**Historical Summary of Survey Station Relocations**

The southern Gulf snow crab annual survey has a 34-year history, from initial exploratory forays in 1987 and 1988 up to the present. During this period, the survey has undergone gradual expansions of the survey area, as well as changes in its spatial sampling design. Details on the sampling protocol and development of this survey can be found in Moriyasu et al. 2008.

The sampling design was based on randomly selected sampling stations within a regular grid overlaying the survey area. Rectangular 10’x10’ grids were used from 1988 to 2011, which were dropped in favour of square grids in 2012 onwards. Subsets of sampling stations were generally held fixed from year to year, though new sampling stations were continually added through survey expansions, relocation of sampling stations from difficult to more favourable trawling locations, and changes in spatial sampling design in 1991, 2006, 2012 and 2013.

**Figure 1** shows a generated historical summary of sampling stations used in the snow crab surveys from 1988 to 2020. Stations lying within a 1.5 km distance of each other were labelled as belonging to the same sampling station.

Macintosh HD:Users:crustacean:Desktop:Stock-Assessment-2020:results:figures:Survey Station History.pdf

**Figure 1**: Historical cumulative summary of sampling stations added during the annual southern Gulf of Saint Lawrence snow crab survey. Shaded lines indicate that a station was successfully sampled for a particular year. The y axis shows the order of appearance of sampling stations, with older sampling stations found near the bottom and the most recent stations near the top. Annotations show major changes in survey sampling design.

From an initial set of stations in 1988, this figure shows that stations were added or redistributed for the majority of survey years. In particular, new stations were rapidly added in the early part of the survey, which had its greatest areal expansion from 1988 to 1993. Due to funding collapse, only a partial survey was conducted in 1996.

The period from 1994 to 2005 saw progressively smaller proportions of stations being re-located, in part due to improvements in geo-location technologies.

After a major survey sampling redesign in 2006, the set of sampling stations remained constant from 2006 to 2011, indicating that the survey crews heavily favoured resampling after a failed tow attempt, rather than relocating at an alternate sampling station.

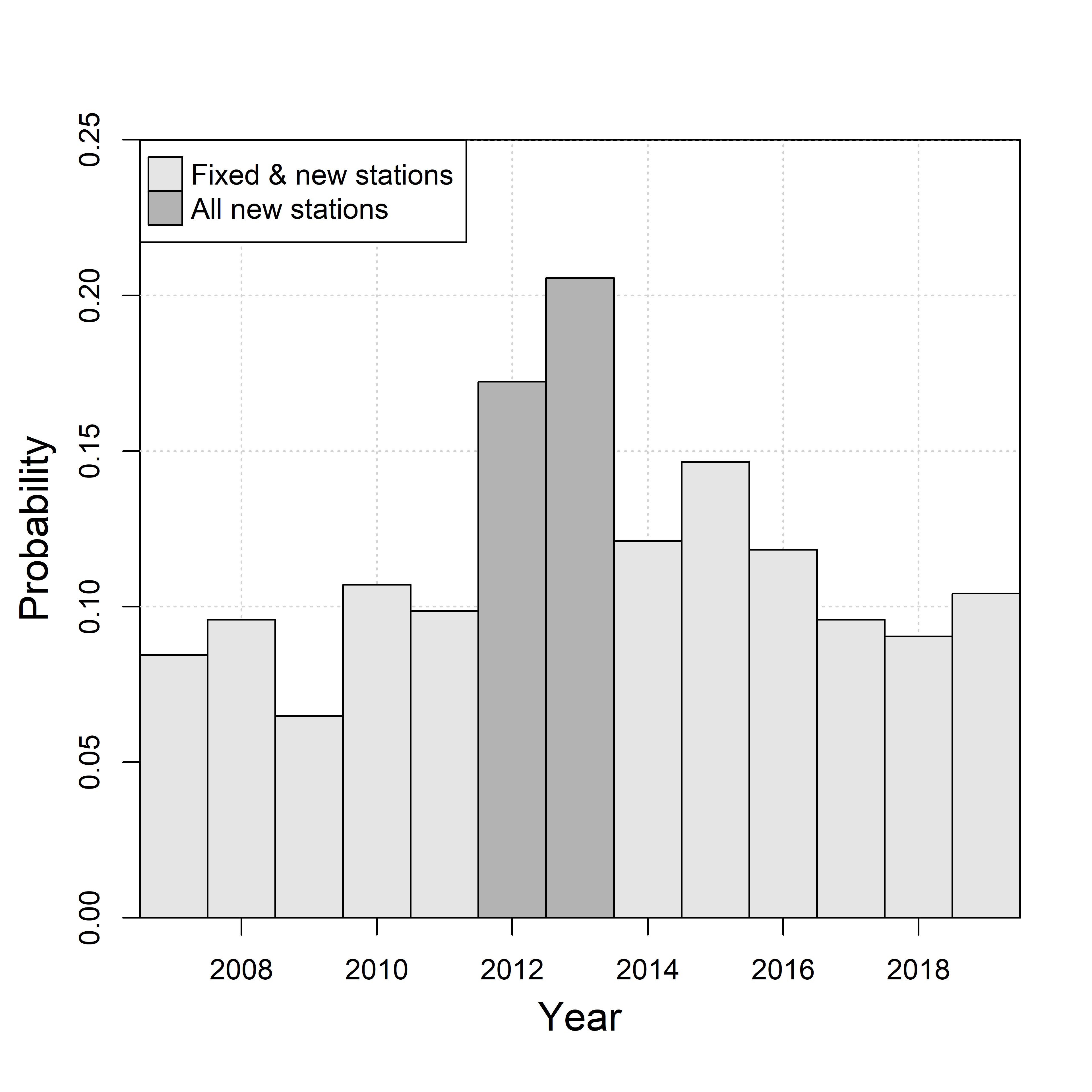
Following a spatial sampling design was changed in 2012 a completely new set of survey stations were generated. The process was repeated in 2013.

