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# Trends in the biomass, spatial distribution and size composition of snow crab (*Chionoecetes opilio*) based on the multi-species bottom trawl survey of the southern Gulf of St. Lawrence, 1980-2016

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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 research vessel bottom-trawl survey of the southern Gulf of St. Lawrence undertaken each September (RV survey) provides reliable standardized indices of biomass, spatial distribution and habitat use of commercial-sized male snow crab (*Chionoecetes opilio*) for 2001 to 2016 and of all snow crab (aggregated index) for 1980 to 2016. This document provides an update for these indices based on the results of the 2016 RV survey. This information was provided in support of the regional snow crab assessment process that took place in Moncton, NB on January 25 and 26, 2017. Of particular note, the RV survey confirmed an important increase in the biomass of commercial-sized adult male snow crab in 2016 as was also estimated by the dedicated snow crab survey. Also, RV surveys since 2012 had captured unusually high numbers of small crabs (≤15 mm) in several areas of the southern Gulf of St. Lawrence, whereas catches in 2016 were considerably lower and around values observed in the late 2000s.

**Tendances de la biomasse, de la distribution, de la composition des tailles et des estimations de crabe des neiges (*Chionoecetes opilio*) de taille commerciale basées sur le relevé annuel multi-espèces au chalut de fond du sud du golfe du Saint-Laurent, 1980 à 2016**

## RÉSUMÉ

Le relevé annuel au chalut de fond effectué en septembre par un navire de recherche (NR) dans le sud du golfe du Saint-Laurent (ci-après nommé relevé par NR) produit des indices normalisés fiables de biomasse, de répartition spatiale et d'utilisation de l'habitat pour le crabe des neiges (*Chionoecetes opilio*) mâle de taille commerciale depuis 2001 à 2016, et pour tous les crabes des neiges (indice agrégé) depuis 1980 à 2016. Dans le présent document de recherche une mise-à-jour des indices de biomasse, de distribution spatiale et de répartition des tailles sont présentés basés sur les résultats du relevé par NR de 2016. Ces informations sont fournies en appui au processus d'évaluation régionale du crabe des neiges de 2017, lequel a eu à Moncton, au N.-B., les 25 et 26 janvier, 2017. En particulier, le relevé par NR confirme une augmentation importante dans la biomasse de crabes adultes de taille commerciale en 2016, qui a aussi été observée dans le cadre du relevé dédié au crabe des neiges. De plus, depuis 2012 le relevé par NR a capturé un nombre anormalement élevé de petits crabs (≤15 mm) à plusieurs endroits dans le sud du golfe du Saint-Laurent. Cependant en 2016 les captures furent beaucoup plus faibles et se situaient à un niveau similaire aux valeurs observées à la fin des années 2000.

## INTRODUCTION

There are two fishery-independent bottom-trawl surveys that provide relative abundance indices for snow crab in the southern Gulf of St. Lawrence (sGSL). One of the surveys is principally directed at snow crab and has been conducted annually since 1988 (henceforth called the crab survey, CS) (Hébert et al. 2014). The second is a multi-species research vessel bottom-trawl survey conducted annually since 1971 (henceforth called the research vessel survey, RVS), which was initially focused on demersal fish but which has provided information on snow crab in the catches since 1980 (Benoît 2014). Both surveys provide a coherent picture of the abundance, spatial distribution, habitat preferences and demographic structure of sGSL snow crab (Benoît 2012).

This document provides an update for biomass indices, spatial distribution, and size composition of sGSL snow crab based on the results of the 2016 RVS. This information was provided in support of the regional snow crab assessment process that took place in Moncton, NB during January 25 and 26, 2017.

## METHODS

### BACKGROUND AND DATA

The RVS has been undertaken each September since 1971. It follows a random-stratified design, with strata defined on the basis of depth and area (Fig. 1) (see Hurlbut and Clay 1990 for details on the survey methodology). A common group of strata has been sampled annually since 1971, covering most of the southern Gulf of St. Lawrence (Northwest Atlantic Fishery Organization area 4T). Three inshore strata (strata 401, 402, and 403) were added to the survey in 1984. There are very few snow crab caught in these strata (Benoît and Cadigan 2013) and these strata and data are excluded from analyses that include years prior to 1984 so that the same set of strata are used in the time series analyzed. The target fishing procedure at each station during the survey is a 30-min. tow at a speed of 3.5 knots. The number of valid fishing sets completed annually has varied from approximately 70, during the early 1980s, to 175 or more during much of the 1990s and 2000s. In 2016, 162 valid sets were completed (Table 1).

Catches of snow crab (numbers and mass per tow) have consistently been recorded in the survey since 1980 (Tremblay 1997). Prior to 1992, there was a small number of sets for which catch numbers were recorded but mass was not when the mass was <1 kg (Table 1). This was the consequence of the precision of the spring scales used at that time to weigh catches, and these cases were generally when catch per tow was ≤ 0.5 kg; amounts were generally rounded up to the nearest kg otherwise. For the calculation of an aggregated biomass index (kg/tow) the mass was assumed to be 0.5 kg in these cases, producing a very comparable result to that obtained using an estimated mean mass of crabs multiplied by the observed number in a set to estimate catch mass. In most years prior to 2001 there was a small proportion of sets for which snow crab catch mass was recorded, but not catch numbers (Table 1). In these instances, the number caught was inferred using the stratum and year specific average catch mass per crab derived from sets with both catch and mass observations.

