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Gulf Region

ASSESSMENT OF SNOW CRAB (*CHIONOECETES OPILIO*) IN THE SOUTHERN GULF OF ST. LAWRENCE (AREAS 12, 12E, 12F AND 19) TO 2020 AND ADVICE FOR THE 2021 FISHERY

*Snow crab (*Chionoecetes opilio*).*
Credit: Fisheries and Oceans Canada

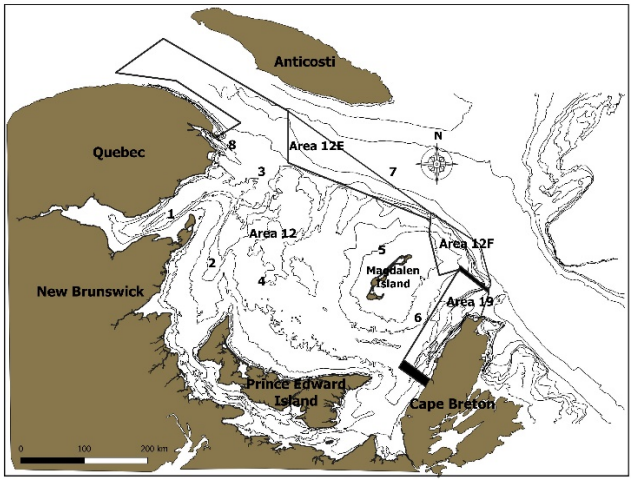

Figure 1. Map of the southern Gulf of St. Lawrence showing the Crab Fishing Areas (12, 12E, 12F, and 19), fishing grounds, and management buffer zones (shaded area). Fishing grounds are labeled as follows: 1) Chaleur Bay, 2) Shediac Valley, 3) Orphan Bank, 4) Bradelle Bank, 5) Magdalen Channel, 6) Cape Breton Corridor, 7) Laurentian Channel, and 8) American Bank.

Context:

*Snow crab (*Chionoecetes opilio*) has been commercially exploited in the southern Gulf of St. Lawrence since the mid-1960s. There are four individually managed fishing areas among which Area 12 (Figure 1) is the largest fishery in terms of its fishable surface, number of participants and landings. In Areas 12, 12E and 12F, the fishing season generally starts in April or May as soon as the Gulf is clear of ice and continues into early summer. In Area 19, the fishery opens after June 30 and typically ends in mid-September. The landing of females is prohibited and only hard-shelled males ≥ 95 mm of carapace width are commercially exploited.*

DFO Gulf Region Fisheries and Aquaculture Management requested an assessment of the resource status in 2020 and catch advice for the 2021 fishery. This document provides an overview of the assessment results. Catch rates and other fishery performance indicators are reported. The assessment of the status of the southern Gulf snow crab resource (Areas 12, 19, 12E and 12F) is based on fishery independent trawl surveys that provide indicators of: abundance (commercial biomass), reproductive potential (abundance of mature females), and recruitment. A science peer review virtual meeting was held via Zoom on February 10-11, 2021. Participants at the science review were from DFO Science, DFO Fisheries and Aquaculture Management, fishing industry, and Indigenous organizations.

SUMMARY

- Snow crab in the southern Gulf of St. Lawrence (sGSL) is considered to be a single stock unit for assessment purposes and comprises snow crab fishing areas 12, 12E, 12F, and 19.
- The landings of snow crab from the sGSL in 2020 were 28,270 tonnes (t) from a revised quota of 31,152 t. Catch per unit of effort have decreased in all fishing areas in 2020 from 2019.
- Concerns of biomass overestimation were raised during the 2019 assessment and persisted in 2020. Indicators of survey biases were presented with supporting data and hypotheses were discussed.
- The exploitation rate of the 2020 fishery was estimated at 35.6% based on the 2019 survey commercial biomass estimate. However, overestimation of the commercial biomass would imply that the exploitation rate during the 2020 fishing season was higher than estimated.
- The 2020 commercial biomass was estimated at 77,748 t and composed of 75% recruitment and 25% of residual biomass.
- Overestimation biases ranged from 30 to 40% among mature females and sub-legal males. Overestimation bias estimates among commercial crab were estimated at 14%, though this value was deemed less reliable because of complex fishery-related dynamics.
- Recurrent overestimations of the commercial biomass would result in exploitation rates exceeding the agreed upon level in the Precautionary Approach harvest decision rules.
- The risks of biomass indicators falling under the limit and upper stock reference points assuming different levels of overestimation biases were presented. However, no consensus on the level of overestimation bias was reached.
- Despite overestimation in the abundance indices, the stock continues to show signs of sustained recruitment and productivity. Overall, the stock is expected to remain in the healthy zone of the Precautionary Approach.
- A plan will be developed to address bias and catchability issues for the upcoming surveys and consistency in the indicators used in the stock assessment.
- There is continued evidence of warming conditions in the sGSL and the extent to which it could impact snow crab population dynamics and distribution is not well understood.

BACKGROUND

Species Biology

Snow crab (*Chionoecetes opilio*) is a crustacean with a flat, almost circular body and five pairs of legs. In order to grow, the hard outer shell is periodically shed in a process called molting. After molting, crabs have a soft shell for a period of 8 to 10 months. Soft-shelled crab is defined by shell hardness (< 68 durometer units) and includes both new-soft (condition 1) and clean hard-shelled crab (condition 2). The term white-crab is used in the summer fishery of Area 19 because the newly-molted crabs have reached a relatively harder carapace than those observed during the spring fishery (Areas 12, 12E and 12F). White crab is defined by shell hardness < 78 durometer units and includes both new soft (condition 1) and clean hard-shelled crab (condition 2).

Snow crab do not continue to molt throughout their lifespan. Females stop growing when they acquire a wide abdomen for carrying eggs, occurring at carapace widths (CWs) less than 95 mm. Males stop growing when they acquire large claws on the first pair of legs, which can occur at CWs between 40 and 150 mm. Females produce eggs that are carried beneath the abdomen for approximately two years in the southern Gulf of St. Lawrence (sGSL). The eggs hatch in late spring or early summer and the newly-hatched crab larvae spend 12-15 weeks in the water column. At the end of this period, they settle on the bottom. It takes at least 8-9 years (post-settlement) for males to reach legal commercial size.

Fishery

Until 1994, the snow crab fishery in Area 12 (Figure 1) involved 130 mid-shore crab harvesters from New Brunswick, Quebec, and Nova Scotia. Since 1997, the Prince Edward Island (PEI) coastal fishery, (formerly Areas 25/26) has been integrated into Area 12. In 2003, a portion of the coastal fishery off Cape Breton (formerly Area 18) was also integrated into Area 12. For the purpose of this assessment, Area 12 refers to the management unit that includes snow crab fishing zones 12, 18, 25, and 26 (as defined in regulation) (Figure 1). The number of allocation shares in Area 12 was 244 in 2020 (Table 1).

Area 19 (Figure 1) was established in 1978 for the exclusive use of Cape Breton inshore fish harvesters with vessels less than 13.7 meters (45 feet) in length. There were 158 allocation shares in Area 19 in 2020.

Areas 12E and 12F were introduced in 1995 as exploratory fisheries. In 2002, the status of Areas 12E and 12F was changed from exploratory to commercial fishing areas. There were four snow crab allocation shares in Area 12E and 43 allocations shares in Area 12F in 2020. For 2020, harvesters in Area 12F requested a lower Total Allowable Catch (TAC) than the value originally assigned for the area based on the decision rule.

