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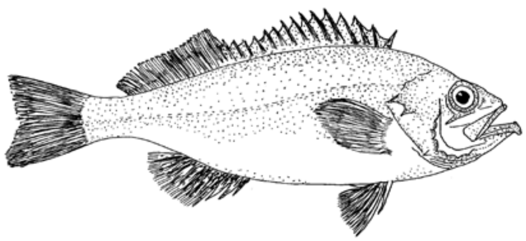
Canadian Science Advisory Secretariat
Science Advisory Report 2016/047

ASSESSMENT OF REDFISH STOCKS (*SEBASTES FASCIATUS* AND *S. MENTELLA*) IN UNITS 1 AND 2 IN 2015



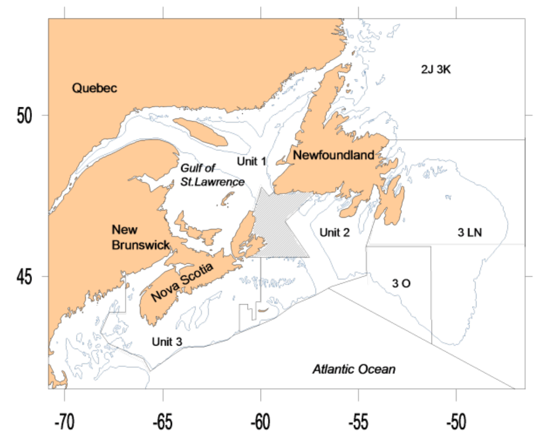


Figure 1. Units 1 and 2 Redfish stock management areas. The (grey) area, where Northwest Atlantic Fisheries Organization (NAFO) Subdivisions 3Pn and 4Vn are located, indicates the seasonal common area (January to May, Unit 1 and June to December, Unit 2).

Context

The Redfish fishery in Units 1 and 2 (Gulf of St. Lawrence and Laurentian Channel) targets two Redfish species, the Deepwater Redfish (Sebastes mentella) and the Acadian Redfish (Sebastes fasciatus). These two species share morphological similarities and their ranges overlap. However, they have different life histories, particularly in terms of reproduction and recruitment mechanisms. Units 1 and 2 contain a single biological population of each species and they are assessed separately. Combined landings of both species and both units have dropped from over 100,000 t in the 1970s to less than 10,000 t since 2004.

In 2010, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) designated S. mentella from the Gulf of St. Lawrence and Laurentian Channel Designatable Unit (DU)(Units 1 and 2) as endangered and S. fasciatus in the Atlantic DU (including Units 1 and 2) as threatened. The results of a recovery potential assessment of each of these populations in 2011 indicated that the spawning stock biomass of each of the two species was in the critical zone.

Fisheries and Oceans Canada currently manages these two species as a single stock with two management units. This resource is managed mainly by an annual total allowable catch (TAC). Other management measures (type of gear, area closures to protect fertilization and larval extrusion periods, observers, dockside monitoring, minimum size, bycatch monitoring, etc.) are also applied. Since 1995, the Redfish fishery has been under a moratorium in Unit 1 and a 2000 t/year index fishery has been authorized there since 1999. There has been no moratorium on the commercial fishery in Unit 2 and the TAC has been 8500 t/year since 2006. This Science Advisory Report is from the March 3, 2016 meeting on the Assessment of Redfish Stock (Sebastes fasciatus and S. mentella) 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.

SUMMARY

- Both species of Redfish are distributed according to depth. In summer surveys, *Sebastes fasciatus* dominates in water depths of less than 300 m, along the slopes of channels and on banks, except in the Laurentian Fan where it is found in deeper waters. *Sebastes mentella* mostly predominates in the main channels at depths of over 300 m.
- From 2010 to 2015 (2014 and 2015 data are preliminary), average annual landings were 481 t in Unit 1 (annual 2000-tonne TAC). During the same period, average landings in Unit 2 were 3775 t (annual 8500-tonne TAC). Industry reported that market conditions and restrictions related to management measures had a major impact on taking all of the TAC.
- Since 2004, the performance index for the bottom trawl index fishery has been stable and comparable to the average in Unit 1. There is no performance index available for Unit 2.
- The abundance of juvenile Redfish, largely dominated by *S. mentella*, increased significantly in research surveys starting in 2013. In the Northern Gulf of St Lawrence, the abundance of juvenile *S. mentella* and *S. fasciatus* was 80 and 4 times higher, respectively, than their average abundance for 1993–2012. The first large cohort, from 2011, had a modal size of 17 cm in summer 2015.
- The strong 2011 and 2012 year-classes of *S. mentella* have the genetic signature of the adult population of Units 1 and 2. The 2011 cohort seems to be as abundant as the last large cohort of *S. mentella* (1980) that contributed significantly to the fishery and adult population in Units 1 and 2.
- *S. fasciatus* juveniles observed in recent surveys have the genetic signature of the adult population of Units 1 and 2. In comparison, the large cohorts of *S. fasciatus* from 1973, 1985, 1988 and 2003 observed at the juvenile stage in Unit 1 had the genetic signature of the population along the southern edge of the Grand Banks.
- Based on Redfish growth estimates and assuming the population is balanced, almost 50% of the fish in the 2011 cohort should be over 22 cm, the minimum harvest size, by 2018. By 2020, 51% of fish in the 2011 cohort should be over 25 cm, size at sexual maturity.
- The biomass of *S. mentella* and *S. fasciatus* spawning stocks estimated in research surveys fell in the early 1990s to its lowest observed values and has remained stable to date. The species in the Unit 2 survey could not be separated in 2014.
- Despite the potential for strong recruitment, the spawning stock biomass for both species is still in the critical zone, based on the 2011 precautionary approach.
- The Redfish stock outlook for Units 1 and 2 is very encouraging in the short term due to the large cohorts from 2011, 2012 and 2013. Large numbers of these fish will start recruiting to the fishery from 2018 to 2020, which could lead to a rapid increase in the spawning biomass. Until then, bycatch of Redfish under 22 cm should be minimized.
- The arrival of large Redfish cohorts will most likely have a significant impact on the ecosystem in the area, especially due to increased predation on small invertebrates and fish.
- Current harvesting has not led to an additional decrease in the spawning biomass since the last assessment. The outlook is good for recruitment to the fishery for 2018 and an increase in the 2020 mature biomass for both species. Currently, the main concern is to maximize the survival of this potential recruitment for the next five years.

BACKGROUND

Species biology

Redfish inhabit cold waters along the slopes of banks and deep channels at depths ranging from 100 to 700 m. *Sebastes fasciatus* is typically found in shallower waters than *S. mentella*. In the Gulf of St. Lawrence and Laurentian Channel, *S. mentella* predominates in the main channels at depths ranging from 350 to 500 m. In contrast, *S. fasciatus* dominates 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 generally live near the bottom. However, various studies have shown that these species reside near the bottom during the day, leaving the sea floor at night to follow their prey as they migrate. Juvenile Redfish feed mainly on various species of crustaceans, including several species of shrimp. The adult Redfish diet is more varied and includes fish.

Redfish is a slow growing and long lived species. *S. fasciatus* grows more slowly than *S. mentella*, although this difference in growth rates becomes obvious only 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.

Males reach sexual maturity one to two years earlier than females (*S. fasciatus,* males mature at 7 years (L50: 19.6 cm) and females mature at 9 years (L50: 24.1 cm) and *S. mentella*, males mature at 9 years (L50: 22.8 cm) and females mature at 10 years (L50: 25.4 cm)).

Unlike many cold water marine fish species, fertilization in Redfish occurs internally and females are ovoviviparous. Mating occurs in the fall, most likely between September and December, and the females carry developing embryos until they are expelled 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. Mating and larval extrusion do not necessarily occur in the same locations. In the Gulf of St. Lawrence, *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.

Redfish species identification criteria

Sebastes fasciatus and *S. mentella* in Units 1 and 2 have traditionally been assessed as "*Sebastes sp.*" because they are difficult to identify. As part of the multidisciplinary research program on Redfish (1995–1998), various meristic, morphometric and genetic tools were assessed in order to distinguish the two species to document their specific life history and identify distribution and recruitment patterns specific to each species. Only microsatellite genetic markers were able to clearly distinguish the species, with a minimum of 4 loci required to assign individuals to a species. However, analysis of microsatellite markers remains costly and logistically challenging, which restricts their use for monitoring the specific composition of catches.

Three characteristics were traditionally used to distinguish *S. mentella* and *S. fasciatus* in the Northwest Atlantic: the number of soft rays on the anal fin (anal fin count or AFC), extrinsic gasbladder muscle passage patterns (EGM) and the genotype at the malate dehydrogenase locus (MDH-A*). In the absence of information about microsatellites, the MDH-A* genotype has historically been considered the genetic criterion. These three criteria (MDH-A*, AFC, EGM) were used to describe the geographic range of the species in the North Atlantic.

Since 2009, Redfish stocks in Units 1 and 2 have been assessed by species. Species identification based on anal fin counts and depth data are integrated to determine the proportion of each species caught during the surveys. Anal fin count patterns vary between the two species and this criterion can easily be identified at sea. For this reason, it was selected as a practical, economical alternative to genetic analysis for estimating the specific composition of catches.

