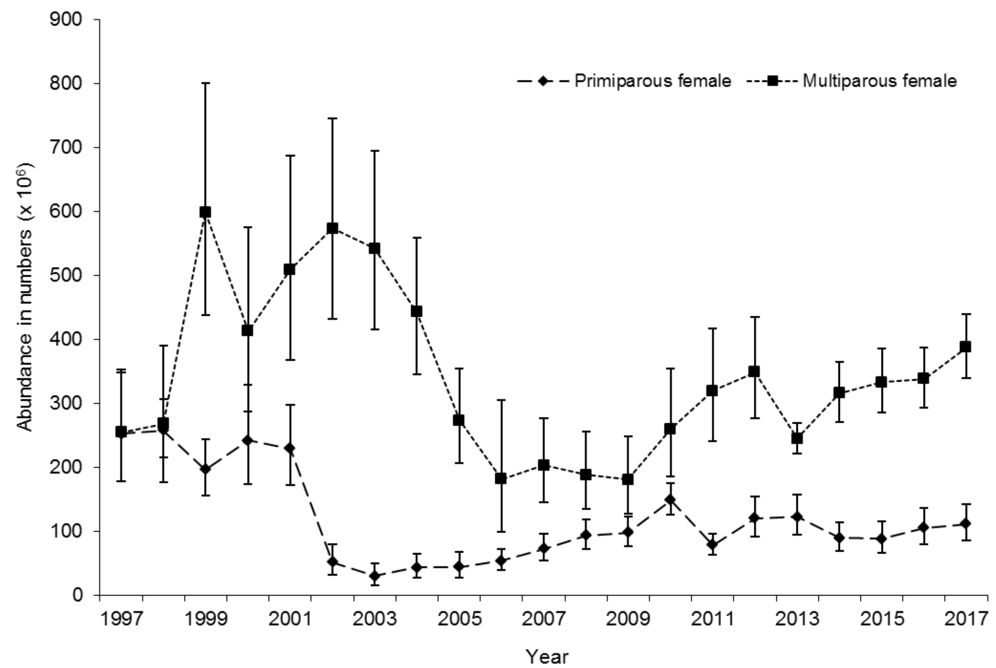


Figure 13. Abundance (number in millions) of mature and pubescent (above), and primiparous, and multiparous (i.e. mature; below) snow crab (Chionoecetes opilio) females in the southern Gulf of St. Lawrence, 1997 to 2017.

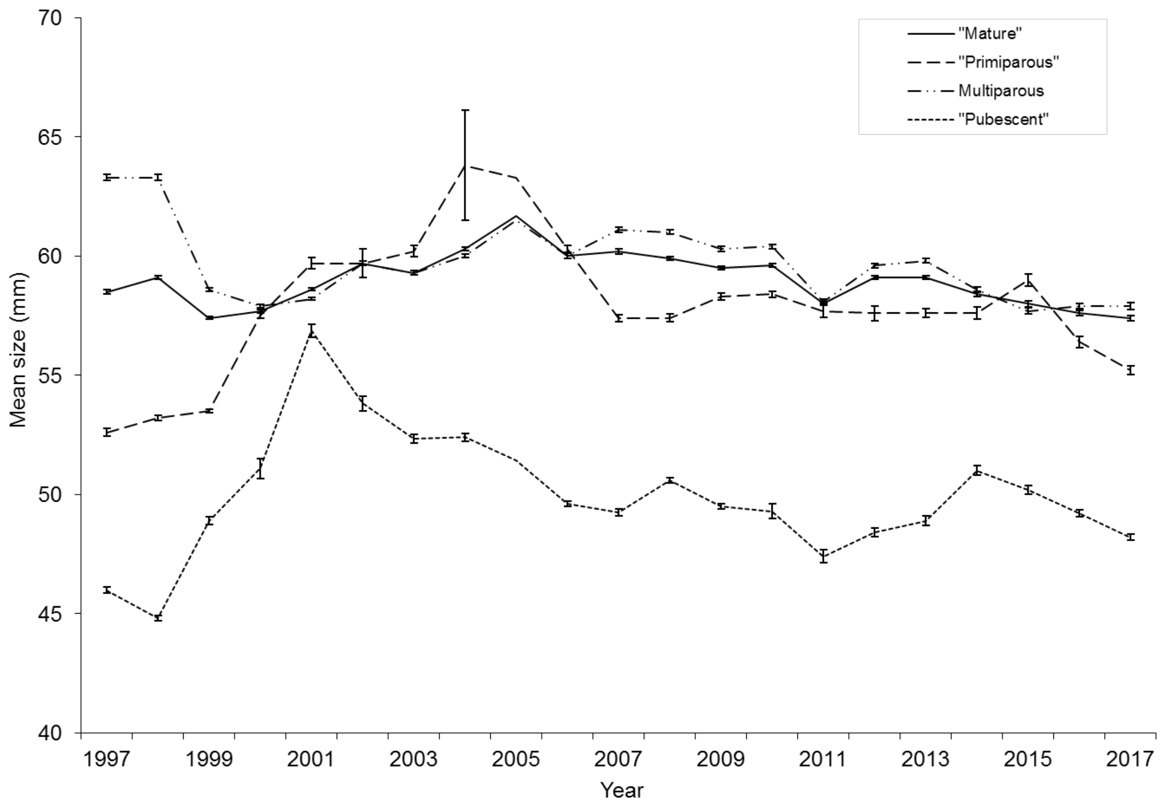


Figure 14. Mean size (carapace width in mm) with standard errors of pubescent, primiparous, multiparous and mature snow crab (Chionoecetes opilio) females based on samples from the trawl surveys, 1997 to 2017.

