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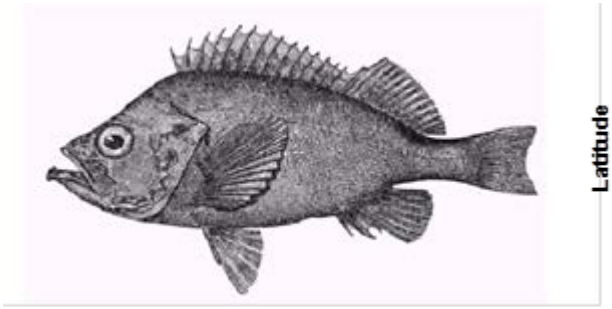
RECOVERY POTENTIAL ASSESSMENT OF REDFISH (*SEBASTES MENTELLA* AND *S. FASCIATUS*) IN THE NORTHWEST ATLANTIC



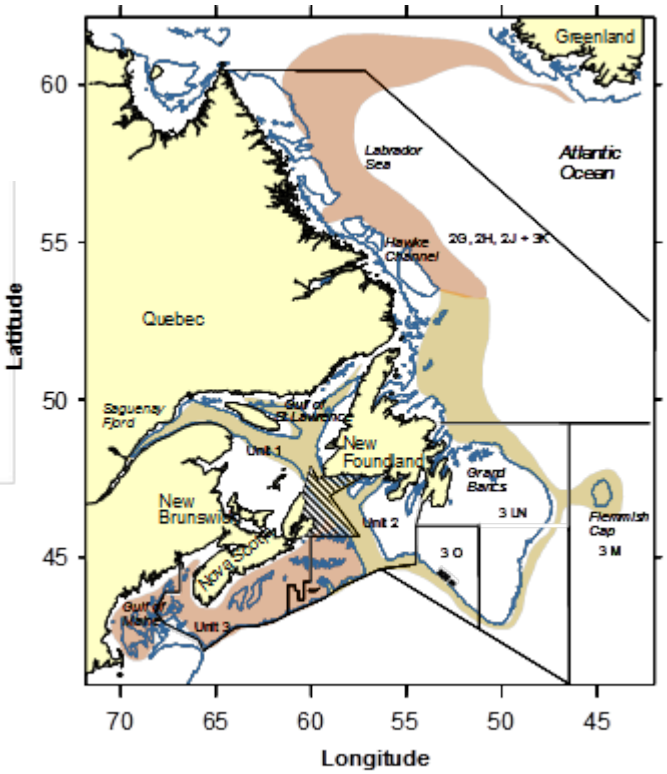


Figure 1. Map of the northwest Atlantic showing the distribution of redfish and the boundaries of the management units

Context

In April 2010, following a significant decline in the abundance of mature individuals, the Deepwater redfish (Sebastes mentella) population in the Gulf of St. Lawrence/Laurentian Channel was designated as "endangered" while the northern population was given the status of "threatened" species by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). Meanwhile, the Acadian redfish (S. fasciatus) population in Atlantic Canada was designated as "threatened".

A Recovery Potential Assessment (RPA) was implemented by DFO Science to provide information and the scientific advice required to meet various requirements of the Species at Risk Act (SARA) and develop, where appropriate, a recovery strategy.

This advice describes the status of redfish populations of the Northwest Atlantic that have been designated as "threatened" and "endangered". Recovery targets as well as projections are presented for each population. The main threats are described and measures to promote population recovery have been identified. Various recovery scenarios are presented and a recovery potential advice is provided.

SUMMARY

- COSEWIC identified two designatable units (DU) for deepwater redfish (*Sebastes mentella*): Gulf of St. Lawrence/Laurencian Channel (Unit 1+2) and northern population (SA0+2+3KLNO). Due to a lack of data in the north, the areas considered here for the northern population are 2+3KLNO[1]. These two DU's match assessment units.

- In the case of Acadian redfish (*Sebastes fasciatus*), two designatable units were identified by COSEWIC: Bonne Bay and Atlantic populations. The latter included three assessment units for the purpose of this RPA: (1) Unit 3, (2) Unit 1+2, 3LNO, and (3) 2J3K. Bonne Bay was not examined here.

- Long term projections were undertaken for the five above assessment units using Bayesian surplus production models. While the Bayesian approach used in the assessment provides a mechanism to include uncertainty in estimating the current status of the population, managers and stakeholders are advised that not all sources of uncertainty have been addressed and the true uncertainty is even greater with the 20-year and 60-year forecasting. These projections assume the population will respond to the future environment as it did to the past environment, an assumption which may not hold due to the effects of cyclical or long-term climate change and/or other external processes.

- Projections are illustrated using the median and the 5th and 95th percentiles, as well as alternatives for model inputs and historic catch scenarios. The full range of uncertainty should be considered when interpreting these projections.

- DFO fishery decision making framework incorporating the Precautionary Approach states that 40% of B_{MSY} is the default critical zone boundary. This is used here as a reconstruction target for the purpose of this RPA.

Deepwater redfish (Unit 1+2; Gulf of St. Lawrence/Laurentian Channel DU)

- The estimated biomass in 2010 is 19,000 t, with 90% probability intervals ranging from 11,000 t to 35,000 t, which is 2-6% of B_{MSY}. With a catch level of 1000 t, the stock has a 46% chance of exceeding 40% of B_{MSY} in three generations (60 years, i.e., in 2070).

Deepwater redfish (2+3KLNO[2]; northern population DU)

- The estimated biomass in 2010 is 54,000 t, with 90% probability intervals ranging from 27,000 t to 118,000 t, which is at 7-29% of B_{MSY}. With current catch levels of 3000 t, the stock has a 90% chance of exceeding 40% of B_{MSY} by 2070.

