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**Update on trends in the biomass, distribution and size composition
of snow crab (*Chionoecetes opilio*)
in the September multi-species bottom trawl survey
of the southern Gulf of St. Lawrence, 1980-2013**

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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) has been shown to provide reliable standardized indices of biomass, spatial distribution and habitat use of commercial male snow crab (*Chionoecetes opilio*) for 2001-present and of all snow crab (aggregated index) for 1980-present. This document provides an update for biomass indices, spatial distribution and size composition based on the results of the 2013 RV survey. This information is provided in support of the 2014 regional snow crab assessment process that took place in Moncton, NB on January 29-31. Of particular note, the RV survey confirms a continued high biomass of commercial-sized adult male snow crab also observed in 2011, 2012 and 2013 in a dedicated snow crab survey. The 2013 RV survey also captured an unusually high number of small crabs (≤ 15 mm) in several areas of the southern Gulf of St. Lawrence, a phenomenon that was even more pronounced than in 2012. These crabs may represent a very early signal of strong incoming recruitment that will hopefully be tracked over the coming years.

Mise à jour sur les tendances liées à la biomasse, la distribution et à la composition selon la taille, du stock de crabes des neiges (*Chionoecetes opilio*) lors des relevés plurispécifiques au chalut de fond effectués en septembre dans le sud du golfe du Saint-Laurent, 1980-2013

RESUME

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 et d'utilisation de l'habitat pour le crabe des neiges (*Chionoecetes opilio*) mâle adulte de taille commerciale depuis 2001, et pour tous les crabes des neiges (indice agrégé) depuis 1980. Dans le présent document de recherche, une mise-à-jour des indices de biomasse, de distribution et de répartition des tailles du relevé par NR sont présentés basés sur les résultats du relevé de 2013. Ces informations sont fournies en appui au processus d'évaluation régionale du crabe des neiges de 2014, lequel a eu à Moncton, au N.-B., du 29 au 31 janvier. En particulier, le relevé par NR confirme l'existence soutenue d'une biomasse élevée de crabes adultes de taille commerciale, qui a aussi été observée dans le cadre d'un autre relevé dédié au crabe des neiges. En 2013, 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, un phénomène qui était encore plus accentué qu'en 2012. Ces crabes pourraient constituer un signal hâtif de fort recrutement que l'on espère pouvoir suivre lors des années à venir.

INTRODUCTION

The assessment for the southern Gulf of St. Lawrence (sGSL) snow crab (*Chionoecetes opilio*) stock has been founded in large part on a dedicated bottom-trawl survey, undertaken annually since 1988 to provide a fishery-independent index of stock status (Hébert et al. 2014). However, the spatial domain for this survey has changed over time and was considerably smaller than the stock area in all years prior to 1997; consequently the data for those years are presently not considered as part of the standardized series for the stock assessment (DFO 2012). Another research vessel (RV) bottom-trawl survey of the sGSL, undertaken each September (henceforth the RV survey), has been shown to provide reliable standardized indices of abundance, biomass, spatial distribution and habitat use of commercial-sized adult male snow crab for 2001-2012 and of all snow crab (aggregated index) for 1980-2012 (Benoît 2012a, 2012b). The indices from the RV survey therefore provide information that is complimentary to that from the snow crab survey for the contemporary period, while extending standardized fishery-independent indices for sGSL snow crab back to 1980 (Benoît and Cadigan 2013).

This document provides an update for biomass indices, spatial distribution and size composition of sGSL snow crab based on the results of the 2013 RV survey. This information was provided in support of the 2014 regional snow crab assessment process that took place in Moncton, NB from January 29-31, 2014.

METHODS

THE SEPTEMBER MULTI-SPECIES RV SURVEY

The RV survey 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. However, data from these strata are excluded here from analyses that include years prior to 1984, in order to maintain the consistency of the time series presented. 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. Due to unanticipated delays and interruptions during the 2013 survey, only 132 valid sets were completed compared to a target of around 160 sets.

