Fisheries and Oceans Canada | Pêches et Océans Canada
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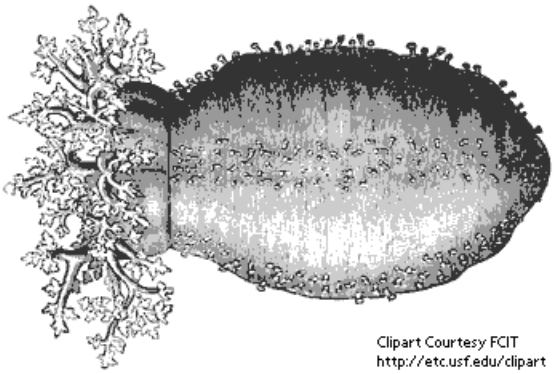
Maritimes Region

Canadian Science Advisory Secretariat
Science Advisory Report 2021/007

GUIDANCE FOR SETTING REFERENCE POINTS FOR THE SEA CUCUMBER (*CUCUMARIA FRONDOSA*) FISHERY IN THE MARITIMES REGION, AND STATUS OF THE SWNB SEA CUCUMBER FISHERY 2019



Orange-Footed Sea Cucumber – *Cucumaria frondosa*

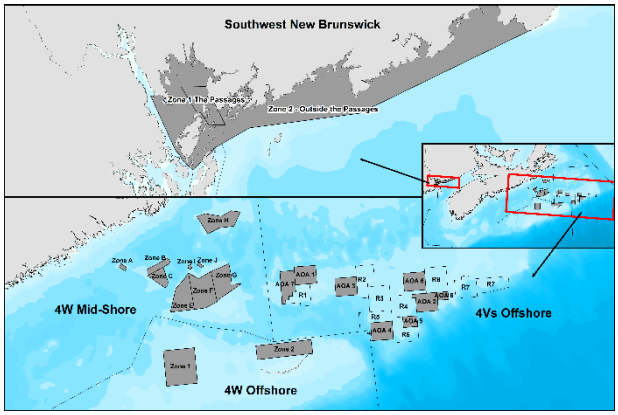


Figure 1. Maritime Region Sea Cucumber fishing areas excluding 4X inshore N.S.

Context:

Science advice was requested by Fisheries and Oceans Canada Resource Management on guidance for setting reference points for the Sea Cucumber fisheries in the Maritimes Region, and status of the southwest New Brunswick (SWNB) Sea Cucumber fishery. This is the first assessment of the SWNB Sea Cucumber fishery since all licences were converted from Stage II Exploratory to limited-entry in 2011. No stock assessment framework has previously been adopted for this stock, and no formal science advice has been provided for this fishery since 2009 following an assessment of the Stage II Exploratory status (DFO 2009; Rowe et al. 2009). Science advice was also provided on this fishery in 2006 before it moved from Stage I Experimental to Stage II Exploratory status (DFO 2006).

Science advice was also requested to provide guidance on establishing spatial fishing reserves for the 4W offshore fishing areas, which can be used for establishing reserves for other Sea Cucumber fishing areas in the future.

This Science Advisory Report is from the May 28–30, 2019 regional peer review on the Review of Indicators and Reference Points for the Maritimes Region Sea Cucumber (Cucumaria frondosa), and Status of the southwest New Brunswick Sea Cucumber population. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

Canada

SUMMARY

- Current stock status indicators for Orange-Footed Sea Cucumber (*Cucumaria frondosa)* in the Maritimes Region are based on fishery dependent information: catch rates and split weight.
- Caution is warranted when using catch rate-based indicators due to the possibility that catch rates could remain stable as the population declines.
- Limit Reference Points (LRP) were established for Sea Cucumber fishing areas that have been regularly fished, including Southwest New Brunswick (SWNB) Zone 1, 4W Offshore Zones 1 & 2, 4W Mid-shore Zone F, and 4Vs Area of Access 2.
- The highest mean catch rate in each time series was used as the basis for setting LRPs, as a proxy for unfished biomass (B_0).
- The LRPs for 4W Offshore Zones 1 & 2, 4W Mid-shore Zone F, and 4Vs AOA2 were set as 20% of B_o (0.045 kg/m^2, 0.061 kg/m^2, 0.127 kg/m^2 and 0.052 kg/m^2, respectively).
- The LRP for SWNB Zone 1 was set as 30% of B_0 (811.53 kg/hr*m). Reference points for SWNB Zone 1 were more precautionary due to the risk associated with fishing all known available Sea Cucumber habitat in that fishing area.
- Reference points should be re-evaluated as additional fishery independent information becomes available.
- The assessment of SWNB Zone 1 was based on catch rate and split weight indicators.
- The catch rate indicator for SWNB Zone 1 is near the LRP and in the cautious zone. Focus should be on rebuilding.
- In SWNB Zone 1, there has been a decline in the catch rate indicator for the past 14 years; the decline from 2005–2019 was 66%.
- The average split weight indicator in SWNB Zone 1 has declined by 25% since the start of the time series in 2012. Split weight indicates the size distribution of the commercial catch has shifted to become composed of smaller animals.
- It is unknown what level of fishing in SWNB Zone 1 would allow stabilization and recovery of the stock within a reasonable time frame. In 2019, the Total Allowable Catch was reduced to 500 t; however, the catch rate indicator remains near the LRP.
- Reserves and rotational harvesting are some of the options that can be used as effective spatial management tools for assumed low mobility species such as sea cucumber. Broad guidance was given to set aside at least 30% of expected Sea Cucumber habitat from fishing in data-limited situations. Any strategy to set aside areas from fishing should be re-evaluated on a 3–5 year time period to ensure objectives are being met.
- A map of expected *C. frondosa* habitat has been provided by DFO as guidance for setting aside 30% of habitat on the Scotian Shelf. The map should be updated and validated as more data become available.

INTRODUCTION

Species Biology

Cucumaria frondosa is the most common sea cucumber in the North Atlantic (Hamel and Mercier 2008). They aggregate in high densities (Hamel and Mercier 1995; Singh et al. 2001), although their distribution is patchy. Compared to other sea cucumber species commercially harvested elsewhere, they are small, thin-walled, and filter feed plankton from the water column.

Very limited information exists on the life-history characteristics of *C. frondosa* in the Maritimes Region, including growth rates, age and size at maturity, mortality, recruitment, and stock structure. Much of our understanding of this species comes from research in other areas, particularly the Gulf of St. Lawrence (Hamel and Mercier 1995; 1996a; 1996b). While some of this information is applicable to Sea Cucumber populations in the Maritimes Region, site-specific differences are expected.

Growth rates for *C. frondosa* in the Maritimes Region have not been determined. However, studies from the Gulf of St. Lawrence show that individuals grow to 12 cm in 4.5–5.5 years, reaching commercial size (25–30 cm) in approximately 10 years (Hamel and Mercier 1996b).

