



Gulf Region

# ASSESSMENT OF SNOW CRAB (*CHIONOECETES OPILIO*) IN THE SOUTHERN GULF OF ST. LAWRENCE (AREAS 12, 12E, 12F AND 19) TO 2021 AND ADVICE FOR THE 2022 FISHERY



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

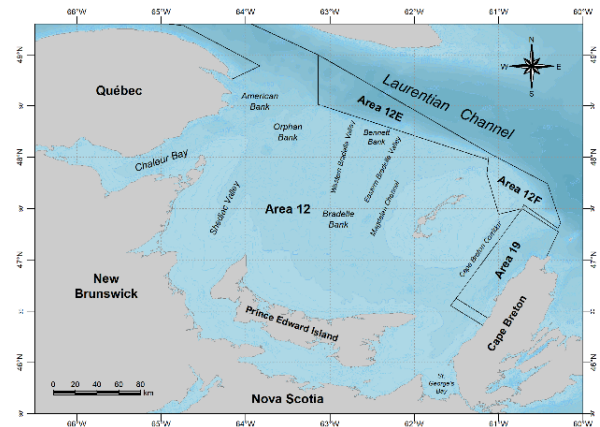


Figure 1. Map of the southern Gulf of St. Lawrence showing the Crab Fishing Areas (12, 12E, 12F and 19).

**Context:**

DFO Gulf Region Fisheries and Aquaculture Management requested an assessment of the resource status in 2021 and catch advice for the 2022 fishery. This document provides an overview of the assessment results and the science advice. Catch rates and other fishery performance indicators are reported. The assessment of the status of the southern Gulf snow crab resource (Areas 12, 12E, 12F and 19) 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 meeting was conducted January 25 - 27, 2022 in Moncton, New Brunswick. Participants at the science review were from DFO Science, DFO Fisheries and Aquaculture Management, National Oceanic and Atmospheric Administration (NOAA), fishing industry, Indigenous organizations, and provincial governments.

## SUMMARY

- Snow crab in the southern Gulf of St. Lawrence (sGSL) is considered as a single stock unit for assessment purposes.
- Issues with survey catchability led to concerns of over-estimation in recent stock indices. As a precaution, the estimate for the commercial biomass was reduced by 15% before establishing the catch option for 2021, as agreed to during an Advisory Committee meeting on February 24<sup>th</sup>, 2021.
- Landings of sGSL snow crab in 2021 were 24,479 tonnes (t), comprised of 21,423 t in Area 12, 223 t in Area 12E, 592 t in Area 12F, and 2,241 t in Area 19.
- Following slight adjustments in the survey protocol, the 2021 estimates are considered to provide better population indices compared to previous year's estimates.
- Commercial stock biomass from the post-fishery survey is estimated at 80,950 t, composed of 77% new recruitment and 23% of residual biomass.
- Based on the harvest control rule, the commercial stock biomass index corresponds to a target exploitation rate of 40.96% resulting in a Total Allowable Catch (TAC) of 33,163 t for the 2022 fishery.
- A risk analysis indicates that a catch option of 33,163 t in 2022 would result in a very low likelihood that the residual stock biomass would be below the limit reference point ( $B_{lim}$ ) and a very high likelihood that the 2022 commercial stock biomass would be above the upper stock reference point ( $B_{usr}$ ), as defined by the Precautionary Approach (PA).
- The stock is considered to be in the healthy zone of the PA.
- Spawning stock abundance and recruitment indices are high.
- 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

### Biology

Snow crab (*Chionoecetes opilio*) is a crustacean with a flat, almost circular body and five pairs of legs. The hard outer shell is periodically shed in a process called moulting. After moulting, 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-moulted 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 moult 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, then settle on the bottom. It takes at least 8-9 years (post-settlement) for males to grow to commercial size.

## Fishery

Snow crab has been commercially exploited in the southern Gulf of St. Lawrence since the mid-1960s. There are four fishing management Areas, of which Area 12 is the largest terms of geographic area and fishery (Figure 1). In Areas 12, 12E and 12F, the fishing season generally starts as soon as the ice clears in April or May, and continues into early summer. In Area 19, the fishery opens after June 30<sup>th</sup> and typically ends in mid-September.

Management of these fisheries is based on quotas and effort controls (trap allocations, trap dimensions and seasons). Only hard-shelled males  $\geq 95$  mm of carapace width are commercially exploited and landing of female crab is prohibited. 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.

Fishery landings and effort data were compiled from crab harvesters logbook data. Catch per unit of effort (CPUE), an index of fishery performance, expressed as kilograms per trap haul (kg/th), was calculated directly from landings and effort data. CPUE values were not standardized by soak time, fishing practices, or changes in fleet dynamics such as those brought about by NARW local Area closures in recent years. Even when CPUE are standardized, the relation between CPUE and population abundance is generally not linear (Erisman et al. 2011).

Since 2018, protective measures were implemented to minimize fishery interactions with endangered North Atlantic Right Whales (NARW). In 2021, temporary and season-long fishing Area closures were in effect during the fishing season, based on confirmed observations of NARW (Figure 2). Soft crab and NARW closures can result in significant displacement of fleet fishing effort.

Snow crab 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 2021 (Figure 3). Amid concerns of overestimation in recent survey biomass indices, DFO took the unusual step of applying a 15% reduction to the 2020 commercial biomass estimate before establishing the total allowable catch (TAC) for 2021. Under this correction, applying the harvest decision rule resulted in a target exploitation rate of 38.3% rather than 40.4%. After quota adjustments and recommendations from industry, the revised quota was set at 24,125 t for the 2021 fishery. Landings for the 2021 fishery were 24,479 t.

The 2021 fishing season in Area 12 opened on April 3<sup>rd</sup> and closed on June 30<sup>th</sup> with last landings reported on June 17<sup>th</sup> (Tables 1 and 2). Total landings of 20,842 t from a revised quota of 20,402 t were reported. Fishing grids in Area 12 that were closed due to the occurrence of soft-shelled crab were mainly concentrated in and around Bradelle Bank (Figure 2). Later in the fishery on June 16<sup>th</sup>, sector 1 in Baie des Chaleurs closed due to high incidence of soft shelled crab. Area 12 was also affected by local Area closures due to the presence of NARW (Figure 2).

Annual mean CPUE increased in Area 12 in 2021 (57.4 kg/th) compared to 2020 (Table 2; Figure 4). The fishing effort estimated from logbooks has varied from 161,148 to 556,780 trap hauls between 1987 and 2021, with the lowest effort in 2010 and the highest effort in 2020 (DFO 2020). The fishing effort was 363,136 trap hauls in 2021, a decrease from 2020 (556,780 trap hauls) (Table 2).

