Fisheries and Oceans Canada | Pêches et Océans Canada
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Canadian Science Advisory Secretariat (CSAS)

Research Document 2013/112

Gulf Region

Update on trends in the abundance, distribution and size-composition of snow crab (*Chionoecetes opilio*) in the September multi-species bottom trawl survey of the southern Gulf of St. Lawrence, 1980-2012

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March 2014

Canada

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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Published by:

Fisheries and Oceans Canada
Canadian Science Advisory Secretariat
200 Kent Street
Ottawa ON K1A 0E6

http://www.dfo-mpo.gc.ca/csas-sccs/
csas-sccs@dfo-mpo.gc.ca

ISSN 1919-5044

Correct citation for this publication:

Benoît, H.P. 2014. Update on trends in the abundance, distribution and size-composition of snow crab (*Chionoecetes opilio*) in the September multi-species bottom trawl survey of the southern Gulf of St. Lawrence, 1980-2012. DFO Can. Sci. Advis. Sec. Res. Doc. 2013/112. iv + 12 p.

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 abundance, spatial distribution and habitat use of commercial-sized male snow crab (*Chionoecetes opilio*) for 2001-present and of all snow crab (aggregated index) for 1980-present. This document provides an update for abundances indices, spatial distribution and size composition based on the results of the 2012 survey. This information was provided in support of the 2013 regional assessment process for the stock, that took place in Moncton, NB on January 30 and 31. Of particular note, the RV survey confirms a continued high abundance of commercial-sized male snow crab also observed in 2011 and 2012 in a dedicated snow crab survey. The 2012 RV survey also captured an unusually high number of small crabs (≤15 mm) in several areas of the southern Gulf of St. Lawrence. 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 l'abondance, la distribution et à la composition selon la taille, selon la tailles des crabes des neiges (*Chionoecetes opilio*) capturés lors des relevés plurispécifiques au chalut de fond effectués en septembre dans le sud du golfe du Saint-Laurent, 1980-2012

RESUME

Le relevé au chalut de fond effectué par un navire de recherche (NR) dans le sud du golfe du Saint-Laurent (ci-après nommé relevé par NR) sur une base annuelle au mois de septembre produit des indices normalisés fiables d'abondance, de répartition et d'utilisation de l'habitat pour le crabe des neiges (*Chionoecetes opilio*) mâle 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 d'abondance, de distribution et de répartition des tailles du relevé par NR sont présentés basés sur les résultats du relevé de 2012. Ces informations ont été fournies en appui au processus d'évaluation régionale de 2013, lequel a été effectué à Moncton, au N.-B., les 30 et 31 janvier. En particulier, le relevé par NR confirme l'existence soutenue d'une abondance élevée de crabes mâles de taille commerciale, qui a aussi été observée dans le cadre d'un autre relevé dédié au crabe des neiges. En 2012, le relevé par NR à capturé un nombre anormalement élevé de petits crabs (≤15 mm) à plusieurs endroits dans le sud du golfe du Saint-Laurent. 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. 2011). 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 survey (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, spatial distribution and habitat use of commercial-sized male snow crab for 2001-present and of all snow crab (aggregated index) for 1980-present (Benoît 2012 a,b). 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 abundance indices, spatial distribution and size composition of sGSL snow crab based on the results of the 2012 RV survey. This information was provided in support of the 2013 regional assessment process for the stock that took place in Moncton, NB on January 30 and 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 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 2012, 153 valid sets were completed.

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 because 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 Fig. 3 of Benoît (2012b). Since 2001, captured crabs have also been measured (carapace diameter) and sexed, though the recording of crab maturity only became part of the RV survey protocol in 2012. During the 2012 survey, 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 2012a).

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 (see 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 corrections are applied to the *E.E. Prince* data as a result (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 2014). Given these results, as well the relatively small difference in abundance trends that is produced by applying the estimated conversion factor (Benoît 2012b), no correction 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 (2014) does provide such an estimate, and once that model is finalized estimates for 2003 will be available.