Table 1. Number of allocation shares, vessels, traps, revised quotas, opening dates, and dates of the last landing of the snow crab fishery by management area in the southern Gulf of St. Lawrence in 2020.

Characteristics	Area 12	Area 12E	Area 12F	Area 19	Southern Gulf
Allocation shares [1]	244	4	43	158	449
Number of active vessels	309	4	24	106	440
Total number of traps allowed	37,402	475	1,655	1,699	41,231
Opening date	April 24	April 24	April 24	July 2	-
Date of the last landing	July 1	June 30	July 1	August 13	-
Revised quota (t) [2]	27,435	238	1,192	2,287	31,152 [3]
Landings (t)	24,668	234	1,084	2,284	28,270

[1] The number of quota allocations among which the Total Allowable Catch (TAC) is divided (Source: DFO Administrative List for Snow Crab Areas 12, 12E, 12F, and 19).
[2] For reasons of interannual quota adjustments, reconciliations, and re-distribution of the scientific quota among areas, the revised quota does not necessarily correspond to the TAC in the notice to harvesters.
[3] Quota includes 450 t set aside to finance the trawl survey in 2020 (under Section 10 of the Fisheries Act).

The minimum legal CW for this male only fishery is 95 mm; soft-shelled and white crab are not targeted or retained by the fishery.

Management of these fisheries is based on quotas and effort controls (trap allocations, trap dimensions, and seasons). At-sea soft-shelled and white crab catch monitoring protocols allow for the closure of portions of fishing areas when the proportion of these males exceeds 20% in

the catch. The protocols are in place to maximize the yield and the reproductive potential of the resource. Due to the COVID-19 pandemic, there were few at-sea observers deployed onboard snow crab vessels during the 2020 fishing season. The soft-shelled protocol was consequently not applied in Areas 12, 12E and 12F. As COVID-19 restrictions eased during the summer, observers were deployed on Area 19 fishing vessels and the white-shelled crab protocol was applied in the area. Because of limited data, analyses based on the at-sea observer data to monitor the fishery performance such as the catch composition, the mean size of commercial-sized males and the percentage of soft-shelled crabs could not be performed for the 2020 fishing season.

Grid closures were implemented at different times during the fishing season based on confirmed observations of North Atlantic right whales (NARW). These closures displaced some of the fishing effort from traditional grounds in 2020. Information on the closures can be found here.

The landings from the sGSL were low in the 1970s and increased with four periods of high landings: 1981-1986, 1994-1995, 2002-2009, and more recently 2012 to 2020 (Figure 2). Snow crab landings from the sGSL in 2020 were 28,270 t from a revised quota of 31,152 t. Factors that could explain why portions of the quota were not landed, a first for the time-series, include displaced fishing effort in response to grid closures for NARW, overall lower catches, and lower than expected abundance of commercial-sized adult male crabs.

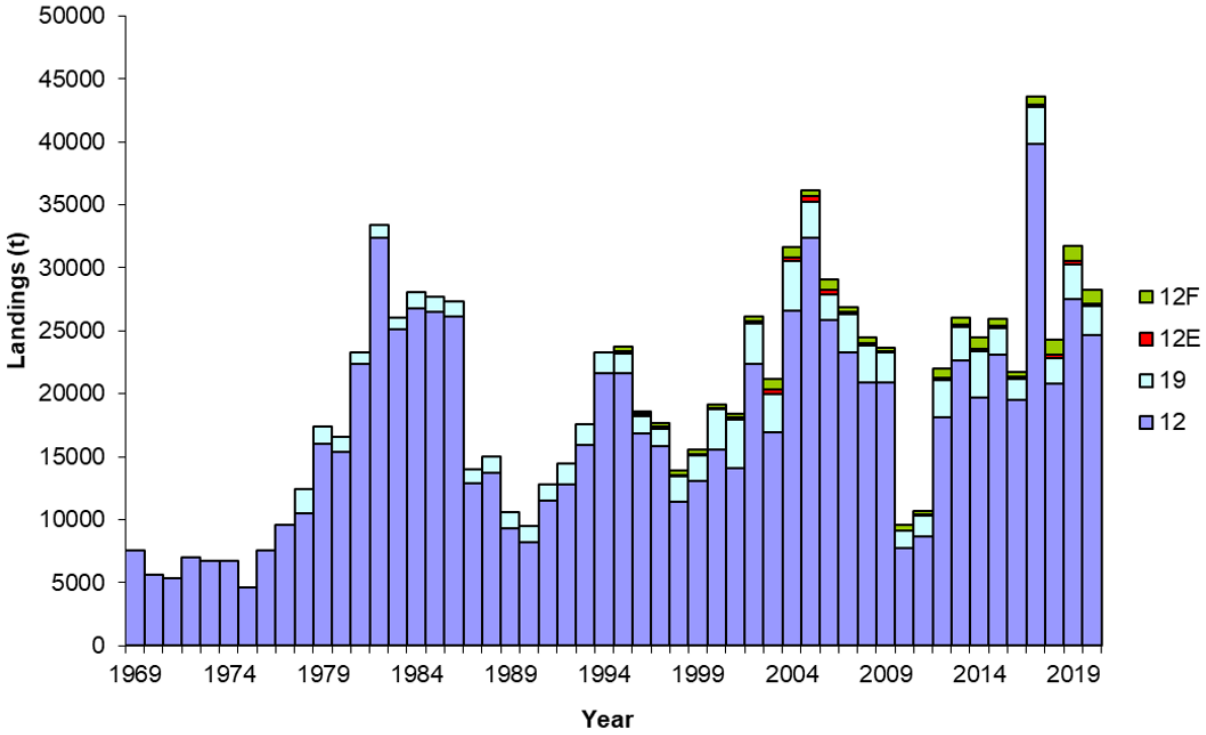

Figure 2. Landings (tonnes; t) in the southern Gulf of St. Lawrence snow crab fishery by fishing area from 1969 to 2020.

Landings in Area 12 were 24,668 t from a revised quota of 27,435 t (Tables 1 and 2; Figure 2). The fishing effort estimated from logbooks has varied from 161,148 to 559,365 trap hauls between 1987 and 2020, with the lowest effort in 2010 and the highest effort in 2020 (Hébert et al. 2021).

Table 2. Quota and landings (tonnes; t), catch per unit of effort (CPUE; kg/trap-haul), fishing effort (trap hauls), soft-shelled crab percentages, and associated closed grids for the snow crab fishery in Area 12, 2012 to 2020.

Fishery descriptor	2012	2013	2014	2015	2016	2017	2018	2019	2020
Quota (t) [1]	18,143	22,548	19,409	23,021	19,393	39,651	20,909	28,051	27,435
Landings (t)	18,159	22,645	19,633	23,080	19,499	39,825	20,769	27,554	24,668
CPUE (kg/trap-haul)	68.0	76.4	61.8	67.9	64.0	72.0	44.2	55.5	44.1
Effort (trap hauls)	267,044	296,398	317,689	339,912	304,624	553,125	469,887	496,468	559,365
Soft-shelled crab (%) in catches [2]	3.7	2.8	4.4	4.9	5.3	6.0	4.4	5.2	NA[4]
Grids closed (total of 323)	7	5	8	41	5	57	4[3]	9[3]	NA[4]

[1]Since 2012, quotas were revised for inter-annual quota adjustments, reconciliations, and re-distribution of the scientific quota among areas, the revised quotas do not necessarily correspond to the TAC in the notice to harvesters.
[2] The percentages are based on durometer readings < 68. Catches are defined as male crabs of all sizes.
[3] Grids closed according to the soft-shelled crab protocol. Additional closures to minimize fishery interactions with North Atlantic right whales are not accounted for in this table.
[4] At-sea observer coverage was limited in 2020 due to the COVID-19 pandemic.

