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Gulf Region

Canadian Science Advisory Secretariat
Science Advisory Report 2016/010

ASSESSMENT OF SNOW CRAB (CHIONOECETES OPILIO) IN THE SOUTHERN GULF OF ST. LAWRENCE (AREAS 12, 19, 12E AND 12F) AND ADVICE FOR THE 2016 FISHERY

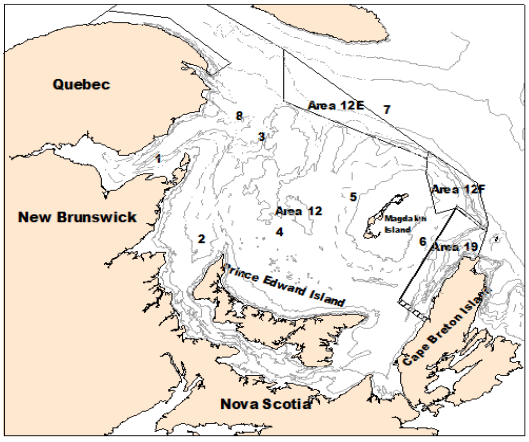

Figure 1: Map of the southern Gulf of St. Lawrence showing the Crab Fishing Areas (CFAs), fishing grounds and management buffer zones (shaded area). Fishing grounds are labeled as follows: 1 Chaleur Bay, 2 Shediac Valley, 3 Orphan Bank, 4 Bradelle Bank, 5 Magdalen Channel, 6 Cape Breton Corridor, 7 Laurentian 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-May as soon as the Gulf is clear of ice and continues into early summer while in Area 19, the fishery opens after June 30 and usually 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 2015 and catch advice for the 2016 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, 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 meeting was conducted January 27-28, 2016 in Moncton, NB. Participants at the science review were from DFO Science, DFO Fisheries Management, fishing industry, Aboriginal organizations, and provincial governments.

SUMMARY

- Snow crab in fishing areas 12, 19, 12E, and 12F comprise a single biological population and the southern Gulf of St. Lawrence stock is considered as one unit for assessment purposes.
- The landings of snow crab from the southern Gulf of St. Lawrence in 2015 were 25,911 t from a revised quota of 25,842 t.
- The resulting exploitation rate of the 2015 fishery in the southern Gulf of St. Lawrence was estimated at 38.4%.
- The 2015 post-fishery survey biomass of commercial-sized adult male crabs was estimated at 58,808 t (95% confidence interval of 52,754 to 65,466 t), a decrease of 12.9% from 2014. The available biomass for the 2016 fishery, derived from the 2015 survey, is within the healthy zone of the Precautionary Approach (PA) framework.
- Total commercial biomass in the 2015 survey was composed 59% of new recruitment (34,929 t) and 41% of residual biomass (24,022 t). The recruitment to the commercial biomass decreased by 19.9% relative to the previous year.
- Based on the agreed harvest decision rule which has been assessed as compliant with the PA, the point estimate of the biomass in the 2015 survey of 58,808 t corresponds to an exploitation rate of 37% giving a Total Allowable Catch (TAC) of 21,759 t for the 2016 fishery.
- The risk analysis indicates that the 2016 TAC derived from the harvest decision rule will result in a near 100% chance of the biomass for the 2017 fishery being above B_{USR} and in the healthy zone of the PA.

Fishery performance in 2015 in Area 12:

- The 2015 landings in Area 12 were 23,080 t from a revised quota of 23,021 t.
- The CPUE (expressed as kg per trap haul (kg/th)) in 2015 (67.9 kg/th) increased compared to 2014 (61.8 kg/th).
- The incidence of soft-shelled crab in 2015 (4.9%) is comparable to 2014 (4.4%).

Fishery performance in 2015 in Area 19:

- The 2015 landings in Area 19 were 2,129 t from a revised quota of 2,130 t.
- The CPUE in 2015 (144.8 kg/th) is comparable to 2014 (147.4 kg/th).
- The incidence of white-crab increased from 1.0% in 2014 to 5.5% in 2015.

Fishery performance in 2015 in Area 12E:

- In Area 12E, the landings were 192 t from a revised quota of 189 t.
- The CPUE in 2015 (65.8 kg/th) increased compared to 2014 (47.3 kg/th).
- The incidence of soft-shelled crab in 2015 increased from 7.8% in 2014 to 9.8% in 2015.

Fishery performance in 2015 in Area 12F:

- The 2015 landings in Area 12F were 510 t from a revised quota of 502 t.

- The CPUE in 2015 (38.2 kg/th) is comparable to 2014 (38.1 kg/th).
- The incidence of soft-shelled crab increased from 1.7% in 2014 to 3.3% in 2015.

BACKGROUND

Species Biology

Snow crab (*Chionoecetes opilio*) is a crustacean, like lobster and shrimp, but with a flat, almost circular body and five pairs of spider-like legs. 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).

Unlike lobsters, snow crabs do not continue to molt throughout their lives. Females stop growing when they acquire a wide abdomen for carrying eggs, which occurs at carapace widths (CW) less than 95mm. 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. 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, Québec and Nova Scotia. Since 1997, the 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 252 in 2015.

In 1978, Area 19 (Figure 1) was established for the exclusive use of Cape Breton inshore fish harvesters with vessels less than 13.7 m (45 feet) in length. There were 156 allocation shares in Area 19 in 2015.

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 (from New Brunswick, PEI and Québec) and sixteen snow crab allocation shares in Area 12F (from Nova Scotia and Québec) in 2015.

The minimum legal carapace width for males is 95 mm, females are not harvested and soft-shell and white crab are not targeted by the fishery. Baited traps, constructed of wire or tubular steel, are used to catch crab, mainly on mud or sand-mud bottoms at temperatures ranging from -1 to 4.5°C, and depths ranging from 50 to 280 m. The fishery takes place from spring to early summer in Areas 12, 12E and 12F and after June 30 in Area 19.

Management of these fisheries is based on quotas and effort controls (trap allocations, trap dimensions, and seasons). There are at-sea soft-shelled and white crab catch monitoring

protocols which allow for closure of portions of each fishing area when the proportion of the catch of males of these carapace conditions exceeds 20%. The protocols are in place to maximize the yield and the reproductive potential of the resource.

Table 1. Number of allocation shares, vessels, traps, revised quotas, opening dates, and dates of last landing of the snow crab fishery by management area in the southern Gulf of St. Lawrence in 2015.

Characteristics	Area 12	Area 12E	Area 12F	Area 19	Southern Gulf
Allocation shares [1]	252	4	16	156	428
Number of active vessels	292	4	16	103	415
Total number of traps allowed	35,375	450	1,290	1,699	38,814
Opening date	May 11	May 10	May 15	July 15	-
Date of last landing	July 22	June 24	July 17	August 19	-
Revised quota (t) [2]	23,021	189	516	2,130	25,856 [3]
Landings (t)	23,080	192	510	2,129	25,911

[1] The number of quota allocations among which the Total Allowable Catch 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 400 t set aside to finance the trawl survey in 2015 (under Section 10 of the Fisheries Act).

The landings from the southern Gulf of St. Lawrence were low in the 1970s and increased with three periods of high landings: 1981-1986, 1994-1995, and more recently 2002 to 2009 (Figure 2). The peak landing of the entire history was in 2005 at 36,118 t. The landings of snow crab from the southern Gulf of St. Lawrence in 2015 were 25,911 t from a revised quota of 25,842 t.

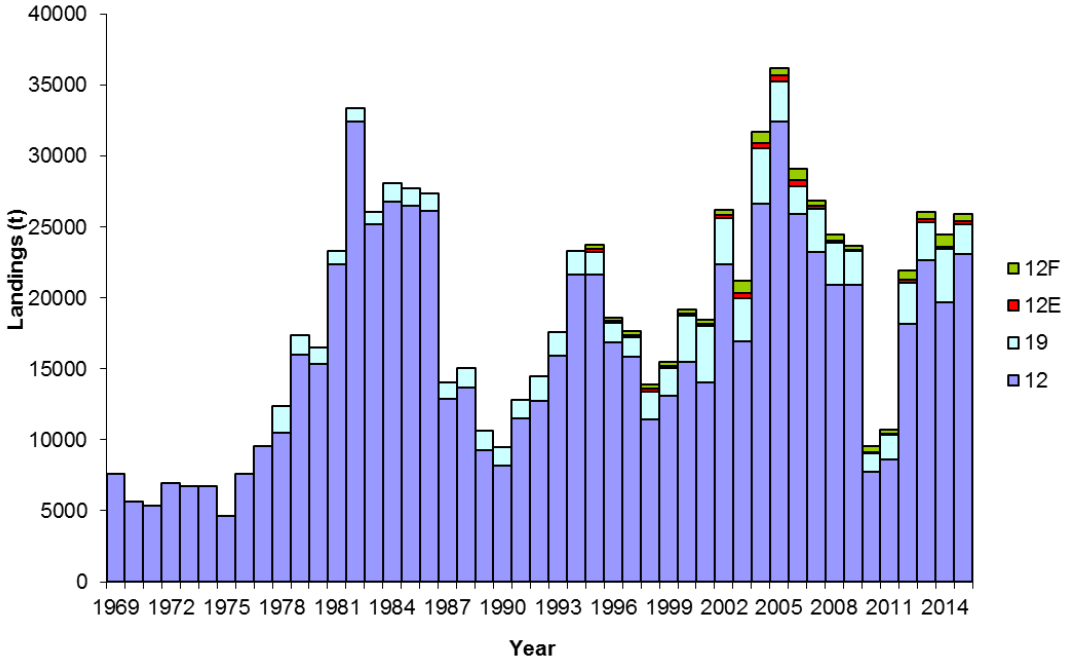

Figure 2: Landings (tonnes) in the southern Gulf of St. Lawrence snow crab fishery, 1969 to 2015.