The age at maturity for *C. frondosa* in the Maritimes Region has not been determined; however, in the St. Lawrence Estuary, sexual maturity was reached after approximately 3–4 years at 8–10 cm and appeared more rapid in deeper water (20 m) (Hamel and Mercier 1996b). Individuals observed at shallower (< 15 m) depths did not reach maturity within a 5-year time frame (Hamel and Mercier 1996b).

Recruitment of Sea Cucumbers in the Maritimes Region is unknown, although significant recruitment events are assumed to be episodic. The stock structure of *C. frondosa* in the Maritimes Region (i.e., the relationship of individuals in this area to adjacent areas) is unknown, including source of recruits and the extent of movement among areas. There is potential that the mid-shore and offshore Sea Cucumber fishing areas are connected by recruitment, given the duration of the larval Sea Cucumber water column phase and the current patterns in the area (Shackell et al. 2013). In general, larval dispersal of benthic species is broad, depending on a variety of biological and physical conditions (Cowen and Sponaugle 2009). The exact patterns of Sea Cucumber larval dispersal in the Maritimes are unknown (Shackell et al. 2013).

Fishery

The Sea Cucumber fishery in the Maritimes Region has been divided into five management areas:

1. Southwest New Brunswick (SWNB)
2. 4W Mid-shore
3. 4W Offshore
4. 4Vs
5. 4X

Each management area has had its own evolving harvest strategy, that has been co-developed with DFO and industry over time.

Fishing is restricted to designated Sea Cucumber fishing areas in Northwest Atlantic Fisheries Organization Divisions (NAFO) 4W, 4Vs, and 4X (Figures 1–3). The designated Sea Cucumber fishing areas in 4W and 4X are referred to as Zones, while in 4Vs they are referred to as Areas of Access (AOAs). In 2017–18, Fisheries and Oceans Canada (DFO) Science staff conducted a

review of the indicator reports provided by the industry since quota was introduced in 2012. This review identified potential concerns related to fishing activities in one small concentrated area. Following the review, DFO Resource Management began to work with licence holders to formalize management measures to support the addition of reserve areas in 4V. This work began in NAFO Division 4Vs in the 2018–19 fishing season (Figure 3).

Catch and effort was minimal between 2012 and 2015 in NAFO Division 4X (excluding SWNB). No fishing has occurred in this area since 2015; therefore, an evaluation of the 4X management component was not conducted for this report.

In SWNB, the fishing season runs from the second Tuesday in January to March 31. The fishing season in both 4W and 4Vs runs from May 1 to March 31 the following year. The month of April is closed to fishing, as it is believed that spawning occurs during that time. The authorized gear for all Sea Cucumber fishing areas is a modified scallop drag, with some differences between the gear used in SWNB and in 4VW.

Southwest New Brunswick

The SWNB sea cucumber fishery has been active since 1999. From 1999 to 2006, two inshore experimental Sea Cucumber licences were authorized to harvest in the portion of NAFO Division 4X, known as Lobster Fishing Area (LFA) 36 (Figure 2), using variations of modified scallop/urchin gear. The two licence holders were limited to an operating season beginning in January and ending by March 31.

In 2006, an overall total allowable catch (TAC) of 1,370 metric tons (t) was implemented and distributed within 4 specific fishing zones: The Passages, Magaguadavic River, South Deer Island, and Upper Passamaquoddy Bay. The zones and associated TACs were created based on previous fishing effort, the average annual landings during the previous 5 years, and a survey conducted on July 27–29, 2004.

In 2010, after consultations through the advisory process, three zones were eliminated. The Passages Zone (Zone 1) with a TAC at 1,010 t was maintained, and the remaining 360 t allocation was made available to harvesters inside the new fishing Zone 2, a segment of LFA 36 (Figure 2).

In 2006, the “Tongue Shoal” area located in St. Andrews Harbour was closed to commercial Sea Cucumber fishing (Figure 2). This area was identified as having high concentrations of Sea Cucumbers and was considered to have a high level of benthigc species diversity (Rowe et al. 2009). The closure reduces benthic contact and protects the high concentration of Sea Cucumbers in this area. A second reserve, outside the current fishing zones, was established near Campobello (Figure 2).

In 2011, the two licences were converted from exploratory to limited entry. In 2012, both licences changed ownership.

In 2019, “The Passages” or Zone 1 TAC was reduced from 1,010 t to 500 t based on concerns of declining trends in catch rates. The Zone 2 TAC remained at 360 t. Since the beginning of the SWNB sea cucumber fishery in 1999, approximately 90% of landings have come from Zone 1.

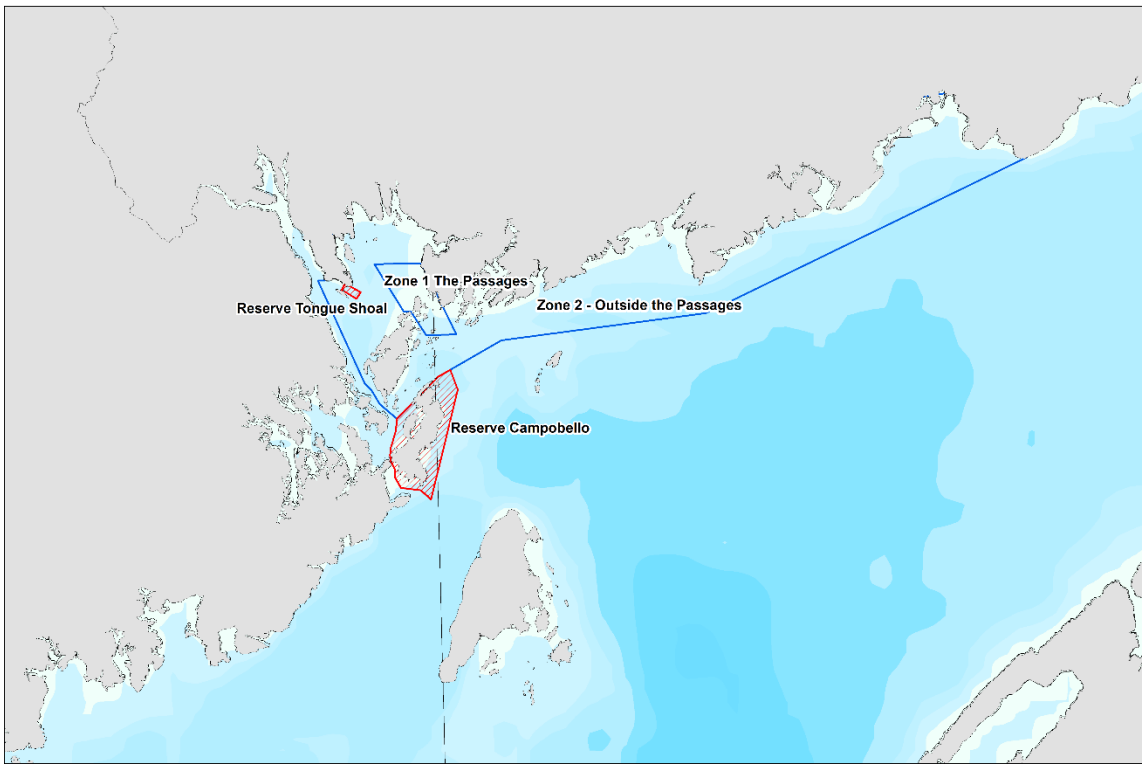


Figure 2. Current Maritimes Region Sea Cucumber fishing zones in Southwest New Brunswick.