The 2020 landings in Area 12E were 234 t from a revised quota of 238 t (Tables 1 and 3; Figure 2). The fishing effort in Area 12E has varied from 1,825 to 10,074 trap hauls between 1995 and 2020, with the lowest effort in 2010 and the highest effort in 2006 (Hébert et al. 2021). The fishing effort in Area 12E increased from 3,415 trap hauls in 2019 to 5,098 trap hauls in 2020.

Table 3. Quota and landings (tonnes; t), catch per unit of effort (CPUE; kg/trap-haul), fishing effort (trap hauls), soft-shelled crab percentages, and associated closed grids for the snow crab fishery in Area 12E, 2012 to 2020.

Fishery descriptor	2012	2013	2014	2015	2016	2017	2018	2019	2020
Quota (t) [1]	251	204	170	189	144	199	266	217	238
Landings (t)	185	204	178	192	144	203	260	224	234
CPUE (kg/trap-haul)	32.9	40.1	47.3	65.8	51.5	60.9	46.6	65.7	45.9
Effort (trap hauls)	5,623	5,097	3,765	2,918	2,796	3,333	5,579	3,415	5,098
Soft-shelled crab (%) in catches [2]	3.3	15.9	7.8	9.8	1.1	2.0	4.6	3.1	NA[3]
Grids closed (total of 8)	0	0	0	0	0	0	0	0	NA[3]

[1]Since 2012, quotas were revised for interannual quota adjustments, reconciliations, and re-distribution of the scientific quota among areas, the revised quotas do not necessarily correspond to the TAC in the notice to harvesters.
[2] The percentages are based on durometer readings < 68. Catches are defined as male crabs of all sizes.
[3] At-sea observer coverage was limited in 2020 due to the COVID-19 pandemic.

In Area 12F, the landings were 1,084 t from a revised quota of 1,192 t (Tables 1 and 4; Figure 2). The fishing effort in Area 12F has varied from 4,437 to 23,163 trap hauls between 1995 and 2020, with the lowest effort in 2002 and the highest effort in 2014 (Hébert et al. 2021). The fishing effort increased from 18,083 trap hauls in 2019 to 22,168 trap hauls in 2020.

Table 4. Quota and landings (tonnes; t), catch per unit of effort (CPUE; kg/trap-haul), fishing effort (trap hauls), soft-shelled crab percentages, and associated closed sectors for the snow crab fishery in Area 12F, 2012 to 2020.

Fishery descriptor	2012	2013	2014	2015	2016	2017	2018	2019	2020
Quota (t) [1]	706	543	906	516	373	680	1,218	1,155	1,192
Landings (t)	706	543	882	510	381	684	1,183	1,166	1,084
CPUE (kg/trap-haul)	41.8	49.0	38.1	38.2	43.9	72.6	69.1	64.5	45.2
Effort (trap hauls)	16,890	11,086	23,163	13,351	8,667	9,421	17,120	18,083	22,168
Soft-shelled crab (%) in catches [2]	9.4	2.4	1.7	3.3	10.4	1.9	1.3	2.1	NA[3]
Sectors closed (total of 3)	0	0	0	0	0	0	0	0	NA[3]

[1]Since 2012, quotas were revised for interannual quota adjustments, reconciliations, and re-distribution of the scientific quota among areas, the revised quotas do not necessarily correspond to the TAC in the notice to harvesters.
[2] The percentages are based on durometer readings < 68. Catches are defined as male crabs of all sizes.
[3] At-sea observer coverage was limited in 2020 due to the COVID-19 pandemic.

The 2020 landings in Area 19 were 2,284 t from a revised quota of 2,287 t (Tables 1 and 5; Figure 2). The fishing effort in Area 19 has varied from 11,138 to 56,517 trap hauls between 1987 and 2020, with the lowest effort in 2010 and the highest effort in 2004 (Hébert et al. 2021). The effort in 2020 was 22,458 trap hauls, a decrease from 2019.

Table 5. Quota and landings (tonnes; t), catch per unit of effort (CPUE; kg/trap-haul), fishing effort (trap hauls), white crab percentages, and associated closed sectors for the snow crab fishery in Area 19, 2012 to 2020.

Fishery descriptor	2012	2013	2014	2015	2016	2017	2018	2019	2020
Quota (t) [1]	2,907	2,654	3,745	2,130	1,701	2,945	2,046	2,792	2,287
Landings (t)	2,906	2,657	3,745	2,129	1,701	2,944	2,048	2,792	2,284
CPUE (kg/trap-haul)	178.1	148.5	147.4	144.8	142.5	142.8	156.1	112.7	101.7
Effort (trap hauls)	16,317	17,890	25,407	14,703	11,937	20,616	13,120	24,774	22,458
White crab (%) in catches [2]	4.5	3.0	1.0	5.5	8.2	11.6	8.8	20.9	NA
Sectors closed[3]	0/9	0/9	0/9	2/9	4/9	3/9	1/9	4/9	6/9

[1]Since 2012, quotas were revised for interannual quota adjustments, reconciliations, and re-distribution of the scientific quota among areas, the revised quotas do not necessarily correspond to the TAC in the notice to harvesters.
[2] The percentages are based on durometer readings < 72. Catches are defined as male crabs of all sizes.
[3] Total number of sectors was changed from 4 to 9 in 2009.

Catch per unit of effort (CPUE; expressed as kilogram per trap-haul, kg/th) is considered an index of fishery performance and is calculated directly from logbook data as the ratio of total landings (kg) to total effort (trap-hauls). CPUE values are not standardized and do not account for changes in management measures and fishing practices and as a result may not be directly proportional to biomass. The fishery CPUE indices are not used to infer on abundance of the commercial adult male snow crab. The unstandardized CPUE from the fishery correlates weakly with the estimated biomass from the assessment. This results in differences in perception of stock abundance based on fishing industry observations (CPUE variations within season and between years) from those of the assessment.

Average CPUE during the 2020 fishery decreased in all areas compared to 2019 (Figure 3).

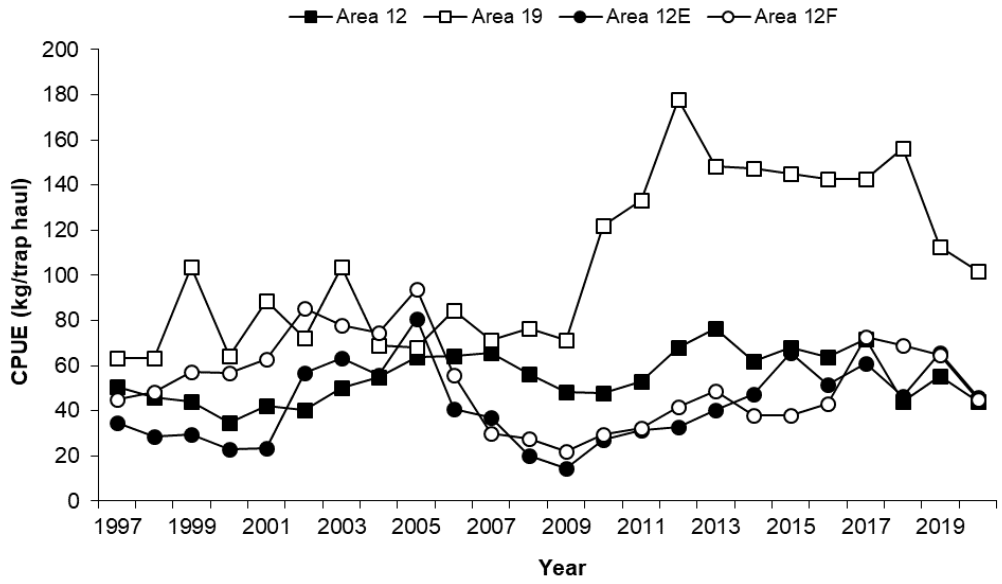

Figure 3. Catch per unit effort (CPUE; kg / trap-haul) in the southern Gulf of St. Lawrence snow crab fishery, Areas 12 (black squares), 12E (black circles), 12F (open circles) and 19 (open squares) based on logbooks, 1997 to 2020.