Genetic structure of stocks in Units 1 and 2

An analysis of genetic variation (13 microsatellite loci) suggests that Units 1 and 2 contain a single population of *S. mentella*. This population is itself distinct from other populations of *S. mentella* distributed in the Northwest Atlantic Ocean. For *S. fasciatus*, the results suggest the presence of five populations in the Northwest Atlantic, three of which overlap Units 1 and 2. A first *S. fasciatus* population is found in the area covered by Units 1 and 2, excluding the southern edge of Unit 2. A second *S. fasciatus* population includes the southern edge of Unit 2 (including the mouth of the Laurentian Channel (fan)), and extends along the continental shelf break from the Grand Banks (Div. 3LNO) to Nova Scotia (4W), which we will refer to as the “Atlantic population of the continental shelf break.” A third, geographically small *S. fasciatus* population has been highlighted in the east inlet of the Bonne Bay fjord, on the west coast of Newfoundland (Appendix 1).

Recruitment events

In the Northwest Atlantic, Redfish is characterized by significant variability in recruitment. Genetic analysis results indicated that 30 years ago Units 1 and 2 produced the last strong year-class of *S. mentella* that 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* with the genetic signature of the Atlantic population of the continental shelf break (adults). Consequently, these *S. fasciatus* year-classes, which seemed strong in their early stages, particularly in 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 this *S. fasciatus* population uses the Gulf of St. Lawrence as a nursery. The larvae/juveniles apparently drifted to the Gulf of St. Lawrence, and 5 to 6 years later the older juveniles returned to the Atlantic population of the continental shelf break.

The most recent DFO research surveys indicated that there were three abundant Redfish year-classes in Unit 1, the 2011, 2012 and 2013 cohorts. Genetic analyses performed on the 2011 and 2012 cohort indicated that 91% of these fish belonged to the *S. mentella* species within the adult population of Units 1 and 2. This information suggested that these Redfish will remain in the area and could promote the recovery of *S. mentella* in Units 1 and 2. The 2011 cohort seems as abundant as the 1980 cohort, which has supported the fishery for over 20 years.

Juveniles of the 2011 and 2012 *S. fasciatus* year-classes have the genetic signature of introgression with *S. mentella*, which is characteristic of adult Redfish in Units 1 and 2, indicating a local origin. Analyses of samples from the 2013 cohort (collected in 2015) were not completed at the time of the assessment.

Ecosystem

Fisheries and Oceans Canada’s Atlantic Zone Monitoring Program (AZMP) annually assesses prevailing physical oceanographic conditions in the Gulf of St. Lawrence. Conditions encountered in the northern Gulf in the last five years (2011 to 2015) were generally warmer than historical average surface and deep water temperatures. However, the 2013–2014 and 2014–2015 winters were slightly colder than average, which means that the characteristics of the cold intermediate layer in the summers of 2014 and 2015 were more representative of the historical average. In 2015, deep water temperatures were warmer than the historical average. Consequently, temperatures at 200 and 300 m have increased in most areas since 2014, especially in the Anticosti Channel at 200 m and in the estuary, northwestern Gulf and central Gulf at 300 m.

The various herring stocks (4R, 4S, 4T) are healthy, and the Gulf capelin stock (4RST) is stable, while the mackerel stock (subareas 3 and 4) is low. Greenland Halibut stock (4RST) is stable while Atlantic Halibut stock (4RST) is increasing. The southern Gulf of St. Lawrence cod stock (4T) is very low and stable. The cod stock in the Northern Gulf (3Pn, 4RS) is also low but has increased slightly. The Northern Shrimp stock in the Estuary and Gulf of St. Lawrence is high and has remained in the healthy zone for several years.

Fishery

In the late 1950s, a directed Redfish fishery developed in the Gulf of St. Lawrence and the Laurentian Channel outside the Gulf. Prior to 1993, the Redfish fishery was managed as three divisions established by NAFO (Northwest Atlantic Fisheries Organization): Divisions 4RST, Division 3P and Divisions 4VWX. In 1993, these management units were redefined to provide a stronger biological basis and take various factors into account, including the Gulf Redfish stock's winter migration to the Cabot Strait area. The resulting management units were divided as follows: Unit 1 included Divisions 4RST and Subdivisions 3Pn4Vn from January to May; Unit 2 included Subdivisions 3Ps4Vs, Subdivisions 4Wfgj, and Subdivisions 3Pn4Vn from June to December; and Unit 3 included Divisions 4WdehklX (Figure 1).

The first total allowable catches (TAC) of Redfish stocks set according to the 1993 management structure were 60,000 t in Unit 1 and 28,000 t in Unit 2. They are now 2000 t/year (since 1999) for the index fishery in Unit 1 and 8500 t/year for the commercial fishery in Unit 2 (since 2006).

Redfish catches reported in directed fisheries for most commercial fisheries conducted in Units 1 and 2 from 1985 to 2014 were examined (there were insufficient data for 2015). This analysis revealed that more than 90% of the reported Redfish catches came from the directed Redfish fishery.

Redfish conservation measures include: implementation of a protocol for protecting small fish (22 cm), 100% dockside monitoring, mandatory hail reports upon departure and arrival, imposition of a level of coverage by observers (25% or 10% with the Vessel Monitoring System (VMS) in Unit 1, 10% for fixed gear and 5% to 20% for mobile gear in Unit 2), implementation of a bycatch protocol (5% to 15% in Unit 1 and 10% for fleets > 65 feet using mobile gear in Unit 2). Closure periods were also introduced, 1) to protect Redfish mating (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 cod (Divisions 4RS). In addition, since the index fishery was introduced in 1998, fishing is allowed only between longitudes 59° and 65° at depths > 100 fathoms, and to avoid Greenland Halibut bycatch, an area has been closed in Division 4T since August 2009.

Unit 1 landings

The Redfish fishery in the Gulf of St. Lawrence has been characterized by two periods of high landings: the first in the early 1970s, and the second in the early 1990s (Figure 2). From 1960 to 1969, annual landings averaged 46,000 t and reached 82,000 t from 1970 to 1976 (Table 1).

Landings peaked at 136,000 t in 1973. From 1977 to 1994, average annual landings were 37,000 t. In 1995, a moratorium was imposed on the Redfish fishery because of low stock abundance and poor recruitment. An index fishery began in 1998 with a 1000-tonne TAC. From 1999 to date, the TAC has been maintained at 2000 t/year. Between 2004 and 2008, average annual landings from the index fishery and bycatch reached 626 t in Unit 1. From 2010 to 2015, average annual landings were 481 t (preliminary data for 2014 and 2015) with a 2000-tonne TAC.

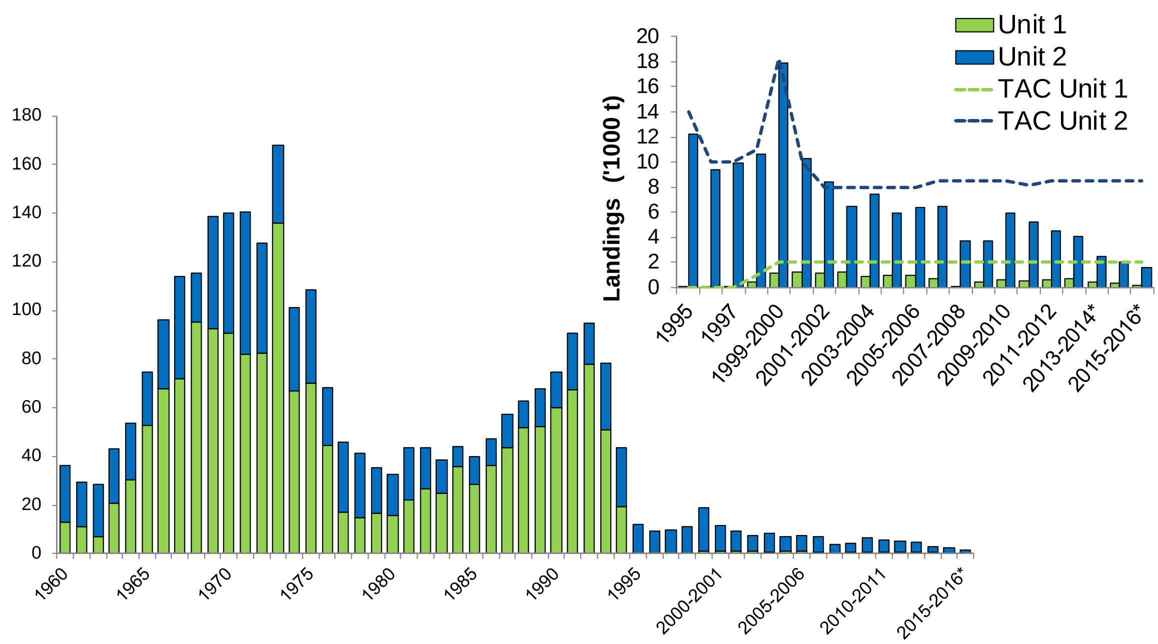


Figure 2. Landings and TAC (t) for Redfish stocks in Units 1 and 2. Landings are for the management years from May 15 of the current year to May 14 of the following year for Unit 1 and from April 1 to March 31 for Unit 2.