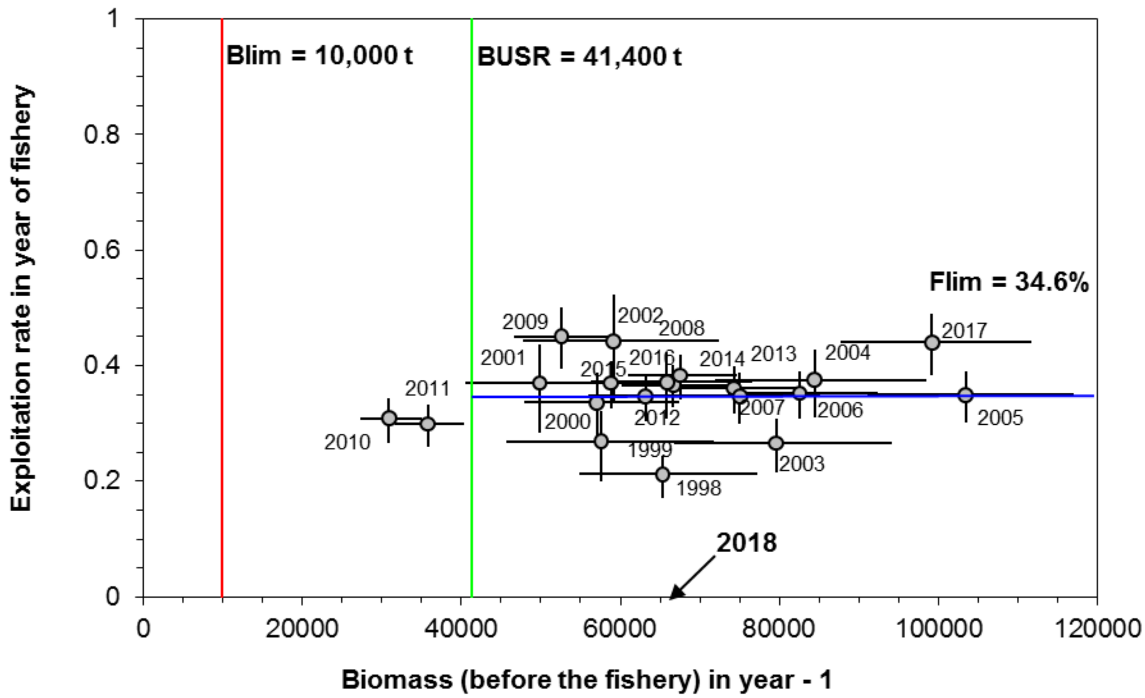


Figure 15. Trajectory of stock abundance (biomass of commercial-sized adult male snow crab (Chionoecetes opilio) as estimated from the trawl survey in year t – 1 versus exploitation rate of this biomass in the fishery of year t. Year of the fishery is labelled on the figure. B_{lim} = limit reference point for biomass; F_{lim} = fishing removal rate reference point; and B_{USR} = upper stock reference point.