ASSESSMENT

Snow crab in the sGSL is considered as a single stock unit for assessment purposes. This stock unit comprises snow crab fishing areas 12,12E,12F and 19.

Details of the snow crab survey design and protocol can be found in DFO 2012a. The polygons used for the assessment can be seen in Figure 4. In 2020, the number of sampling stations remained at 355. As per the recommendations from the 2014 scientific peer review (DFO 2014a), the 350 successful sampling stations from the 2019 trawl survey were used as fixed stations and a new set of five sampling stations (i.e. the three stations that were abandoned and the two sampling stations that were conducted outside their assigned grids in 2019) was generated randomly. The survey was conducted from the vessel Avalon Voyager II, a new vessel used since 2019. A total 353 stations were successfully trawled in 2020; two sampling square grids had to be abandoned due to failures to successfully trawl the area. The survey was conducted between July 11 and September 10, 2020. Sampling protocols were identical to previous years (Hébert et al. 2021).

The survey in 2020 was financed through a collaborative agreement with the fishing industry under Section 10 of the *Fisheries Act*.

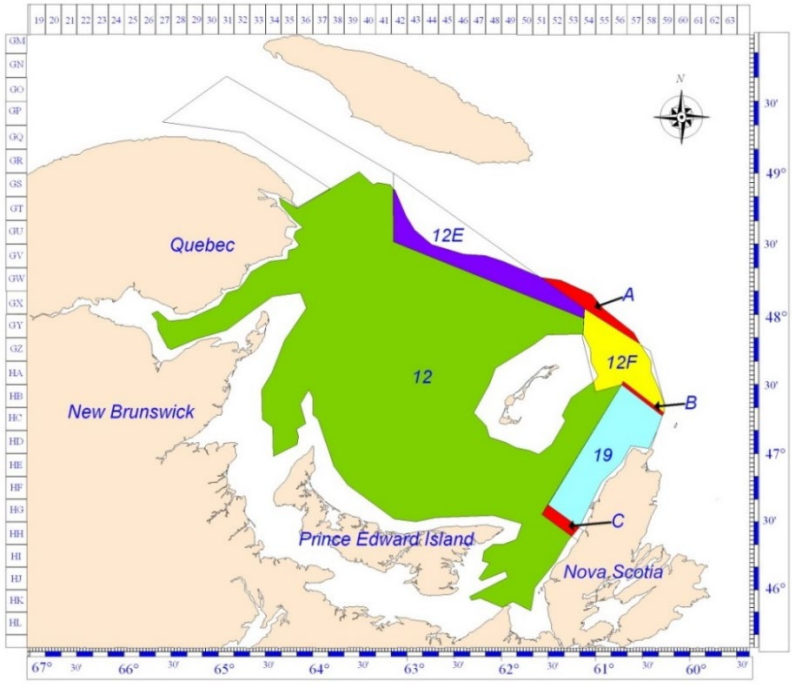

Figure 4. The survey and estimation polygon of 57,842.8 km^2 used for the 2020 snow crab stock assessment in the southern Gulf of St. Lawrence (all of the coloured areas) and corresponding estimation polygons for the four crab fishing areas (12, 12E, 12F, and 19). The unassigned zone north of areas 12E and 12F (label A) and buffer zones (labels B and C) are also shown.

Stock Status, Trends and Recent Survey Issues

Stock status is assessed from various abundance and biomass indices calculated using kriging with external drift (KED), with depth as a secondary variable (DFO 2012a; Wade et al. 2014), applied to standardized survey catches (numbers or weights per trawl swept area). Commercial crab biomass (legal-sized adult males) was sub-divided by residual biomass (hard-shelled adult males of legal size remaining after the fishery) and recruitment biomass (soft-shelled adult males >= 95 mm CW referred to as R-1 that will be available to the fishery the following fishing season). Predictors of four- three- and two-year fishery recruitment indices are also estimated, referred to as R-4, R-3 and R-2, respectively (see DFO 2020 for definitions). A population recruitment index is estimated from survey catches of small male crabs (34-44 mm CW), which take at least six years to reach commercial size.

The change in survey vessel in 2019 was accompanied by significant catch increases of 30-40% among male crab from 34 mm to 95 mm CW and mature female crab (Figure 5). These catches suggest an increase in survey catchability, as natural processes such as recruitment, migration or mortality cannot account for these increases over such a broad size range. Investigations in 2019 suggested that an increase of unaccounted bottom trawling during the hauling of the net, referred to as the passive trawling phase, partially accounted for 12.9% of the increase in trawl swept area (DFO 2020). In 2020, despite additional measures implemented to control the passive trawling phase, the survey catches remained significantly high compared to 2018.

In contrast, commercial sized-crab abundance and biomass remained at comparable levels over the same period (2018-2020). Despite the uncertainties and unknown mechanisms surrounding the increased survey catchability among sub-legal males and mature females accompanying

the change in survey vessel, quantifying the increase in catchability on commercial-sized males component, which is highly affected by the fishery, is complex to resolve. Hypotheses were proposed to explain this apparent stability of the commercial index of the crab stock in 2019 and 2020 despite the survey catchability increases among sub-legal male and female crab. Among the probable hypotheses are; 1) a strong increase in commercial-sized male crab mortality in 2019 and 2020 that counterbalanced a survey catch increase among commercial crab that would otherwise have been observed and, 2) that survey catchability increases are size-dependent and strongly focused on sub-legal-sized crab. Other proposed hypotheses were large-scale crab migration, or increases in catchability located in areas of high female and sub-legal male abundance. However, these additional hypotheses cannot account for the degree of the increases nor their restricted association to sub-legal sizes.