Acadian redfish (Unit 3)

- The estimated biomass in 2010 is 2,254,000 t, with 90% probability intervals ranging from 325,000 t to 8,642,000 t, which is 150-230% of B_{MSY}. With catch levels of 6000 t (slightly above current catch), the stock has a 99% chance of staying above 40% of B_{MSY} by 2070.

[1] Erratum: June 2013 - 2J3KLNO was replaced with 2+3KLNO
[2] Erratum : June 2013 - 2J3KLNO was replaced with 2+3KLNO

Acadian redfish (Unit 1+2+3LNO)

- The estimated biomass in 2010 is 1,876,000 t, with 90% probability intervals ranging from 175,000 t to 8,778,000 t, which is 30-225% of B_{MSY}. With catch levels of 9000 t (slightly above current catch), the stock has a 99% chance of staying above 40% of B_{MSY} by 2070.

Acadian redfish (2GHJ3K)

- The estimated biomass in 2010 is 8,000 t, with 90% probability intervals ranging from 3,000 t to 23,000 t, which is 4-32% of B_{MSY}. With no catch (about equivalent to current minimal catches), the stock has a 95% chance of exceeding 40% of B_{MSY} by 2070.

Acadian redfish (Atlantic Canada DU)

- Population reconstructions of two of the three assessed areas within the DU suggest that there is a low probability that there has been a 30% decline in spawning stock abundance across the DU since the 1960s. Analyses suggest that most of the biomass resides in these two stock areas.

BACKGROUND

Identification of redfish species

Three species of redfish can be found in the Northwest Atlantic: *Sebastes mentella* and *S. fasciatus*, which dominate commercial fisheries, and *S. marinus* which is much less abundant. *S. marinus* can be distinguished from the two other species by its colour, eye size and the size of its bony protrusion on its lower jaw; however, *S. mentella* and *S. fasciatus* are visually similar.

Three characteristics are used to discriminate *S. mentella* from *S. fasciatus* in the Northwest Atlantic: 1) the number of soft rays in the anal fin, 2) extrinsic gasbladder muscle passage patterns, and 3) genotype at the liver malate dehydrogenase locus. In the Gulf of St. Lawrence and the Laurentian Channel, the occurrence of hybrid individuals has also been confirmed.

Distribution

In the Northwest Atlantic, redfish distribution ranges from the Gulf of Maine, northwards off Nova Scotia and the southern Newfoundland Banks, in the Gulf of St. Lawrence and along the continental slope and deep channels from the southwestern Grand Bank to areas as far north as Baffin Island. Redfish are also present in the area of Flemish Cap and west of Greenland (Fig. 1).

Sebastes mentella and *S. fasciatus* are distributed according to a gradient in the Northwest Atlantic. In fact, *S. mentella* is the dominant species in Baffin Bay and in Labrador waters, while *S. fasciatus* dominates in the Gulf of Maine and in the basins and on the continental slopes of the western part of the Scotian Shelf. The distribution of both species overlaps in the Gulf of St. Lawrence, the Laurentian Channel, off southern Newfoundland and in the southern Labrador Sea. The distribution of the two species is also characterized by an area of introgressive hybridization which is geographically circumscribed to the Gulf of St. Lawrence and Laurentian Channel, and to a lesser extent to the Flemish Cap area.

Designatable units and COSEWIC status

Sebastes mentella

In the Northwest Atlantic, the occurrence of two designatable units has been confirmed for *S. mentella*:

- The Gulf of St. Lawrence and Laurentian Channel population;
- The northern population (Grand Banks, the Labrador Shelf, Davis Strait and Baffin Bay).

COSEWIC evaluated each designatable unit separately. The *S. mentella* population of the Gulf of St. Lawrence and Laurentian Channel was designated as “endangered” following a steady decline in the abundance of mature individuals of 98% since 1984, the equivalent of just over one generation (generation time of 18 years).

The northern *S. mentella* population has received the status of “threatened”. The abundance of mature individuals has declined by 98% from 1978, the equivalent of just over one generation (generation time of 23 years). However, this decline ceased in the mid-1990s, and increases were even observed in some regions. COSEWIC has evaluated that the northern *S. mentella* qualifies as "endangered" but it is designated as "threatened" because it is widely distributed and still contains millions of mature individuals, and has been stable or has increased since the mid-1990s.

Sebastes fasciatus

The overall structure of *S. fasciatus* in the northwest Atlantic appears to be more complex. Genetic differences are less significant than those observed in *S. mentella*. Hence groups from different regions have been pooled into two designatable units.

- The Canadian Atlantic population which includes:
  - The Gulf of St. Lawrence and Laurentian Channel;
  - The northern region (Grand Banks/Labrador);
  - The southern region (Scotian Shelf, Bay of Fundy, Gulf of Maine).
- The Bonne Bay population.

The Canadian Atlantic *S. fasciatus* population received the status of endangered species following a decline in the abundance of mature individuals of 99% within about two generations (generation time of 16-18 years) in regions that historically showed the highest abundance. However, since the 1990s, decline have halted in one sector and trends have either been either stable or have even increased in others. According to the COSEWIC assessment, the Canadian Atlantic *S. fasciatus* population corresponds to the "endangered" category criteria, but it is designated "threatened species" because it is widely distributed and includes hundreds of millions of mature individuals, and the abundance indices have been stable or increasing in some sectors since the 1990.

The Bonne Bay population is considered of special concern because of its limited distribution range.

This scientific advice focuses on redfish populations (*S. fasciatus* and *S. mentella*) in the Northwest Atlantic that have been designated "threatened" and "endangered" by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC).