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 2001-2012, a size-specific correction is applied.

ANALYSIS

Trawlable abundance of male snow crab ≥95 mm in year t, RV_t, was calculated as:

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

for t=2001,…,2012 (excluding 2003), where 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, and $y_{i,j,t}$ is the standardized number of male crab of carapace width j caught in tow i in year t. 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 abundance greatly underestimates the actual abundance of snow crab because of low efficiency of the gear at catching crab (e.g., Benoît 2012a). Nonetheless because substantial efforts are undertaken to maintain the standardization of the RV survey (Benoît and Swain 2003a,b; Benoît 2006; Benoît et al. 2009), average efficiency should not have changed over time and the RV survey is very likely to produce relative abundance indices that reliably track actual abundance.

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

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

for t=1980,…,2012 (excluding 2003), where U is the total number of trawlable units in the survey domain and $b_{i,t}$ is the biomass (kg) of snow crab in set i of year t.

Analyses for RV_t were undertaken for two geographic areas of inference: the current snow crab assessment area, representing 57,840 km^2, and the RV survey area for strata 401-439 (Fig. 1), representing 73,182 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 B_t were also undertaken for two geographic areas of inference: the current snow crab assessment area and the RV survey area for strata 415-439 (Fig. 1), representing 70,061 km^2.

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), s, were calculated as:

$$P_{j,s,t} = \sum_{i} \left(w_{i,t} \cdot y_{i,j,s,t} \right) \Big/ \sum_{s} \sum_{j_s} \sum_{i} \left(w_{i,t} \cdot y_{i,j_s,s,t} \right) \quad \text{where } w_{i,t} = \frac{U_l}{U \cdot n_l} \qquad 3)$$

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

Catch rates of commercial-sized 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, 2001-2012 (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.

RESULTS AND DISCUSSION

For the period 2001-2012, the abundance of commercial-sized 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). In 2011, the abundance of commercial-sized male snow crab increased sharply to a level almost twice that observed in 2010. The estimated value for 2012 is slightly lower than that for 2011, though the confidence intervals for the two estimates overlap substantially. The trend is consistent whether abundance is calculated for the snow crab

assessment inference area or the RV survey area, though estimates for the latter are approximately 10% higher.

The RV survey biomass index 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. To the extent that this was also true prior to 2001, the size-aggregated index would provide a reasonable proxy for the abundance of commercial-sized male crabs back to 1980.

The RV survey size-aggregated biomass index suggests that crab biomass since the mid-1990s has been low relative to levels observed in the early 1980s and in 1991, and in particular relative to the high level observed in 1990. The stock was at least 40-50% larger in certain years during the period prior to 1997, compared to the years in the period following, which are currently considered high abundance years for commercial-sized male crabs. Trends in the biomass index for the snow crab assessment area are nearly identical to those for the RV survey area that excludes strata 401-403.

The size-frequency distributions of crabs in the RV survey are shown in Fig. 4. Generally speaking, the late 2000s were characterized by a higher proportion of snow crab <30 cm, relative to the early 2000s. In particular, a very high proportion of small crab ($\leq$15 mm) was observed in the 2012 survey. Crabs of this size were captured at higher abundances and in more locations in 2012 compared to surveys in 2001-2011 (Fig. 5). These crabs may represent a very early signal of strong incoming recruitment that will hopefully be tracked over the coming years.

The relative composition of male crab ≥95 mm in 2012 was comparable to the levels seen in 2007, 2008 and 2011 (Fig. 4). As in 2011, the proportion of crab larger than 110 mm remained small, at a level comparable to that observed during the relatively low abundance years of 2001 and 2009.

Densities of commercial-sized male snow crabs over the Magdalen shallows and the west of Cape Breton Island in the 2012 RV survey were similar to those observed in 2011 (Fig. 6). The densities for these areas were greater than in 2009-2010, but not as elevated as during the high abundance years of 2004-2006.

ACKNOWLEDGEMENTS

Stephen Smith and Marcel Hébert provided useful comments on the working draft of this report.