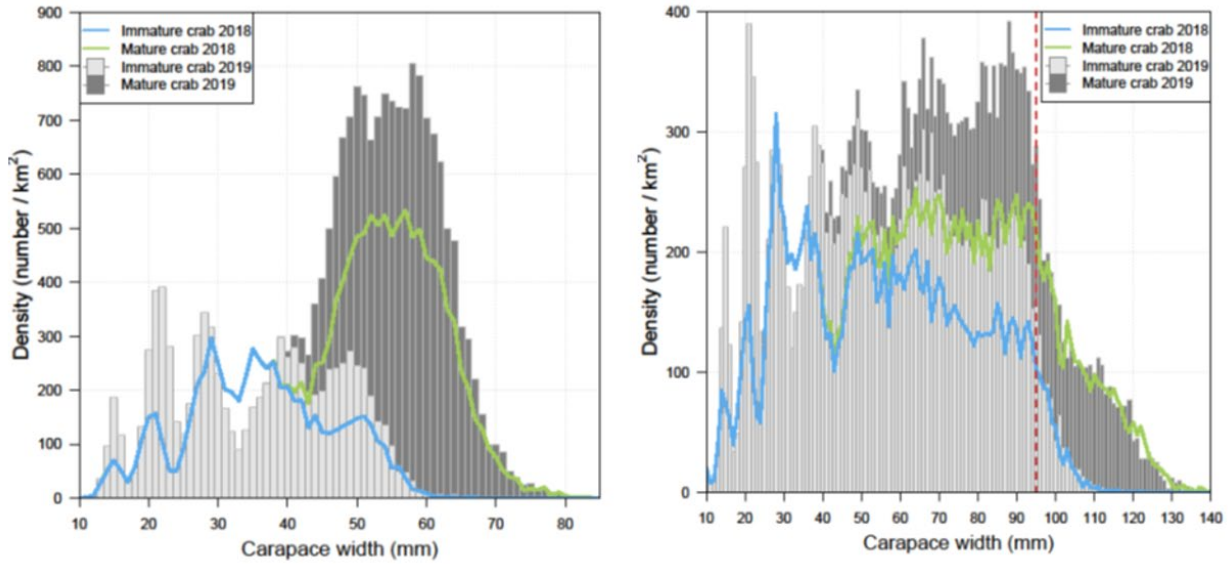

Figure 5. Comparison of the size-frequency distributions from the 2018 and 2019 snow crab surveys for male (left panel) and female (right panel) snow crab. Blue lines indicate 2018 immature crab, green lines represent 2018 mature crab, vertical dash red line indicates the 95 mm CW legal size. 2019 immature crab are indicated by light grey bars while 2019 mature crab are represented by dark grey bars.

As a result of the repeated high catches of mature female and sub-legal male snow crab in 2020, methods were proposed to estimate the potential bias on the commercial-sized male survey biomass using the 2020 fishery landings data and/or the residual biomass from the 2020 post-fishery survey. The first method compared the sum of the 2020 landings plus the 2020 residual biomass with the commercial biomass estimate from the 2019 survey with a 70% survival rate applied (5-years moving average on commercial-sized adult males). The sum of the residual biomass plus the landings in 2020 was 14.4% lower than the commercial biomass estimate from the 2019 survey. This difference between the predicted and observed biomass values suggests an overestimation bias of 14.4% in the commercial biomass for the 2020 fishery. Moreover, the overestimation of the survey indices would also apply to the residual biomass estimate, resulting in the difference from the method described above being possibly higher than 14.4%.

A Leslie analysis was explored as a second method, estimating the initial, or pre-fishery, biomass based on the depletion of the weekly CPUE during the 2020 fishery. The use of CPUE as core data raised concerns as fishery catches are known to be influenced by many factors and may not reflect true stock abundance signals. While the results of the Leslie analysis

supported an overestimation bias of >14.4% on the commercial biomass estimate, the method was deemed unreliable.

In summary, data are suggesting that mature female and sub-legal male abundance indices for 2019 and 2020 are over-estimated by 30-40%, while commercial-sized crab could be over-estimated by at least 14.4%. These biases will be considered in the following assessment and risk analysis, though corrections will not be directly applied, unless otherwise stated.

The point estimate for the biomass of commercial-sized adult males in the sGSL from the 2020 trawl survey was estimated at 77,748 t (Table 6; Figure 6). In the 2020 trawl survey, concentrations of commercial-sized adult males were located in Bradelle Bank, in Shediac valley, in Chaleur Bay, in the central and southern parts of the Magdalen Channel, in Area 12F and in the southeastern part of the sGSL (Figure 6). The majority (81.6%) of the biomass in 2020 was located in Area 12, followed by Area 19, 12F, 12E with respectively 9.0, 8.5, and 0.9%.

Table 6. Total commercial, recruitment, and residual biomass (t; means with 95% confidence intervals) of commercial-sized adult male crabs (>= 95 mm carapace width) in the southern Gulf of St. Lawrence, 2009 to 2020. Data from the 2019 and 2020 surveys are likely overestimated.*

Year of the survey	Commercial Biomass (t)	Recruitment Biomass (t)	Residual Biomass (t)
2009	31,015 27,519-34,829	20,618 17,747-23,818	10,454 8,687-12,474
2010	35,929 32,049-40,147	20,477 17,815-23,423	15,490 13,022- 18,289
2011	62,841 55,985-70,299	29,643 25,676-34,045	33,679 28,430-39,613
2012	74,778 64,881-85,748	49,010 40,382-58,931	25,615 21,607-30,147
2013	66,709 54,294-81,108	39,988 31,504-50,055	27,092 22,041-32,952
2014	67,990 59,802-76,978	44,285 37,440-52,014	23,863 20,356-27,799
2015	58,927 51,368-67,278	34,982 29,145-41,643	24,108 20,290-28,429
2016	98,394 87,150-110,677	74,124 64,811-84,392	24,309 20,876-28,143
2017	65,738 57,221-75,157	51,127 43,976-59,103	14,650 12,134-17,534
2018	80,746 70,984-91,467	59,609 51,755-68,310	21,432 17,271-26,291
2019*	79,066* 69,072-90,091	58,995* 50,215-68,863	20,291* 16,940-24,109
2020*	77,748* 67,706-88,852	58,438* 49,759-68,189	19,107* 16,235-22,339

The estimated recruitment to the fishery at the time of the 2020 survey represented 75% of the commercial biomass estimate. The remaining 25% is the residual biomass estimate. Though the proportion of the residual biomass in 2020 is similar to previous years, its distribution appears more diffused in 2020 (Figure 7). High concentrations of residual biomass have not been observed despite many fishing grid closures, suggesting a high fishing pressure on the commercial biomass or an increase in discard mortality on these crabs during the 2020 fishing season.