Table 1. Redfish landings and TACs (in thousands of tonnes) in Units 1 and 2.

	Year	1960 1969	1970 1976	1977 1994	1995 1998	1999 2003	2004 2009	2010 2014	2015
Unit 1	TAC			45[2]	1[3]	2[1]	2[1]	2[1]	2
	Landings	46[1]	82[1]	37[1]	0,1[1]	1[1]	0,6[1]	0,6[1]	0,4[4]
Unit 2	TAC			27[2]	11[1]	10[1]	8[1]	8,5[1]	8,5
	Landings	27[1]	40[1]	18[1]	11[1]	10[1]	6[1]	4[1]	1,5[4]
Units 1 and 2	Landings	73[1]	122[1]	55[1]	11[1]	11[1]	6[1]	4,7[1]	2[4]

[1] *Average*
[2] *1993–1994 only*
[3] *1998 only*
[4] *Preliminary*

Unit 2 landings

Between 1960 and 1969, average annual landings were 27,000 t; from 1970 to 1976, they averaged 40,000 t primarily due to the increased catches recorded by foreign fleets. Following the introduction of the 200 nautical mile limit in 1977, landings decreased to an 18,000-tonne average from 1977 to 1994 (with an annual TAC of 27,000 t in 1993–1994, Table 1). Landings continued to decrease between 1995 and 2003 to a 10,500-tonne average, identical to the TAC in force during this period. From 2004 to 2008, average landings in Unit 2 were 5250 t, with an average annual 8333-tonne TAC. From 2010 to 2015, average annual landings were 3775 t (preliminary data for 2014 and 2015) with an 8500-tonne TAC. It should be noted that for several years, there has been an increase in the percentage of catches from the Laurentian Fan area (southern edge of Unit 2 at the mouth of the Laurentian Channel located about 300 km southeast of Nova Scotia) primarily in Subdivisions 4Vsc as a result to an initiative implemented by industry in 2011 aimed at reducing *S. mentella* catches. Laurentian Fan landings can account for more than 50% of annual landings in Unit 2 (Figure 1 and Appendix 2).

Index fishery in Unit 1

An index fishery to collect data on trawl net catches per unit effort (CPUE) during moratoriums was introduced in 1998. The spatial distribution of fishing effort varied during the series. Between 1999 and 2006, nearly 60% of fishing effort occurred in Division 4R along the Laurentian Channel. Between 2006 and 2015, more than 70% of fishing effort occurred in Division 4T along the slope of the Laurentian Channel (Figure 1 and Appendix 2).

The fishery performance index, comparing CPUE from the commercial fishery prior to the moratorium (1981–1994) to those of the index fishery (1999–2015), is presented in Figure 3. This index dropped sharply between 1993 and 1994, and stabilized at a low level from 1999 to 2003. Since 2004, the index has been stable and comparable to the series average. 2015 data are preliminary.

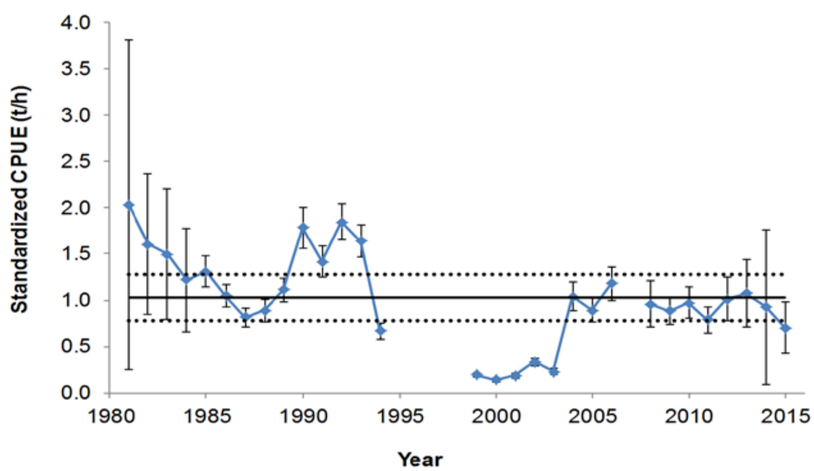


Figure 3. Standardized bottom trawl catch per unit effort (average CPUE ±95% confidence interval) in Unit 1 in the commercial fishery between May and October (1981–1994) and the index fishery (1998–2015). The solid line represents the average for the period 1981 to 2014; the dashed lines represent a ± ½ standard deviation.

Commercial catch at length in Unit 1

From 1981 to 1988, the commercial catch at length in Unit 1 indicated that catches primarily consisted of fish born in the early 1970s. From 1988 to 1994, catches predominantly consisted of fish born in the early 1980s (Figure 4). From 1999 to 2015, most fish caught were larger than 30 cm. Since 1999, commercial catch at length has been more difficult to establish because landings have dropped significantly (especially since 2006). As a result, fewer fish are measured by observers and through DFO sampling programs. However, it appears that the

1980 year-class, consisting primarily of *S. mentella* with the genetic signature of Units 1 and 2, began to be recruited to the fishery in 1987 and has remained in catches to date.

Commercial catch at length in Unit 2

From 1995 to 2004, commercial catch at length in Unit 2 indicated that most catches consisted of the strong 1980 year-class (Figure 4). Starting in 2005, size frequency distributions were broader, indicating the presence of numerous cohorts in the fishery. During this period, especially from 2006 to 2012, more than 50% of annual landings came from the southern edge of Unit 2 (Laurentian Fan area, Appendix 2). *S. fasciatus* were observed in this area. Their genetic signature was that of the Atlantic population of the continental shelf break, which could account for the presence of fish smaller than 30 cm. Also, the 2003 *S. fasciatus* cohort apparently left Unit 1 and returned to their area of origin (Atlantic coast along the continental shelf break) contributing to the fishery in Unit 2 starting in 2010.

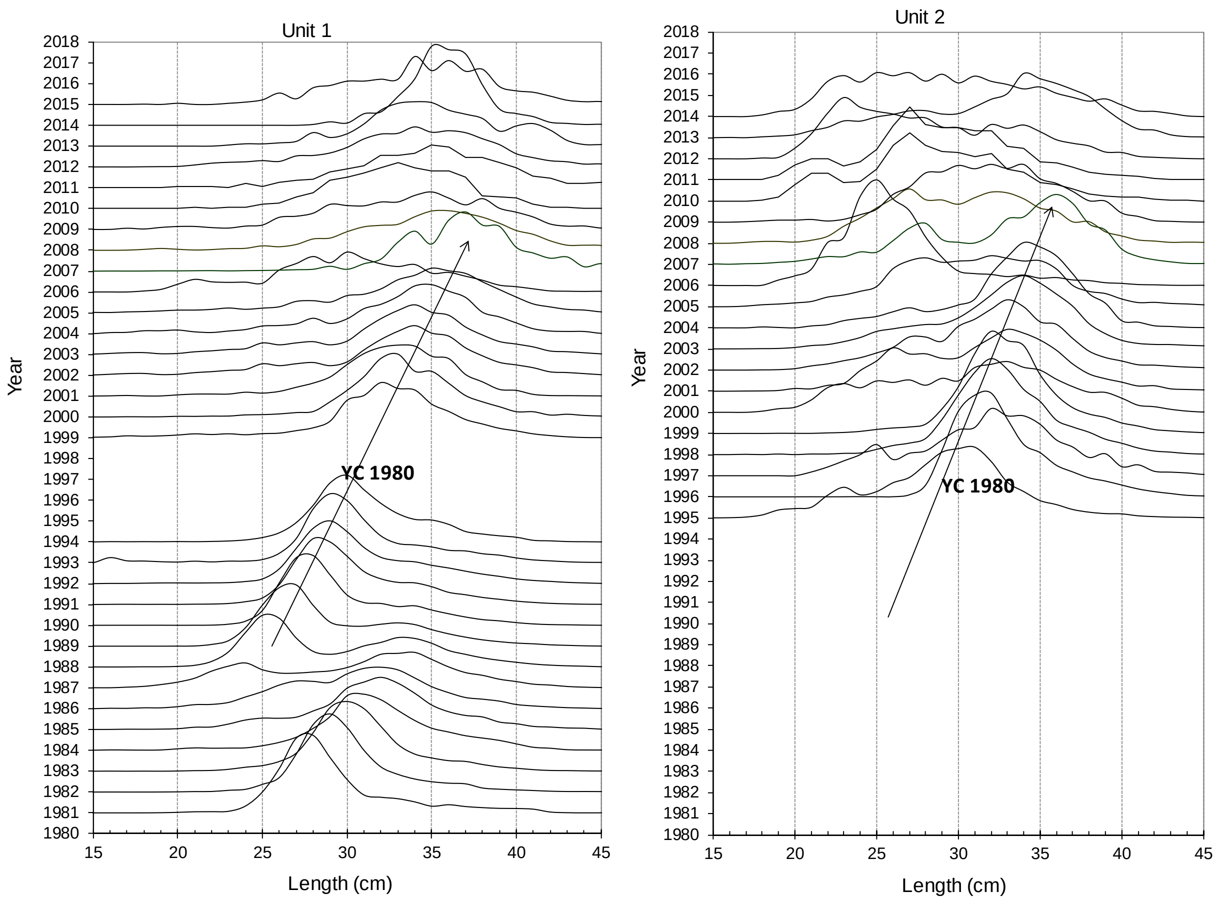


Figure 4. Commercial catch at length in % in Unit 1 (1981 to 2015) and Unit 2 (1995 to 2014).

