



Gulf Region

ASSESSMENT OF SNOW CRAB (*CHIONOECETES OPILIO*) IN THE SOUTHERN GULF OF ST. LAWRENCE (AREAS 12, 12E, 12F AND 19) TO 2022 AND ADVICE FOR THE 2023 FISHERY



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

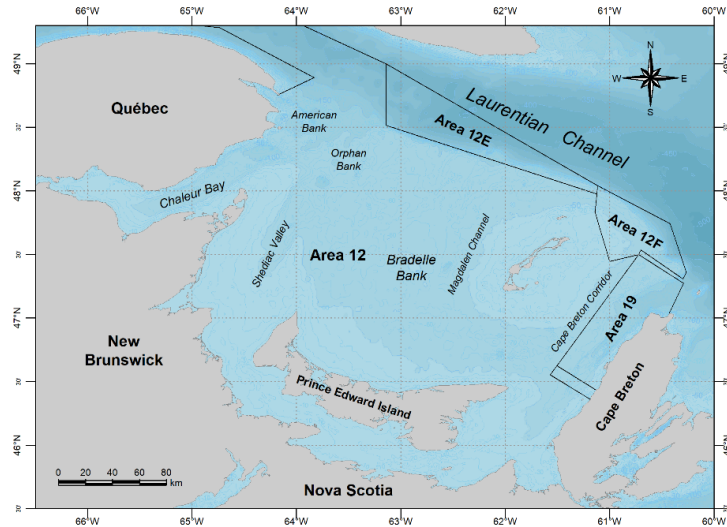


Figure 1. Map of the southern Gulf of St. Lawrence showing the snow crab fishing areas (12, 12E, 12F and 19).

Context:

Fisheries and Oceans Canada (DFO) Gulf Region Fisheries and Harbour Management requested an assessment of the resource status in 2022 and catch advice for the 2023 fishery. This document provides an overview of the assessment results and the science advice. The assessment of the status of southern Gulf of St. Lawrence snow crab resource (Areas 12, 12E, 12F and 19) is based on an annual fishery-independent trawl survey that provides indices of commercial crab abundance and biomass, reproductive potential, and recruitment. A science peer review virtual meeting was held on January 25-26, 2023. Participants at the science review were from DFO Science, DFO Fisheries and Harbour Management, National Oceanic and Atmospheric Administration (NOAA), Indigenous organizations, snow crab fishing industry and provincial governments.

SUMMARY

- Snow crab in the southern Gulf of St. Lawrence (sGSL) is considered as a single stock unit for assessment purposes.
- Preliminary landings of sGSL snow crab in 2022 were 31,661 tonnes (t), comprised of 27,620 t in Area 12, 197 t in Area 12E, 1,173 t in Area 12F, and 2,671 t in Area 19.
- Commercial stock biomass from the post-fishery survey is estimated at 85,532 t (composed of 80% new recruitment and 20% of residual biomass), thus, the stock is in the healthy zone as per the sGSL snow crab Precautionary Approach (PA).
- Based on the harvest decision rule, this commercial stock biomass estimate corresponds to a target exploitation rate of 41.79% and a catch option of 35,745 t for the 2023 sGSL fishery.
- A risk analysis indicates that this catch option would result in a very high likelihood that the commercial stock would remain in the healthy zone of the PA after the 2023 fishery.
- Spawning stock abundance and population recruitment indices remain at high levels.
- Despite the overall health of the stock, the surveyed abundance of snow crab in deep areas has declined in recent years coinciding with warming water temperatures at these depths, but a causal relationship has not been established.

BACKGROUND

Biology

Snow crab (*Chionoecetes opilio*) is a cold-water crustacean with a flat, circular body and five pairs of legs. Snow crab grow by a process called moulting: the old shell is shed and replaced by a new, soft shell which hardens over a period of 8 to 10 months. Growth proceeds until full sexual maturity, attained after crab perform a final, or terminal moult. Male snow crab moult to maturity at sizes ranging from 40 to 150 mm carapace width (CW) and coincides with the development of larger claws on the first pair of legs. Mature females are smaller than males, ranging in size from 40 to 90 mm CW, with shorter legs and a wide abdomen for carrying eggs. In the southern Gulf of St. Lawrence (sGSL), females carry eggs from one to two years. Eggs hatch in late spring or early summer and larvae spend 12-15 weeks in the water column before settling on the bottom. About 8-9 years are required for males to grow to commercial size (i.e. larger than 95 mm CW) after settlement.

Fishery Management

Snow crab has been commercially exploited in the sGSL since the mid-1960s. Currently, there are four snow crab fishing areas in the sGSL: Area 12, which is the largest in terms of geographic area and fishery, Area 12E, Area 12F and Area 19 (Figure 1). Management of these fisheries is based on quota and effort controls (trap allocations, trap dimensions and seasons). Only hard-shelled males larger than 95 mm CW are commercially exploited and landing of female crab is prohibited.

Local area closures during the fishing season occur when 1) the proportion of soft-shelled crab exceeds 20% in monitored catches, or 2) North Atlantic Right Whales (NARW) are detected in a given area. Soft-shell closures are intended to minimize incidental mortality of newly-moulted crab during fishing. These crab are vulnerable and of little worth commercially due to low meat yields, but nonetheless represent future recruitment to the commercial stock. NARW closures,

on the other hand, are intended to minimize the risk of entanglement of whales in snow crab fishing gear, which represents a major risk of injury and mortality for this critically endangered species (Moore et al. 2021). Local area closures over the course of the season can result in significant displacement of fishing effort.