4W Offshore

In 2004, Ocean Leader Fisheries Limited began to harvest Sea Cucumber with an experimental license beyond the 50 nautical mile (nm) limit in NAFO Division 4W, excluding the haddock closed area west of Sable Island. This area is herein referred to as 4W Offshore (Figure 3). Industry surveys were conducted from June to July in an area designated as Zone 1. In the summer of 2005, five additional Zones (2, 3, 4, 5 and 6) were included in the experimental area designated to be surveyed.

In 2006, DFO issued license conditions for Zone 1 under a Stage II exploratory fishery with a TAC of 800 t. In 2007, pre-season surveys were conducted in Zones 1 and 2. An additional area accompanying Zone 2, designated the Zone 2 extension, was also surveyed. Upon completion of the surveys, Ocean Leader was allocated a TAC of 800 t for Zone 1 and 200 t for Zone 2. A maximum of 40 fishing days could occur in Zone 1 and 10 days in Zone 2, with an end of season date of October 31, 2007. In 2011, DFO issued Ocean Leader Limited an enterprise allocation licence for Zones 1 & 2 only in NAFO Division 4W.

In 2013–2015, the TAC was changed to a combined 880 t for Zone 1 & 2, with a maximum of 50 fishing days. In 2016, Zone 1 & 2 changed configuration at the request of the industry (Figure 3). The total combined TAC was reduced as recommended by the licence holder in 2017 to 600 t. In 2018, zonal TAC caps were implemented with the intention of stabilizing landings from both zones. The caps were 400 t for Zone 1 and 200 t for Zone 2. Zone 2 removals were capped at 200 t to keep removals similar to historical levels until such time as the impact of this level of removals on the population could be determined. In addition, the licence holder also agreed to distribute fishing effort within the zone on a voluntary basis. This is expected to continue for the 2019–20 season.

4W Mid-shore

In 2004, WT Grover Fisheries began conducting surveys and fishing commercially for Ocean Leader Fisheries Limited through a Joint Project Agreement. In 2006, WT Grover Fisheries applied for, and was granted, a Stage 1 experimental licence in the mid-shore (12–50 nm) of NAFO Division 4W in Zones A–J (Figure 3) . In 2007, all zones were surveyed except Zone D. Large aggregations of Sea Cucumbers, known as beds, were found in Zones E, F, and G. Sea Cucumbers were located in Zones B, C, and H but required more extensive surveying to determine abundance.

In 2008, a TAC of 800 t was approved for the 4W Mid-shore and was limited by a maximum of 45 fishing days. Since the implementation of a TAC, almost all fishing in 4W Mid-shore has been focused in one small area of Zone F (Figure 3). Zone D is closed to fishing as it is located near sensitive sponge grounds, and considerations would have to be given to the potential impacts to the sponge grounds before fishing could be authorized.

In 2018–19, effort was moved to different areas within Zone F, and the catch rates remained at some of the highest levels of all Sea Cucumber fishing areas in the Maritimes Region. In 2019–20, fishers may voluntarily move effort from the small patch they have been fishing in Zone F since 2008. The expectation is that they will determine if other areas within Mid-shore Zone F or other Mid-shore zones have Sea Cucumber densities to support the 800 t removal.

4Vs Offshore

In 2005, Louisbourg Seafoods Limited applied for, and was granted, a Stage I experimental licence in the offshore (outside 50 nm) of NAFO Division 4Vs (Figure 3). Due to a combination of factors including markets, economics, and opportunity costs, Louisbourg Seafoods Limited decided to postpone the commencement until 2008. In 2009, a Stage II exploratory licence was approved for Louisbourg Seafoods Limited within eight fishing areas of access (AOA) (Figure 3). The objective of authorizing eight fishing areas was to promote rotational harvesting. In an effort to achieve rotational harvest, up to 25% of the fishing effort (i.e., days and/or quota) could be committed to each area. A TAC of 800 t was initially approved for the offshore 4Vs area, further limited by a maximum of 45 fishing days.

Removals from AOA 2 were capped at 600 t in 2018–19, based on a DFO Science review of the previous fishing seasons, which identified a decline in indicator values and concentrated fishing effort in this one area since 2011. The licence holder, in consultation with DFO Science, elected to institute Sea Cucumber reserves for the 2018–19 season. These were in response to a request from the licence holder to change their fishing area locations and the previously stated concentrated fishing effort in one AOA. This system of reserves has been adopted on a provisional basis, as DFO continues to work with industry to confirm their suitability. A camera survey was to be completed by the licence holder for one reserve area each season. This was not completed in 2018–19. Discussion of the theory behind Sea Cucumber reserves and guidance on establishing reserves is discussed in a subsequent section of this document.

In 4Vs, the 800 t TAC has been consistently caught since 2011, with a buildup phase of two years in 2009 and 2010. The majority of landings have come from AOA 2, although there has been continual exploration of areas outside of that zone. In 2018, high concentrations of Sea Cucumber were found in the newly configured AOA 6. This area had not been explored previously, and it was not part of the initial eight fishing areas designed in 2009. In 2018 landings were spread almost equally between AOA 2 and AOA 6, reducing pressure on AOA 2.

