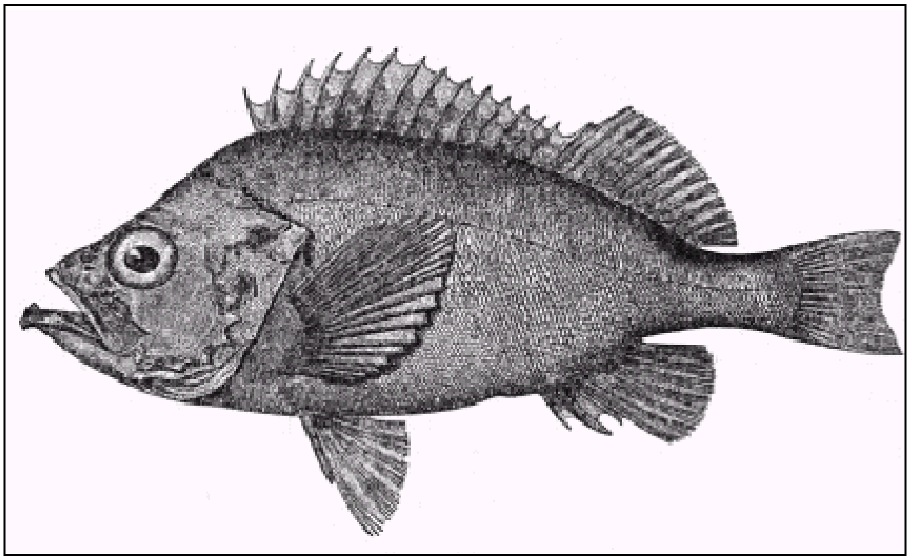
COSEWIC
Assessment and Status Report

on the

Deepwater Redfish/Acadian Redfish complex
Sebastes mentella and *Sebastes fasciatus*

Deepwater Redfish Gulf of St. Lawrence - Laurentian Channel Population
Deepwater Redfish Northern Population
Acadian Redfish Atlantic Population
Acadian Redfish Bonne Bay Population

in Canada



Deepwater Redfish Gulf of St. Lawrence - Laurentian Channel Population – ENDANGERED
Deepwater Redfish Northern Population – THREATENED
Acadian Redfish Atlantic Population – THREATENED
Acadian Redfish Bonne Bay Population – SPECIAL CONCERN
2010

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

COSEWIC status reports are working documents used in assigning the status of wildlife species suspected of being at risk. This report may be cited as follows:

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COSEWIC
Assessment Summary

Assessment Summary – April 2010

Common name
Deepwater Redfish - Gulf of St. Lawrence - Laurentian Channel population

Scientific name
Sebastes mentella

Status
Endangered

Reason for designation
As with other members of the family Sebastidae, this species is long-lived (maximum age about 75 yr), late-maturing (generation time 18 yr), and highly vulnerable to mortality from human activities. Recruitment is episodic, with strong year-classes only occurring every 5-12 years. Abundance of mature individuals has declined 98% since 1984, somewhat more than one generation, and the decline has not ceased. Directed fishing and incidental harvest in fisheries for other species (bycatch) are the main known threats. Harvesting in parts of this population (Gulf of St. Lawrence) is currently limited to an index fishery, but commercial fisheries remain open in other areas (Laurentian Channel). Bycatch in shrimp fisheries has been substantially reduced since the 1990s by use of separator grates in trawls, but could still be frequent enough to affect recovery.

Occurrence
Atlantic Ocean

Status history
Designated Endangered in April 2010.

Assessment Summary – April 2010

Common name
Deepwater Redfish - Northern population

Scientific name
Sebastes mentella

Status
Threatened

Reason for designation
As with other members of the family Sebastidae, this species is long-lived (maximum age about 75 yr), late-maturing (generation time 23 yr), and highly vulnerable to mortality from human activities. Recruitment is episodic, with strong year-classes only occurring every 5-12 years. Abundance of mature individuals has declined 98% since 1978, somewhat over one generation. However, declines have stopped since the mid-1990s and increases have been observed in some areas. Directed fishing and incidental harvest in fisheries for other species (bycatch) are the main known threats. Fisheries in parts of this designatable unit are currently closed, but remain open in other areas. Bycatch in shrimp fisheries has been substantially reduced since the 1990s by use of separator grates in trawls, but could still affect population recovery.

Occurrence
Arctic Ocean, Atlantic Ocean

Status history
Designated Threatened in April 2010.