Since 2001, captured crabs have also been measured (carapace width) and sexed. Since 2012 all individual crabs were meant to be sexed, measured, weighed and their maturity determined based on the shape of the abdomen for females and based on measurements of chela height using the method of Conan and Comeau (1986) for males. In addition, any missing or regenerated appendages were meant to be noted. However, problems with the survey data entry system arising mid-way through the 2014 survey prevented the recording of chela height

and appendage data. Consequently, the maturity of males could not be determined for the last 49 sets that caught males in 2014.

Beginning in 2016, subsampling was employed to determine the individual weights and maturities for the captured crab. In each tow, all individuals were measured for carapace width and their sex was determined; however, individual weights and maturity determinations were obtained for the first two crabs encountered of a given mm size increment and sex.

Fishing during the RV survey was carried out by the E.E. Prince from 1971 to 1985 using a Yankee-36 trawl. Since then, a number of different vessels have been used, each fishing a Western IIA trawl: the Lady Hammond (1985 to 1991), the CCGS Alfred Needler (1992 to 2002 and 2004 to 2005), the CCGS Wilfred Templeman (2003), and the CCGS Teleost (2004 to 2016). Parameters for the trawls and vessels used in the RV survey are provided in Tables 2 and 3, respectively. Note that both trawls used in the survey are meant for fishing groundfish, though a liner is used in the codend to retain small animals.

Prior to the gear change and all but one of the vessel changes in the RVS (CCGS Wilfred Templeman used in 2003), paired tows involving the two vessels/gears at common sites were undertaken to estimate their relative catchabilities (Benoît and Swain 2003a; Benoît 2006). Based on these comparative fishing experiments, the E.E. Prince fishing the Yankee-36 was found to be less efficient at capturing snow crab compared to the Lady Hammond and CCGS Alfred Needler, and as a result corrections are applied to the E.E. Prince data prior to the calculation of indices for the RVS (Benoît and Swain 2003a; Benoît 2006). No corrections are applied for the CCGS Teleost (Benoît 2014).

The absence of comparative fishing with the CCGS Wilfred Templeman used in 2003 precludes the direct estimation of catchability relative to other RVS vessels. Though the model of Benoît and Cadigan (2013, 2014) does provide an estimate for commercial-sized crabs (details below), it does not provide an estimate for size-aggregated catches and still needs to be validated with simulation testing. Consequently, results of the indices based exclusively on the RVS for 2003 are not presented in this report.

From 1971 to 1984, fishing in the RVS was restricted to daylight hours (07:00-19:00). Since 1985, fishing has been conducted 24 hours per day. Because fishing efficiency can vary by time of day, survey catches were standardized post-hoc for the calculation of indices from the RVS, based on the results of analyses of survey catches and comparative fishing over the diel cycle (Benoît and Swain 2003b; details in Benoît 2014).

## ANALYSIS

In previous updates of survey indices (e.g., Benoît and Cadigan 2016) trawlable biomass (kg) of commercial male snow crab in year t ($RV_t$), was calculated as:

$$RV_t = Padult_t \sum_{l=1}^{L} \frac{U_l}{n_{l,t}} \sum_{i=1}^{n_{l,t}} \sum_{j=95}^{J} y_{i,j,t} \alpha j^{\beta} \qquad (1)$$

for t = 2001 to 2016 (excluding 2003),

where $Padult_t$ is the proportion of snow crab ≥ 95 mm that were adults in year *t*,

$U_l$ is the number of trawlable units in stratum *l* (i.e., surface area / area swept by a standard tow),

$n_{l,t}$ is the number of survey tows in stratum *l* and year *t*,

$y_{i,j,t}$ is the standardized number of male crab of carapace width *j* caught in tow *i* in year *t*, and

$\alpha$ = 2.665E-7 and $\beta$ = 3.089 are parameters for the relationship between carapace width (in mm) and mass (in g) (Hébert et al. 2014).

The values for $Padult_t$ were taken from the dedicated snow crab survey for all years for reasons of consistency (Hébert et al. 2014; M. Hébert pers. comm. for 2014 and 2015 values). This approach was modified slightly for this document for the years 2012, 2013, 2015 and 2016, given the availability of set specific information on the proportion of snow crab ≥ 95 mm that were adults. For those years, $RV_t$ was therefore calculated as:

$$RV_t = \sum_{l=1}^{L} \frac{U_l}{n_{l,t}} \sum_{i=1}^{n_{l,t}} \sum_{j=95}^{J} Padult_{i,j,t} y_{i,j,t} \alpha j^{\beta} \tag{2}$$

The results of the former and current calculation are compared. For both sets of estimates, confidence intervals were calculated using the standard estimator for standard error based on stratified random sampling (Krebs 1989) and using a Satterthwaite approximation for the degrees of freedom for the t-value.