The 2015 fishing season in Area 12 opened on May 11 and the last landings were recorded on July 22 with reported landings of 23,080 t from a revised quota of 23,021 t (Tables 1, 2; Figure 2). In accordance with the soft-shelled crab protocol, 41 of 323 grids were closed during the 2015 fishing season including the entire Chaleur Bay sector (38 grids) which was closed due to the soft-shelled crab limit having been realized in several grids within the area. The fishing effort estimated from logbooks has varied from 161,148 to 544,454 trap hauls between 1987 and 2015, with the lowest effort in 2010 and the highest effort in 2002. The fishing effort was 339,912 trap hauls in 2015, an increase from 2014 (317,689 th) (Table 2).

Table 2. Revised quota (2012 to 2015), and landings (tonnes), fishing effort (trap hauls) and catch performance for the snow crab fishery in Area 12, 2007 to 2015.

Fishery descriptor	2007	2008	2009	2010	2011	2012	2013	2014	2015
Revised quota (t) [1]	23,207	20,900	20,900	7,700	8,585	18,143	22,548	19,409	23,021
Landings (t)	23,243	20,911	20,896	7,719	8,618	18,159	22,645	19,633	23,080
CPUE (kg/trap-haul) [2]	65.7	56.4	48.2	47.9	53.0	68.0	76.4	61.8	67.9
Effort (trap hauls)	353,775	370,762	433,527	161,148	162,604	267,044	296,398	317,689	339,912
Soft-shelled crab (%) in catches [3]	2.0	3.0	5.0	6.5	6.2	3.7	2.8	4.4	4.9
Grids closed (total of 323)	5	3	78	74	233	7	5	8	41

[1] 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.
[2] CPUE values are not standardized and do not account for changes in management measures.
[3] The percentage is based on a durometer reading of 68. Catches are defined as male crab of all sizes (commercial >= 95 mm and non-commercial) in traps.

The 2015 fishing season in Area 19 opened on July 15 and the last date of landings was August 19 with reported landings of 2,129 t from a revised quota of 2,130 t (Tables 1, 3; Figure 2). In accordance with the white crab protocol (shell hardness <72 durometer units), two sectors within Area 19 were closed during the 2015 fishing season. The fishing effort in Area 19 has varied from 11,138 to 56,517 trap hauls between 1987 and 2015, with the lowest effort in 2010 and the highest effort in 2004. The effort in 2015 was 14,703 trap hauls, a decrease from 2014 (Table 3).

Table 3. Revised quota (2012 to 2015) and landings (tonnes), fishing effort (trap hauls) and catch performance for the snow crab fishery in Area 19, 2007 to 2015.

Fishery descriptor	2007	2008	2009	2010	2011	2012	2013	2014	2015
Revised quota (t) [1]	3,074	3,002	2,433	1,360	1,703	2,907	2,654	3,745	2,130
Landings (t)	3,034	2,929	2,370	1,360	1,701	2,906	2,657	3,745	2,129
CPUE (kg/trap-haul) [2]	71.3	76.3	71.4	122.1	133.3	178.1	148.5	147.4	144.8
Effort (trap hauls)	42,553	38,388	33,193	11,138	12,761	16,317	17,890	25,407	14,703
White crab (%) in catches [3]	7.4	9.0	11.6	6.4	11.5	4.5	3.0	1.0	5.5
Sectors closed [4]	0/4	4/4	9/9	4/9	0/9	0/9	0/9	0/9	2/9

[1] 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.
[2] CPUE values are not standardized and do not account for changes in management measures.
[3] The percentage is based on a durometer reading of 72. Catches are defined as male crab of all sizes (commercial >= 95 mm and non-commercial) in traps.
[4] Total number of sectors was changed from 4 to 9 sectors in 2009.

The 2015 fishing season in Area 12E began on May 10 and the date of last landings was June 24 with reported landings of 192 t from a revised quota of 189 t (Tables 1, 4; Figure 2). The fishing effort in Area 12E has varied from 1,825 to 10,074 trap hauls between 1995 and 2015, with the lowest effort in 2010 and the highest effort in 2006. The fishing effort in Area 12E decreased from 3,765 trap hauls in 2014 to 2,918 trap hauls in 2015. In accordance with the soft-shelled protocol, no grids within Area 12E were closed during the 2015 fishing season.

Table 4. Revised quota (2012 to 2015) and landings (tonnes), fishing effort (trap hauls) and catch performance for the snow crab fishery in Area 12E, 2007 to 2015.

Fishery descriptor	2007	2008	2009	2010	2011	2012	2013	2014	2015
Revised quota (t) [1]	221	400	200	67	75	251	204	170	189
Landings (t)	220	187	67	50	76	185	204	178	192
CPUE (kg/trap-haul) [2]	37.2	20.3	14.4	27.4	31.5	32.9	40.1	47.3	65.8
Effort (trap hauls)	5,914	9,232	4,653	1,825	2,413	5,623	5,097	3,765	2,918
Soft-shelled crab (%) in catches [3]	1.3	10.1	7.8	14.7	8.4	3.3	15.9	7.8	9.8
Grids closed (total of 8)	0	0	2	0	0	0	0	0	0

[1] 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

[2] CPUE values are not standardized and do not account for changes in management measures.

[3] The percentage is based on a durometer reading of 68. Catches are defined as male crab of all sizes (commercial >= 95 mm and non-commercial) in traps.

In Area 12F, the fishery in 2015 opened on May 15 and the last date of recorded landings was July 17 with reported landings of 510 t from a revised quota of 502 t (Tables 1, 5; Figure 2). The fishing effort in Area 12F has varied from 4,437 to 23,163 trap hauls between 1995 and 2015, with the lowest effort in 2002 and the highest effort in 2014. The fishing effort decreased from 23,163 trap hauls in 2014 to 13,351 trap hauls in 2015. In accordance with the soft-shelled protocol, no sector within Area 12F was closed during the 2015 fishing season.

Table 5. Revised quota (2012 to 2015) and landings (tonnes), fishing effort (trap hauls) and catch performance for the snow crab fishery in Area 12F, 2007 to 2015.

Fishery descriptor	2007	2008	2009	2010	2011	2012	2013	2014	2015
Revised quota (t) [1]	408	585	465	420	314	706	543	906	516
Landings (t)	370	431	309	420	313	706	543	882	510
CPUE (kg/trap-haul) [2]	30.2	27.8	22.0	29.3	32.5	41.8	49.0	38.1	38.2
Effort (trap hauls)	12,252	15,504	14,045	14,335	9,631	16,890	11,086	23,163	13,351
Soft-shelled crab (%) in catches [3]	2.4	7.3	11.4	8.6	2.6	9.4	2.4	1.7	3.3
Sectors closed (total of 3)	1	3	3	2	0	0	0	0	0

[1] 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

[2] CPUE values are not standardized and do not account for changes in management measures.

[3] The percentage is based on a durometer reading of 68. Catches are defined as male crab of all sizes (commercial >= 95 mm and non-commercial) in traps.

Catch per unit of effort (CPUE) expressed as kg per trap-haul (kg/th) 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. In Area 12, the annual mean CPUE increased in 2015 (67.9kg/th) compared to 2014 (Table 2; Figure 3). In Area 19, the CPUE (144.8 kg/th) in 2015 is comparable to 2014 (Table 3, Figure 3). The CPUE increased in Area 12E (65.8 kg/th) in 2015 compared to 2014 while in Area 12F, the CPUE (38.2 kg/th) in 2015 is comparable to 2014 (Tables 4, 5; Figure 3).