FISHERY SUMMARY

Quota and Landings

Snow crab landings from the sGSL were low in the early 1970s but increased more than threefold from 1975 to 1982. There were four periods of high landings (exceeding 20,000 tonnes (t)): 1981 to 1986, 1994 and 1995, 2002 to 2009, and the current period, from 2012 to 2022, the longest in the series (Figure 2). Crab landings were compiled from a combination of dockside monitoring data and crab harvesters' logbook data.

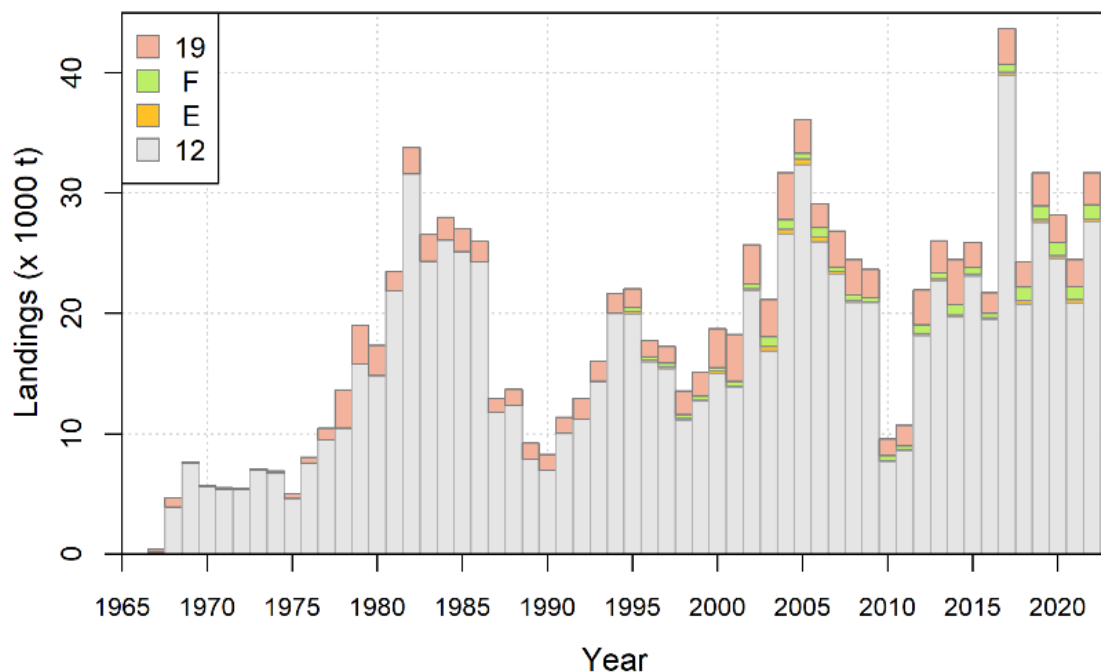


Figure 2. Annual landings (tonnes) of southern Gulf of St. Lawrence snow crab by fishing area.

The revised quota was set at 32,129 t for the 2022 fishery. For reasons of annual quota adjustments, reconciliations, and re-distribution of the scientific quota (450 t) among areas, the revised quota does not necessarily correspond to the Total Allowable Catch (TAC) set at the start of the fishing season. Preliminary total landings of sGSL snow crab in 2022 were 31,661 t, with 27,620 t in Area 12, 197 t in Area 12E, 1,173 t in Area 12F, and 2,671 t in Area 19. Revised quotas and landings by fishing area from 2013 to 2022 are shown in Table 1.

Table 1. Revised quota and landings for sGSL snow crab by fishing area (tonnes).

Year	Area 12		Area 12E		Area 12F		Area 19	
	Quota	Landings	Quota	Landings	Quota	Landings	Quota	Landings
2013	22,548	22,645	204	204	543	543	2,654	2,657
2014	19,409	19,633	170	178	906	882	3,745	3,745
2015	23,021	23,080	189	192	516	510	2,130	2,129
2016	19,393	19,499	144	144	373	381	1,701	1,701
2017	39,651	39,825	199	203	680	684	2,945	2,944
2018	20,909	20,769	266	260	1,218	1,183	2,046	2,048
2019	28,051	27,554	217	224	1,155	1,166	2,792	2,763
2020	27,435	24,554	238	234	1,192	1,084	2,287	2,284
2021	20,402	21,423*	288	223	1,191	592	2,244	2,241
2022	28,075	27,620*	195	197	1,177	1,173	2,682	2,671

*Total landings in Area 12 include a portion of landings allocated to Areas 12E and F (2021) and Area 12E (2022) that were fished in Area 12.

ASSESSMENT

Snow crab in the sGSL is considered as a single stock unit for assessment purposes. This stock unit comprises fishing Areas 12, 12E, 12F and 19. The survey area is currently bounded by the 20 to 200 fathom depth contours, which corresponds to the majority of favorable snow crab habitat in the sGSL. From July 13 to September 7, 2022, 343 sampling stations were successfully trawled while 12 were abandoned due to significant trawl damage.