From 2013 onward, the survey crew favoured alternate sampling stations, rather than repeating tows after a failed attempt at towing.

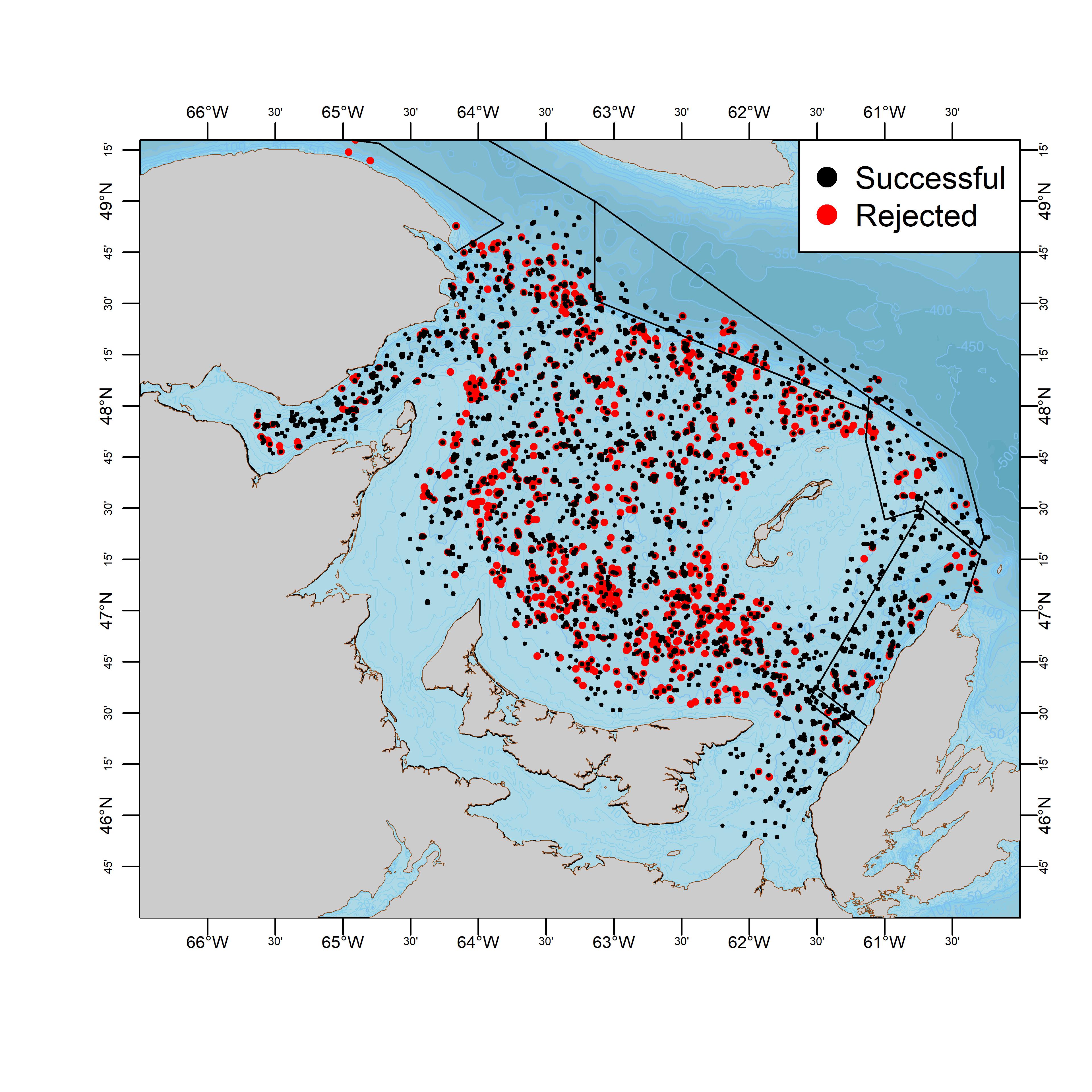
**Figure 2** shows the proportion of failed tows for each survey year. In 2012 and 2013, 17% and 20% of attempted tows failed on the first attempt. Given that the spatial sampling density over the survey area is fairly uniform, these proportions also represent the proportion of the current survey area which is trawlable on the first attempt.