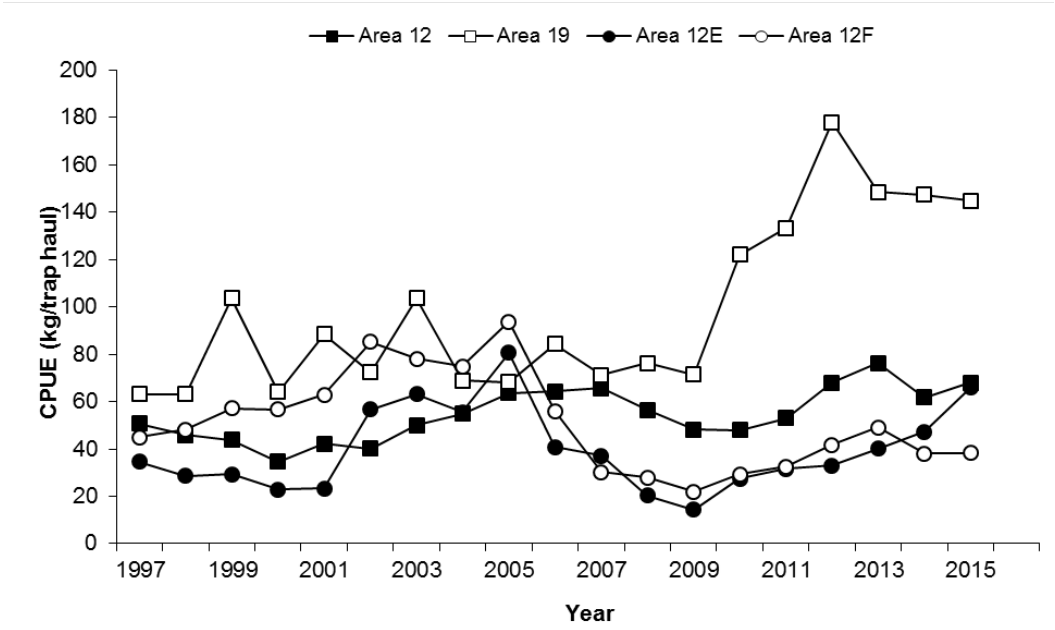

Figure 3: Catch per unit effort (kg per trap haul) in the southern Gulf of St. Lawrence snow crab fishery, Areas 12, 19, 12E and 12F, based on logbooks, 1997 to 2015.

The percentage of soft-shelled crab and white crab is calculated using data collected from the at-sea observer program. The incidence of soft-shelled crab and white crab in catches is strongly influenced by the fishing strategy used by harvesters during the season, as well as the hard-shell commercial-sized adult crab abundance in the area.

The percentage of soft-shelled crab in Area 12 in 2015 was 4.9%, comparable to 2014, and has remained low since 2007 (Table 2). In Area 19, the percentage of white crab was 5.5% in 2015, an increase from 2014, and has remained low since 2011 (Table 3). The percentage of soft-shelled crabs in Area 12E in 2015 was 9.8%, an increase from 2014 (Table 4). In Area 12F, the percentage of soft-shelled crabs in 2015 remained low at 3.3% (Table 5).

ASSESSMENT

Snow crab in fishing areas 12, 19, 12E, and 12F comprise a single biological population and the southern Gulf of St. Lawrence stock is considered as one unit for assessment purposes.

The survey design and biomass estimation polygon covers the entire area of the southern Gulf of St. Lawrence defined by the 20 to 200 fathoms depth contours (which approximately corresponds to the areal extent of bottom temperatures < 5 ˚C which are considered favorable for all life stage of snow crab and encompassing the area of the southern Gulf of St. Lawrence biological unit) (Figure 4). The survey spatial sampling design partitioned this area into square grids of 12.7 km x 12.7 km. In 2015, the number of sampling stations remained at 355. The 348 successful sampling stations from the 2014 trawl survey were used as fixed stations as per the recommendations from the 2014 scientific peer review (DFO 2014a) and a new set of 7

sampling stations (the 2 that were abandoned and the 5 sampling stations that were conducted outside their assigned grids in 2014) was generated randomly. A total 353 stations were successfully trawled in 2015; two sampling squares had to be abandoned due to failures to successfully trawl the area. The survey was conducted between July 9 and October 15, 2015. All at-sea survey and sampling protocols were identical to previous years.

The survey in 2015 was financed through a collaborative agreement with the fishing industry under Section 10 of the Fisheries Act.

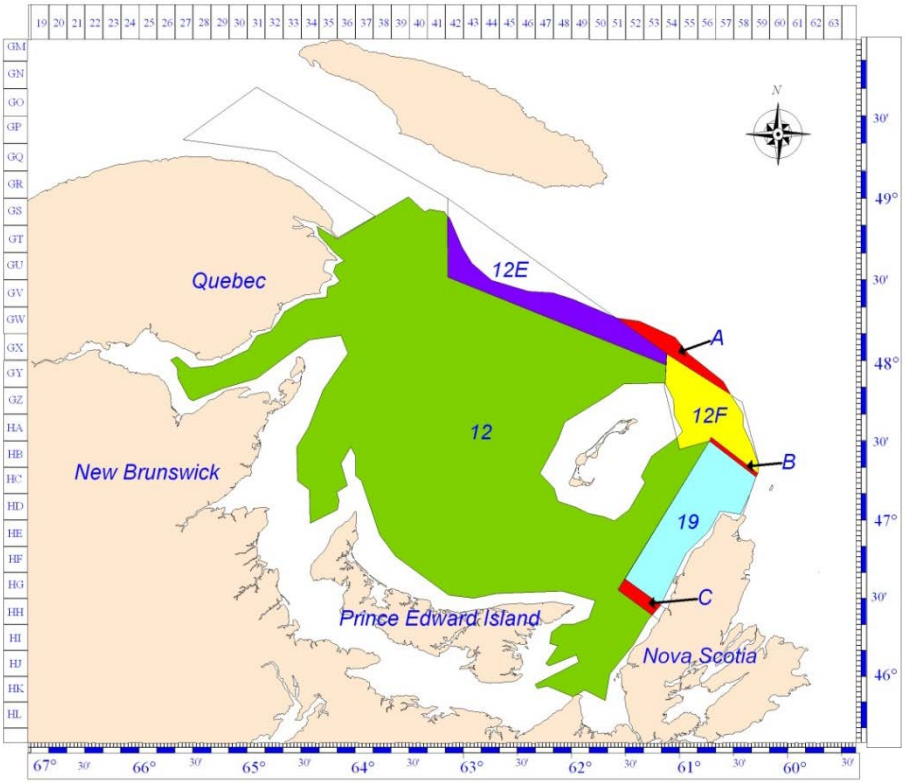

Figure 4: The survey and estimation polygon of 57,840 km^2 used for the 2015 snow crab stock assessment in the southern Gulf of St. Lawrence (all of the coloured areas) and corresponding estimation polygons for the four crab fishing areas (12, 12E, 12F, and 19). The unassigned zone north of areas 12E and 12F (label A) and buffer zones (labels B and C) are also shown.

Stock Trends and Current Status in the Southern Gulf

Interpretation of stock status is based on inferences from abundance data from the snow crab trawl surveys conducted during July to October, over the entire area of snow crab distribution in the southern Gulf. The surveys provide estimates of commercial biomass which are comprised 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 R-1 that will be available to the fishery the following fishing season). The snow crab trawl survey also provides indices of future male recruitment to the fishery (pre-recruits defined as R-4, R-3 and R-2). The pre-recruits R-4, R-3 and R-2 represent adolescent male crabs with a carapace width range of 56-68, 69-83, and larger than 83 mm, respectively. A portion of these crabs could be available to the fishery in 4, 3 and 2 years, respectively. An index of abundance of small male crab (34-44 mm CW) is also presented as an indicator of potential long-term recruitment. 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 females (pubescent and mature). The term pubescent refers to females that will molt to maturity and mate the following year and become primiparous females (first brood). The term 'multiparous' refers to females which are carrying a brood for the second time or more. The term 'mature females', includes primiparous and multiparous females.

The biomass of commercial-sized adult males in the southern Gulf of St. Lawrence from the 2015 trawl survey was estimated at 58,808 t (95% confidence interval (C.I.) range of 52,754 t to 65,466 t; Table 6; Figure 5). The estimated commercial biomass in the southern Gulf decreased by 12.9% relative to the 2014 estimate (67,534 t; 95% C.I. 60,994 t – 74,579 t).

The recruitment to the fishery at the time of the 2015 survey was 34,929 t (95% C.I. 31,670 t to 38,429 t), comprising 59% of the commercial biomass (Table 6; Figure 5). The recruitment to the fishery in 2015 decreased by 19.9% compared to the 2014 estimate. The residual biomass (carapace conditions 3 to 5) of commercial-sized adult male crab after the 2015 fishery was estimated at 24,022 t (95% C.I. 20,761 t to 27,647 t), a comparable level to the 2014 estimate (Table 6; Figure 5).