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Table 1. Parameters for the two trawls used in the RV survey of the southern Gulf of St. Lawrence.

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

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.

	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

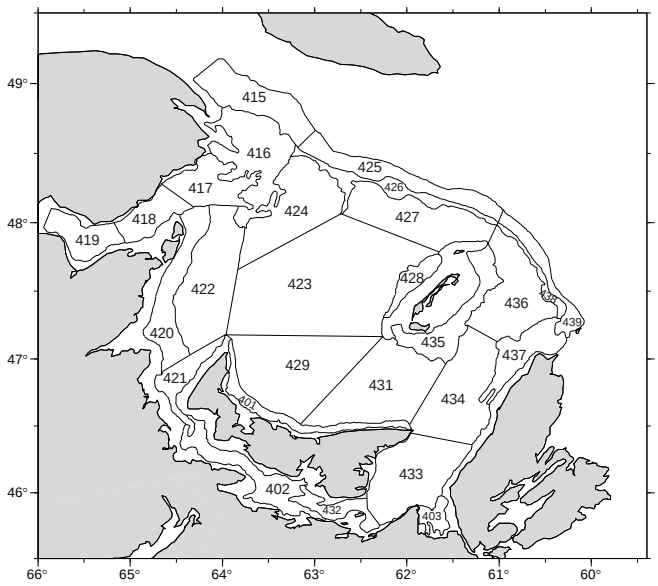

Figure. 1. Stratum boundaries for the southern Gulf of St. Lawrence September RV survey.

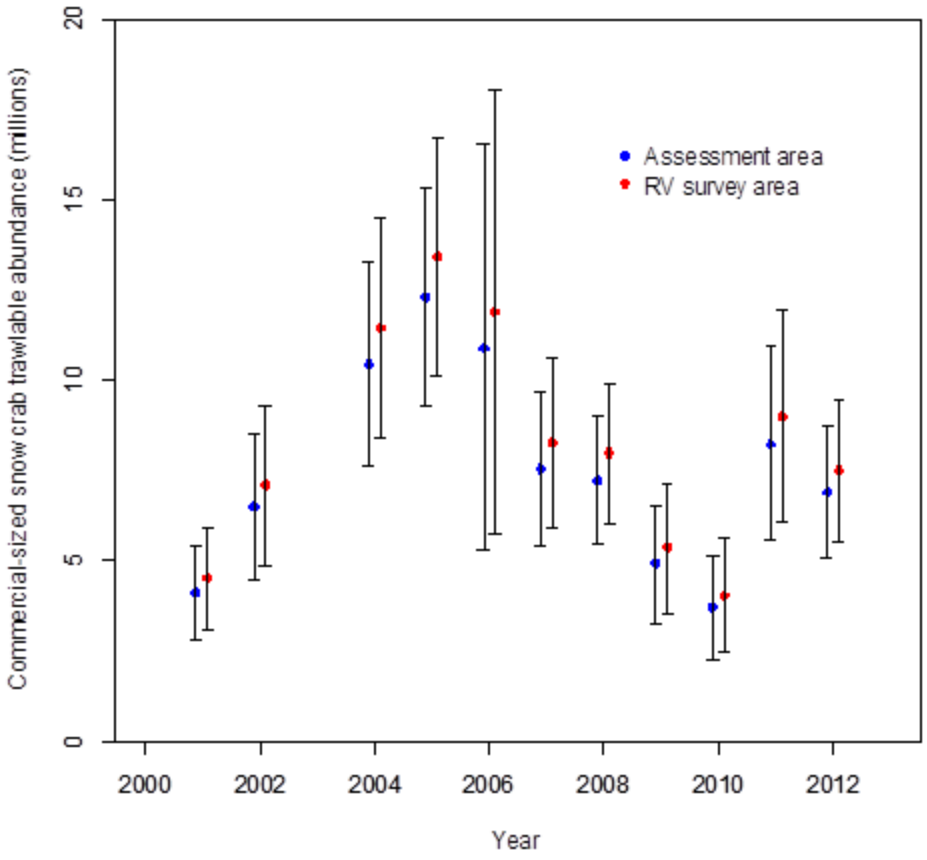

Figure 2. Trawlable abundance in number (millions ± 95% confidence interval) of male snow crab ≥95 mm in the RV survey 2001-2012, based on a geographic area comparable to that used for the current snow crab assessment (blue symbols) and for the entire RV survey area (red symbols).