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. For the present purposes, in these cases, mass was assumed to be 0.5 kg. This produced 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, as can be seen by contrasting the results presented below with those in Figure 3 of Benoît (2012b). Since 2001, captured crabs have also been measured (carapace width) and sexed, though the recording of crab maturity only became part of the RV survey protocol in 2012. Since 2012 all individual crabs were sexed, measured, weighed and their maturity was 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 noted, which will allow for the future development of size-weight relationships that account for incomplete sets of appendages.

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* (1985-1991), the *CCGS Alfred Needler* (1992-2002 and 2004-2005), the *CCGS Wilfred Templeman* (2003), and the *CCGS Teleost* (2004-present). Parameters for the trawls and vessels used in the RV survey are provided in Tables 1 and 2, 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. Though snow crab are routinely captured in the RV survey, the configuration of the footgear is such that catchability is much lower than in the crab survey (Benoît and Cadigan 2013).

The gear change and all of the vessel changes in the RV survey, except for the use of the *CCGS Wilfred Templeman* in 2003, involved comparative fishing to estimate the relative catchability of the vessels/gears (Benoît and Swain 2003a; Benoît 2006). During the years in which the comparative fishing experiments between the *CCGS Alfred Needler* and the *CCGS Teleost* took place (2004 and 2005), both vessels were used to complete the surveys. Based on all of the 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 (Benoît and Swain 2003a; Benoît 2006). Comparative fishing results also suggest that the *CCGS Teleost* may be more efficient at catching snow crab of all sizes aggregated, relative to the *CCGS Alfred Needler* and the *Lady Hammond*, though the statistical significance of the effect was very weak (Benoît 2006). Meanwhile, the estimated relative catchability of these vessels for large snow crab (95+mm) was clearly not statistically different from one (Benoît and Cadigan 2013). Given these results, as well the relatively small difference in abundance trends that is produced by applying the estimated conversion factor (Benoît 2012b), no corrections were applied here for the change to the *CCGS Teleost*.

Prior to the January 2013 assessment meeting, there was no estimate of the relative efficiency of the *CCGS Wilfred Templeman* used in the 2003 RV survey. In the absence of such an estimate, results for 2003 are not presented here. However, the model developed by Benoît and Cadigan (2013) does provide such an estimate which be available once that model is finalized.

Fishing in the RV survey was restricted to daylight hours (07:00-19:00) from 1971 to 1984 but has been conducted 24 hours per day since 1985. Because fishing efficiency can vary by time of day as a result of species-specific diel behaviours such as hiding and trawl avoidance, survey catches were standardized post-hoc based on the results of analyses of survey catches and comparative fishing over the diel cycle (Benoît and Swain 2003b). Overall, from a size aggregated basis, snow crab are more catchable at night in the survey. However, the diel effect is size dependent, with small crabs (<100 mm carapace width) being more catchable during the day, and larger crabs (≥100 mm) more catchable at night. For analyses dealing with biomass, which also extend to years in which no measurements were taken, a size-aggregated correction is applied (Benoît and Swain 2003a). For analyses dealing with crab numbers, which here are limited to 2001-2013, a size-specific correction is applied.

ANALYSIS

Trawlable biomass (kg) of commercial male snow crab in year t (RV_t), was calculated as:

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

for $t = 2001$ to 2013 (excluding 2003),

where $Padult_t$ is the proportion of snow crab $\geq 95\text{mm}$ that were adults in the dedicated sGSL snow crab survey (Hébert et al. 2014) 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

$\alpha = 2.665\text{E-}7$ 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. 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. Note that RV survey trawlable biomass greatly underestimates the actual biomass of snow crab because of low efficiency of the gear at catching crab (Benoît and Cadigan 2013). Nonetheless, because substantial efforts are undertaken to maintain the standardization of the RV survey (Benoît and Swain 2003a, 2003b; Benoît 2006; Benoît et al. 2009), average efficiency should not have changed over time and the RV survey is very likely to produce trawlable biomass values that reliably track actual biomass.