However, these proportions were much higher than in previous years, which were around 8% to 10% in 2006 to 2011. Largely because of this, the trawl stations were held fixed from 2013 onward, with the proportion of failed tows again decreasing as alternate sampling stations replaced many stations from the original 2013 station set. Since 2013, about 200 sampling stations have been moved, which represent an important proportion of the survey’s 355 stations.

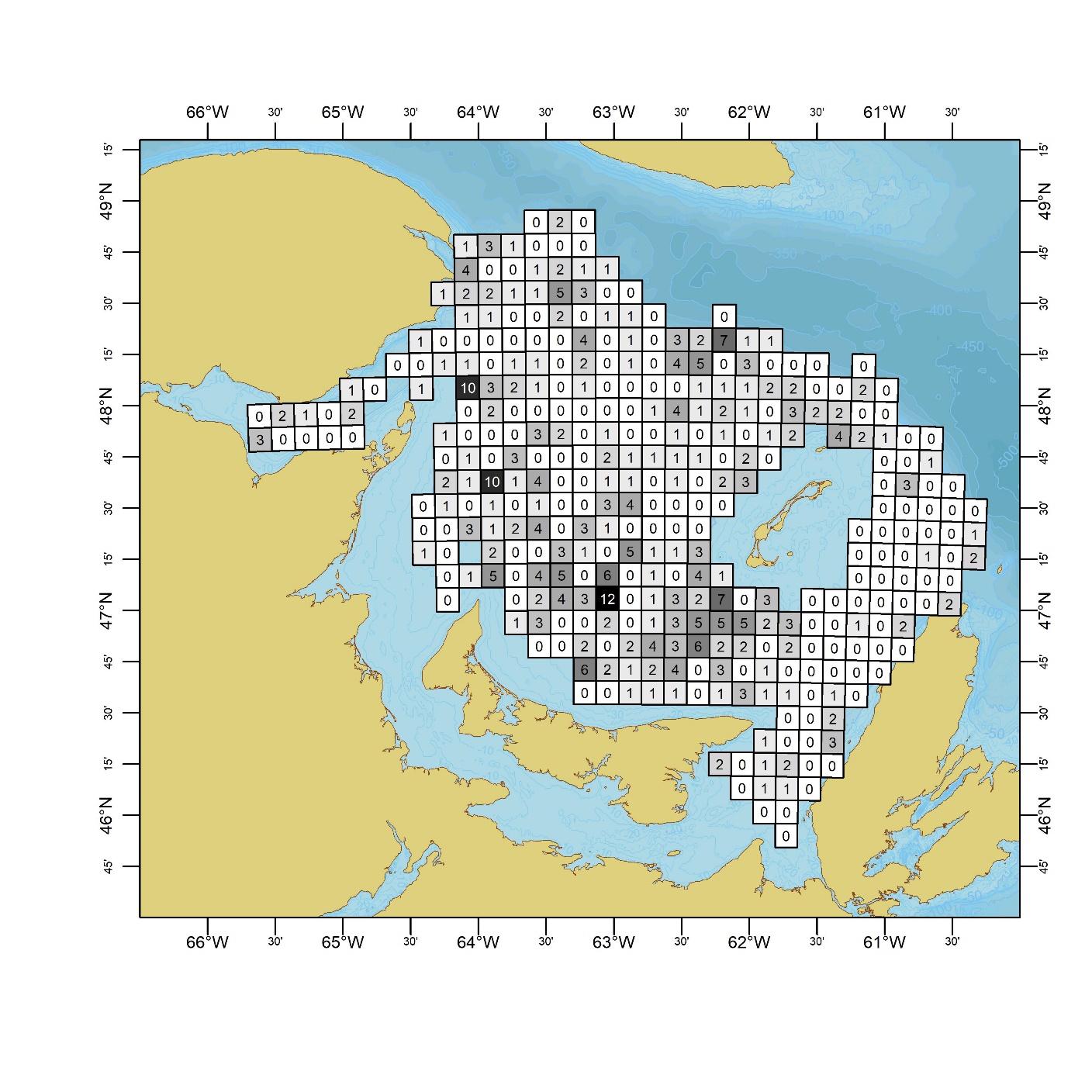
**Figure 3** shows where the relocations have occurred, indicating that problematic areas lie mostly between Prince Edward Island and the Magdalen Islands and along the Laurentian Channel.