An aggregated biomass index for snow crab per standard 1.75 NM tow (mean kg/tow, $B_t$ ; all sizes and sexes) was calculated as:

$$B_t = \sum_{l=1}^{L} \frac{U_l}{U \cdot n_{l,t}} \sum_{i=1}^{n_{l,t}} b_{i,t} \tag{3}$$

for $t$ = 1980 to 2016 (excluding 2003),

where $U$ is the total number of trawlable units in the survey domain and

$b_{i,t}$ is the observed biomass (kg) of snow crab in set $i$ of year $t$.

Analyses for $B_t$ were undertaken for two geographic areas of inference; the current snow crab assessment area representing 57,840 km², and the RV survey area for strata 415 to 439 (Fig. 1) representing 70,061 km². To approximate the snow crab assessment area, strata 401 to 403, 420, 421, 428, 432, and 435 were excluded from the analysis. Analyses for $RV_t$ described above were only undertaken for the geographic area equivalent to the current snow crab assessment area because the values of $Padult_t$ are pertinent to this area.

Annual survey-weighted proportions ($P_{j,s,t}$) of sGSL crab as a function of each mm carapace width $j$, and each sex (for 2001 to 2011) or sex and maturity stage (2012 to 2016) $s$, were calculated as:

$$P_{j,s,t} = \sum_{i} \left( w_{i,t} \cdot y_{i,j,s,t} \right) \Big/ \sum_{s} \sum_{j_s} \sum_{i} \left( w_{i,t} \cdot y_{i,j_s,s,t} \right) \tag{4}$$

where $w_{i,t} = \frac{U_l}{U \cdot n_{l,t}}$ .

These values were used to produce annual histograms for the RV survey catches.

Catch rates expressed as numbers per tow of commercial-sized male snow crab in the RV survey were mapped using inverse distance weighted gradient interpolation. The contour levels for plotting were defined as the 10th, 25th, 50th, 75th, and 90th percentiles of non-zero catches over the period of interest, 2001 to 2016 (excluding 2003). The same was done for commercial-sized mature male snow crab, but was limited to those years for which maturity information was

collected during the entire survey, 2012 to 2013 and 2015 to 2016. Catch rates of small crab (≤ 15 mm) were likewise mapped to illustrate their spatial distribution for the 2001 to 2016 period.

## RESULTS AND DISCUSSION

The biomass of commercial-sized adult male snow crab increased from a relatively low level in 2001, to a relatively high level mid-decade. It then declined to the lowest levels of the 2000s in 2010, before increasing to high levels again subsequently (Fig. 2). The estimated value in 2016 is considerably higher than the elevated values observed in 2013 and 2014 and is the highest value in the series. The approach used to account for the proportion of snow crab ≥ 95 mm that were adults did not affect the estimates significantly (Fig. 2). It is proposed to henceforth use the set-specific estimates of the proportion for the calculation of the index for the years for which those values are available and to use an annual average otherwise.

The RV survey aggregated biomass index (all sizes, both sexes) provides a longer-term perspective of snow crab population dynamics in the sGSL (Fig. 3). Trends in this index during the 2000s and 2010s generally match those observed for large male crab (Fig. 2) because the large males typically comprise the bulk of the biomass in the catches. The estimate for 2016 is the highest observed since the early 1990s and is well above the long-term average of around 6.0 kg per tow.

The size-frequency distributions of crabs in the RV survey are shown in Figure 4. Generally, the late 2000s were characterized by a higher proportion of snow crab < 30 mm, relative to the early 2000s. In particular, a very high proportion of small crab (≤ 15 mm) was observed in the 2012 to 2015 surveys, but not in the 2016 survey. Crabs of this size were captured at higher abundances and in more locations in 2013 to 2015 compared to surveys in 2001 to 2011 (Fig. 5). In fact, high densities of small crabs were caught throughout most of the survey area. Distribution patterns in 2016 were closer to those observed in 2012.

The relative size composition of commercial-sized adult male crab in 2016 was comparable to the levels seen in 2005 to 2007, with relatively high densities at the larger sizes, > 110 mm (Fig. 4). Densities of commercial-sized male snow crab in 2016 were highest in a band that ran south of the Magdalen Islands, from the New Brunswick shore to the northern portion of Cape Breton Island (Fig. 6). The overall pattern of distribution was generally similar to patterns observed in 2013 to 2015. The spatial distribution of commercial (mature) snow crab (Fig. 7) was very similar to the distribution for large male snow crab (mature and immature; Fig. 6) indicating that there are no strong spatial patterns in maturity for large crabs in the survey.