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

$$B_t = \sum_{l=1}^L \frac{U_l}{U \cdot n_{l,t}} \sum_{i=1}^{n_{l,t}} b_{i,t} \quad (2)$$

for $t = 1980$ to 2013 (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 $57,840 \text{ km}^2$, and the RV survey area for strata 415-439 (Fig. 1) representing $70,061 \text{ km}^2$. To approximate the snow crab assessment area, strata 401-403, 420, 421, 428, 432, and 435 were excluded from the analysis. Analyses for RV_t 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 diameter j , and each sex (for 2001-2011) or sex and maturity stage (2012-2013) s , were calculated as:

$$P_{j,s,t} = \frac{\sum_i (w_{i,t} \cdot y_{i,j,s,t})}{\sum_s \sum_{j_s} \sum_i (w_{i,t} \cdot y_{i,j_s,s,t})} \quad (3)$$

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

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

Catch rates of commercial-sized adult male snow crab in the RV survey (numbers/tow) 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, 2001-2013 (excluding 2003). Catch rates of small crab (≤ 15 mm) were likewise mapped to look at their spatial distribution given an observed high abundance in 2012 and 2013.

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, declining to the lowest levels of the 2000s in 2010 (Fig. 2). Since then, the index has increased, reaching a level in 2013 that is comparable to that of the mid-2000s.

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 generally match those observed for large male crab (Fig. 2) because the large males typically comprise the bulk of the biomass in the catches. However, the two indices diverged somewhat in 2013, as the aggregated biomass index reached its highest value since the early 1990s (Fig. 3). This reflects a relatively high biomass of crabs < 95 mm in 2013.

The size-frequency distributions of crabs in the RV survey are shown in Figure 4. Generally speaking, 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 survey and especially the 2013 survey. Crabs of this size were captured at higher abundances and in more locations in 2013 compared to surveys in 2001-2011 (Fig. 5). In fact, high densities of small crabs were caught throughout most of the survey area. These crabs may represent a very early signal of strong incoming recruitment that will hopefully be tracked over the coming years. Higher proportions of such small crabs are expected in the RV survey compared to the dedicated crab survey because of a smaller mesh size in the RV survey trawl codend (19 mm in RV survey compared to 40 mm in the snow crab survey). This may explain why abundance of crabs ≤ 15 mm has not appeared particularly elevated in the dedicated crab survey in 2012 and 2013.

The relative composition of commercial-sized adult male crab in 2013 was comparable to the levels seen in 2007, 2008 and 2011-2012 (Fig. 4). As in 2012, the proportion of crab larger than 110 mm remained small and at a level comparable to that observed during the relatively low abundance years of 2001 and 2009.

Densities of commercial-sized adult male snow crab over the Magdalen shallows and the west of Cape Breton Island in the 2013 RV survey were similar to those observed in 2012 (Fig. 6). The densities for these areas were slightly lower than during the high abundance years of 2004-2006, but greater than those observed during most of the intervening years.

ACKNOWLEDGEMENTS

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TABLES

Table 1. 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	80'	106'
Headline length	60'	75'
Headline height	9'	15'
Wingspread	35'	41'
Door type	Steel bound wood	Portuguese (all steel)
Door weight	1,000 lb	1,800 lb
Lengthening piece liner	1.25 inches'	1.25 inches'
Codend liner	0.25 inches	0.75 inches

Table 2. Parameters for the vessels used in the RV survey of the southern Gulf of St. Lawrence for the years presented in this report.

