REDFISH (*SEBASTES MENTELLA* AND *S. FASCIATUS*) STOCKS ASSESSMENT IN UNITS 1 AND 2 IN 2019

Image: Redfish (Sebastes spp.)
Credit: Fisheries and Oceans Canada

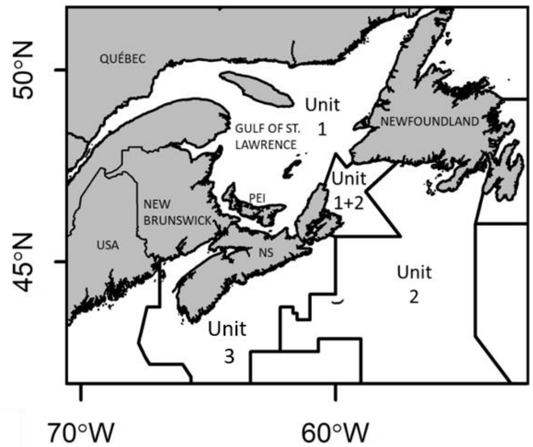

Figure 1. Units 1 and 2 Redfish stock management areas. The Unit 1+2 area, where Northwest Atlantic Fisheries Organization (NAFO) Subdivisions 3Pn and 4Vn are located, indicates the seasonal common area (January to May, Unit 1 and June to December, Unit 2).

Context

The Redfish index and experimental fisheries in Unit 1, and commercial fishery in Unit 2 harvest two Redfish species, Deepwater Redfish (Sebastes mentella) and Acadian Redfish (S. fasciatus), each considered a single stock in Units 1 and 2. Combined annual landings of both species and both Units dropped from over 100,000 t in the 1970s to less than 12,000 t as of 1995. Management measures have been applied to promote stock recovery for both species. Since 1995, the Redfish fishery has been under a moratorium in Unit 1 and a 2,000 t/year index fishery has been authorized since 1999. An experimental fishery in Unit 1 was established with an additional TAC of 2,500 t for 2018-2019 and 3,950 t for 2019-2020, which can be harvested all year round. There has been no moratorium on the commercial fishery in Unit 2 and the TAC has been 8,500 t/year since 2006.

In 2011, 2012 and 2013, three strong cohorts recruited to the stock. Genetic analyses have indicated that they were dominated by S. mentella associated with the Gulf of St. Lawrence ecotype. Since then, S. mentella biomass has increased in research surveys in each of Units 1 and 2.

This Science Advisory Report is from the January 20-22, 2020 meeting on the Assessment of Redfish Stocks (Sebastes mentella and S. fasciatus) in Units 1 and 2. Problems associated with important fishery and scientific source data for Unit 2 identified at the meeting prevented the provision of advice for Unit 2. Nonetheless, reference points for the two species covering both Units 1 and 2 were identified at the meeting. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada Science Advisory Schedule *as they become available.*

SUMMARY

- During the ongoing 2019-2020 fishery management year (preliminary data as of December 2019), Redfish landings reached 592 t in Unit 1 under the combined TAC for the index fishery (2,000 t) and the experimental fishery (3,950 t).
- From 2017 to 2019, the Unit 1 index fishery catch-per-unit-effort (CPUE) increased by a factor of 6.7, reaching the highest value since 1980.
- Bycatch represented 9% of total landings in the Redfish index and experimental fisheries in Unit 1 from 2000 to 2019. The main bycatch species were Greenland Halibut, White Hake, Atlantic Cod, and Atlantic Halibut. Forecasted increase in Redfish fishing effort could increase the incidental catch of several species, including some depleted species.
- Based on historical knowledge and preliminary analysis, bycatch and undersized Redfish catches could be mitigated by modifying fishing gear, fishing deeper than 300 m, and avoiding fishing during winter in the Laurentian Channel. However, reducing bycatch of multiple species could be challenging.
- Total minimum research survey trawlable biomass of *S. mentella* in 2019 was estimated at 4,365,000 t, the highest value observed in the time series (since 1984). Of that amount, 3,044,000 t were for fish larger than 22 cm (minimum regulatory size) and 497,000 t for fish larger than 25 cm.
- Total minimum research survey trawlable biomass of *S. fasciatus* was estimated to be 78,000 t in 2019, suggesting a decrease from 2017. Of that amount 57,000 t were for fish larger than 22 cm and 18,000 t for fish larger than 25 cm.
- In the summer 2019, the modal size for the 2011 to 2013 Redfish cohorts was 23 cm. If the anticipated growth of these cohorts continues, 51% of the individuals of the 2011 cohort should be larger than 25 cm by 2020.
- In the research survey in 2019, Redfish accounted for 90% of the total captured biomass as compared to 15% between 1995 and 2012. This relative biomass of Redfish is unprecedented and could have important ecological impacts on other species.
- A limit reference point (LRP), and proposed upper stock reference point (USR) were estimated for the two species for both management Units 1 and 2, based on surveys in Unit 1. For *S. mentella*, LRP and USR were estimated at 43 kt and 265 kt, respectively. For *S. fasciatus*, LRP and USR were estimated at 25 kt and 168 kt, respectively.
- In 2019, based on the empirical reference points, *S. mentella* was well above its proposed USR and therefore would be considered in the Healthy Zone. Estimates of adult abundance for 2019 were at or above levels that preceded declines since the mid-1980s that led the COSEWIC to designate the Gulf of St. Lawrence and Laurentian Channel Designable Unit (equivalent to Units 1 and 2) as endangered in 2010.
- In 2019, based on the empirical reference points, *S. fasciatus* was between the LRP and proposed USR and therefore would be considered in the Cautious Zone.
- Advice for Redfish in Unit 2 could not be provided due to data limitations and meeting time constraints.

BACKGROUND

Species biology

Redfish inhabit cold waters along the slopes of banks and deep channels at depths ranging from 100 to 700 m. *Sebastes mentella* is typically found in deeper waters than *S. fasciatus*. In the Gulf of St. Lawrence (GSL) and Laurentian Channel, *S. mentella* is found primarily in the main channels at depths ranging from 200 to 400 m. In contrast, *S. fasciatus* is present mainly at depths of less than 300 m, along the slopes of channels and on the banks, except in the Laurentian Fan, where it inhabits deeper waters. Redfish reside near the bottom during the day, leaving the sea floor at night to follow their prey as they migrate.

Redfish are slow growing and long lived species. *S. fasciatus* grows more slowly than *S. mentella*, although this difference in growth rates only becomes obvious after 10 years of age. In both species, females grow faster than males after about 10 years of age. On average, it takes Redfish seven to eight years to reach the 22 cm minimum legal size. Based on the information currently available, males reach sexual maturity one to two years earlier than females. Male *S. mentella* mature at 9 years (length at 50% maturity, L50: 22.8 cm) and females at 10 years (L50: 25.4 cm), whereas males *S. fasciatus* mature at 7 years (L50: 19.6 cm) and females at 9 years (L50: 24.1 cm).

Unlike many cold-water marine fish species, Redfish are ovoviviparous. Copulation occurs in the fall, most likely between September and December, and the females carry developing embryos until they are extruded in spring at the larval stage when they are able to swim. Larval extrusion occurs from April to July, depending on the area and species. Copulation and larval extrusion do not necessarily occur in the same locations. In the GSL, *S. mentella* releases its larvae approximately three to four weeks earlier than *S. fasciatus*. The larvae develop in surface waters and juveniles gradually migrate to greater depths as they grow.

Stock structure based on genomics

New genomic analyses from samples collected from 2001 to 2015 confirmed a pronounced genetic distinction between *S. mentella* and *S. fasciatus*, despite strong morphological similarity between these species. Three distinct ecotypes of *S. mentella* were characterised in the Northwest Atlantic: deep, shallow, and Gulf (GSL) (Figure 2). Surprisingly, 33 individuals of *S. mentella* GSL ecotype were sampled outside of Units 1 and 2, in sites associated with the *S. mentella* shallow ecotype, indicating mixed ecotype composition in the NAFO Divisions from 2G to 3K. At least five populations of *S. fasciatus* were identified, three occurring within the GSL. *S. fasciatus* samples near Strait of Belle Isle were also grouped with samples from Northeast Newfoundland, indicating gene flow and therefore migration between the GSL and the southern Labrador Sea via the Strait of Belle Isle. This result indicates a mismatch between stock structure and management units. Sample sizes in the Laurentian Fan area for the new genomic analyses were not sufficient to confirm or refute previous conclusions about a distinct population of *S. fasciatus* in that area.