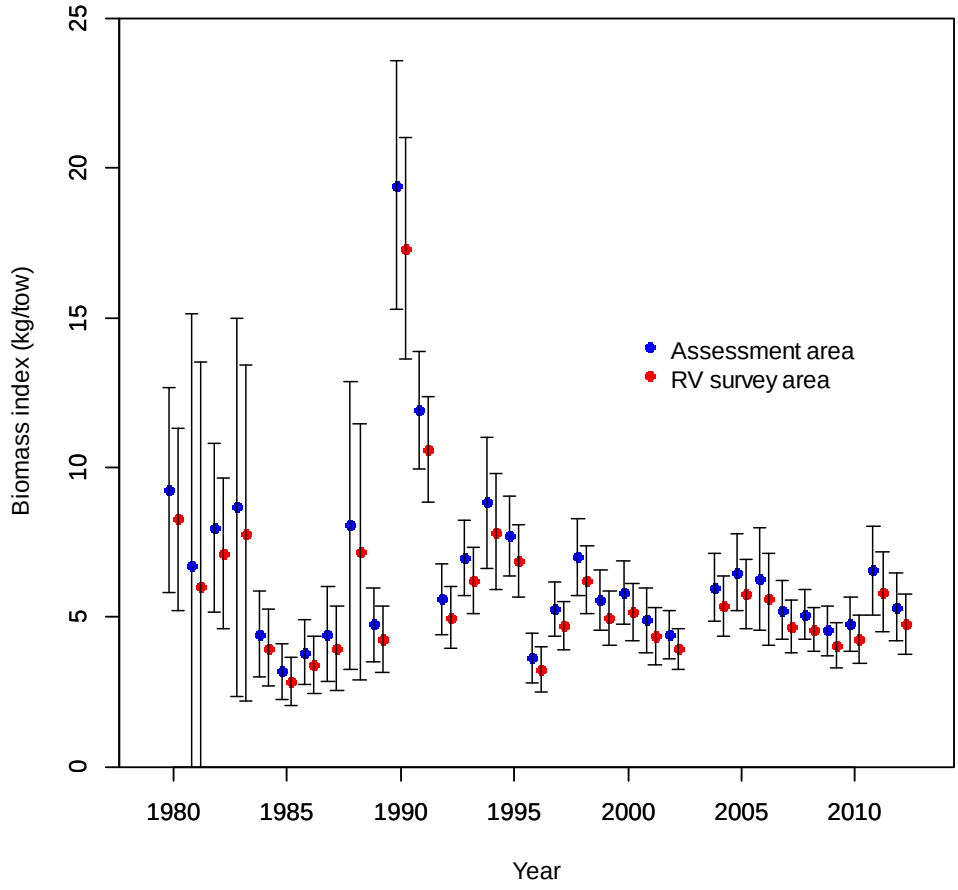

Figure 3. Biomass index (mean kg/tow ± 95% confidence interval) for all snow crab (male and female) in the RV survey 1980-2012, based on a geographic area comparable to that used for the current snow crab assessment (blue) and for the entire RV survey area (red).

