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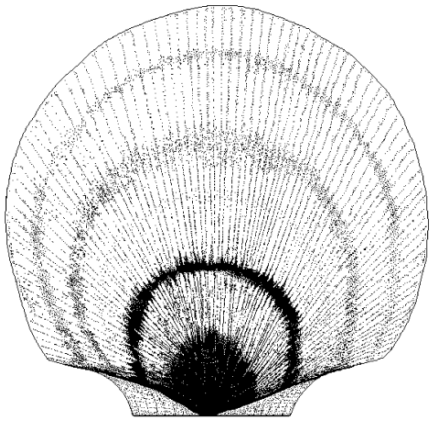
Gulf Region

Canadian Science Advisory Secretariat
Science Advisory Report 2019/006

FISHERY AND STOCK STATUS OF THE SEA SCALLOP (*PLACOPECTEN MAGELLANICUS*) FROM THE SOUTHERN GULF OF ST. LAWRENCE TO 2016



Sea scallop (Placopecten magellanicus)

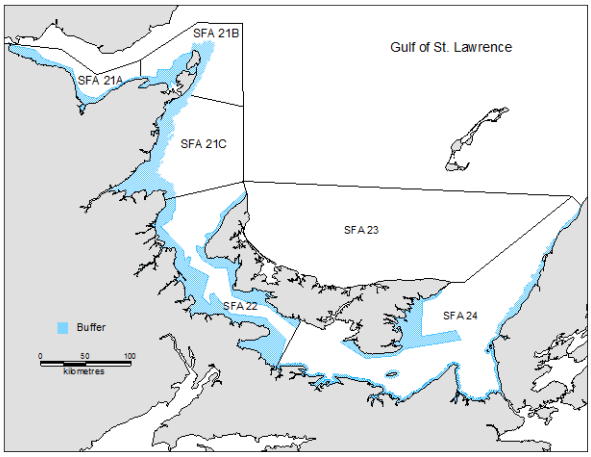


Figure 1. Scallop fishing areas and locations of scallop fishery buffer zones in the southern Gulf of St. Lawrence.

Context:

The sea scallop fishery in the southern Gulf of St. Lawrence is mostly a supplementary fishery to the lobster, herring and groundfish fisheries. Scallops are harvested with mobile gear (drag) using small vessels. In Fisheries and Oceans Canada (DFO) Gulf Region there are over 700 commercial scallop fishing licences, although many are inactive. Almost all scallop harvesters hold more than one fishing licence.

In the Gulf Region, the scallop fishery is important to many coastal communities and dispersed over a large area. The scallop grounds in the Gulf Region are divided into four Scallop Fishing Areas (SFA) with one zone (SFA 21) divided into three sub-zones (Fig. 1). There are SFA specific management measures related to effort controls. In most SFAs, buffer zones that prohibit scallop dragging over selected habitat have been implemented mainly to protect lobster habitat. First recorded landings were in the early 1900's and peak landings of 900 t occurred in 1968. Preliminary landings were just over 66 t in 2016.

The last assessment of the Gulf Region scallop fishery dates to 2011 (DFO 2011; Lanteigne and Davidson 1992). To date, stock status has been limited to indices of abundance based on fishery catch rates with limited and periodic surveys of scallop beds. DFO Ecosystem and Fisheries Management (EFM) has requested an assessment of the scallop fishery and an assessment of status of the scallop stock in the southern Gulf of St. Lawrence. This Science Advisory Report is from the October 16 and 17, 2018, regional peer review meeting on the fishery and stock status of the sea scallop (Placopecten magellanicus) from NAFO Division 4T, southern Gulf of St. Lawrence. Participants at the meeting were from DFO Science, DFO EFM, provincial governments, industry, and an Indigenous organization. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

SUMMARY

- The sea scallop fishery in the southern Gulf of St. Lawrence (sGSL) is a competitive fishery with fishing effort and landings mostly concentrated on three beds (West Point, Cape Tormentine and Pictou) within Scallop Fishing Areas (SFA) 22 and 24, all within the Northumberland Strait area.
- Reported landings have declined from approximately 900 t in 1968 to around 100 t since 2002. Preliminary reported landings in 2016 were 66 t.
- There is a large amount of latent effort in this fishery. Just under 20% of the 770 licence holders were actively fishing in 2016, based on reported landings.
- Missing and inaccurate sales slip and logbook information are the main drivers of uncertainty of the landings and the effort data that are used in this assessment.
- Catch rates derived from logbook information are generally low (6 kg per h) and decline rapidly within a few weeks of the fishery opening in most areas.
- Depletion models were used to develop relative indices of annual fishery exploitable biomass and exploitation rates. Despite the uncertainties in the data and the modelling assumptions to be respected, there is evidence of a rapid depletion over a period of a few weeks of the estimated exploitable biomass in the major scallop beds in SFA 22.
- Indices of commercial sized biomass of scallop from research surveys on the major beds in singular years provide further evidence of relatively high exploitation rates in this fishery taking place on a stock at low abundance.
- The abundance indices, based on catch rates and densities, of scallop in the southern Gulf are considered to be at low levels relative to other areas of eastern Canada.
- Biological characteristics data from research surveys show evidence of recruitment (< 80 mm shell height) in each SFA surveyed.
- There is no information available from the sea scallop stock of the sGSL with which to define abundance and removal rate reference points as per the Precautionary Approach.
- There are no current indicators that could be used to signal if a significant unexpected change in stock status has occurred. However, indices to assess performance of the fishery, including landings and catch rates, could be provided by major beds that support the fishery in the sGSL.

INTRODUCTION

Biology

The sea scallop (*Placopecten magellanicus*) is a bivalve mollusc found in the Atlantic coastal waters from the north shore of the Gulf of St. Lawrence (Canada) to Cape Hatteras, North Carolina (USA). It is an epibenthic species and a sessile active filter-feeder ingesting phytoplankton, small zooplankton, ciliates, detrital material and bacteria. Scallops are frequently found in dense localized aggregations called beds which support commercial fisheries. In the southern Gulf of St. Lawrence (sGSL), scallop beds are located at depths of 15 m to 37 m. Sea scallops seem to prefer sand-gravel or gravel-pebble substrate although they are occasionally found on sand-mud or rocky bottoms.

In the sGSL, the larger scallop commonly reach between 125 and 145 mm in shell height. Sea scallop growth rates are highly variable, depending on location. Growth occurs at temperatures ranging from 8 to 18˚C while the ideal temperature for growth is around 10˚C. Sea scallop prefer salinities of 30 to 32 ppt but they can tolerate salinities as low as 25 ppt. In the sGSL, scallops encounter temperatures ranging from -2 to 20˚C. The sea scallop show physiological stress at temperatures between 18 to 23˚C but can survive at these temperatures if well acclimated. Scallop mortality may occur at temperatures above 23˚C where mass mortality events have historically been reported in portions of the southern Gulf.

The sexes are separate in sea scallop and they typically reach reproductive maturity at shell heights > 70 mm, approximately 3 years old in the sGSL. Fecundity is exponentially related to the shell height and can vary annually. During the spawning period, the males and females release their gametes synchronously and fertilisation occurs in the water column. The larvae are planktonic for 4 to 5 weeks after which time they metamorphose and settle on suitable substrates to begin their benthic life.

The adductor muscle of the scallop is the part of the organism which is extracted in the fishery. The meat weight to shell height relationships vary within a season, among SFAs and among years (Fig. 2).

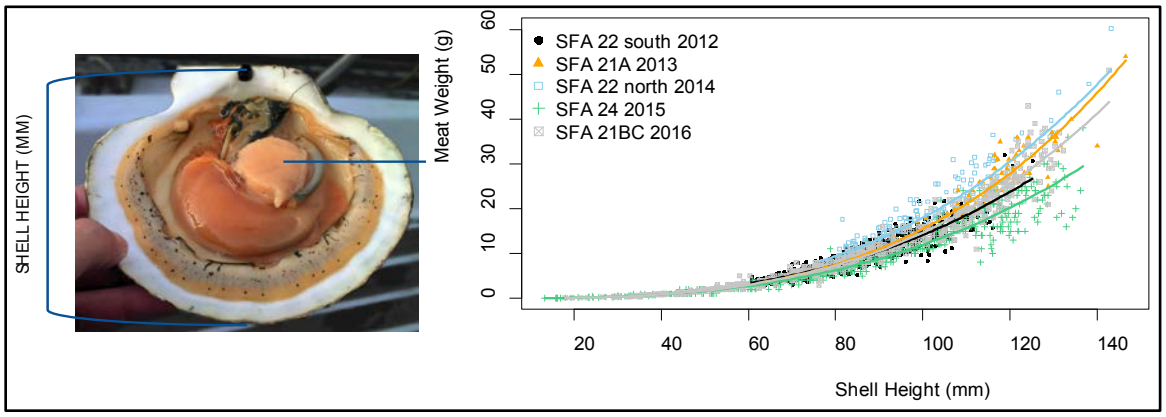


Figure 2. Meat weight (g) to shell height (mm) relationships of the sea scallop sampled from five scallop fishing areas in the southern Gulf of St. Lawrence, 2012 to 2016.

Fishery

Management of the scallop fishery in the sGSL is structured into four Scallop Fishing Areas (SFA) with one zone (SFA 21) divided into three sub-zones (Fig. 1). Each SFA has its own management measures (Table 1). Commercial and limited Indigenous Food, Social and Ceremonial, as well as recreational fisheries for scallop occur in the sGSL. The sea scallop fishery is competitive, without quotas, and is managed by input controls including a limited number of licences, fishing seasons, spatial closures, gear restrictions, and meat count limits. Buffer zones have been implemented to prevent trawling and dredging, including scallop dredging, over selected areas to primarily protect lobster habitat (Fig. 1).