Industry's perspective

According to some industry representatives in Unit 1, market conditions and management measures (restricted areas) have had a major impact on catch levels in recent years. In Unit 2, industry representatives report that market conditions would explain why the TAC was not taken.

ASSESSMENT

Sources of information

The status of Redfish stocks was assessed using data from Units 1 and 2 fisheries (commercial landings and length frequencies). Standardized CPUE from the commercial fishery (index) were calculated only for Unit 1. These CPUE are considered a fishery performance index rather than representing changes in stock abundance.

Abundance indices derived from surveys were also available: for Unit 1, the August DFO research survey (1990–2015), and for Unit 2, the September *Groundfish Enterprise Allocation Council* (GEAC) industry survey (2000–2014). Since the last assessment, two surveys were completed in Unit 2, in 2011 and 2014. During the 2014 survey, Redfish species could not be differentiated due to an issue with the anal fin count (AFC) data.

Every survey analysis focused on each species, *S. fasciatus* and *S. mentella*. A combined series (2000–2011) was created for each species in Units 1 and 2 using DFO scientific survey data (Unit 1) and GEAC data (Unit 2) converted into CCGS Teleost/Campelen equivalents.

Stock trends

Redfish abundance and biomass indices in Unit 1 (1984–2015)

According to the DFO research survey in Unit 1, *S. fasciatus* and *S. mentella* abundance and biomass declined sharply from 1990 to 1994 (Figures 5 and 6). Subsequently, the indices of mature individuals remained stable until 2009, after which they increased slightly until 2015. Periods of increases followed by decreases in the number of immature *S. fasciatus* were observed in 1990 and 2005. These two periods were primary attributable to the onset and subsequent decline of the 1988 and 2003 cohorts, which according to their genetic signature, originated in the Atlantic population of the continental shelf break; the subsequent decreases were consistent with their return migration to their original population (see “Recruitment events” section). From 2013 to 2015, a high abundance of immature Redfish was observed in the two species (Figures 5 and 6), mainly dominated by the 2011 year-class (Figure 7). However, the abundance of these juveniles was largely dominated by *S. mentella,* with the genetic signature of the adult population of Unit 1 and 2. In the northern Gulf of St Lawrence, the abundance of juvenile *S. mentella* and *S. fasciatus* was 80 and 4 times higher, respectively, than their average abundance for 1993–2012.

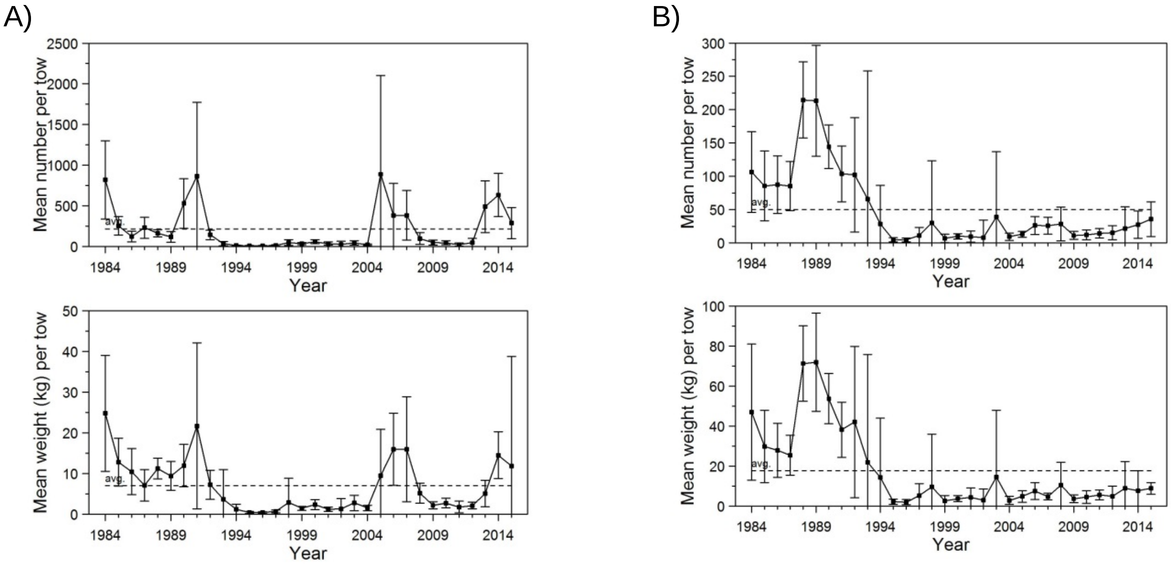


Figure 5. Mean number per tow and mean weight (kg) per tow of Sebastes fasciatus in the Unit 1 DFO survey; A) immature and B) mature. The dotted horizontal line represents the mean for the 1990–2014 period.

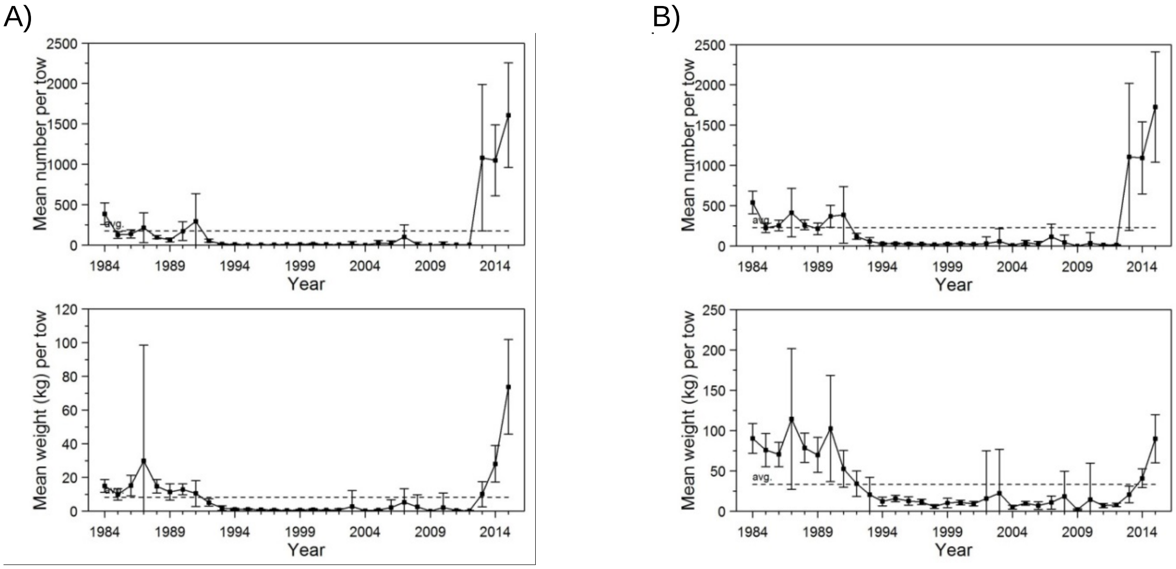


Figure 6. Mean number per tow and mean weight per tow (kg) of Sebastes mentella in the Unit 1 DFO survey; A) immature and B) mature. The dotted horizontal line represents the mean for the 1990–2014 period.

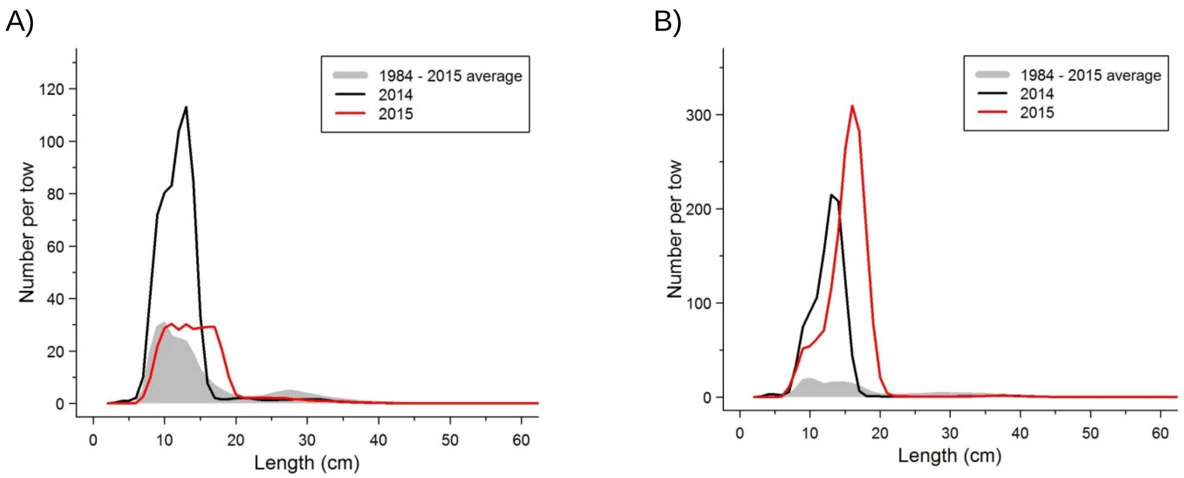


Figure 7. Size frequencies of Sebastes fasciatus (A) and S. mentella (B) in the Unit 1 DFO survey.