Redfish Biology

Redfish is a slow-growing species with high longevity that can commonly live up to 40 years, and exceptionally up to 75 years. The growth of *S. fasciatus* is not as rapid as that of *S. mentella*, although this difference in growth rates becomes apparent only after the age of 10 years. In both species, females grow faster than males after the age of about 10 years. Growth is usually faster in areas further south. The maximum size attained by males of the species *S. mentella* varies between 40 and 45 cm while females reach 45 to 60 cm. For *S. fasciatus*, the maximum size attained is 45 cm (Gulf of Maine). On average, 6 to 8 years are needed to reach the minimum legal 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. *S. fasciatus* (males and females) mature 1-2 years earlier and at a size which is 1-3 cm smaller than that of *S. mentella*. *S. fasciatus* males mature at a younger age and smaller size than either female *S. fasciatus*, or male and female *S. mentella*.

Unlike many other marine coldwater fish species, redfish is ovoviviparous. Fertilization is internal and females bear live young. Mating takes place in the fall between September and December and females carry the developing embryos until they are extruded as free swimming larvae (7 mm) in spring (April to July). Mating and larval extrusion do not necessarily occur in the same locations. Fecundity varies according to female size, from 1,500 to 107,000 larvae. It seems that fecundity is higher in *S. fasciatus* than in *S. Mentella*. *S. mentella* releases its larvae about 3 to 4 weeks earlier than *S. fasciatus* in the Gulf of St. Lawrence and on Flemish Cap. Larvae are larger in *S. mentella.*

Redfish recruitment success varies significantly. With minor exploitation and low abundance conditions, significant year-classes are observed at 5-12 year intervals.

The diet of *S. fasciatus* and *S. mentella* appears similar. In the larval stage, redfish feed mainly on fish eggs and invertebrates. The larger larvae feed on copepods and euphausids. Juvenile and adult individuals add to their diet: copepods, euphausids and fish.

In the Gulf of St. Lawrence, harp seals and skates are important redfish predators. However, before its decline, cod was the main predator. On the Labrador Shelf, Greenland halibut and skate are the main predators of redfish. On the eastern Scotian Shelf, haddock, pollock and grey seals are important predators.

ASSESSMENT

Current Status and Trend

Sebastes mentella

Gulf of St. Lawrence and Laurentian Channel population (Unit 1+2)

During the 2000-2009 period, the biomass and abundance indices of *S. mentella* declined steadily in Unit 1+2. Between 2000 and 2005, the biomass of *S. fasciatus* and *S. mentella* were comparable, whereas in recent years, the abundance of *S. mentella* is smaller than that of *S. fasciatus*. Similar trends were observed for mature biomass. The combined index of mature biomass of *S. mentella* decreased from 273,000 tons in 2000 to 115,400 t in 2009, for an average of 170,300 t (2000-2009). Since 2000, the mean proportion of spawning biomass in Unit 1 is 27%. The combined abundance index has decreased from 469 million mature individuals in 2000 to 181 million mature individuals in 2009: an average of 318 million mature individuals (2000-2009).

The northern population (Grand Banks and Labrador Shelf) (NAFO Divisions 2+3KLNO[3])

Trends in mature numbers were evaluated from spring and autumn DFO research survey series. These surveys have been conducted with various vessels, gears, depth and seasonal coverage over the years. In the following description of the status of abundance, survey estimates are only provided for those series that have been adjusted by conversion factors and are also comparable with regard to coverage. Otherwise, only broad trends are noted in those years where this was not possible. Generally, a comparable index in terms of depth coverage and equivalent vessel/sampling gear units is only available from 1991-2010 for Div. 3LNO (spring to 2010 and autumn to 2009) and from 1978-2009 for 2J3K (autumn). In addition, there are differences in the magnitude of abundance estimates between spring and autumn surveys related to changes in either catchability or availability between these seasons. Generally, *S. fasciatus* is the more abundant species in Div. 3LNO whereas *S. mentella* is more abundant in the northerly areas in Div. 2GHJ3K.

In Division 3O, both total and mature population spring abundance index for *S. mentella* was highly variable without trend between 1973 and 1982 but declined between 1984 and 1990 (Fig. 2). Since 1991, an upward trend has been noticed in both spring and autumn surveys. The estimated number of mature individuals increased from the lowest estimate in the series at 3 million in 1992 to 20 million in the 2010 spring survey, and from 1 million in 1992 to 36 million in the 2009 autumn survey.

[3] Erratum: June 2013
(Grand Banks, Labrador Shelf, Davis Strait and Baffin Bay) (NAFO Divisions 2GHJ+3KLNO was replaced with (Grand Banks and Labrador Shelf) (NAFO Divisions 2+3KLNO)

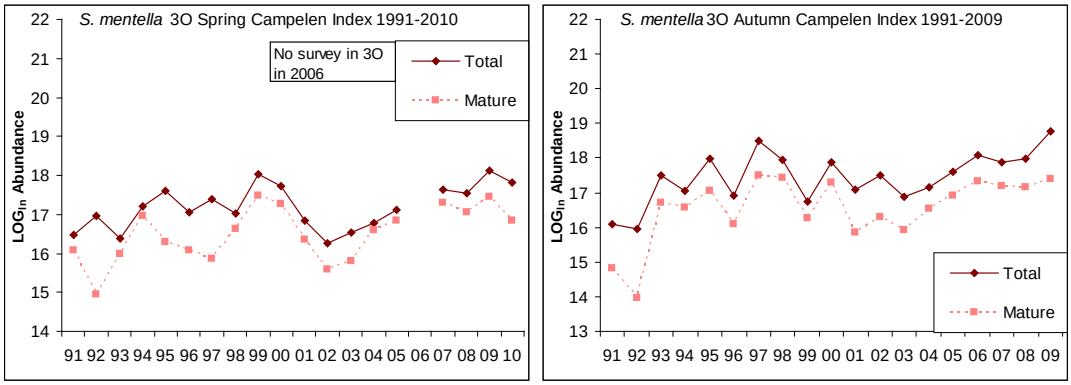


Figure 2: Abundance estimates (Natural log) of Sebastes mentella from stratified-random DFO surveys conducted in Division 3O in the spring (left panel) and autumn (right panel) from 1991-spring 2010. Results for 1991- spring 1995 were adjusted to Campelen trawl survey units.