There are no minimum sizes for commercial scallop harvesting but the size of the scallop harvested is to a certain extent dictated by the minimum ring size of the drag (82.6 mm). There is a regulatory meat count (number of scallop meats per 500 grams) that varies by SFA (Table 1). The regulatory meat count is highest in SFA 24 because of the smaller meat weights to shell heights in this area (Fig. 2). Fish harvesters are required to shuck the scallop at sea.

The common practice of blending the catch allows for small scallop to be shucked together with larger ones while still respecting the meat count limit.

Table 1. Summary of management measures for the scallop fishery in the southern Gulf of St. Lawrence.

Management measure	Scallop Fishing Area (SFA)					
	21A	21B	21C	22	23	24
Season in 2015	July 14 to Aug 8	May 10 to Aug. 8	June 22 to July 24	May 11 to June 15	July 6 to Aug. 29; Nov. 5 to Dec 1	Oct 26. to Nov. 28
Season in 2016	Closed	May 10 to Aug. 8[a]	July 4 to July 30	May 2 to June 4	July 4 to Aug.27; Oct.24 to Nov. 26	Nov. 1 to Dec. 15
Number of fishing days in season	24	42	24	30	72[b]	39
Time open	6:00 to 18:00	5:30 Monday to 14:00 Friday	5:00 to 18:00	6:00 to 17:00[c]	6:00 to 18:00	6:00 to 18:00
Days closed	Saturday & Sunday	Saturday & Sunday	Sunday	Sunday	Sunday	Sunday
Meat count (number per 500 g)	35	39	39	44	33	52
Ring size (mm)	82.6	82.6	82.6	82.6	82.6	82.6
Width of dredge (m)	6	6	6	4.88	6	5
Tow bar specifications[d]	ns	ns	ns	with 50.8 mm runners	ns	ns
Washers	Steel (8 max) & Chaffing gear or 2 rubbers on the vertical					

[a] maximum of 42 consecutive days within this season
[b] reduced to 50 in 2017
[c] 6:00 to 18:00 in 2015
[d] not specified

Commercial scallop fishing takes place with fishing vessels less than 14 m (45'). Most of the industry uses a Digby-type drag (Fig. 3). The total length of the drag, the ring size, type and number washers and tow bar are described in the condition of licence for each SFA (Table 1). There were 770 to 773 commercial scallop fishing licences issued in 2012 to 2016, including 44 communal commercial licences held by 15 Indigenous groups. Over half of the commercial licences are in SFA 24 (Table 2). Active licences, estimated from records of landings in statistics and from logbooks, are much less than issued licences and ranged from 145 to 189 over the same time period. During 2011 to 2016, between 19% and 25% of the licence holders were active, i.e. had recorded landings. The highest percentage of active participants has been in SFA 22 (42% to 54%) and the lowest percentage of active participants has been in SFA 23 (1% to 10%) (Table 2).

There were 264 recreational licences, by scuba diving, issued in 2016; management measures in this fishery include a maximum daily limit per diver (50, except SFA 24 which is 100), a season (May 1 – Oct. 31), and shell height minimum size limit (102 mm). The number of active licences (reporting landings in logbooks) varied between 11 and 55 over the 2003 to 2016 time period. Most of the activity occurs in SFA 21.

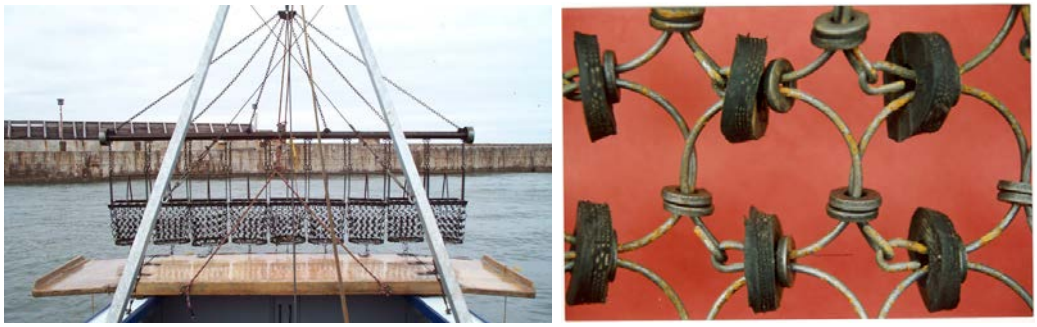


Figure 3. Digby-type drag commonly used in the commercial scallop fishery in DFO Gulf Region showing tow bar and steel ring buckets. In the panel on the right is shown the configuration of the bucket showing rings linked with steel washers and vertically placed rubber washers.

Table 2. Distribution of commercial scallop fishing licences and estimates of active fishing licences and total fishing licences (in parentheses) by SFA in 2011 to 2016.

SFA	Status	2011	2012	2013	2014	2015	2016	Active in 2016
21	Active (total)	6 (103)	3 (103)	11 (103)	15 (103)	3 (103)	6 (103)	6%
21A	Active (total)	0 (28)	0 (28)	9 (28)	13 (28)	1 (28)	0 (28)	0%
21B	Active (total)	3 (27)	1 (27)	1 (27)	1 (27)	1 (27)	4 (27)	15%
21C	Active (total)	3 (48)	2 (48)	1 (48)	1 (48)	1 (48)	2 (48)	4%
22	Active (total)	97 (202)	109 (201)	101 (200)	92 (200)	84 (200)	83 (200)	42%
23	Active (total)	1 (78)	2 (78)	2 (78)	8 (78)	6 (78)	5 (78)	6%
24	Active (total)	77 (390)	75 (390)	68 (390)	63 (390)	52 (389)	51 (389)	13%
sGSL	Active (total)	181 (773)	189 (772)	182 (771)	178 (771)	145 (770)	145 (770)	19%

Landings

Estimated annual reported landings in the recreational fishery, as reported in logbooks, ranged between 0.02 t and 0.19 t over the 2003 to 2016 period, mostly (85%) from SFA 21. In terms of landings, the recreational fishery is considered negligible in comparison to the commercial fishery and is therefore not included in this assessment.

Commercial landings are monitored through sales slips from registered buyers and logbooks from scallop harvesters. Logbooks are included in the licence conditions and are mandatory. Fish harvesters must complete logbooks of fishing activity for each day fished with daily information including date fished, hours fished, number of tows, average duration of tows in minutes, landings in pounds, drag width in feet, latitude and longitude of general fishing location, as well as a comment box for observations such as meat count and anomalies. Commercial data to 2016 were available for this assessment.

Commercial landings and the number of trips fished in the sGSL scallop fishery to 2016 are presented in Figure 4. Landings have been low and relatively stable since 2002, averaging 102 t annually, following a persisting decrease in landings since 1996. Landings for 2015 and 2016 are 71 t and 66 t, respectively, well below the long term (1968 to 2010) mean of 264 t.

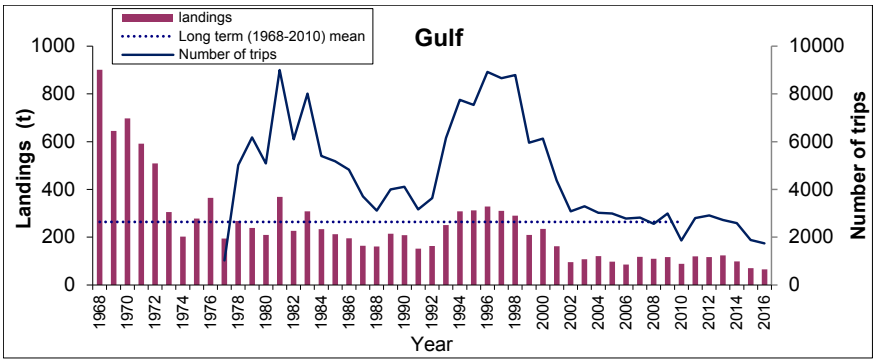


Figure 4. Commercial sea scallop landings (tonnes of meat weight) and the number of trips (sum of days with individual reported landings) in the southern Gulf of St. Lawrence fishery, 1968 to 2016. The long term mean landing from 1968 to 2010 is shown as the dotted line.

Scallop Fishing Areas were established around 1987 and corresponding annual landings and number of trips by SFA for the period 1987 to 2016 are shown in Figure 5. On average, landings from SFA 22 (64%) and SFA 24 (24%) account for 88% of the total annual landings from the sGSL.

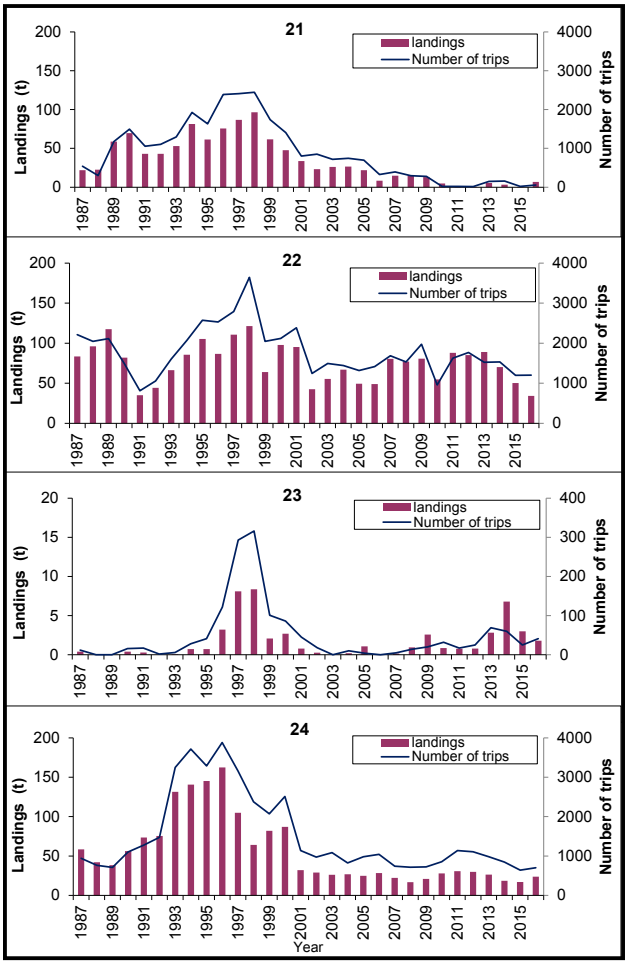


Figure 5. Commercial sea scallop landings (tonnes of meat weight) and the number of trips (sum of days with individual reported landings) in Scallop Fishing Areas (SFA) 21, 22, 23 and 24 in the southern Gulf of St. Lawrence fishery, 1987 to 2016. Note different y axis scale for SFA 23.