Assessment Summary – April 2010

Common name
Acadian Redfish - Atlantic population

Scientific name
Sebastes fasciatus

Status
Threatened

Reason for designation
As with other members of the family Sebastidae, this species is long-lived (maximum age about 75 yr), late-maturing (generation time 16-18 yr), and highly vulnerable to mortality from human activities. Recruitment is episodic, with strong year-classes only occurring every 5-12 years. Abundance of mature individuals has declined 99% in areas of highest historical abundance over about two generations. However, since the 1990s, there has been no long-term trend in one area, and trends have been stable or increasing in other areas where large declines have been previously observed. Directed fishing and incidental harvest in fisheries for other species (bycatch) are the main known threats. Fisheries in parts of the range of this designatable unit (DU) are currently closed, but remain open in other areas. Bycatch in shrimp fisheries has been substantially reduced since the 1990s by use of separator grates in trawls, but could still be frequent enough to affect population recovery.

Occurrence
Atlantic Ocean

Status history
Designated Threatened in April 2010.

Assessment Summary – April 2010

Common name
Acadian Redfish - Bonne Bay population

Scientific name
Sebastes fasciatus

Status
Special Concern

Reason for designation
As with other members of the family Sebastidae, this species is long-lived (maximum age about 75 yr), late-maturing (females 50% mature at 8-10 yr in the adjacent Gulf of St. Lawrence/Laurentian Channel population), and highly vulnerable to mortality from human activities. Little is known of the biology of this designatable unit (DU). It has a small range of occurrence but there is no indication of decline. The population has been exploited by fishing in the past, but is currently closed to directed fishing. This DU is susceptible to extirpation by random events such as oil spills.

Occurrence
Atlantic Ocean

Status history
Designated Special Concern in April 2010.

COSEWIC
Executive Summary

Deepwater Redfish/Acadian Redfish complex
Sebastes mentella and *Sebastes fasciatus*

Deepwater Redfish Gulf of St. Lawrence - Laurentian Channel Population
Deepwater Redfish Northern Population
Acadian Redfish Atlantic Population
Acadian Redfish Bonne Bay Population

Summary of species differences

Latin name	*Sebastes fasciatus*	*Sebastes mentella*
Common name	Acadian Redfish	Deepwater Redfish
Distinguishing characters (some overlap observed)	≤ 7 soft anal rays Gas bladder muscle: ribs 3-4	≥ 8 soft anal rays Gas bladder muscle: ribs 2-3
World distribution	Northwest Atlantic only: Hudson Strait to Gulf of Maine, Flemish Cap	Northwest and Northeast Atlantic: Scotian Shelf to Baffin Bay, Greenland, Iceland, southern Norway to Barents Sea
Canadian distribution	Hudson Strait to Gulf of Maine	Northeast Scotian shelf to Baffin Bay
Typical depth (some overlap observed)	150-300 m	350-500 m
DUs	1. Atlantic 2. Bonne Bay	1. Northern 2. Gulf of St. Lawrence/ Laurentian Channel

Species information

Class:	Actinopterygii
Order:	Scorpaeniformes
Family:	Sebastidae
Binomial Name:	*Sebastes mentella* (Travins 1951) and *Sebastes fasciatus* (Storer 1854)
Common Names:	French: sébaste atlantique and sébaste d'Acadie English: Deepwater Redfish and Acadian Redfish

Because these two species cannot be easily distinguished, fisheries management treats them as a single complex. For this reason the two species have been assessed together in this status report.

Designatable units

Based on information from genetics, morphometric and meristic studies, and a parasite study, the following designatable units are proposed for these species.

Acadian Redfish
1. Atlantic
2. Bonne Bay

Deepwater Redfish
1. Northern
2. Gulf of St. Lawrence/Laurentian Channel

Distribution

Redfish inhabit cold waters along slopes of banks and channels at depths of between 100 and 700 m.

Deepwater Redfish is found on both sides of the Atlantic Ocean. In Canadian waters, its range extends from the Grand Banks to Baffin Bay, and includes the Gulf of St. Lawrence, the Laurentian Channel and the Labrador Sea.

Acadian Redfish is only found in the western Atlantic. Its range extends from the Gulf of Maine to the southern Labrador Sea, and includes the Gulf of St. Lawrence, the Laurentian Channel and the Grand Banks.

Habitat

Larvae are found primarily in surface waters, although they are reported to make marked vertical migrations in some regions. Juveniles move below the thermocline upon reaching a length of 25 mm (in the Gulf of Maine). Juveniles remain pelagic for approximately 4-5 months. In general, depths inhabited by redfishes increase with increasing length. Deepwater Redfish generally live at depths from 350 to 500 m, whereas Acadian Redfish generally are found between 150 and 300 m. Redfishes are considered semi-pelagic species, because they make long daily vertical migrations.