It is very difficult to distinguish *S. mentella* and *S. fasciatus* morphologically and too costly to distinguish them genetically in large scale fishery and scientific monitoring. However, species composition of samples can be inferred using anal fin ray (AFR) counts. This technique may be sensitive to sample size which may underestimate or overestimate the contribution of a given species.

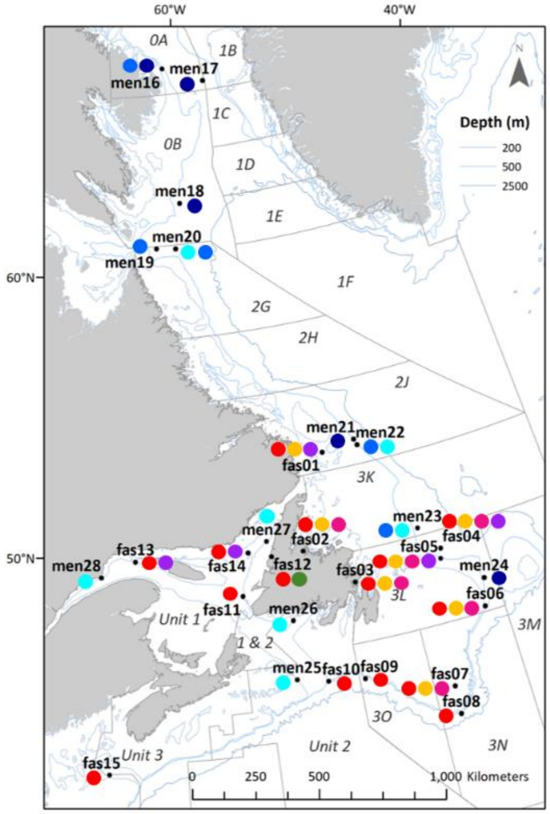

Figure 2. Map of the 28 locations (black points) sampled from 2001 to 2015 in the Northwest Atlantic. The colored points next to each sampling point indicate the presence of genetic clusters. A genetic cluster was indicated as present if one individual showed at least 50% associated ancestry in the sampling area. Three ecotypes were described for S. mentella: GSL (cyan), shallow (blue), and deep (dark blue). Five populations were described for S. fasciatus and are indicated by color: red, yellow, green, pink, and purple.

Recruitment events

In the Northwest Atlantic, annual recruitment in Redfish is characterized by low abundances punctuated by sporadic strong recruitment events. Genetic analysis results have indicated that around 1980, Units 1 and 2 produced the last strong year-class of *S. mentella*, which subsequently greatly contributed to the fishery. Until 2011, all other strong year-classes found in Units 1 and/or 2 (1974, 1985, 1988, and 2003) were identified as *S. fasciatus*. These initially strong year-classes, particularly associated with Unit 1, decreased significantly within a few years without contributing significantly to adult populations and the fishery. Ocean currents and aged-based spatial and temporal abundance trends suggest that these *S. fasciatus* only used the GSL as a nursery.

Recent DFO research surveys have observed three abundant Redfish year-classes in Unit 1, the 2011, 2012, and 2013 cohorts. These cohorts are the most abundant ever observed in the surveys. Genetic analyses performed on the 2011 cohort have indicated that 91% of these fish were *S. mentella* from the GSL ecotype. Current evidence suggests that these Redfish will remain in the area and should promote the recovery of *S. mentella* in Units 1 and 2.

Ecosystem

Oceanographic conditions in the GSL from 2011 to 2018 were generally warmer than historical averages. Temperatures in deep waters where Redfish reside have been increasing in recent years, reaching the highest levels observed at some depths (*e.g.,* 250 and 300 m). The bottom area covered by waters warmer than 6°C remained elevated in 2018 in the Anticosti Channel, Esquiman Channel and Central GSL, and increased sharply in the northwest GSL to a series high (Galbraith et al. 2019).

The GSL ecosystem was dominated by groundfish during the 1990s and subsequently dominated by forage species. Increases in Redfish have caused the ecosystem to shift back to one dominated by groundfish. In 2019, *Sebastes* spp. represented the most common taxon, accounting for 90% of the sampled biomass during the DFO survey in Unit 1, as compared to 15% between 1995 and 2012 (Figure 3). The combined biomass for both species increased by 72% compared to the 2017 estimate reported in the previous assessment for these stocks. This biomass increase may have important repercussions on other species, through predation and competitive interactions.

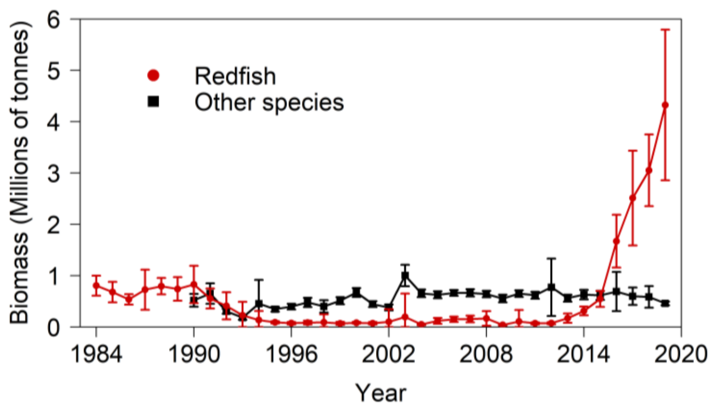

Figure 3. Trawlable biomass (millions of tonnes, with 95% confidence intervals) of Redfish spp. (red circles) and all other species (black squares) sampled in the Unit 1 DFO survey from 1984 to 2019.

The summer diet of Redfish in Unit 1 varies according to fish size (Figure 4). Redfish smaller than 25 cm consume mostly zooplankton. Once Redfish reach 25 cm, fish and shrimp (Pink Glass Shrimp, *Pasiphaea multidentata*, and Northern Shrimp, *Pandalus borealis*) become more prominent in the diet. It was estimated that approximately 81,000 t of Northern Shrimp was consumed annually by Redfish in the GSL during the 2017-2019 period. Although this estimate is highly uncertain, it clearly indicates an increase from 2017 to 2019. There are concerns that predation by Redfish may be contributing to important declines in Northern Shrimp abundance in the GSL.

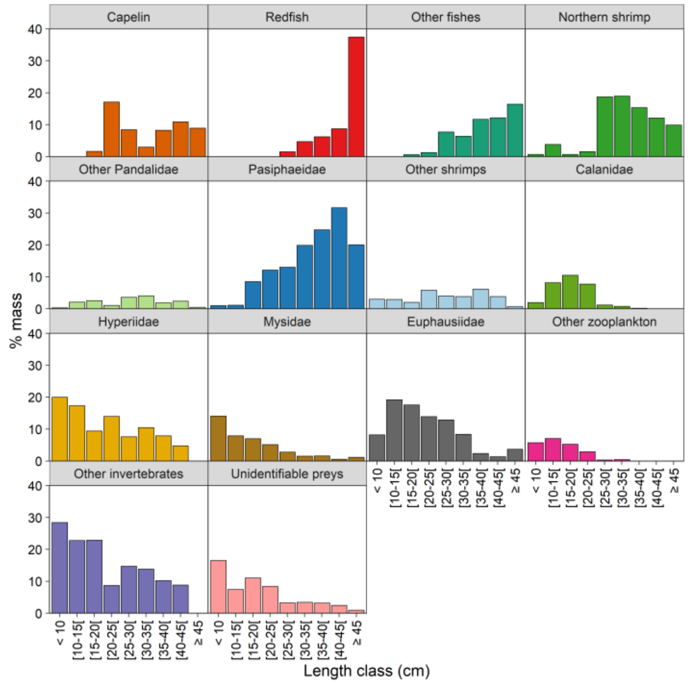

Figure 4. Redfish stomachs partial fullness index according to length class, and prey taxonomic group, based on sampling from 1993-2019.

ASSESSMENT

Fishery

In the late 1950s, a directed fishery for Redfish was developed in the GSL and the Laurentian Channel outside the GSL. In 1993, Redfish management units were redefined to better align with the biology of the stocks. The resulting management units were divided as follows: Unit 1, which includes Divisions 4RST and Subdivisions 3Pn4Vn from January to May; Unit 2, which includes Subdivisions 3Ps4Vs, Subdivisions 4Wfgj, and Subdivisions 3Pn4Vn from June to December; and Unit 3 which includes Subdivisions 4WdehklX (Figure 1).