**Figure 2**: Proportion of tows rejected on the first attempt during the 2007 to 2019 snow crab surveys.



**Figure 3**: Locations of successful (black) and rejected (red) tows in the 2000 to 2019 snow crab surveys.

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**Figure 4 :** Map of survey sampling grids and the total number of sampling station relocations which have occurred within them over survey years 2013-2019.

**Darrell Mullowney Comments (RAP, 2019)**

Major Concern of Increasing survey catchability (q) over the time series, particularly in recent years.

* This concern extends beyond the 2019 extended tow length issue.
* *There is now an extended period of a positive residual pattern between the survey and predicted R1 biomass, effectively since about 2012 and constituting near-half of the time series.*
* A new survey design was instituted in 2012 with expanded boundaries and new site selection.
* Since 2014, there has been a practice to maintain successful sets from the previous survey and abandon unsuccessful sets in lieu of successfully occupied alternates.
* My guess is the successful alternates that become a fixed part of the survey design thereafter *would be systematically associated with softer substrates, upon which q would be higher (intro of trawl survey document says footrope digs into soft-sediment and increases q.*
* Survey Protocol section of Trawl Document says in 2018 31 stations (= near 10% of total survey) were re-assigned in 2019 survey design. Furthermore, the Characteristics of Tows in 2019 section says an additional 33 sites were completed on additional stations. This is a high rate of attrition, presumably toward softer sediments.
* Figure 7 in the trawling document suggests it’s mostly peripheral areas that are becoming abandoned. This pattern is even more exacerbated in previous assessment documents, such as in 2013-2015 survey years.
* The increasing attrition of shallow/hard bottom areas and increasing prominence of deeper/softer areas would lead to decreased presence of what would typically conform to small crab habitat and increased presence of what would typically conform to larger crab habitat and ultimately increase overall survey q, particularly for large crab (Mullowney review document on crab distribution and migration - Reviews Fish Biology & Fisheries).
* Potential issues of increasing survey q are also consistent with a pattern of increasing vessel horsepower on the survey vessels throughout the time series (ie. Benoit and Cadigan documents on the catchability of the RV vessels).
* There is a flat or negligibly positive slope on the 34-44mm CW crab index since 2006. In contrast, larger crab stages R4-R1, which inform the stage-based model have more strongly increasing slopes. The document claims the model starts at 56-68mm CW because of decreasing trawl catchability at lower sizes, but this would not seem to explain the disconnect between the stages if there is a constant survey q at each stage over time.
* Trends in American Plaice capture in this survey appear consistent with an increasing survey q over the time series.
* Priors used in the stage-based model come from a period of suspected lower survey q.
* Fig. 15 in the fishery document shows a loose positive correlation between biomass and CPUE over the time series (probably significant, not sure). Yet, CPUE in Area 12, the major crab area, has been flat for a decade and actually down in the past two years. This doesn’t appear to be associated with a trap saturation point, as other areas are/have shown higher CPUE.
* If I understand Fig. 11 and Fig 12. correctly, annual m for new-intermediate hard-shelled large adult males would be about 0.2-0.4 = Zm(0.2-0.5). This seems kinda high? I don’t see why a crab in it’s prime physical condition, virtually immune from predation, would have m this high? I could see if it was more relevant to older-shelled or smaller crab. All above points on increasing survey q would suggest exploitation rate is probably higher than suggested.