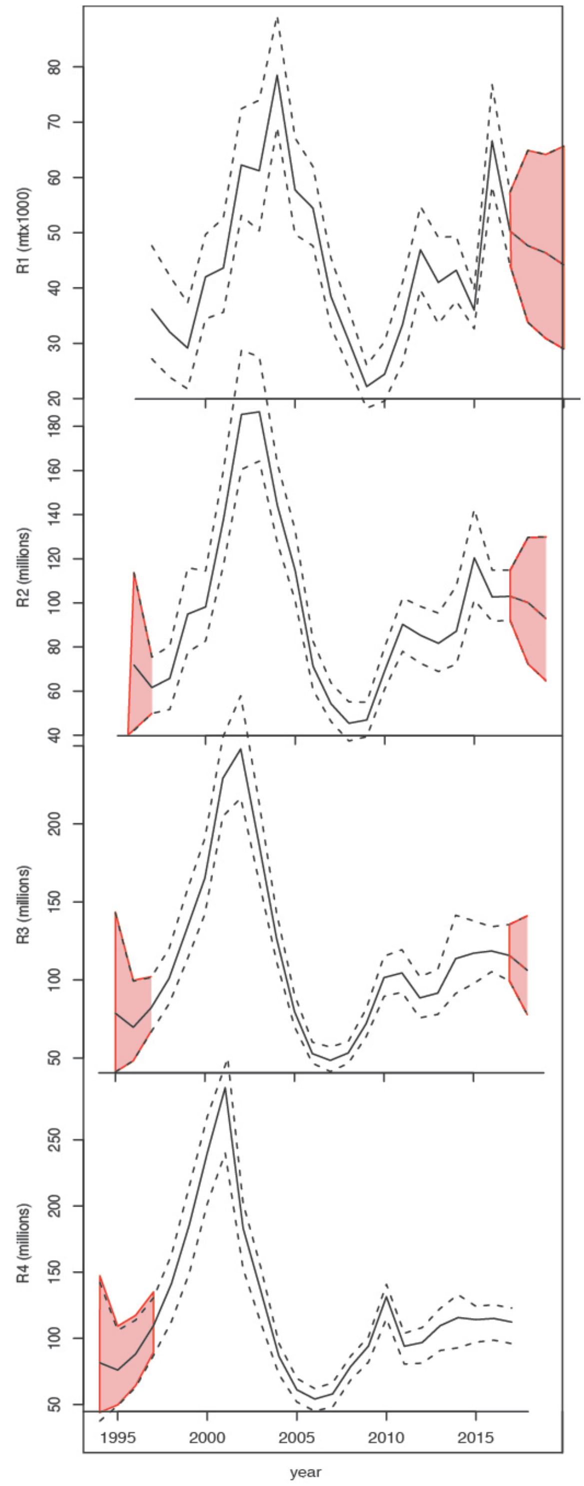


Figure 16. Snow crab (Chionoecetes opilio) recruitment (R) abundance (mean with 95% confidence intervals) by pre-recruit stages (Rj), where j =1,…,4 years until recruitment to the fishery based on the survey data estimates. Shaded areas are forecasted abundance from the Bayesian model (Wade et al. 2014).

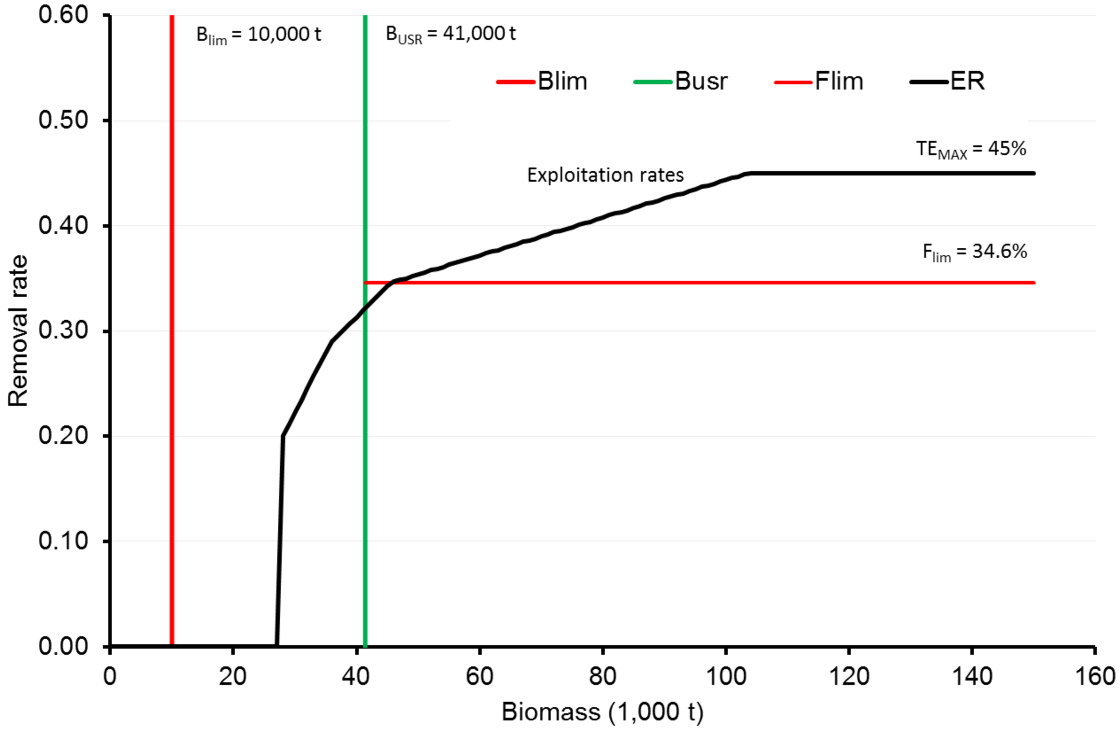


Figure 17. Harvest proportional decision rule (variant 4) compliant with the precautionary approach for the southern Gulf of St. Lawrence snow crab (Chionoecetes opilio) fishery (DFO 2014). B_{lim} = limit reference point for biomass; F_{lim} = fishing removal rate reference point; B_{USR} = upper stock reference point; ER = exploitation rate based on the proportional harvest decision rule; TE_{max} = maximum exploitation rate based on the proportional harvest decision rule.