The first total allowable catches (TAC) for Redfish, set according to the 1993 management structure, were 60,000 t in Unit 1 and 28 000 t in Unit 2. Following important reductions in stock abundance, a moratorium was implemented in Unit 1 while commercial fishing continued in Unit 2. TACs were fixed to 2,000 t/year in 1999 for the index fishery in Unit 1 and to 8,500 t/year in 2006 for the commercial fishery in Unit 2. With the arrival of the strong cohorts, an experimental fishery was established in Unit 1 with an additional TAC of 2,500 t for 2018-2019 and 3,950 t for 2019-2020, which can be harvested all year round. The objectives of the experimental fishery are to target *S. mentella*, which are currently more abundant than *S. fasciatus*, to investigate ways to limit bycatch of other species and undersized Redfish, and to better understand the spatio-temporal distribution of Redfish and bycatch species.

Redfish conservation measures for the index, experimental and commercial fisheries include: implementation of a protocol to protect small fish (< 22 cm), 100% dockside monitoring, mandatory hail reports upon departure and arrival, imposition of a level of coverage by at-sea observers and, implementation of a bycatch protocol (5% to 15% in Unit 1 and 10% for fleets > 65 feet using mobile gear in Unit 2). At-sea observer coverage was set at 25% or otherwise

10% in Unit 1 for vessels with a Vessel Monitoring System (VMS), and 10% for fixed gear and 5% to 20% for mobile gear in Unit 2. Closure periods were also introduced to 1) protect Redfish copulation (fall) and larval extrusion periods (spring), 2) minimize catches of Unit 1 Redfish migrating in Subdivisions 3Pn4Vn at the end of fall and winter, and 3) protect spawning Atlantic Cod (*Gadus morhua*, Divisions 4RS). In addition, since the index fishery was introduced in 1998, fishing has been allowed only between longitudes 59° and 65° at depths > 100 fathoms. To avoid Greenland Halibut (*Reinhardtius hippoglossoides*) bycatch, an area in NAFO Division 4T has been closed since August 2009.

New fisheries management measures for the conservation of corals and sponges have been put in place. Since December 15, 2017, 11 areas in the GSL, totaling an area of 8,571 km^2, have been closed to fisheries using gears that interact with the bottom, such as bottom trawls. Also, a marine protected area (MPA) was created in 2019 in the Laurentian channel in the south of Newfoundland. This MPA has an area of 11,580 km^2 and fishing with trawls is also prohibited. A second MPA located in NAFO Division 4T, the Banc-des-Américains MPA, does not occur in areas inhabited by Redfish.

Landings in Unit 1

The Redfish fishery has been characterized by two periods of high landings: the first in the 1970s where the landings reached more than 130,000 t, and the second in the early 1990s where the landings were close to 100,000 t (Figure 5).

In Unit 1, from 1965 to 1976, annual landings averaged 79,000 t, peaking at 136,000 t in 1973. From 1987 to 1992, average annual landings were 59,000 t. In 1995, a moratorium was imposed on the Redfish fishery due to low stock abundance and poor recruitment. Between 1999 and 2005, average annual landings from the index fishery and bycatch in other fisheries reached 1,054 t in Unit 1. On average, since 2010, 500 t of Redfish were caught annually. The additional experimental quota resulted in a small increase in preliminary estimates of landings in 2018 (748 t) and 2019 (592 t)

Several factors have influenced the landings in recent years including the absence of market and temporary closures associated with excess catches of undersized Redfish or bycatch. Landings are therefore not taken as a measure of stock status.

Landings in Unit 2

Due to inconsistencies in historical catch data and the possibility of error propagation throughout the time series of catches, a full examination of Unit 2 catch and bycatch was not possible, particularly with respect to analyses of landings by NAFO Division and gear type. These inconsistencies were created due to incomplete inclusion of all landings in Unit 2. Due to the above concerns, neither a fishery performance index (catch-per-unit-effort, CPUE) nor commercial length frequencies were calculated for Unit 2.

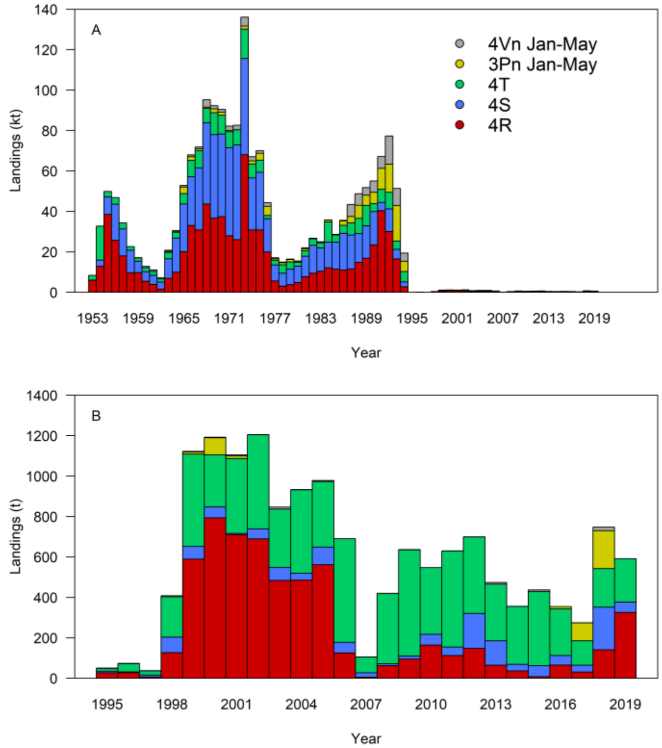

Figure 5. Commercial fishery annual Redfish landings in Unit 1 per NAFO Division and Subdivision from 1953 to 2019 (A, in kilotonnes) and from 1995-2019 (B, in tonnes). Data include fisheries directed to all species. No Redfish-directed fishery took place from 1995 to 1997. 2018 and 2019 values are preliminary.

Fishery performance index in Unit 1

Catch rates (CPUE) are considered as an index of fishery performance rather than a measure of changes in stock abundance for Redfish in Units 1 and 2. In Unit 1, CPUE from the commercial fishery (prior to the moratorium) and from the index fishery were standardized using a multiplicative model to produce an index representing fishing performance before and after the moratorium. This index shows high values prior to the moratorium, followed by a marked decrease in 1994. Between 1999 and 2007, the index was below or close to the time series average (1981-2018). Standardized CPUE started increasing in 2018, reaching an estimate in 2019 that is 6.7 times that of 2017 (Figure 6).

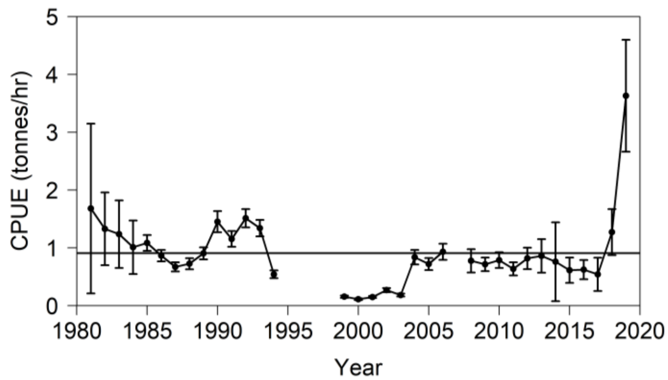

Figure 6. Standardized bottom trawl catch-per-unit-effort (CPUE with 95% confidence intervals) in the Unit 1 commercial fishery between May and October (1981-1994) and the index fishery (1999-2006 and 2008-2019). The solid line represents the series average. 2018 and 2019 values are preliminary.

Length frequency of commercial catches in Unit 1

From 1981 to 1988, commercial catch length frequencies in Unit 1 indicated that catches primarily consisted of Redfish born in the early 1970s (Figure 7). From 1988 to 2008, catches predominantly consisted of Redfish born in the early 1980s. From 1999 to 2016, most Redfish caught were larger than 30 cm. It appears that the 1980 year-class began to recruit to the fishery in 1987 and remained in catches for many years. Redfish larger than 30 cm were less frequent in 2018 and 2019, while catches were dominated by the 2011-2013 cohorts.

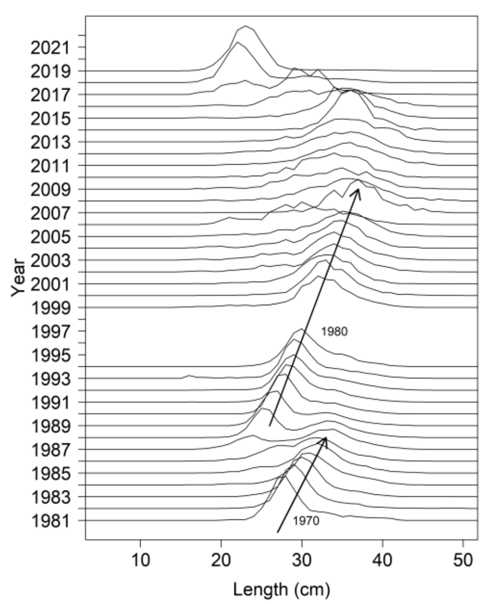

Figure 7. Commercial catch length frequencies in percentage in Unit 1 from 1981 to 2019. No Redfish directed fishery took place from 1995 to 1997. 2018 and 2019 values are preliminary.