The spatial distribution of catch rates for Redfish in the DFO survey indicated that between 1984 and 1995 the Laurentian, Esquiman and Anticosti channels were densely populated by both species (Figures 8 and 9). Subsequently, there was a significant decrease in the density of mature individuals in both Redfish species, in particular west of Anticosti Island and north of Esquiman. Distributions of immature Redfish from 2011 to 2015 and 1984 to 1990 were similar (Figures 8 and 9).

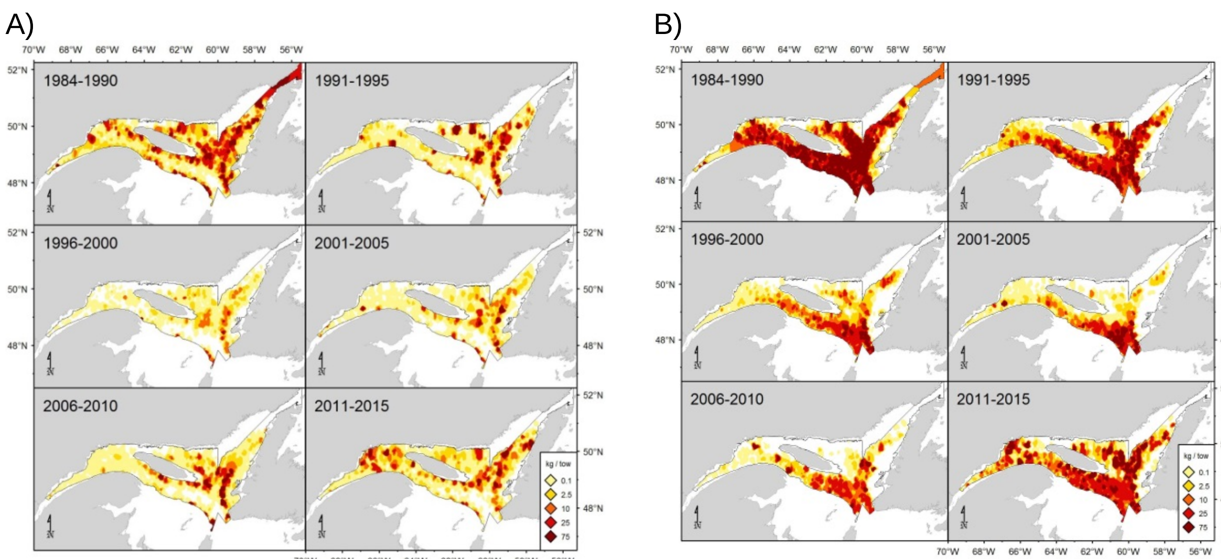


Figure 8. Distribution of catch rates of Sebastes fasciatus (kg/15-minute tow) in the Unit 1 DFO survey; A) immature and B) mature.

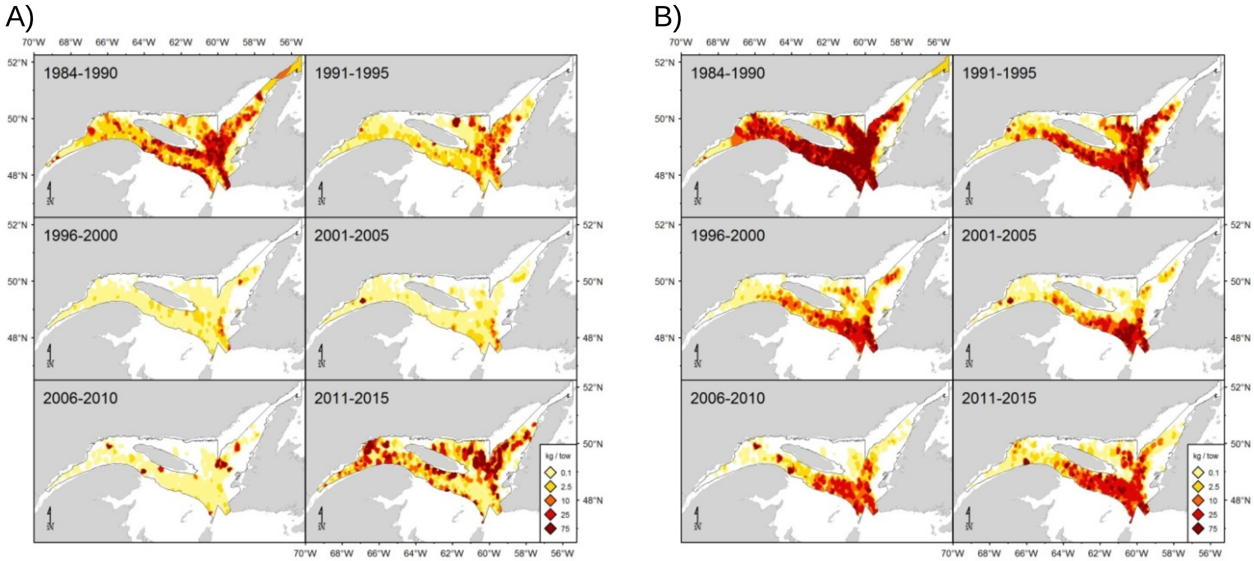


Figure 9. Distribution of catch rates of Sebastes mentella (kg/15-minute tow) in the Unit 1 DFO survey; A) immature and B) mature.

Redfish abundance and biomass indices in Unit 2 (2000–2014)

Because the information was not available by species for 2014, industry survey data are presented for both species combined, *Sebastes* sp., from 2000 to 2014 (Figures 10 and 11) and by species, from 2000 to 2011 (Figures 12 and 13). The abundance and biomass indices of *Sebastes sp*., *S. fasciatus* and *S. mentella* in Unit 2 show no particular trends over the time series and were relatively stable (Figures 12 and 13). The highest abundance and biomass values of immature *S. fasciatus*, observed in 2007, was attributable to the strong 2003 year-class (Figures 12 and 13). In 2014, a high abundance of immature Redfish was observed in Unit 2, ranging from 9 to 17 cm, which suggested the possibility of strong recruitment in 2011 and 2012 (Figure 11).

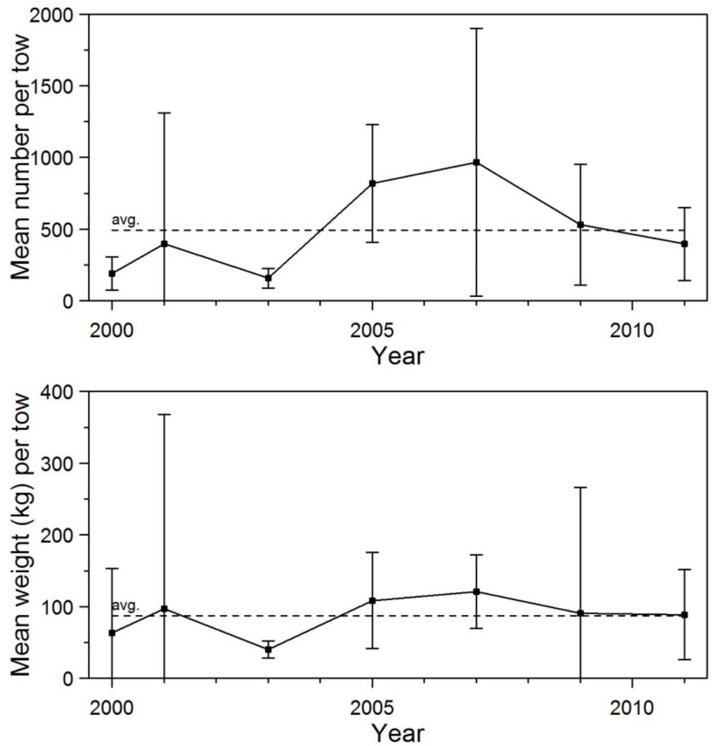


Figure 10. Mean number per tow and mean weight per tow (kg) of Sebastes sp. in the Unit 2 GEAC survey. The dotted horizontal line represents the mean for the 2000–2011 period.