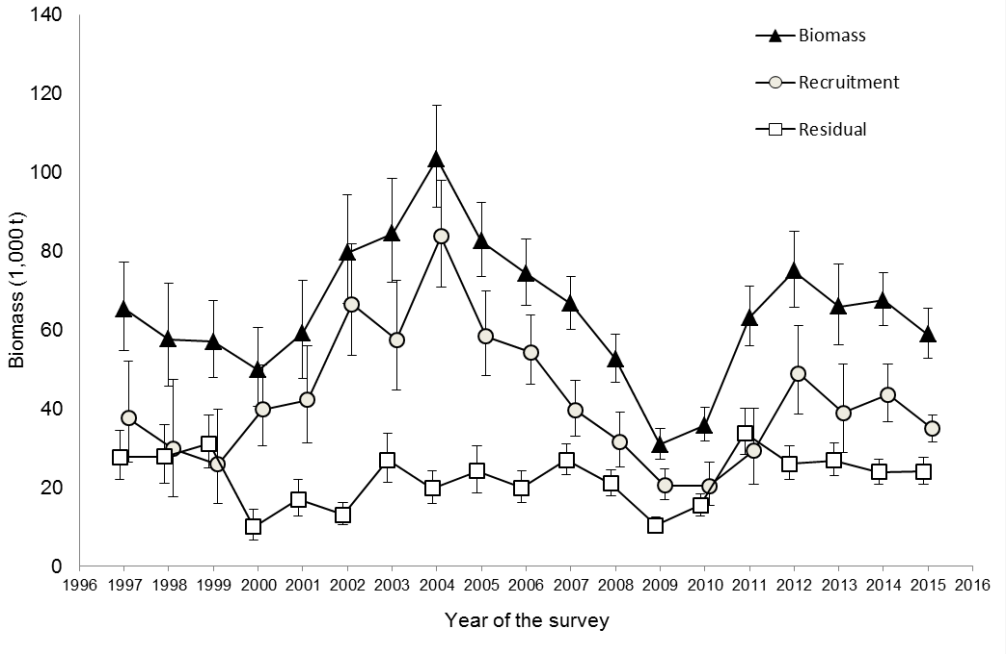

Figure 5: Total commercial biomass, recruitment commercial biomass, and residual commercial biomass (in 1,000 tonnes; means with 95% confidence intervals) in the southern Gulf of St. Lawrence, 1997 to 2015.

A second fishery independent survey of the southern Gulf of St. Lawrence is used to provide an index of biomass of commercial-sized adult male crab. The multi-species research vessel bottom trawl survey, a stratified random design, has been conducted annually in September since the early 1970's although the estimation of commercial-sized adult male crab biomass is available only since 2001.

Over the available time series, the September multi-species bottom trawl survey index shows generally similar trends (within the estimation precisions of the surveys) for commercial adult male snow crab biomass between 2001 and 2015 as do the estimates from the dedicated snow crab trawl survey (Figure 6).

Table 6. Total commercial, recruitment, and residual biomass (in tonnes; means with 95 % confidence intervals) of commercial-sized adult male crabs (>= 95 mm carapace width) in the southern Gulf of St. Lawrence, 1997 to 2015.

Year of the survey	Commercial Biomass	Recruitment Biomass	Residual Biomass
1997	65,310 54,801-77,239	37,619 26,376-52,064	27,690 21,995-34,407
1998	57,595 45,630-71,735	29,818 17,580-47,435	27,775 21,022-36,013
1999	57,051 47,946-67,376	25,874 15,918-39,818	31,177 25,051-38,346
2000	49,823 40,473-60,682	39,845 30,543-51,093	9,977 6,649-14,401
2001	59,150 47,740-72,460	42,243 31,198-55,942	16,905 12,657-22,125
2002	79,559 66,688-94,181	66,481 53,434-81,746	13,075 10,451-16,157
2003	84,423 71,964-98,410	57,503 44,809-72,679	26,919 21,223-33,674
2004	103,429 91,029-117,036	83,702 70,955-98,069	19,726 15,836-24,280
2005	82,537 73,487-92,387	58,398 48,417-69,824	24,140 18,726-30,632
2006	74,285 66,192-83,087	54,371 46,124-63,660	19,914 16,161-24,275
2007	66,660 60,183-73,638	39,635 33,089-47,092	27,025 23,354-31,106
2008	52,564 46,658-59,006	31,555 25,181-39,048	21,010 17,960-24,426
2009	30,920 27,237-34,959	20,520 16,848-24,754	10,399 8,560-12,516
2010	35,795 31,681-40,291	20,351 15,360-26,450	15,444 12,859- 18,394
2011	63,162 55,965-71,022	29,394 20,909-40,190	33,768 28,297-39,985
2012	74,997 65,822-85,086	48,969 38,667-61,173	26,028 21,950-30,641
2013	65,868 56,283-76,610	38,981 28,969-51,346	26,886 22,909-31,352
2014	67,534 60,994-74,579	43,630 36,774-51,388	23,897 20,927-27,168
2015	58,808 52,754-65,466	34,929 31,670-38,429	24,022 20,761-27,647

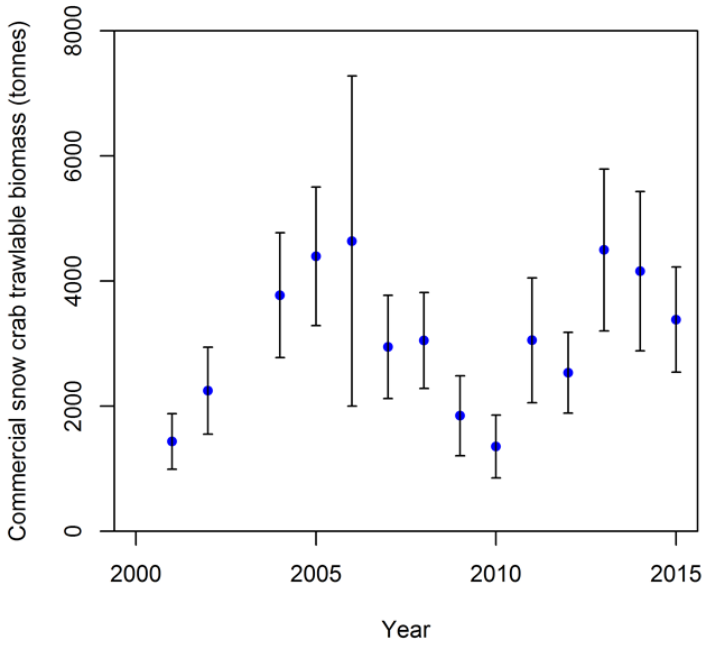

Figure 6: Index of trawlable biomass (in tonnes, means and 95% confidence intervals) of adult male snow crab ≥95 mm carapace width in the September RV survey for 2001 to 2015 excluding 2003, based on a geographic area comparable to that used for the current snow crab assessment.

In the 2015 trawl survey, geographic concentrations of commercial-sized adult males were located in Bradelle Bank, in Shediac valley, in Chaleur Bay, the central and in the southern parts of the Magdalen Channel and in the southeastern part of the sGSL (Figure 7). The spatial distributions of commercial-sized adult males have varied annually during increasing and decreasing phases of the commercial biomass (Figure 8).

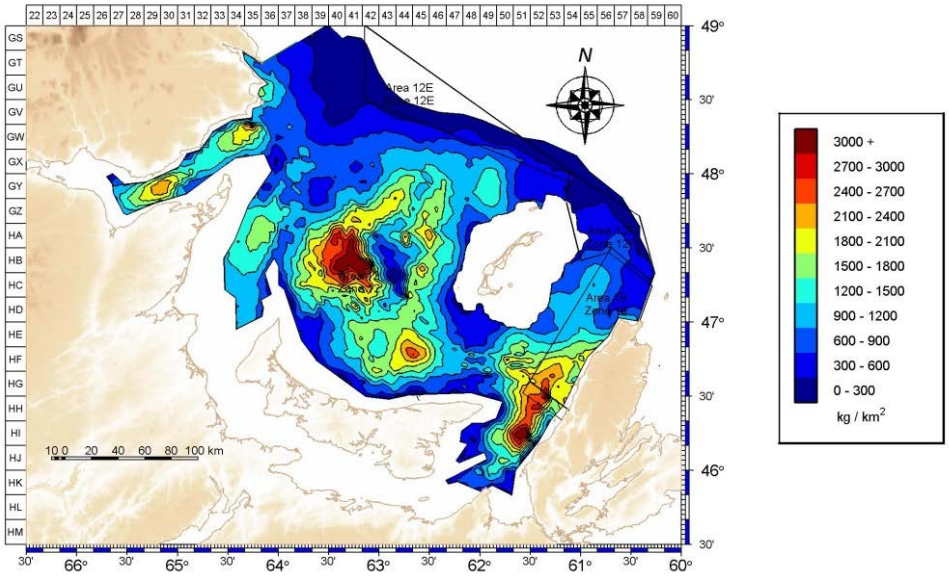

Figure 7: Density (kg per km^2) contours of commercial-sized adult male crab (≥95 mm CW) in the southern Gulf of St. Lawrence in 2015, based on the snow crab trawl survey.