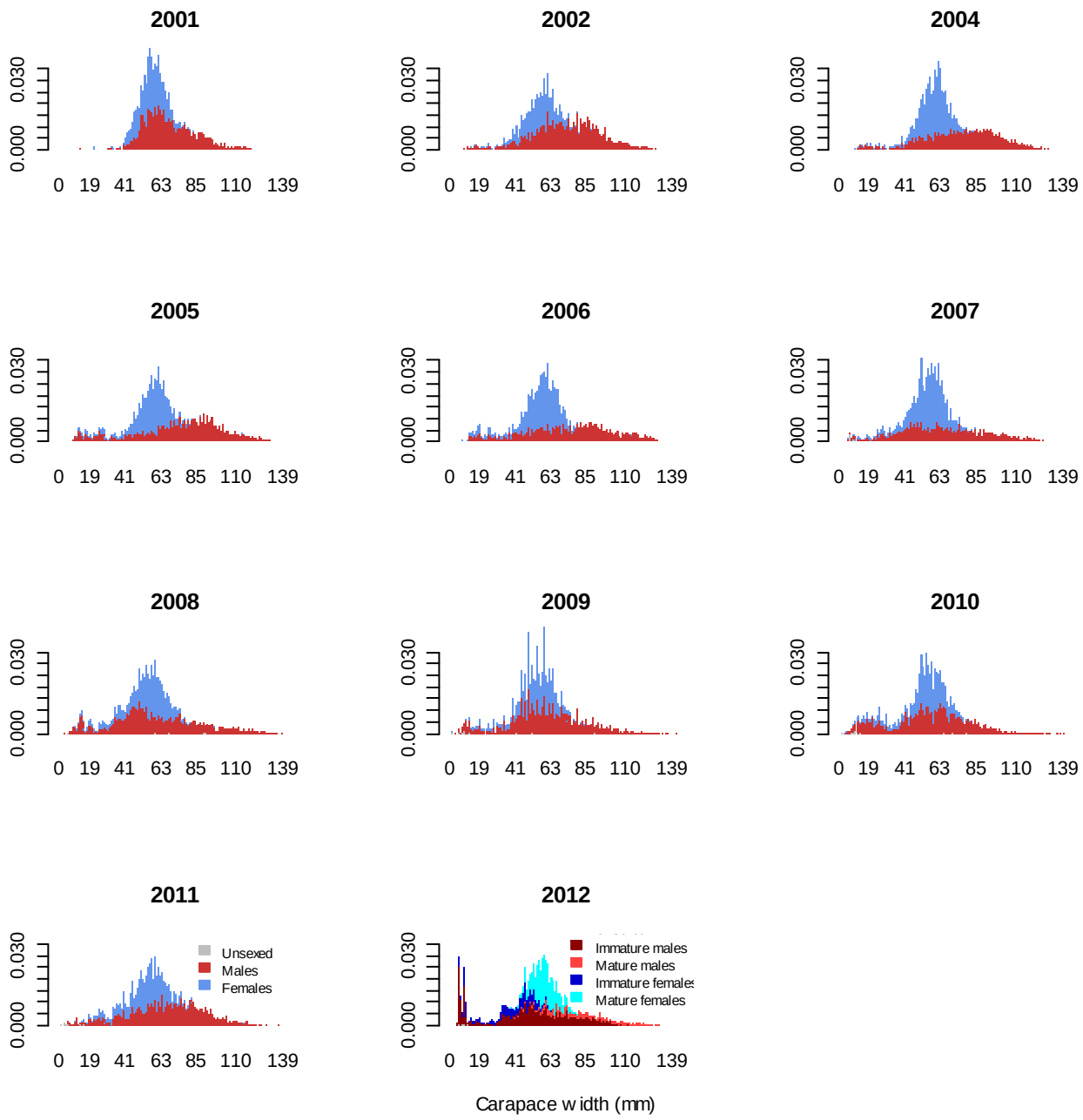

Figure 4. Annual survey-weighted relative frequency distributions (expressed as proportions) of snow crab by carapace diameter category, as a function of sex (for 2001-2011) or sex and maturity stage (for 2012). Because the survey in 2003 was incomplete, the data are not shown for that year.

