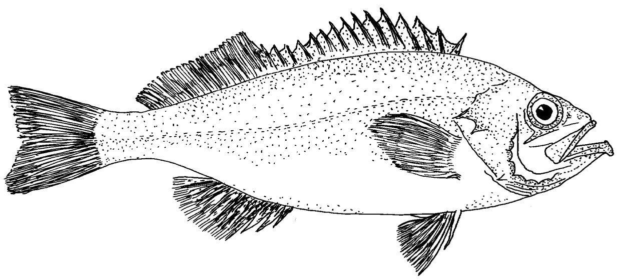
ASSESSMENT OF REDFISH STOCKS (*SEBASTES FASCIATUS* AND *S. MENTELLA*) IN UNITS 1 AND 2 IN 2009



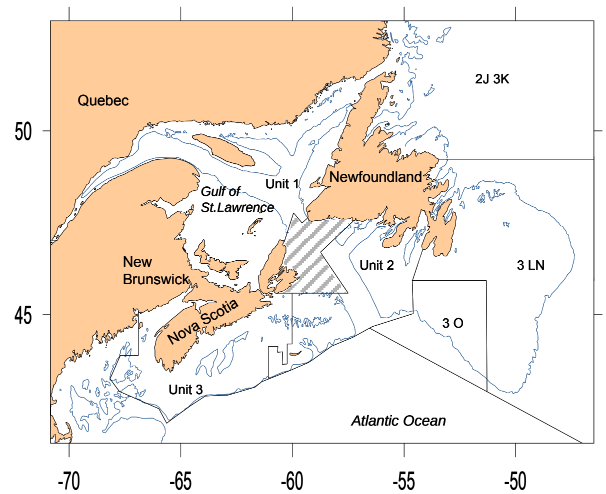


Figure 1: Units 1 and 2 management areas for Redfish stocks.

Context

Stock assessments for redfish in Unit 1, Unit 2, Unit 3 and, NAFO Division 3O were conducted at Zonal Advisory Processes (ZAP) between 1995 and 1999. Units 1 and 2 and Division 3O continued to be assessed at ZAP until 2001. Since that time it was inter-regionally agreed to suspend ZAP to focus research efforts on the species identification and stock structure issues as evidence was mounting in the direction of biological similarity between Unit 1 and Unit 2. Regional assessment updates were last published in 2004 for both Unit 1 and Unit 2. Div. 3O has been assessed by NAFO Scientific Council since 2003.

*The Department of Fisheries and Oceans has reviewed the stock definition of redfish (*Sebastes fasciatus *and* S. mentella*) at two ZAP meetings in February 2006 and September 2007. The main conclusions were:*

- *In Unit 1 and 2, there are two commercially important species of redfish: Sebastes fasciatus and S. mentella.*
- *Population data indicate that the two species do not have the same life history, particularly in terms of reproduction and recruitment mechanisms.*
- *A review of the biological data (genetics, morphometrics and otolith chemical signature) suggests that Units 1 and 2 correspond to a single biological population of each species.*

It was therefore recommended:

- *That the two species,* Sebastes fasciatus *and* S. mentella*, be assessed separately at a ZAP meeting.*
- *That Units 1 and 2 be grouped as a single biological unit for each of the two species and assessed as such.*
- *To explicitly take into consideration the spatial structuring of the populations in the assessment and in the development of conservation and management strategies.*

This present zonal assessment addresses the 2006 and 2007 conclusions and recommendations.

SUMMARY

- This assessment follows two zonal reviews on redfish (*Sebastes fasciatus* and *S. mentella*) stock structure in Units 1 and 2. These reviews concluded that Units 1 and 2 correspond to a single biological population of each species. It was therefore recommended that Units 1 and 2 be grouped as a single biological unit for each of the two species and that they be assessed separately.

- From 2004 to 2009 (2009 data are preliminary) the average annual landings of the index fishery and by-catch in Unit 1 reached 622 t (mean annual TAC of 2,000 t). During the same period, landings and by-catch in Unit 2 averaged 5,229 t (mean annual TAC of 8,333 t). Industry reports that market conditions and by-catch limitations had a major effect on catches.

- The catch per unit of effort of bottom trawls in the Unit 1 index fishery declined between 2004 and 2009. Data for Unit 2 were not analysed.

- Recruitment mechanisms for both species are not well understood. Annual typical recruitment seems stable and low and has not resulted in an increase of the population.

- Strong year-classes of *S. fasciatus*, exhibiting the genetic signature of the southern edge of the Grand Banks population appeared in 1974, 1985, 1988, and 2003 in Units 1 and 2. These did not persist in Unit 1, but did contribute to the Unit 2 commercial fishery.

- The last strong *S. mentella* year-class from Unit 1 appeared around 1980 and expressed the genetic signature of Units 1 and 2. This cohort has supported the fishery for more than 20 years.

- The two species are distributed according to depth. *Sebastes fasciatus* is generally found in shallower waters than S. mentella. In summer surveys, *S. fasciatus* dominates water depths of less than 300 m, except at the Laurentian Fan where it is found in deeper waters. *Sebastes mentella* is mostly predominant in depths of more than 300 m.

- A unified survey index series was constructed for each species from 2000 to 2009. Over this period, estimates of *S. fasciatus* survey biomass appear stable and *S. mentella* has declined continuously. From 2000-2005, the biomass of *S. fasciatus* and *S. mentella* were similar, but in recent years, there are lower levels of *S. mentella* compared to S. fasciatus. The same trends are observed for the spawning stock biomass.

- Survey index of spawning stock biomass of *S. fasciatus* was estimated at 146,400 t in 2009. Since 2000 the average percentage of spawning biomass estimated in Unit 1 and Unit 2 are 18% and 82%, respectively.

- Survey index of spawning stock biomass of *S. mentella* was estimated at 115,400 t in 2009. Since 2000 the average percentage of spawning biomass estimated in Unit 1 and Unit 2 are 27% and 73%, respectively.

- Relative exploitation rates are estimated at 2% and 3% in Unit 1 and Unit 2, respectively, in 2009. Since the commercial catch can not be broken down by species, the exploitation rate cannot be estimated for each species.

- Given the relatively low level of biomass observed and the prospect of only typical low recruitment, it is recommended that the exploitation rate remains low for both species.

- In order to reduce exploitation on *S. mentella*, it is recommended to concentrate the exploitation in the shallower waters and along the edge of the outer shelf.

BACKGROUND

Species biology

Redfish inhabit cool waters along the slopes of banks and deep channels in depths of 100-700 m. *Sebastes fasciatus* typically occurs in shallower waters (150-300 m), whereas *S. mentella* is distributed at depths varying between 350 and 500 m. Redfish are generally found near the bottom. However, different studies have shown that these species undertake diel vertical migrations, moving off the bottom at night to follow the migration of their prey.

Redfish are slow-growing and long-lived species. *Sebastes fasciatus* does not grow as fast as *S. mentella*, although the differences in growth rate become apparent only after about age 10. In both species, females grow faster than males after about age 10. On average, redfish take approximately 7 to 8 years to reach the regulated minimum fishable size of 22 cm.

Males mature 1-2 years earlier than females of the same species and at a size which is 3-5 cm smaller than females. *Sebastes fasciatus* of a given sex mature 1-2 years earlier and at a size which is 1-3 cm smaller than that of *S. mentella*. *Sebastes fasciatus* males mature at a younger age and smaller size than either female *S. fasciatus*, or male and female *S. mentella*. Comparisons between Units 1 and 2 redfish show that there is no difference in size at maturity between redfish from the two management units.

Unlike many other cold water marine fish species, fertilization in redfish is internal and females bear live young. Mating takes place in the fall most likely between September and December and females carry the developing embryos until they are extruded as free swimming larvae in spring. Larval extrusion takes place from April to July depending on the areas and species. Mating and larval extrusion do not necessarily occur in the same locations. *Sebastes mentella* releases its larvae about 3 to 4 weeks earlier than *S. fasciatus* in the Gulf of St. Lawrence.

Redfish species identification criteria

Although it has been know for some time that redfish in Unit 1 and 2 were composed of two commercially important species, *Sebastes fasciatus and S. mentella*, they have always been assessed as “redfish sp.” because of difficulties in their identification. Now that it has been stressed that these two species have important biological, recruitment, and reproductive differences and that there are concerns of possible overexploitation and disappearance of one of the two species (*S. mentella*), important efforts have been put forward to assess redfish by individual species.