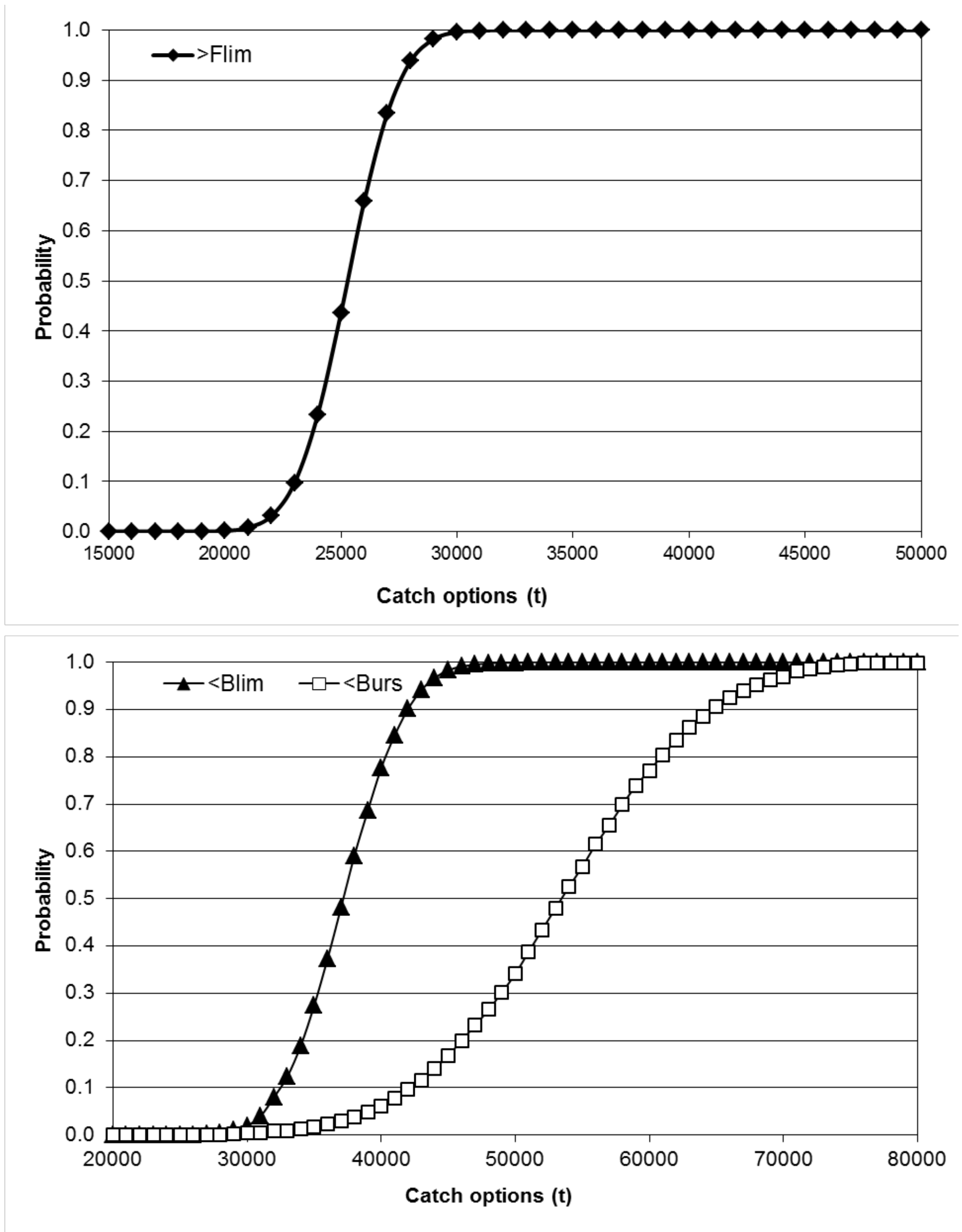


Figure 18. Risk analysis of catch options (t) for the 2018 fishery based on the expanded polygon for the southern Gulf of St. Lawrence snow crab, Chionoecetes opilio, showing probabilities of exceeding the fishing removal rate limit reference point (F_{lim}), of the hard-shelled commercial-sized adult male remaining biomass in 2018 falling below the limit reference point for biomass (B_{lim}) and of the commercial-sized adult male biomass in 2018 will be below the upper reference point (B_{USR}) after the 2018 fishing season.