Bycatch in Unit 1

Redfish captured in groundfish-directed fisheries must be landed and are therefore monitored in the dockside monitoring program. Since 2000, 93% of reported Redfish catches in Unit 1 have come from the directed Redfish fishery. Fisheries targeting Greenland Halibut and Atlantic Cod were responsible for 3% and 2% of Redfish landings on average, respectively. Bycatch of other species has constituted 9% on average of landings in the directed Redfish fishery (Figure 8a). The most common bycatch species were Greenland Halibut, White Hake (*Urophycis tenuis*), Atlantic Halibut (*Hippoglossus hippoglossus*), and Atlantic Cod (Figure 8b).

Potential drivers of bycatch rates (CPUE) in the Redfish-directed fishery in Unit 1 were examined using a two-part generalized linear model: a binomial model to analyze presence-absence, and a log-normal model to analyze positive CPUE values. The objective was to identify factors that might be relevant for minimizing unwanted bycatch, including the fishing gear, depth, season, and geographic area. Data for the analysis were limited to 1986-1990. This period was chosen because midwater and bottom trawl were used at a large spatial scale all year round. Results suggest that bycatch rates could be minimized by using midwater trawls, and avoiding fishing during winter in the Laurentian channel. However, this strategy may not be beneficial for White Hake and reducing bycatch rates of multiple species will be challenging (Table 1). The impact of different trawl types within the bottom and mid-water trawl categories could not be assessed. Furthermore, because the abundance of different bycatch species has changed since 1990, this result should only be interpreted as indicating potential mitigation measures.

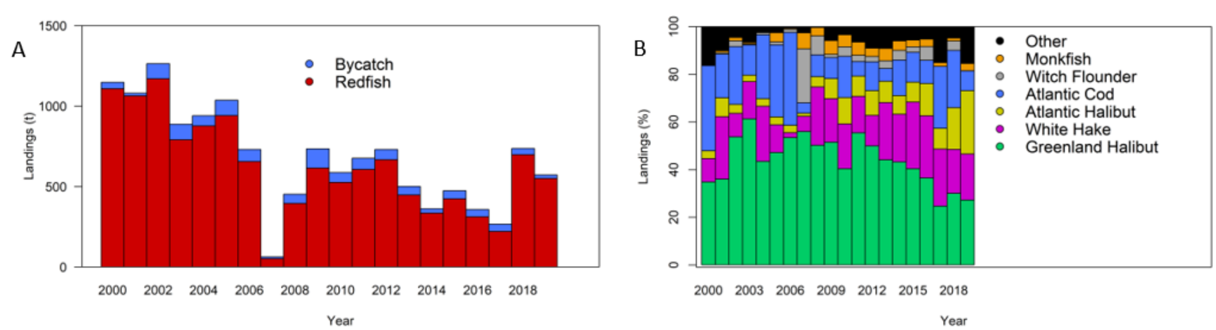

Figure 8. Declared landings (tonnes) of Redfish and bycatch species (A), and bycatch species composition (B, in percentage), in the directed Redfish fishery in Unit 1 from 2000 and 2019.

Table 1. Summary of the influence of gear, depth, season, and geographic areas on Redfish and bycatch CPUE quantified by generalized linear models. The directionality of significant drivers are indicated by arrows, where an increase in CPUE is illustrated by an upward arrow and a decrease by a downward arrow. Desirable effects (increase in Redfish CPUE and decrease in bycatch CPUE) are in green and disadvantageous effects in red.

Model	Variable	Redfish	Greenland Halibut	Atlantic Halibut	Atlantic Cod	White Hake
Binomial	Midwater trawl	↓	↓	↓	↑	↑
	Depth	-	↑	↓	↓	↑
	Winter	-	↑	-	↑	-
	Laurentian Hermitage area	-	↓	-	↑	↑
	NE Gulf area	-	-	↓	-	↑
Log-normal	Midwater trawl	↑	↓	↓	↓	-
	Depth	↓	↑	-	-	↑
	Winter	-	↑	-	↑	↓
	Laurentian Hermitage area	↓	-	↑	↑	↑
	NE Gulf area	-	-	-	-	↑

Recent trawl selectivity experiments

In July of 2019, Memorial University conducted a covered codend experiment in Unit 1 to compare the catch length composition of a regulated, diamond-shaped mesh codend with a 90 mm mesh opening to length composition for three different T90 codends with mesh sizes of 90, 100, and 110 mm. A T90 mesh codend turns the mesh 90° in the direction of the tow and has been shown to reduce the capture of small roundfish (Madsen *et al.* 2012, Bayse *et al.* 2016). Results, based on short (less than 20 min) tows, showed that the traditional codend was not size selective, catching greater than 97% of Redfish over all length classes available. Compared to the traditional codend, the T90 codend (90 and 100 mm mesh) would retain 30% fewer undersized Redfish (< 22 cm), while limiting reductions of legal-sized Redfish to 16%. The T90 codend with 110 mm mesh would retain 50% fewer undersized and 40% fewer Redfish larger than 22 cm. The T90 codend could therefore reduce the retention of small Redfish. However, commercial users of the T90 codend and preliminary results suggested a significant increase in the number of Redfish that were caught in the meshes (meshing). Although the number of fish was small, it could be higher in a commercial fishing application involving longer tows (> 2 hrs). Furthermore, the survival of Redfish passing through the mesh is not known and could generate some unaccounted mortality. In contrast, mortality from the traditional codend is largely accounted for in the landings data. In both cases, small Redfish mortality could potentially be managed by implementing protocols such as catch caps and temporary spatial closures to avoid catch once unacceptable levels have been observed.

Research surveys

A DFO bottom-trawl research survey has taken place annually in August in Unit 1 since 1984.

A biennial industry-led bottom-trawl research survey has been undertaken by the *Atlantic Groundfish Council (AGC; formerly the Groundfish Enterprise Allocation Council)* since 2000 in Unit 2. Due to inconsistencies in assessing the validity of anal fin ray counts and species composition from the Unit 2 industry survey, no biomass or abundance indices could be provided for Unit 2 in 2018. The lack of reliable survey indices has precluded the assessment of Unit 2 Redfish at this assessment.

Abundance and biomass indices, and length composition in Unit 1

Survey biomass indices for *S. mentella* and *S. fasciatus* declined sharply from the late 1980s to 1994 (Figure 9). Subsequently, the indices of small and large Redfish remained low and stable (Figure 10). The new cohorts (2011-2013), mainly dominated by the 2011 year-class, started being caught in the survey in 2013. These juveniles were largely dominated by *S. mentella*, with the genetic signature of the GSL ecotype.

In 2019, total minimum trawlable biomass was estimated to be 4,365,000 t for *S. mentella*, the highest value observed since 1984. Total minimum trawlable biomass of *S. fasciatus* was estimated to be 78,000 t, suggesting a decrease from 2017 to 2019 to values comparable to the 2014-2016 period (Figure 9).

Minimum trawlable biomass of Redfish greater than 22 cm in length began to increase in 2017. In 2019, it was estimated to be 3,044,000 t for *S. mentella*, an important increase. In contrast, minimum trawlable biomass was estimated to be 57,000 t for *S. fasciatus*, indicating a decrease from 2018 to 2019. Biomass of *S. mentella* greater than 25 cm in length increased from 56,000 t in 2017 to 497,000 t in 2019, whereas biomass of *S. fasciatus* decreased from 56,000 t in 2017 to 18,000 t in 2019 (Figure 10). In the summer 2019, Redfish modal size was 23 cm (Figure 11), suggesting that both species are following their anticipated growth curve. If the anticipated growth of these cohorts continues, 51% of the individuals from the 2011 cohort (62% biomass) should be larger than 25 cm by 2020.