Characteristics	<i>E.E. Prince</i>	<i>Lady Hammond</i>	<i>CCGS Alfred Needler</i>	<i>CCGS Teleost</i>
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

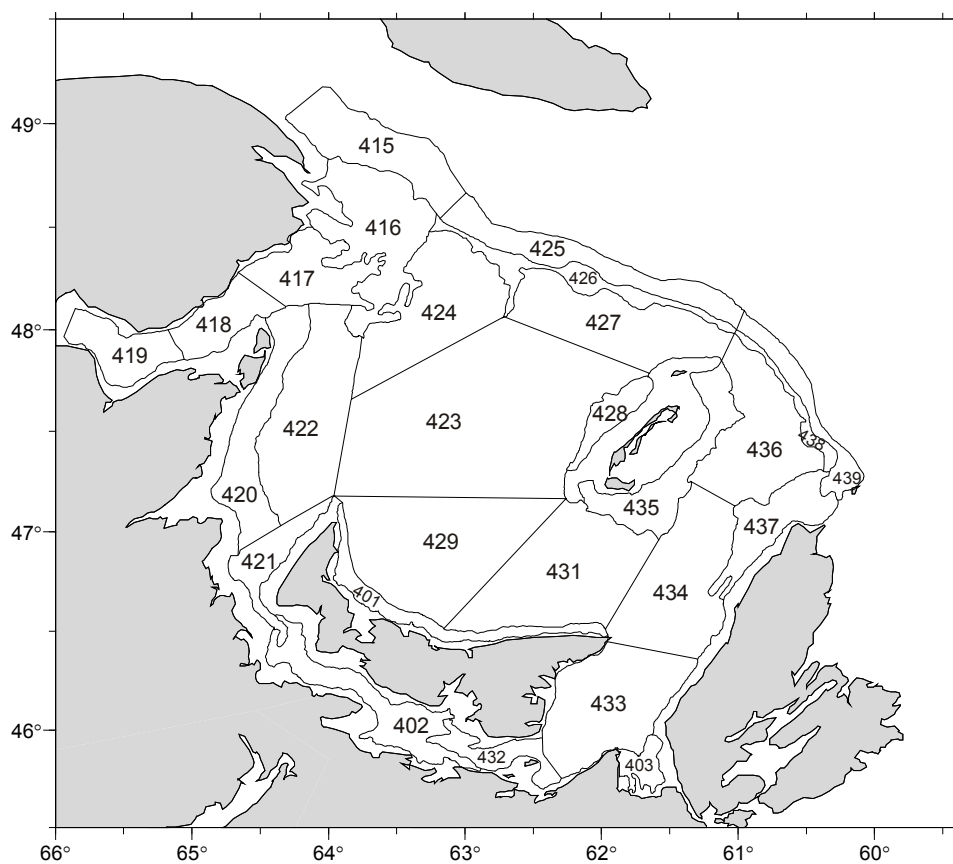


Figure. 1. Stratum boundaries for the southern Gulf of St. Lawrence September RV survey.