In Division 3LN, the mature population abundance index varied considerably between 1973 and 1982 but declined between 1985 and 1990. Since 1991, an general upward trend has been noticed in both spring and autumn surveys (Fig. 3). The estimated number of mature individuals increased from the lowest estimate in the series at 4 million in 1994 to 47 million in the 2010 spring survey, and from 27 million in 1991 to 133 million in the 2009 autumn survey. The 3LN directed fishery was under moratorium from 1998-2009 then re-opened in 2010.

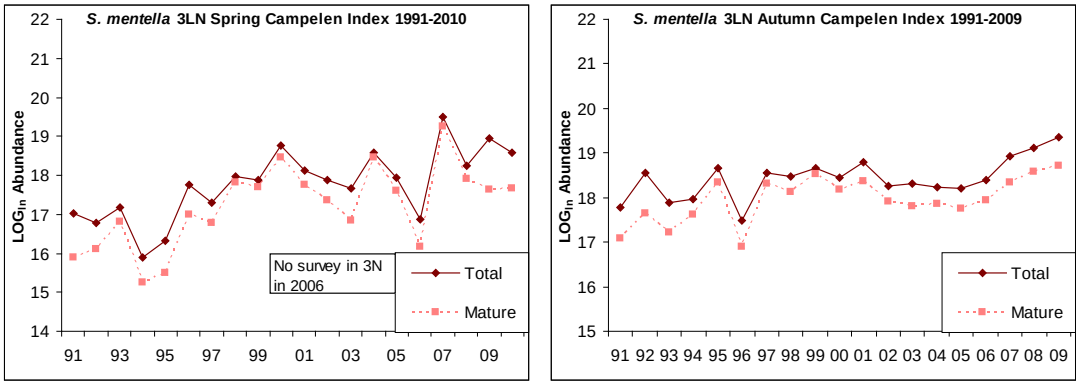


Figure 3: Abundance estimates (Natural log) of Sebastes mentella from stratified-random DFO surveys conducted in Division 3LN in the spring (left panel) and autumn (right panel) from 1991- spring 2010. Results for 1991- spring 1995 were adjusted to Campelen trawl survey units.

In Division 2J3K, the estimated number of mature individuals declined from 4278 million in 1978 to 14 million in 1995 then increased to 413 million by 2009 (Fig. 4). The Subarea 2 + Div. 3K management unit has been under a moratorium that began in 1997. The Div. 2GH surveys are sporadic, frequently have unsampled strata and only 2H has been covered since 1999. There was no trend in mature abundance observed in years over which 2GH was covered.

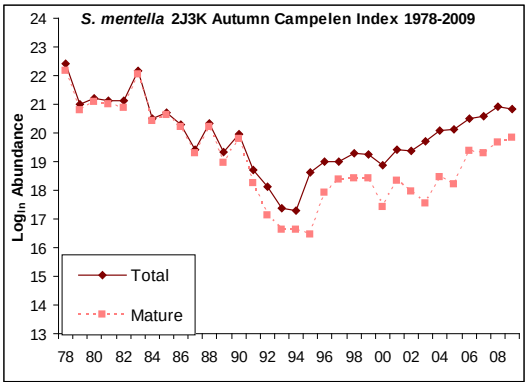


Figure 4: Abundance estimates (Natural log) of Sebastes mentella from stratified-random DFO surveys conducted in Division 2J3K in the autumn from 1978-2009. Results for 1978-1994 were adjusted to Campelen trawl survey units.

Sebastes fasciatus

Atlantic Canada population

Abundance estimates for this population are presented for each region: the Gulf of St. Lawrence and Laurentian Channel, the northern region (Grand Banks/Labrador) and the southern region (Scotian Shelf/Bay of Fundy/Gulf of Maine).

The Gulf of St. Lawrence and Laurentian Channel (Unit 1+2)

During the 2000-2009 period, *S. fasciatus* biomass was stable in Units 1 and 2 combined. The combined mature biomass index for *S. fasciatus* was estimated in 2009 at 146,400 t, compared to an average of 166,600 t for the 2000-2009 period. Since 2000, the average proportion of spawning biomass in Unit 1 is 18%. The combined abundance index was estimated at 505 million mature individuals in 2009, compared to an average of 538 million mature individuals for the 2000-2009 period.

Northern region (Grand Banks/Labrador) – NAFO Divisions 2GHJ3KLNO

Trends in mature numbers were evaluated from spring and autumn DFO research survey series. The same caveats are noted for the various survey series as described for *S. mentella* (see above) apply to *S. fasciatus*.

In Division 3O, both total and mature population spring abundance index for *S. fasciatus* was highly variable without trend in surveys between 1973 and 1982. A similar observation can be made for the series between 1984 and 1990. Since 1991, both spring and autumn surveys have shown a period of increase to the mid-1990s followed by a decline to the early 2000s followed by an increase (Fig. 5). The estimated number of mature individuals increased from the lowest estimate in the series at 19 million in 1991 to 167 million in the 2010 spring survey, and from 75 million in 1991 to 182 million in the 2009 autumn survey.