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## TABLES

*Table 1. Annual summary of the number of sets from the research vessel survey. The summary is broken down to indicate the number of sets for which both catch mass and numbers were recorded and sets for which values of only one of the two variables was recorded.*

| Year | Total valid sets | Sets with numbers and mass | Sets with numbers only | Sets with mass only |
|---|---|---|---|---|
| 1980 | 70 | 47 | 2 | 21 |
| 1981 | 70 | 57 | 13 | 0 |
| 1982 | 65 | 47 | 17 | 1 |
| 1983 | 67 | 48 | 14 | 5 |
| 1984 | 102 | 85 | 12 | 5 |
| 1985 | 209 | 162 | 41 | 6 |
| 1986 | 164 | 156 | 0 | 8 |
| 1987 | 152 | 128 | 13 | 11 |
| 1988 | 147 | 121 | 19 | 7 |
| 1989 | 166 | 143 | 14 | 9 |
| 1990 | 141 | 134 | 6 | 1 |
| 1991 | 188 | 184 | 0 | 4 |
| 1992 | 162 | 154 | 0 | 8 |
| 1993 | 183 | 176 | 0 | 7 |
| 1994 | 154 | 150 | 0 | 4 |
| 1995 | 175 | 168 | 0 | 7 |
| 1996 | 194 | 189 | 0 | 5 |
| 1997 | 202 | 185 | 0 | 17 |
| 1998 | 192 | 145 | 0 | 47 |
| 1999 | 180 | 175 | 0 | 5 |
| 2000 | 182 | 181 | 0 | 1 |
| 2001 | 141 | 141 | 0 | 0 |
| 2002 | 173 | 173 | 0 | 0 |
| 2003 | 78 | 78 | 0 | 0 |
| 2004 | 212 | 212 | 0 | 0 |
| 2005 | 231 | 231 | 0 | 0 |
| 2006 | 165 | 165 | 0 | 0 |
| 2007 | 163 | 163 | 0 | 0 |
| 2008 | 177 | 177 | 0 | 0 |
| 2009 | 148 | 148 | 0 | 0 |
| 2010 | 137 | 137 | 0 | 0 |
| 2011 | 126 | 126 | 0 | 0 |
| 2012 | 142 | 142 | 0 | 0 |
| 2013 | 122 | 122 | 0 | 0 |
| 2014 | 156 | 156 | 0 | 0 |
| 2015 | 161 | 161 | 0 | 0 |
| 2016 | 162 | 162 | 0 | 0 |

*Table 2. Parameters for the two trawls used in the RV survey of the southern Gulf of St. Lawrence.*

| Characteristics | Yankee 36 | Western IIA |
|---|---|---|
| Years in operation | 1971-1984 | 1985-present |
| Footrope | 7 inch (outer sections) and 14 inch (inner sections) rubber disc spacers + 17 lb. iron spacers | 21 inch (outer) and 18 inch (inner) rubber bobbins and 6.75 inch diameter 7 inch long rubber spacers |
| Footrope length (feet) | 80 | 106 |
| Headline length (feet) | 60 | 75 |
| Headline height (feet) | 9 | 15 |
| Wingspread (feet) | 35 | 41 |
| Door type | Steel bound wood | Portuguese (all steel) |
| Door weight (lbs) | 1,000 | 1,800 |
| Lengthening piece liner (inches) | 1.25 | 1.25 |
| Codend liner (inches) | 0.25 | 0.75 |

*Table 3. Parameters for the vessels used in the RV survey of the southern Gulf of St. Lawrence for the years presented in this report.*

| Characteristics | *E.E. Prince* | *Lady Hammond* | *CCGS Alfred Needler* | *CCGS Teleost* |
|---|---|---|---|---|
| Vessel type | Stern trawler | Stern trawler | Stern trawler | Stern trawler |
| Tonnage | 406 | 897 | 959 | 2,405 |
| Length | 40 m | 58 m | 50 m | 63 m |