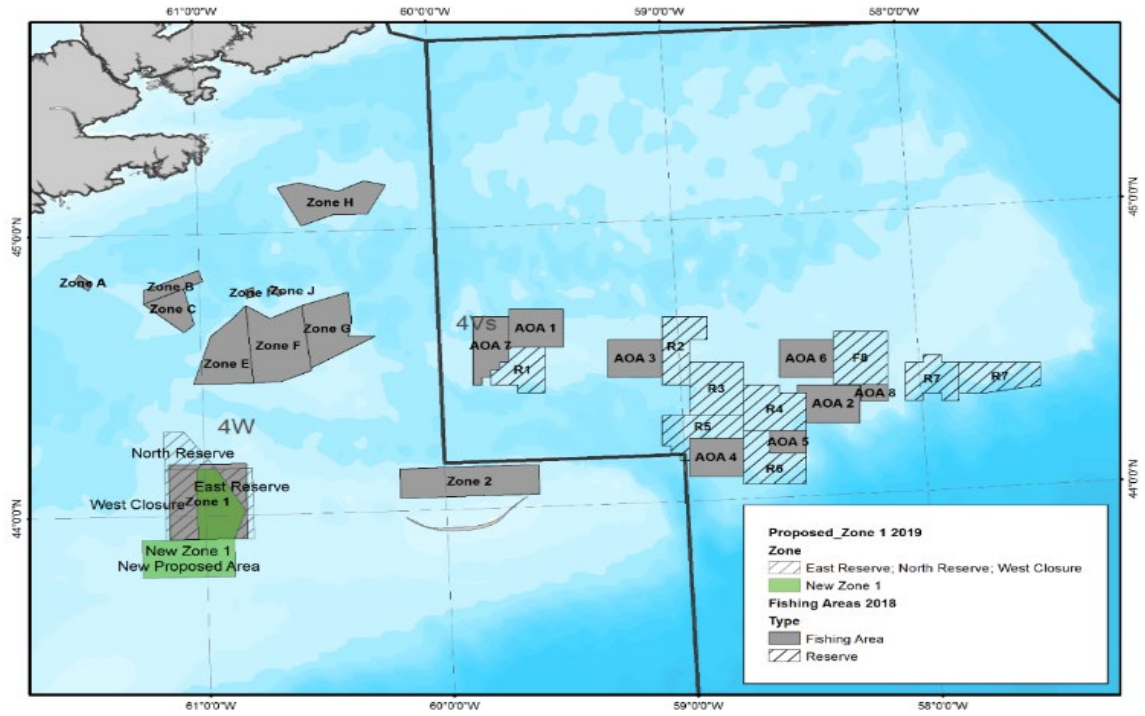


Figure 3. Current Maritimes Region Sea Cucumber fishing zones and Areas of Access (AOA) in NAFO Divisions 4VsW.

ASSESSMENT

Stock Indicators

Currently, there are no surveys in the Maritimes Region that provide sufficient fishery-independent information on abundance of Sea Cucumber; thus, any assessment of Sea Cucumbers must be based on fishery-dependent data. It was agreed that kg/m^2, calculated as:

$$\frac{\text{catch (kg)}}{\text{distance towed (m)} * \text{drag width (m)}}$$

and split weight would be used as stock status indicators going forward. One additional indicator was included for SWNB, kg/hr*m, which is calculated as:

$$\frac{\text{catch (kg)}}{\text{tow duration (hour)} * \text{drag width (m)}}$$

This indicator may be more representative of effort patterns in SWNB. There are difficulties recording the precise location of the start and end of tows due to drift associated with extreme tidal currents as fishers haul their gear. Both catch rate-based indicators (kg/m^2 and kg/hr*m) were calculated as a mean catch rate per year (bootstrapped mean with replacement, with 5,000 iterations) with 95% confidence intervals (Bias Corrected and Accelerated (BCa), which corrects for bias and skewness in the distribution of bootstrap estimates).

Indicators are presented for all fishing zones and areas that are regularly fished, including SWNB Zone 1 (Figures 4 and 5), 4W Offshore Zones 1 & 2, 4W Mid-shore Zone F, and 4Vs AOA2 (Figure 6). Catch and fishing locations recorded on commercial log sheets are used to

calculate the area-based catch rate (kg/m^2). Tow distances are calculated between the start and end of set locations using R programming (function 'distHaversine', package 'geosphere'), which is considered the shortest distance between two points, and does not take into account the possibility of a non-linear tow. Non-linear tows are noted on fishery logbooks; however, time did not permit the calculation of distances of curved tows for this analysis.

Indicators for SWNB (kg/m^2 and kg/hr*m) do not include the first six years of fishing (1999–2004), as fishing was largely exploratory and fishing practices changed in 2005 when vessels were replaced. Gear modifications (i.e., widening of the mouth of the drag) that occurred in 2009 and 2012 were accounted for in both catch rate indicators, multiplying the gear width by either distance towed (kg/m^2) or tow duration (kg/hr*m).

Round and split weight samples have been collected in all areas starting in different years (Table 1) and provide a size-based indicator of stock status. Split weight is the weight of individuals that are drained of water with the viscera (guts) removed and the head/flower intact. Split weight is considered a more reliable size-based indicator than round weight, as it removes some of the variability associated with water retention in the body walls. The number of samples collected for weighing in each fishing area have differed over time, as have the sampling protocols. The sampling protocol was updated in January 2019 and standardized across all fishing areas. Processing facilities are now expected to sample 100 individuals for round and split weight from each trip in all areas. Fishers are encouraged to set aside samples from each area if more than one area (Zone, AOA, or area within these) is fished in a trip to ensure zone specific indicators are available.

Table 1. Annual round and split weight averages of port sampled Sea Cucumber from the Maritimes Region. The methods used to measure split weights may differ among areas.

Area	Fishing Season	# Samples	Avg. Round Weight(g)	Avg. Split Weight(g)
SWNB	2019	2522	167	133
	2018	750	187	145
	2017	660	183	143
	2016	619	196	154
	2015	619	202	163
	2014	660	211	175
	2013	660	216	174
	2012	760	229	178
	2011	640	208	n/a
	2010	600	219	n/a
	2009	n/a	n/a	n/a
	2008	1660	225	n/a
	2007	1140	236	n/a
	2006	1420	208	n/a
	2005	1699	236	n/a
	2004	1040	256	n/a

Area	Fishing Season	# Samples	Avg. Round Weight(g)	Avg. Split Weight(g)
4W Mid-shore	2017/18	1903	184	109
	2016/17	1702	164	101
	2015/16	4850	165	109
	2014/15	2174	202	102
	2013/14	2100	161	108
	2012/13	299	191	n/a
	2011/12	300	193	n/a
	2010/11	100	248	n/a
	2009/10	200	239	n/a
	2008/09	160	351	n/a
4W Offshore Zone 1	2017/18	700	207	127
	2016/17	1310	214	126
	2015/16	651	279	158
	2014/15	700	182	120
	2013/14	1625	236	135
	2012/13	199	247	217
	2011/12	120	198	136
	2010/11	120	284	n/a
	2009/10	200	303	n/a
	2008/09	120	399	n/a
4W Offshore Zone 2	2017/18	1000	248	153
	2016/17	700	221	139
	2015/16	849	316	161
	2014/15	1000	225	155
	2013/14	300	244	143
	2012/13	120	221	203
	2011/12	60	212	n/a
4Vs Offshore	2017/18	1600	n/a	357
	2016/17	1800	n/a	262
	2015/16	380	n/a	357
	2014/15	320	n/a	342
	2013/14	400	n/a	349
	2012/13	140	n/a	344
	2011/12	220	n/a	344
	2010/11	n/a	n/a	156
	2009/10	n/a	n/a	279