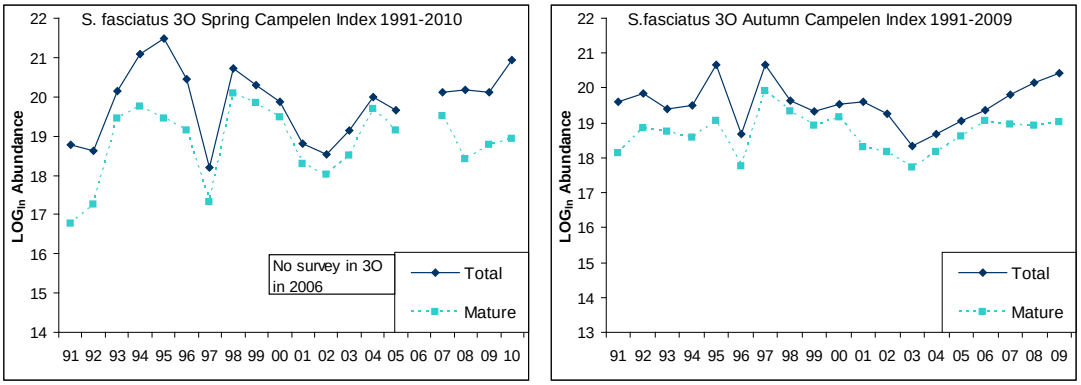


Figure 5: Abundance estimates (Natural log) of Sebastes fasciatus from stratified-random DFO surveys conducted in Division 3O in the spring (left panel) and autumn (right panel) from 1991-spring 2010. Results for 1991- spring 1995 were adjusted to Campelen trawl survey units.

In Division 3LN, the mature population abundance index varied considerably between 1973 and 1982 but declined between 1985 and 1990. Since 1991, the spring survey abundance has shown a general increase to 2010 whereas the autumn surveys have been quite variable to 2004 then show an increase (Fig. 6). The estimated number of mature individuals increased from the lowest estimate in the series at 6 million in 1994 to 326 million in the 2010 spring survey, and from 13 million in 1993 to 247 million in the 2009 autumn survey. The 3LN directed fishery was under moratorium from 1998-2009 then re-opened in 2010.

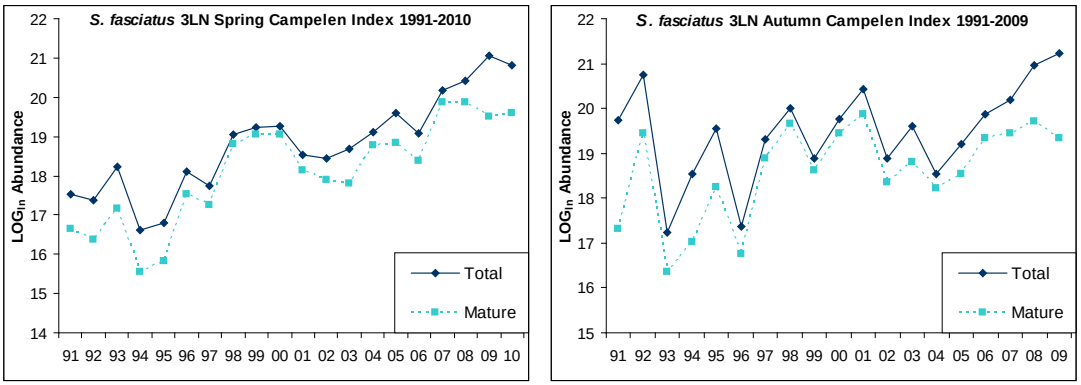


Figure 6: Abundance estimates (Natural log) of Sebastes fasciatus from stratified-random DFO surveys conducted in Division 3LN in the spring (left panel) and autumn (right panel) from 1991- spring 2010. Results for 1991- spring 1995 were adjusted to Campelen trawl survey units.

In Division 2J3K, the estimated number of mature individuals declined from 1300 million in 1978 to 1 million in 1994 then increased to 110 million by 2009 (Fig. 7). The Subarea 2 + Div. 3K management unit has been under a moratorium that began in 1997. The Div. 2GH surveys are sporadic, frequently have unsampled strata and only 2H has been covered since 1999. There was no trend in mature abundance observed in years over which 2GH was covered.

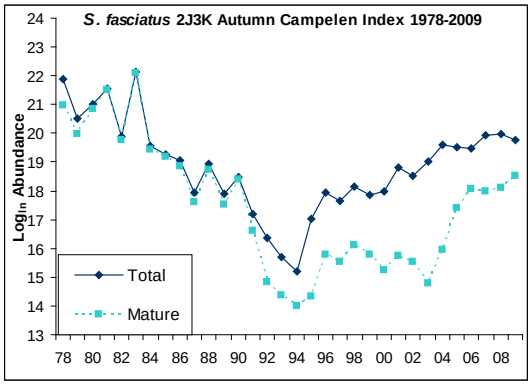


Figure 7: Abundance estimates (Natural log) of Sebastes fasciatus from stratified-random DFO surveys conducted in Division 2J3K in the autumn from 1978-2009. Results for 1978-1994 were adjusted to Campelen trawl survey units.

Southern region (Scotian Shelf/Bay of Fundy/Gulf of Maine) – Divisions 4VWX 5Y

The biomass index has followed an upward trend since 2004, reaching its highest level of the series in 2009. The abundance indices were above average for most redfish at different lengths in 2009, with an apparent strong modal value in length frequency (21 cm).

Significant variations were observed in Unit 3, between 29 and 343 million mature individuals, between 1982 and 2006, but without any long-term trend. No decline was observed.

Habitat Requirements

In general, knowledge on habitat requirements for redfish (*S. fasciatus* and *S. mentella*) remains limited, particularly in the case of *S. mentella*. However, the availability of physical habitat does not appear to be a limiting factor with respect to redfish abundance.