Logbook records are matched to sales slip from registered buyers. Logbook reported landings that do not have a corresponding sales slip are interpreted as local sales or personal consumption. Sales slips without corresponding logbook records of landings are considered non-compliant to the licence conditions. Over the period 2001 to 2016, compliance has been variable over the years but seemingly deteriorating for SFA 22, with compliance rates of about 70% since 2012 (Fig. 6). There is no mechanism in place at the present time to quantify unreported landings, i.e., landings that were not purchased by registered buyers (i.e. no sales slips) and not recorded in logbooks.

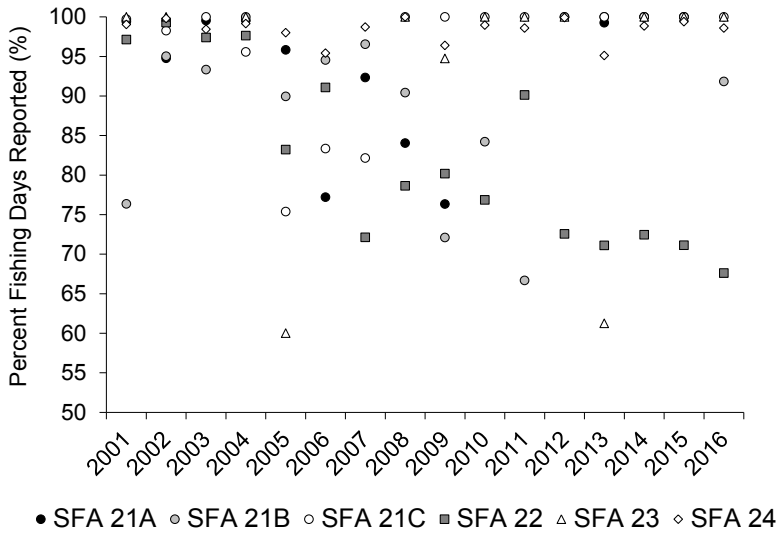


Figure 6. The percentage of the commercial fishery sales slips with matching recorded harvests in logbooks by Scallop Fishing Area in the scallop fishery of the southern Gulf of St. Lawrence, 2001 to 2016. There was an insufficient number of reports from SFA 23 in 2007 for a reliable calculation.

The spatial distribution of effort, based on geographic positions reported in logbooks for each day of fishing during 2001 to 2016 (Fig. 7), corresponds with scallop beds delineated from past surveys and indicates that the scallop bed locations in the sGSL have been stable over time. Fishing effort occurs primarily on three beds; West Point (SFA 22 north), Cape Tormentine (SFA 22 south) and Pictou (SFA 24), all within the Northumberland Strait. Approximately 80% of the Gulf landings are harvested from these three beds alone. Marginal beds, in terms of effort and landings are in Chaleur Bay (SFA 21A), Miminegash and Cap St Louis (SFA 22 north), and Wood Island (SFA 24).

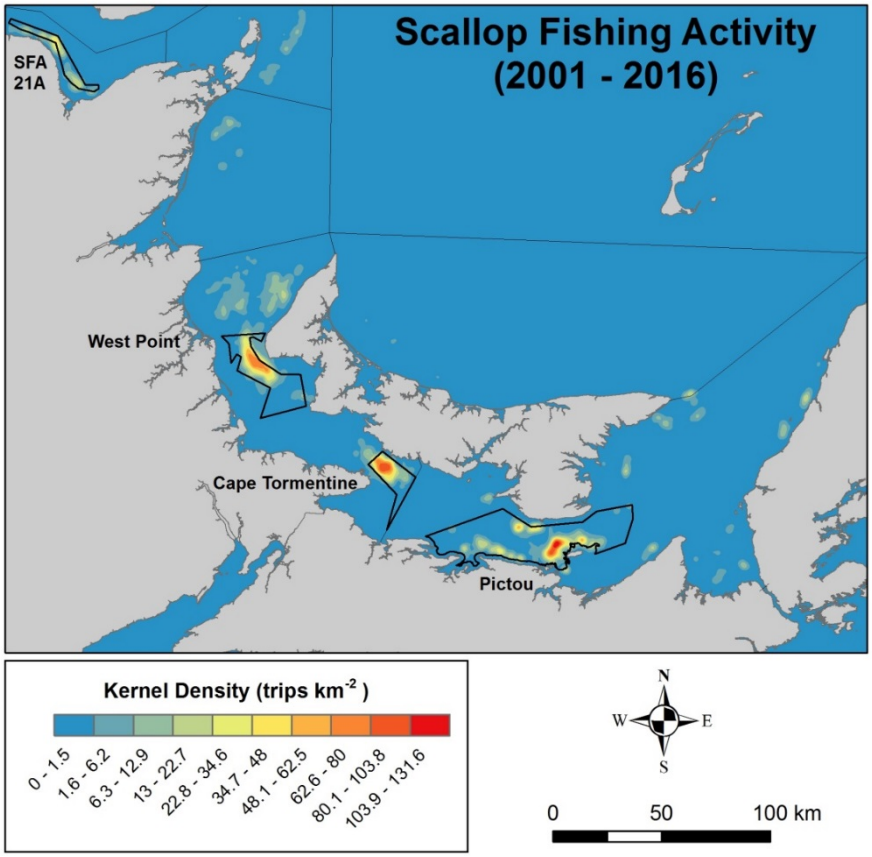


Figure 7. Kernel density plot of scallop fishing trips, expressed as number of trips with positional data per km², for the southern Gulf of St. Lawrence commercial scallop fishery, summed over years 2001 to 2016. Fishing effort occurs primarily in three main scallop beds; from north to south, West Point and Cape Tormentine in SFA 22 and Pictou in SFA 24. Also shown are the respective survey sampling strata (black line) used during the scallop research surveys (2012 to 2016), which are used to define the scallop bed for catch rate and other estimates of abundance.

ASSESSMENT

Fishery dependent data – size of the catch

The size (shell height) distributions of scallop in the commercial fishery were described from at-sea sampling programs conducted during 2001 to 2005 (Davidson et al. 2011). The size distribution of scallop retained in the commercial gears are strongly peaked in the vicinity of 90 mm, and decline rapidly on either side of this mode (Fig. 8). The truncated distribution above 90 mm reflects the relative lower abundance of these large animals in the Cape Tormentine and Pictou beds. This pattern is consistent among years and reflects the size selectivity of the commercial drag (minimum ring diameter 82.6 mm) for the larger sizes.

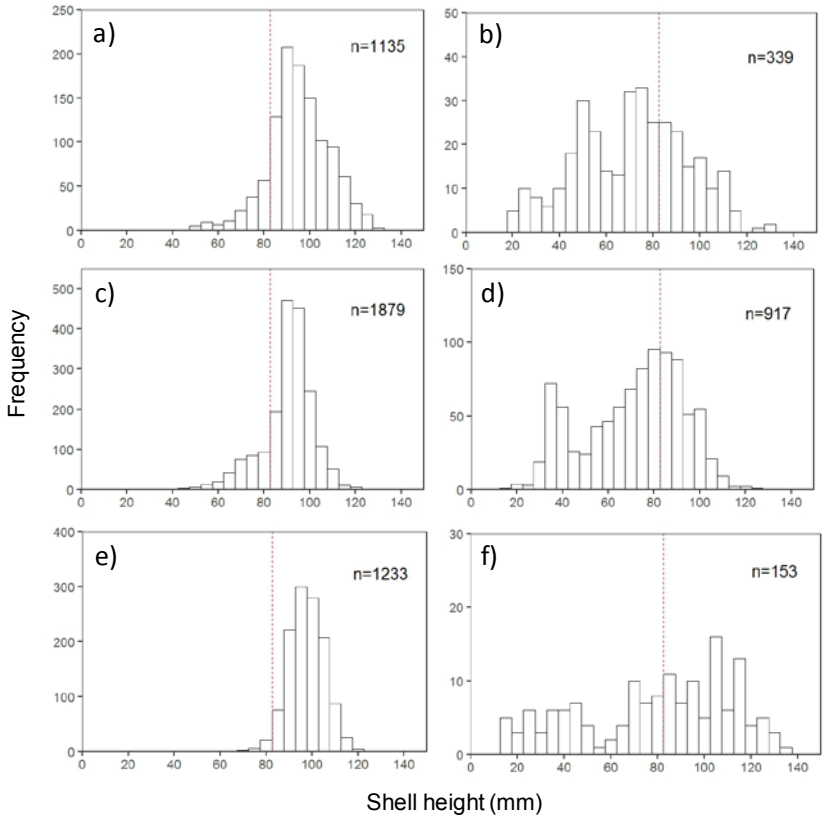


Figure 8. Example of shell height distribution of scallop based on sea sampling (2001 to 2005) of the fishery catches (left column; a,c,e) and from research surveys (2012 to 2016) using a14 mm liner (right column; b,d,f) from West Point (SFA 22 north; top row, a, b), Cape Tormentine (SFA 22 south; middle row, c,d) and Pictou (SFA 24; bottom row, e,f) scallop beds, southern Gulf of St. Lawrence. The red vertical dashed line in each panel shows the 82.6 mm mark corresponding to ring size.