## FIGURES

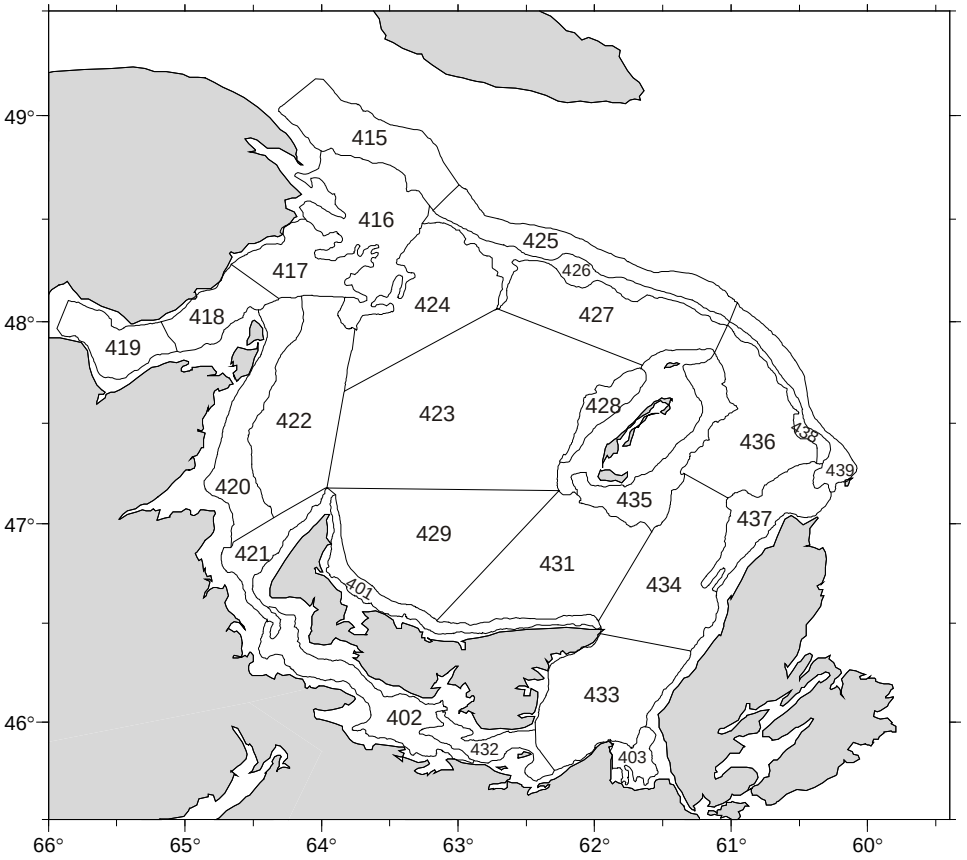


*Figure 1. Stratum boundaries for the southern Gulf of St. Lawrence September RV survey.*

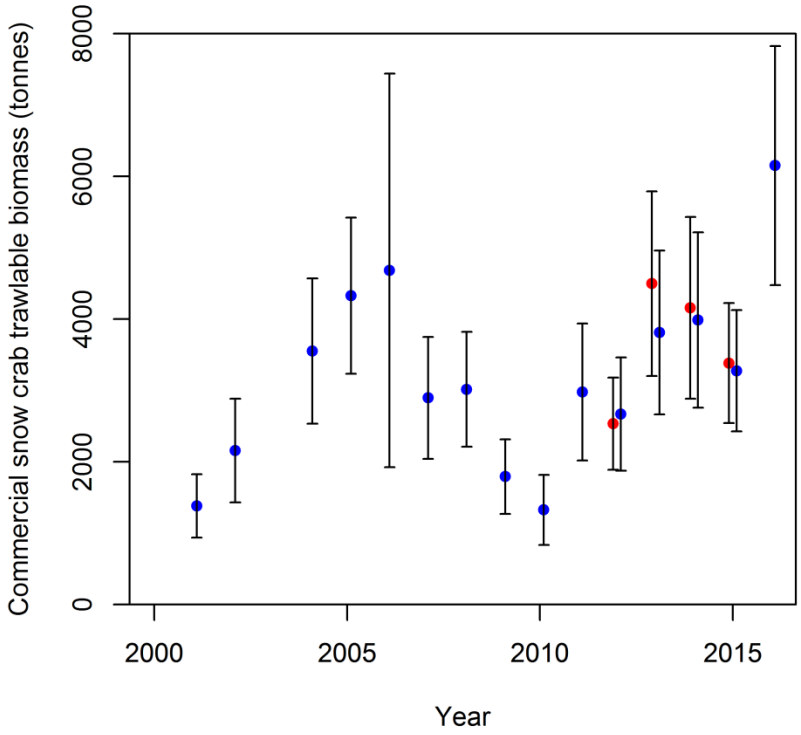


*Figure 2. Estimated trawlable biomass (tonnes; mean ± 95% confidence interval) of commercial-sized adult male snow crab in the RV survey, 2001 to 2016, for a geographic area comparable to that used for the current snow crab assessment. Values presented with blue circles are based on annual estimates of the proportion of snow crab ≥95mm that were adults for 2001 to 2011 and 2014 and set specific estimates for the remaining years. Values in red are based on annual estimates in all years.*

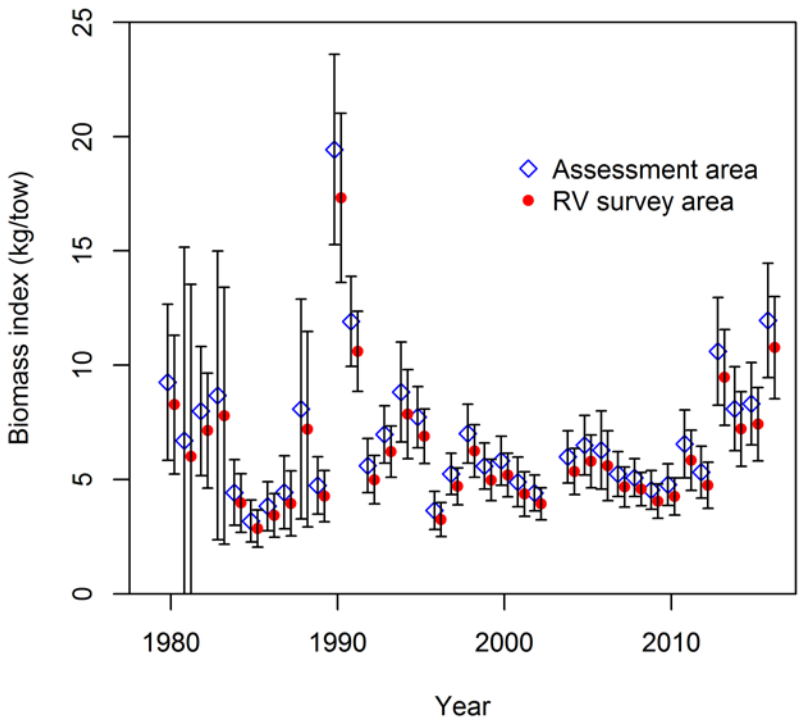


*Figure 3. Biomass index (kg/tow; mean ± 95% confidence interval) for all snow crab (male and female) in the RV survey, 1980 to 2016, for a geographic area comparable to that used for the current snow crab assessment (open blue diamond) and for the entire RV survey area (solid red circle).*