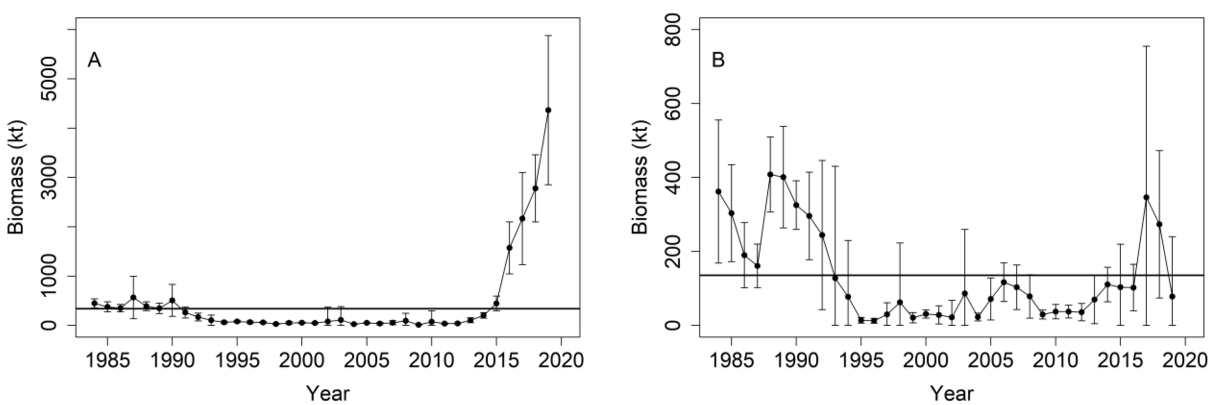

Figure 9. Minimum trawlable biomass in kilotonnes (kt, with 95% confidence intervals) of S. mentella (A) and S. fasciatus (B) in the Unit 1 DFO survey from 1984 to 2019. The solid lines represent the 1984-2018 average.

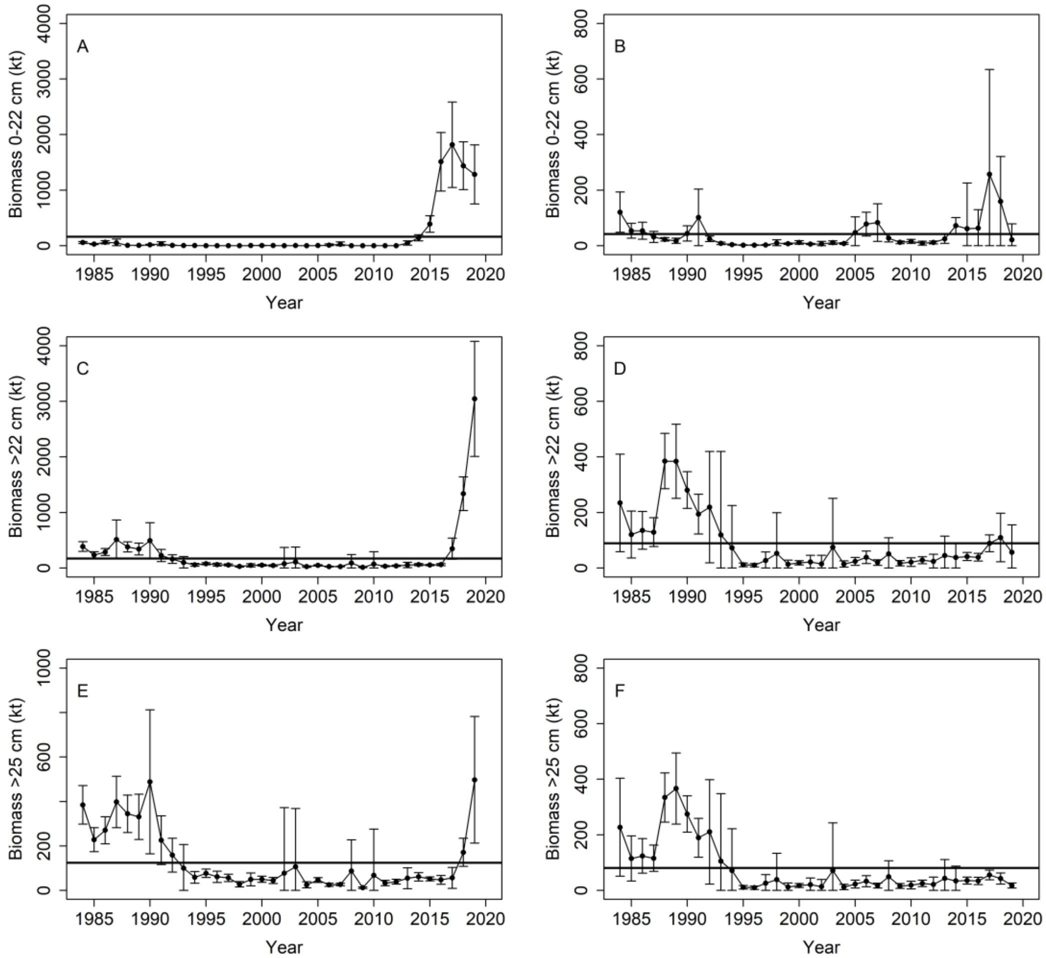

Figure 10. Trawlable biomass in kilotonnes (kt, with 95% confidence intervals) of S. mentella on the left side (A, C, and E) and S. fasciatus on the right side (B, D, and F) in the Unit 1 DFO survey from 1984 to 2019, by size classes: 0-22 cm (A-B), > 22 cm (C-D), and > 25 cm (E-F). The solid lines represent the mean for the 1984-2018 period.

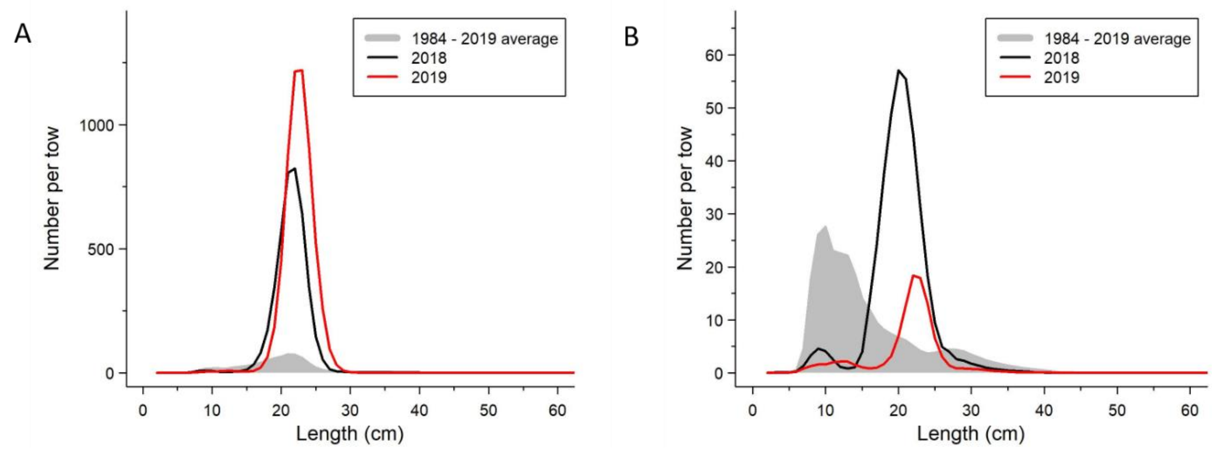

Figure 11. S. mentella (A) and S. fasciatus (B) length frequency in Unit 1 the DFO research survey for 2018, 2019, and the 1984 to 2019 average.

In 2010, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) designated the GSL and Laurentian Channel designable unit (DU) of *S. mentella* (equivalent to the Units 1 and 2 stock) as *endangered,* based on a 98% decline in mature fish abundance in the survey in Unit 1 (COSEWIC 2010). Since 2016, the abundance of mature *S. mentella* in the survey has exceeded the levels observed prior to the decline and abundance in 2019 was several fold higher than those levels (Figure 12a). A revision of the status by COSEWIC of this *S. mentella* DU appears warranted.

The Atlantic Population DU of *S. fasciatus* was designated as *threatened* by COSEWIC in 2010, based on a 99% decline in mature fish abundance over two generations (COSEWIC 2010). Units 1 and 2 *S. fasciatus* were believed to constitute a majority of the DU, which also includes the Labrador, Newfoundland and Scotian shelves. Abundance trends in the survey in Unit 1 were therefore influential in establishing the designation. Although the abundance of mature *S. fasciatus* in the survey in Unit 1 increased from 2013 to 2017, declines in the estimates in 2018 and 2019 suggest that it would be premature for COSEWIC to revisit the status of the DU (Figure 12b).