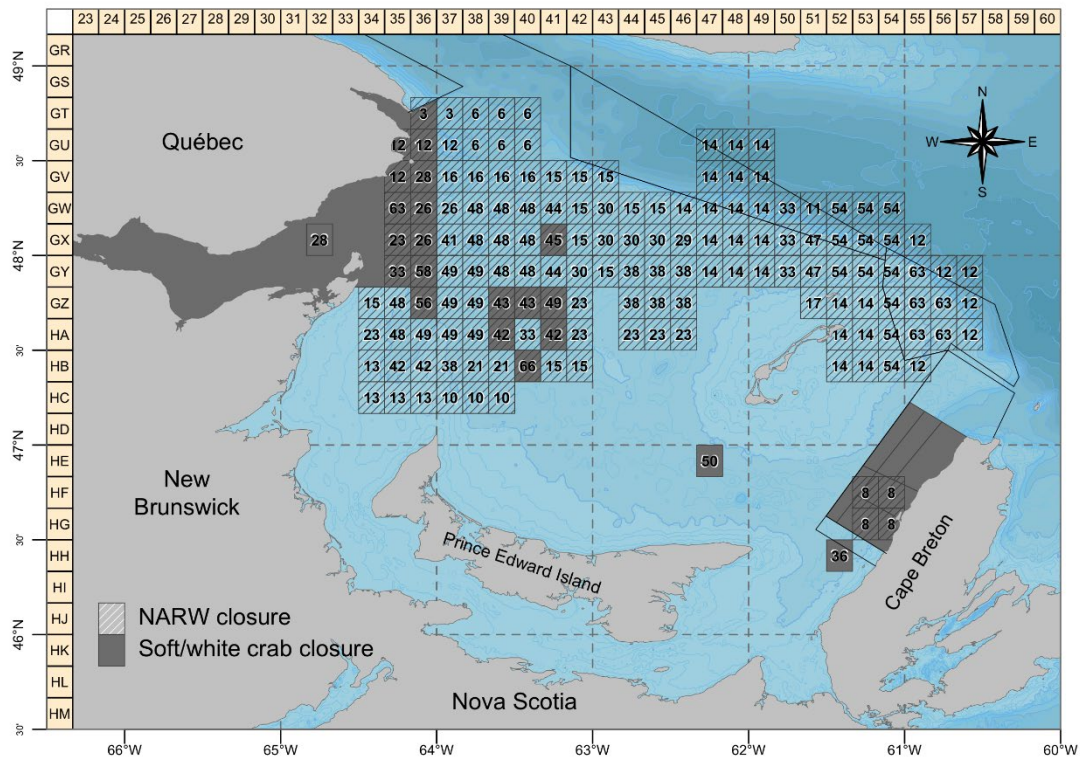


Figure 2. Local Area closures of soft/white crab (solid grey) and for the protection of North Atlantic Right whales (NARW) (hatched) in 2021. Numbers represent the total number of days grids were closed during the fishery. The Baie des Chaleurs sector closed on June 16<sup>th</sup> while in Area 19, 5 sectors closed on July 30<sup>th</sup> and a 6<sup>th</sup> sector closed on August 6<sup>th</sup>.

Table 1. Number of allocation shares, number of active vessels, season opening and closing dates, dates last landing dates, revised quotas, and total landings of the snow crab fishery by management Area in the southern Gulf of St. Lawrence in 2021.

	Area 12	Area 12E	Area 12F	Area 19	Southern Gulf
Allocation shares	243	4	43	158	448
Active vessels	319	4	32	108	464
Season opening date	April 3	April 2	April 3	July 13	-
Season closing date	June 30	June 30	June 30	September 13	-
Last day of landings	June 17	June 24	June 29	August 18	-
Revised quota (t) <sup>1</sup>	20,402	288	1,191	2,244	24,125 <sup>2</sup>
Landings (t)	21,423 <sup>3</sup>	223	592	2,241	24,479

<sup>1</sup> For reasons of annual 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.

<sup>2</sup> Quota includes 450 t set aside to finance the trawl survey in 2021 (under Section 10 of the Fisheries Act).

<sup>3</sup> Total landings in Area 12 include landings allocated to Areas 12E (73 t) and 12F (508 t) that were fished in Area 12. Landings exclusive by Area 12 harvesters were 20,842 t.

The 2021 fishing season in Area 12E began on April 2<sup>nd</sup> and closed on June 30<sup>th</sup> with last landings reported on June 24<sup>th</sup> (Tables 1 and 3). Total landings of 296 t from a revised quota of 288 t were reported. Mean CPUE increased in Area 12E (55.7 kg/th) in 2021 compared to 2020 (Table 3, Figure 4). Fishing effort has varied from 1,825 to 10,074 trap hauls between 1995 and 2021, with the lowest effort in 2010 and the highest effort in 2006 (Hébert et al. 2019). The

fishing effort in Area 12E increased from 5,098 trap hauls in 2020 to 5,314 trap hauls in 2021 (Table 3). As the majority of fishing grounds in Area 12E were closed on May 11<sup>th</sup> for the protection of NARW, snow crab harvesters from this fishing Area were permitted temporary access to fishing Area 12 until June 30<sup>th</sup> (Figure 2). No grids were closed due to soft-shelled crab (Figure 2).

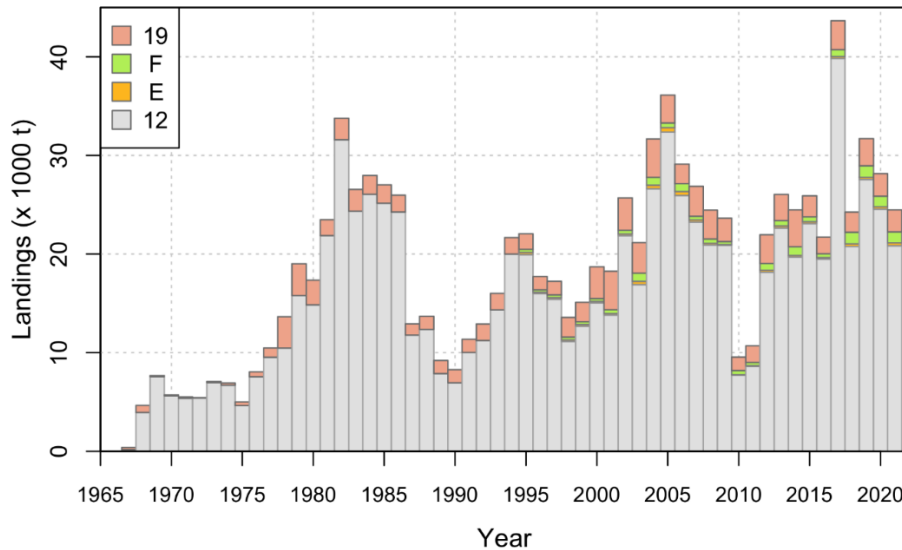


Figure 3. Annual landings (tonnes; t) in the southern Gulf of St. Lawrence snow crab fishery by fishing Area.

Table 2. Quota and landings (tonnes; t), catch per unit of effort (CPUE; kg/trap haul) and fishing effort (trap hauls) for the snow crab fishery in Area 12, 2013 to 2021.

Fishery descriptor	2013	2014	2015	2016	2017	2018	2019	2020	2021
Quota (t) <sup>1</sup>	22,548	19,409	23,021	19,393	39,651	20,909	28,051	27,435	20,402
Landings (t)	22,645	19,633	23,080	19,499	39,825	20,769	27,554	24,554	21,423 <sup>3</sup>
CPUE (kg/trap haul) <sup>2</sup>	76.4	61.8	67.9	64.0	72.0	44.2	55.5	44.1	57.4
Effort (trap hauls)	296,398	317,689	339,912	304,624	553,125	469,887	496,468	556,780	363,136

<sup>1</sup> For reasons of annual 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.

<sup>2</sup> Quota includes 450 t set aside to finance the trawl survey in 2021 (under Section 10 of the Fisheries Act).

<sup>3</sup> CPUE values are not standardized and do not account for changes in management measures.

<sup>3</sup> Total landings in Area 12 include landings allocated to Areas 12E (73 t) and 12F (508 t) that were fished in Area 12. Landings exclusive by Area 12 harvesters were 20,842 t.

In Area 12F, the fishery in 2021 opened on April 3<sup>rd</sup> and closed on June 30<sup>th</sup> with last landings reported on June 30<sup>th</sup> (Tables 1 and 4). Total landings of 1,100 t from a revised quota of 1,191 t were reported. Mean CPUEs (59.1 kg/th) in 2021 increased compared to 2020 (Table 4; Figure 4). The fishing effort in Area 12F has varied from 4,437 to 23,163 trap hauls between 1995 and 2021, with the lowest effort in 2002 and the highest effort in 2014 (Hébert et al. 2019). The fishing effort decreased from 22,168 trap hauls in 2020 to 18,612 trap hauls in 2021 (Table 4). As the majority of fishing grounds in Area 12F were closed on April 29<sup>th</sup> for the season for the protection of NARW, snow crab harvesters from this fishing Area were permitted temporary access to fishing Area 12 until June 30<sup>th</sup> (Figure 2). No grids were closed due to soft-shelled crab (Figure 2).

*Table 3. Quota and landings (tonnes; t), catch per unit of effort (CPUE; kg/trap haul) and fishing effort (trap hauls), for the snow crab fishery in Area 12E, 2013 to 2021.*

Fishery descriptor	2013	2014	2015	2016	2017	2018	2019	2020	2021
Quota (t) <sup>1</sup>	204	170	189	144	199	266	217	238	288
Landings (t)	204	178	192	144	203	260	224	234	223 <sup>2</sup>
CPUE (kg/trap haul) <sup>3</sup>	40.1	47.3	65.8	51.5	60.9	46.6	65.7	45.9	55.7
Effort (trap hauls)	5,097	3,765	2,918	2,796	3,333	5,579	3,415	5,098	5,314

<sup>1</sup> For reasons of annual 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.