Three characteristics are most commonly used to discriminate *Sebastes mentella* from *S. fasciatus* in the Northwest Atlantic. These are (1) number of soft rays in the anal fin (anal fin count (AFC); mostly ≥8 for *S. mentella*, mostly ≤7 for *S. fasciatus*), (2) extrinsic gasbladder muscle passage patterns (EGM; primarily between ribs 2 and 3 for *S. mentella*, primarily between ribs 3 and 4 or beyond for *S. fasciatus*), (3) genotype at the liver malate dehydrogenase locus (*MDH-A*; MDH-A*11* for *S. mentella*, *MDH-A*22* for *S. fasciatus*)*.* The first two criteria are routinely assessed on Unit 1 DFO and Unit 2 GEAC surveys, respectively. The agreement between these three criteria is high (97%) in allopatric areas (region with only one species) but decreases in sympatric areas (regions with the two species) like Units 1 and 2 (56% and 68% respectively). The reduced agreement is caused by introgressive hybridization i.e., cross fertilization between *S. fasciatus* and *S. mentella.* This gives rise to hybrids that have incorporated genes of the other species. Another factor that can help discriminate between species is depth. It has been demonstrated from summer survey data that *S. fasciatus* is found in waters of less than 300 m while *S. mentella* is predominant in depths of more than 300 m.

Fishery

A directed redfish fishery developed in the Gulf of St. Lawrence and in the Laurentian Channel outside the Gulf by the late fifties. Prior to 1993, redfish were managed as three units within the NAFO (Northwest Atlantic Fisheries Organisation) framework: Divisions 4RST, Divisions 3P, and Divisions 4VWX. In 1993 these management units were redefined to have a firmer biological basis and to account, among other things, for the winter migration of the Gulf redfish stock in the Cabot Strait area. The resulting management units were divided as follows: Unit 1 included 4RST Divisions and Subdivisions 3Pn4Vn from January to May; Unit 2 included Divisions 3Ps4Vs, Subdivisions 4Wfgj, and Subdivisions 3Pn4Vn from June to December; and Unit 3 included Divisions 4WdehklX (Figure 1). Although these managements units were thought to be more biologically appropriate, uncertainties remained about the amount of exchange among units, most particularly between Unit 1 and Unit 2. Recent research has shown no genetic differences between Unit 1 and Unit 2 within each redfish species.

Landings in Unit 1

The redfish fishery in the Gulf of St. Lawrence has been characterized by two periods of high landings: the first at the beginning of the 1970s and the second in the 1990s (Figure 2). For the period 1960-1969, landings averaged 46,000 t annually and increased to 82,000 t for the 1970-1976 period (Table 1). Landings peaked in 1973 at 136,000 t. Average annual landings were lower at 37,000 t for the period 1977-1994. In 1995, the directed fishery was closed as a result of low stock abundance and the absence of significant recruitment. The directed fishery has remained closed since then. However a small index fishery established in 1998 has been prosecuted with an allocation of 2000 t (1000 t in 1998). From 2004 to 2008 the average annual landings of the index fishery and by-catch in Unit 1 reached 626 t for a total allowable catch (TAC) of 2,000 t. For 2009, preliminary data indicate landings of 600 t for an allocation of 2000 t.

Landings in Unit 2

From 1960 to 1969, annual landings averaged 27,000 t, and increased to an average of 40,000 t for the period 1970-1976 due mainly to increased catches by non-Canadian fleets. Subsequent to the establishment of the 200-mile limit, landings were lower with an average of 18,000 t for the period 1977-1994 (Table 1). Landings further decreased to an average of 10,500 t between 1995 and 2003, following reductions in TAC. From 2004 to 2008, landings in Unit 2 averaged 5,250 t compared to a mean annual TAC of 8,333 t. Industry reported that market conditions had a major effect on catches falling short of the TAC. In 2009 preliminary data indicated landings of 5,132 t from a TAC of 8,500 t.

In recent years, there has been an increase in the proportion of catch taken at the Laurentian Fan, which is in an area along the mouth of the Laurentian Channel primarily in 4Vsc.

Table 1. Redfish landings and TAC (in thousands of tons) in Units 1 and 2

	Year	1960-1969	1970-1976	1977-1994	1995-1998	1999-2003	2004-2008	2009[4]
Unit 1	TAC	-	-	45[2]	1[3]	2[1]	2[1]	2
	Landings	46[1]	82[1]	37[1]	0,1[1]	1[1]	1[1]	1
Unit 2	TAC	-	-	27[2]	11[1]	10[1]	8[1]	8,5
	Landings	27[1]	40[1]	18[1]	11[1]	10[1]	5[1]	5
Units 1&2	Landings	73[1]	122[1]	55[1]	12[1]	11[1]	6[1]	6

[1]Average
[2]1993-1994
[3] 1998
[4] Preliminary data

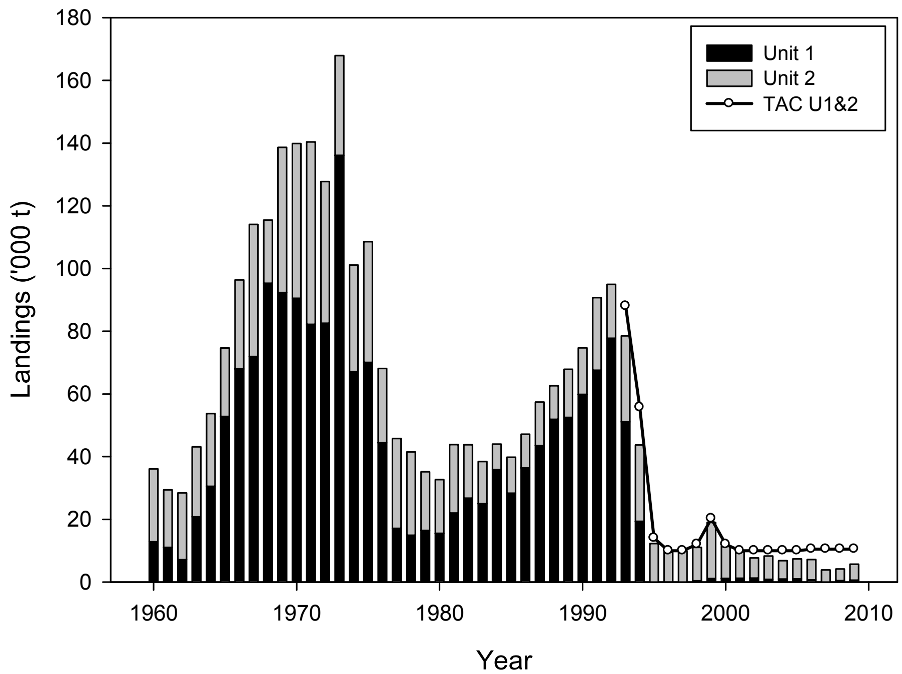


Figure 2. Landings and TAC (t) for Unit 1 and 2 redfish stocks. Landings are for the respective management years, which are May 15 of the current year to May 14 of the following year for Unit 1 and from April 1 to March 31 for Unit 2. TAC represent the sum for management Units 1 and 2 since their establishment in 1993.

Conservation measures and area of closure

Conservation measures for redfish include a small fish protocol (22 cm), 100% dock side monitoring, mandatory hail out prior to departure and hail in, observer coverage (25% in Unit 1, 10% fixed gear and 5-20% mobile gear in Unit 2), and a by-catch protocol (Unit 1 varies from 5-15%, Unit 2 is 10% for > 65' mobile gear fleets).

Closures are in place to protect redfish fertilization and larval extrusion periods and to minimize possible harvests of Unit 1 redfish migrating into 3Pn4Vn in late fall and winter.

Unit 1 index fishery

A redfish industry survey (RIS) program was established in 1998 in response to a recommendation from the Fisheries Resource Conservation Council to gather more information on Unit 1 redfish during the moratorium period. This program had two components: a systematic scientific survey intended to develop a new abundance index and an index fishery intended to collect data on bottom trawlers catch per unit of effort (CPUE). The former part of the program, the systematic survey, ended in 2003.

Although the index fishery is permitted in 4RST, spatial distribution of fishing effort has varied over the time series. From 1999 to 2003 most of the effort was deployed in 4T and 4R, along the Laurentian slopes north of Cabot Strait. From 2004 to 2006, in addition to the previous fishing sites, some effort has been deployed in 4S within the Laurentian Channel. In 2008 and 2009, most of the effort was concentrated in 4T at an average fishing depth of 348 m, typical of *S. mentella*. According to industry representatives, market conditions would be responsible for the concentration of effort in 4T and the avoidance of 4S would be due to high halibut abundance and low by-catch allocation.