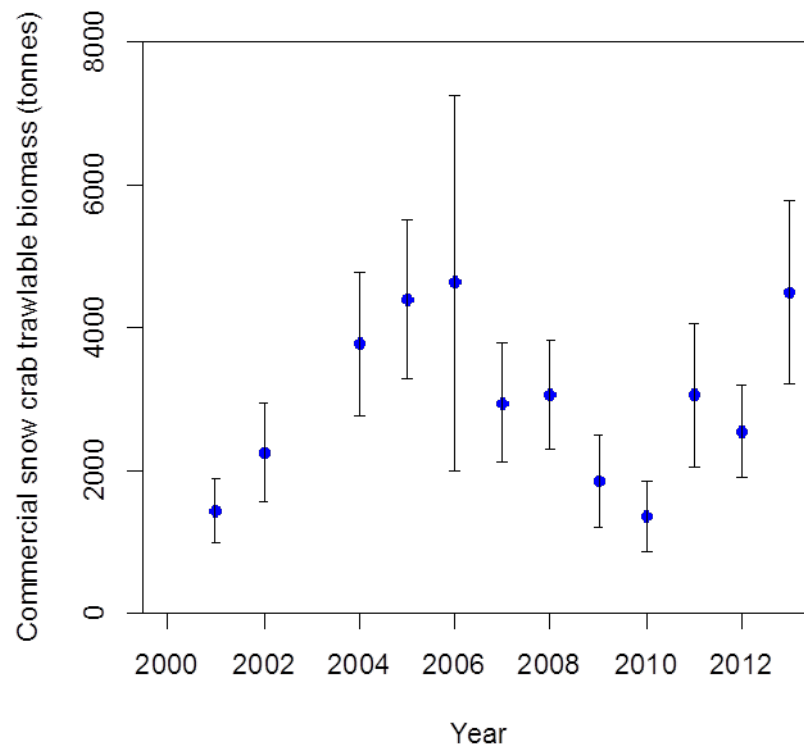


Figure 2. Estimated trawlable biomass (tonnes; mean \pm 95% confidence interval) of commercial-sized adult male snow crab in the RV survey, 2001-2013, for a geographic area comparable to that used for the current snow crab assessment.

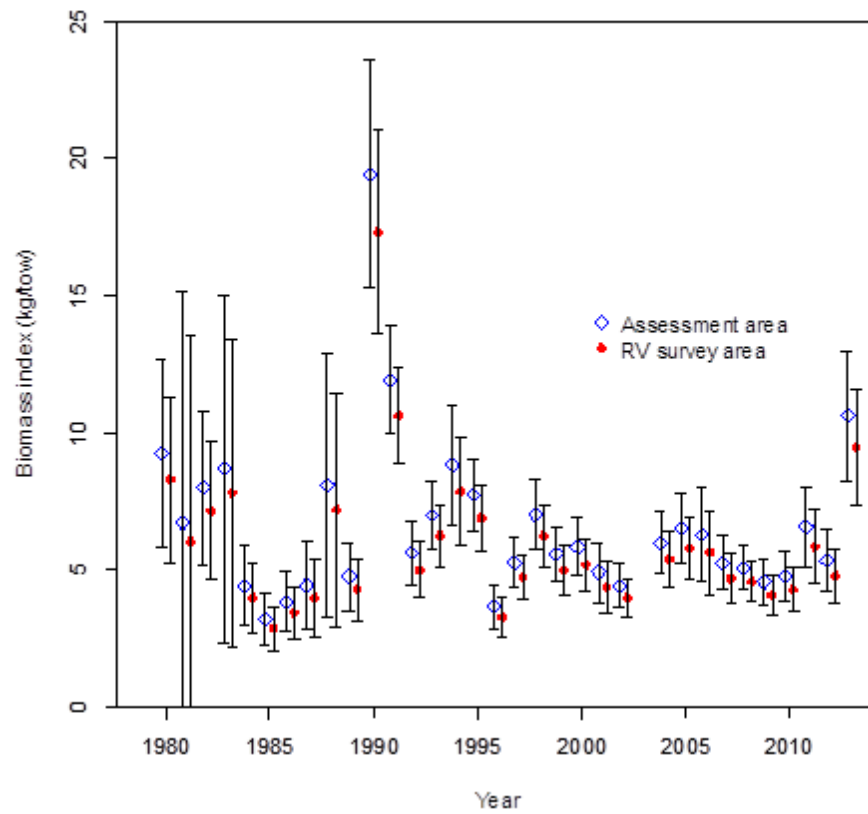


Figure 3. Biomass index (kg/tow; mean \pm 95% confidence interval) for all snow crab (male and female) in the RV survey, 1980-2013, for a geographic area comparable to that used for the current snow crab assessment (open blue diamond) and for the entire RV survey area (solid red square).