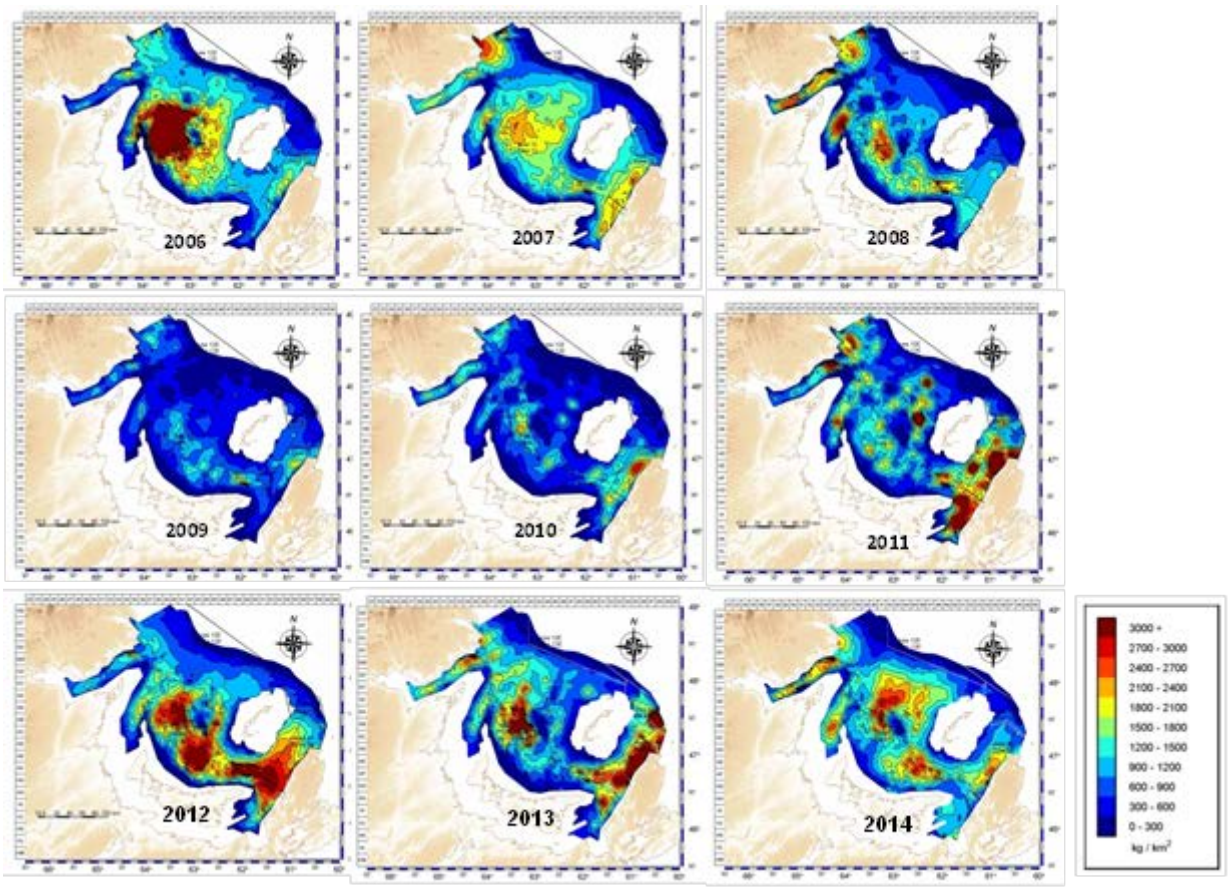

Figure 8: Density (kg per km^2) contours of commercial-sized adult male crab (≥95 mm CW) in the southern Gulf of St. Lawrence, 2006 to 2014.

The exploitation rate in the southern Gulf of St. Lawrence is calculated as the ratio between the catch of the fishery in the year of the assessment and the commercial biomass estimated from the trawl survey in the previous year. The exploitation rates varied between 21% and 45% from 1998 to 2015 (Figure 9). In 2015, the exploitation rate was 38.4%.

Total mortality is calculated as residual biomass estimated from the survey in the year of the assessment divided by the biomass available to the fishery as estimated in the previous year's survey. In 2015, total mortality was estimated at 64.4% (Figure 9). The total mortality has varied between 45.8% and 82.5% since 1997, except for 2011 when it was estimated at 5.6% (Figure 9).

Over the time series, the estimated commercial biomass from the survey was 29.2% higher than the sum of the residual biomass and the landings of the following year. This difference (termed non-fishing directed mortality) and the associated inter-annual variability could be attributed to a number of factors including misattribution of recruitment and residual groups, variability in survey estimates, natural mortality, non-directed fishery induced mortalities, as well as crab movement in and out of the sampling area.

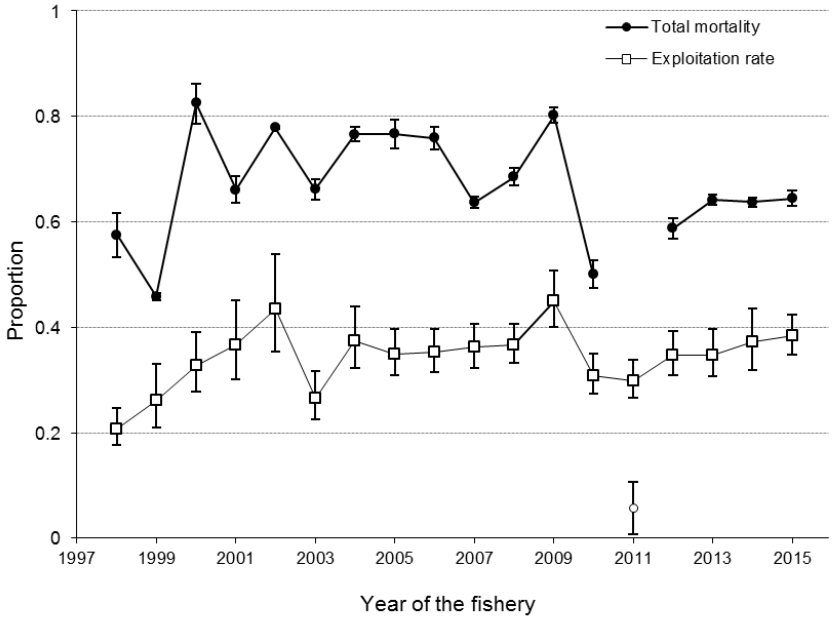

Figure 9: Exploitation rates (means and 95% confidence intervals) by the fishery and total mortality of commercial-sized adult male snow crab in the southern Gulf of St. Lawrence, 1997 to 2015. The 2011 total mortality point is isolated from the series due to uncertainties.

As requested by DFO Fisheries and Aquaculture Management, the 2015 commercial biomass estimates in snow crab fishing areas (12, 19, 12E and 12F), 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 4, are summarized in Table 7. The majority of biomass was found in Area 12, followed by Area 19, 12F, 12E, buffer zones, and the unassigned zone (Table 7).

Table 7. Estimates of commercial biomass (in tonnes; means and 95% confidence intervals) in 2015 for the southern Gulf of St. Lawrence estimation polygon of 57,840 km^2 and for each of the snow crab fishing areas 12, 19, 12E, 12F, the buffer zones, and the unassigned zone. Labels refer to those in Figure 4.

		Commercial biomass (t)	
Areas	Surface area (km^2)	Mean	95% confidence intervals
Southern Gulf [1]	57,840	58,808	52,754 – 65,466
Area 12	48,028	52,146	46,692 – 58,057
Area 19	3,833	4,595	3,534 – 5,876
Area 12E	2,443	396	45 – 1,553
Area 12F	2,438	961	343 – 2,160
Subtotal of crab fishing areas	56,742	58,098	na
Unassigned zone above 12E and 12F (label A)	674	6	0 – 42
Buffer zone 19 / 12F (label B)	112	65	18 - 168
Buffer zone 12 / 19(label C)	310	645	458 - 948
Total of all individual area estimates [1]	57,838	58,814	na

[1] Small difference in the sum of all individual area estimates compared to the southern Gulf estimates are due to rounding of intermediate calculation precisions.