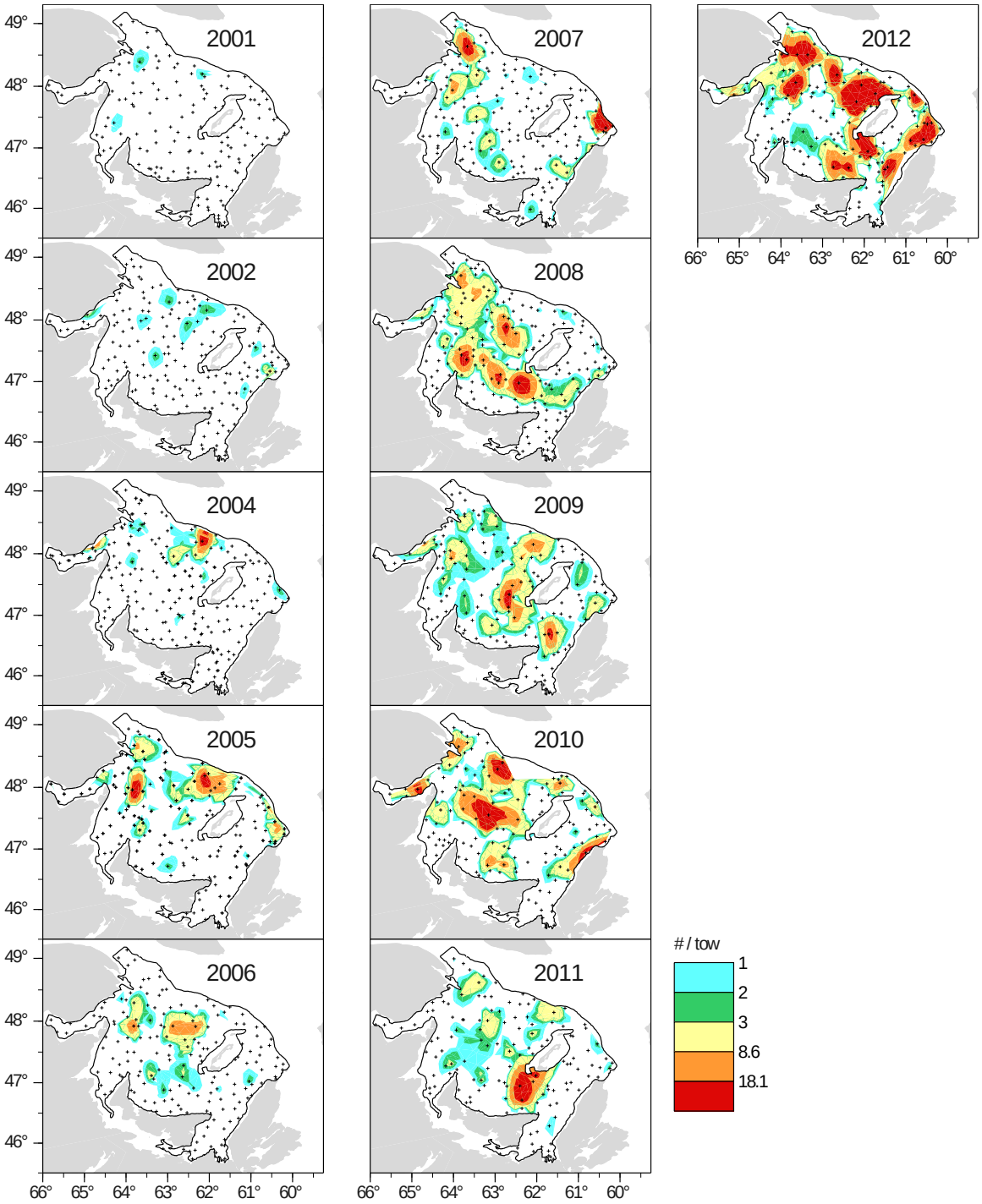

Figure 5. Annual geographic distribution of catch rates of small snow crab (≤15 mm carapace width) in the September RV survey, 2001-2012 (excluding 2003). The small crosses indicate the set locations. The contour levels represent the 10th, 25th, 50th, 75th and 90th percentiles of non-zero catches for the entire period.