Fishery dependent data - catch rates

Logbook data are used to calculate the catch per unit effort (CPUE) expressed as kilograms of scallop meat divided by hours towed of fishing effort (kg per h). Here, hours towed is simply the number of tows multiplied by the average duration of tows. Landings are assigned to scallop beds within SFAs. Landings within an SFA without specific fishing locations are assigned to beds by proration based on landings data from the SFA with positional information.

SFA 21A

During 2001 to 2016, annual landings from SFA 21A accounted for 34% to 96% of SFA 21 landings, except for the years 2010 to 2012 as well as 2016 when the SFA 21A fishery was closed (Fig. 9). Mean catch rates varied from a low of 1.9 kg per h (in 2009) to a peak of 5.3 kg per h (in 2013). The highest catch rate in the time series was recorded in 2013 after a three year closure of the SFA. Catch rates at the start of season were around 7.4 kg per h in 2013 and 2.8 kg per h in 2014 and declined to 3.5 and 1.9 kg per h by the end of the four week season, respectively. Weekly cumulative catch shows that over 75% of the catch is reached by the end of the third week.

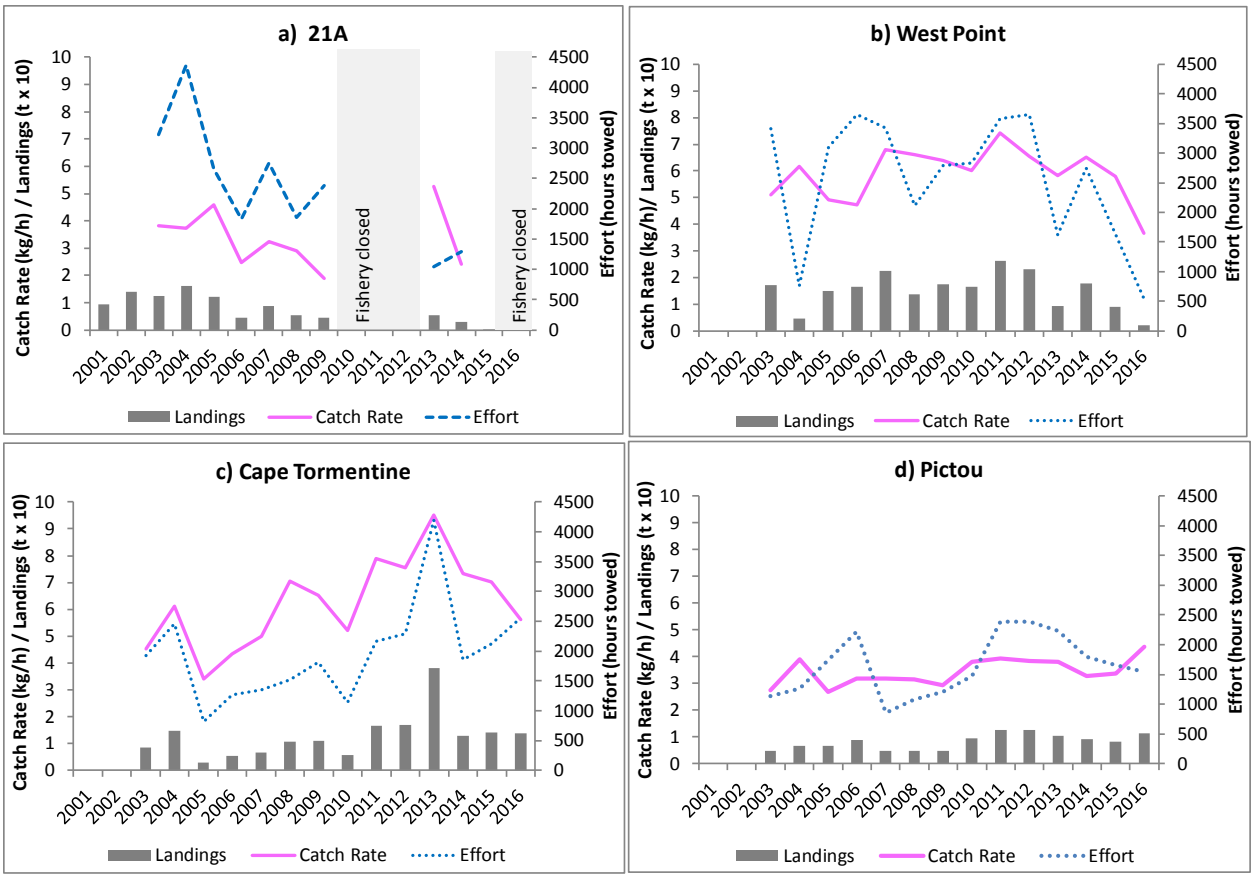


Figure 9. Annual catch rates (kg per hours towed) and estimated effort (hours towed) from logbooks, and corresponding landings data based on logbooks, 2003 to 2016 for a) SFA 21A (upper left panel) b) West Point bed (SFA 22, upper right panel), c) Cape Tormentine bed (SFA 22, lower left panel), and d) Pictou bed (SFA 24, lower right panel). Scallop fishing beds are shown in Figure 7. For the Cape Tormentine, there was a partial closure of the western portion in 2005 to 2010 (landings in grey hatch, catch rates in solid pink and effort in dashed blue).

SFA 22

SFA 22 landings for the logbook time series (2001 to 2016) varied annually from a maximum of 91 t (2001) to low of 32 t (2016) following five years of declining landings, effort, and catch rates. The majority of SFA 22 landings are shared between the Cape Tormentine and the West Point beds (Fig. 7). Seasonally, the partition between the two beds varies, sometimes starting with a higher proportion of landings from Cape Tormentine in the first weeks of the season and ending with a higher proportion of landings from West Point or vice versa. Weekly cumulative landings show that 73% to 94% of the total landings are generally taken by the end of the third week. Annual catch rates averaged 6.0 kg per h, fluctuating between 4.4 kg per h (2006) and 8.1 kg per h (2013) since the beginning of the time series in 2003.

West Point

During 2001 to 2016, annual landings from the West Point bed represented 9% to 64% of SFA 22 landings. Low landings in 2016 may reflect small meat weights in relation to shell size as reported by fish harvesters. Mean annual catch rates for the 2003 to 2016 period varied from a low of 3.6 kg per h (2016) to 7.4 kg per h (2011) (Fig. 9). There is a general decline in catch rates over the five-week fishing season. The weekly catch rates at the start of the season are at

about 8 kg per h (range: 4.5 to 9.5 kg per h). The season typically ends with catch rates at around 4 kg per h (range 3.2 to 5.5 kg per h).

Cape Tormentine

There was a partial closure of the western portion of the Cape Tormentine bed in 2005 to 2010. During 2001 to 2016, landings from the Cape Tormentine bed accounted for 12% to 80% of SFA 22 landings. Mean annual catch rates for the 2003 to 2016 period varied from 3.4 kg per h (2005) to 9.5 kg per h (2013) (Fig. 9). Landings, effort and catch rates all increased and peaked in 2013. A breakdown of catch rates by week depicts a general decline over the five-week fishing season, and this trend is consistent yearly. The catch rates at the start of the season are higher than those for the West Point bed at about 10 kg per h (range: 7.3 to 12.2 kg per h) and end at around 5 kg per h (range: 3.5 to 6.2 kg per h). Effort also tends to decline over the season.

SFA 24

In contrast to other SFAs, a majority of the landings (65%) recorded in logbooks from SFA 24 are local sales. Annual catch rates over the 2003 to 2016 time series averaged 3.6 kg per h and varied within a narrow range of 2.6 kg per h (2005) to 4.6 kg per h (2016).

Pictou Bed

A large percentage (66% to 86%) of the landings from SFA 24 is taken from the Pictou bed. During 2003 to 2016, catch rates varied from 2.7 kg per h (2005) to 4.4 kg per h (2016) and were generally higher post 2009 (Fig. 9). The catch rates are generally lower than for the two major beds in SFA 22. In contrast to the seasonal pattern of catch rates from scallop beds in SFA 22, there was little variation in the catch rates from the Pictou bed over the six or seven weeks of fishery activity. The mean catch rates from the start to end of the season are low, at about 4.5 kg per h (range: 2.7 to 4.8 kg per h). More than 75% of the landings are caught by the end of week five. On average, meat weights for a given shell height are lower in this SFA than in the other areas (Fig. 2; DFO 2011).

Fishery dependent data – depletion estimates of biomass and exploitation rate

A stock assessment depletion model was applied to the logbook reported data of landings and effort (kg per h) for the most important scallop beds in the sGSL. Logbook and landings data considered for each bed were defined by the survey strata shown in Figure 7. The model is used to estimate the fishery exploitable biomass (B_0) prior to fishing and the annual exploitation rate for the bed. For the depletion model, the estimates are for the effective area fished which may be smaller than the stratum area, and may vary over years.

Daily cumulative landings are the sum of the daily reported landings (per SFA or bed) up to that day. Daily commercial catch rates (kg per h) are obtained from the logbook data. A statistically significant model is one for which the slope of the linear relationship between daily catch rate and cumulative catch over the season is significantly different from zero, and negative in sign. Depletion models have a number of assumptions, the most important being that the index of abundance (catch rate) is proportional to exploitable biomass and that catchability is constant within the season.

Considering the uncertainties associated with the data input and model assumptions, only the mean results from the depletion model are presented to provide a relative index of exploitable biomass and exploitation rate.

SFA 21A

The SFA 21A commercial landings and catch rate data for 2003 to 2006 and 2013 were amenable to depletion analysis; in the other years the data were not statistically informative (no decline in catch rates over the season) or the fishery was closed. The estimated initial exploitable biomass and exploitation rates are shown in Figure 10. The estimate for the exploitable biomass before the fishery in 2003 and 2004 was 45 t and 55 t, respectively, but declined rapidly to 15 t by 2006.