<sup>2</sup> Quota includes 450 t set aside to finance the trawl survey in 2021 (under Section 10 of the Fisheries Act).

<sup>2</sup> Approximately 24% (73 t) of the quota allocated to Area 12E was fished in Area 12 due to NARW closures in 12E early in the fishing season. Crab harvesters from Area 12E were permitted a temporary fishing access in Area 12 until June 30<sup>th</sup>, 2021.

<sup>3</sup> CPUE values are not standardized and do not account for changes in management measures.

*Table 4. Quota and landings (tonnes; t), catch per unit of effort (CPUE; kg/trap haul) and fishing effort (trap hauls) for the snow crab fishery in Area 12F, 2013 to 2021.*

Fishery descriptor	2013	2014	2015	2016	2017	2018	2019	2020	2021
Quota (t) <sup>1</sup>	543	906	516	373	680	1,218	1,155	1,192	1,191
Landings (t)	543	882	510	381	684	1,183	1,166	1,084	592 <sup>2</sup>
CPUE (kg/trap haul) <sup>3</sup>	49.0	38.1	38.2	43.9	72.6	69.1	64.5	45.2	59.1
Effort (trap hauls)	11,086	23,163	13,351	8,667	9,421	17,120	18,083	22,168	18,162

<sup>1</sup> For reasons of annual 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.

<sup>2</sup> Quota includes 450 t set aside to finance the trawl survey in 2021 (under Section 10 of the Fisheries Act).

<sup>2</sup> Approximately 46% (508 t) of the quota allocated to Area 12F was fished in Area 12 due to NARW closures in 12F early in the fishing season. Crab harvesters from Area 12F were permitted a temporary fishing access in Area 12 until June 30<sup>th</sup>, 2021.

<sup>3</sup> CPUE values are not standardized and do not account for changes in management measures.

The 2021 fishing season in Area 19 opened on July 13<sup>th</sup> and closed on September 13<sup>th</sup> with last landing reported on August 18<sup>th</sup> (Tables 1 and 5). Total landings of 2,241 t from a revised quota of 2,244 t were reported. During the snow crab fishery, 6 sectors in Area 19 closed due to soft-shelled crab and 4 grids closed due to the presence of NARW (Figure 2). Mean CPUEs (121.0 kg/th) in 2021 increased compared to 2020 (Table 5, Figure 4). The fishing effort in Area 19 has varied from 11,138 to 56,517 trap hauls between 1987 and 2021, with the lowest effort in 2010 and the highest effort in 2004 (Hébert et al. 2019). The effort in 2021 was 18,384 trap hauls, a decrease from 2020 (Table 5).

*Table 5. Quota and landings (tonnes; t), catch per unit of effort (CPUE; kg/trap haul) and fishing effort (trap hauls), for the snow crab fishery in Area 19, 2013 to 2021.*

Fishery descriptor	2013	2014	2015	2016	2017	2018	2019	2020	2021
Quota (t) <sup>1</sup>	2,654	3,745	2,130	1,701	2,945	2,046	2,792	2,287	2,244
Landings (t)	2,657	3,745	2,129	1,701	2,944	2,048	2,763	2,284	2,241
CPUE (kg/trap haul) <sup>2</sup>	148.5	147.4	144.8	142.5	142.8	156.1	112.7	101.7	121.0
Effort (trap hauls)	17,890	25,407	14,703	11,937	20,616	13,120	24,518	22,458	18,384

<sup>1</sup> For reasons of annual 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.

<sup>2</sup> Quota includes 450 t set aside to finance the trawl survey in 2021 (under Section 10 of the Fisheries Act).

<sup>2</sup> CPUE values are not standardized and do not account for changes in management measures.

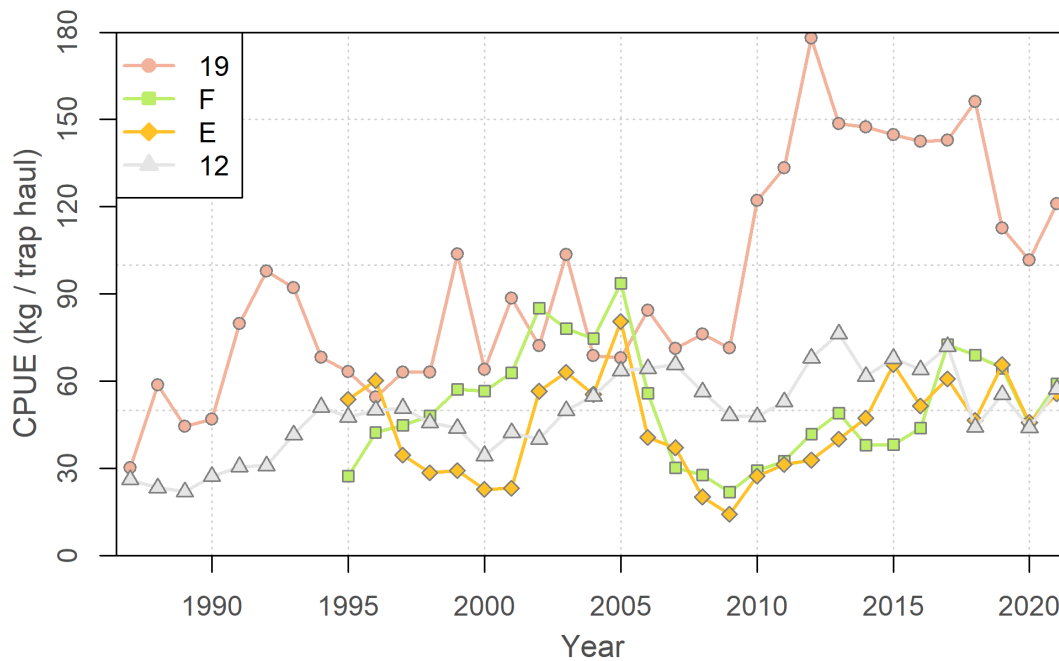


Figure 4. Catch per unit effort (CPUE; kg / trap haul) by management Area in the southern Gulf of St. Lawrence, based on fishery logbook data.

## 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 (Figure 5). From July 17<sup>th</sup> to September 22<sup>nd</sup>, 2021, 350 sampling stations were successfully trawled while 5 were abandoned.

An experiment was conducted during the survey to test whether the practice of relocating survey stations since 2013 had resulted in biases among survey catches in 2021. Thus, 100 of the 2021 survey's complement of 355 stations were randomly selected and moved to their original locations from 2013. The survey vessel was required to sample at these 100 locations, with a limit of three fishing attempts before stations were abandoned. The remaining 255 tows were fished as per the usual protocol, allowing movement to new alternate stations if required.

Before the survey began, another experiment was performed to identify the best method to control latent trawling during the winching of the trawl net. Two methods were considered: a slow method, characterized by a slower winching and reversal of vessel speed, and a fast method, characterized by higher winch speed operation and an increase in vessel speed, with the aim of increasing cable tension so as to raise the trawl from the sea bottom as rapidly as possible.

The fast method yielded an average passive trawling phase duration of 20 seconds (s), which was much shorter than 169 s for the slow method. Application of the fast method to the 2021 survey resulted in a much shorter passive trawling phase duration than in any previous years, with a median duration of 18 s, compared to ~90 s in 2019 and 2020, and 45 s in 2017 and 40 s

in 2018, prior to the vessel change. Consequently, the trawl swept area is likely not being significantly overestimated in 2021 as was the concern in 2019 and 2020.