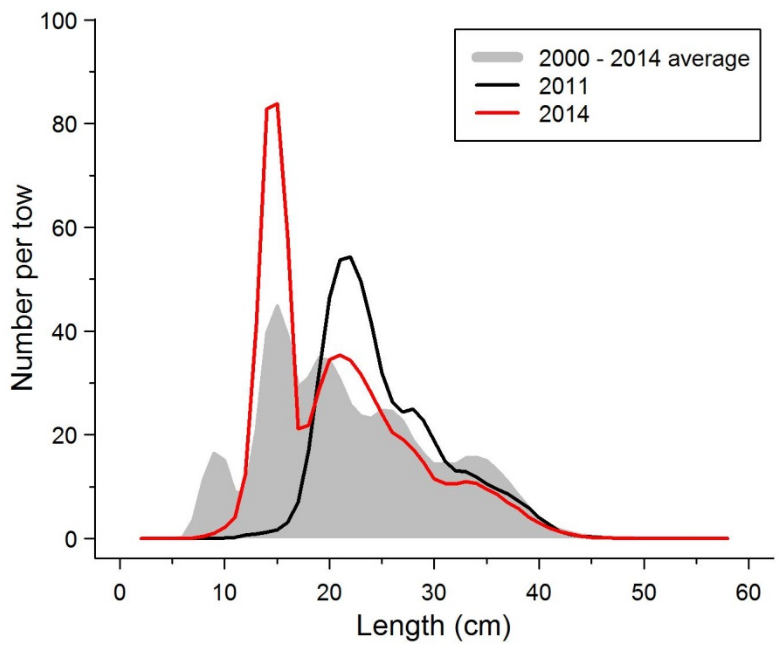


Figure 11. Size frequencies of Redfish in the Unit 2 GEAC survey.

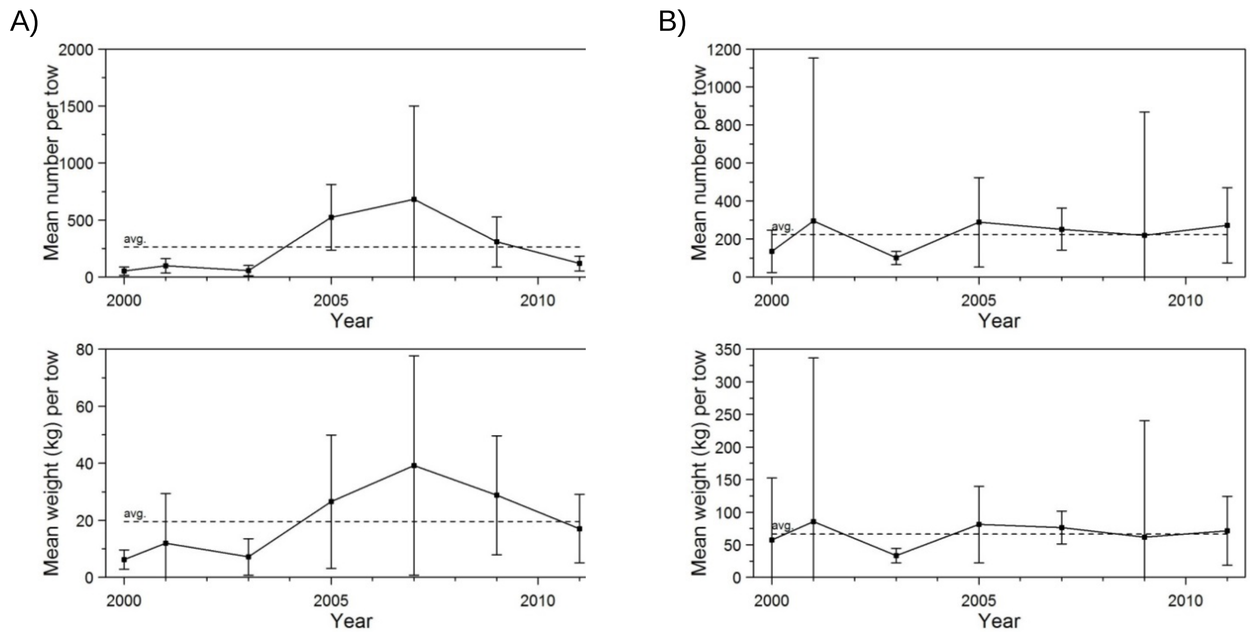


Figure 12. Mean number per tow and mean weight per tow (kg) of Sebastes fasciatus in the Unit 2 GEAC survey; A) immature and B) mature. The dotted horizontal line represents the mean from 2000 to 2009.

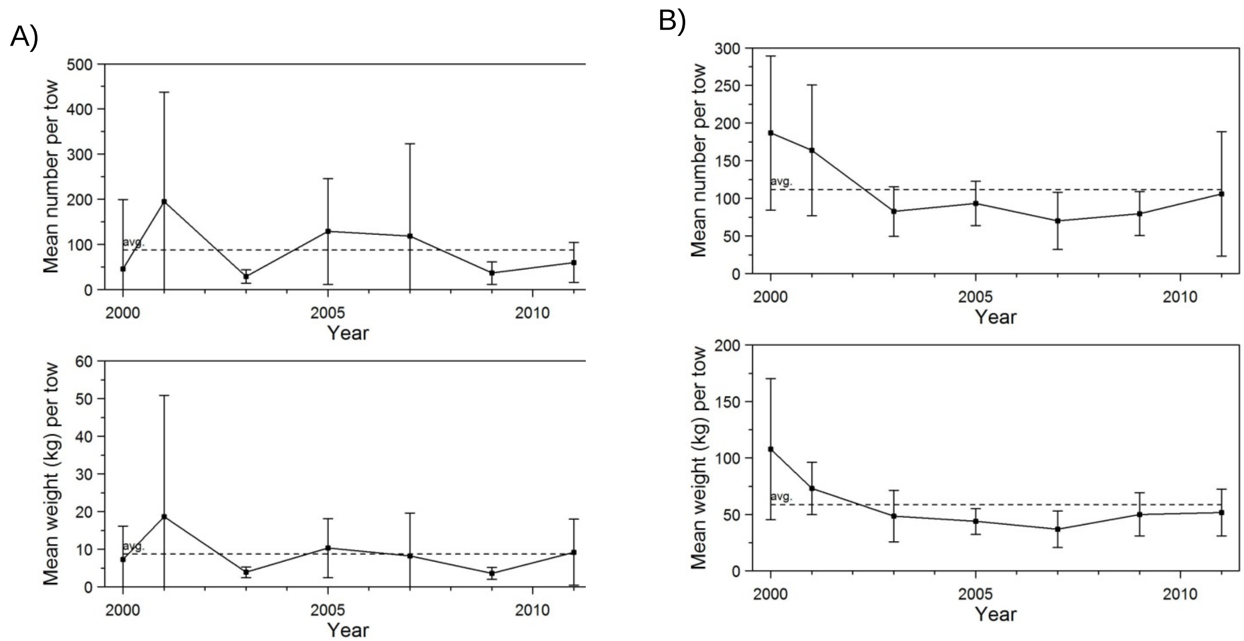


Figure 13. Mean number per tow and mean weight per tow (kg) of Sebastes mentella in the Unit 2 GEAC survey; A) immature and B) mature. The dotted horizontal line represents the mean from 2000 to 2009.

Combined abundance and biomass indices of *Sebastes* sp., *S. fasciatus* and *S. mentella* in Units 1 and 2

The combined index of *Sebastes* sp. shows that the total biomass was stable from 2000 to 2014. The index (Figure 14) also shows that the total Redfish biomass was greater in Unit 2 than in Unit 1 between 2000 and 2011. In 2014, the percentage of biomass was similar in both units. The increase in biomass in Unit 1 was attributable to the high abundance of immature individuals (Figures 15 and 16).

The biomass indices of mature *Sebastes fasciatus* and *S. mentella* individuals (Figures 15 and 16) also showed a higher biomass for both species in Unit 2 between 2000 and 2011. The biomasses of immature individuals of both species were comparable in both units. There was no comparison available for 2014 because the data in Unit 2 were not available by species.

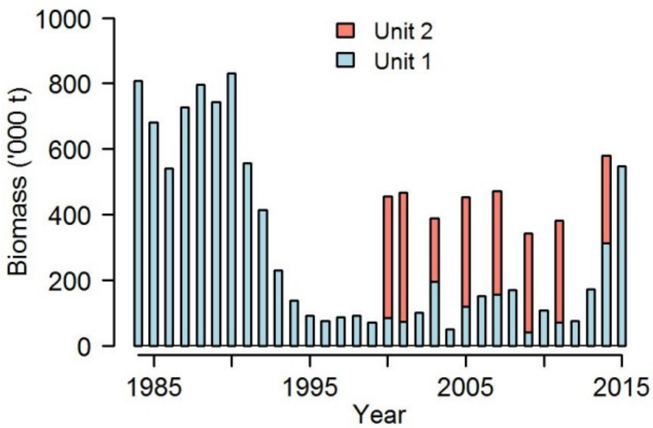


Figure 14. Minimum trawlable biomass of Redfish (Sebastes mentella and S. fasciatus) in Units 1 and 2 based on DFO and GEAC indices.