The standardized catch per unit of effort (CPUE) of bottom trawls in the Unit 1 index fishery declined gradually from 2004 to its lowest value in 2009 (Figure 3) indicating a lower performance of the fishery in recent years.

Fishers raised concerns regarding the validity of this index fishery and have put forward some points that could bias downward the CPUE in the index fishery. First, the lack of experience of new fishers entering the index fishery each year could result in lower catch rates. Second, due to recent restrictions imposed on the industry, the redfish fishery is not prosecuted as it used to be. In the past, a fisher would do few small tows to look for big aggregations and then fish on those. Nowadays, the small daily allocation would not allow searching for big aggregations resulting in lower CPUE.

Unit 1 commercial catch at length

Size composition of the Unit 1 fishery for the 1981-1988 period shows that catches were mainly composed of fish born at the beginning of the 1970s (mainly the 1970 year-class) (Figure 4). From 1988 to 2007, fish born at the beginning of the 1980s, mainly the 1980 year-class dominated the fishery. This 1980 year-class, identified as mainly *S. mentella* (but with a significant amount of *S. fasciatus*) originating from Units 1 and 2 by genetic analyses, entered the fishery in 1987 and has persisted until 2009. *Sebastes mentella* has contributed to the Unit 1 fishery for over 20 years. In recent years (2006-2009), contribution from subsequent year-classes is indicated by the presence of fish between 25 and 35 cm. Since 1999, the signal in the catch at length distribution is noisier due to a much reduced fishery and thereby fewer numbers of fish measured by observers and DFO sampling programs.

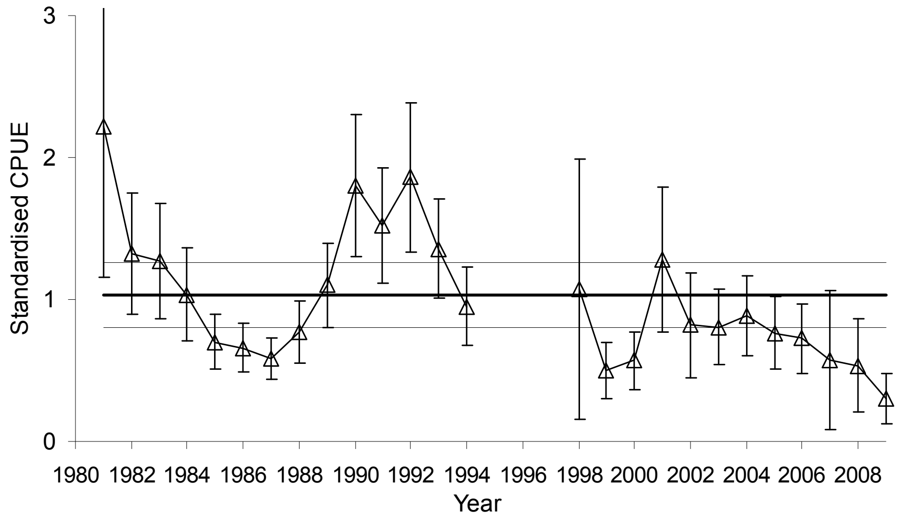


Figure 3. Standardized catch per unit of effort (Mean CPUE ± 95% confidence intervals) of bottom trawls fishing activities between May and October in the commercial fishery (1981-1994) and index fishery (1998-2009). The thick solid line represents the 1981-2008 average, thin lines represent ± ½ standard deviation.

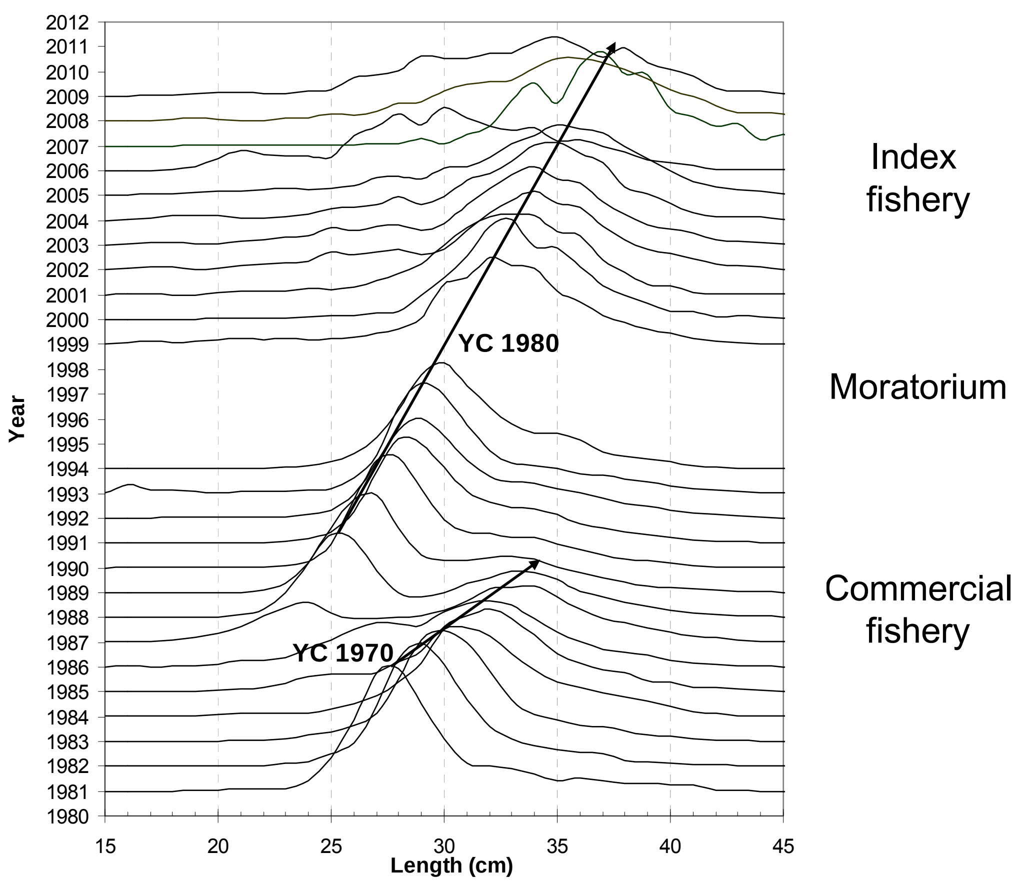


Figure 4. Commercial catch-at-length (%) for Unit 1 redfish from 1980 to 2009.

Unit 2 commercial catch at length

Size compositions from the Unit 2 fishery from 1995-2004 and 2009 indicate that most of the catch from 1995-2002 was dominated by the strong 1980 year-class which subsequently declined. This year-class was identified as mainly *S. fasciatus*. The 2009 catch at length was dominated by lengths between 28-35 cm corresponding to year-classes born in 1988 and later (Figure 5). There were three above average year-classes tracked as pre-recruits in research vessel (RV) surveys (1988, 1994 and 1998 year-classes) that now comprise the majority of the 2009 commercial catch at length. However, their combined relative contribution is not thought to be as great as the strong 1980 year-class which dominated the catch for 15 years and still contributed marginally to the 2009 fishery. Past genetic sampling has identified the relatively strong 1988 year-class to be *S. fasciatus*.