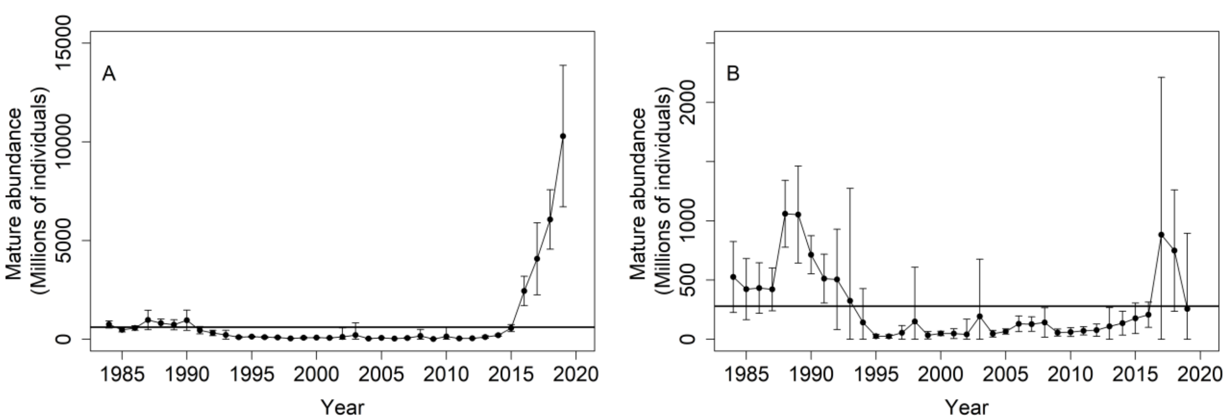

Figure 12. Trawlable mature fish abundance (millions of individuals, with 95% confidence intervals) of S. mentella (A) and S. fasciatus (B) in the Unit 1 DFO survey from 1984 to 2019. The solid lines represent the 1984-2018 average.

Spatial distribution in Unit 1

The spatial distribution of catch rates in the Unit 1 survey indicated that between 1984 and 1996, the Laurentian, Esquiman and Anticosti Channels were populated by both species (Figures 13-16). Subsequently, there was a substantial decrease in the density of mature individuals in both species particularly west of Anticosti Island and north of Esquiman Channel (Figures 14 and 16). Recently, density of immature and mature *S. mentella* has increased in the Esquiman, Anticosti, and Laurentian Channels, and the Southwestern edge of Cabot Strait (Figures 13 and 14).

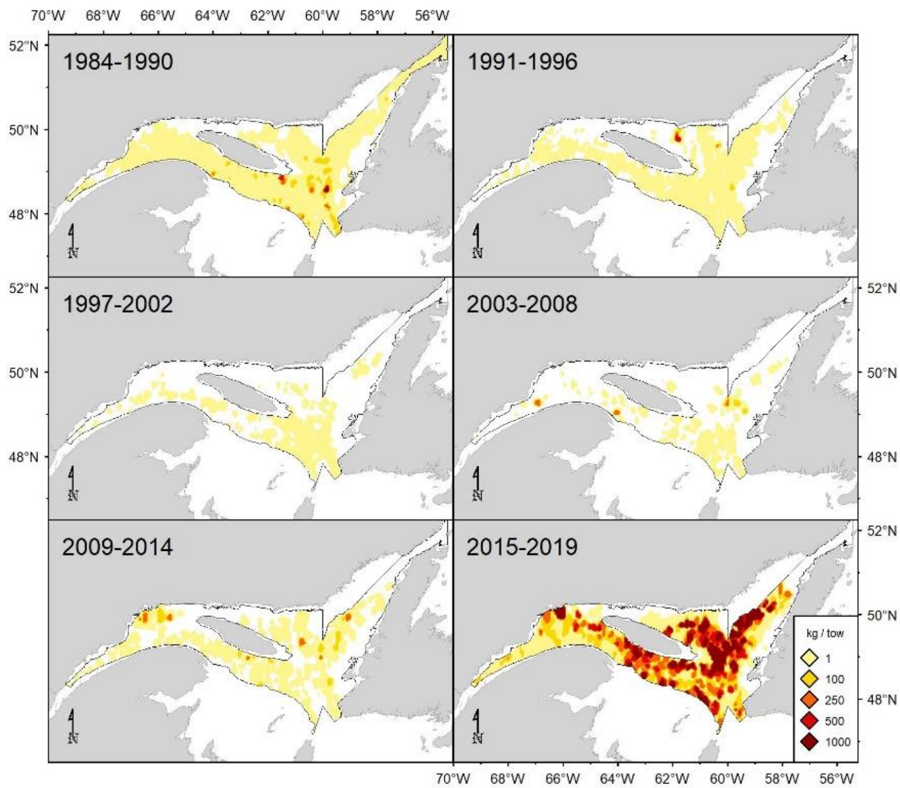

Figure 13. Catch rate distribution for immature S. mentella (kg/tow) in the Unit 1 DFO survey from 1984 to 2019.

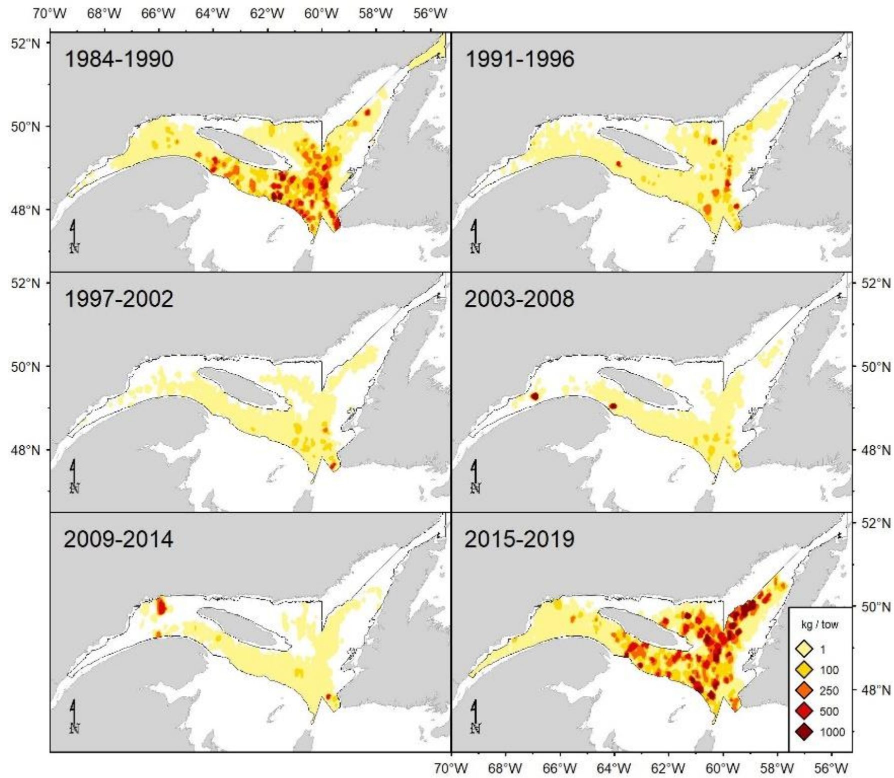

Figure 14. Catch rate distribution for mature S. mentella (kg/tow) in the Unit 1 DFO survey from 1984 to 2019.

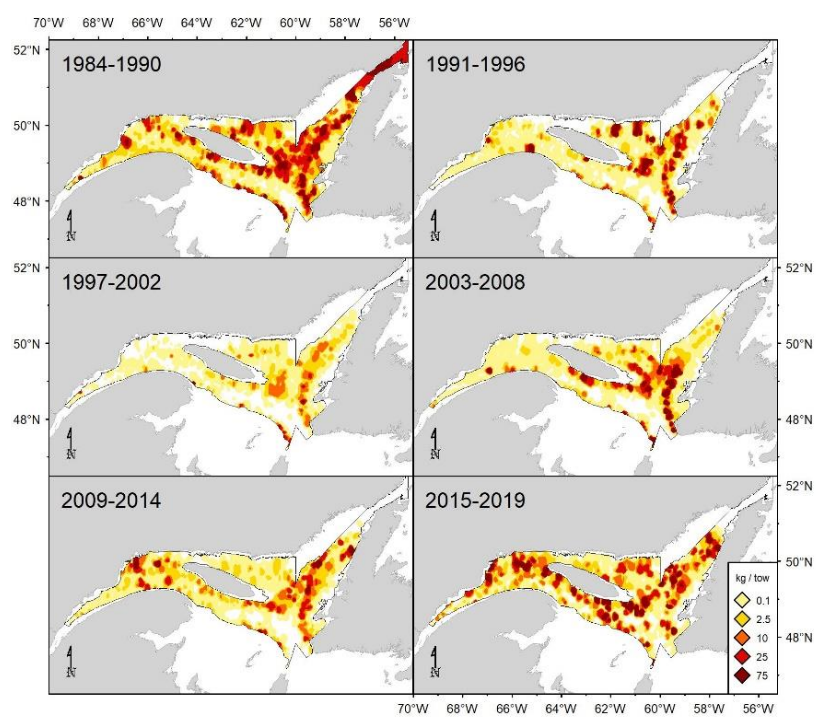

Figure 15. Catch rate distribution for immature S. fasciatus (kg/tow) in the Unit 1 DFO survey from 1984 to 2019.