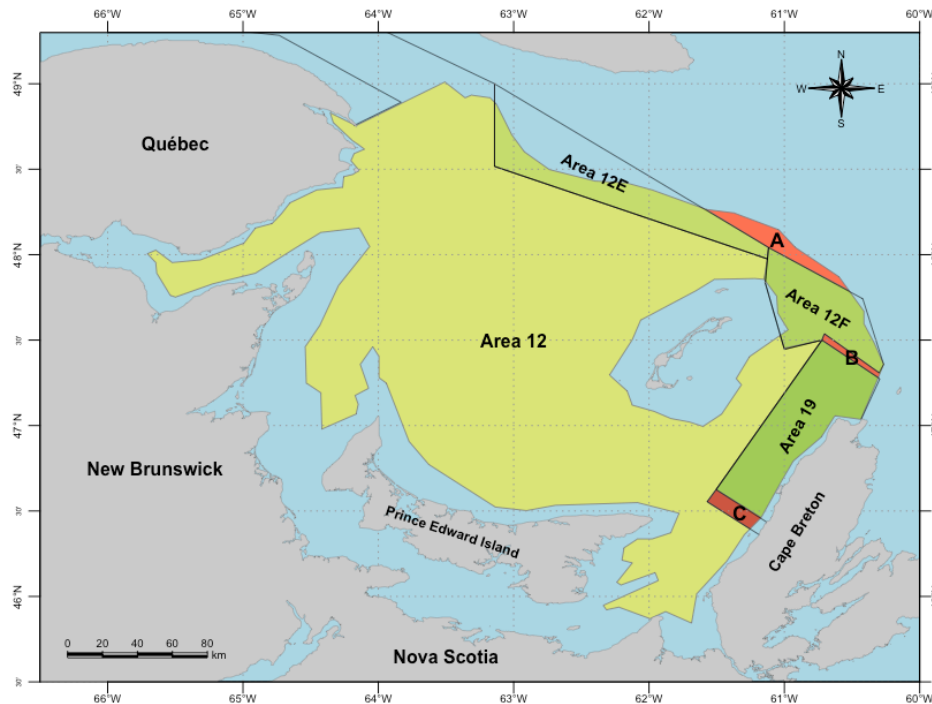


Figure 5. Polygons used for estimating survey stock indices. The unassigned zone north of Areas 12E and 12F (label A) and buffer zones (labels B and C) are also shown.

### Stock Trends and Current Status in the sGSL

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  $\geq 95$  mm CW defined as commercial crab that will be available to the fishery the following fishing season).

A population recruitment index is defined as the abundance of small male crabs (34-44 mm CW). It takes at least six years for these small male crabs to reach the commercial size of 95 mm CW.

Spawning stock abundance consists of mature females (primiparous and multiparous). The term primiparous refers to females that moult to maturity (terminal moult) and mate for the first time (first brood). The term multiparous refers to females which are carrying a brood for the second time or more.

The biomass of commercial-sized adult males in the sGSL from the 2021 trawl survey was estimated at 80,950 t (Table 6; Figure 6). Despite the uncertainty related to survey catchability, commercial biomass estimates have been more or less constant for the past four years, with 77,748 t in 2020 being the lowest and the 2021 estimate being the highest. The 2021 commercial biomass estimates in snow crab fishing Areas (12, 12E, 12F and 19), two buffer zones (between Areas 12F and 19, between Areas 12 and 19) and the unassigned zone (north of Areas 12E and 12F), as shown in Figure 5 and summarized in Table 7.

The recruitment to the fishery at the time of the 2021 survey was 62,473 t, representing 77% of the commercial biomass (Table 6; Figure 6). The recruitment to the fishery in 2021 is similar to



the 2020 estimate. The residual biomass of commercial-sized adult male crabs after the 2021 fishery was estimated at 19,144 t which was nearly identical to 19,107 t in 2020 (Table 6; Figure 6).

The predicted fishery recruitment for 2022 is 73,120 t (95% CI 48,590 t to 105,200 t) (Surette and Wade 2006; Wade et al. 2014) (Figure 7). However, predictions in 2019 and 2020 were about 15,000 t more than what was observed in the surveys. The discrepancy between the predicted and observed values in recent years are likely driven in part to survey catchability increases in 2019 among sub-legal sized crab, though it is unclear to what extent this remains a factor for the 2021 survey. Even considering these possible overestimations, fishery recruitment is projected to be high in 2022.

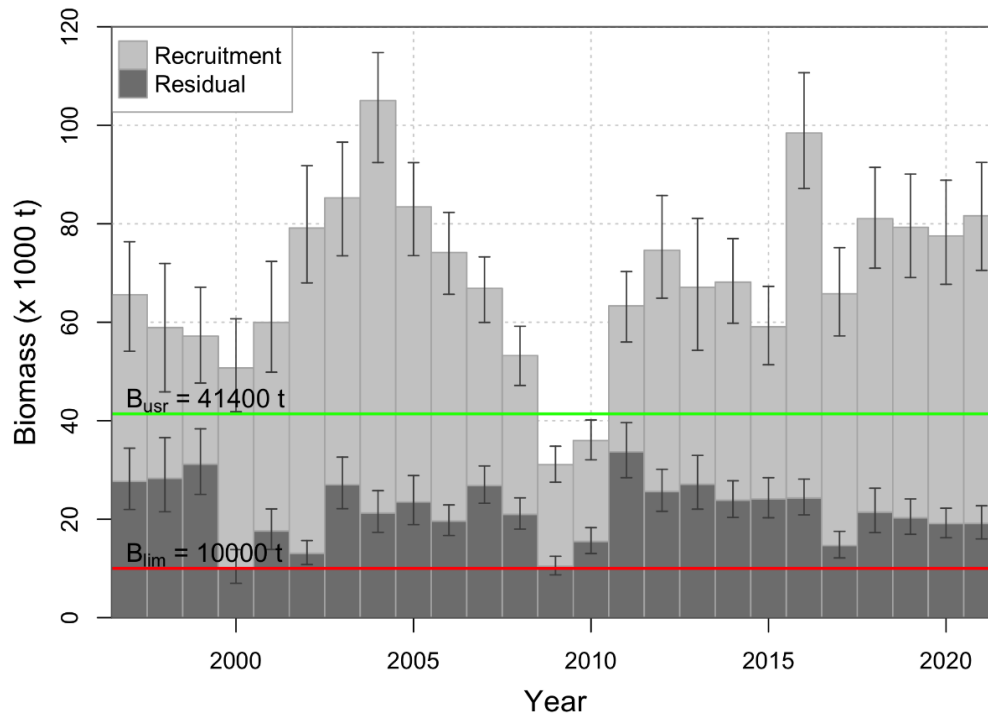


Figure 6. Biomass of commercial recruitment (light grey bars) and residual (dark grey bars), as estimated from trawl survey data. Error bars show 95% confidence intervals. Also shown are the corresponding reference limit for the residual biomass ( $B_{lim}$ ; red line) and upper stock reference ( $B_{usr}$ ; green line) points.

The spatial distribution of commercial crab in 2021 was similar to 2018 - 2020, with crab concentrations over Bradelle Bank, to the south and west of the Magdalen Islands and moderate concentrations in Shediac Valley and Area 19 (Figures 8 and 9). Relative to 2020, concentrations decreased in Area 12F, and increased in the Baie des Chaleurs and off the coast of Gaspé.

Table 6. Total, recruitment, and residual commercial biomass (in tonnes, t; means with 95% confidence intervals).

Survey year	Commercial biomass (t)	Recruitment biomass (t)	Residual biomass (t)
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)	24,106 (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)

Table 7. Commercial biomass by management Area and buffer zones based on the 2021 sGSL survey data. Parentheses show 95% confidence intervals. Labels refer to those in Figure 5.

Areas	Area (km <sup>2</sup> )	Biomass (t)
Southern Gulf	57,842.8	80,950 (70,543 - 92,451)
Area 12	48,074.0	69,022 (60,169 - 78,804)
Area 19	3,813.0	6,550 (4,806 - 8,722)
Area 12E	2,436.9	453 (25 - 2,213)
Area 12F	2,426.8	4,244 (2,938 - 5,937)
Sum of management Areas <sup>1</sup>	56,750.7	80,269
Unassigned zone above 12E (A)	667.9	61 (0 - 413)
Buffer zone 19/12F (B)	134.2	203 (61 - 509)
Buffer zone 12/ 19 (C)	289.5	480 (158 - 1,133)
Sum of total areas and zones	57,842.7	81,013