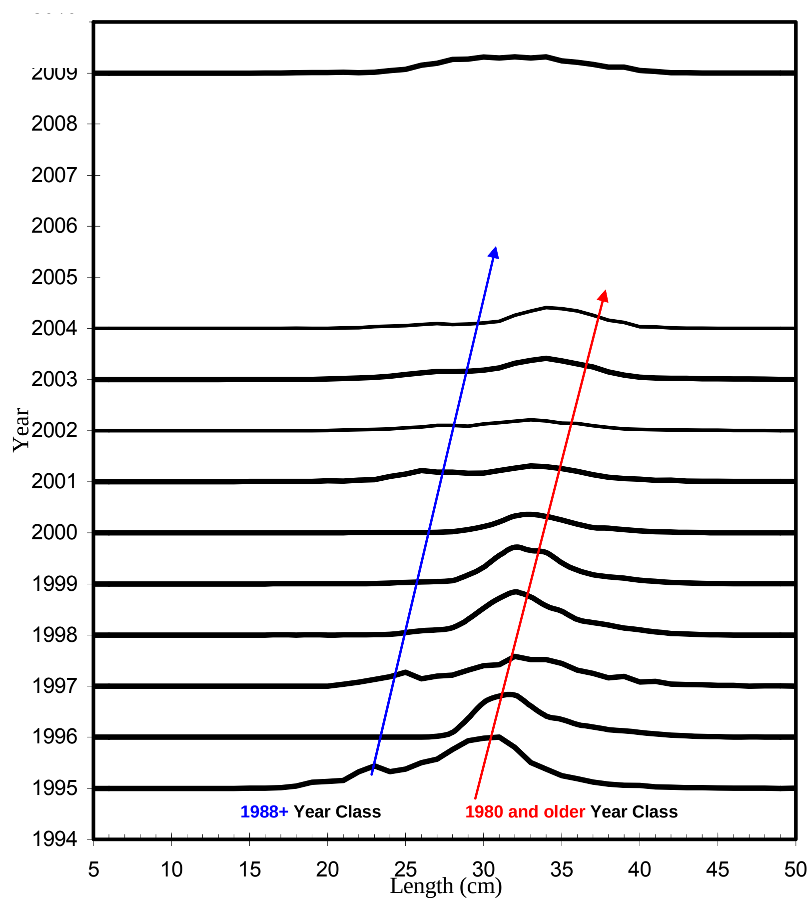


Figure 5. Commercial catch-at-length (%) for Unit 2 redfish from 1995-2004 and 2009.

By-catch in the redfish fishery

The reported by-catch in the redfish directed fisheries of Units 1 and 2 was examined for the period 2006 to 2009. The by-catch of each of the recorded species sold was looked at per NAFO Division, and month, along with the redfish directed catch. An annual proportion between the by-catch and the directed redfish catch was calculated and a few cases of relatively high by-catch levels were highlighted.

Overall, the total tonnages of reported by-catch did not cause concern given they are also accounted for in the by-catch allocations for those species.

ASSESSMENT

Sources of information

Stock status was assessed using data from Unit 1 and Unit 2 fisheries: commercial landings, catch at length, and exploitation rates. Standardized catch per unit of effort (CPUE) of the commercial (index) fishery was calculated for Unit 1 only. This CPUE is interpreted as an index of the performance of the fishery. Indices of abundance derived from DFO and industry surveys were also available for Unit 1 and Unit 2. In Unit 1, the July otter trawl Sentinel survey (1995-2009) and the DFO research vessel (RV) August survey (1990-2009) were examined. For Unit 2, the industry September GEAC survey (1997-2009, partially funded by DFO since 2007) was analyzed. Stock status was assessed in a stepwise manner. Each survey was analyzed in terms of pooled redfish species and when possible, further analyzed by species, *S. fasciatus* and *S. mentella*. A unified Unit 1 and 2 index of abundance (2000-2009) for each of the two species was derived using the Unit 1 annual DFO RV survey and the Unit 2 GEAC industry survey through comparative fishing trials that allowed a conversion of each series into Campelen trawl equivalent estimates.

Recruitment events

In the Northwest Atlantic, redfish is characterised by extensive variability in recruitment with stronger tractable pulses generally occurring at 5-12 year intervals. However, recruitment has been low in both Units 1&2 in the last 20 years. Some year-classes that appeared strong at young ages in research surveys, particularly in Unit 1, subsequently declined to a great extent within a few years without contributing to either the adult populations or the fishery. The factors responsible for the disappearance of these year-classes remain unknown, but the species composition of a given year-class may be a key factor in the recruitment dynamics.

Genetic research was undertaken to: (1) determine the species composition of strong year-classes that have either contributed significantly to the fisheries or that disappeared before contributing in order to determine if redfish recruitment success or failure is atttributed to a particular species (*S fasciatus* or *S. mentella*); and (2) assess the temporal variability of the redfish species distribution and stock structure. The information needed was obtained through DNA analyses (using 13 microsatellite markers) extracted from the material adhering to archived otoliths or from redfish tissue samples.

Five relatively strong recruitment pulses were tracked in the RV survey data. A total of 1014 samples were selected and analyzed for the following combination of year-classes and regions: 1974 in Unit 2; (1979)-1980 in Units 1 and 2, and 3O; 1985 in Units 1 and 2, and 3O; (1987)-1988 in Units 1 and 2, 3L, 3N, and 3O; and 2003 in Units 1 and 2. Although other above-average year-classes were noted in Unit 2 in 1994 and 1998, these were not considered in the genetic study.

All those strong year-classes were strongly dominated by *S. fasciatus*, with two exceptions: the 1987 year-class in 3L was composed of *S. mentella*, and the 1980 year-class in Unit 1 was dominated by *S. mentella*, with a significant amount of *S. fasciatus*. Closer examination of the

RV survey data indicates that two consecutive recruitment pulses may have occurred in the 1980s in Units 1 and 2. Additional analysis of samples corresponding to these two events is required.

These genetic results led to the conclusions that 30 years ago, Units 1 and 2 produced the last strong *S. mentella* year-class that greatly contributed to the fishery; all the recent strong year-classes are *S. fasciatus* (1974, 1985, 1988, and 2003) in Units 1 and/or 2 and they express the genetic signature of the south margin of Unit 2 and 3LNO. These *S. fasciatus* year-classes disappeared well before recruiting to the Unit 1 fishery but contributed to Unit 2 fisheries, with the exception of the 2003 year-class which is still largely pre-recruit. Although enlightening, this genetic research on strong recruitment events raises more questions on the recruitment mechanisms for both species.

Stock trends

Unit 1 redfish abundance and biomass indices based on the July mobile gear sentinel survey (1995-2009)

The July mobile gear Sentinel survey (1995-2009) follows a depth-stratified random sampling design similar to that used in the DFO RV survey. Nine trawlers participate in this survey using a Star Balloon 300 bottom trawl with a 40 mm mesh size liner in the codend. The trawl is equipped with a restrictor cable to maintain a constant and comparable trawl opening during fishing operations. Three hundred stations are fished in depths of more than 20 fathoms over the 3Pn, 4RS Divisions and in the deep portion (> 100 fathoms) of the 4T Division. None of the characteristics (AFC, MDH) that enable the separation of redfish into species are collected on the Sentinel survey which explains that the data are presented as total redfish.

The minimum trawlable abundance index indicated stability between 1996 and 1999, then decreased up to 2003 (Figure 6C). There was a rapid increase to the highest value in the series in 2007, mainly due to the increasing selectivity to the trawl of the strong 2003 year-class (Figure 6B). This was followed by a large decline in 2008 and again in 2009, indicating the disappearance of the 2003 year-class. The 2009 value was the lowest of the series. The minimum trawlable biomass index (Figure 6D) was stable and higher between 1996 and 1999, then decreased to 2003 and remained low and stable to 2009. The 2009 value was the lowest of the series. Mature and exploitable biomasses closely follow the total biomass.

Unit 1 Redfish abundance and biomass indices based on the DFO RV survey (1990-2009)

DFO stratified-random research surveys have been conducted in the Estuary and northern Gulf of St. Lawrence in August since 1990. Between 1990 and 2003, the survey was conducted on board the CCGS *Alfred Needler* equipped with a URI (shrimp) trawl. Since 2004, the survey has been conducted by the *CCGS Teleost* equipped with a Campelen (shrimp) trawl. Inter-calibrations were conducted in 2004 and 2005 to account for changes in vessel, gear and tow duration (Bourdages et al. 2007). The *CCGS Teleost* survey is 2.3 times more efficient than the *CCGS Needler* at catching redfish. Catches in weights and in numbers by the CCGS *Alfred Needler URI were* converted into Teleost Campelen equivalents.