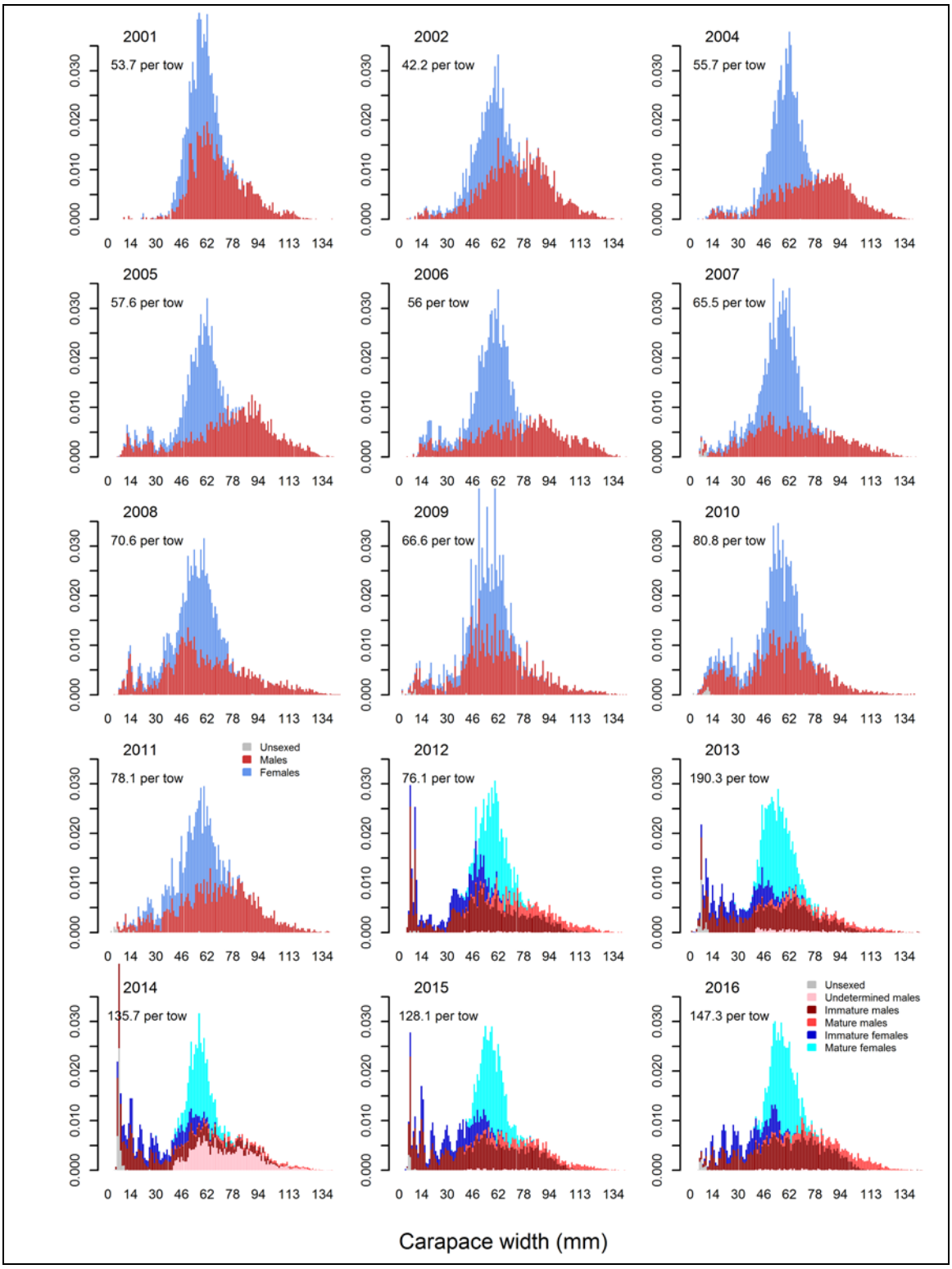


*Figure 4. Annual survey-weighted relative frequency distributions (expressed as proportions) of snow crab by carapace width (mm) as a function of sex (for 2001 to 2011) or sex and maturity stage (2012 to 2016). The numbers in each panel indicate the value of the annual abundance index (numbers per tow) for snow crab (all sizes and sexes). The data for 2003 are not shown because that survey was incomplete.*