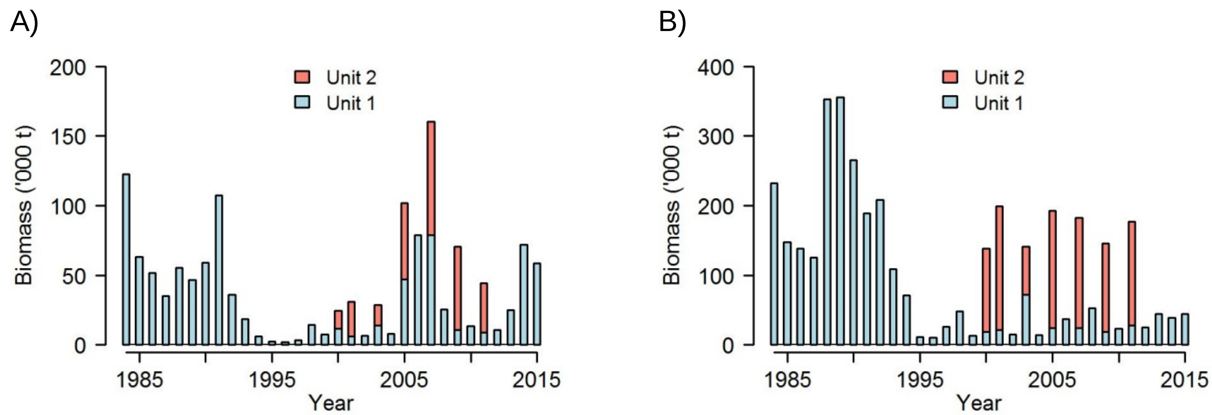


Figure 15. Minimum trawlable biomass of Sebastes fasciatus in Units 1 and 2 based on DFO and GEAC indices; A) immature and B) mature.

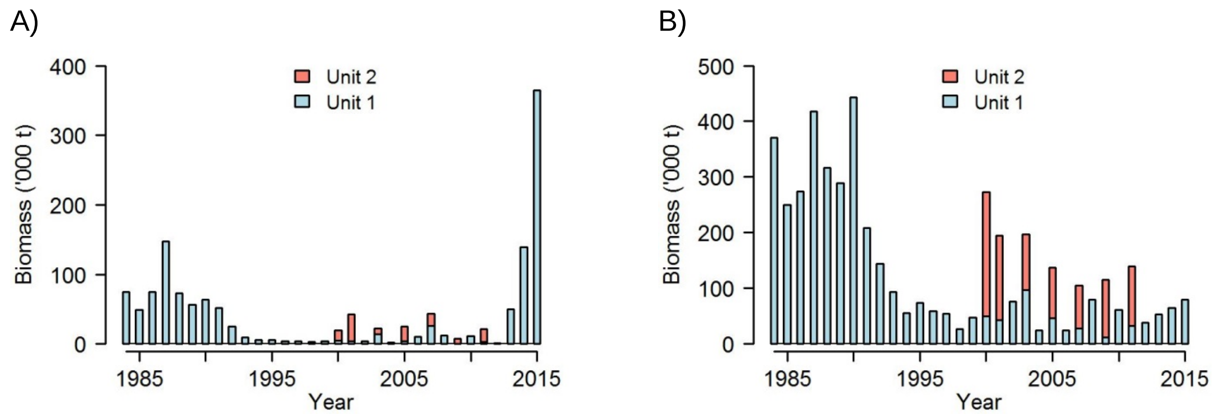


Figure 16. Minimum trawlable biomass of Sebastes mentella in Units 1 and 2 based on DFO and GEAC indices; A) immature and B) mature.

The spatial distribution maps of Redfish biomass (kg/tow) from 2006 to 2011 show a continuous distribution of Redfish between Units 1 and 2 along the Laurentian Channel to the head of the Esquiman, Anticosti and Laurentian channels in the Gulf of St. Lawrence (Figure 17). These maps indicate that *S. fasciatus* occupies shallower waters than *S. mentella*, with the exception of the Laurentian Fan area where *S. fasciatus* inhabits deep waters.

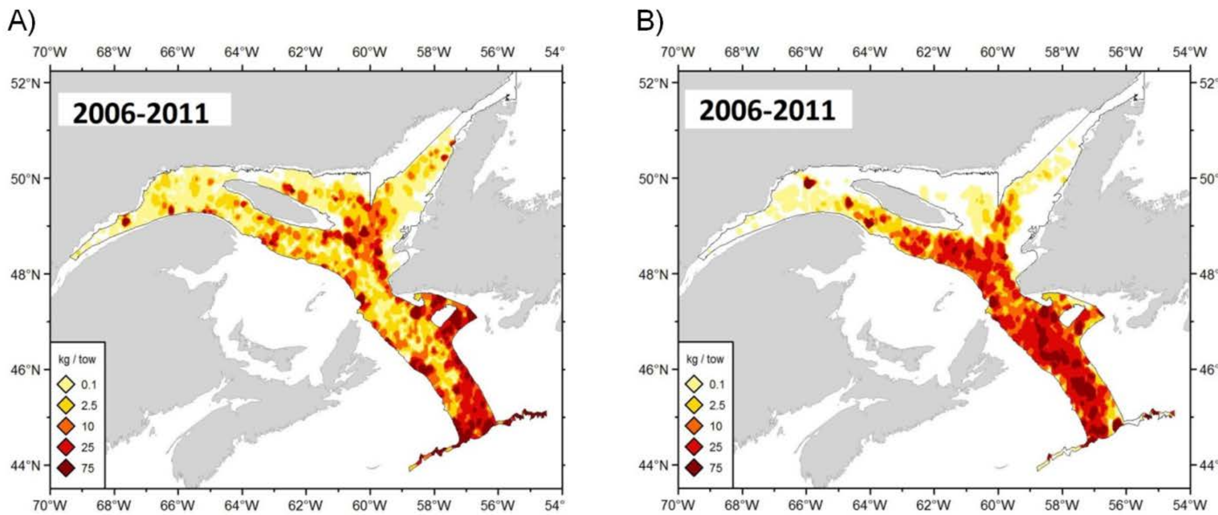


Figure 17. Distribution of catch rates of mature fish (kg/15-minute tow); Sebastes fasciatus (A) and S. mentella (B) based on DFO (Unit 1) and GEAC surveys (Unit 2).

Outlook

Based on Redfish growth estimates and assuming the population is balanced, almost 50% of the fish in the 2011 cohort should be over 22 cm, the minimum harvest size, by 2018. By 2020, 51% of fish in the 2011 cohort should be over 25 cm, size at sexual maturity. There should also be large quantities of fish less than 25 cm from the 2011, 2012 and 2013 cohorts.

According to precautionary approach reference points developed in 2011, derived from a mature biomass surplus production model, both stocks have improved. However, mature biomasses are still in the critical zones: *S. mentella*, 32 kt (216 kt Blim); *S. fasciatus*, 43 kt (147 kt Blim) (Figure 18). This finding should not change over the next three years.

The arrival of large cohorts of Redfish will likely have a significant impact on the ecosystem in Units 1 and 2, for example, by increasing predation on small invertebrates and fish, which may cause a reoccurrence of the situation that existed prior to 1993.

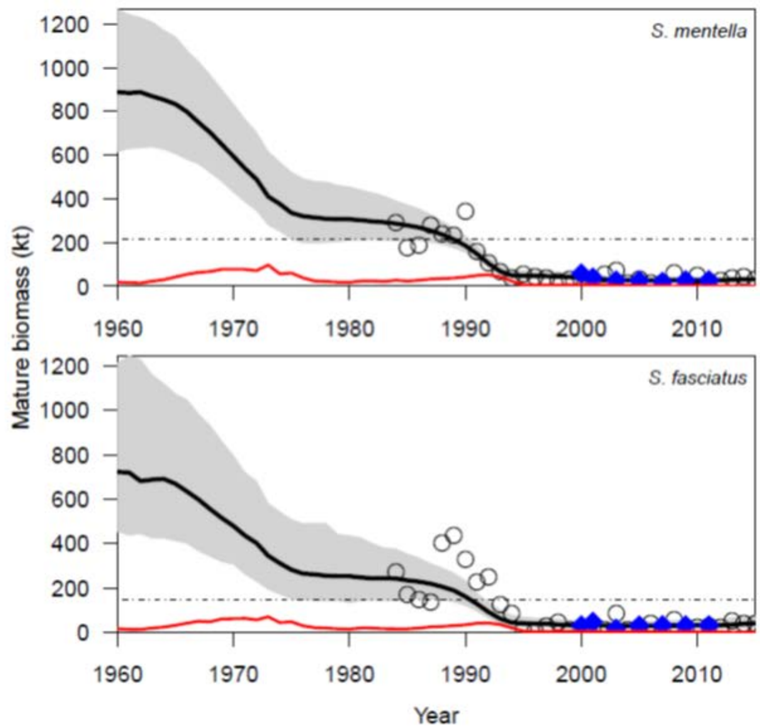


Figure 18. Adjustment of the (biomass) production model for each Redfish species (solid dark line) with a 90% confidence interval (grey area), catches (solid red line), Unit 1 biomass index (clear circle) adjusted by the survey catchability (qU1) Unit 2 biomass index (dark diamond) adjusted by the survey catchability (qU2) and 40% B_{msy} (Limit Reference Point) (dotted line).