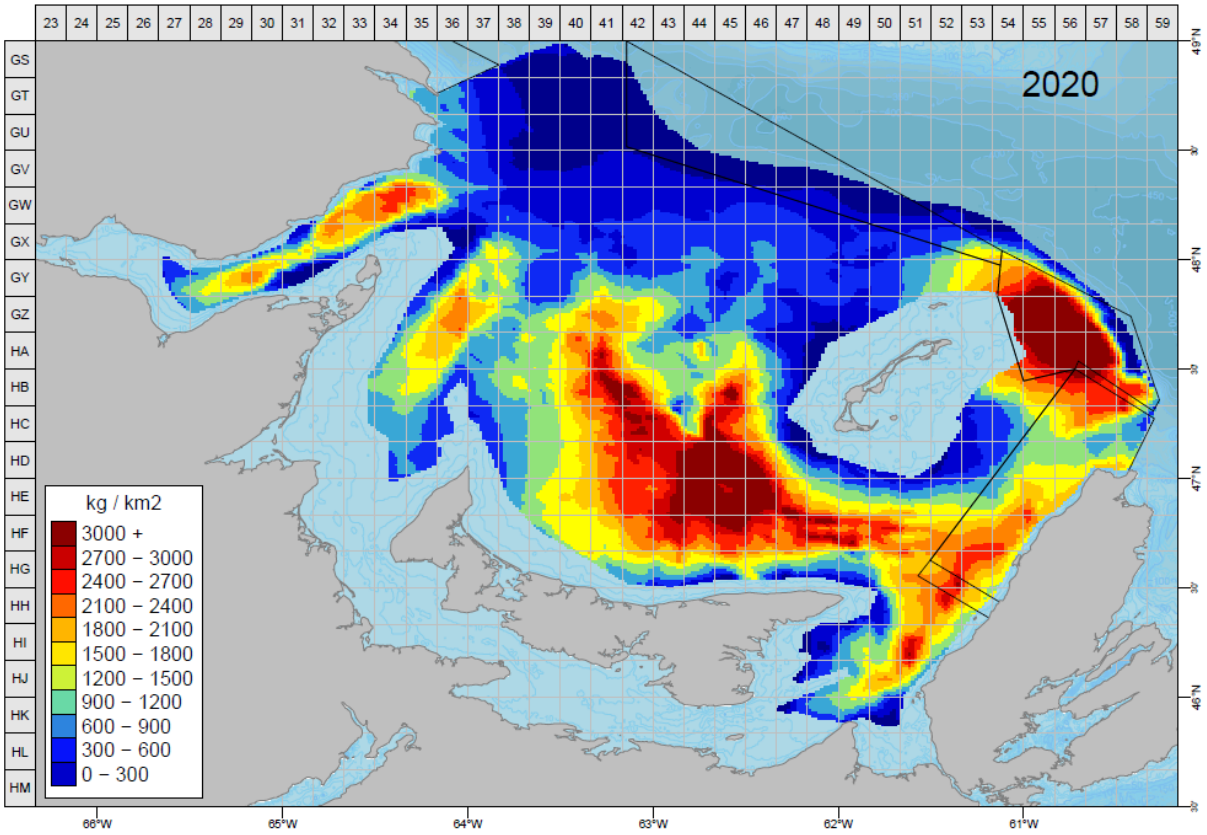

Figure 6. Densities (kg per km^2) of commercial snow crab caught in the 2020 sGSL snow crab trawl survey.

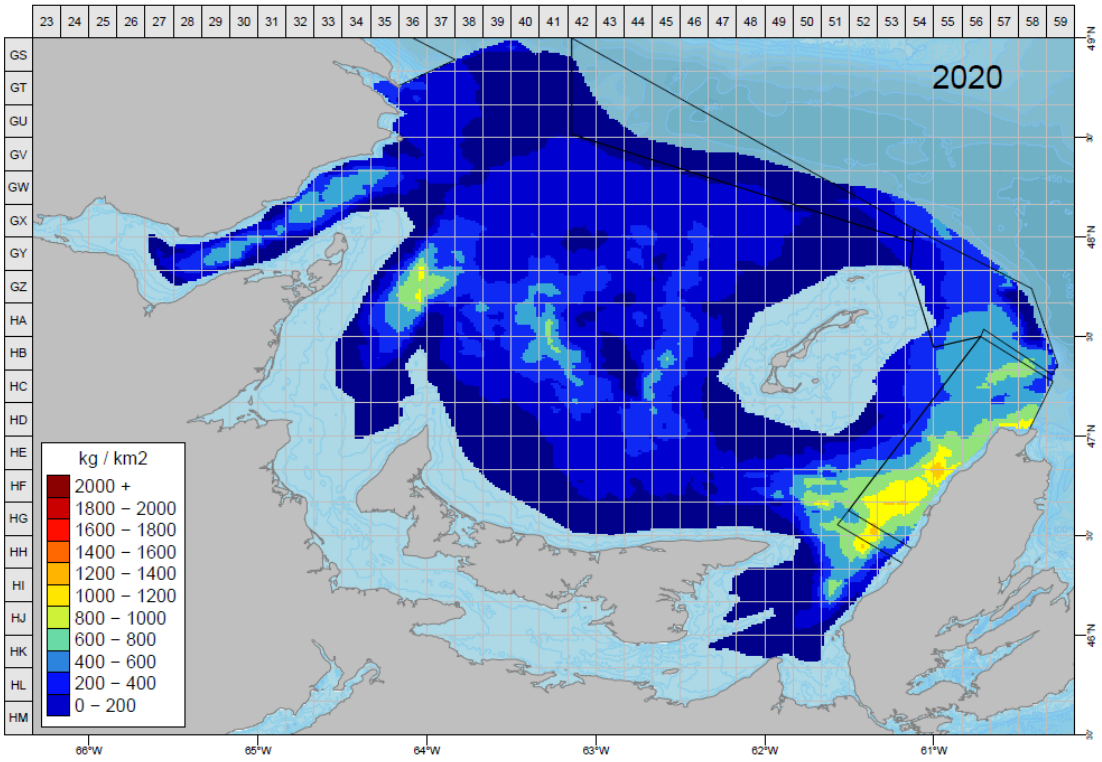

Figure 7. Densities (kg per km^2) of the residual biomass of snow crab caught in the 2020 sGSL snow crab trawl survey.

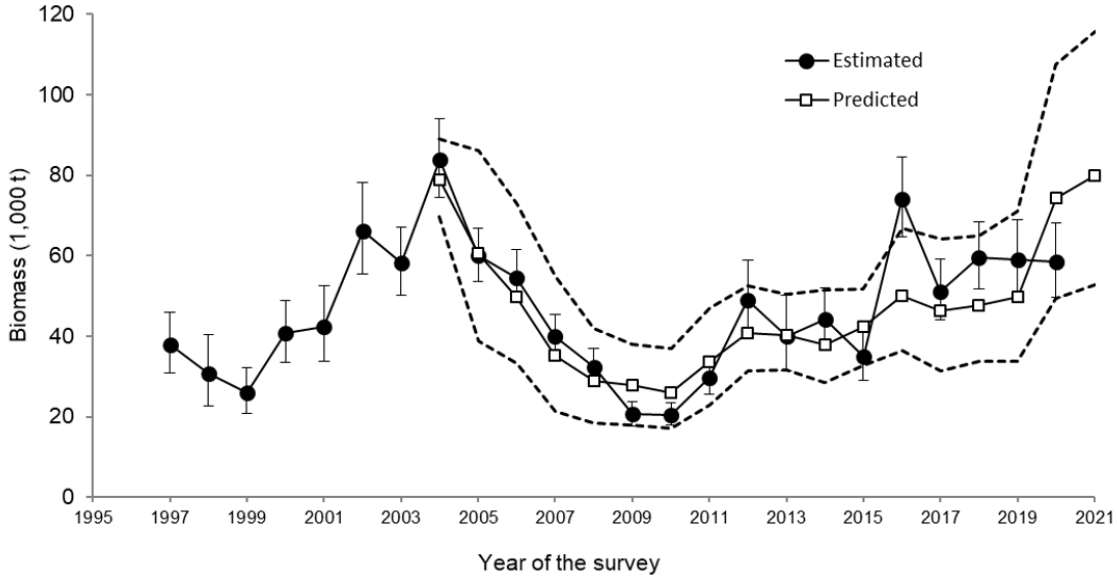

Figure 8. Estimated (black circles are the means with 95% confidence interval vertical bars) and predicted (open squares are the means with the 95% confidence interval bands as dashed lines) biomasses of R-1 (adult male crabs >= 95 mm carapace width of carapace condition 1 and 2) snow crab in the year of the survey, 1997 to 2020. The predicted abundances are based on a relationship to the estimated abundances of R-2 (adolescent male crabs with a carapace width larger than 83 mm) in the previous year. Prediction of R-1 biomass for 2021 is based on abundances of R-2 estimated in 2020 and shown in Figure 9.

From 2015 to 2019, the estimated abundance of commercial-sized adult male recruitment has been higher than the predicted values (Figure 8). Following the vessel change in 2019, the high predicted recruitment to the fishery for 2021 is driven by the overestimated abundance of R-2 crab from the survey in 2020. The extent to which recruitment to the fishery will be realized in 2021 is uncertain given the overestimation in the survey estimates.