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

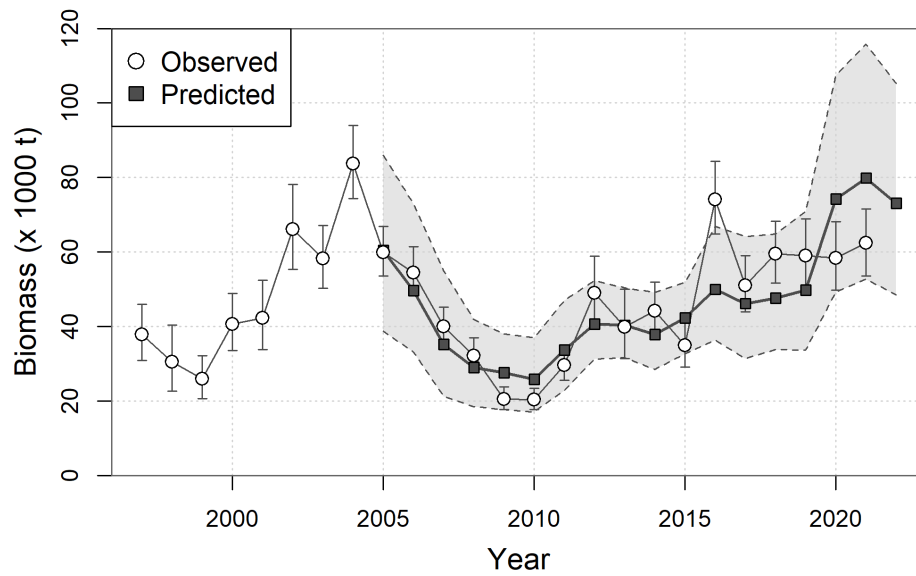


Figure 7. Estimated (open circles are the means with 95% confidence interval vertical bars) and predicted (black squares are the means with the 95% confidence interval bands as dashed lines) biomasses of R-1 (adult male crabs  $\geq 95$  mm carapace width of carapace condition 1 and 2) snow crab in the year of the survey, 1997 to 2021. 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.

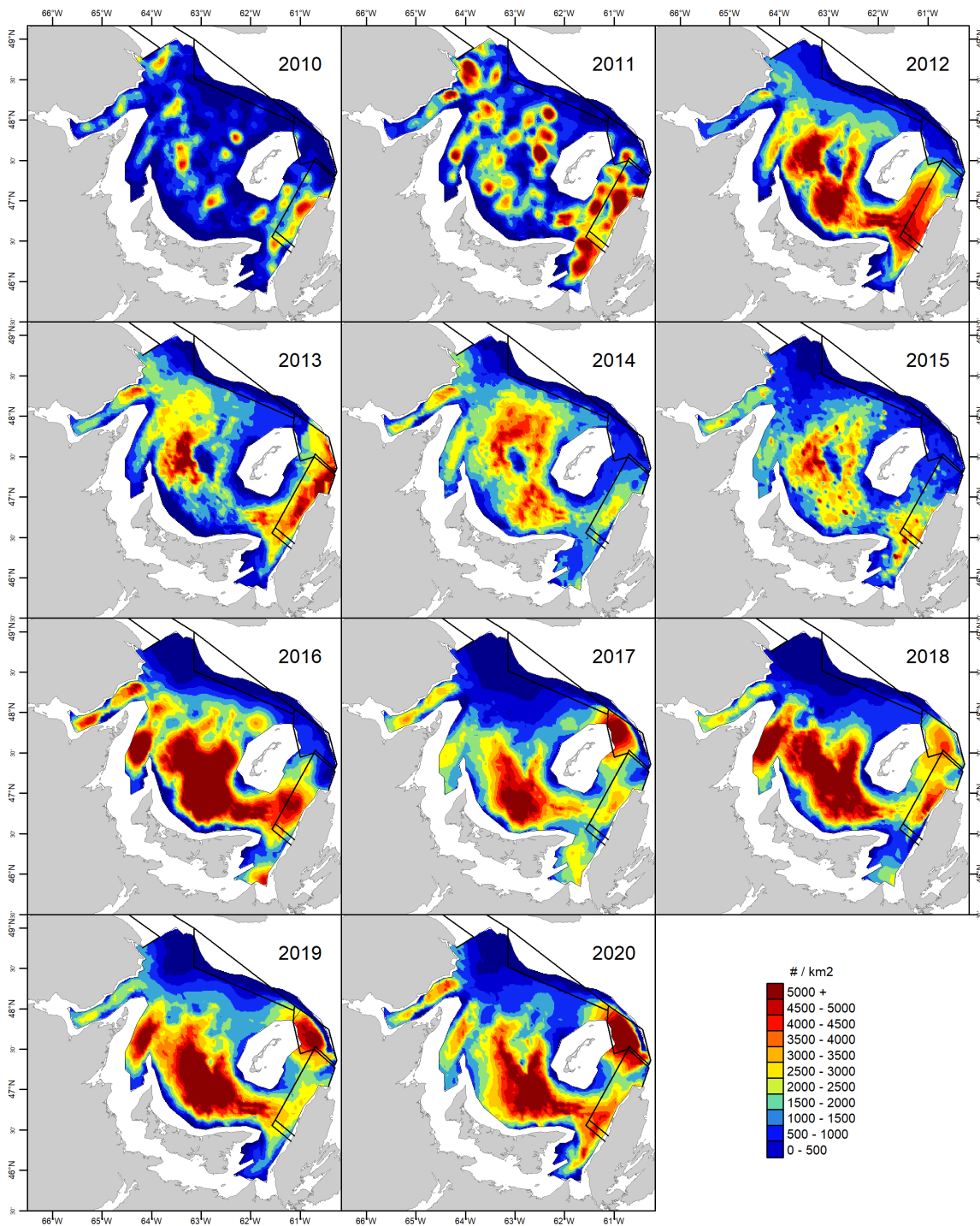


Figure 8. Density (number per km<sup>2</sup>) contours of commercial crab in the southern Gulf of St. Lawrence from 2010 to 2020, based on the snow crab trawl survey.

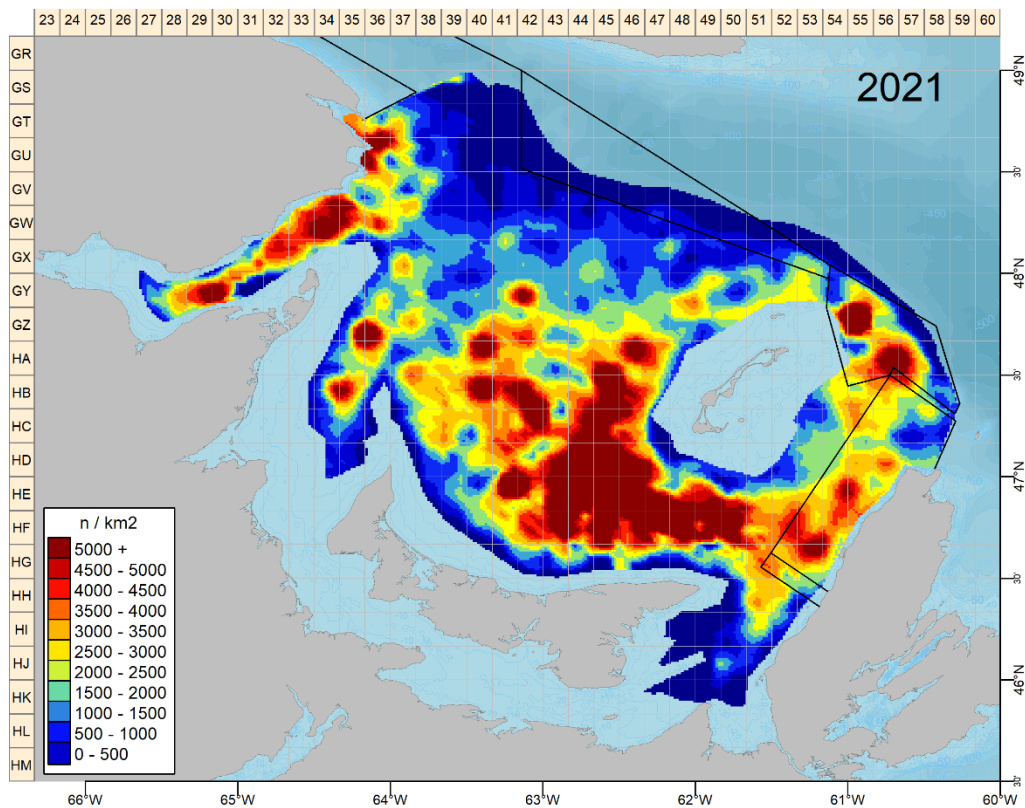


Figure 9. Density (number per km<sup>2</sup>) contours of commercial crab in the southern Gulf of St. Lawrence in 2021, based on trawl survey data.