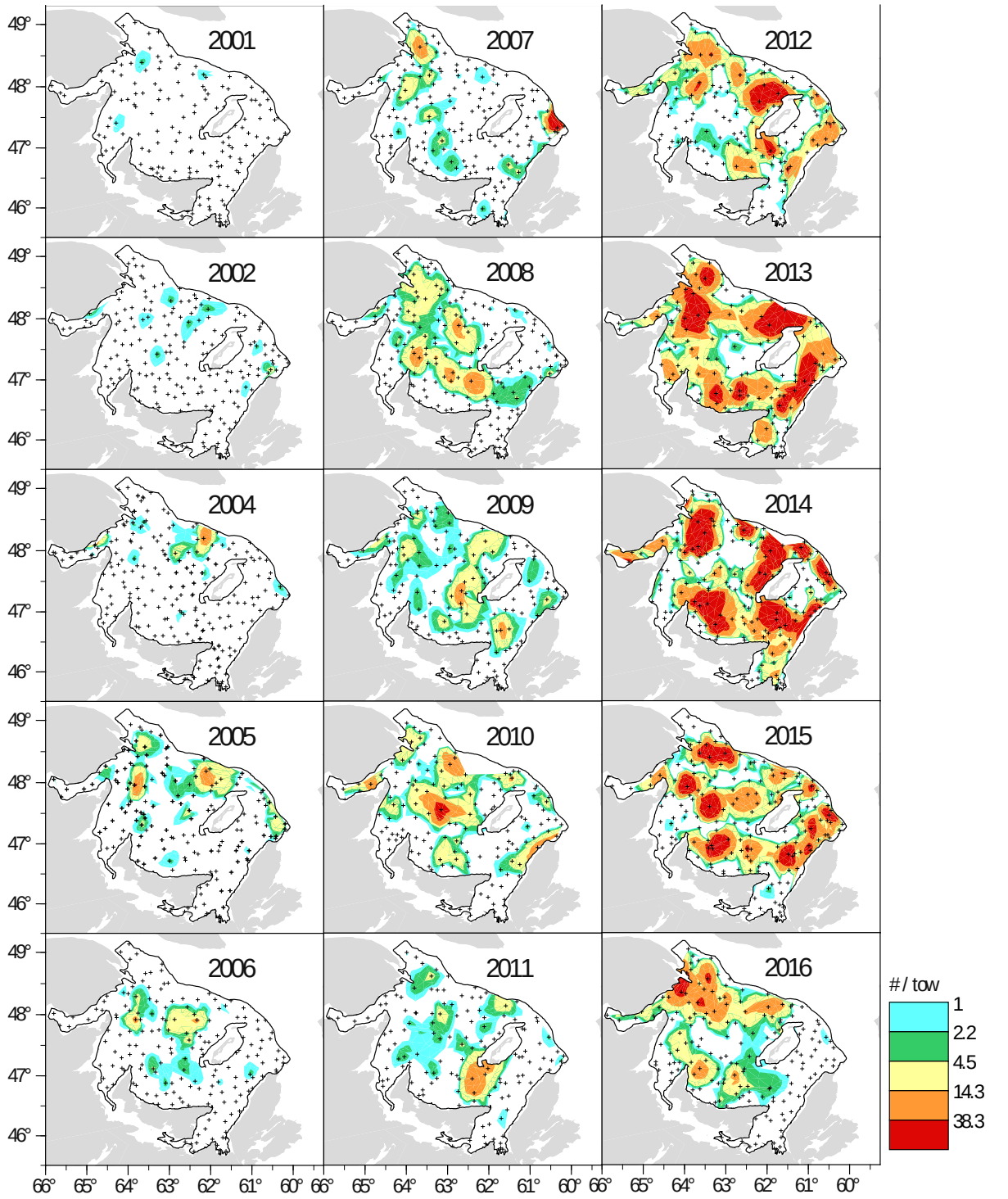


*Figure 5. Annual geographic distribution of catch rates (number of crabs per tow) of small snow crab (≤15 mm) in the September RV survey, 2001 to 2016 (excluding 2003). The small crosses indicate the set locations. The contour levels represent the 10th, 25th, 50th, 75th and 90th percentiles of non-zero catches for the entire period.*