Based on abundances of adolescent males of R-2, R-3 and R-4 from recent surveys, the predicted recruitment of commercial-sized adult male crab for the 2016 survey, available for the 2017 fishery, was estimated at 50,000 t (95% C.I. 36,400 to 66,900 t) (Figures 10 and 11).

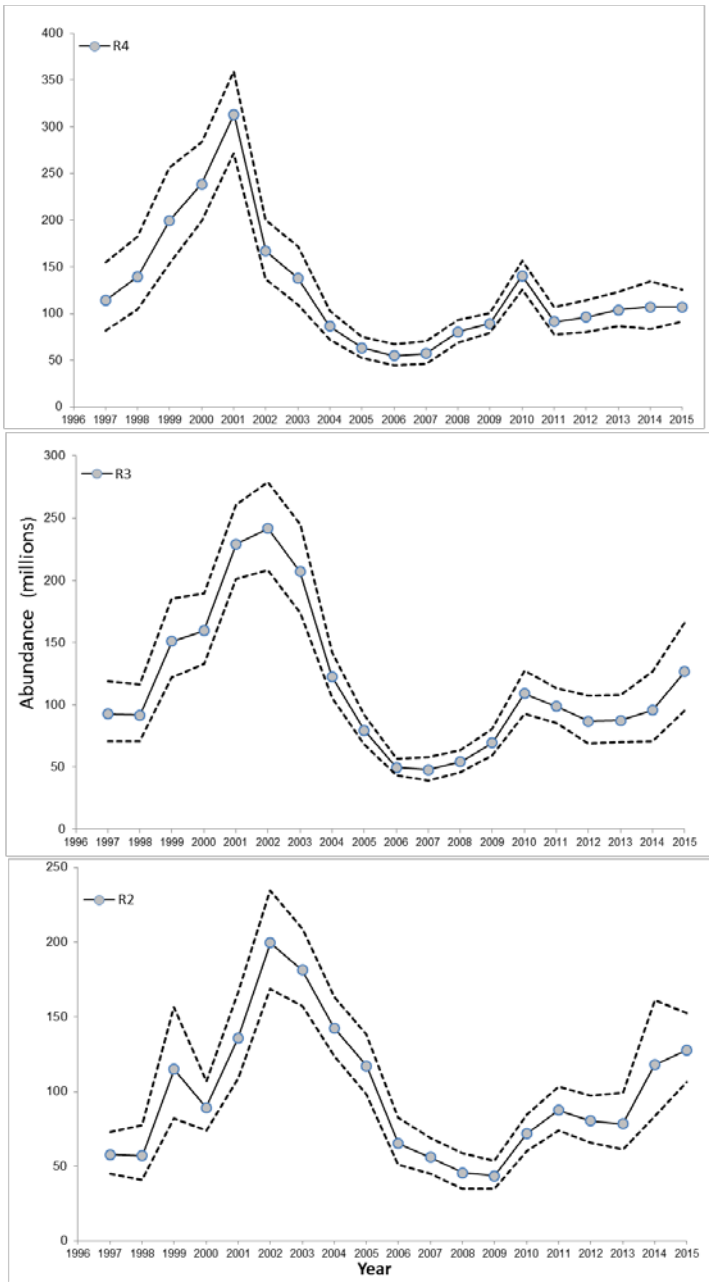

Figure 10: Estimated abundances (in millions; means and 95% confidence intervals) of R-4 (upper panel), R-3 (middle panel) and R-2 (lower panel) adolescent male crabs in the southern Gulf of St. Lawrence for the survey years 1997 to 2015.

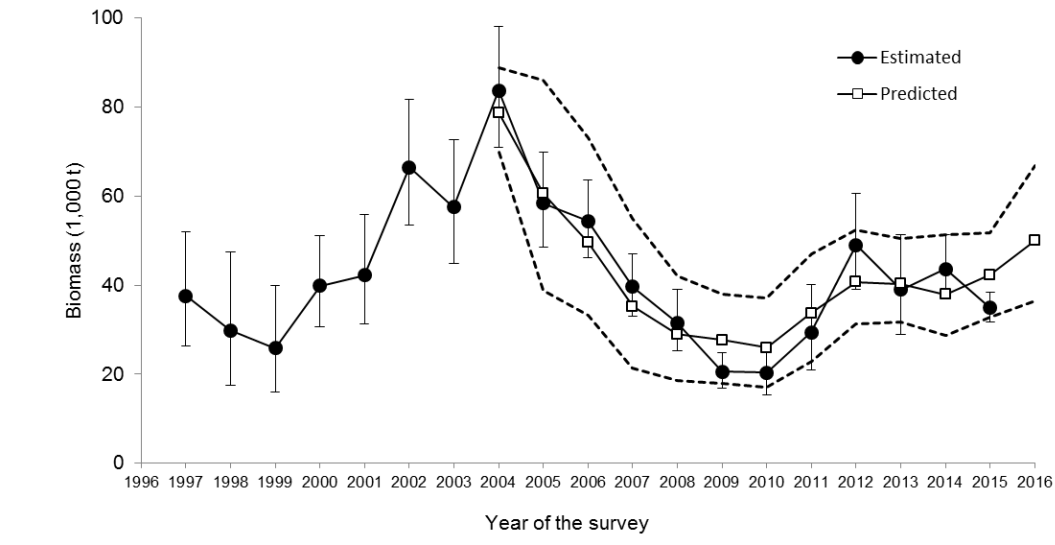

Figure 11: Estimated (black circle symbols are the means with 95% confidence interval vertical bars) and predicted (open square symbols are the means with the 95% confidence interval bands as dashed lines) biomasses of R-1 (adult male crabs >= 95 mm carapace width of carapace condition 1 and 2) snow crab in the year of the survey, 1997 to 2015. The predicted abundances are based on a relationship to the estimated abundances of R-2 (adolescent male crab larger than 83 mm CW) in the previous year. Prediction of R-1 biomass for 2016 is based on abundances of R-2 estimated in 2015 and shown in Figure 10.

The index of abundance of small male crab (34-44 mm CW) from the trawl survey in 2015 increased compared to the index estimated in 2014 (Figure 12).

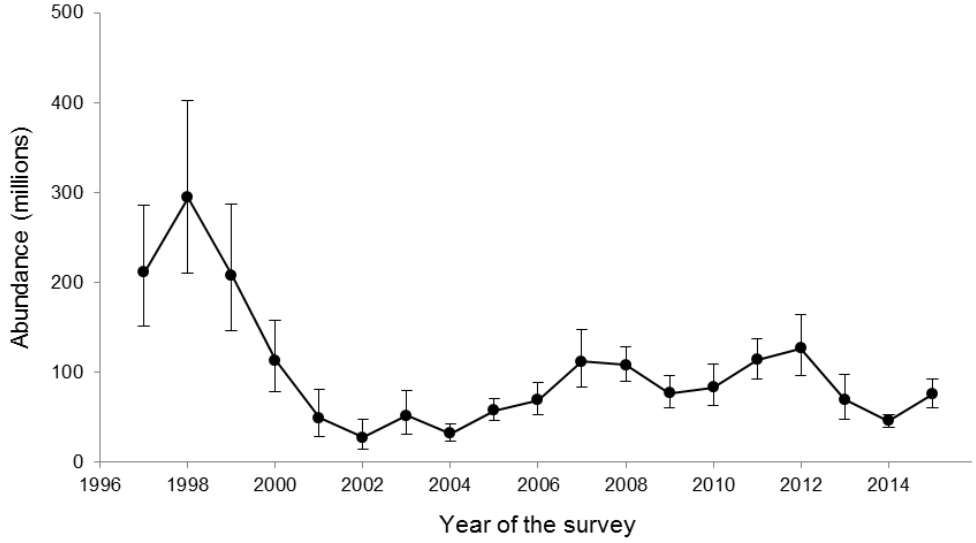

Figure 12: Index of abundance (in millions; means with 95% confidence intervals) of small male crab of 34 to 44 mm CW, based on the trawl surveys conducted in the southern Gulf of St. Lawrence, 1997 to 2015.

Reproduction

The abundance of mature females increased in 2015 compared to 2014 but was lower than the historical average (1997-2013), (Figure 13). The increase of pubescent females observed in the

2015 survey suggests that the abundance of mature females may increase in the coming years (Figure 13).