Stock Trends and Current Status

Stock status is based on commercial biomass indices from the snow crab trawl survey. The commercial stock is composed of residual biomass (hard-shelled adult males of legal size remaining after the fishery) and recruitment biomass (soft-shelled adult males ≥ 95 mm CW defined as commercial crab that will be available to the fishery the following fishing season).

The biomass of commercial-sized adult males in the sGSL from the 2022 trawl survey was estimated at 85,532 t (Table 2). Despite the uncertainty related to survey catchability (Hébert et al. 2021), commercial biomass levels have been similar since 2018, ranging from 77,748 t in 2020 to the high of 85,532 t in 2022.

Table 2. Total, recruitment, and residual commercial biomass (in tonnes; means with 95% confidence intervals).

Survey year	Total biomass (t)	Recruitment biomass (t)	Residual biomass (t)
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)	24,106 (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 (16,235-22,239)
2021	80,950 (70,543-92,451)	62,473 (53,650-71,590)	19,144 (15,997-22,726)
2022	85,532 (74,658-97,535)	68,348 (58,894-78,880)	17,388 (14,040-21,292)

The recruitment to the fishery at the time of the 2022 survey was 68,348 t, representing a 9.5% increase from 2021. The residual biomass of commercial-sized adult male crabs after the 2022 fishery was estimated at 17,388 t, representing a 9.0% decrease relative to 2021 (Table 2; Figure 3). The commercial biomass is composed of 80% new recruitment and 20% of residual biomass.

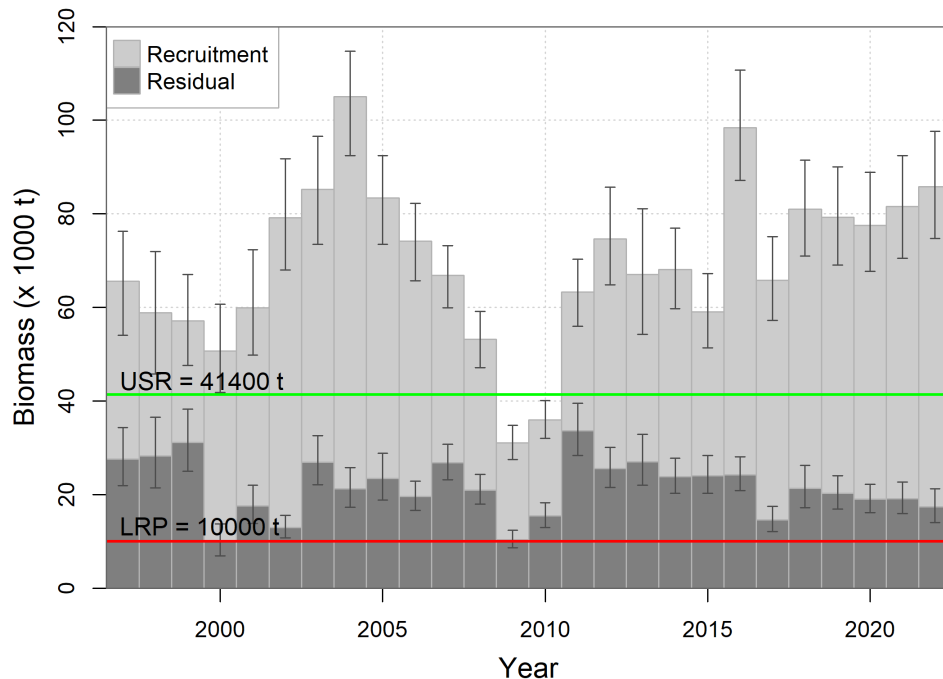


Figure 3. Biomass of commercial recruitment (light grey bars) and residual (dark grey bars), as estimated from trawl survey data. Error bars show 95% confidence intervals. Also shown are the corresponding limit reference point (LRP) for the residual biomass (red line) and upper stock reference point (USR) (green line) points.

A breakdown of the 2022 commercial biomass estimates by fishing area, buffer zones, and the small unassigned zone north of Areas 12E and 12F, is shown in Table 3.

Table 3. Commercial biomass by fishing area and buffer zones based on the 2022 sGSL survey data. Parentheses show 95% confidence intervals.

Areas	Area (km ²)	Biomass (tonnes)	
Southern Gulf	57,842.8	85,532	(74,658 - 97,535)
Area 12	48,074.0	75,742	(66,447-85,966)
Area 12E	2,436.9	685	(74 – 2,721)
Area 12F	2,426.8	4,320	(2,949 – 6,113)
Area 19	3,813.0	4,094	(2,465 – 6,408)
Sum of fishing areas¹	56,750.7	84,841	
Unassigned zone above 12E/12F	667.9	43	(0 - 292)
Buffer zone 19/12F	134.2	137	(25 - 436)
Buffer zone 12/ 19	289.5	552	(184 – 1,293)
Sum of total areas and zones	57,842.7	85,573	(74,744 - 97,622)

¹ Small difference in the sum of all individual area estimates compared to the southern Gulf estimates is due to rounding of intermediate calculations.