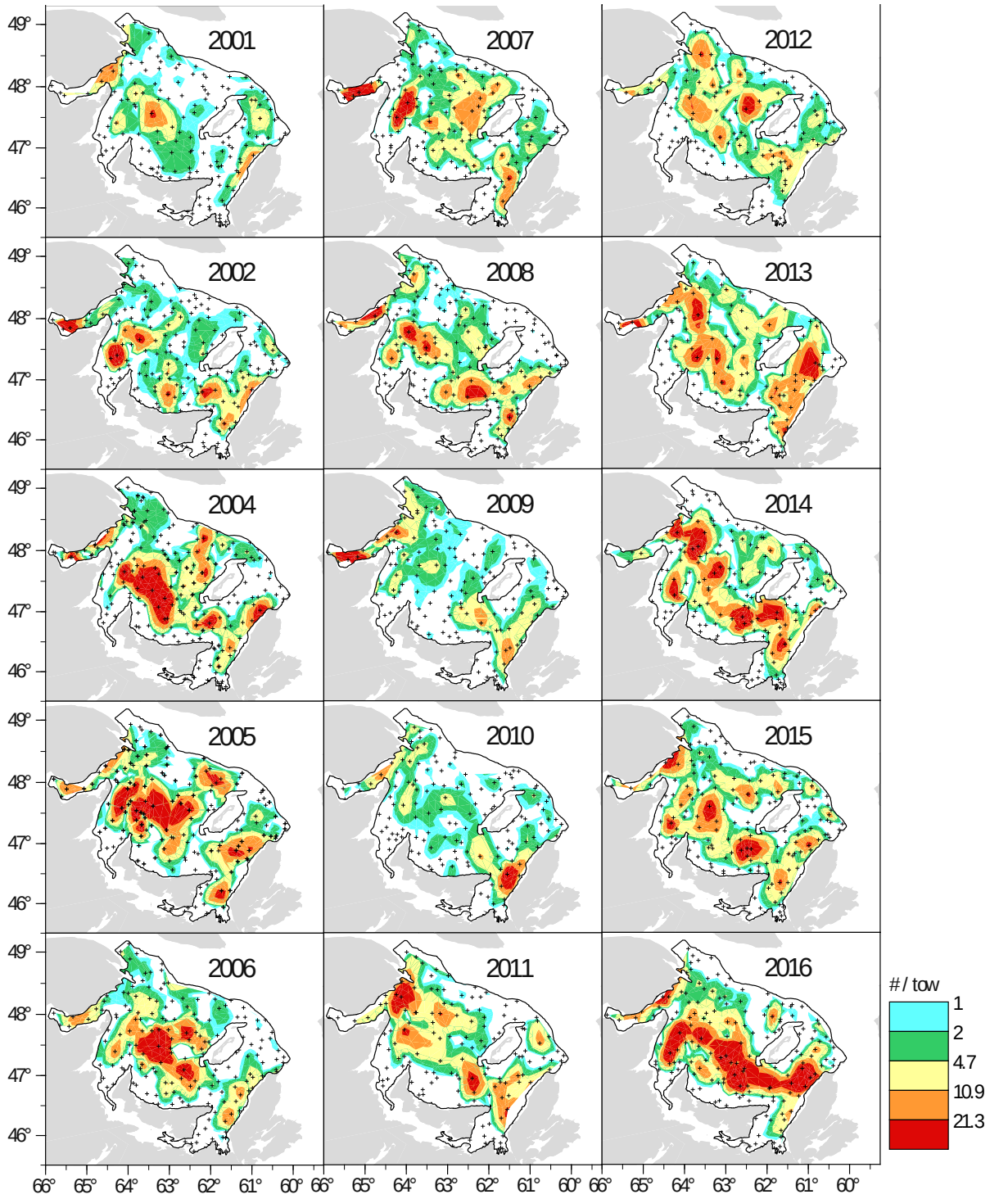


*Figure 6. Annual geographic distribution of snow crab catch rates (number of crabs per tow; males ≥95 mm) in the September RV survey, 2001 to 2016 (excluding 2003). The small crosses indicate the set locations. The contour levels represent the 10$^{th}$, 25$^{th}$, 50$^{th}$, 75$^{th}$ and 90$^{th}$ percentiles of non-zero catches for the entire period.*

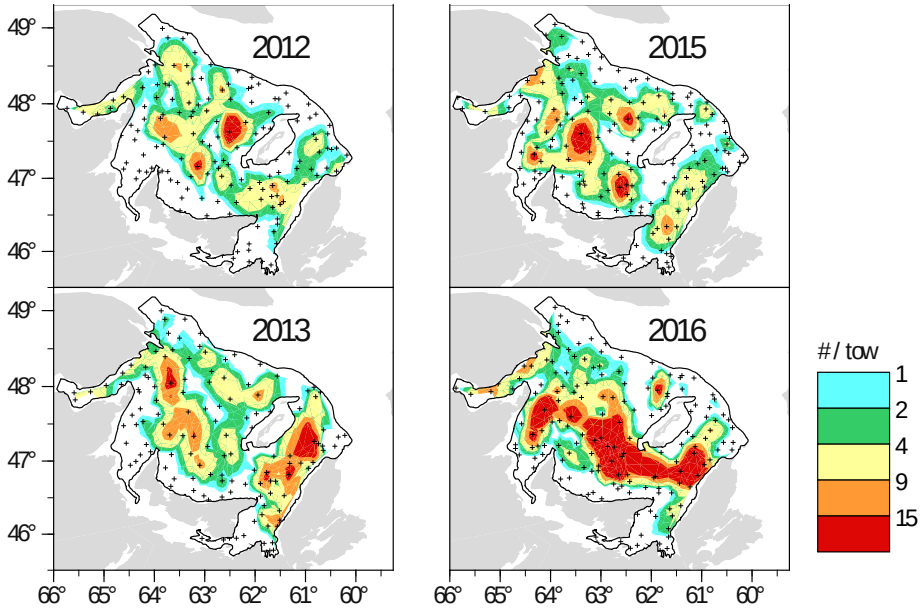


*Figure 7. Annual geographic distribution of commercial-sized adult male (commercial) snow crab catch rates (number per tow) in the September RV survey for the years for which data on crab maturity were collected in all survey sets. The small crosses indicate the set locations. The contour levels represent the 10th, 25th, 50th, 75th and 90th percentiles of non-zero catches for the entire period.*