Larval Stage

In the Gulf of St. Lawrence, redfish larvae are mainly concentrated in the deep waters of the Laurentian Channel and Esquiman. High abundances were observed to the south and east of Anticosti. *S. mentella* seem to prefer deeper areas in the mid-channels while *S. fasciatus* prefer shallower areas alongside the channels. This difference involves little overlapping between the species in terms of preferred larval extrusion sites. Larvae perform a daily vertical migration, moving at depths of 11-30 m during the day and moving upward at night between 0 and 10 m. Despite a preference for certain depths, larvae have been observed at up to 200 m. Some studies suggest that vertical migration is greater for *S. mentella* than *S. fasciatus*.

By comparison, in the Gulf of Maine, the newly extruded larvae remain in the first 10 meters. When they grow to between 10 and 25 mm, they occur in the area corresponding to the thermocline (10-30 m). The temperature preferences of *S. fasciatus* larvae, at the southern limit of their distribution, are between 4 and 11°C. Larval mortality increases at temperatures above 14°C and at low temperatures (0.3 to 1.6°C).

Redfish dispersion is not well documented. It probably occurs during the younger stages (larvae and juveniles). The larvae are extruded in the spring, settle on the seabed in the fall, during the juvenile stage. This stage is crucial for habitat choice. This interval allows sufficient time for

dispersal by currents. During strong year-class events, dispersion appears to be most significant, possibly to meet high needs in terms of habitat.

Juveniles

In the Gulf of Maine, *S. fasciatus* juveniles occur below the thermocline until they reach 25 mm. Juveniles are pelagic for four to five months. Generally, small size redfish occupy shallower waters (75-175 m), where the availability of shelters protects them from predators. In the Gulf of St. Lawrence, the west coast of Newfoundland (including shallow waters and Esquiman Channel) represents an important area of concentration of juvenile redfish. *S. fasciatus* appear to occupy coastal habitats and surrounding deep channels more than *S. mentella.* Juvenile *S. mentella* can be found in the deep channels. Juveniles occur in waters with a wider range of temperatures (1-6°C) than adults (3-6°C).

Adults

Adult redfish live in cold waters along the bank slopes and deep channels, at depths of 100-700 m. Both species are distributed according to depth. *S. fasciatus* are typically found in shallower waters (150 to 300 m) while *S. mentella* is found at depths exceeding 300 m.

In the Gulf of St. Lawrence and the Laurentian Channel, adult redfish prefer temperatures of 4.5 to 6°C. Redfish generally live near the bottom but it is considered a semi-pelagic species because it carries out daily vertical migrations, leaving the bottom at night to follow the migration of their prey. The distribution of redfish in the water column also varies by season. With age, redfish tend to settle in deep water and be more sedentary. The various aggregations of redfish do not mix much. Exchanges occur mostly at younger stages.

In the Gulf of St. Lawrence, there is also a seasonal southeast migration outside the Gulf in fall/winter and a reverse migration in spring/summer. Each year, large concentrations of redfish overwinter in Cabot Strait and off southern Newfoundland. Since it takes place during the mating season, this gathering may be motivated by reproduction. Redfish are more concentrated in winter than in the summer.

Residence

According to the SARA, residence is defined as:

"A dwelling-place, such as a den, nest or other similar area or place, that is occupied or habitually occupied by one or more individuals during all or part of their life cycles, including breeding, rearing, staging, wintering, feeding or hibernating".

Current information suggests that *S. mentella* and *S. fasciatus* do not have a residence as defined above.

Stochastic Projections and Allowable Harm

Projections for redfish population trends accounting for uncertainty and under different fishing (allowable harm) scenario were made for each of the five population units. Projections of about 3 mean generation times or 60 years were conducted and results reported relative to various biomass based points of interest.

Recovery targets for redfish have not yet been established and are the purview of fisheries management. The DFO Sustainable fisheries framework incorporating the precautionary framework suggests, as guidance, using 40% Bmsy as a limit reference point if a more direct metric for serious harm is not possible and 80% Bmsy as an Upper Stock reference point.

The Schaefer production model fitting employed here allows one to determine Bmsy which is internationally seen as the anchor for precautionary approach reference points. Commonly 40% of Bmsy is used as a limit reference point and in Canada, 80% of Bmsy is used as the upper stock reference point. Projections are presented relative to these points with the knowledge that even if one of these points is not chosen as a target, management actions are likely to change as stock biomass surpasses a point on a growth trajectory. Another target or indicator of stock state concerns the change in biomass over the projection period relative to current biomass.

Sebastes fasciatus - Unit 3

Past, current and projected status is very uncertain for this stock. Despite large changes in historical catch, survey indices did not respond thus model fits are imprecise. The 2010 biomass for this stock is about 2.25 million t, but could be as low as 2.25 thousand t or as high as 8.64 million t. There is a 99% chance that this stock is above 80% Bmsy. Current catch for this stock was about 4800 t in 2009. Long term projections suggest that with catch up to 6000 t per year the stock has a 99% chance of remaining above Bmsy. The current status of this stock would suggest it is healthy and can easily sustain current fishing levels.

Sebastes fasciatus - Unit 1+ Unit 2 + 3LNO

Mature biomass in 2010 was about 1.88 million t for this stock. With an 84% chance of being above 40% Bmsy and 64% chance of being above 80% Bmsy in 2010. Current catch for this stock was about 9000 t in 2009. Long terms projections suggest that the stock will have a 99% chance of being above 80% Bmsy with status quo catch but shorter projections (5 years) suggest that status quo catch will lead to a 71% chance the stock will remain above 80% Bmsy. It must be noted that there is a particular type of uncertainty associated with model fitting to this stock which would warrant prudence in the interpretation of an abundant stock state.