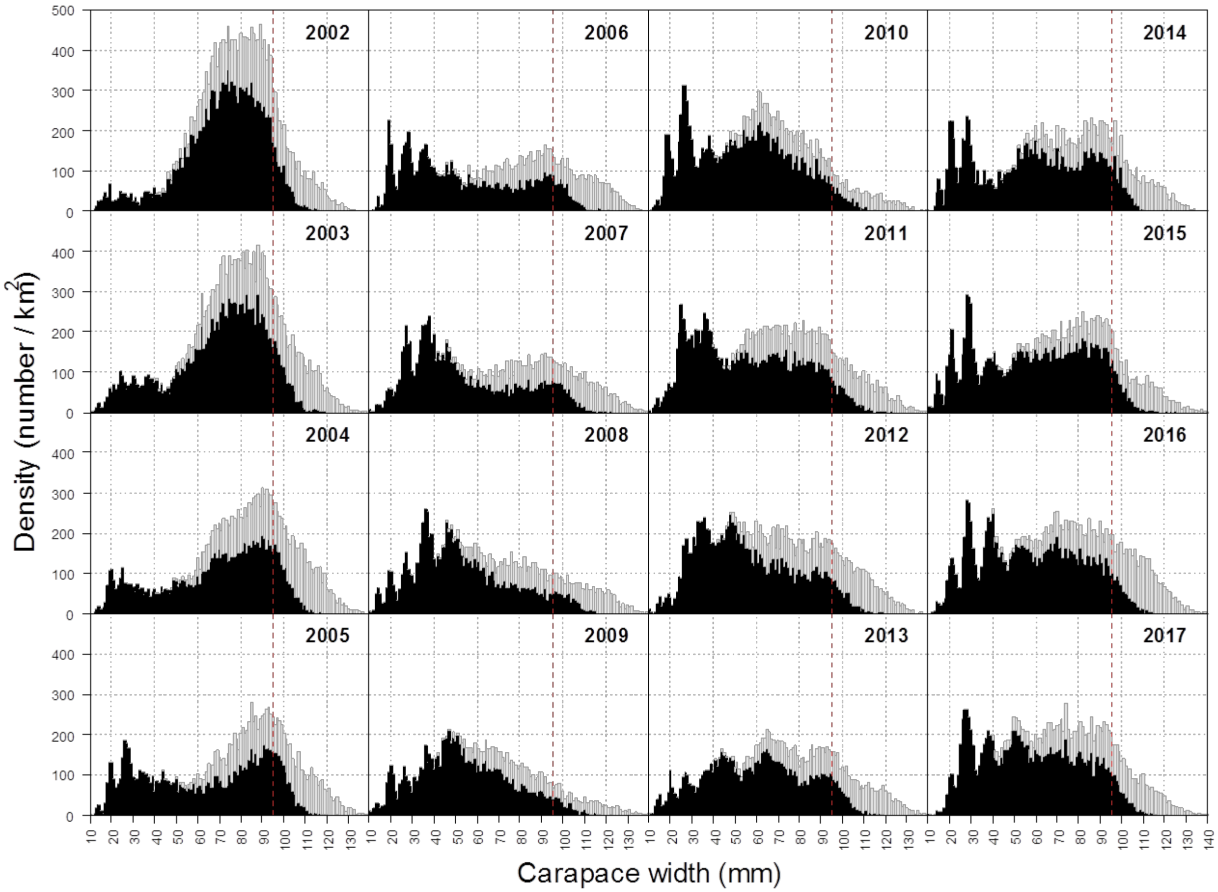


Figure 19. Size frequency distributions (by 1 mm carapace width interval) for male snow crabs (white bars are adult males and black bars are adolescent males) based on samples from the post-fishery trawl surveys in the southern Gulf of St. Lawrence, 2001 to 2017. These size frequency distributions represent the mean number of male snow crab (Chionoecetes opilio) per km^2 based directly on samples in the trawl survey.

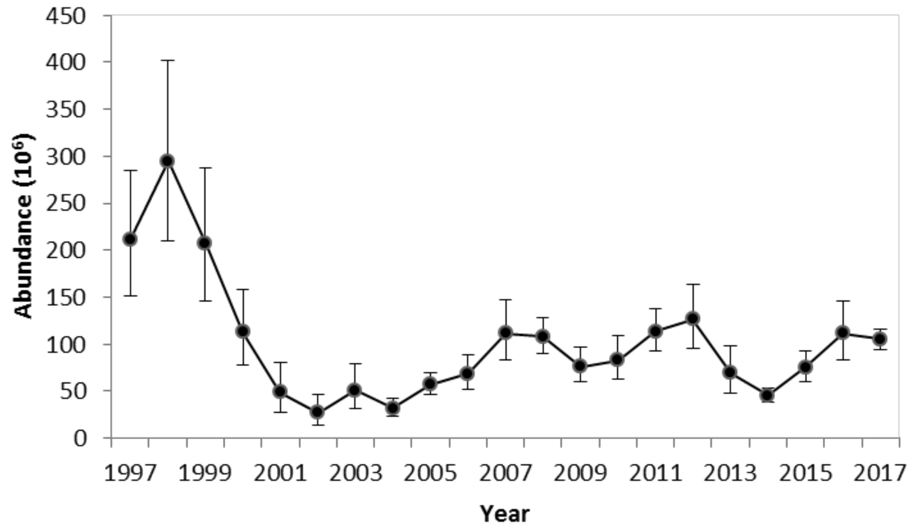


Figure 20. Abundance indices of small adolescent male snow crab (Chionoecetes opilio) with carapace width between 34 to 44 mm estimated from the trawl survey data in the southern Gulf of St. Lawrence, 1997 to 2017. These are crabs which reach legal size in approximately 6 years.