According to the survey data, the spatial distribution of commercial crab in 2022 was similar to that from 2018 to 2021, with crab concentrations over Bradelle Bank, to the south and west of the Magdalen Islands and moderate, but decreasing concentrations in Shediac Valley (Figure 4). Densities in the Baie des Chaleurs remained high relative to previous years and increased slightly in 2022. Densities within Area 12F were similar to those of last year. Densities within the northern and middle portions of Area 19 showed a strong decrease, relative to 2021.

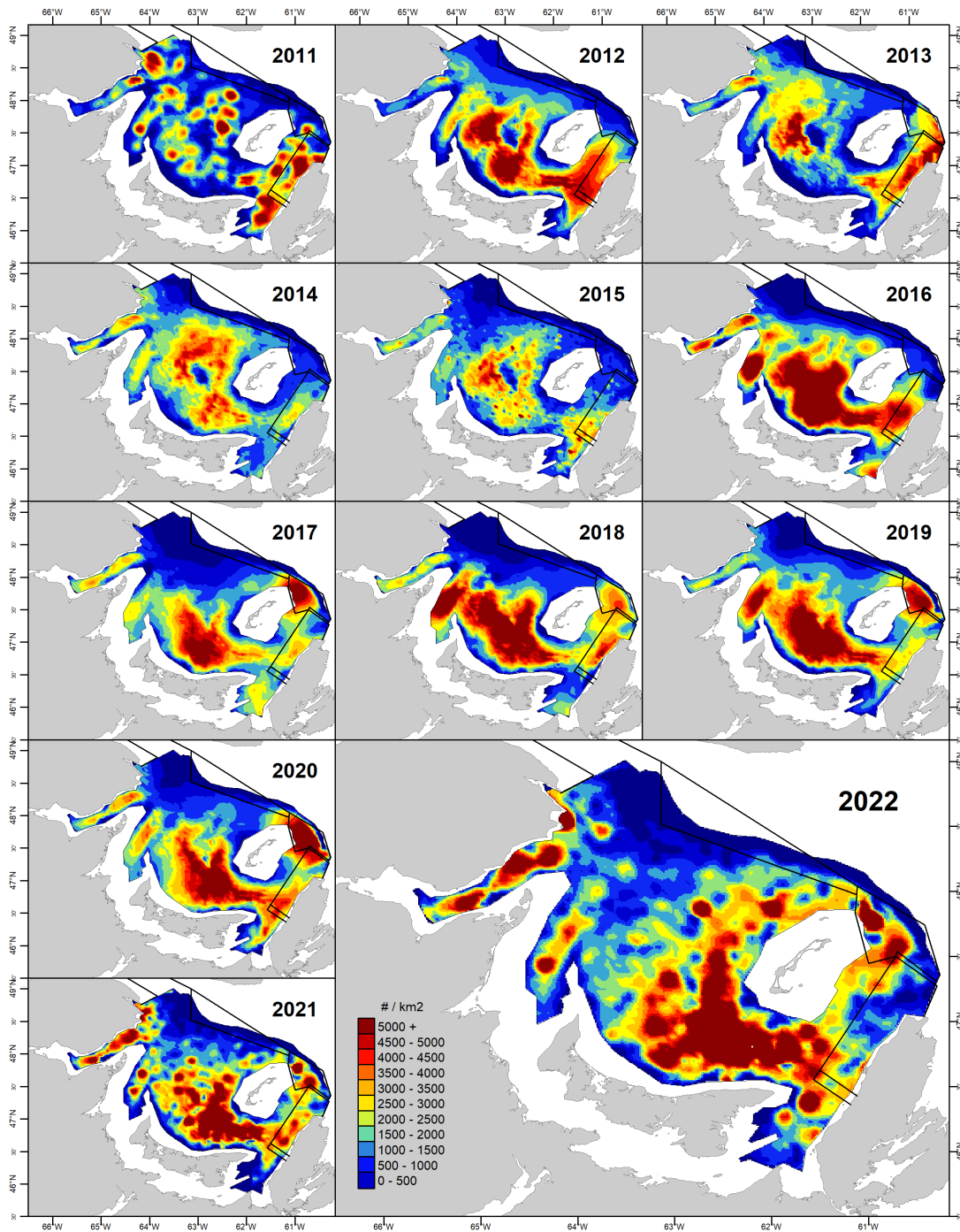


Figure 4. Density (number per km²) contours of commercial crab in the southern Gulf of St. Lawrence from 2011 to 2022, based on the snow crab trawl survey.

The population recruitment index is defined as the abundance of small male crabs (34-44 mm CW). This recruitment index decreased from a record 329 million crab in 2021 to 201 million crab in 2022, a decrease of 38.8% (Figure 5). The index for 2022 is the fifth highest in the series, and the record abundance last year was due to a strong cohort growing though the

population. It takes at least six years for these small male crabs to grow to the commercial size of 95 mm CW.