Biology

Redfishes are viviparous: fertilization is internal, and females carry the young until they are released as larvae. Female fecundity is between 1,500 and 107,000 larvae, depending on length. Breeding occurs between September and December, and larvae are released at the end of spring and beginning of summer. Recruitment is highly variable in these species, with strong year-classes only produced every 5-12 years in unexploited or lightly exploited popuations.

These species have a long lifespan (up to 75 years) and exhibit slow growth. They can reach up to 60 cm in length.

Preferred temperature for larvae is between approximately 4^{o}C and 11^{o}C, varying across the range. Temperature preference of juvenile Acadian Redfish in the Gulf of Maine is between 5^{o}C and 10^{o}C, between 4.5^{o}C and 7.0^{o}C for adults.

Population sizes and trends

Abundance estimates for the mature population come from scientific surveys conducted by Fisheries and Oceans Canada (DFO). Abundance estimates are relative, since results may be affected by vessel, gear, surface and depth sampled, season, and time of day. The two redfish species are distinguished on survey cruises by sampling and examining individuals, which could add to uncertainty to trends by species.

Trends in survey abundance are presented for management units for which surveys are conducted. Both species have shown substantial (>95%) declines over 1-2 generations in areas where they were historically abundant, although in some areas abundance indices have been stable or increasing since the mid-1990s.

<u>Deepwater Redfish</u>

Gulf of St. Lawrence/Laurentian Channel DU

Survey abundance of mature individuals in the Gulf of St. Lawrence has declined by 98% since 1984. No rate of decline has been estimated for the Laurentian Channel owing to incomplete survey coverage.

Northern DU

This DU is primarily distributed from the Grand Banks to the northern Labrador Sea. Available data show a decline in a single region, 2J3K, of 98% since 1978. In other parts of this DU, surveys between 1991 and the present do not show a declining trend. The information from 2J3K is given greatest weight because of relative abundance of Redfish here and the long duration of the time series.

Acadian Redfish

Atlantic DU

Gulf of St. Lawrence and Laurentian Channel: Acadian Redfish in the Gulf of St. Lawrence have declined by 98.5% since 1984. No rate of decline has been assessed in the Laurentian Channel owing to a lack of relevant data.

Northern area: Available data show a decline in a single region, 2J3K, of 99.7% since 1978. In other regions, the surveys dating from 1991 to date do not show a declining trend. Survey information from 2J3K is given greatest weight because of relative abundance of Redfish in this area and long duration of the time series.

Southern area: Abundance indices in the Scotian Shelf fluctuate widely, but show no overall trends. In the Gulf of Maine, abundances are increasing and several significant year classes have appeared over the past few years.

Bonne Bay DU

Given the small size of the fjord, the population is considered to be small. No abundance data are available for this population. Area of occupancy is estimated at 72 km^2.

Limiting factors and threats

Long life span, late maturation, and slow growth give this species low resilience and are considered limiting factors.

Directed fisheries have been the principal threat, with substantial catches taken in the various regions since the 1950s. Directed fisheries are closed in some areas but continue in others. Bycatches in other fisheries could also affect redfish populations; although the introduction of the Nordmore grate has considerably reduced the impact of shrimp fishing on redfishes, this fishery could affect population recovery. Unfavourable environmental conditions may have contributed to the decline of redfishes in certain regions, just as they have for other groundfish. Redfishes are a significant part of the diet of seals, and seal predation may be an important component of population mortality in some areas.

Special significance of the species

Deepwater and Acadian Redfish are (or have been) major commercial species. Moreover, given their large historical abundance, redfishes have an important place in marine ecosystems.

Existing protection and other status designations

The Acadian Redfish is on the IUCN Red List of Threatened Species. Management measures including catch quotas, size and mesh limits, and seasonal closures are used by management authorities to control fisheries. Management is under the responsibility of DFO for stocks in Canadian waters, NAFO for straddling stocks, and Canada-US for the Gulf of Maine. Stocks in the Gulf of St. Lawrence, NAFO 3LN, and NAFO 2J3K have been closed to directed fishing since the mid- to late 1990s, although the 3LN fishery was reopened in 2010.

COSEWIC HISTORY

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was created in 1977 as a result of a recommendation at the Federal-Provincial Wildlife Conference held in 1976. It arose from the need for a single, official, scientifically sound, national listing of wildlife species at risk. In 1978, COSEWIC designated its first species and produced its first list of Canadian species at risk. Species designated at meetings of the full committee are added to the list. On June 5, 2003, the *Species at Risk Act* (SARA) was proclaimed. SARA establishes COSEWIC as an advisory body ensuring that species will continue to be assessed under a rigorous and independent scientific process.