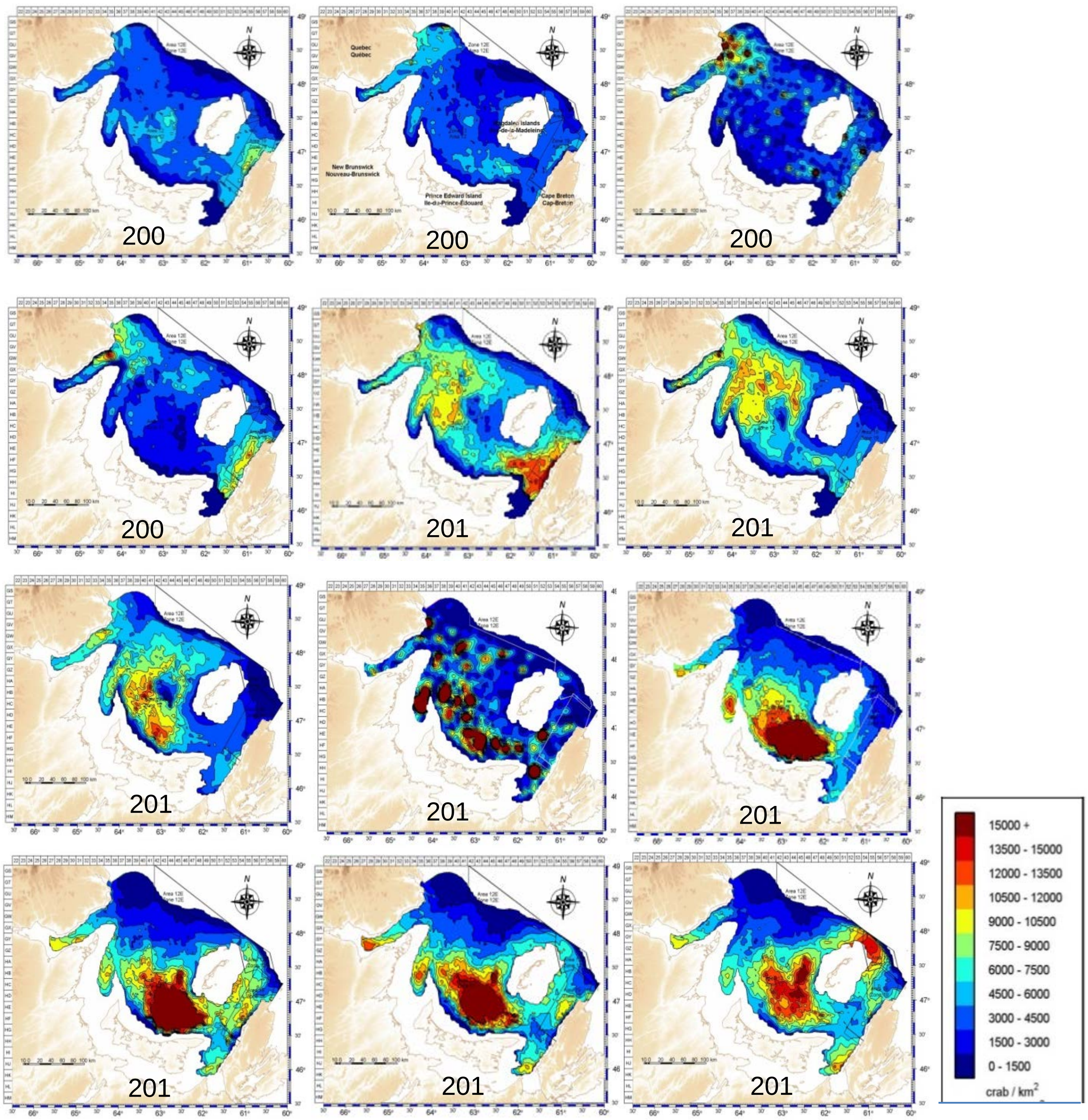


Figure 21. Density (number per km²) contours of adolescent male snow crab, (Chionoecetes opilio), ≥ 56 mm of carapace width, based on the trawl surveys conducted in the southern Gulf of St. Lawrence, 2006 to 2017.