Sources of uncertainty

The absence of identification of species in the commercial fishery is a major gap in the assessment of these stocks. A more extensive sampling campaign should be conducted to clearly identify the species caught in each management unit.

The anal fin count (AFC) method is less effective at sea with fish less than 15 cm, consequently recruitment indicators for each species should be based on fish larger than 15 cm, unless genetic tests confirm the species.

Genetic analyses indicate that a percentage of commercial fishery catches in the Laurentian Fan, i.e. the southern edge of Unit 2, may be composed of *Sebastes fasciatus*, which apparently belong to the Atlantic population of the continental shelf break. This factor should be taken into consideration in assessing the stock and managing this fishery. Work will continue on developing a new assessment model. Updating reference points and developing sampling rules would both be advisable.

CONCLUSION

Current harvesting has not led to a further decrease in the spawning biomass since the last assessment. However, the spawning stock biomass for both species is still in the critical zone, based on the 2011 precautionary approach.

The Redfish stock outlook for Units 1 and 2 is very encouraging in the short term due to the large cohorts from 2011, 2012 and 2013. Large numbers of these fish will start recruiting to the fishery from 2018 to 2020, which could lead to a rapid increase in the spawning biomass. Until then, bycatch of Redfish under 22 cm should be minimized.

The arrival of large Redfish cohorts will most likely have a significant impact on the ecosystem in the area, especially due to increased predation on small invertebrates and fish.

The outlook is good for recruitment to the fishery for 2018 and an increase in the 2020 mature biomass for both species. Currently, the main concern is to maximize the survival of this potential recruitment for the next five years.

SOURCES OF INFORMATION

This Science Advisory Report is from the March 3, 2016 meeting on the Assessment of Redfish stocks (*Sebastes mentella* and *Sebastes fasciatus*) in Units 1+2. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada Science Advisory Schedule as they become available.

Bourdages, H., Brassard, C., Desgagnés, M., Galbraith, P., Gauthier, J., Légaré, B., Nozères, C., Parent, E. and Schwab P. 2016. Preliminary results from the groundfish and shrimp multidisciplinary survey in August 2015 in the Estuary and northern Gulf of St. Lawrence. DFO Can. Sci. Advis. Sec. Res. Doc. 2016/004. v + 88 p.

DFO. 2010. Assessment of redfish stocks (*Sebastes fasciatus* and *S. mentella*) in Units 1 and 2 in 2009. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2010/037.

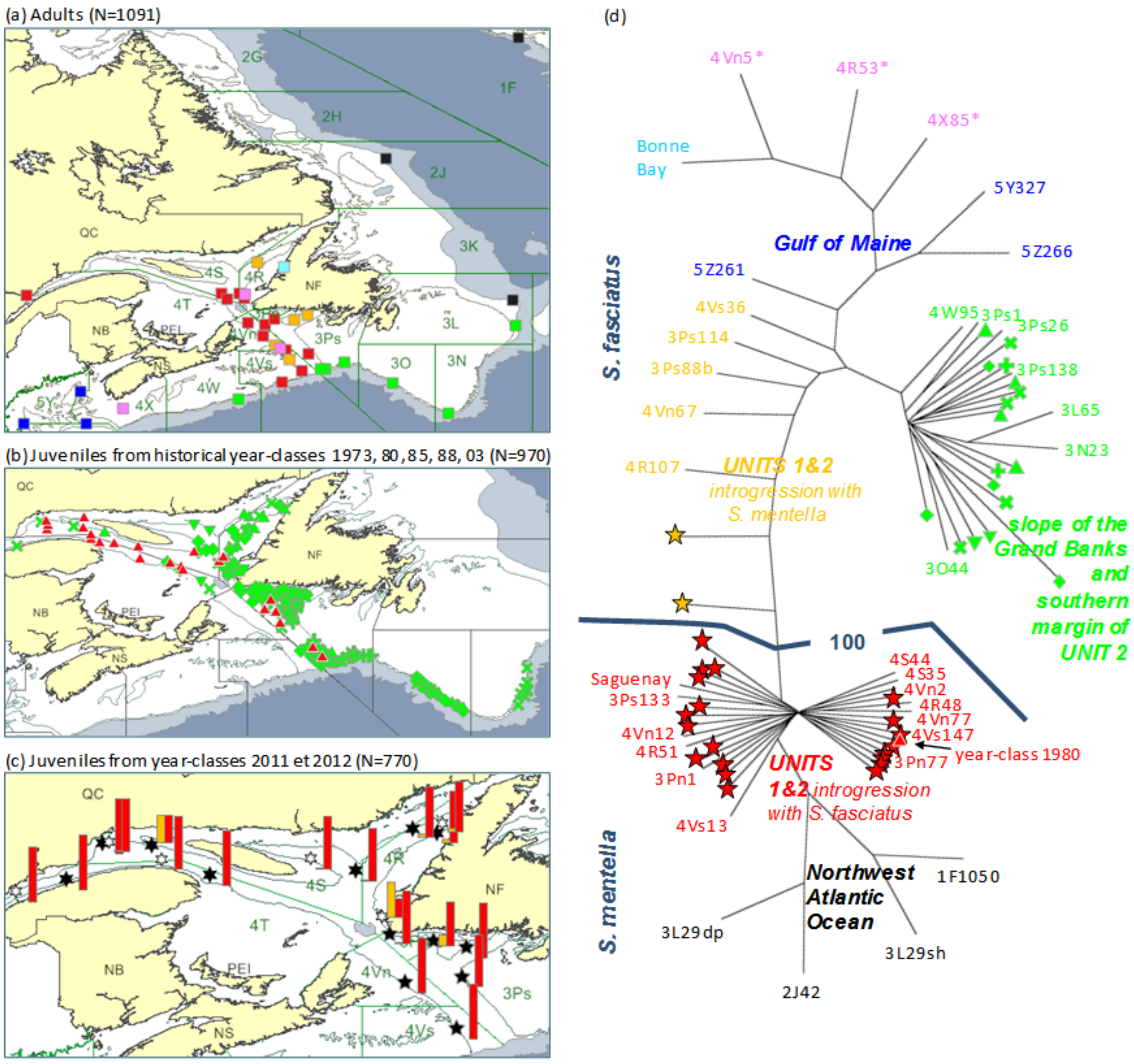
DFO. 2011. Recovery potential assessment of redfish (*Sebastes fasciatus* and *S. mentella*) in the northwest Atlantic. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2011/044.

DFO. 2012. Reference points for redfish (*Sebastes mentella* and *Sebastes fasciatus*) in the northwest Atlantic. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2012/004.

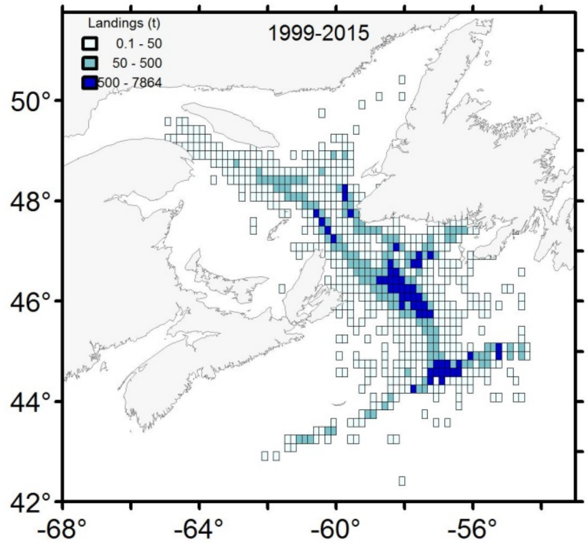
Valentin A.E., Power D. and Sévigny J-M. 2015. Understanding recruitment patterns of historically strong juvenile year-classes in redfish (*Sebastes spp*.): the importance of species identity, population structure, and juvenile migration. Can. J. Fish. Aquat. Sci 72(5): 774-784. doi.org/10.1139/cjfas-2014-0149.

APPENDICES

Appendix 1. Geographic location of (a) 35 samples (■) of adult Redfish (16 S. mentella, n=495; 19 S. fasciatus, n=596) analyzed to describe population structures by species in the Northwest Atlantic; (b) 970 juveniles belonging to five historical year-classes [1973 (✚),1980 (▲), 1985 (◆), 1988 (✖), 2003(▼)] analyzed to document the species' recruitment dynamics and patterns; these individuals are divided into 18 samples (17 S. fasciatus + 1 S. mentella), by age and area, in the genetic tree (see panel d); (c) 20 samples that include 770 juveniles from the abundant 2011 (★) and 2012 year-classes (☆), analyzed to determine the composition of the original population. Histograms illustrate the percentage of S. fasciatus (■) and S. mentella (■). In (d) the tree of the closest relative was built based on calculated genetic distances between each pair of samples. Samples of adults are identified with a label indicating their geographic origin (management unit) and their original name; the names of the main populations identified using samples of adults are indicated. Juveniles are identified with symbols identical to those used in maps B and C.



Appendix 2. Spatial distribution of Redfish catches (t), directed Redfish fisheries.



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