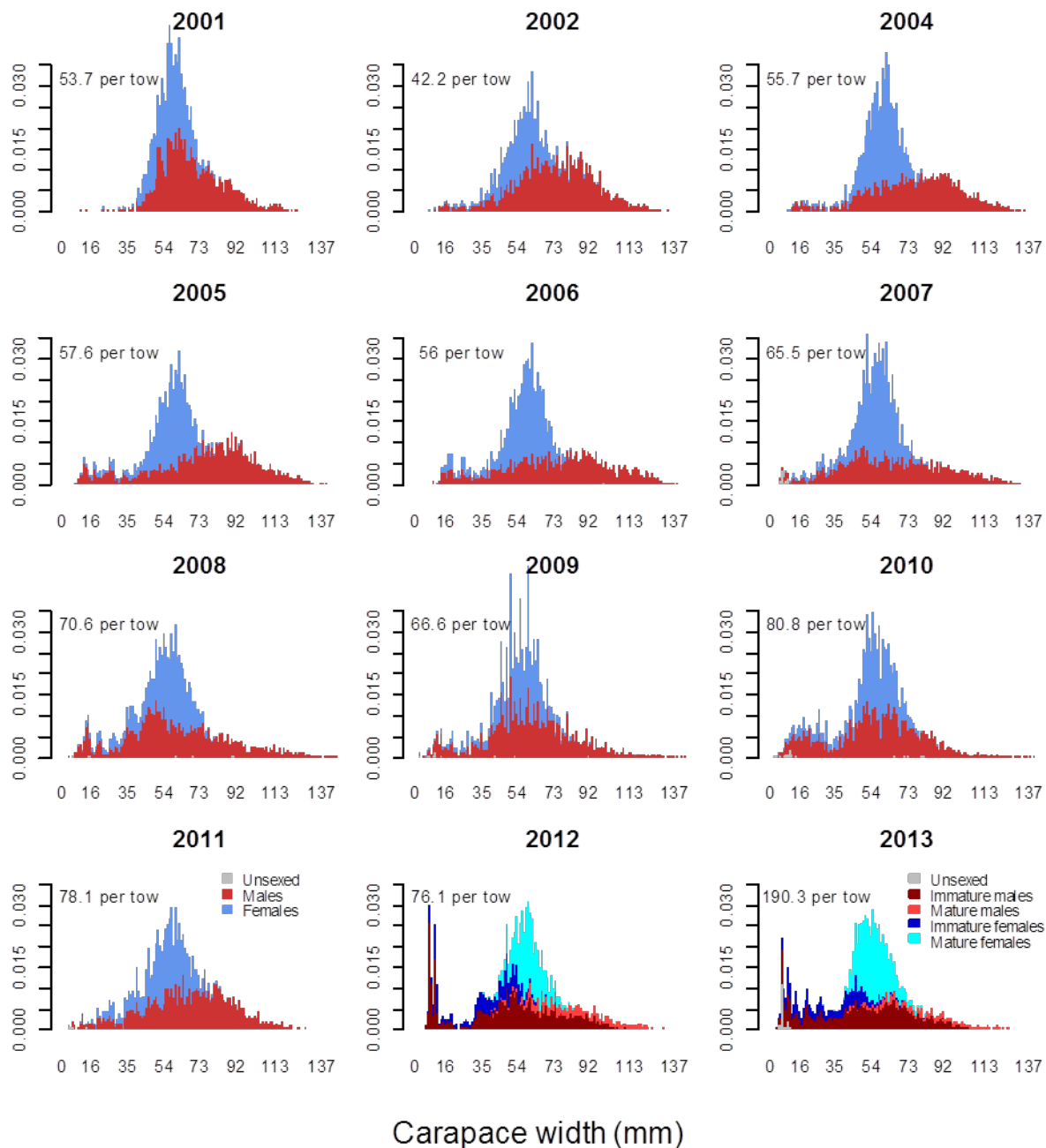


Figure 4. Annual survey-weighted relative frequency distributions (expressed as proportions) of snow crab by carapace width (mm) as a function of sex (for 2001-2011) or sex and maturity stage (2012-2013). The numbers in each panel indicate the value of the annual abundance index (numbers per tow) for snow crab (all sizes and sexes). The data for 2003 are not shown because that survey was incomplete.