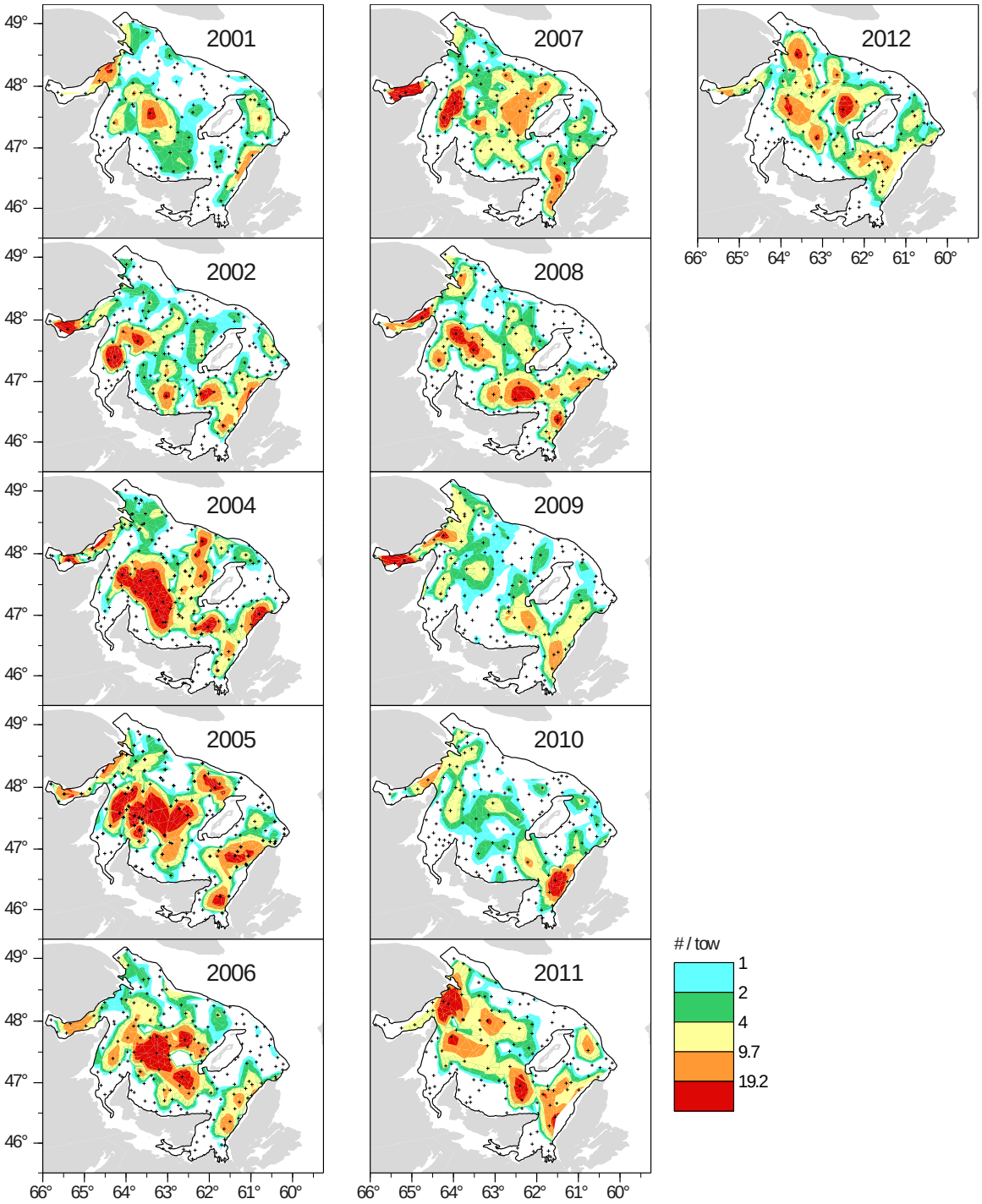

Figure 6. Annual geographic distribution of snow crab catch rates (males ≥95 mm carapace width) in the September RV survey, 2001-2012 (excluding 2003). The small crosses indicate the set locations. The contour levels represent the 10th, 25th, 50th, 75th and 90th percentiles of non-zero catches for the entire period.