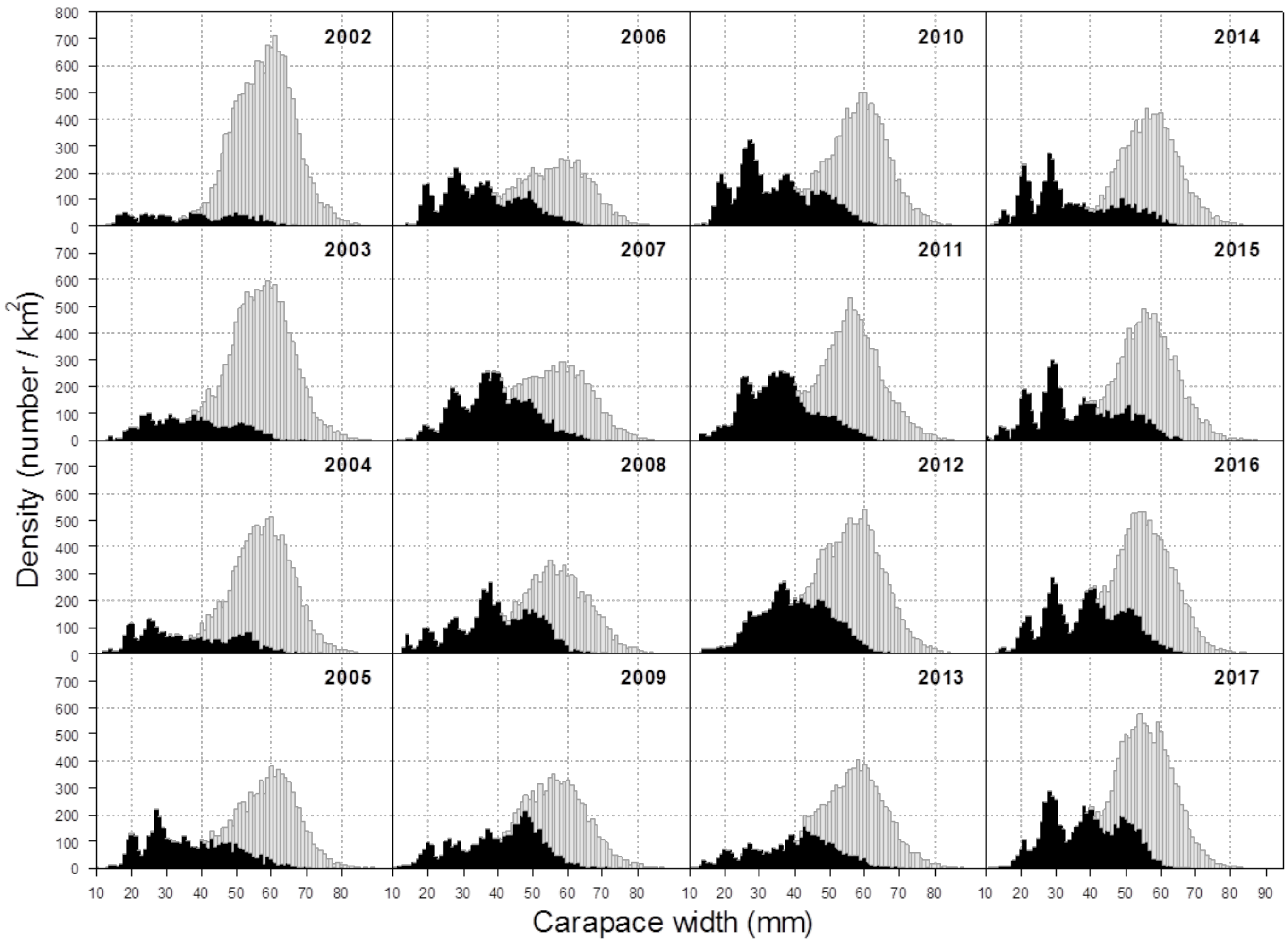


Figure 22. Size frequency distributions (carapace width by 1 mm interval) for female (white bars are mature females and black bars are pubescent and immature females) snow crab (Chionoecetes opilio) based on samples from the post-fishery trawl surveys in the southern Gulf of St. Lawrence, 2002 to 2017. These size frequency distributions represent the mean number of female crab per km^2 directly based on samples in the trawl survey.

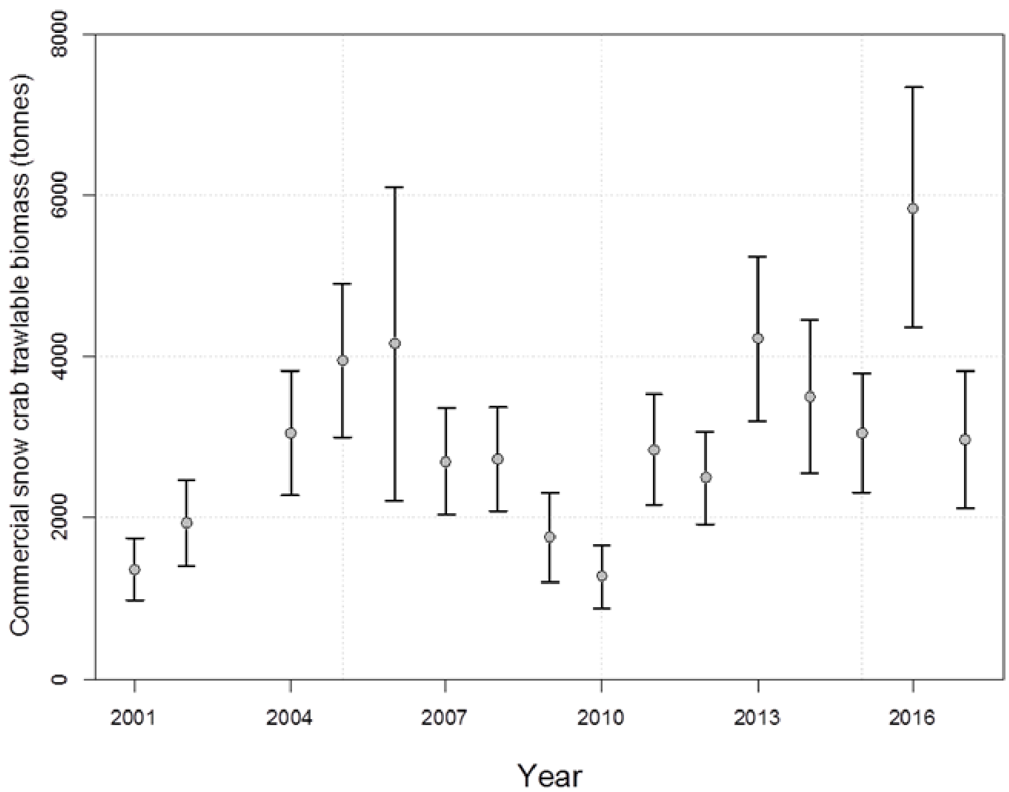


Figure 23. Index of trawlable biomass (in tonnes; means and 95% confidence intervals) of adult male snow crab ≥ 95 mm carapace width in the September multi-species bottom trawl survey for 2001 to 2017 excluding 2003, based on a geographic area comparable to that used for the current snow crab assessment.