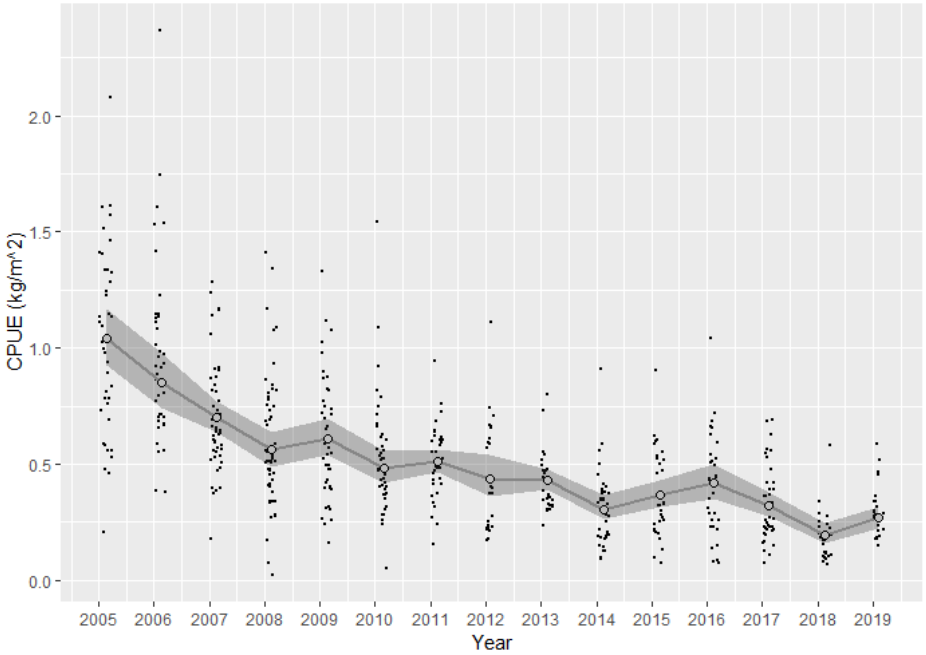


Figure 4. Sea Cucumber catch rates (kg/m^2) in Zone 1 of Southwest New Brunswick from fisheries logbook data. Small black dots are daily catch rates, and the larger grey dots represent annual mean catch rates. The shaded gray area represents the 95% confidence interval.

Reference Points

Limit Reference Points (LRP) were established for each Sea Cucumber fishing area in the Maritimes Region that have been regularly fished, including SWNB Zone 1, 4W Offshore Zones 1 & 2, 4W Mid-shore Zone F, and 4Vs AOA2. For each fishing area, a proxy for B_0 (the highest mean catch rate in the time series) was used as the basis for setting LRPs. The decision to use the highest mean catch rate in the time series as the proxy for B_o, rather than the catch rate from the first year of fishing, is based on the assumption that the catch rates in the early years of the fishery are not a true representation of potential catch rates given the exploratory nature of the fishery during that time.

The approach to setting LRPs in the Mid-shore/Offshore fishing areas was consistent. The LRPs were set as 20% of the B_0 proxy based on the kg/m^2 indicator. This is expected to be precautionary, corresponding to 50% BMSY (Hilborn and Stokes 2010). The basis for establishing 20% of B_0 was reached by defining BMSY as 40% of B_0, a generally accepted 'default' proxy for BMSY (Hilborn and Stokes 2010), and setting the LRP as 50% of BMSY. Reference points for each zone are as follows:

- 4W Offshore Zones 1: 0.045 kg/m^2
- 4W Offshore Zone 2: 0.061 kg/m^2
- 4W Mid-shore Zone F: 0.127 kg/m^2
- 4Vs AOA2: 0.052 kg/m^2

For SWNB Zone 1, the LRP was based on the kg/hr*m catch rate indicator. The highest catch rate in the time series was again used as the proxy for B_0 and the LRP was set at 30% of B_0 (811.53 kg/hr*m) (Figure 5). This is more precautionary compared to the other Sea Cucumber fishing areas in the Maritimes Region due to consistently declining indicators over 15 years

(catch rates and size-based) and the risk associated with fishing the majority of available Sea Cucumber habitat in SWNB.

Globally, 20% of B_0 has been commonly applied as an LRP in fisheries management for sea cucumber fisheries (Hart et al. 2018); however, some have suggested caution using this approach, as inaccuracies in estimating B_0 driven by the assumption of stationarity (i.e., no density-dependent processes) has resulted in critical thresholds set below the range of observations (Hilborn and Stokes 2010). Sea Cucumber populations in the Maritimes Region are expected to be density-dependent; however, an LRP of 20% B_0 was considered appropriate for the Mid-shore and Offshore fishing areas because: i) the catch rate indicators have been stable over their respective time series; ii) spatial reserves are currently in place for 4Vs Offshore with the option for licence holders to establish reserves in the other Mid-shore and Offshore fishing areas; and iii) fishers have the voluntary option to move fishing effort to other zones within their management area. In SWNB, indicators have been declining since the beginning of the time series and fishing is concentrated in Zone 1, with limited available habitat outside of Zone 1; therefore, a more precautionary LRP was set for SWNB Zone 1 at 30% of the B_0 proxy.

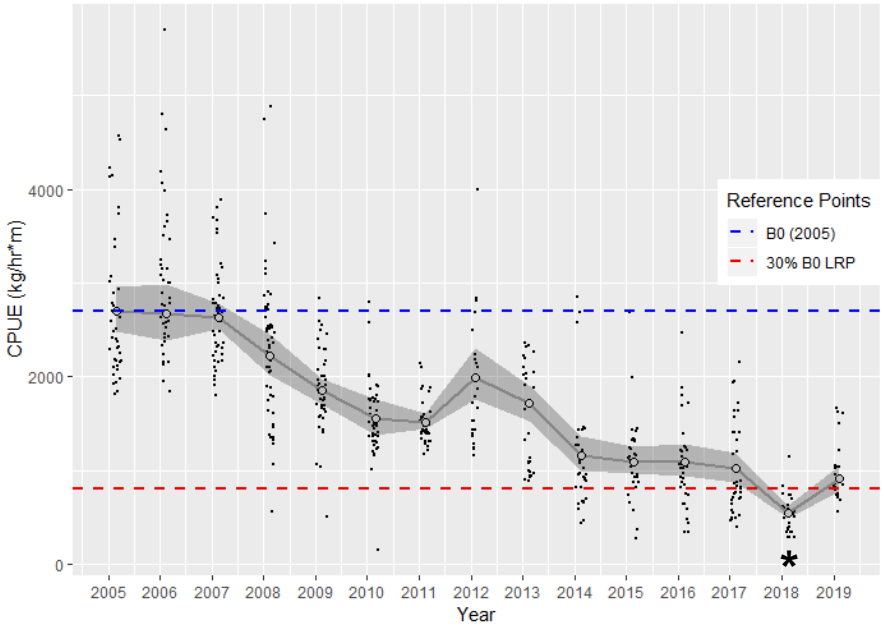


*Figure 5. Sea Cucumber catch rates (kg/hr*m) for Southwest New Brunswick Zone 1 from fisheries logbook data from one licence holder. Small black dots are daily catch rates, and the larger grey dots represent yearly mean catch rates. The shaded gray area represents the 95% confidence intervals. The blue line represents B_0 proxy (virgin biomass) based on the 2005 catch rate value. The red line represents the Limit Reference Point of 30% of the B_0 proxy. The 2018 mean catch rate value is marked with an asterisk as a reminder to interpret the value with caution as unusual environmental conditions and mechanical problems with vessels affected the reliability of the 2018 mean catch rate.*