The exploitation rate was defined as the ration 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 2021 fishery was relatively low at 31.5% (Figure 10).

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 69% over the period from 1998 to 2021. 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. This decrease in survival is of concern and may be driven by natural and fishery induced processes, though it is also subject to misattribution of recruitment and residual groups.

The index of abundance of small male crabs (34-44 mm of CW) from the trawl survey increased a record high level in 2021 (Figure 11). This is due to a strong cohort moving through the population.

The abundance of mature females showed an increasing trend from 2006 to 2020 (Figure 12). The abundance index of mature females in 2021 remained high compared to previous values from 2005 to 2018.

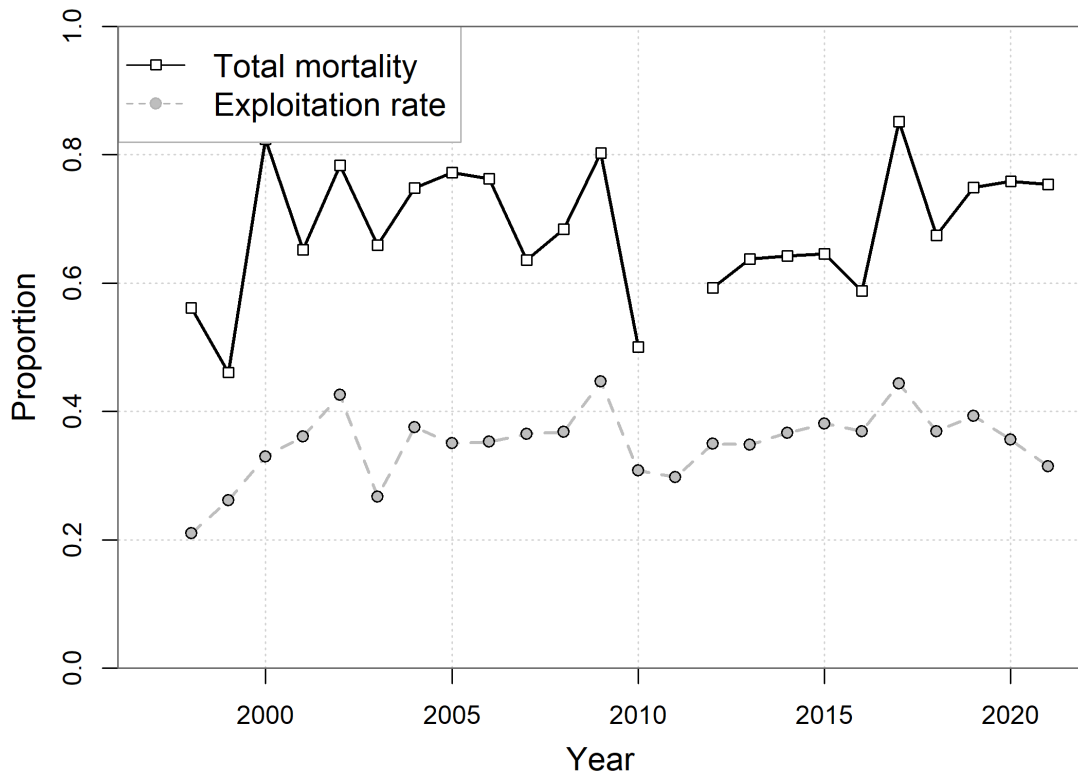


Figure 10. Exploitation rates (open squares; means) by the fishery and total mortality (grey circles) of commercial-sized adult male snow crab.

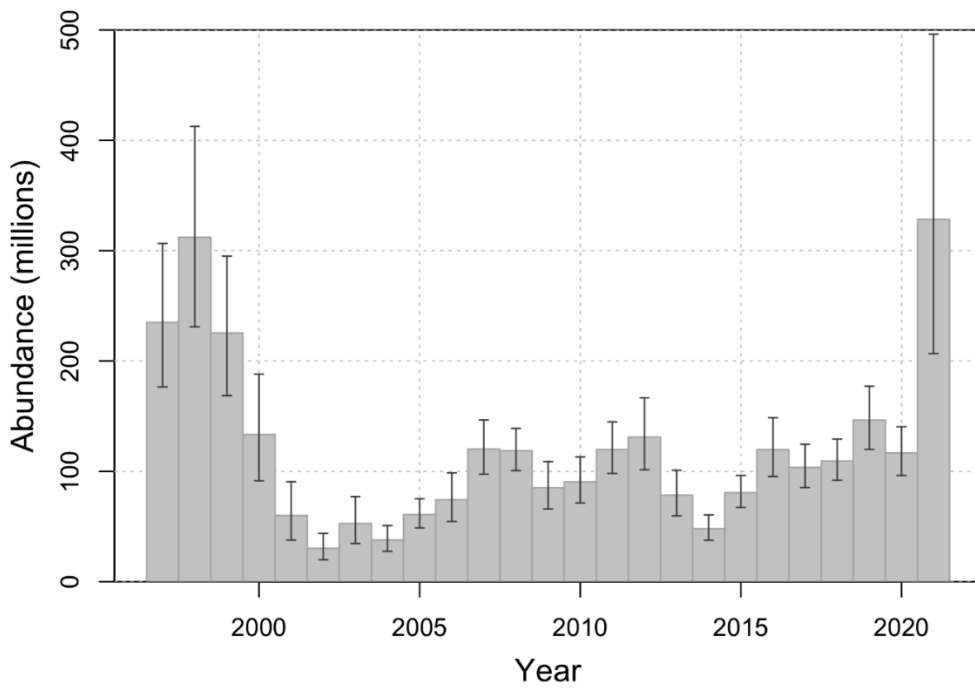


Figure 11. Annual abundance (in millions; means with 95% confidence intervals) of small male crabs of 34 to 44 mm of carapace width, based on the trawl survey data from 1997 to 2021.

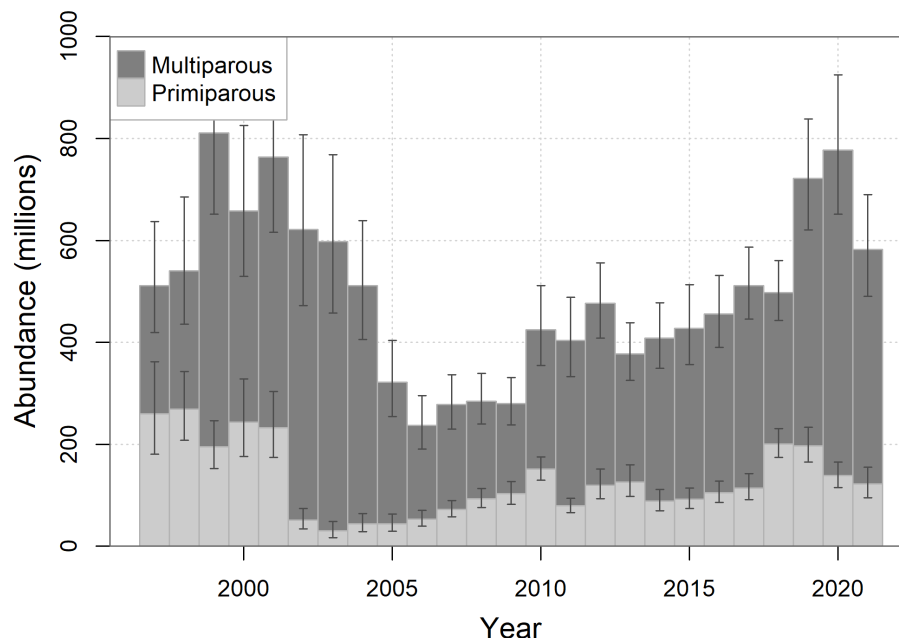


Figure 12. Survey abundance of primiparous and multiparous female snow crab in the sGSL from 1997-2021.

## 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 between  $-1^{\circ}\text{C}$  and  $3^{\circ}\text{C}$ , a temperature range suitable for snow crab habitat. Bottom temperatures in deeper waters of Areas 12E and 12F are higher ( $1$  to  $7^{\circ}\text{C}$ ) than in snow crab grounds in Area 12. Bottom temperatures in Area 19 are usually  $1$  to  $2^{\circ}\text{C}$  warmer than on the traditional crab grounds in Area 12 (Chassé and Pettipas 2009).