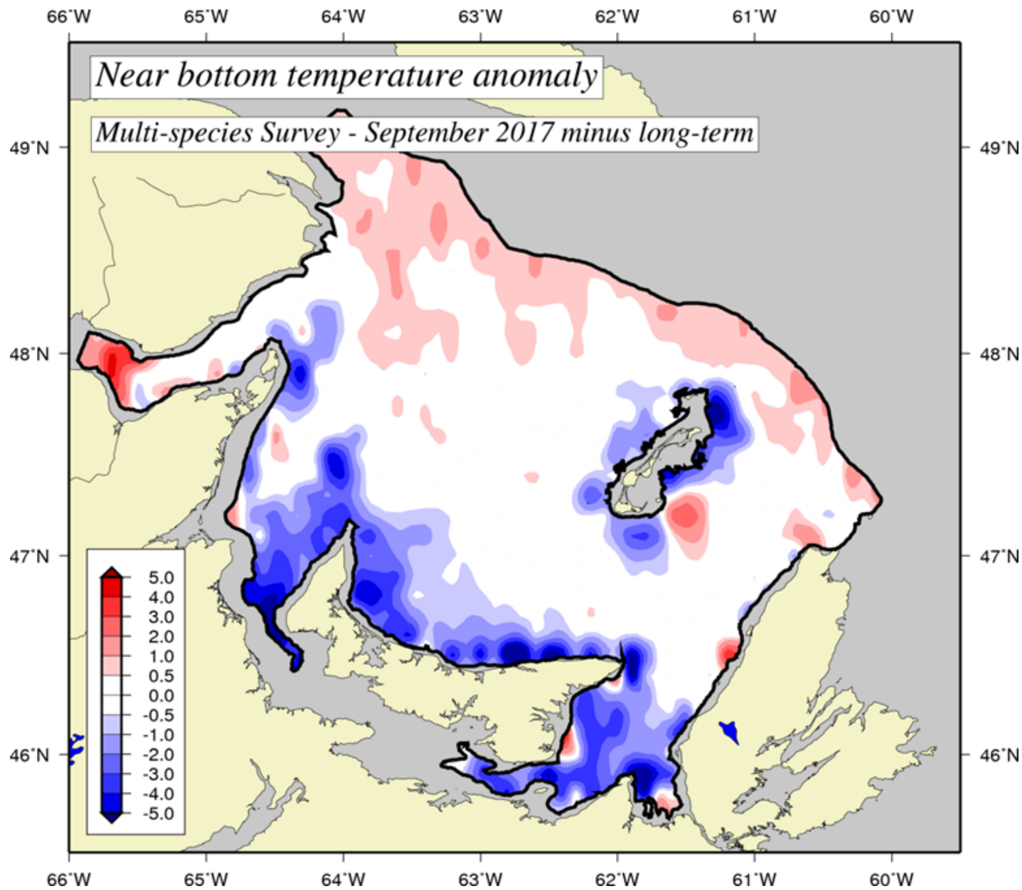


Figure 24. Near-bottom temperature departure (°C) from the long-term (1981-2010) mean in the southern Gulf of St. Lawrence based on data collected during the 2017 September multi-species survey. Blue areas represent colder-than-normal temperatures while red regions represent warmer-than-normal conditions.

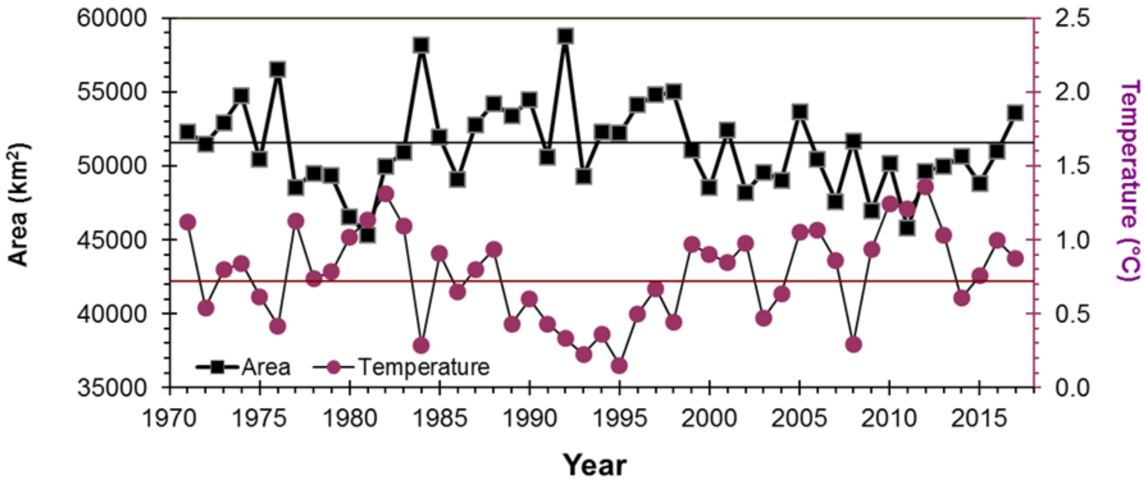


Figure 25. Snow crab temperature habitat area index (km2) that encompasses water temperatures of -1 to 3°C (upper panel) and the mean temperature (°C) within the temperature area index (lower panel) in the southern Gulf of St. Lawrence, 1971 to 2017.