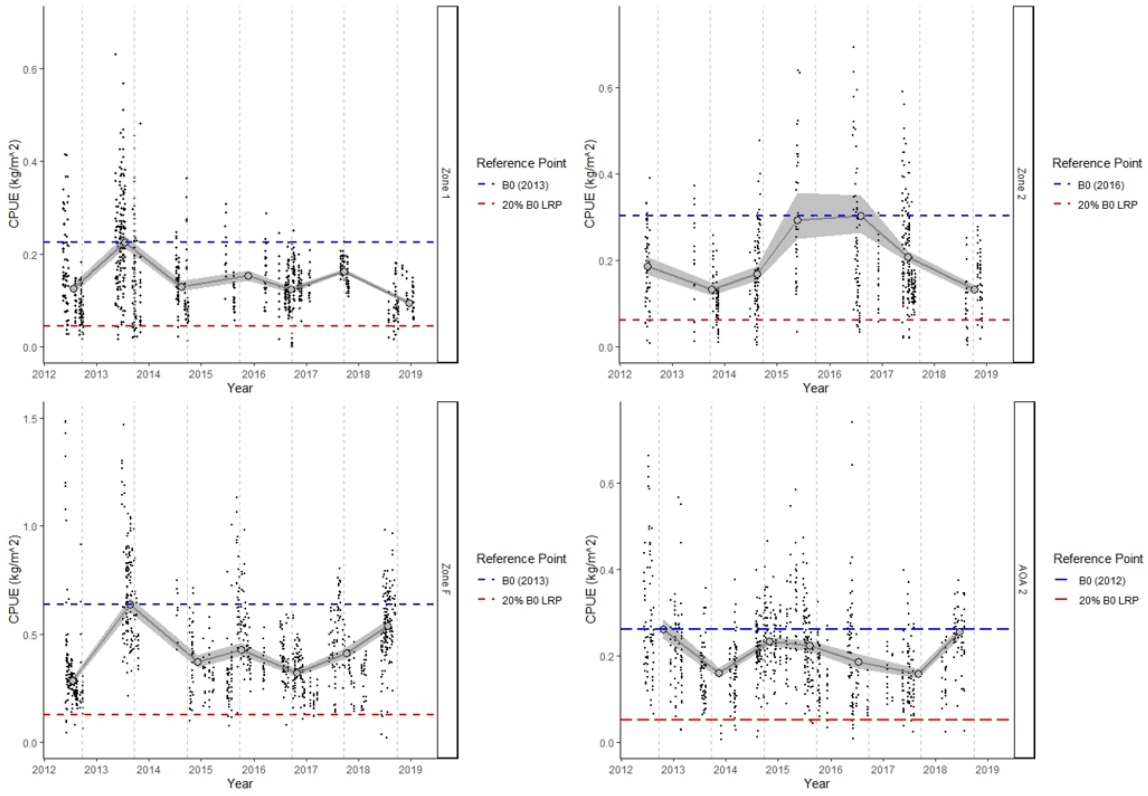


Figure 6. Catch rates (kg/m^2) of Sea Cucumber in 4W Zone 1 (top left), 4W Zone 2 (top right), 4W Mid-shore Zone F (bottom left), and 4Vs AOA 2 (bottom right) from fisheries logbook data. Small black dots are daily catch rates, and the larger grey dots represent yearly mean catch rates. The shaded gray area represents the 95% confidence intervals. The blue lines represent B_0 (virgin biomass) based on the highest catch rate for the respective time series, while the red lines represent the Limit Reference Point of 20% of B_0. Please note that the CPUE scale for area Zone F is different.

Assessment of SWNB Sea Cucumber

The status of the SWNB Sea Cucumber population is unknown. The assessment of SWNB Sea Cucumber is based on catch rate (kg/hr*m) and size-based indicators. Exploration of the SWNB data revealed issues with the quality and consistency of the information recorded on commercial log sheets, as well as the efficiency in fishing practices between the two licence holders. Due to a variety of issues, catch rate indicators for SWNB Zone 1 were based on records from only one licence holder (Martin and Greenlaw unpublished report[1]).

There has been a decline in catch rates over the past 14 years. The decline in the kg/hr*m indicator from 2005–2019 was 66% (Figure 5), while the decline in kg/m^2 was 73% (Figure 4). It should be noted that catch rate indicators for the 2018 fishing season are considered unreliable as unusual environmental conditions and mechanical problems with one vessel affected fishing, and, ultimately, catch rates for that vessel. The catch rate based indicator is currently near the LRP and in the cautious zone. Focus should be on rebuilding the population.

Indicators based on size (average split weight and round weight) have been declining since the start of the time series (Table 1; Figure 7). At the start of the fishery, only round weight was

[1] Martin, R. and M. Greenlaw. Guidance for Setting Reference Points for the Sea Cucumber (*Cucumaria Frondosa*) Fishery in the Maritimes Region and Status of the SWNB Sea Cucumber Fishery 2019. DFO Unpublished Report.

recorded. This is a problematic indicator due to the Sea Cucumber's ability to absorb and dispel water. However, the average round weight indicator has declined 35% since the beginning of the time series in 2004 (Table 1). Split weight is considered a better indicator than round weight and has declined 25% since it started being recorded in 2012 (Table 1). Annual split weight frequencies show a similar decline in the proportion of larger Sea Cucumbers and potential truncation of size classes (Figure 7).

The fishery is not currently providing the necessary information to allow a detailed assessment and evaluation of the impacts of the fishery on the SWNB Sea Cucumber stock. Collection of better monitoring data would provide a link between the catch rate data and the population in SWNB. The collection of split weight data and indicators based on catch rate remain important until there is an adequate time series of fishery-independent monitoring information. Currently, there are no surveys available in the Maritimes Region that adequately sample sea cucumbers. Therefore, any assessment must be based on fishery-dependent data, such as catch rates. Camera surveys have been completed by industry in the 4W offshore area between 2015 and 2019 and are being further explored as a fishery-independent data source to estimate annual biomass.

Based on previous surveys and fishing patterns (Rowe et al. 2009), the SWNB Sea Cucumber population is presumed to be highly aggregated. In Zone 1, the catch rate and body weight indicators have been declining since the start of the fishery. These declines could be higher than observed due to hyperstability of the indicators, which is commonly associated with species that aggregate (Orensanz et al. 1998).