**What are the implications of these changes?**

**Does the progressive redistribution of tows to more favourable areas for trawling entail biases in the abudance and biomass estimates?**

**How would we address the above questions ?**

* **We know which stations have been redistributed, so we can calculate abundance and biomass estimates with and without these stations. We can check how much the estimates vary.**
* **Are there hints of progressive changes in the abundance trends of snow crab ? In the survey’s other species ?**

**Table 1** : Summary of survey stations having a fixed or new location relative to the those of the previous survey year. For the time period prior to 2012, new tows were labelled as such if the distance from its center point was more than 1.5 km of the previous year’s station. Also shown if the total number of rejected tows.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **Stations** | | |  | **Survey** |  |  |
| **Year** | **Vessel** | **Fixed** | **New** | **Total** | **Rejects** | **Survey area (km2)** | **Grid size** | **Comment** |
| 1989 | Emy Serge | 63 | 92 | 155 | 16 |  | 10'x10' |  |
| 1990 | Emy Serge | 40 | 172 | 212 | 43 |  | 10'x10' |  |
| 1991 | Emy Serge | 56 | 159 | 215 | 19 |  | 10'x10' | New survey stations |
| 1992 | Emy Serge | 59 | 174 | 233 | 9 |  | 10'x10' |  |
| 1993 | Emy Serge | 122 | 86 | 208 | 11 |  | 10'x10' |  |
| 1994 | Emy Serge | 128 | 131 | 259 | 23 |  | 10'x10' |  |
| 1995 | Emy Serge | 152 | 109 | 261 | 38 |  | 10'x10' |  |
| 1996 | Emy Serge | 41 | 31 | 72 | 3 |  | 10'x10' | Partial survey |
| 1997 | Emy Serge | 127 | 132 | 259 | 18 |  | 10'x10' |  |
| 1998 | Emy Serge | 125 | 136 | 261 | 16 |  | 10'x10' |  |
| 1999 | Den C Martin | 151 | 126 | 277 | 26 |  | 10'x10' |  |
| 2000 | Den C Martin | 255 | 25 | 280 | 26 |  | 10'x10' |  |
| 2001 | Den C Martin | 268 | 24 | 292 | 26 |  | 10'x10' |  |
| 2002 | Den C Martin | 270 | 49 | 319 | 24 |  | 10'x10' |  |
| 2003 | Marco Michel | 306 | 11 | 317 | 44 |  | 10'x10' |  |
| 2004 | Marco Michel | 314 | 33 | 347 | 27 |  | 10'x10' |  |
| 2005 | Marco Michel | 283 | 72 | 355 | 51 |  | 10'x10' |  |
| 2006 | Marco Michel | 209 | 145 | 354 | 37 | 44302 | 10'x10' | Station redistribution |
| 2007 | Marco Michel | 351 | 4 | 355 | 47 | 44302 | 10'x10' |  |
| 2008 | Marco Michel | 347 | 8 | 355 | 50 | 44302 | 10'x10' |  |
| 2009 | Marco Michel | 354 | 1 | 355 | 38 | 44302 | 10'x10' |  |
| 2010 | Marco Michel | 354 | 0 | 354 | 47 | 44302 | 10'x10' |  |
| 2011 | Marco Michel | 352 | 1 | 353 | 46 | 44302 | 10'x10' |  |
| 2012 | Marco Michel | 8 | 313 | 321 | 80 | 57840 | 13.1 x 13.1km | Complete survey redesign |
| 2013 | Jean Mathieu | 13 | 339 | 352 | 92 | 57840 | 12.6x 12.6km | Complete survey redesign |
| 2014 | Jean Mathieu | 306 | 47 | 353 | 56 | 57840 | 12.6 x 12.6km |  |
| 2015 | Jean Mathieu | 298 | 55 | 353 | 71 | 57840 | 12.6 x 12.6km |  |
| 2016 | Jean Mathieu | 314 | 40 | 354 | 55 | 57840 | 12.6 x 12.6km |  |
| 2017 | Jean Mathieu | 319 | 34 | 353 | 50 | 57840 | 12.6 x 12.6km |  |
| 2018 | Jean Mathieu | 315 | 39 | 354 | 41 | 57840 | 12.6 x 12.6km |  |
| 2019 | Avalon Voyager II | 315 | 37 | 352 | 67 | 57842.8 | 12.6 x 12.6km |  |
| 2020 | Avalon Voyager II | 327 | 26 | 352 | 38 | 57842.8 | 12.6 x 12.6km |  |

**Bibliography:**

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.