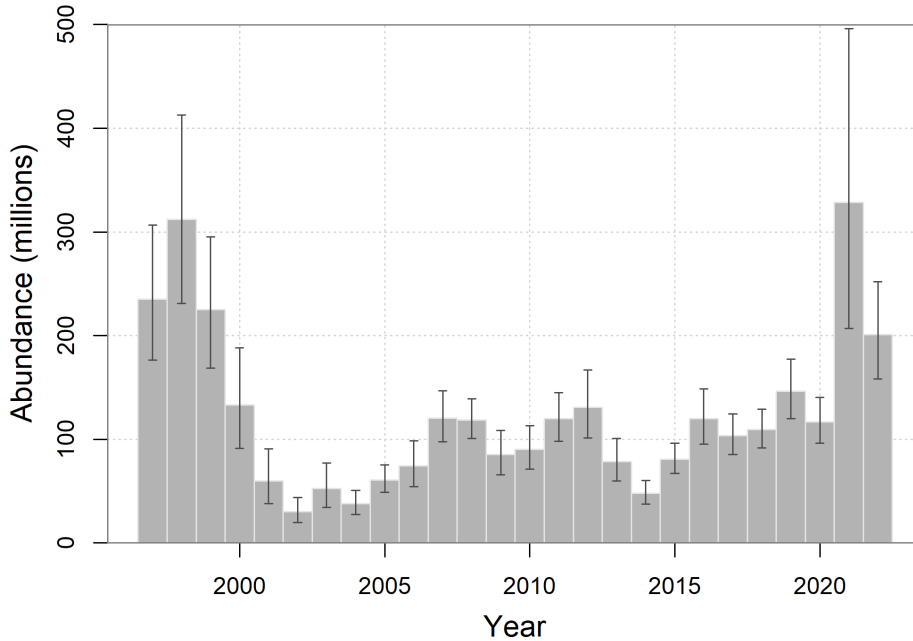


Figure 5. Annual abundance (in millions; means with 95% confidence intervals) of small male crabs of 34 to 44 mm of carapace width, based on the trawl survey data.

Spawning stock abundance is composed of primiparous females, i.e. females carrying their first egg clutch, and multiparous females, i.e. females carrying their second or third egg clutch. The abundance of mature females showed an increasing trend from a low of 237 million crab in 2006 to a high of 777 million crab in 2020 (Figure 6). Levels declined to 582 million crab in 2021 and increased by 3.7% to 602 million crab in 2022, which is still considered to be a high level.

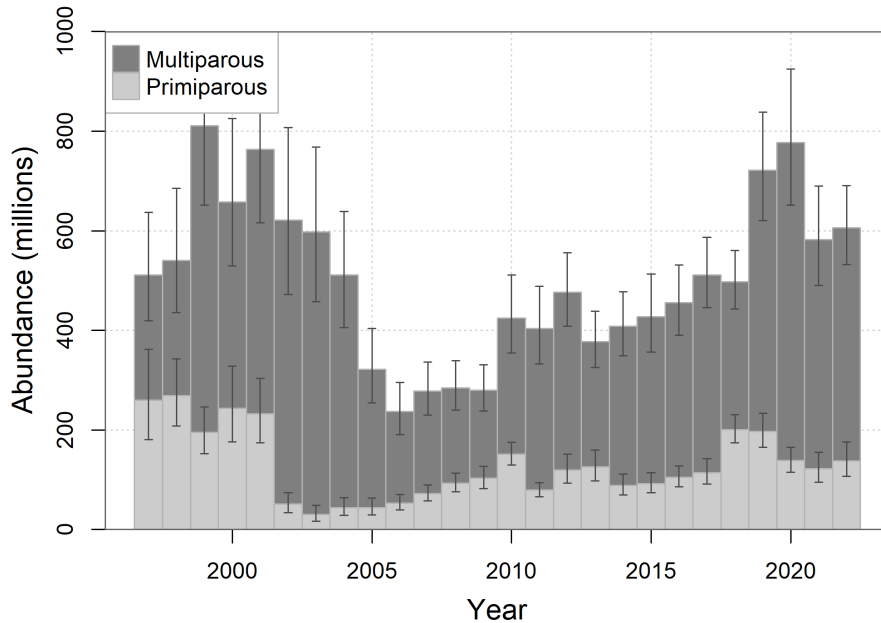


Figure 6. Survey abundance of primiparous and multiparous female snow crab in the sGSL.

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 (Surette and Wade 2006; Wade 2014). The predicted fishery recruitment for 2023 is 57,280 t (95% CI 39,220 to 80,840 t) (Figure 7), representing a 16.2% decrease from the observed recruitment in the 2022 survey. Even considering this decrease, the projected fishery recruitment is considered to be high in 2023.

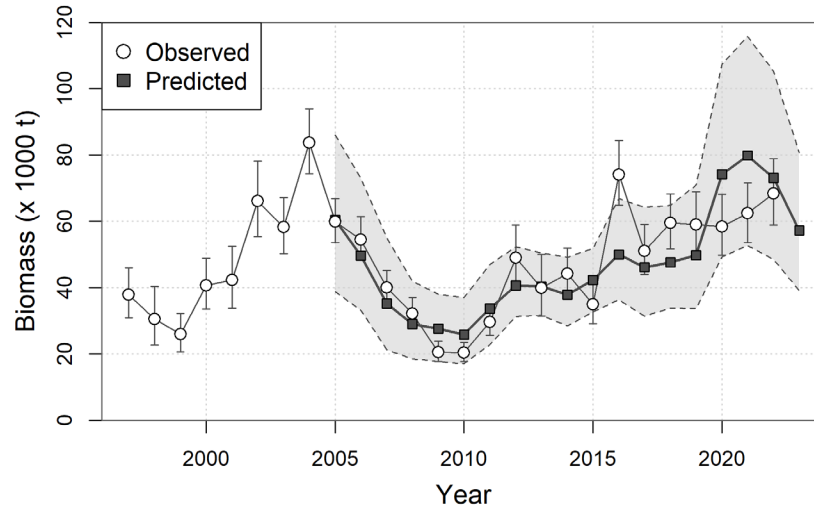


Figure 7. Estimated (open circles are the means with 95% confidence interval vertical bars) and predicted (black squares are the means with the 95% confidence interval bands as dashed lines) fishery recruitment biomasses (R-1) (adult male crabs ≥ 95 mm carapace width of carapace condition 1 and 2) snow crab in the year of the survey, 1997 to 2022.