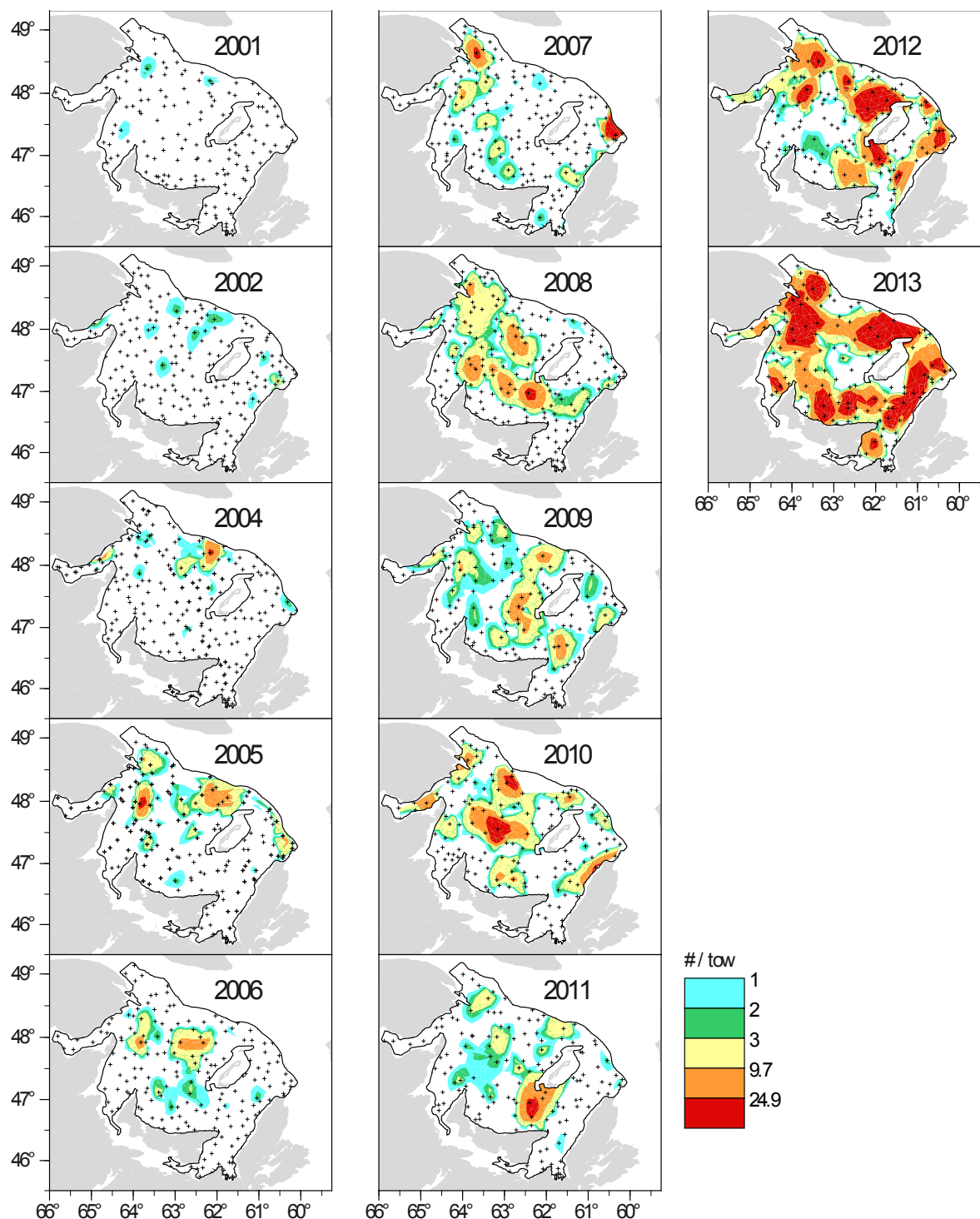


Figure 5. Annual geographic distribution of catch rates (number of crabs per tow) of small snow crab (≤ 15 mm) in the September RV survey, 2001-2013 (excluding 2003). The small crosses indicate the set locations. The contour levels represent the 10th, 25th, 50th, 75th and 90th percentiles of non-zero catches for the entire period.