Despite overestimation in the abundance indices, the stock continues to show signs of sustained recruitment and productivity, along with a strong cohort (25-34 mm CW) among small male and female crabs in 2020 (Figure 9). Overall the stock is expected to remain in the healthy zone of the Precautionary Approach (PA) framework (DFO 2014b, Figure 10).

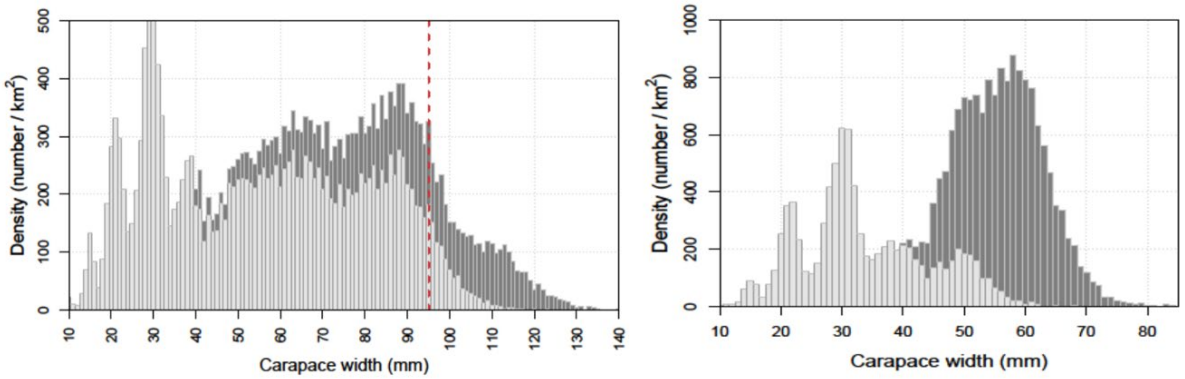

Figure 9. Size-frequency distributions from the 2020 snow crab survey for male (left panel) and female (right panel) snow crab. Immature crab are indicated by light grey bars while mature crab are represented by dark grey bars. The vertical dash red line indicates the 95 mm CW legal size for male.

To account for probable bias in the 2020 trawl survey commercial biomass estimate, different options were proposed. The first approach was to apply a 15% correction factor to the 2020 survey biomass estimate of 77, 748 t and perform a risk analysis for catch options with a 30% bias on the abundance of R-2 in 2019 and 2020. This resulted in a corrected commercial biomass of 66,086 t and an exploitation rate of 38.3% based on the harvest decision rules and a catch option of 25,311 t for the 2021 fishing season. The second approach addressed uncertainties around the quantification of the bias on the 2020 survey commercial biomass estimate. A risk analysis was performed applying equal weight to a bias range from 0 to 30% and is considered to be a robust analytical approach to deal with the range of potential bias levels. Under this option, in order to maintain a less than 5% probability of the stock reference point to fall under B_{lim}, the catch option would need to be set lower than 26,000 t. The last approach presented was the use of the F_{lim} of 34.6% as identified in the PA (DFO 2012b) on the uncorrected commercial biomass of 77, 748 t. This resulted in a catch option of 26,901 t for the 2021 fishing season.

Using the 2020 point estimate for the commercial biomass (77,748 t), notwithstanding indicators suggesting potential overestimation would define a 40.4% exploitation rate and a catch option of 31,410 t.

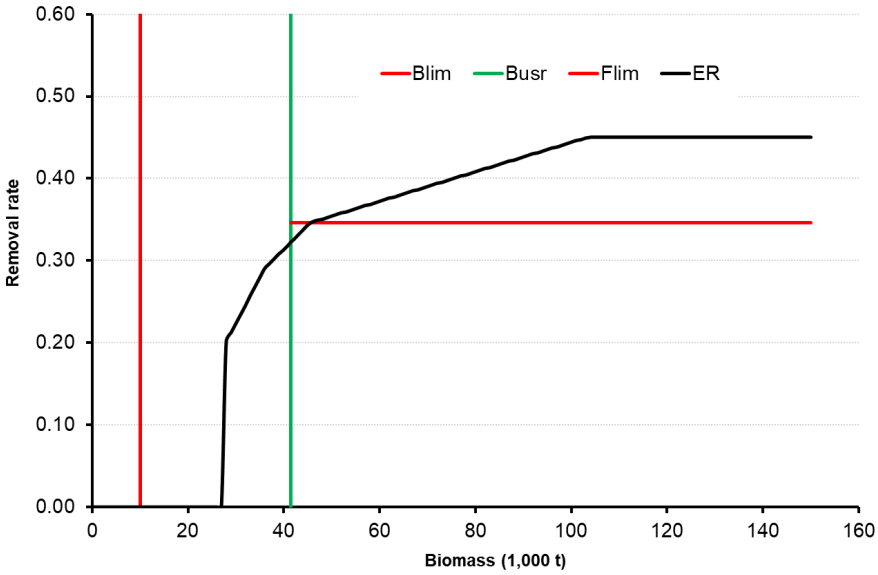

Figure 10. Harvest decision rule (solid black line; proportional variant 4; DFO 2014b) for the southern Gulf of St. Lawrence snow crab fishery.

Environmental Considerations

In September 2020, near-bottom temperatures were near the mean value of the period 1991 to 2020 in the central portion of Area 12 as well as in the western part Chaleur Bay. However, the bottom waters in large portions of Area 12, Area 19, the deeper parts of Area 12E and 12F, and both entrances of Northumberland Strait were significantly warmer than normal. The channels connecting the slope of the Laurentian Channel to the mouth of Chaleur Bay were also warmer than normal. Colder-than-normal bottom waters were only present in a small area south of Shediac Valley and in St. George's Bay.

In September 2020, the snow crab habitat index (bottom area with temperatures from -1 to 3°C) was the fourth lowest of the 1971-2020 time series (Figure 11). It was 10% below the 1991-2020 average in 2020 and is similar to the 2019 value which was down 11% from the 2018 value. The mean temperature (1.3°C) within the defined snow crab habitat area index (-1 to 3°C) in 2020 increased by about 0.3°C compared to 2019 (1.0ºC, Figure 11). Looking at the last three decades, the mean temperature was at the highest of the time series in 2012, decreased in 2013 and 2014, and remained above the normal since then.

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).