For the purposes of the assessment, the exploitation rate was defined as the ratio of the fishery landings for a given year over the abundance of commercial biomass index from the preceding year. Over the period from 1998 to 2021, the exploitation rate varied between 21.0% and 44.7%, with an average of 35.0%. The exploitation rate for the 2022 fishery was 39.1% (Figure 8).

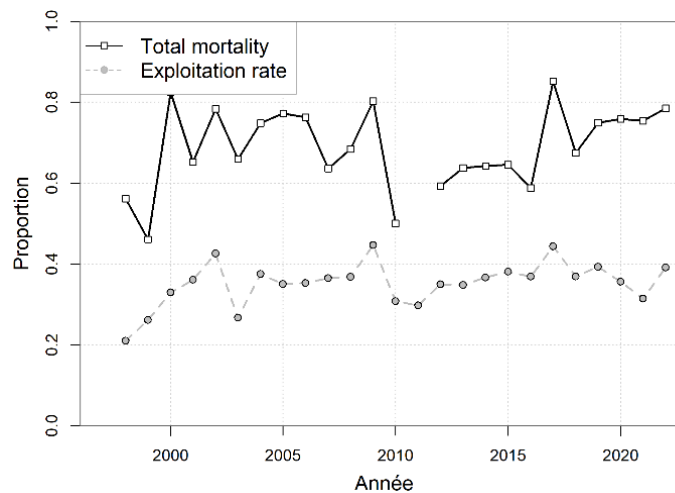


Figure 8. Exploitation rates (open squares; means) by the fishery and total mortality (grey circles) of commercial-sized adult male snow crab.

The survival rate is defined as the sum of the fishery landings plus the residual biomass from the post-fishery survey divided by the commercial biomass estimate from the preceding year. The average survival rate was 66.6% over the period from 1998 to 2022. The annual survival rate has gone from 69.5% in 2018 to 64.4% in 2019 to 59.8% in 2020 down to 56.1% in 2021, up to 60.6% in 2022.

Environmental Considerations

Environmental factors, such as water temperature, can affect the timing of moulting and reproduction, as well as the movement of snow crab. Bottom temperatures over most of the sGSL are typically less than 3 °C, a temperature range suitable for snow crab habitat.

Overall, September bottom temperatures for the sGSL during 2022 were still much warmer than normal except for the coastal area north of Prince Edward Island (PEI) and on the eastern side of Northumberland Strait, including St. Georges Bay (Figure 9). Temperatures for Area 12 in September 2022 were 0.5 to 1 °C (or more) above normal in most of Baie des Chaleurs and over a large area between the Acadian Peninsula, the Magdalen Islands and the Gaspé Peninsula. This area includes the Orphan's and Bradelle Banks. Bottom temperatures near the coast of PEI were significantly colder than normal in some areas. Bottom temperatures in Areas 12E, 12F and 19 were 1 to 2 °C above normal. Areas with below normal temperatures were around PEI, the southern area of the Magdalen Islands and the most western part of Baie des Chaleurs.