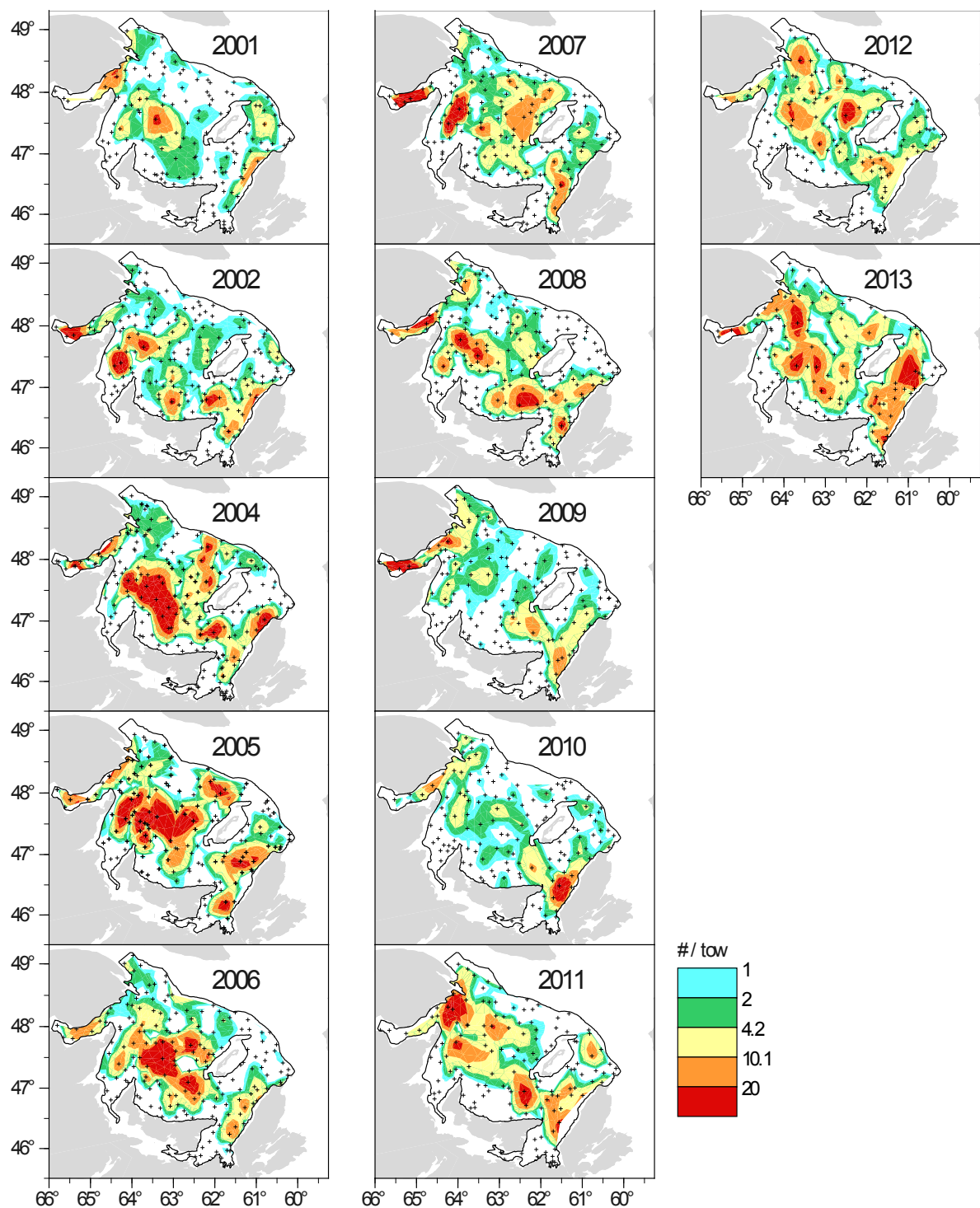


Figure 6. Annual geographic distribution of snow crab catch rates (number of crabs per tow; males ≥ 95 mm) in the September RV survey, 2001-2013 (excluding 2003). The small crosses indicate the set locations. The contour levels represent the 10th, 25th, 50th, 75th and 90th percentiles of non-zero catches for the entire period.