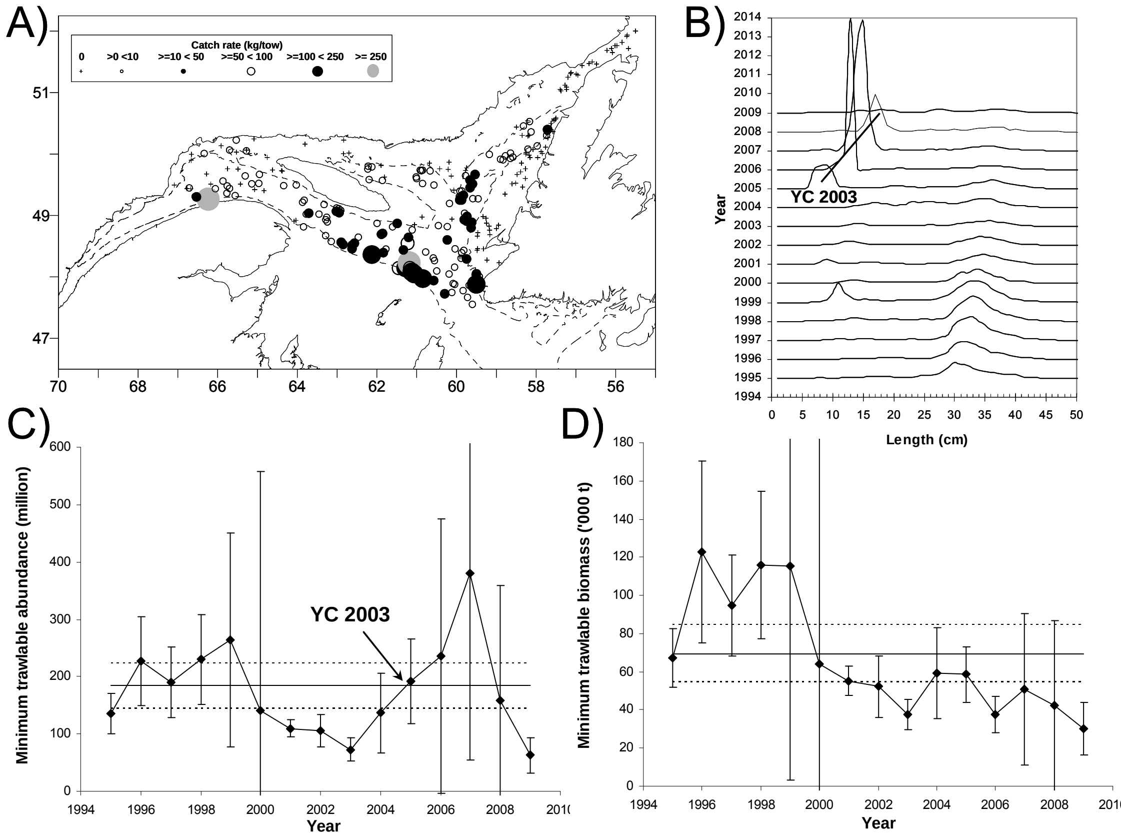


Figure 6. Results from the July mobile gear sentinel survey. A) Redfish catch rate (kg/tow) distribution in 2009. B) Length frequency distribution in numbers observed from 1995 to 2009. C) Survey abundance (millions). D) Survey biomass (thousand t). C and D are results from a multiplicative model to correct for strata not sampled. Error bars indicate the 95% confidence intervals. Solid lines represent the 1995-2008 time series average. Dotted lines represent ± ½ standard deviation.

From 1990 to 2009 there has been a contraction of the area occupied by redfish in Unit 1 (Figure 7). Between 1990 and 1994, redfish densely occupied the full extent of the Esquiman, Laurentian and Anticosti Channels in the northern Gulf of St. Lawrence. Since then, there has been a clear reduction in density throughout most of the channels. Although the recent period (2005-2009) indicates sparser densities, there are still good concentrations north of the Cabot Strait along the areas where slopes of the Laurentian and Esquiman Channels converge.

DFO RV survey indices of abundance and biomass showed a marked decline from 1990 to 1994 (Figure 8). The decrease is due to 2 factors; 1) the arrival and subsequent disappearance of the strong 1988 year-class and 2) a decrease in exploitable population (which had a greater role in the biomass reduction). From 1994 to 2004, the indices indicated a period of stability at low levels of abundance and biomass followed by an increase which is more pronounced in the abundance index. This increase was the result of the strong 2003 year-class entering the survey at age 2. This increase is again followed by a decrease caused by the disappearance of the strong year-class. The 2009 value is among the lowest for this survey index and well below the 1990-2008 time series average.

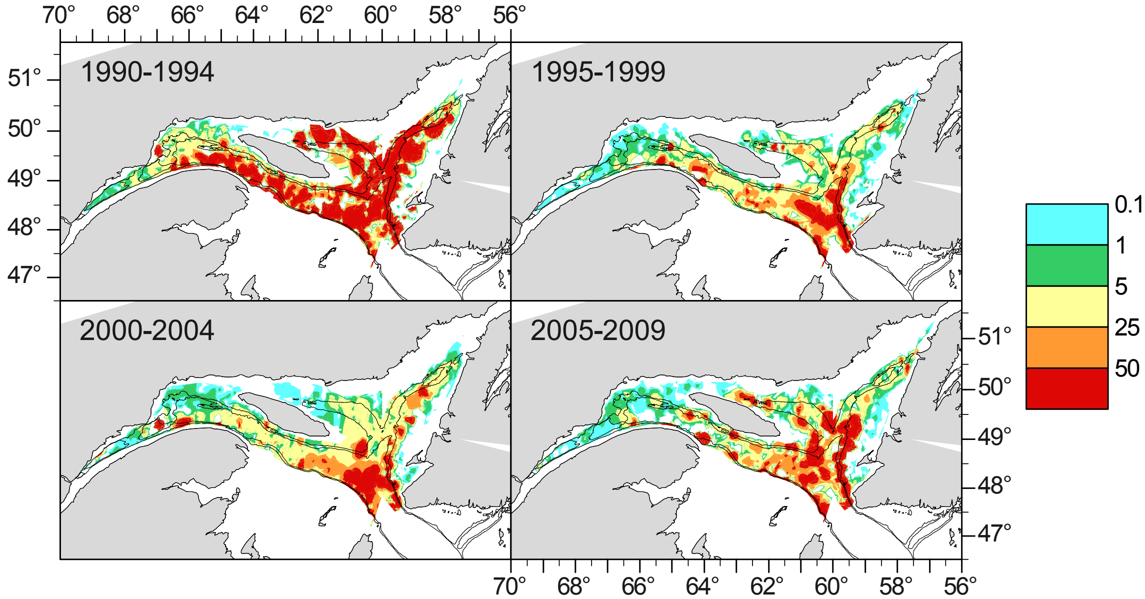


Figure 7. Geographic distribution of redfish catches (color chart represents range of kg/tow) in the August survey of the northern Gulf of St. Lawrence (1990-2009) represented in 5 year blocks.

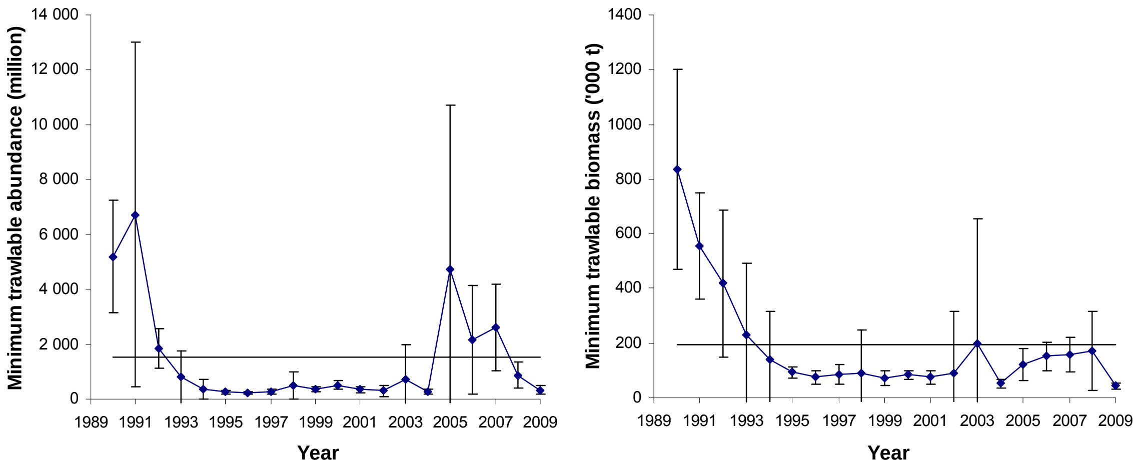


Figure 8. Unit 1 redfish abundance and biomass indices for the August DFO RV survey. Solid lines represent the 1990-2008 time series average.

Unit 1 *S. fasciatus* and *S. mentella* abundance and biomass indices based on the DFO RV survey (1990-2009)

DFO RV survey data were separated by species using a modification of an earlier method published by Méthot et al. in 2004. This new method enables to work on a set-by-set basis and involves the use of AFC and MDH discriminating criteria.