Following the three years of the fishery closure in 2010 to 2012, the estimate of the exploitable biomass before the fishery in 2013 was only 8 t, of which 5 t were estimated to have been landed in this area. The catch rates declined rapidly from 8 kg h^{-1} at the start of the season to 3 kg per h when the fishery ended in week 4.

Estimated exploitation rates have been above 30% every year of the assessment, and were over 60% in 2013 (Fig. 10).

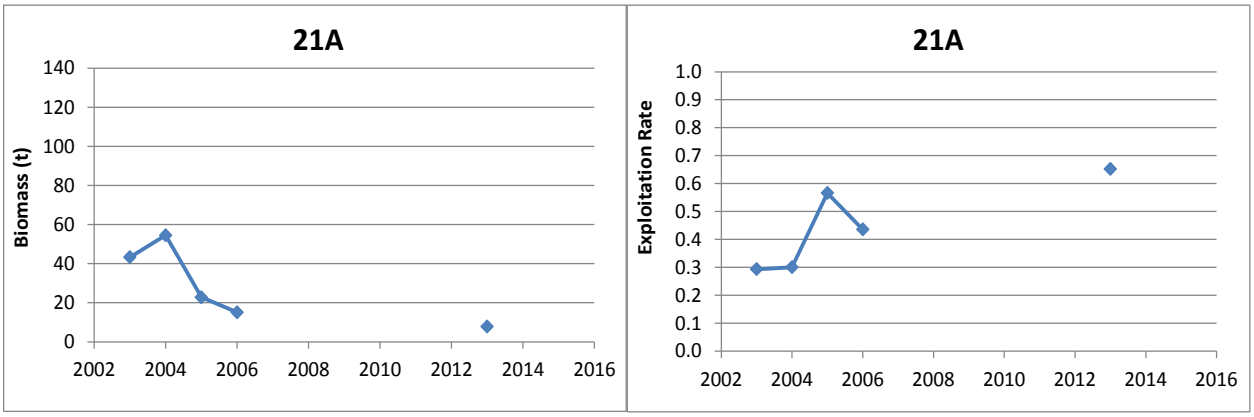


Figure 10. Depletion model estimates of relative fishery exploitable biomass (B_0; left panel, t) at the start of the fishery and exploitation rate (right panel) for the scallop bed in SFA 21A from 2003 to 2006 and 2013.

SFA 22

SFA 22 West Point bed

The depletion model, fit to the West Point commercial landings and catch rate data for 2003 to 2016, was significant for all years. Over the time series, the exploitable biomass estimates before the fishery varied between 7 t (2016) and 83 t (2007) and averaged 55 t. Annual exploitation rates varied from 22% to 65% (Fig. 11).

SFA 22 Cape Tormentine bed

The depletion model, fit to the Cape Tormentine bed commercial landings and logbook catch rate data, was statistically significant for all years (2003 to 2016) and indicated strong within season depletion of the exploitable biomass. Over the time series, exploitable biomass before the fishery fluctuated from a low of 12 t (2005) to 112 t (2013) and averaged 43 t over the time series (Fig. 11). Annual exploitation rates varied from 42% to 62%.

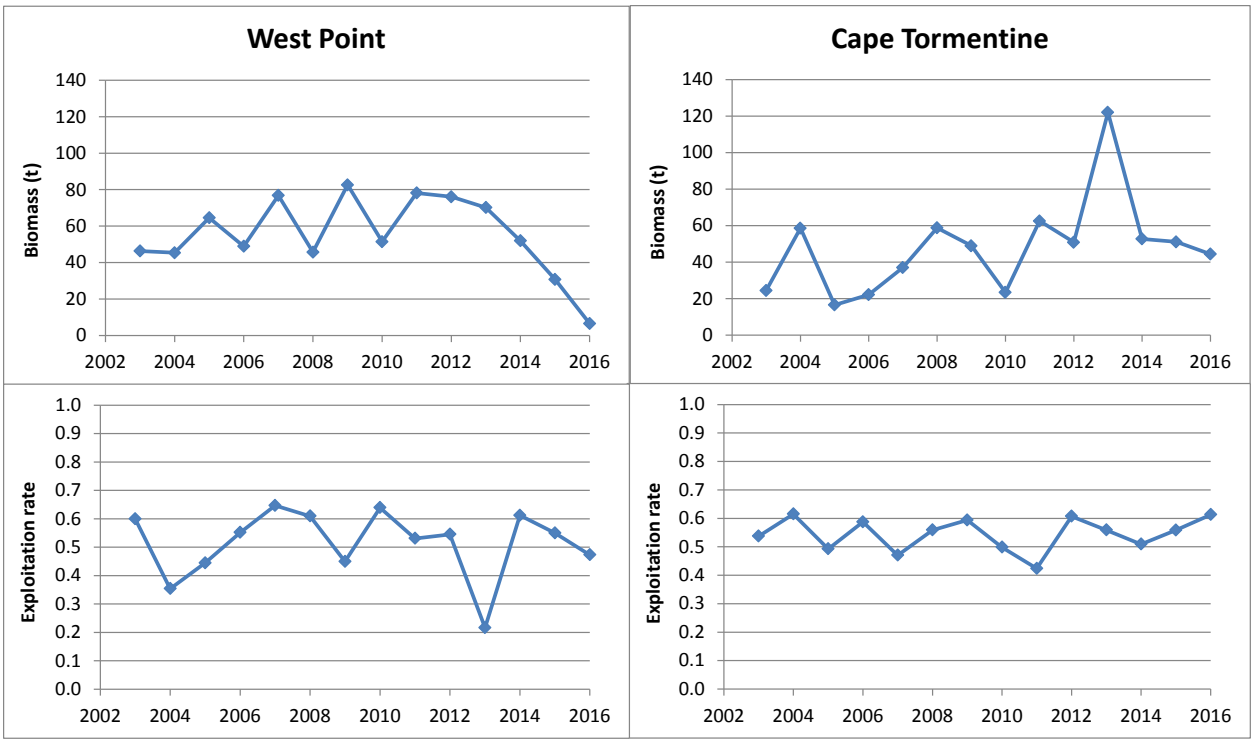


Figure 11. Depletion model estimates of fishery exploitable biomass (B_0) at the beginning of the fishery (top row) and estimates of exploitation rate (bottom row) for the major scallop beds in SFA 22 (West Point left column; Cape Tormentine right panel) in the southern Gulf of St. Lawrence, 2003 to 2016.

SFA 24

The depletion model relating catch rates and cumulative landings from the Pictou bed of SFA 24 was significant for only one year, 2011. The catch rates are very low for this area and there are little to no declines in catch rates over the season. The model estimate for exploitable biomass before the fishery in 2011 was 42 t for a corresponding exploitation rate of 28%.

Fishery independent data

An annual, rotational, multispecies research survey program for scallop in the sGSL was initiated in 2012 to obtain fishery independent indices of abundance, biomass estimates, and biological characteristics information (shell height, meat weight, sex, clappers). One section of a SFA or the SFA in its entirety was surveyed per year, with the exception of SFA 23 which was excluded because of the low scallop fishing effort reported from this area in recent years. A stratified random design, with strata defined by sea scallop commercial fishing effort distributional patterns, was used to sample waters of depth greater than 5.5 m (Fig. 12).The number of survey tows was allocated proportionally to the size of the stratum and subsequently weighted by fishing effort to assign more stations where fishing effort was highest. An eight-gang Digby scallop drag was used as the survey fishing gear, with buckets lined with a Vexar® liner of 14 mm mesh size to retain the scallop recruits and small benthic species. At each sampling station, a 2 minute tow at a speed of 2.5 knots was conducted.

The catch data were standardized to a tow area of 437.3 m² (target tow duration of 2 minutes at 2.5 knots multiplied by the inside width of the gear of 2.8 m). The mean abundance and weight per standard tow were calculated for each stratum. The abundance (number) and biomass

(meat weight) of scallop, uncorrected for gear efficiency, are reported for the main scallop fishing areas which are defined by the survey stratum corresponding to high effort (Fig. 12).

The surveys conducted in SFA 21A and SFA 24 occurred before the fishery whereas the surveys in SFA 22, SFA 21B and 21C occurred after the fishery.

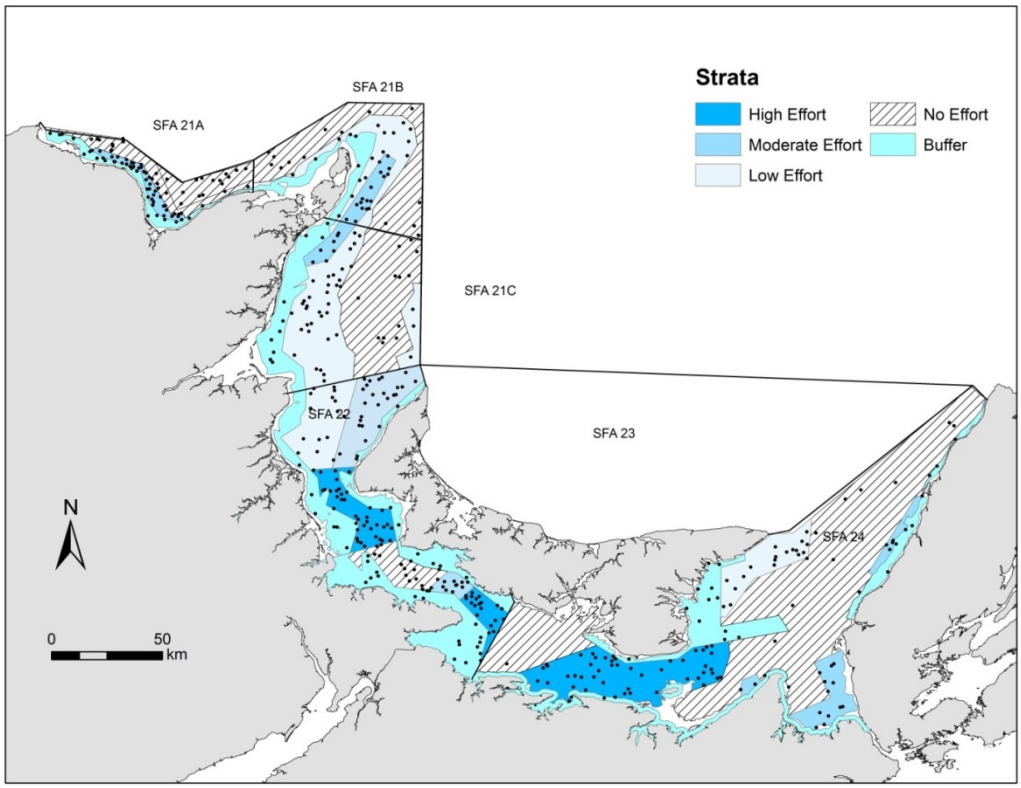


Figure 12. Survey strata and positions of randomly assigned (by stratum) sampling tows (black dots) for the scallop surveys in the southern Gulf of St. Lawrence during 2012 to 2016. Note that SFA 22 is divided into SFA 22 north and SFA 22 south and strata were assigned to each. Similarly for SFA 21A, SFA 24, and for the combined 21B and 21C.