Sebastes fasciatus - Divisions 2+3K

Mature biomass in 2010 was about 8000 t for this stock with only a small chance of biomass being above 40% Bmsy. Currently this stock is under moratorium with about 54 t taken per year presently. Long term projections at 50 t and 75 t both suggest that after 60 years the stock will have about an 82% chance of being above 80% Bmsy. Recovery even to only 50% Bmsy is slow and in the short term increases are very small. The low biomass of this stock suggests a long term strategy of extremely low catch would be necessary in order to achieve any internationally acceptable management target.

Sebastes mentella - Unit 1+Unit 2

Mature biomass in 2010 was about 19,000 t for this stock with no chance of biomass being above 40% Bmsy. About 3000 t of catch were taken from this stock in 2009 which is 2.15X the replacement yield (i.e. catch is 2.15X higher than the break-even point). Projections show that even with 0 catch, there would be no chance of recovery to only 40% Bmsy in 5 years. After 60 years with 0 catch there would be a 79% chance that that stock reached 40% Bmsy but only a 1% chance the stock would get there under status quo fishing. Catches of 1400 t would give a 50% chance of increase (risk neutral point) while a 700 t catch would give a 95% chance of the

stock showing a small increase in the short term. This stock appears to be in a tenuous situation presently with a very low biomass and a relatively large and unsustainable fishery.

Sebastes mentella - Northern population – NAFO Divisions 2+3KLNO[4]

Mature biomass in 2010 was about 54,000 t with only a 1% chance of the stock being above 40% Bmsy. In 2009, about 1000 t of biomass were taken from this stock which is about 20% of the replacement yield (i.e. the current fishery allows some stock growth). With current catches, the stock is projected to have about a 12% chance of being above 40% Bmsy in five years. Over the long term (60 years) catches of even 3000 t can be sustained with a relatively high probability that the stock will get to and remain above 40% Bmsy. The current status of this stock is poor but the stock has potential for good growth and current fishing levels would appear to be sustainable and should lead to stock size increases.

Threats

Limiting Factors

Redfish longevity, its late maturity and slow growth affect the resilience of the species and may limit its survival. In addition, recruitment varies considerably and strong year-classes occur only every 5-12 years in the case of healthy populations.

Anthropogenic Sources of Mortality

Directed Fishery

Directed fisheries are the main threat to the survival and recovery of redfish. In the Gulf of St. Lawrence and the Laurentian Channel, the redfish fishery was marked by two periods of intensive fishing, in the early 1970s and during the 1990s. These two periods were closely related to the recruitment of strong year-classes. Interest in this fishery increased in the 1990s, following the collapse of cod populations. The average annual catch between 1970 and 1976 was 123,000 t. In 1992, there were about 90,000 t landed, including 78,000 t from the Gulf (Unit 1). Since then, catches have remained below 10,000 t and, following the moratorium imposed in 1995 in Unit 1, most of the catches were made in the Laurentian Channel (Unit 2). An index fishery was introduced in Unit 1 beginning in 1999. Between 2004 and 2009, the average annual landings from the index fishery and by-catches in Unit 1 totalled 622 t for an average annual total allowable catch (TAC) of 2,000 t. Over the same period, landings and by-catches in Unit 2 totalled 5,229 t on average, for an average TAC of 8,333 t. In 2009, the relative exploitation rates for both species combined were estimated at 2% and 3%. A new concentration of fishing effort was also observed at the mouth of the channel, which suggests an increase in *S. fasciatus* catches. However, the fishery still mostly targets *S. mentella* (1980 cohort) and has been since the mid-1990s. Commercial exploitation of *S. mentella* and *S. fasciatus*, without differentiating species, likely generates excessive pressure on *S. mentella*.

For the northern population, the most significant landings were made in the late 1980s and early 1990s. Before this period, the only notable catches were made in Division 2+3K, where a significant fishing effort was observed between 1950 and 1960. In 1959, catches in this division represented 187,000 t. After 1990, catches decreased considerably in 3LN and 2+3K and

[4] Erratum: June 2013
NAFO Divisions 2+3KLNO was added

remained high in Division 3O. In 2000, most catches in this division consisted of fish measuring between 21 and 25 cm. Divisions 3LN and 2+3K have been under moratorium since 1998. However, the redfish fishery in 3LN, outside the Canadian 200-mile limit, was re-opened in 2010. Most of the landings from these regions have been or are from foreign origin.

Regarding *S. fasciatus* in the southern region, catches have been much more modest. In fact, there has been no noticeable decline in this region.

By-catches

In the Gulf of St. Lawrence (Unit 1), nearly 95% of the redfish landings are from the directed fishery (1999-2009). The largest by-catches observed are from the turbot fishery and represent 1 to 2% of the total landings during the 2000s. In terms of the Northern shrimp fishery, redfish by-catches have significantly declined since the introduction of the Nordmore grate in the 1990s, and they consist mainly of small individuals. These catches of smaller redfish could however affect redfish recovery. In Division 2J3K, redfish by-catches from the 2000 shrimp fishery were estimated at less than 1% of the catches made by the directed fishery.

The unreported catches from the redfish fishery and other fisheries are difficult to estimate but may represent another source of mortality.

Anthropogenic Threats to Habitat

The deepwater in the Gulf of St. Lawrence is poor in oxygen. In addition to the natural processes that affect oxygen levels in deep waters, anthropogenic factors may contribute to reducing oxygen levels in deep Gulf waters. The tolerance threshold to low oxygen levels varies from one species to another but remains unknown for redfish.

Furthermore, fishing gear could impact redfish because of habitat disturbance. In international fishing gear studies, dredges and bottom trawls are considered the most harmful to populations, communities and benthic habitats per unit effort.

Redfish are a species likely to occur in the region targeted by oil and gas exploration. There is some evidence suggesting the possibility that seismic exploration may cause sublethal effects at the individual level. The airguns can produce low noise levels at a considerable distance from the source. However, compared to other ocean sounds and animal behaviour, the cacophony of vessel-based noise could be more significant.