The new method allows reinterpretation of the redfish index trends by species. The marked decrease in abundance and biomass during the 1990-1994 period is seen in both species, *Sebastes fasciatus* and *S. mentella* (Figure 9). However it is the immature portion of *S. fasciatus* that has contributed the most to the decline in abundance, while the reduction in biomass is predominantly caused by mature populations of both species. The 1994-2004 period of low and stable levels is similar for mature and immature populations of both species. The subsequent increase in abundance from 2005 to 2007 was caused by immature *S. fasciatus* from the 2003 strong year-class, which decreased thereafter. These findings are consistent with genetic data that have identified the 1988 and 2003 strong year-classes as *S. fasciatus*. The 2009 abundance and biomass values for immature and mature *S. fasciatus* and *S. mentella* are both below their respective time series averages.

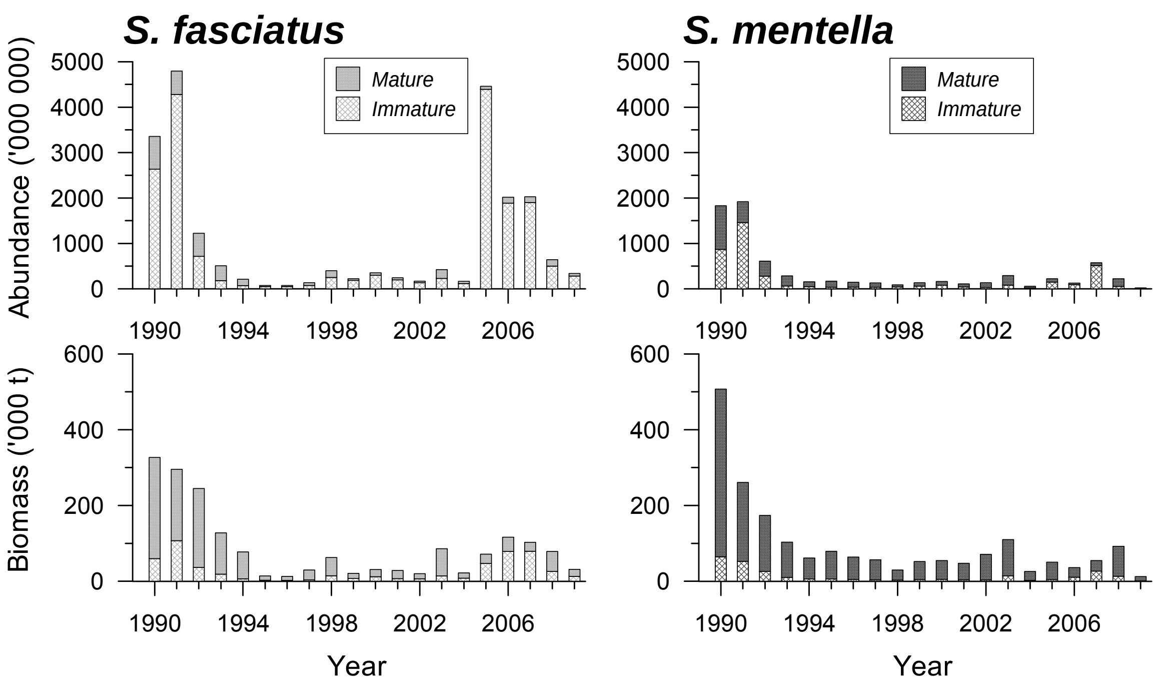


Figure 9 Unit 1 Sebastes fasciatus *and* S. mentella *minimum trawlable abundance and biomass for the mature and immature fish based on the August DFO RV survey.*

Unit 2 redfish abundance index based on the GEAC survey

The Groundfish Enterprise Allocation Council (GEAC) has funded redfish surveys in Unit 2 since 1997 to be complementary to DFO Unit 2 redfish surveys that began in 1994. However, given DFO last conducted its survey in 2002, the GEAC surveys are the only available index that covers most of the Unit 2 area.

The GEAC survey began in December 1997 on the MV Cape Beaver then switched to August/September from 1998 to 2001 and has continued bi-annually to 2009. The sister ship Cape Ballard has conducted four of the nine surveys including the most recent two surveys in 2007 and 2009. The GEAC vessels deployed an Engel 170 trawl with a 30 mm liner in the lower 7 m of the codend since 2000. The DFO Unit 2 surveys deployed a Campelen 1800 survey trawl with a 12.7 mm liner in the lower 7 m of the codend. Comparative fishing trials were conducted in August 2000 between the Cape Beaver and the CCGS Teleost and these results were modeled to provide a length-based conversion of the GEAC series from 2000 on into Teleost/Campelen equivalents (Cadigan and Power, 2010) in order to provide a basis for a unified index for the whole Unit 1-2 area (see below).

Abundance from this survey has been variable over the time series, peaking in 2007 (due to the 2003 strong year-class) (Figure 10AB). The most recent survey point (2009) is slightly above the long term average. Biomass generally showed a decline from 1996-2003 and has increased slightly since then, but remains below the long term mean (Figure 10C). Mature and exploitable biomass trends generally follow the total biomass. It should be noted that the large confidence intervals for 1998 are the result of a large catch in one stratum.

The strongest peak in length frequencies, observed in 2007, was due to the strong 2003 year-class (Figure 10A). This declined by 2009 indicating that this year-class has almost disappeared from the survey.

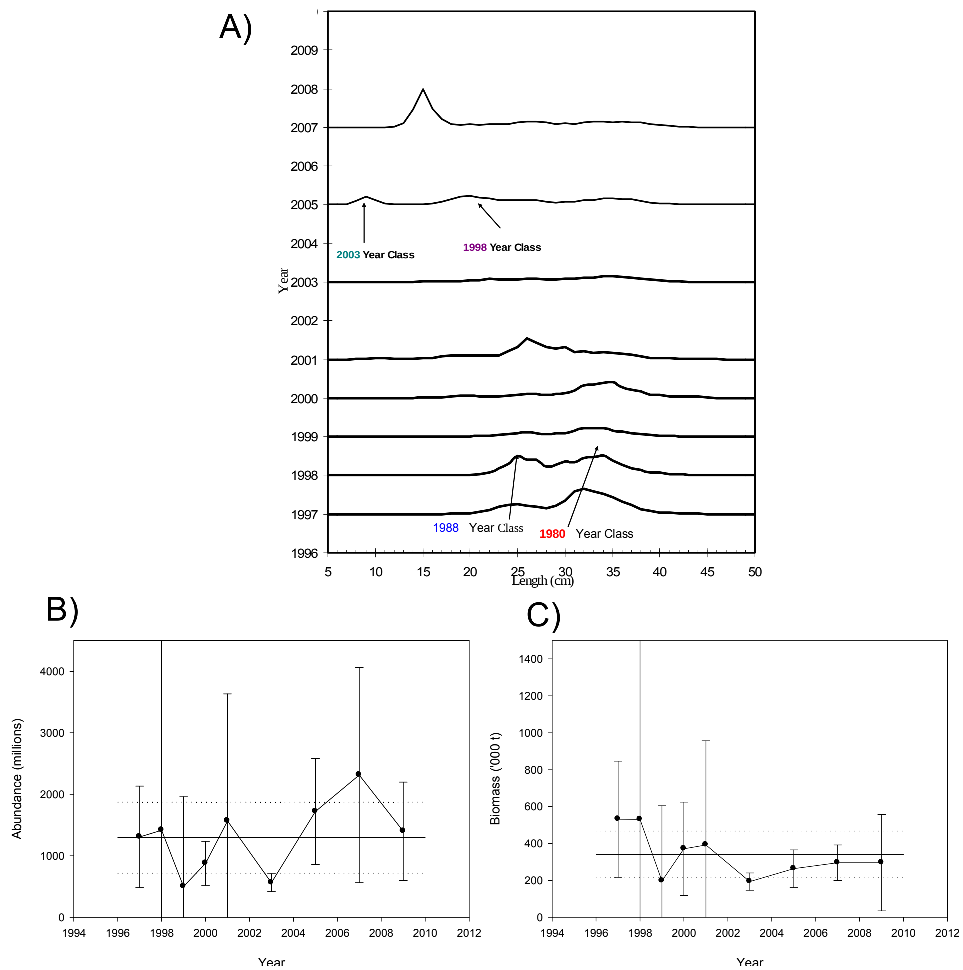


Figure 10. Results from the converted GEAC survey time series. A) Length frequency distribution in number observed from 1997 to 2009. B) Survey abundance (millions). C) Survey biomass (thousands of t). Error bars indicate the 95% confidence intervals. Solid lines represent the 1997-2009 long-term mean. Dotted lines represent ± standard deviation.