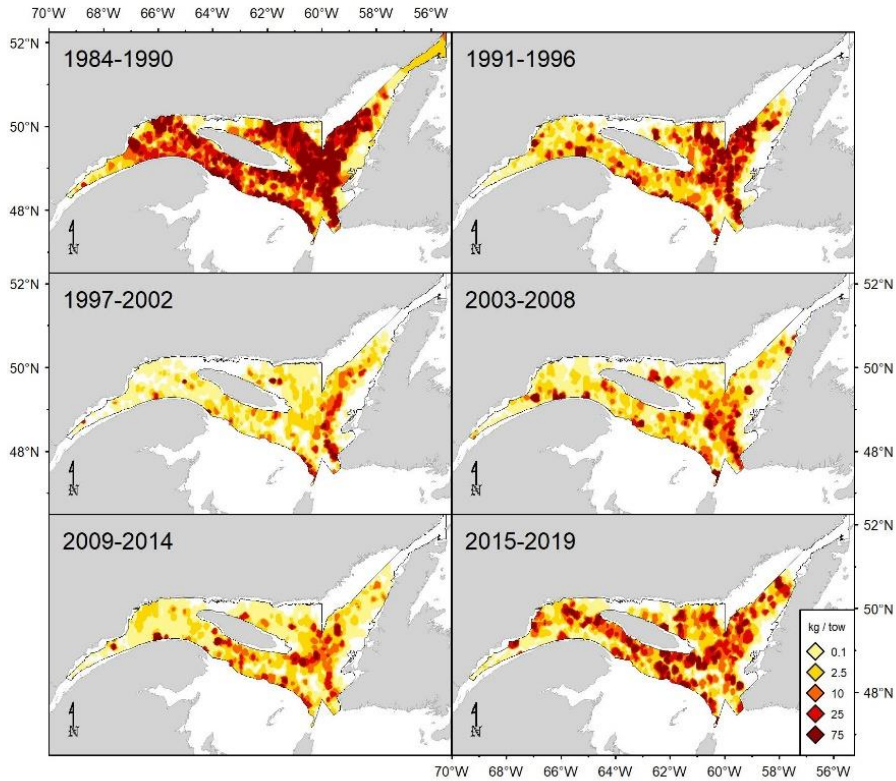

Figure 16. Catch rate distribution for mature S. fasciatus (kg/tow) in the Unit 1 DFO survey from 1984 to 2019.

Depth distribution in Unit 1

Based on the August research survey in Unit 1, both Redfish species are distributed according to depth (Figure 17). Although the depth distributions of the two species overlap, *S. mentella* is found deeper than *S. fasciatus*.

As Redfish grow, larger individuals appear to concentrate in deeper areas (Figure 18). From 1984 to 1994, 83% of the biomass corresponded to individuals larger than 25 cm distributed evenly between deep and shallow areas. Between 1995 and 2012, the stock was at low abundance and 50% of the biomass was composed of fish larger than 25 cm in deep areas. During this period, Redfish smaller than 22 cm corresponded in average to 20% of the biomass. In 2013, the arrival of new cohorts increased the biomass of Redfish smaller than 22 cm mainly in shallow areas (up to 77% in 2015). The percentage of the biomass composed of Redfish larger than 22 cm located in deep areas accessible to the fishery has been increasing steadily since 2017, reaching about 50% in 2019.

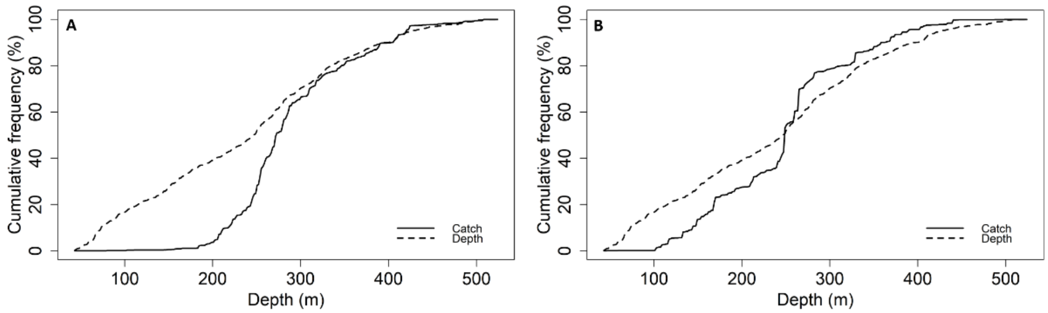

Figure 17. Depth distribution of S. mentella (A) and S. fasciatus (B) in the Unit 1 DFO survey from 2015-2019. The solid lines represent the cumulative frequency of Redfish catches with respect to depth, while the dotted lines reflect the cumulative distribution of available depths in the survey area.

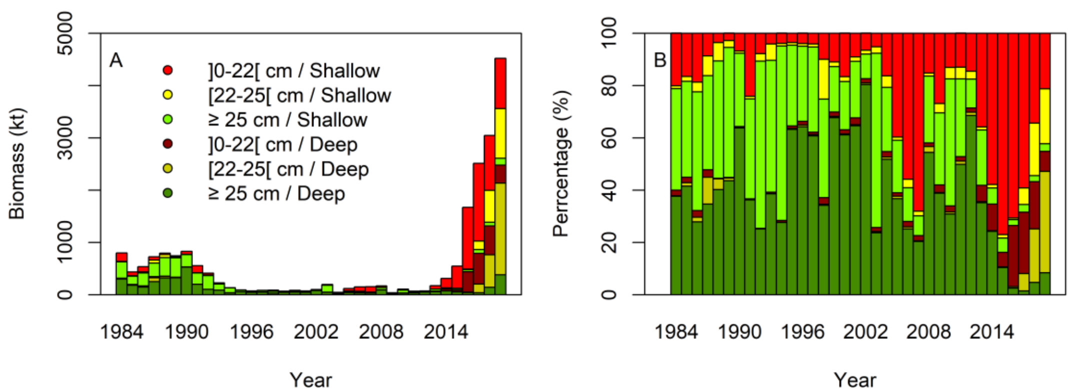

Figure 18. Redfish biomass in kilotonnes (A) and percentage (B) in the Unit 1 DFO survey (1984-2019) as a function of size classes ([0-22] cm, [22-25] cm, and ≥ 25 cm) and depth class areas ("Deep" or "Shallow"). Deep areas were defined as strata greater than 274 meters located between 59°W and 65°W (the area in which the index fishery takes place), while the "Shallow" areas constitute the rest of the study area.

Fishery closures

In Unit 1 an annual copulation closure from November 1 to March 31, and a larval extrusion closure from April 1st to June 15th were initially implemented to protect reproduction and promote Redfish recovery. In Unit 2, there is an annual larval extrusion closure from April 1st to June 30th, and a closure in NAFO Subdivisions 3Pn and 4Vn from October 1st to June 30th when Unit 1 Redfish were suspected to occur in these areas. According to published information, Unit 1 Redfish move from the GSL to deep waters of the Laurentian Channel (near the mouth of the GSL) to overwinter (Morin et al. 1994). In June, Redfish appeared to return to the GSL (Atkinson and Power 1991). Given the absence of winter surveys and year-round commercial fishing since the mid-1990s, it is not possible to determine if these previously inferred movement patterns remain valid and whether the fishery closures are still necessary. The GSL and Laurentian Channel are important habitats for Redfish and many other groundfish species including Greenland Halibut, White Hake, Atlantic Cod, and Atlantic Halibut. Notably, in winter Redfish may overlap with areas of aggregation for 4RS3Pn and 4T Atlantic Cod, and 4T White Hake, which are all depleted stocks, with the latter two considered at high risk of extirpation. The efficacy of the fishery closures for reducing bycatch of vulnerable species should be re-evaluated relative to other existing management measures.