Overall, bottom temperatures for the sGSL for 2021 were much warmer than normal. Bottom temperatures in September 2021 were compared to the mean temperatures over the period from 1991 to 2021 using data from the September multi-species survey. Temperatures for Area 12 were  $1^{\circ}\text{C}$  or more above normal in the 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 coasts of New Brunswick and PEI were significantly warmer than normal, up to  $5^{\circ}\text{C}$  in some areas. Bottom temperatures in Area 12E were  $1$ - $2^{\circ}\text{C}$  above normal, Area 12F temperatures were normal, and Area 19 temperatures were from  $0.5$ - $2^{\circ}\text{C}$  above normal. The only areas with below normal temperatures were around the northeastern tip of PEI, the western area of the Magdalen Islands and a small area to the northeast of the Acadian Peninsula (Figure 13). Bottom temperatures at the Shediac Valley station (Viking buoy) consistently warmed up during the summer of 2021, leading up to a temperature anomaly for September of  $+1.9^{\circ}\text{C}$ .

The surface area of the sGSL with bottom temperatures from  $-1$  to  $3^{\circ}\text{C}$  in September, an index of snow crab habitat, rose slightly in 2021 from 2020. However the temperature within this area, at an average  $1.6^{\circ}\text{C}$ , represents an increase of  $0.3^{\circ}\text{C}$  from 2020 ( $1.3^{\circ}\text{C}$ ) and a  $0.6^{\circ}\text{C}$  increase from 2019 ( $1.0^{\circ}\text{C}$ ). This average temperature within snow crab habitat is now at its highest of the 1971-2021 time series (Figure 14).

Surface waters in 2021 warmed up very quickly during the last three weeks of August, with sea surface temperatures becoming much warmer than normal. Sea surface temperature anomalies decreased somewhat in September, but they rose again in October and November, at an average value of about 2 °C warmer than normal. At the same time, deep waters of the Laurentian channel continued their warming trend and were much warmer than normal. The above conditions led to the volume of water corresponding to the Cold Intermediate Layer (CIL), defined as waters <1 °C, being one of the three lowest on record for September, from 1971 to 2021, with the first in 1980 and another in 2012. The CIL water volume for 2021, at ~500 km<sup>3</sup>, is about 5 times lower than normal, and may be the lowest of the three on record, as the data for 1980 were scarce.

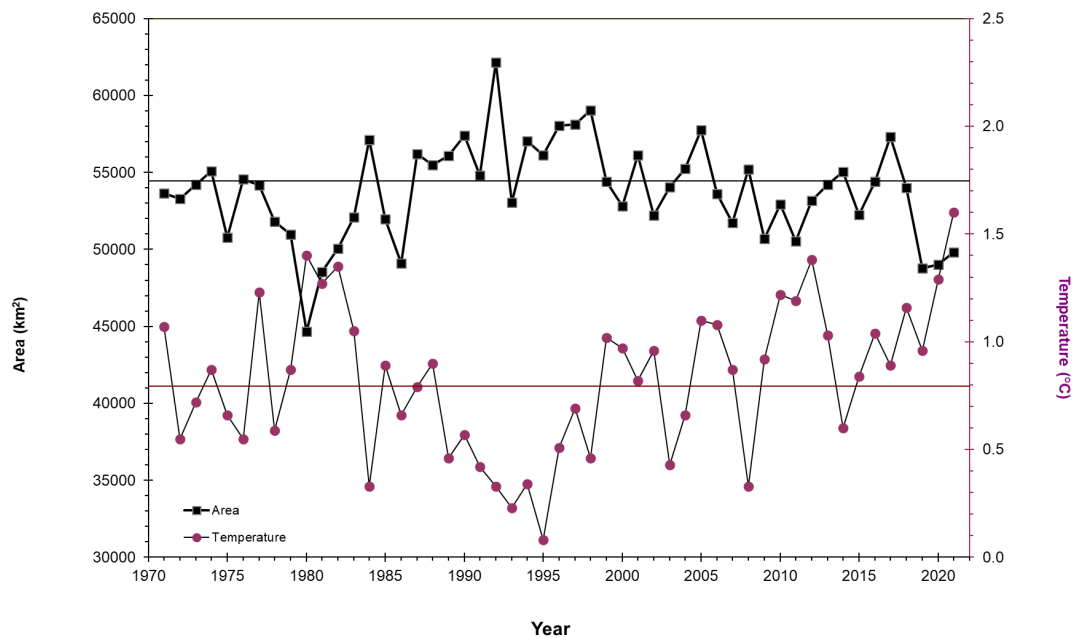


Figure 13. Surface area of the sGSL with bottom temperatures colder than 3 °C, an index of snow crab habitat, along with the mean temperature within the area.

### Sources of Uncertainty

Meaningful inference of temporal variation and long-term trends of snow crab stocks from survey catches relies on the survey having a robust sampling protocol, sampling design and proper standardization of observed catches. Survey catchability has likely varied in response to historical changes in sampling design, such as multiple areal expansions, survey station redistributions, and survey vessel changes. In particular, gradual relocating survey stations to alternate positions from year to year remains as possible source of bias in survey indices. Consequently, these changes in survey catchability imply that the commercial biomass indices on which the reference points for snow crab were defined in 2014 (DFO 2014) may not be on the same scale as those of 2021.

Density and extent of local concentrations of snow crab vary in response to environmental changes, which can result in changes in crab movement, recruitment levels and mortality rates. Such changes, along with the uncertainties from the survey mentioned above, result in annual fluctuations in the observed local crab densities and specifically the proportion of commercial biomass among the different management Areas.



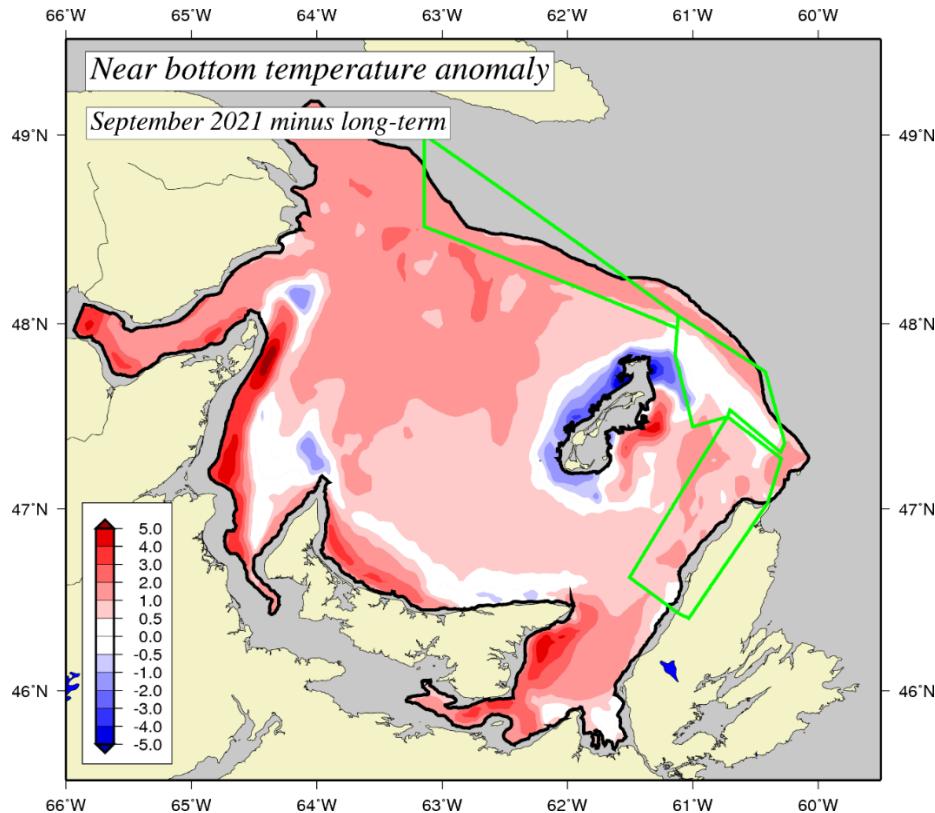


Figure 14. Difference between September 2021 local bottom temperatures and their long-term means from the period from 1991 to 2021. Blue areas represent colder-than-normal temperatures while red regions represent warmer-than-normal conditions. Differences are in °C.