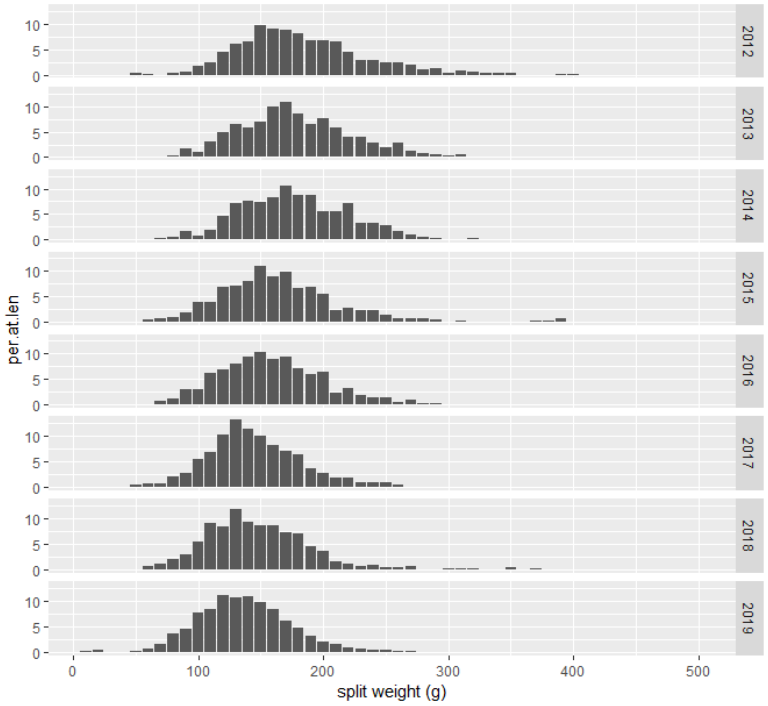


Figure 7. Sea Cucumber split weight frequencies collected from SWNB Zone 1.

Guidance for Establishing Reserves

Recent reviews of sea cucumber fisheries management in other areas have highlighted sustainable practices to meet conservation, social, and economic objectives in the long term (Anderson et al. 2011; Friedman et al. 2008, 2011; Purcell 2010; Purcell et al. 2013). Rotational

or permanent fishery reserves have become part of a common adaptive management plan for the protection of sea cucumbers populations (Humble et al. 2007; Plaganyi et al. 2015; Purcell 2010). Reserves would also protect the population against overexploitation if catch rate based indicators remain stable as the population declines (i.e., hyperstability). This is often the case for strongly aggregating species such as sea cucumber (Orensanz et al. 1998).

Studies suggest that marine reserves for sea cucumber need not be large to protect breeding populations (Sale et al. 2005). Subpopulations of sea cucumbers are expected to be interconnected through dispersal of larvae from spawning events, and the spatial structure of stocks tends to persist over a long time (Purcell 2010). Reserve sizes of 0.5–3 km^2 have been suggested (Purcell 2010), although possibly more important for maintaining critical spawning density is the quality and amount of habitat set aside (Shackell et al. 2013, Purcell 2010). Limited guidance is available for the percentage of habitat that is important for protection of the breeding stock; however, many have suggested 30% may be sufficient to preserve sea cucumber stocks (Purcell 2010).

In the 4Vs Offshore fishing area, sea cucumber reserves were designated in the 2018–19 fishing season (Figure 3). These were added in response to DFO Science's 2017–18 review of industry indicator reports from previous seasons. The review highlighted concerns with fishing activities concentrated in one small area.

To establish reserves in 4Vs Offshore and provide guidance on potential reserve placement in 4W Offshore, an 'expected habitat' map of *C. frondosa* was created (Figure 8). This map presents expected habitat classes for *C. frondosa*, classifying habitat into Primary, Secondary, and Tertiary Habitat, based on DFO's annual Research Vessel (RV) Ecosystem and Snow Crab surveys. Broad guidance was given to set aside at least 30% of expected sea cucumber habitat from fishing activity.

Fishing areas in 4Vs were changed from round to square as they are easier to visualize while at sea. Other requirements of reserves were to:

- avoid Ecologically and Biologically Significant Areas,
- survey the reserve sites with camera or trawl to ground truth areas and verify that they would be considered Primary, Secondary, or Tertiary 'expected *C. frondosa* habitat'

The expected habitat map should be updated, and reserves validated, as more information becomes available.

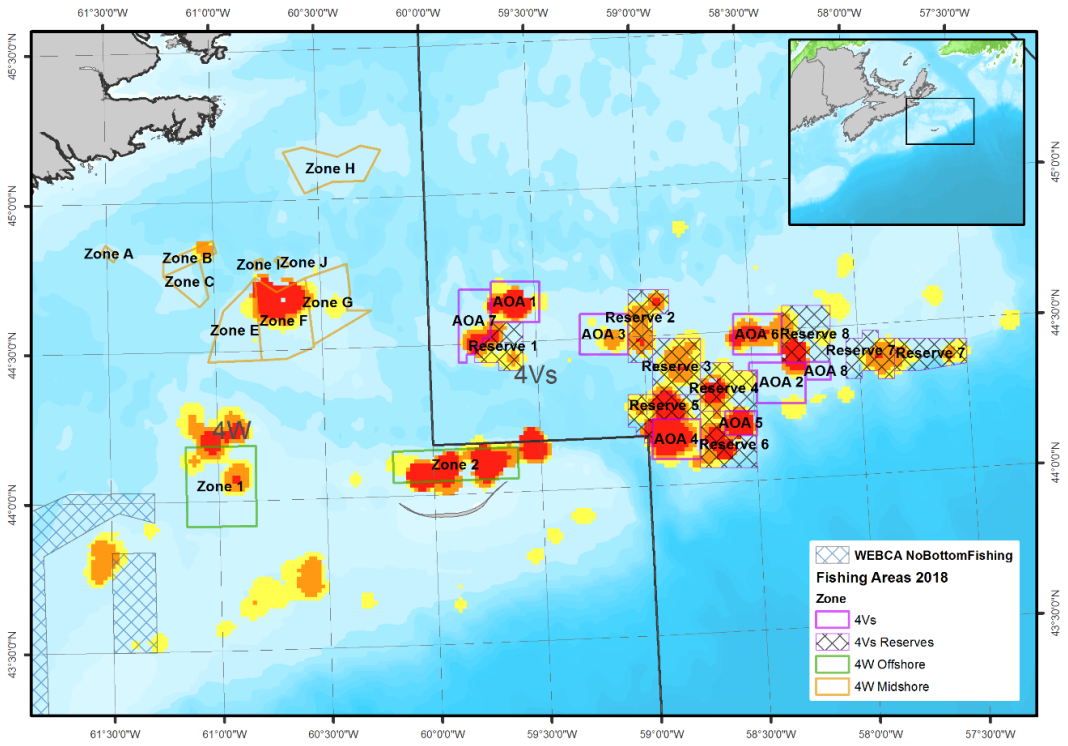


Figure 8. The current distribution of Sea Cucumber fishing Zones, Areas of Access (AOAs), and reserves in NAFO Divisions 4W and 4Vs, overlayed onto the the final expected C. fondosa habitat map, classified into Primary, Secondary, and Tertiary habitats.