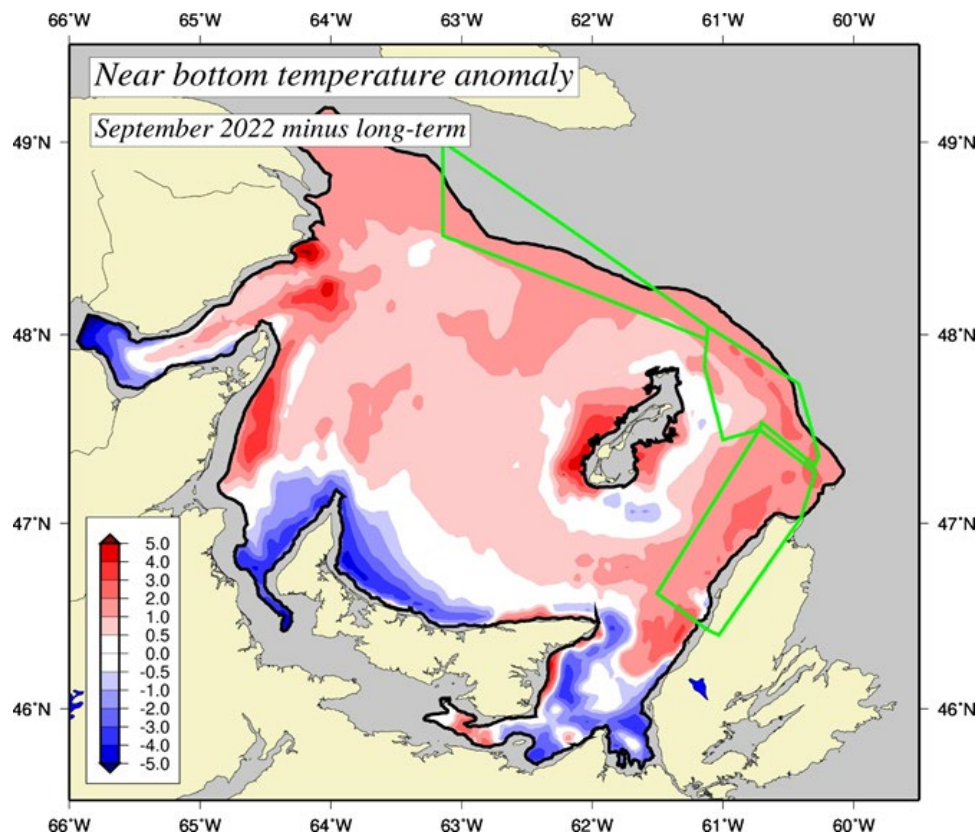


Figure 9. Difference between September 2022 local bottom temperatures and their long-term means from the period from 1991 to 2021. Blue areas represent colder-than-normal temperatures while red regions represent warmer-than-normal conditions. Differences are in °C.

The surface area of the sGSL with bottom temperatures less than 3 °C in September, an index of snow crab habitat, rose slightly in 2022 from 2021, but remained low (Figure 10). The temperature within this area, at an average 1.4 °C, is still well above the long term average (1991-2021). The 2022 average temperature within the snow crab habitat is the second highest of the 1971-2022 time series (Figure 10). The highest value was observed in 2021.

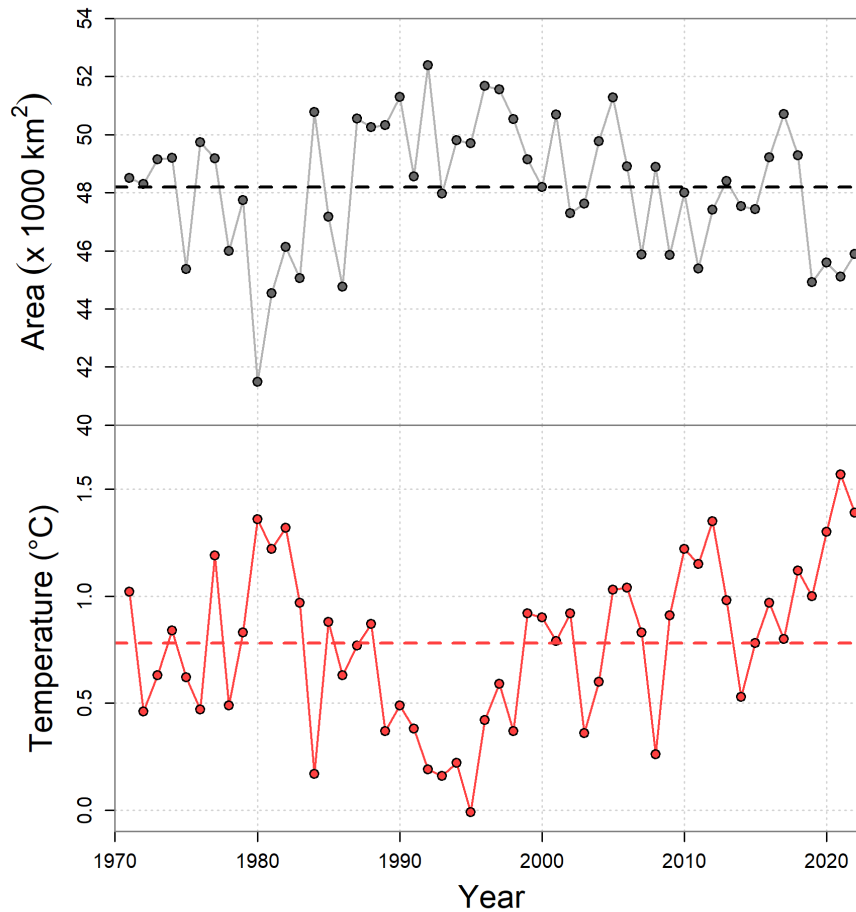


Figure 10. Habitat index of sGSL snow crab (extent of area with bottom temperatures less than 3 °C) (top panel) and the mean temperature within the area (bottom panel). Horizontal dashed lines represent the means over the series.

The deep waters of the Laurentian channel continued their warming trend and were much warmer than normal. The temperature at 200 m near Cabot Strait reached 7.3 °C, which is 2.0 °C warmer than the long term average of 5.2 °C.

Sources of Uncertainty

A survey requires a proper sampling design, catch standardization methods, and a robust sampling protocol in order to meaningfully infer annual variations and long-term trends of stock abundance. The catchability of the snow crab survey has likely changed over time due to changes in sampling design, which includes areal expansions, survey station redistributions, and survey vessel changes. Other sources of possible bias include the practice of relocating

survey sampling stations to other areas more favourable to trawling. A multi-year experiment is on-going to assess the level of bias from this source.