Changes in the environment, such as the general warming trend and the record high bottom temperatures observed in the sGSL in 2021 will likely lead to changes in life history processes including moulting and growth, reproduction, mortality and larval development, though how these processes will be impacted are presently not known.

## CONCLUSIONS AND ADVICE

Commercial biomass from the 2021 snow crab survey, which would be available to the fishery in 2022, is estimated at 80,950 t, which is comparable to levels from the past three years. For this level of commercial biomass, the target exploitation rate would be 40.96% for the 2022 fishery as per the Precautionary Approach (PA) compliant harvest control rule, corresponding to a TAC of 33,163 t (Figure 15, DFO 2014). Exploitation rate versus commercial biomass is shown in Figure 16.

For this TAC level, a risk analysis indicated that there was a very low likelihood of the residual biomass would be below the limit reference point ( $B_{lim}$ ) and a very high likelihood that the 2022 commercial stock biomass would be above the upper stock reference point ( $B_{usr}$ ), as defined by the PA (Table 8).

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 2021 survey biomass estimate is considered to be in the healthy zone and the stock is very likely to remain in the healthy zone in 2022.

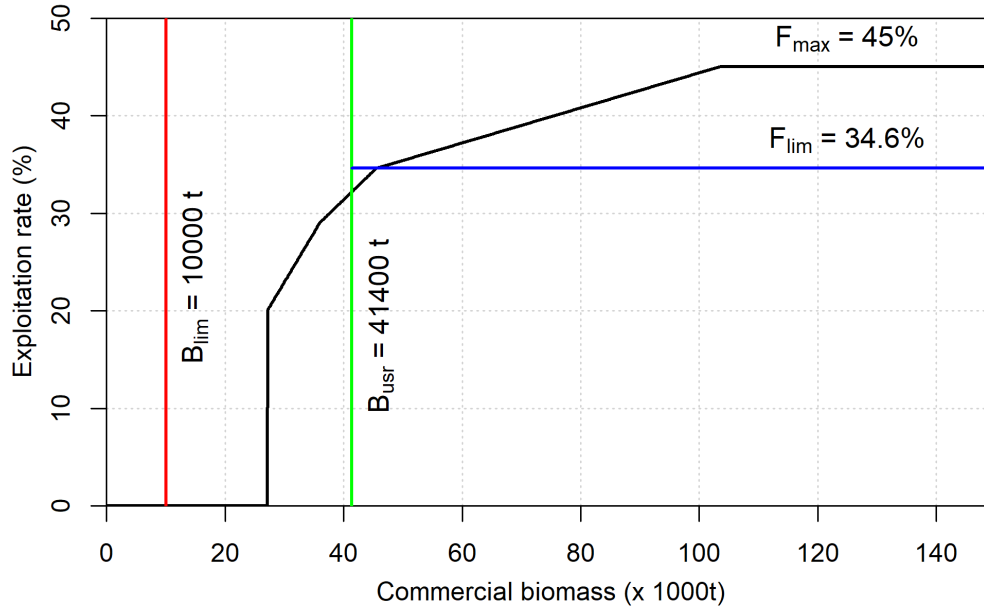


Figure 15. Harvest control rule used for the southern Gulf of St. Lawrence snow crab fishery (DFO 2014), expressed as exploitation rate versus commercial biomass (black line). Coloured lines represent reference points:  $B_{lim}$  (red line) is the limit reference point for residual biomass,  $F_{lim}$  (blue line) is the limit reference point for fishing removal rate, and  $B_{usr}$  (green line) is the upper stock reference point for commercial biomass.  $F_{max}$  represents the maximum exploitation rate harvest control rule.

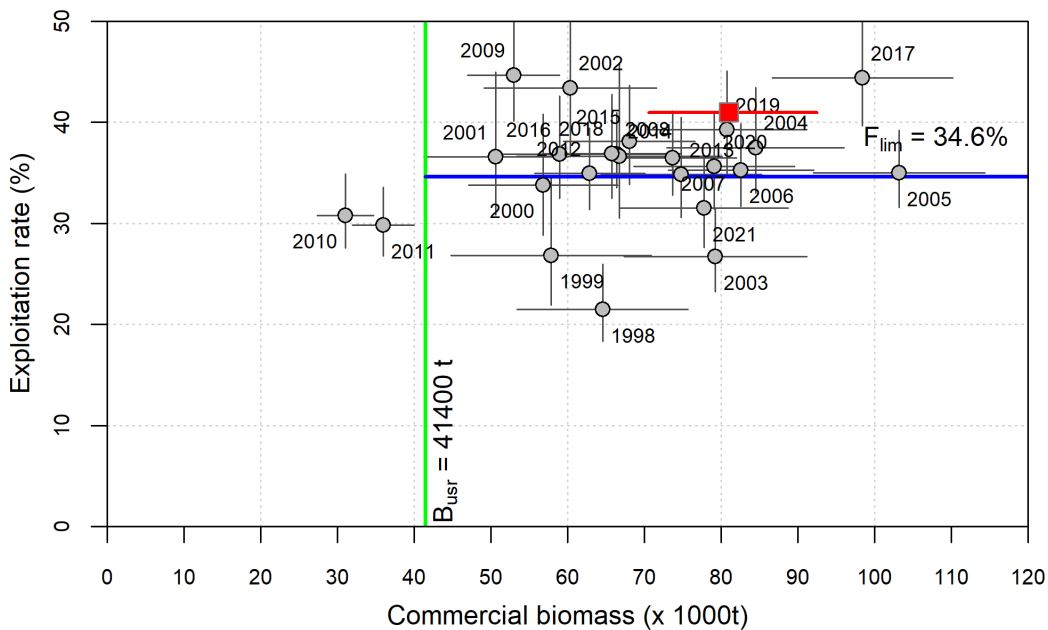


Figure 16. Exploitation rate versus the commercial biomass, with 95% confidence intervals. Year labels represent the fishery year. Coloured lines represent reference points,  $F_{lim}$  (blue line) is the limit reference point for fishing removal rate, and  $B_{usr}$  (green line) is the upper stock reference point for commercial biomass. Red square corresponds to the commercial biomass estimate with the target exploitation rate for the 2022 fishery.

Table 8. Risk analysis for different catch options for the 2022 sGSL snow crab fishery showing the probability that the residual commercial biomass would be below limit reference point, the probability that the total commercial biomass would be below the upper stock reference, and the expected biomass for the 2022 survey. In bold is the catch option corresponding to an exploitation rate of 40.96%, the rate as per the harvest control rule.

Catch option (t)	Probability		Predicted biomass for 2022 (t)
	$B_{res} < B_{lim}$	$B < B_{usr}$	
28,000	0%	0%	95,378 (70,101-128,140)
29,000	0%	0%	94,378 (69,101-127,140)
30,000	0%	0%	93,378 (68,101-126,140)
31,000	0.2%	0%	92,378 (67,101-125,140)
32,000	0.5%	0%	91,378 (66,101-124,140)
33,000	1.3%	0%	90,378 (65,101-123,140)
<b>33,163</b>	<b>1.5%</b>	<b>0%</b>	<b>90,214 (64,938-122,977)</b>
34,000	2.9%	0%	89,378 (64,101-122,140)
35,000	5.8%	0%	88,378 (63,101-121,140)
36,000	10.6%	0%	87,378 (62,101-120,140)
37,000	17.4%	0%	86,378 (61,101-119,140)
38,000	26.3%	0%	85,378 (60,101-118,140)
39,000	36.9%	0%	84,378 (59,101-117,140)
40,000	48.3%	0%	83,378 (58,101-116,140)
45,000	91.0%	0.1%	78,378 (53,101-111,140)
50,000	99.5%	0.4%	73,378 (48,101-106,140)
80,000	100.0%	48.1%	43,378 (18,101-76,140)
81,000	100.0%	50.9%	42,378 (17,101-75,140)

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## SOURCES OF INFORMATION

This Science Advisory Report is from the Fisheries and Oceans Canada, Canadian Science Advisory Secretariat, regional advisory meeting of January 25-27, 2022 on the Stock status in 2021 and fishery advice for 2022 for Snow Crab from the Southern Gulf of St. Lawrence.

Additional publications from this process will be posted on the [Fisheries and Oceans Canada \(DFO\) Science Advisory Schedule](#) as they become available.

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