Units 1 and 2 *S. fasciatus* and *S. mentella* unified abundance and biomass indices (2000-2009)

A unified Units 1 and 2 series was constructed for each species using Unit 1 DFO RV data and Unit 2 Teleost/Campelen equivalent GEAC survey data for those years when the entire Unit 1&2 area was covered (2000, 2001, 2003, 2005, 2007 and 2009) (Figure 11). Maps of redfish biomass distribution (kg/tow) for aggregated periods (2000-2004 and 2005-2009) show a continuum of redfish distribution between Unit 1 and Unit 2 all along the Laurentian Channel up to the head of Esquiman, Anticosti and Laurentian Channels in the Gulf of St. Lawrence. These maps indicate that *S. fasciatus* are found in shallower waters than *S. mentella* except at the Laurentian fan where *S. fasciatus* is found in deep waters. Immature *S. fasciatus* are found along the edge of the channels at shallower depth than mature *S. fasciatus*. Mature and immature *S. mentella* are found mainly in the deeper part of the channels.

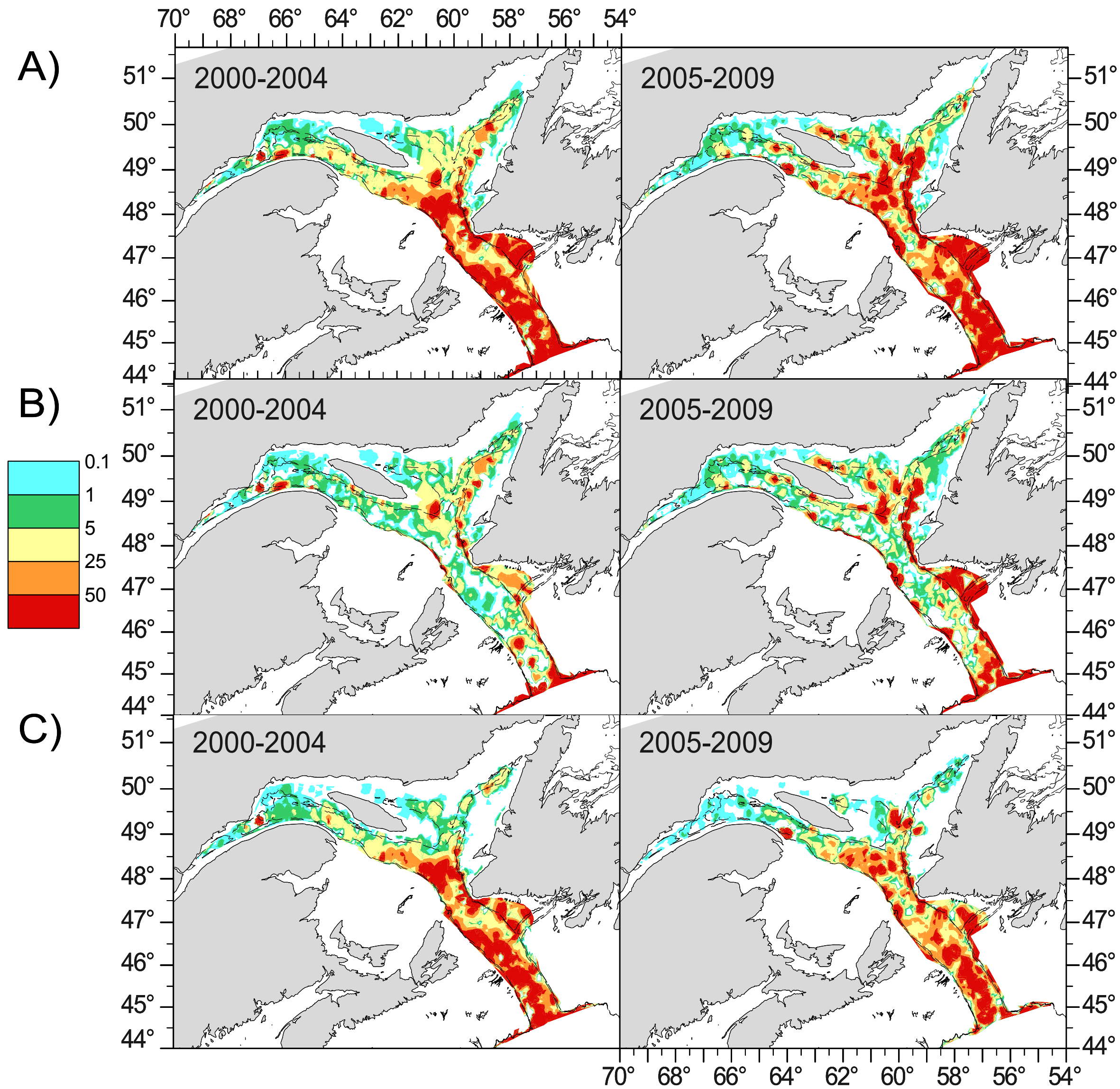


Figure 11. Geographic distribution in blocks of 5 years of A) redfish, B) S. fasciatus, *and C)* S. mentella *catches (color chart represents range of kg/tow) based on the combined Units 1 and 2 index. Surveys of Units 1 and 2 were only conducted in 2000, 2001, 2003, 2005, 2007 and 2009.*

Over the 2000-2009 period, the unified *S. fasciatus* survey biomass index appeared stable (especially for mature biomass) whereas *S. mentella* declined continuously (Figure 12). From 2000-2005, *S. fasciatus* and *S. mentella* biomasses were comparable, but in recent years, *S. mentella* biomass has been smaller than in *S. fasciatus*. The same trends are observed for the mature biomass.

Survey index of mature biomass of *S. fasciatus* was estimated at 146,400 t in 2009. Since 2000 the average proportion of spawning biomass estimated in Unit 1 compared to total Units 1 and 2 is 18%. Survey index of mature *S. mentella* was estimated at 115,400 t in 2009. Since 2000, the average proportion of spawning biomass estimated in Unit 1 is 27% of the total biomass found in the combined Unit 1&2 area.

These new Units 1 and 2 indices by species are very promising for future work; however the short time series (2000-2009) is not indicative of the past history. To help reconstruct the past, these indices could be further extended with data from Unit 2 DFO redfish survey (1994-2002). Indeed this survey was performed with the same combination of vessel and trawl (Teleost-Campelen), same time of year, and meristic data were collected on redfish.

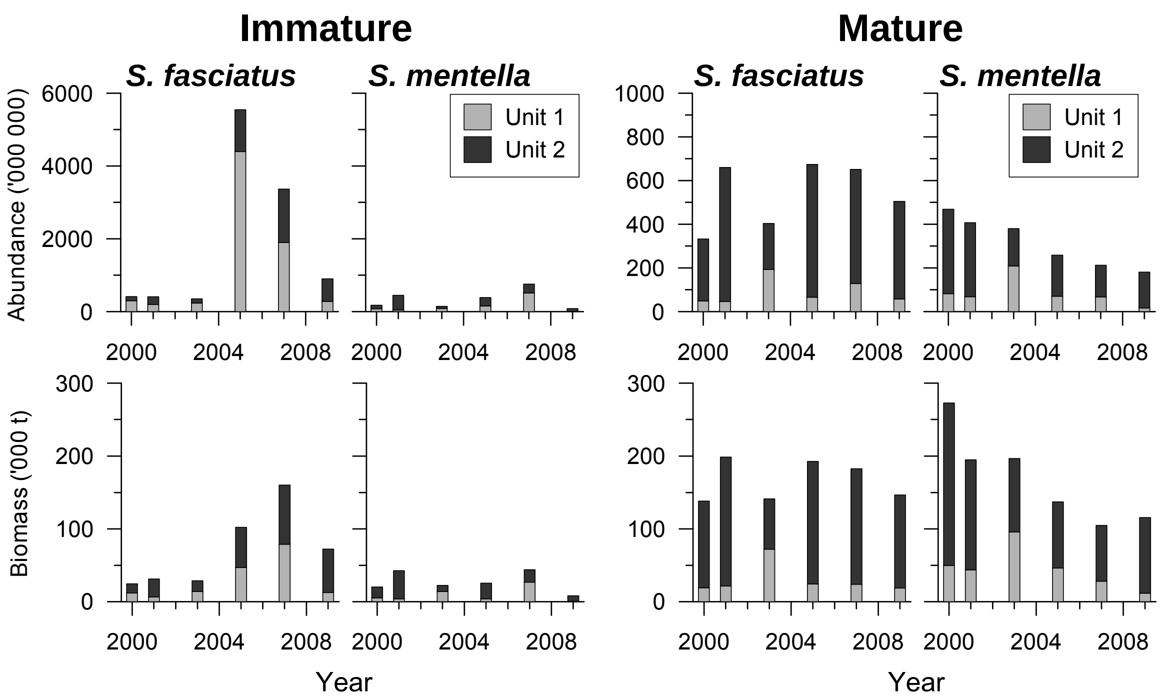


Figure 12. Units 1 and 2 Sebastes fasciatus *and* S. mentella *minimum trawlable abundance and biomass for the mature and immature populations based on the combined index from Unit 1 DFO RV survey and Unit 2 Teleost equivalent GEAC survey.*