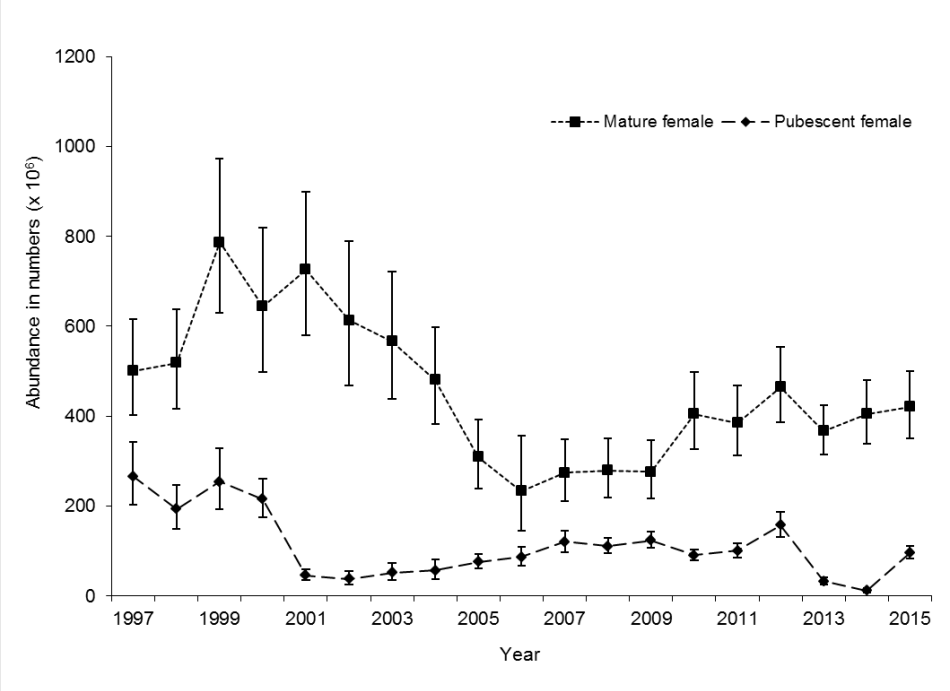

Figure 13: Estimated abundances (in millions; means and 95% confidence intervals) of mature female (black circle symbols) and pubescent females (open square symbols) in the southern Gulf of St. Lawrence based on the trawl surveys during 1997 to 2015.

Environmental Considerations

In September 2015, near-bottom temperatures were near the mean value of the period 1981 to 2010 in most of the central portion of Area 12, as well as in Areas 12E and 12F, and above average on the western and northwestern portions of the southern Gulf of St. Lawrence (i.e. Shediac Valley, Chaleur Bay and the slope of the Laurentian Channel). The near-bottom waters around Magdalen Island and off the northeastern side of PEI were cooler than average. Near-bottom temperatures in Area 19 were slightly lower than average. Most of the snow crab fishing grounds warmed up in 2015 compared to 2014, except for the Shediac Valley area where the water was significantly cooler. The snow crab habitat index (bottom area with temperatures from -1 to 3°C) was 5% below average in 2015 and slightly decreased from 2014 (Figure 14). The snow crab habitat index in 2015 was the 8th lowest value of the time series. The mean near-bottom temperature (0.8°C) within the defined snow crab habitat area index (-1 to 3°C) in 2015 increased by about 0.2°C compared to 2014 (0.6ºC) (Figure 14). The mean near-bottom temperature was at the highest of the 45 year time series in 2012, decreased in 2013 and remained close to the long-term mean in 2014 and 2015.

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 stock may be more vulnerable to commercial fishing pressure under climate-driven changes resulting in increasing temperatures. Furthermore, 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).

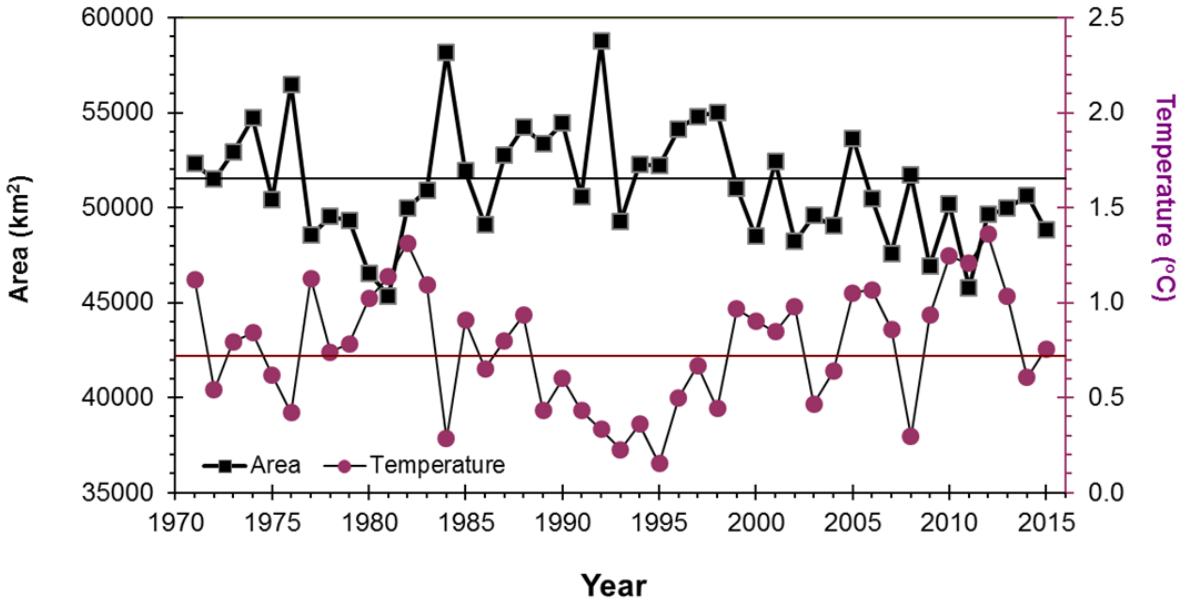

Figure 14: Snow crab temperature habitat area index (km²) that encompasses water temperatures of -1 to 3 ºC (upper panel) and the mean temperature (ºC) within the temperature area index (lower panel) in the southern Gulf of St. Lawrence, 1971 to 2015.

Sources of Uncertainty

There have been changes in snow crab survey vessel over the 1997 to 2015 assessment period, including a change in vessel in 2013 from the vessel which had been used during 2003 to 2012. There have never been any comparative experiments to assess if there were changes in catchability between vessels. Changes in survey catch rates over time may not accurately reflect changes in stock size if survey vessels have different catchabilities.

The unstandardized catch per unit effort from the fishery correlates weakly with the estimated biomass from the assessment. This results in differences in perception of stock abundance from the fishing industry observations (catch per unit of effort variations within season and between years) from those of the assessment. A spatially and temporally designed analysis of the CPUE data and densities of crab from the survey has started.

The distribution of snow crab within the southern Gulf of St. Lawrence and the proportions of the estimated abundance of commercial sized adult male crab in each of the management areas show high inter-annual variations. The factors determining these relative distributions are not known but are seemingly related to movements of crab within and in the boundary areas outside of the southern Gulf rather than variations in finer spatial scale survival or exploitation. Changes in the environment, particularly the size of the Cold Intermediate Layer, are likely important factors but the influence of these factors on the movement dynamics of crab is presently not known.

The differences in the estimated recruitment of commercial adult male crab and the prediction based on the abundance of pre-recruits (R-2) the previous year are highly variable annually. Predicting recruitment is uncertain because of a number of factors including variations in

mortality, growth among stages and the variation in the proportion of pre-recruits that molt in any given year. In 2015, there was a high abundance and proportion of skip molters (crab that had not molted over the year) in the R-2 stage compared to previous years.

Temperature in the southern Gulf varies annually. These changes in temperature can affect a number of life history processes including molting and growth, reproduction, and larval development and the processes are not well understood. The impacts of warming conditions on the snow crab life history are not well understood.

CONCLUSIONS AND ADVICE

Within the Precautionary Approach (PA) framework (DFO 2009), the Limit Reference Point for biomass (B_{lim}) defines the critical / cautious zones and an upper stock reference (B_{USR}) delimits the cautious / healthy zones on the stock status axis. The upper stock reference point (B_{USR}) is 41,400 t of commercial-sized adult males of all carapace conditions as estimated from the trawl survey (DFO 2012b). Commercial sized adult male crabs of all carapace conditions are available for the fishery in the year following the trawl survey. The biomass limit reference point (B_{lim}) value is 10,000 t (DFO 2012b). The biomass limit reference point was chosen as the lowest biomass of hard shelled commercial sized adult males which produced good recruitment rates of small male crabs of 34-44 mm CW (referred to as Instar VIII) (DFO 2010). The removal reference point (F_{lim}) is 34.6% (DFO 2012b). The southern Gulf of St. Lawrence commercial biomass estimate from the trawl survey is used for evaluating catch options relative to the defined reference points.

The trajectory of stock abundance (biomass of commercial-sized adult male crab as estimated from the trawl survey in the year before the fishery) versus exploitation rate in the fishery year for snow crab from the southern Gulf of St. Lawrence is shown in Figure 15. The commercial biomass has varied between 30,920 t and 103,429 t during 1998 to 2015. Over this same period, exploitation rates have varied between 20.8% and 45.0%. The estimated biomass from the 2015 snow crab survey, which would be available to the fishery in 2016, is 58,808 t (95% CI 52,754 – 65,466 t). The 2015 survey biomass estimate is in the healthy zone.