Spatial distribution

With the exception of SFA 24, the spatial distribution of scallop from the survey is in agreement with the commercial fishery data from logbooks (Figs. 13 and 14). For SFA 24, the high fishing effort stratum is large and the random allocation of stations was not optimal to sample the concentrations in the Pictou bed, which is one of the major fishing areas in this SFA.

In general, the distribution of small scallop (< 80 mm) (Fig. 13) and commercial-sized scallop (≥ 80 mm) (Fig. 14) spatially overlapped.

The highest density of scallop (all sizes) was found in SFA 22 south with a mean of 8.6 scallop per tow (0.02 scallop per m^2) and the lowest densities were found in SFA 21B and 21C (1.8 scallop per tow; < 0.01 scallop per m^2). Maximum densities in a tow varied from 0.17 scallop per m^2 (SFA 21A) to 0.44 scallop per m^2 (SFA 22 south).

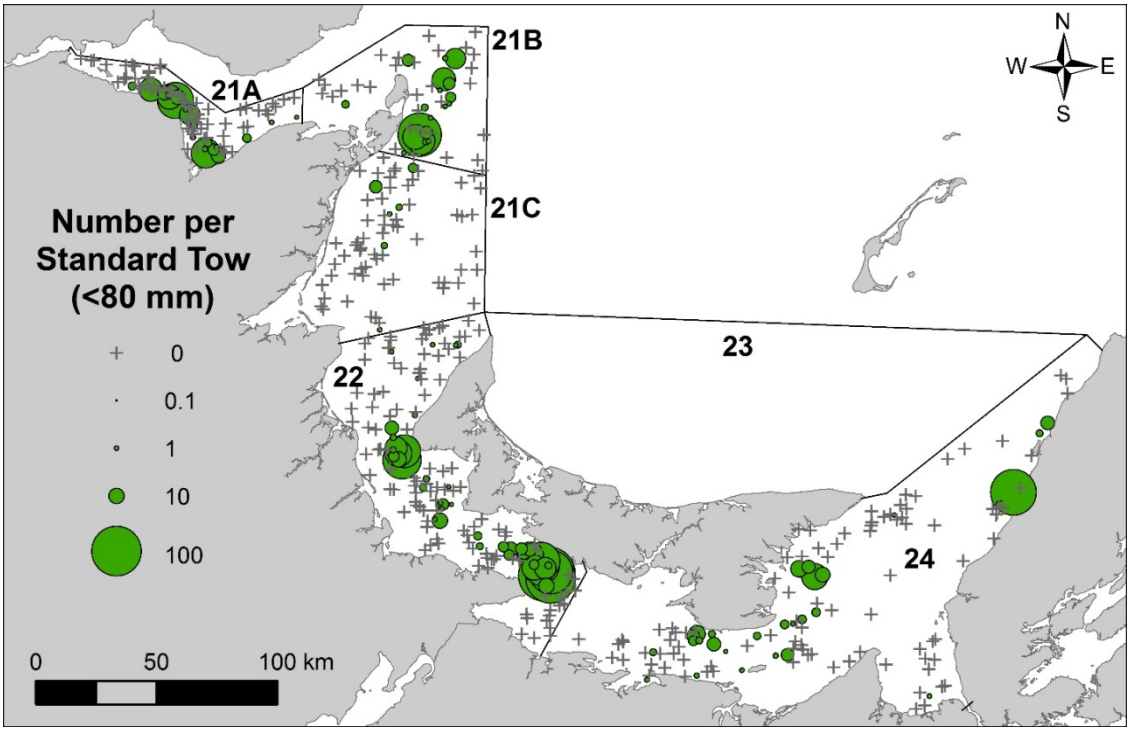


Figure 13. Spatial distribution of sea scallop abundance indices (total number per standard tow) of small size (< 80 mm) scallop in the southern Gulf of St. Lawrence surveys, 2012 to 2016. Circle area is proportional to scallop density.

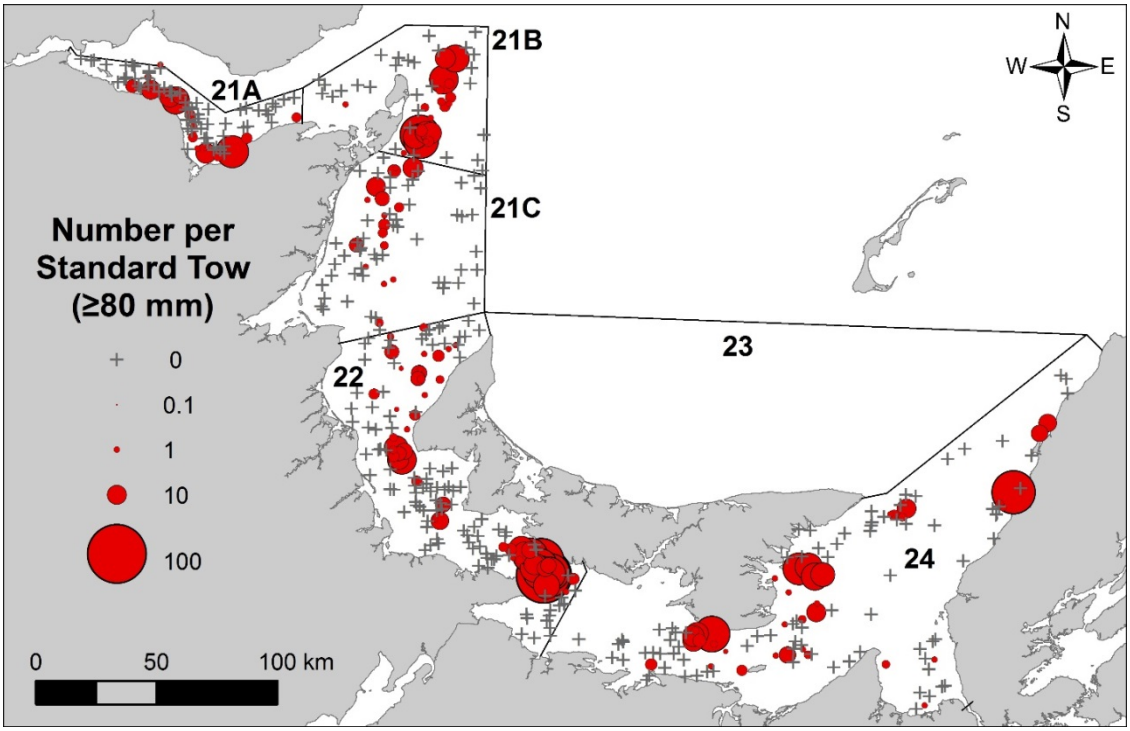


Figure 14. Spatial distribution of sea scallop abundance indices (total number per standard tow) of commercial size (≥ 80 mm) scallop in the southern Gulf of St. Lawrence surveys, 2012 to 2016. Circle area is proportional to scallop density.

Biological characteristics

Biological characteristics of scallop sampled during the research survey are summarized in Table 3 and Figures 8 and 15. The age of the sea scallop retained by the survey drag ranged from 2 to 16 years old. The maximum age observed in SFA 22, SFA 21B and 21C was 13 years old. An index of natural mortality, based on the ratio of clappers (dead scallop with the two shells still attached at the hinge) of scallop shell heights ≥80 mm, ranged from 0.07 in SFA 21B and 21C to 0.38 in SFA 22 south, similar to rates reported in Lanteigne et al. (1987) (Table 3). These indices can be affected by the period when the data are collected; as for example fishery activity can affect the deterioration of the clappers through physical interactions with the gear.

The shell height size frequency distributions from the survey catches are shown in Figure 15. Scallop recruitment (< 80 mm shell height) is evident in all sampled areas. In SFA 21A, pre-recruits sizes (< 80 mm) are abundant, while fewer scallop fall in the size range between 80 and 110 mm. There are very few scallop greater than 110 mm in SFA 22 south and the maximum recorded at this site was only 125 mm. There are fewer small scallop in SFA 24, where 50% of all scallop are greater than 86 mm. Predicted meat weight of a scallop of 100 mm shell height is lowest in SFA 24 and highest in SFA 22 north (Table 3; Fig. 2).