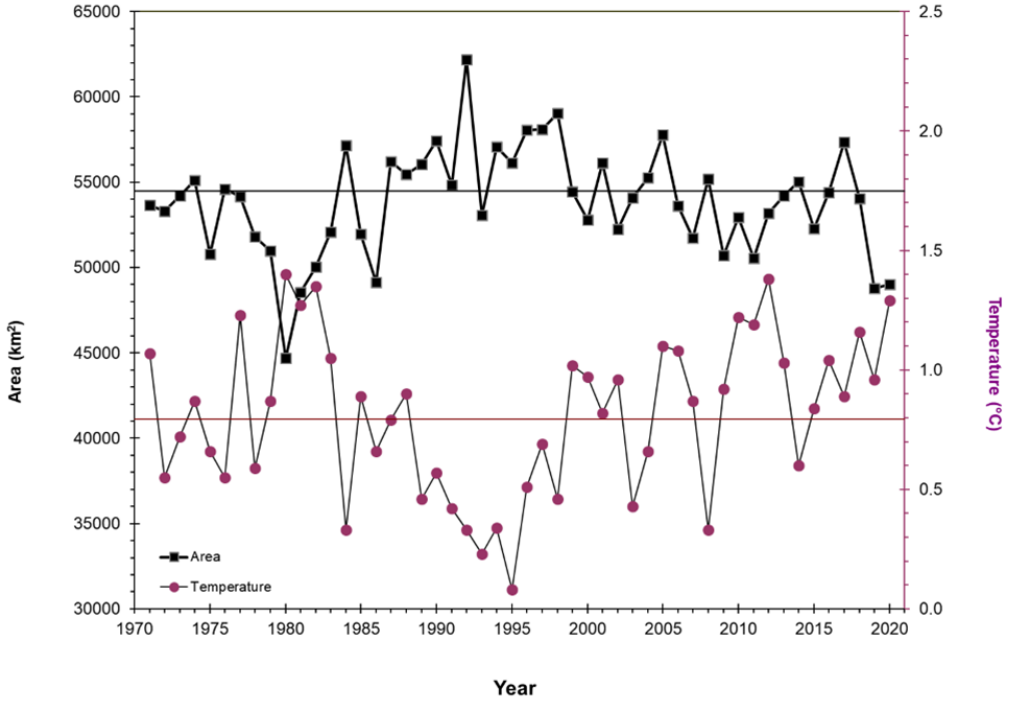

Figure 11. Habitat area index (water temperatures of -1 to 3ºC; km²; square symbols) for commercial-sized adult male snow crab in the southern Gulf of St. Lawrence and the mean temperature (ºC; circle symbols) within the index area from 1971 to 2020.

Sources of Uncertainty

Meaningful interpretation of long-term trends and variations of snow crab stocks relies on a robust sampling protocol, sampling design and standardization of survey catches. In addition to current survey catchability issues, the survey has undergone a number of changes to its sampling design, including multiple areal expansions, survey station redistributions and five survey vessel changes. In particular, only half of the survey stations have remained fixed since the last survey redesign in 2013 due to the practice of relocating survey stations when trawl damage is encountered. The relocation of stations has introduced a potential source of bias when they are consistently moved to more trawlable bottoms. These issues can weaken the ability to track population trends as well as situating the stock with respect to the harvest control rule limits and reference points.

In 2019 and 2020, survey catchability increased among sub-legal and mature female crab. This surge was partially explained by an increase in the extent of the passive trawling phase, brought on by changes in winch speed and end-of-tow vessel maneuvers, though other unknown mechanisms associated with the 2019 vessel change are thought to have played a role. As the catches of commercial-sized male snow crab in 2019 and 2020 was comparable to 2018, the relationship of these mechanisms to the commercial stock is currently unknown.

Environmental conditions in the sGSL are known to affect a number of life history processes including molting and growth, reproduction, larval development and migratory behavior. Varying annual conditions are expected to affect abundance and biomass estimates through seasonal migratory changes, making the timing of survey sampling a potential issue along more marginal survey areas. Longer-term influences of environmental conditions on life history processes may

lessen our ability to predict fishery recruitment, which currently assumes homogeneity through time.

Of major concern for the long-term future of the stock is the consistent warming of the deep waters of the Laurentian Channel. If this warm water mass were to penetrate further into the sGSL it would significantly lower the quality of snow crab habitat. Incursions of these warmer waters are currently limited to peripheral snow crab habitat in areas 12E, 12F and the northeastern part of Area 19.

CONCLUSIONS AND ADVICE

Despite the potential overestimation of the 2019 and 2020 commercial biomass estimates, the snow crab stock continues to be considered in the healthy zone of the PA and shows strong signs of recruitment and productivity.

While the proportion of residual biomass in 2020 is similar to previous years, high concentrations of residual biomass were not observed in the survey despite fishing grid closures, suggesting a high fishing pressure on the commercial biomass or an increase in discard mortality.

The increased survey catchability and corresponding increases in passive phase trawling were identified and presented following the 2019 survey, however no corrective action on the commercial biomass estimate was applied for the 2020 season (DFO 2020). In 2020, 11% of the TAC was left unfished, the first time since 1997 that such a portion of the quota was not landed. Leaving a portion of the quota unharvested is consistent with the interpretation of commercial biomass overestimation, with additional caveats of a later than normal fishery opening and NARW area closures.

A risk table is presented (Table 7) summarizing the probability associated to the lower (B_{lim} or LRP) and upper stock reference points (B_{USR}) for different levels of assumed bias on the commercial biomass, along with the corresponding exploitation rates, for a fixed catch option using the point estimate of 77,748 t. The probability of falling under B_{USR} remains close to zero under every scenario due to the strong predicted recruitment to the commercial stock, even when a 30% overestimation is considered on the recruit abundance index. When an overestimation bias of 10% was applied to the point estimate, the probability of going under B_{lim} (residual biomass of under 10,000 t) was very close to the PA threshold value of 5% and increased rapidly with the level of bias. In scenarios of a 10% bias or more, the realized exploitation rate would exceed the agreed maximum rate of 45% as defined in the harvest decision rules in the snow crab PA (DFO 2014b).

Table 7. Risk table demonstrating the probabilities of falling under the Precautionary Approach (PA) reference points for different levels of presumed overestimation bias applied to the biomass point estimate as well as the realized exploitation rates for the different scenarios.

Bias on the commercial biomass estimate	Biomass estimate (t) (corrected for bias)	Residual biomass < B lim	Commercial biomass < B USR	Exploitation rate (%) assuming TAC of 31,410 t
0%	77,748 t	0%	0%	40.4%
5%	73,861 t	0.7%	0%	42.5%
10%	69,973 t	4.2%	0%	44.9%
15%	66,086 t	17.4%	0.1%	47.5%
20%	62,198 t	44.8%	0.4%	50.5%

With respect to fishing pressure, the overestimated commercial biomass resulted in increases to the projected exploitation rate (Table 7), which could have potential consequences to the stock and fishery. For example, higher than intended exploitation rates could lead to lower fishery performances in 2021, i.e. low CPUE, which would increase the amount of fishing effort required to catch the TAC.

Past changes in survey vessels, fishing practices, statistical design, and survey station relocations have led to variations in survey catchability. Such factors must be either controlled or otherwise accounted for if abundance and biomass estimates are to remain comparable from year to year otherwise perceived changes in abundance and biomass indices may no longer reflect true changes in stock size. For 2021, adopting a subset of fixed survey stations is proposed to address the trend of drifting into trawlable habitat. Changes to the end-of-tow procedure will be proposed to reduce the impact of the passive phase on the time series. Additional technological tools (e.g. camera system, positional sensors) will also be explored to further examine trawl catchability and behavior following the active-trawling phase.

To further refine the time-series indices and confidence in the biomass estimation, other sources of comparative data, when available, will be utilized to develop abundance indicators and to groundtruth survey indices. The development of a population model as a means of estimating annual changes in catchability, in addition to retroactively standardizing the survey time-series, continues to progress. To address questions with respect to spatial and temporal patterns in catch and biomass, and to detect potential bias related to depth and/or bottom temperature, spatial analyses will be examined.

Given the multiple indices indicating an overestimation bias in the 2020 survey estimates ranging up to 40%, in addition to the diffuse and low residual biomass and 11% of the TAC not being captured, options compliant with DFO’s PA have been presented to be considered for the 2021 season.

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SOURCES OF INFORMATION

This Science Advisory Report is from the February 10-11, 2021 regional advisory meeting on the stock status in 2020 and fishery advice for 2021 for Snow Crab from the Southern Gulf of St. Lawrence. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

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Hébert, M., Surette, T., Landry, J.-F., and Moriyasu, M. 2021. Review of the 2019 snow crab (*Chionoecetes opilio*) fishery in the southern Gulf of St. Lawrence (Areas 12, 19, 12E and 12F). DFO Can. Sci. Advis. Sec. Res. Doc. 2021/012. iv + 45 p.

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