The uncertainty associated with abundance and biomass estimates, used as inputs for the harvest decision rules and the risk assessment, are likely underestimated. One example is related to the area swept by each tow, which are used to standardize survey catches. Swept areas are currently treated as point estimates, i.e. their estimation errors are not carried over into those of the resulting survey indices. Estimates in marginal fishing areas are more subject to sampling variability. This can include variation in environmental conditions that can lead to crab movement during the survey sampling season.

Another source of uncertainty are the warming trends in the sGSL which, in the short to long-term, are likely to impact snow crab movement, growth, recruitment and mortality. Although some of these aspects are regularly monitored as part of annual assessments, there is no quantitative model for predicting likely outcomes should environmental conditions worsen.

CONCLUSIONS AND ADVICE

Commercial biomass from the 2022 snow crab survey, which would be available to the fishery in 2023, is estimated at 85,532 t, which is comparable to levels from the past three years. For this level of commercial biomass, the target exploitation rate would be 41.79% for the 2023 fishery as per the Precautionary Approach (PA) compliant harvest decision rule (DFO 2014), corresponding to a catch option of 35,745 t (Figure 11).

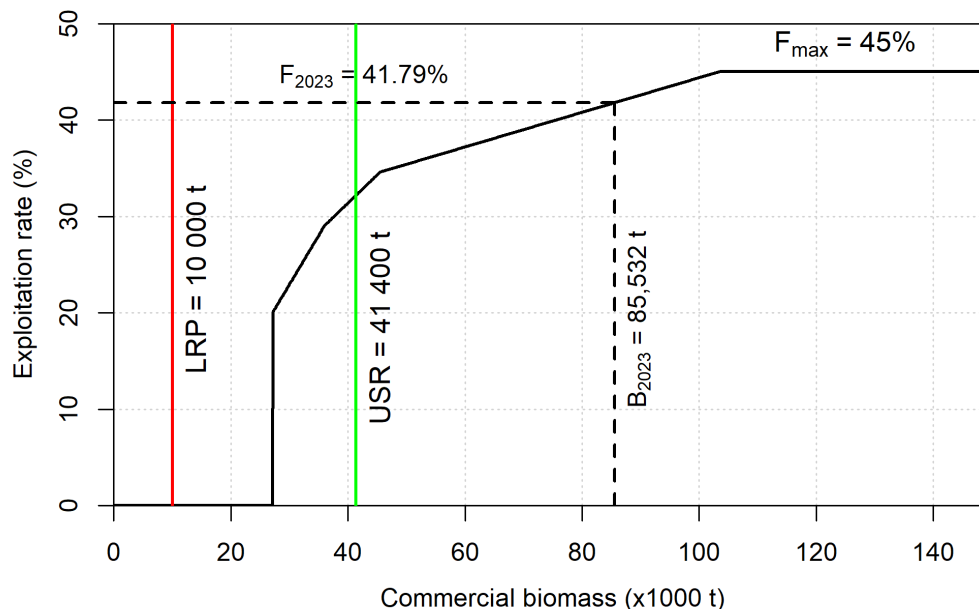


Figure 11. Harvest decision rule used for the southern Gulf of St. Lawrence snow crab fishery (DFO 2014), expressed as exploitation rate versus commercial biomass (black line). Coloured lines represent reference points: LRP (red line) is the limit reference point for residual biomass and USR (green line) is the upper stock reference point for commercial biomass. F_{max} represents the maximum exploitation rate harvest decision rule. The dashed line shows the biomass estimate for 2022 along with the corresponding target exploitation rate.

For this catch option, a risk analysis indicated that there was a very low likelihood of the residual biomass would be below the LRP and a very high likelihood that the 2023 commercial stock biomass would be above the USR as defined by the PA (Table 4).

Table 4. Risk analysis for different catch options for the 2023 sGSL snow crab fishery showing the probability that the residual commercial biomass (B_{res}) would be below the LRP, the probability that the total commercial biomass (B) would be below the USR, and the expected biomass for the 2023 survey. In bold is the catch option corresponding to an exploitation rate of 41.79%, the rate as per the harvest decision rule.

Catch option (t)	Probability		Predicted biomass for 2023 (t)
	$B_{res} < LRP$	$B < USR$	
33,000	0.1%	0.0%	77,640 (58,258 – 101,924)
34,000	0.3%	0.0%	76,640 (57,258 – 100,924)
35,000	0.7%	0.0%	75,640 (56,258 – 99,924)
35,745	1.3%	0.0%	74,896 (55,513 – 99,179)
36,000	1.6%	0.0%	74,640 (55,258 – 98,924)
37,000	3.4%	0.0%	73,640 (54,258 – 97,924)
38,000	6.5%	0.0%	72,640 (53,258 – 96,924)

Despite warming trends in bottom temperatures, abundance indices remain high with strong population and fishery recruitment forecasted, along with strong spawning stock abundances. According to the PA framework for snow crab, the 2022 survey biomass estimate is considered to be in the healthy zone and the stock is very likely to remain in the healthy zone in 2023.

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SOURCES OF INFORMATION

This Science Advisory Report is from the January 25-26, 2023 regional peer review on Assessment of snow crab (*Chionoecetes opilio*) in the southern Gulf of St. Lawrence (Areas 12, 12E 12F and 19) in 2022 and advice for the 2023 fishery. 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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