Reference points

The biomass that produces maximum sustainable yield (B_{msy}) is unknown for both Redfish species, moreover the concept of B_{msy} may not apply for species producing such sporadic recruitment. Indeed, Units 1 and 2 Redfish do not display classical stock-recruitment dynamics and the concept of recruitment over-fishing appears difficult to apply. Throughout its history, periods of high Redfish biomass have been sustained by a very small number of large recruitment events. Redfish have recovered from low levels of spawning stock biomass (SSB). However there are SSB levels from which recovery will become unlikely or impossible. Consequently, a Limit Reference Point (LRP) was estimated as the smallest SSB from which there has been a recovery (B_{rec}) for *S. mentella*, or in the case of *S. fasciatus*, the SSB that produced recruitment that would likely produce recovery if those recruits were to not emigrate from the ecosystem. For both species, B_{rec} was estimated as the geometric mean of 2010-2012 SSB in the Unit 1 survey, i.e. the SSB which produced the 2011-2013 cohorts. The proposed LRP based on B_{rec} is based on a recent period of low SSB occurring in warm and apparently favorable environmental conditions that may not be unusual in the future, although the relationship with the environment is unknown. B_{rec} has been deemed an acceptable basis for the LRP for species with recruitment dynamics like Redfish (*e.g*., scallops).

A proposed Upper Stock Reference (USR) point was defined based on the DFO research survey in Unit 1 for a period of relatively high SSB and landings, considered to be a favorable period for the fishery: 1984-1990 for *S. mentella* and 1984-1992 for *S. fasciatus*. USRs were estimated as 80% of the SSB geometric mean during these periods. While these are not founded in recruitment-overfishing concepts, they do provide a defensible baseline for what has previously been considered a “healthy” stock.

For *S. mentella*, LRP and USR were estimated at 43 kt and 265 kt, respectively. In 2019, *S. mentella* SSB was estimated at 1,718 kt, 6.5 times larger than the USR, indicating that *S. mentella* is in the Healthy Zone of the Precautionary Approach (PA, Figure 19a). For *S. fasciatus*, LRP and USR were estimated at 25 kt and 168 kt, respectively. *S. fasciatus* SSB in 2019 was estimated at 49 kt, which is twice as large as the LRP and a third of the USR, indicating that *S. fasciatus* is presently in the Cautious Zone of the PA (Figure 19b).

The survey in Unit 2 was not used to define reference points. This survey started in 2000, after the target period used to define the USRs. Proposed reference points will need to be revised in the near term once new information is accumulated on the recruitment and dynamics of the Redfish species in Unit 2.

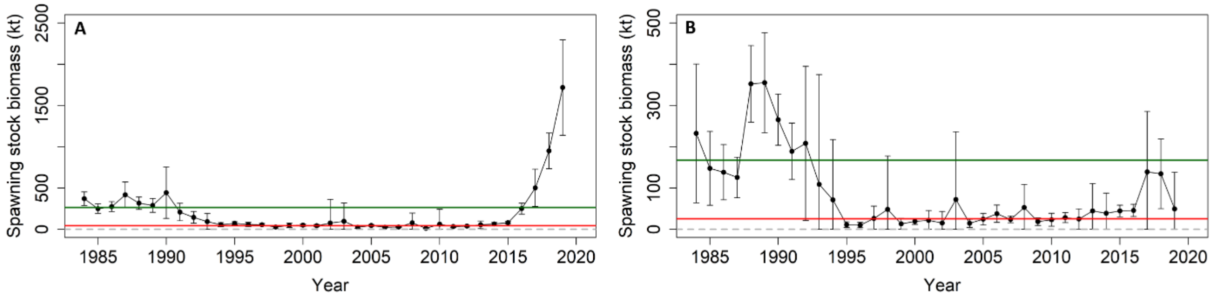

Figure 19. Spawning stock biomass (kilotonnes) in the Unit 1 DFO survey from 1984 to 2019 (black points with 95% confidence intervals), and the proposed Upper Stock Reference (green line) and Limit Reference Point (red line) for S. mentella (A) and S. fasciatus (B). The 0 y-axis value is indicated by a gray dashed line.

Sources of uncertainty

The absence of species identification in the commercial fishery is a major gap in the assessment of these stocks. Effort should be continued to provide training to at-sea observers and port samplers to obtain the soft anal fin ray counts required to determine species composition. Error in species attribution based on the counts should be quantified and the potential role of species misidentification in the perceived recent declines of *S. fasciatus*, the lesser abundant of the two species, should be investigated.

New genomic analyses could not confirm or refute the distinct population of *S. fasciatus,* in the southern edge of Unit 2 in the Laurentian Fan area, that was previously described as belonging to the Atlantic population of the continental shelf break. A larger sample size and a better spatial coverage of the area could improve inferences on populations structure based on genomics.

Bottom-trawl surveys only capture fish occurring a maximum of about 5 meters above the sea bed, possibly following some vertical herding of animals towards the bottom. However, acoustics indicate that Redfish in the GSL are distributed from the bottom up to hundreds of meters in the water column, suggesting that the bottom-trawl index may considerably underestimate total biomass. A project aiming to develop Redfish acoustic indices should provide a more accurate estimate of stock biomass by including fish distributed throughout the water column, and would assess whether bottom trawl survey biomass is representative of actual biomass.

The GSL ecosystem is changing and impacts on Redfish are mostly unknown. Important gaps in our understanding could be filled by research aimed at understanding the relationships between these changes (*e.g.,* increase in temperature, decrease in O_2, density-dependent responses) and Redfish physiology (*e.g.,* metabolism, growth) and demographic rates (*e.g.,* recruitment, mortality).

Most of the recent information for Redfish in Unit 1 comes from summer trawl surveys. There is little information for other seasons on Redfish diet, distribution and movements. Lack of seasonal diet information precludes an accurate estimate of Redfish consumption of prey, which is important for understanding the predatory and competitive interactions with other species. Lack of information on the seasonal distribution of Redfish and potentially co-occurring species is hindering efforts to estimate the potential bycatch of other species in an eventual expanded Redfish fishery.

Inconsistencies in catch data, as well as difficulties in providing survey indices by species for Unit 2, precluded the assessment of this portion of the stock resulting in uncertainty in the status of Unit 2 Redfish.

Reference points were defined for each species in Unit 1 and 2, exclusively using indices from the Unit 1 survey given that the Unit 2 survey only starts in 2000, after the target period used to define the USRs. Furthermore, the strong recruitment for the 2011-2013 cohort evident in the Unit 1 survey and used to define the LRP based on B_{rec}, is not as evident in the Unit 2 survey. Efforts should be made to include information on Unit 2 in the PA for the two species, therefore proposed reference points will need to be revised in the near-term once new information is accumulated.

CONCLUSION

Prospects for *S. mentella* in Unit 1 are positive due to the large cohorts from 2011, 2012 and 2013 that are now mostly larger than the minimum regulatory size of 22 cm. The strong biomass increase may allow higher catches of *S. mentella* in Unit 1, however *S. fasciatus* is still in the Cautious Zone. This increase of *S. mentella* may have important repercussions on other species, through predation and competition interactions.

There are concerns about impacts of an expanded Redfish fishery on depleted bycatch species. Analyses of historical data have identified factors associated with catch rates of incidentally captured species from which management measures aimed at reducing bycatch could be developed. However, contemporary fishery dependent (at-sea observer sampling) and research data (winter surveys) are required to refine the scientific advice on bycatch, particularly as regards vulnerable species.

Although the recent strong cohorts continue to reach minimal regulatory size, there remains a proportion of Redfish biomass comprising undersized individuals. Minimizing fishing mortality on small Redfish was identified as a key priority in a recent management strategy evaluation for Units 1 and 2 Redfish (DFO 2018). Recent selectivity research has shown that the capture of undersized Redfish can be reduced through modification to codend meshes. However undocumented mortality of escaping fish may be a concern for mechanical sorting devices. If undersized individuals escape at depth then this mortality may be limited, but could be higher if escape occurs during haul-back. Additional research on the potential magnitude of through-mesh survival, possibly via a review of information available elsewhere, and on the magnitude of fish meshing in commercial fishing applications is recommended.

Full implementation of the PA will require the definition of a fishing limit reference and harvest control rules. When doing so, information from both Units 1 and 2 should be considered to ensure that the PA represents the entire stock for each of the two Redfish species.

LIST OF MEETING PARTICIPANTS

Name	Affiliation	Jan. 20	Jan. 21	Jan. 22
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Bernier, Denis	DFO – Science	x	-	-
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Vascotto, Kris	GEAC	x	x	x
Voutier, Jan	Kalebay Seafood	x	x	x
Winger, Paul (tel)	Marine Institute, Memorial Univ.	x	x	x

SOURCES OF INFORMATION

This Science Advisory Report is from the January 20-22 2020 meeting on the Assessment of Redfish Stocks (*Sebastes mentella* and *S. fasciatus*) in Units 1 and 2. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada Science Advisory Schedule as they become available.

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