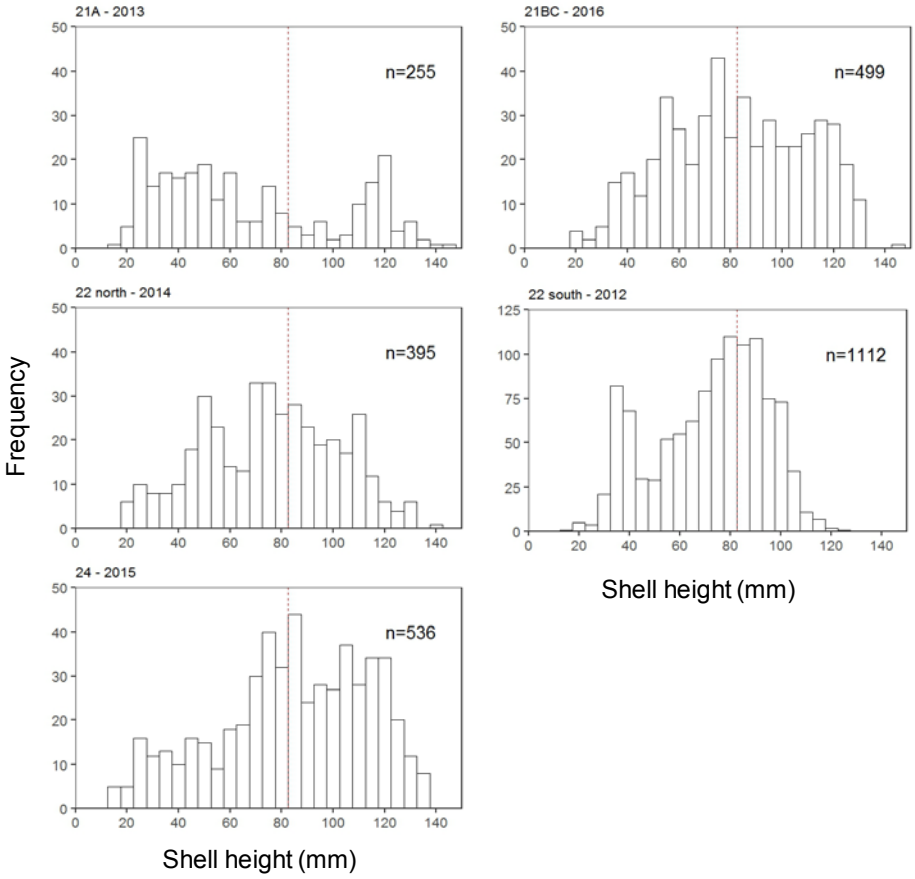


Figure 15. Shell height distribution of scallop by SFA based on research surveys with a scallop drag bucket liner (14 mm) conducted between 2012 and 2016. The red vertical dashed line in each panel shows the 82.6 mm mark corresponding to ring size.

Table 3. Number of scallop sampled (n), shell height (mm; mean, standard deviation, size range), predicted mean weight of a scallop of 100 mm shell height, mean age and maximum age of commercial scallop (≥ 80 mm), and ratio of clappers in the catches of sea scallop from the research vessel scallop survey in the scallop fishing areas of the southern Gulf of St. Lawrence, 2012 to 2016.

			Shell Height (mm)				Predicted meat weight (g) of 100 mm shell height	Age of scallop ≥ 80 mm		Clapper ratio (≥80 mm)
SFA	Year	n	Mean	SD	Min	Max		Mean	Max	
21A	2013	255	68	22.0	17	147	15.6	8.8	15	0.36
21BC	2016	499	82	34.9	18	143	14.8	8.5	13	0.07
22 north	2014	395	76	26.6	20	156	18.2	6.9	13	0.14
22 south	2012	1,112	72	29.4	15	125	14.3	7.3	13	0.38
24	2015	536	84	27.3	13	137	12.2	8.6	16	0.23

Biomass estimates

SFA 21

SFA 21A in Chaleur Bay was surveyed before the fishing season, June 28 to July 5, 2013. The mean density of commercial sized scallop (≥ 80 mm shell height) in the scallop bed was 0.033 g per m^2 (0.14 kg per standard tow) (Table 4). The total meat weight of commercial size scallop before the fishery was estimated to be 8 t (Table 4). At a harvest of 5 t in 2013 for this area, the exploitation rate based on the index of commercial biomass, unadjusted for gear efficiency, would be 59%.

Table 4. SFA specific research vessel scallop survey commercial size (≥ 80 mm shell height) biomass indices (not corrected for drag efficiency) of scallop as meat weight (kg per standard tow of 437.27 m^2; mean, standard error (SE)), density (g m^{-2}), corresponding area for the high effort stratum (km^2), estimated biomass (meat weight, t), pro-rated landings to the stratum, and exploitation rate

Caracteristic	SFA 21A	SFA 22 north	SFA 22 south	SFA 24
Year	2013	2014	2012	2015
Abundance (kg per standard tow)				
Mean	0.014	0.041	0.223	0.023
Standard error	0.006	0.012	0.057	0.008
Density (g per m^2)	0.033	0.090	0.510	0.050
Surface area of the stratum (km^2)	231	557	248	1500
Biomass (t) before the fishery	8	84	158	80
Landings (t)	5	32	31	14
Exploitation rate	59%	38%	20%	18%

SFA 22 West Point

SFA 22 West Point bed was surveyed after the fishing season between May 31 and June 11, 2014. The estimated meat weight of commercial size scallop is equivalent to 52 t. The pre-fishery commercial-sized biomass index, considering the landings that had occurred prior to the survey, is estimated at 84 t giving an estimated exploitation rate of 38% (Table 4).

SFA 22 Cape Tormentine

SFA 22 Cape Tormentine bed was surveyed after the fishing season between June 27 and July 5, 2012. The estimated meat weight of commercial size scallop in the survey is equivalent to 127 t. The pre-fishery commercial size biomass index, considering the landings that occurred prior to the survey, is estimated at 158 t giving an estimated exploitation rate of 20% (Table 4).

SFA 24 Pictou

SFA 24 Pictou bed was surveyed before the fishing season between August 14 and 29, 2015. The estimated meat weight of commercial size scallop in the survey is equivalent to 80 t (Table 4). The estimated exploitation rate for a harvest of 14 t is 18%.

Stock status from depletion models versus surveys

Estimated exploited biomass indices from the depletion models are generally lower than the survey commercial size biomass indices for the corresponding years where both are available. In part, this could be explained by differences in the components of the scallop population which are included in the biomass estimates. The research vessel scallop gear had a liner and the size distribution of the scallop in the catch indicated a higher retention rate (higher relative selectivity) for scallop between 80 and 90 mm shell height than is indicated for the commercial gear (see Fig. 8 for examples). In addition, the depletion model estimates of biomass are driven by the catch rates and depletion on the bed area of high abundance which is smaller in surface area than the survey stratum used to define the research vessel commercial biomass indices. This difference in biomass estimates results in higher exploitation rates inferred from the depletion model than from the survey estimates.

Reference points

There is insufficient information available from the sea scallop stock of the sGSL with which to define abundance and removal rate reference points as per the Precautionary Approach (DFO 2009).

The time series of reliable landings begins in 1968, with the highest landings at the start of the time series and showing generally continuous declines since (Fig. 4). Reliable effort data are only available since 2003. As there is no information on effort, and no estimates of exploitation rates or of stock abundance for the earlier time period, the status of the scallop resource is poorly known. Based on research survey estimates of commercial biomass indices from the three major scallop beds in the sGSL during 2012 to 2015, landings at the levels reported in the late 1960s could not currently be realized, even if the entire commercial biomass was removed by the fishery.

Catch rates based on information which more accurately reflects actual fishing effort (number of tows and average duration of tows) are only available since 2003, corresponding to a time period when the resource was already considered to be at low abundance in the sGSL (DFO 2011). Catch rates from the sGSL fishery, generally less than 10 kg per h even at the start of the fishery and which decrease rapidly over a period of a few weeks, are low relative to those from other scallop fisheries in eastern Canada.

In SFA 21A, the fishing industry established a minimum catch rate (3 kg per h) below which the area would be closed to scallop fishing for a minimum of three years. Density of scallop on the beds, as a metric for spawner density therefore used as a proxy for successful reproduction, could be developed to establish abundance reference points. Detailed population level information (stock and recruitment) to develop such an index is not available at the present time.

Stock status for this resource could be monitored using demographic and life history characteristics that may reflect whether the productivity (growth, survival, reproduction) of the stock could be severely impaired, as per the definition of a stock being in the critical zone. Examples of such metrics could include periodic monitoring of the size composition on exploited scallop beds to ensure that recruitment is not compromised, based on the relative size distribution of scallop from the research survey using a scallop drag with a liner to catch small

scallop. Indices of natural mortality as derived from clapper ratios could provide a signal of changes in mortality, with particular concern for any evidence of increases over time. Finally, condition expressed as meat weight for a standardized length of 100 mm particularly prior to gonad maturation and spawning could be used to assess the productive capacity of the stock.

Sources of Uncertainty

Both fishery independent and fishery dependent data to assess the status of the scallop stocks in the sGSL are poor.

Fishery independent data derived from directed research surveys are sporadic and a synoptic survey of the sGSL scallop beds in the same year has not been conducted since 1986. Much of scallop fishing area in the sGSL is amenable to scallop dragging, being generally near shore and in relatively shallow water. Rotational surveys provided intermittent information on the scallop resource but in the absence of replication through time, this information is of limited use in assessing stock status and developing management advice.

Fishery dependent data include landings and catch rates derived from sales slips and logbooks. Missing and inaccurate data is the main driver of uncertainty of the landings and the effort data that are used in this assessment.

- In some areas, non-compliance with logbook conditions is relatively high, as demonstrated by the number of fishing trips reported in logbooks in relation to that reported in sales slips.
- In many cases, the percentage of logbook reports with information that can be used for quantitative spatial catch rate analysis varied from 45% to 60% of logbook returns.
- A large portion of the uncertainty is associated with inconsistency in the quantification of the effort, reported either as hours fished or as the number and average duration of tows (hours towed), even though the units of effort to be reported are specified in the licence conditions.
- Additional issues arose from geolocation of fishing activity. There is only one fishing coordinate requested per day, even though harvesters may fish at multiple locations in a day. In some logbooks the same geographic coordinates for multiple days were reported and it is unknown if this represented repeated fishing at the same location or convenience in data reporting. Some logbook coordinates are reported in Loran-C which are less accurate and bring conversion issues.
- There is no mechanism in place at the present time to quantify unreported landings, i.e. landings without sales slips (including local sales) and for which no logbooks were returned.