Harvest decision rules that conform to the PA have been developed (DFO 2014b). These PA compliant harvest decision rules include rules for which the exploitation rate exceeds Flim when the stock is in the healthy zone (DFO 2014b). The Snow Crab Advisory Committee agreed on the proportional harvest decision rule (variant 4 in DFO 2014b, Figure 16) to derive the exploitation rate and the TAC based on the estimated biomass from the southern Gulf of St. Lawrence snow crab survey. This decision rule and the corresponding estimated commercial biomass from the 2015 survey of 58,808 t, results in a selected exploitation rate of 37% and corresponding to a TAC of 21,759 t for the 2016 fishery (Figure 16).

A risk analysis was developed for the decision rule TAC and relative to other catch levels in 2016 (Table 8). The risk analysis indicates that the TAC derived from the harvest decision rule will result in a near zero chance of the residual biomass after the fishery being less than B_{lim} and a near 100% chance of the biomass for the next year's fishery being above BUSR and in the healthy zone of the PA (Table 8). The risk analysis also provides predictions of the commercial biomass in the 2016 survey, assuming the corresponding catch level is taken in 2016. At the decision rule TAC value of 21,759 t for the 2016 fishery, the commercial biomass predicted for the 2016 post-fishery survey and for the 2017 fishery, is 73,050 t, with a 95% confidence interval range of 59,690 to 86,250 t, an increased compared to the 2015 survey estimates.

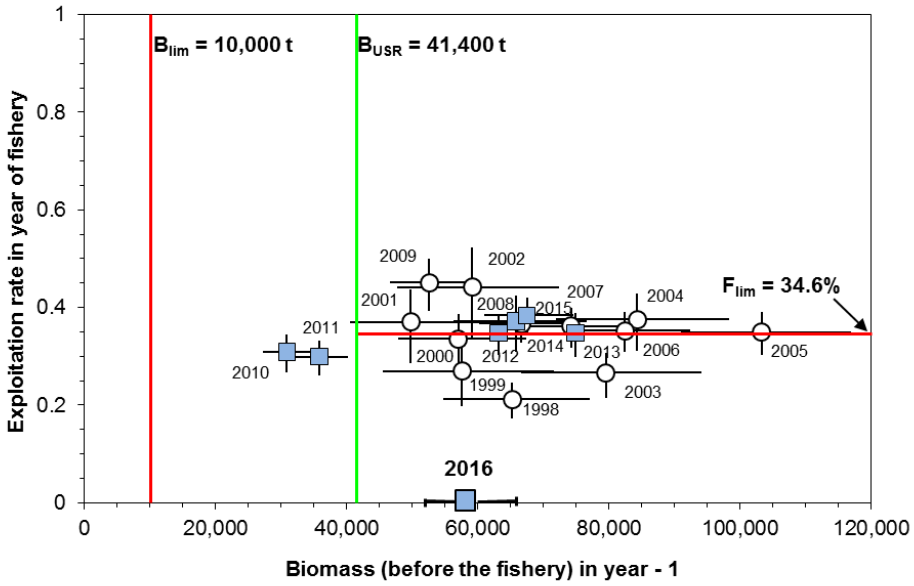

Figure 15: Trajectory of stock abundance (biomass of commercial-sized adult male crab as estimated from the trawl survey in year before the fishery) versus exploitation rate in the fishery year for snow crab from the southern Gulf of St. Lawrence. Year of the fishery is labeled on the figure. Error bars are 95% confidence intervals. White circle symbols are biomass and exploitation rate levels used to define the reference points. The grey squares are the years when the reference points were used within the PA to decide on the fishery quota. The biomass estimate available for the 2016 fishery (with 95% confidence interval) is also shown.

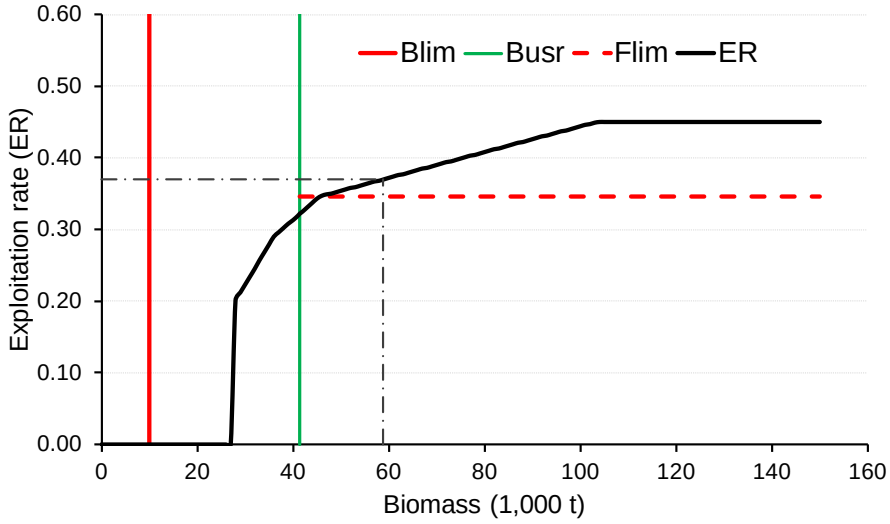

Figure 16: Harvest decision rule (solid black line; proportional variant 4; DFO 2014b) for the southern Gulf of St. Lawrence snow crab fishery and corresponding exploitation rate (0.37) resulting from the commercial biomass estimate (58,808 t) for the 2016 fishery (dashed-dotted line).

Table 8. Risk analysis of catch options in 2016 for the southern Gulf of St. Lawrence snow crab fishery showing probabilities of the hard-shell commercial-sized adult male remaining biomass falling below B_{lim}, and of the total commercial-sized adult male biomass being equal to or above B_{USR} post-fishery in 2016. The catch level of 21,759 t based on the agreed harvest decision rule is highlighted in the table. Also shown is the predicted commercial biomass from the 2016 survey assuming each corresponding catch level is fished.

	Probability		
Catch level (t)	< B_{lim} (10,000 t)	>= B_{USR} (41,400 t)	Expected biomass for the 2016 survey
18,000	0	1	76,810 (63,450-90,010)
19,000	0	1	75,810 (62,450-89,010)
20,000	0	1	74,810 (61,450-88,010)
20,370	0	1	74,440 (61,120-87,920)
21,000	0	1	73,810 (60,450-87,010)
21,759	0	1	73,050 (59,690-86,250)
22,000	0	1	72,810 (59,450-86,010)
23,000	0	1	71,810 (58,450-85,010)
24,000	0	1	70,810 (57,450-84,010)
25,000	0	1	69,810 (56,450-83,010)
26,000	0	1	68,810 (55,450-82,010)
27,000	0	1	67,810 (54,450-81,010)
28,000	0.01	1	66,810 (53,450-80,010)
34,760	0.5	1	60,730 (46,730-73,530)
53,440	1	0.50	41,370 (28,010-54,570)

SOURCES OF INFORMATION

This Science Advisory Report is from the Fisheries and Oceans Canada, Canadian Science Advisory Secretariat, regional advisory meeting of January 27-28, 2016 on the assessment of the status of the southern Gulf of St. Lawrence snow crab stock. Additional publications from this process will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

DFO. 2009. A fishery decision-making framework incorporating the Precautionary Approach.

DFO. 2010. Reference points consistent with the precautionary approach for snow crab in the southern Gulf of St. Lawrence. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2010/014.

DFO 2012a. Proceedings of the Gulf Region Science Peer Review Framework Meeting of Assessment Methods for the Snow Crab Stock of the southern Gulf of St. Lawrence; November 21 to 25, 2011. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2012/023.

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DFO. 2014a. Assessment of snow crab in the southern Gulf of St. Lawrence (Areas 12, 19, 12E and 12F) and advice for the 2014 fishery. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2014/008.

DFO. 2014b. Assessment of candidate harvest decision rules for compliance to the Precautionary Approach framework for the snow crab fishery in the southern Gulf of St. Lawrence. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2014/007.

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ISSN 1919-5087

Correct Citation for this Publication:

DFO. 2016. Assessment of snow crab (*Chionoecetes opilio*) in the southern Gulf of St. Lawrence (Areas 12, 19, 12E and 12F) and advice for the 2016 fishery. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2016/010.

Aussi disponible en français :

MPO. 2016. Évaluation du crabe des neiges (Chionoecetes opilio) du sud du golfe du Saint-Laurent (zones 12, 19, 12E et 12F) et avis pour la pêche de 2016. Secr. can. de consult. Sci. du MPO. Avis sci. 2016/010.