Sources of Uncertainty

The current catch rate (kg/m^2) is based on a calculated shortest distance between two points for SWNB; however, not all tows are linear. Curved tows are recorded on logbooks for all fishing areas in the Maritimes Region and should be considered when calculating catch rates, as this could artificially increase the area-based indicator if tows are longer than calculated. Curved tows accounted for 59%, 27%, 36%, and 34% of the total tows (2012–18) for 4W Offshore Zone 1, 4W Offshore Zone 2, 4W Mid-shore Zone J, and 4Vs Offshore, respectively. In 4W, tow lengths are now recorded from navigational software on board vessels using the OLEX system. This provides an actual tow length and could be used in the future to remove uncertainty. Vessel Monitoring Systems (VMS) data could also provide a better understanding of where and how fishers actually tow. In SWNB Zone 1, curved tows accounted for 14% of all tows since they were first recorded in 2012; however, reference points are based on the kg/hr*m catch rate indicator, which removes the uncertainty in calculated distances due to curved tows.

Caution is warranted when using catch-rate-based indicators due to the possibility that catch rates may remain stable as the population declines (i.e. hyperstability). This phenomenon could occur for a variety of reasons associated with Sea Cucumber fishing. In SWNB, this could arise from spatial contraction of the stock to its preferred habitat; however, it was not possible to determine based on limited data available outside the expected preferred habitat. Another possible scenario in NAFO Divisions 4W and 4Vs could arise if fishers moved to ‘virgin’ or healthy patches, artificially stabilizing the indicators.

To examine the possibility of artificial stabilization of the catch rate indicators by rotating to new fishing Zones/AOAs, indicators were subdivided into records corresponding to sub-fishing areas

in NAFO Divisions 4W and 4Vs. In the majority of cases (4Vs AOA 2 and 4W Offshore Zones 1 & 2), moving to a new area did not influence catch rates, and catch rate indicators may be representative of stock status trends for the whole fishing area. However, there were differences present in 4W Mid-shore Zone F. After 6 years of fishing in one area, fishing moved to a new area approximately 5–6 miles from the original area and higher catch rates were evident in the data. The difference in catch rates between these two locations may warrant independent monitoring of sub-areas going forward, to ensure indicators are representative of the area fished.

In SWNB, one licence holder has been increasing tow times and distances since 2014. Although distance is accounted for in the catch rate indicators, there is a possibility that gear saturation (artificially decreasing catch rates as the gear fills up and can no longer retain more catch on longer tows) is occurring, or small aggregated beds exist in the area fished. Gear saturation is difficult to test in this fishery, as log sheets have not included information at the individual tow level. A cursory investigation into gear saturation compared catch rates for tows from 3–20 minutes to tows between 3–10 minutes (i.e., removing tows > 10 min). When longer tows were excluded, both catch-rate-based indicators (kg/m^2 and kg/hr*m) increased, suggesting that longer tows are not necessarily catching more Sea Cucumbers and that gear saturation may be occurring. To investigate sources of uncertainty, such as gear saturation or depletion, more thoroughly, it is recommended that the SWNB Sea Cucumber industry start recording catch details by set and provide precise fishing locations.

CONCLUSIONS

Current stock status indicators for Sea Cucumbers in the Maritimes Region are based on fishery-dependent information: catch rates and port sampled split weight. Indicators are presented for all fishing zones and areas that are regularly fished, including SWNB Zone 1, 4W Offshore Zones 1 & 2, 4W Mid-shore Zone F, and 4Vs AOA2. Catch rates for all areas are presented in kg/m^2, and an additional catch rate indicator, kg/hr*m, was presented for SWNB Zone 1. Average round and split weights are also available for all fishing areas and provide an additional size-based indicator to monitor in conjunction with catch rates.

Limit Reference Points (LRPs) were established for all areas based on the highest catch rates from their respective time series (B_0). The LRPs for 4W Offshore Zones 1 & 2, 4W Mid-shore Zone F, and 4Vs AOA2 were set as 20% of the B_0 proxies. The LRP for SWNB Zone 1 was set at 30% of the B_0 proxy. Reference points for SWNB Zone 1 are more precautionary due to the risk associated with fishing all known available habitat. Reference points should be re-evaluated as fishery-independent information becomes available and is verified.

The SWNB Sea Cucumber fishery has been in operation for 20 years in a relatively small harvesting area, outlasting many other sea cucumber fisheries globally; however, it is highly uncertain what levels of fishing would not cause further decline in the stock and allow for recovery within a reasonable time frame. In 2019, the SWNB Zone 1 TAC was reduced to 500 t; however, the catch rate indicator remains near the LRP. Further, split weights indicate the size distribution of the commercial catch has shifted to become composed of smaller animals.

Reserves and rotational harvesting are some of the options that can be used as effective spatial management tools for assumed low mobility species such as sea cucumber (Purcell 2010). If reserves are used, a broad guidance was given to set aside at least 30% of expected Sea Cucumber habitat from fishing, in data-limited situations. A map of expected *C. frondosa* habitat has been used as guidance for setting aside 30% of habitat on the Scotian Shelf (Figure 8). The map should be updated, and reserves validated, as more information becomes available. Any

strategy to set aside areas from fishing should be re-evaluated on a 3–5 year time period to ensure objectives are being met.

OTHER CONSIDERATIONS

New research or technology changes that may affect the indicators should be noted going forward, including further use of camera and multi-beam work to find Sea Cucumber aggregations. This could artificially stabilize indicators due to more efficient technology to find aggregations of Sea Cucumbers. Stabilization associated with movement to different areas was examined in this analysis by evaluating fishing areas at smaller sub-areas. This approach should be used similarly when new technology is introduced into the fishery.

Seasonal trends in split weight may be present in the Mid-shore/Offshore and should be investigated. It should also be noted that there is likely a relationship between the amount of water an individual Sea Cucumber holds and their size, with larger Sea Cucumbers likely holding more water. This should be investigated, including possible conversion factors between round weight and split weight by size to understand how the numbers of individuals caught per TAC will change with decreasing size composition in the population.

An examination of the existing observer data from this fishery should be undertaken to determine the usefulness for assessment and management purposes. The goals of the observer data program for this fishery should also be reviewed, as current coverage levels are rarely achieved.

It is recommended that a full assessment and review of reference points for the Maritimes Region Sea Cucumber fisheries be undertaken in 5 years or earlier if significant changes in indicator trends, fishery independent data, or fishing practices occur. Otherwise, informal updates should be provided to DFO Resource Management on an annual basis.

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SOURCES OF INFORMATION

This Science Advisory Report is from the May 28–30, 2019 regional peer review on the Review of Indicators and Reference Points for the Maritimes Region Sea Cucumber (Cucumaria frondosa), and Status of the southwest New Brunswick Sea Cucumber population. 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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