Meat condition (meat weight for a standard shell height) is highly variable among fishing locations, varies within the fishing season as well as interannually. Meat condition variability may be related to environmental conditions to which the scallop are exposed. Annual variations in condition may mask or otherwise falsely contribute to perceptions in variations of numerical abundance, and violate the important assumption in assessments that catch rates are proportional to abundance. The absence of standardized and systematic monitoring of meat condition therefore adds substantial uncertainty regarding the use of catch rates, even from fishery independent data, as an index of stock status.

The depletion estimates can provide a relative index of fishery exploitable biomass provided the assumptions of such approaches are respected. A key assumption is that catch rates are proportional to abundance and this relationship has not been confirmed when stock abundance and catch rates are low, as is the case in the catch rate data for scallop from the sGSL. The relativity of the index also depends upon an assumption that the spatial area of the stock being exploited is consistent within the season and among years and this may also not be the case if

there is a temporal pattern in the locations fished, within a bed and between scallop beds. This switching of effort between beds was apparent, for example in SFA 22 as the effort switched between the Cape Tormentine bed and the West Point bed in 2013.

The assumption that the clapper ratio can be an index of natural mortality may be inappropriate in cases when the clapper ratio data are collected after the fishery. Clapper integrity, beyond natural deterioration of the hinge membrane, can be compromised by interactions with the fishing gear and by stated fishing practices associated with breaking the clappers when retrieved before discarding to reduce handling and sorting effort of the catches. The more relevant information would be obtained when these data are collected prior to the fishery, particularly if the period from the end of the fishery to the survey exceeds the expected duration of clappers, 33 weeks for the sGSL. Clapper ratios should also be presented by size group as the resilience of the membrane may differ according to scallop shell size.

The research vessel surveys conducted in 2012 to 2016 confirmed the locations of scallop beds inferred previously from fishery effort and landings data. However, the survey design for SFA 24 failed to characterize the main Pictou bed due to the large size of the defined stratum and the random allocation of stations resulting in no stations being assigned in the high concentration area.

In all surveys, several survey tows were conducted in areas with few to no scallop. This design is useful for confirming the location of scallop beds but it is not optimal for quantifying population abundances. An alternate survey design that focuses the sampling effort on the defined scallop beds could be more effective at quantifying scallop population abundance, recruitment, and other life history parameters.

By narrowing down the research survey sampling areas, it may be possible to conduct surveys on the most important beds on a more frequent schedule than once every five years, as was the case for the 2012 to 2016 surveys. Such repeated sampling of the population is required to support the development of stock status indicators and to provide management advice for the fishery.

Concerns have been raised regarding the effects of changes in environmental conditions, particularly increases in sea temperatures, on scallop growth, reproduction, as well as survival in the sGSL. The major scallop beds in the sGSL are located within Northumberland Strait, a shallow and well mixed area where water temperatures can exceed the optimal temperatures (10 – 15° C) and even exceed temperatures (> 18° C) that are physiologically stressful for sea scallop. The consequences of this on the productivity of scallop, independent of fishery effects on the population, is unknown but should be considered in the next assessment.

CONCLUSIONS AND ADVICE

The sea scallop fishery in the sGSL is an input control competitive fishery with fishing effort and landings currently mostly concentrated on three scallop beds within SFA 22 and 24, all within the Northumberland Strait area. Reported landings have declined over the available time series beginning in 1968, from approximately 900 t to around 100 t since 2002. Preliminary reported landings in 2016 were 66 t.

There is a large amount of latent effort in this fishery. Just under 20% of the 770 licence holders in the sGSL were considered to be actively fishing (based on reported landings in 2016), a value similar to the previous five years. The scallop harvesters are multi-species licence holders, and price for scallop, as well as participation and access in other fisheries, may play a role in the changes in the number of active harvesters in the past and in the future. The highest

percentage of active scallop harvester is in SFA 22 (West Point and Cape Tormentine beds), 42% in 2016.

Harvesters are expected to complete logbooks and notify DFO at the end of the season whether they fished or not. In some SFAs and in some years, there is a relatively high proportion of active harvesters who are non-compliant with the licence condition, with landings registered to buyers but not reported in logbooks. The completeness of local sales data in logbooks is uncertain and local sales are particularly important in some areas, such as SFA 24. Missing and inaccurate data are the main drivers of uncertainty of the landings and the effort data that are used in this assessment.

Mean catch rates over the fishing period derived from logbook information are generally low (6 kg per h). Mean weekly catch rates start at 10 kg per h in Cape Tormentine and 8 kg per h in West Point and decline rapidly, within a few weeks of the fishery opening, with exception of SFA 24 where catch rates were consistently lower (~ 4 kg per h) throughout the season and years.

Depletion models were examined to develop relative indices of annual fishery exploitable biomass and exploitation rates, using daily catch rate (kg per h) data from logbooks regressed against cumulative landings on specific scallop beds. Despite the uncertainties in the data and the assumptions required to position fishing effort and landings from all commercial harvesters within the specific scallop beds, there is compelling evidence of a rapid depletion of the exploitable biomass over a period of a few weeks in the two major scallop beds of SFA 22.

Estimates of commercial sized (≥ 80 mm shell height) scallop biomass, uncorrected for drag efficiency, from research surveys on the major beds in individual years provide further evidence of relatively high exploitation rates in this fishery, 20% to 40% and higher for some years examined. It is very unlikely that the high landings reported at the start of the time series could be realized from the current commercial biomass of scallop in the sGSL, even if the entire stock was harvested, indicating that relative to historical levels, the stock is at low abundance.

The abundance indices, based on catch rates and densities, are considered to be low relative to other areas of eastern Canada. On the other hand, biological characteristics data from research surveys show evidence of recruitment (< 80 mm shell height) in each SFA.

Reference points that conform to the Precautionary Approach could not be defined at this time. There are no long term indicators of abundance, productivity, or sustainable exploitation with which to define appropriate reference points. Catch rates based on the relatively short time series from fishery logbooks are inherently very uncertain, particularly in terms of being proportional to abundance. In any case, the catch rate data available are from the recent decade and represent a time period for which the resource is already considered to be at low abundance.

Concerns regarding impaired productivity for this resource persist, especially in the context of low densities of spawners which could compromise successful reproduction and recruitment. Based on limited research vessel information from the recent time period, there is evidence of recruitment (< 80 mm shell height) in all surveyed areas, although the recruitments which could be realized from a healthy stock abundance is unknown.

Fishery independent stock monitoring data and indices are required to appropriately assess the status of this resource and to provide management advice compatible with the sustainable fisheries framework. Consideration could be given to undertaking periodic, preferably annual, surveys of those scallop beds which contribute to the majority of the fisheries effort and landings. Efficiency in survey design could be achieved by focusing the monitoring efforts on these scallop beds thus potentially providing an opportunity to monitor the main beds in a single season. Data from these surveys could be used to monitor the productive state of the resource,

including the condition of scallop meats, indices of recruitment, indices of natural mortality, and indices of commercial biomass to estimate relative exploitation rates by the fishery.

Fishery dependent data of size (length and meat weight) structure of the catches could be obtained from regular at-sea sampling programs to more fully characterize the exploited component of the resource and to track conditions of scallop meats.

OTHER CONSIDERATIONS

DFO (2016) provides advice for the development of indicators which could be used in support of the multi-year assessment and management cycle for aquatic resources in Canada. For resources that are on a multi-year management cycle, indicators should be developed to track stock status in the intervening years between full assessments in order to determine if an unexpected change in status occurred and that a re-assessment earlier than scheduled is warranted. The indicators that are developed must meet particular conditions including: that the indicators are linked proportionally or in some manner to stock status and the indicators must be part of a systematic monitoring activity. Additionally, the indicator data and analyses must be available in sufficient time to allow a full assessment to occur if such an action is signaled.

There is no defined multi-year management cycle for sea scallop from the sGSL. The previous assessment summarized fishery data to 2010. Previous management advice provided for this fishery has been in the context of gear modifications such as ring size and the establishment of buffer zones to protect lobster habitat. There are currently no directed monitoring programs for sea scallop in the sGSL, and the only annual information that could be collated are the landings and effort data from logbooks. Catch rates, as a proportional index of abundance, based on these fishery dependent data are highly uncertain, particularly because of the inferred low abundance of the exploitable biomass.

In the absence of appropriate indicators to indicate if a significant unexpected change in stock status has occurred, an update of the fishery dependent data could be provided in three years and a full assessment in five years. Indices that could be collated at that time include landings and catch rates by SFA and specific to the major beds that support the fishery in the sGSL. These data are however only available from the statistics sector a full year after the fishery has ended.

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SOURCES OF INFORMATION

This Science Advisory Report is from the October 16 and 17, 2018 Regional Peer Review meeting of the fishery and stock status of the giant scallop (*Placopecten magellanicus*) from NAFO Division 4T, southern Gulf of St. Lawrence. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

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ISSN 1919-5087

Correct Citation for this Publication:

DFO. 2019. Fishery and Stock Status of the Sea Scallop (*Placopecten magellanicus*) from the Southern Gulf of St. Lawrence to 2016. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2019/006.

Aussi disponible en français :

MPO. 2019. L'état de la pêche et des stocks de pétoncle géant (Placopecten magellanicus) du sud du golfe du Saint-Laurent jusqu'en 2016. Secr. can. de consult. sci. du MPO, Avis sci. 2019/006.