Measures for Promoting Recovery

Fishery Management

In a context where fishing is the main source of anthropogenic mortality, management of this activity appears as the primary measure for helping redfish recovery. Limiting catches appears to be the foremost means to limit the damage.

In the northwest Atlantic, the redfish fishery is managed according to nine management units (Figure 1). These areas are based on NAFO Divisions: West of Greenland (Sub-area 1), Labrador Shelf (2GHJ-3K), Flemish Cap (3M), north and east of the Grand Banks (3LN), South west of the Grand Banks (3O), Gulf of St. Lawrence ("Unit 1", consisting of 4 RST, 3Pn4Vn

[from Jan. to May]), Laurentian Channel ("Unit 2", consisting of 3Ps4Vs4Wfgj, 3Pn4Vn [June to Dec.]), Scotian Shelf ("Unit 3", consisting of 4WdehklX) and Gulf of Maine (sub-area 5).

The directed fishery has been under a moratorium in Unit 1 since 1995, and since 1998 in 2J3K 3LN. However, it was re-opened in 2010 in 3LN (outside the Canadian 200-mile limit). The redfish fishery is currently managed by quota limits. Other measures have also been introduced: minimum legal catch size and mesh size, fishing season limits, prohibited areas.

Historically, the redfish fishery is carried out without species differentiation. However, discussions are underway regarding the management measures that can help discriminate *S. mentella* from *S. fasciatus* in fisheries. In particular, to reduce the exploitation of *S. mentella* in Units 1 and 2, it was recommended by DFO scientists to concentrate exploitation in shallower waters and on the edge of the continental slope. A better understanding of the overall structure of redfish stocks and the inclusion of this structure in stock management would also be positive.

Moreover, the impact of mobile gear could be reduced with spatial management of fishing effort and by creating areas where the use of this gear would be prohibited.

Ecologically and Biologically Significant Areas (EBSA)

The Canada Oceans Act authorizes the Department of Fisheries and Oceans to increase the protection of marine and coastal areas that are of particular biological and ecological significance. The conservation objective for ecologically and biologically significant areas (EBSA) identified for the Estuary and Gulf of St. Lawrence is to ensure that the characteristics of the EBSA that relate to its uniqueness, that makes the area suitable for the aggregation and/or that ensure the reproduction and survival of species dependent on the area (fitness consequences), are not altered by human activities. Of the 10 areas identified as EBSAs for the Estuary and Gulf of St. Lawrence, the west coast of Newfoundland is the main migration corridor for redfish and a major area of concentration for juveniles of the species.

IUCN Red List

S. fasciatus has also been part of the IUCN Red List since 1996 (EN A1bd). It aims to raise public attention and of policy makers on the urgency and extent of conservation issues and to encourage the international community to act in order to limit the rate of species extinction.

Sources of Uncertainty

Recruitment mechanisms for both species are not well understood. Typical annual recruitment appears stable, but weak, and does not seem to generate population growth. Abundant *S. fasciatus* year-classes, expressing the genetic signature of the southern margin of the Grand Banks population were observed in 1974, 1985, 1988 and 2003 in Units 1 and 2. They do not appear to have persisted in Unit 1 beyond the juvenile stage, but they likely contributed to the fishery in Unit 2. The last abundant *S. mentella* year-class in Unit 1 was produced in 1980 and showed the genetic signature of Units 1 and 2. This cohort has supported the fishery for over 20 years. Further work is needed to improve our understanding of the recruitment dynamics and to supplement our knowledge of the overall structure of redfish stocks.

Unreported catches in the redfish fishery and in other fisheries are difficult to estimate and remain an unaccounted source of mortality. Commercial fishery landings, not discriminated by species, are also a source of uncertainty.

Another factor of uncertainty concerns the various methods to assess stock status: segregation by redfish species in Units 1 and 2, GEAC survey data conversion to Teleost equivalent and interchangeable sister ships.

Stochastic projections were conducted in a state-space Bayesian framework from model fitting to historical data. The uncertainty in projections is therefore based up on the variability in the stock trends seen previously. If fitted time series were relatively long then more conditions were likely encountered and the uncertainty encountered is thus carried into the future. In addition, a process error of up to 15% was projected forward. The result of this is that in addition to the uncertainty derived from model fitting to historical data, up to a 15% random biomass variance could be included. This varies from one stock fitting to the next and it 15% is the maximum allowed process error.

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This Science Advisory Report is from the Fisheries and Oceans Canada, Canadian Science Advisory Secretariat, zonal advisory meeting of March 8-9, 2011 on Recovery Potential Assessment for Acadian redfish (S. fasciatus), Atlantic Canada Designatable Unit (DU) and Deepwater redfish (S. mentella), Northern and Gulf of St. Lawrence - Laurentian Channel DU). Additional publications from this process will be posted as they become available on the DFO Science Advisory Schedule at http://www.dfo-mpo.gc.ca/csas-sccs/index-eng.htm.

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FOR MORE INFORMATION

Contact:	Daniel Duplisea Maurice Lamontagne Institute Fisheries and Oceans Canada 850, route de la Mer P.O. Box 1000 Mont-Joli, QC G5H 3Z4	Don Power Northwest Atlantic Fisheries Centre Fisheries and Oceans Canada P.O. Box 5667 St. John's, NL A1C 5X1
Telephone:	(418) 775-0634	(709) 772-4935
Fax:	(418) 775-0740	(709) 772-4105
E-Mail:	daniel.duplisea@dfo-mpo.gc.ca	don.power@dfo-mpo.gc.ca

This report is available from the:

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

Telephone: (418) 775-0825
Fax: (418) 775-0679
E-Mail: Bras@dfo-mpo.gc.ca
Internet address: www.dfo-mpo.gc.ca/csas

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