Exploitation rate proxy

Proxies of exploitation rates, or relative *F*, were estimated for redfish for each unit separately and were expressed as the ratio of annual commercial catches (t) over exploitable biomass in percentages. Redfish exploitable biomasses were derived using Unit 1 DFO survey data and Teleost equivalent Unit 2 GEAC data. Annual numbers of fish at length were computed for the surveys, and transformed into exploitable numbers using a 95-mm bottom trawl selectivity curve. These numbers were further transformed into exploitable biomass using a length weight relationship.

The estimated exploitation proxy in Unit 1 averaged 11% for the period 1990-94. A moratorium was imposed in 1995 after which exploitation decreased to an average of 1.3 % over the 1999-2008 period of the index fishery. For 2009 it was estimated at 2% but would have been 7% if the total allocation had been taken. In Unit 2, the exploitation rate proxy averaged 3% for the 2000-

2007 period. For 2009 it was estimated at 3% and would have been 4% if the total allocation had been taken.

These exploitation proxies are directly comparable between Units since they have been estimated on equivalent survey data with the same method, and can be compared over time giving a good indication of trends. However they are not estimated through a population model and should be interpreted with caution especially when attempting to compare with published exploitation rates for redfish.

Sources of uncertainty

A major problem with assessing stock status of each of the two redfish species in combined Units 1 and 2 is the lack of species identification in the commercial fishery. New initiatives are put in place in 2010 to sample the commercial fishery, based for example on anal fin counts and/or genetic markers that would allow monitoring species in the commercial fishery in the combined Unit 1&2. The effectiveness of such programs will need to be closely monitored.

With respect to the conversion of GEAC trawl data into Teleost equivalents, only 24 comparative fishing sets were conducted. If redfish advice were based on a projection from an analytical assessment, the calibration would directly affect the catch advice. However, precise catch advice is not possible, because it is based on a descriptive assessment. Advice is not sensitive to the conversion given the same perception of stock status with and without conversion. The issue of conversion would be more important for the future if an analytical assessment was developed. It should also be noted that two vessels are involved in the GEAC survey, the MV Cape Beaver and the MV Cape Ballard. Even though the vessels are sister ships, a comparative study would be required to determine if they are equivalent and interchangeable.

The new method to split species still generates some spurious *S. mentella* in the presence of a strong *S. fasciatus* year-class, even though the new method is better that the previous one in this respect. This issue will need to be examined further.

Recruitment mechanisms for redfish species are not well understood. The new genetic research on strong recruitment events gave interesting answers but also raised more questions on recruitment mechanisms for both species. More research is needed to elucidate the fate of strong *S. fasciatus* cohorts originating from the southern margin of the Grand Banks (i.e., from the south of 3Ps to 3L) that were present as juveniles in Units 1 and 2 but that disappeared before contributing significantly to the Unit 1 fishery and only marginally in Unit 2. More research should also be focused on the current low annual recruitment to determine its species composition and identify its origin.

One last point to note is that the unified series distinguishing the two species in combined Units 1 and 2 is short (2000 to 2009). This series could be extended in the past by adding data from a former DFO Unit 2 redfish survey that took place from 1994 to 2002.

CONCLUSIONS AND ADVICE

Recruitment mechanisms for both species are not well understood. Annual typical recruitment seems stable and low and has not resulted in an increase of the population.

A unified survey index series was constructed for each species from 2000 to 2009. Over this period, estimates of *S. fasciatus* survey biomass appear stable while *S. mentella* biomass has declined continuously. From 2000-2005, *S. fasciatus* and *S. mentella* biomasses were similar, but in recent years, *S. mentella* biomass has become lower than *S. fasciatus*. The same trends are observed for the spawning stock biomass.

The survey index of spawning stock biomass of *S. fasciatus* was estimated at 146,400 t in 2009. Since 2000 the average percentage of spawning biomass estimated in Unit 1 is 18%. The index of spawning stock biomass of *S. mentella* was estimated at 115,400 t in 2009. Since 2000 the average precentage of spawning biomass estimated in Unit 1 is 27%.

Relative exploitation rates in 2009 were estimated at 2% and 3% in Unit 1 and Unit 2, respectively. Since the commercial catch cannot be broken down by species, the exploitation rate cannot be estimated for each species.

Given the relatively low level of biomass observed and the prospect of only typical low recruitment, it is recommended that the exploitation rate remains low for both species.

In order to reduce exploitation on *S. mentella*, it is recommended to concentrate the exploitation in the shallower waters and along the edge of the outer shelf.

SOURCES OF INFORMATION

Bourdages, H., D. Archambault, B. Bernier, A. Fréchet, J. Gauthier, F. Grégoire, J. Lambert, and L. Savard. 2010. Preliminary results in the groundfish and shrimp multidisciplinary survey from August 2009 in the northern Gulf of St. Lawrence. Can. Data Rep. Fish. Aquat. Sci. 1226: xii + 72 p.

Bourdages, H., L. Savard, D. Archambault, and S. Valois. 2007. Results fom the August 2004 and 2005 comparative fishing experiments in the northern Gulf of St. Lawrence between the CCGS *Alfred Needler* and the CCGS *Teleost*. Can. Tech. Rep. Fish. Aquat. Sci. 2750. 57 p.

Cadigan, N. G., and D. Power. 2010. Vessel calibration results for redfish (*Sebastes* sp.) from comparative fishing between the Teleost research vessel and the Cape Beaver fishing vessel. DFO Can. Sci. Advis. Sec. Res. Doc. 2010/062.

DFO. 2008. Proceedings of the zonal workshop review of the information on redfish (*Sebastes* sp.) available from DFO Science sector for the COSEWIC assessment, discrimination of redfish stocks of Units 1 and 2, index fishery review; September 19th and 20th, 2007. DFO Can. Sci. Advis. Sec. Proc. Ser. 2007/040.

DFO. 2008. Advice on the stock definition of redfish (*Sebastes fasciatus* and *S. mentella*) in Units 1 and 2. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2008/026.

Gascon, D. (ed.) 2003. Redfish Multidisciplinary Research Zonal Program (1995-1998): Final Report. Can. Tech. Rep. Fish. Aquat. Sci. 2462: xiii + 139 p.

McClintock, J., and M. Teasdale. 2009. Redfish catch results from the summer 2007 survey in Unit 2. DFO Can. Sci. Advis. Sec. Res. Doc. 2009/094.

Méthot, R., B. Morin, and D. Power. 2004. Description of the methods used for estimating the abundance of *Sebastes fasciatus* and *S. mentella* in Units 1 and 2. DFO Can. Sci. Advis. Sec. Res. Doc. 2004/092.

FOR MORE INFORMATION

Contact:	Johanne Gauthier or Martin Castonguay Maurice Lamontagne Institute 850, route de la Mer P.O. Box 1000 Mont-Joli (Quebec) G5H 3Z4	Don Power or Karen Dwyer Fisheries and Oceans Canada P.O. Box 5667 St.John's, NL A1C 5X1
Tel:	(418) 775-0500	(709) 772-4935
Fax:	(414) 775-0679	(709) 772-4105
Email:	Johanne.Gauthier@dfo-mpo.gc.ca Martin.Castonguay@dfo-mpo.gc.ca	Don.Power@dfo-mpo.gc.ca Karen.Dwyer@dfo-mpo.gc.ca

This report is available from the:

Centre for Science Advice (CSA)
Fisheries and Oceans Canada
Québec Region
Maurice-Lamontagne Institute
P.O. Box 1000, Mont-Joli
Québec Canada
G5H 3Z4

Telephone: (418) 775-0825
Fax: (418) 775-0679
E-Mail: Bras@dfo-mpo.gc.ca
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