COSEWIC MANDATE

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses the national status of wild species, subspecies, varieties, or other designatable units that are considered to be at risk in Canada. Designations are made on native species for the following taxonomic groups: mammals, birds, reptiles, amphibians, fishes, arthropods, molluscs, vascular plants, mosses, and lichens.

COSEWIC MEMBERSHIP

COSEWIC comprises members from each provincial and territorial government wildlife agency, four federal entities (Canadian Wildlife Service, Parks Canada Agency, Department of Fisheries and Oceans, and the Federal Biodiversity Information Partnership, chaired by the Canadian Museum of Nature), three non-government science members and the co-chairs of the species specialist subcommittees and the Aboriginal Traditional Knowledge subcommittee. The Committee meets to consider status reports on candidate species.

DEFINITIONS
(2010)

Wildlife Species	A species, subspecies, variety, or geographically or genetically distinct population of animal, plant or other organism, other than a bacterium or virus, that is wild by nature and is either native to Canada or has extended its range into Canada without human intervention and has been present in Canada for at least 50 years.
Extinct (X)	A wildlife species that no longer exists.
Extirpated (XT)	A wildlife species no longer existing in the wild in Canada, but occurring elsewhere.
Endangered (E)	A wildlife species facing imminent extirpation or extinction.
Threatened (T)	A wildlife species likely to become endangered if limiting factors are not reversed.
Special Concern (SC)*	A wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats.
Not at Risk (NAR)**	A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances.
Data Deficient (DD)***	A category that applies when the available information is insufficient (a) to resolve a species' eligibility for assessment or (b) to permit an assessment of the species' risk of extinction.

* Formerly described as "Vulnerable" from 1990 to 1999, or "Rare" prior to 1990.

** Formerly described as "Not In Any Category", or "No Designation Required."

*** Formerly described as "Indeterminate" from 1994 to 1999 or "ISIBD" (insufficient scientific information on which to base a designation) prior to 1994. Definition of the (DD) category revised in 2006.

Environment Canada / Environnement Canada
Canadian Wildlife Service / Service canadien de la faune
Canada

The Canadian Wildlife Service, Environment Canada, provides full administrative and financial support to the COSEWIC Secretariat.

COSEWIC Status Report

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in Canada

2010

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SPECIES INFORMATION

Name and classification

Class:	Actinopterygii
Order:	Scorpaeniformes
Family:	Sebastidae
Sub-family:	Sebastinae
Binomial Name:	*Sebastes mentella* (Travin, 1951) and *Sebastes fasciatus* (Storer, 1854**)**

Common Names:

English – Deepwater Redfish (*Sebastes mentella*) and Acadian Redfish (*Sebastes fasciatus*)

Other names in use: Ocean Perch, Beaked Redfish, Labrador Redfish, American Redfish

French – sébaste atlantique (*Sebastes mentella*) and sébaste d'Acadie (*Sebastes fasciatus*)

Other names in use: sébaste du Nord and sébaste rose (France), poisson rouge, sébaste à bec, sébaste américain

Morphological description

The genus *Sebastes* comprises a hundred or so species, most of which are found in the Pacific Ocean. Redfish of the Atlantic Ocean are apparently descended from a common ancestor that came from the Pacific (Briggs 1995) some three million years ago.

Deepwater Redfish and Acadian Redfish are practically impossible to distinguish visually. Further, a third Redfish species—Golden Redfish *Sebastes norvegicus* (Ascanius, 1772), which is also found in the Northwest Atlantic—resembles the two others. Originally it was believed that the Northwestern Atlantic redfishes formed a single species. The species *S. mentella* and *S. norvegicus* were distinguished by Templeman and Sandeman (1957), while *S. fasciatus* was described by Barsukov (1968). Electrophoretic tests (Payne and Ni 1982; McGlade *et al*. 1983) were then used to confirm that Deepwater Redfish and Acadian Redfish are indeed two separate species.

Deepwater Redfish and Acadian Redfish are spiny-rayed fishes with a distinctive flame-red colouring, sometimes with a brownish cast. These species are characterized by the bony protrusion on the lower jaw, large eyes and fan of bony spines that radiates out from around the gill cover (Figure 1). The body shape of Deepwater Redfish is slightly more fusiform than that of Acadian Redfish (Valentin *et al*. 2002).

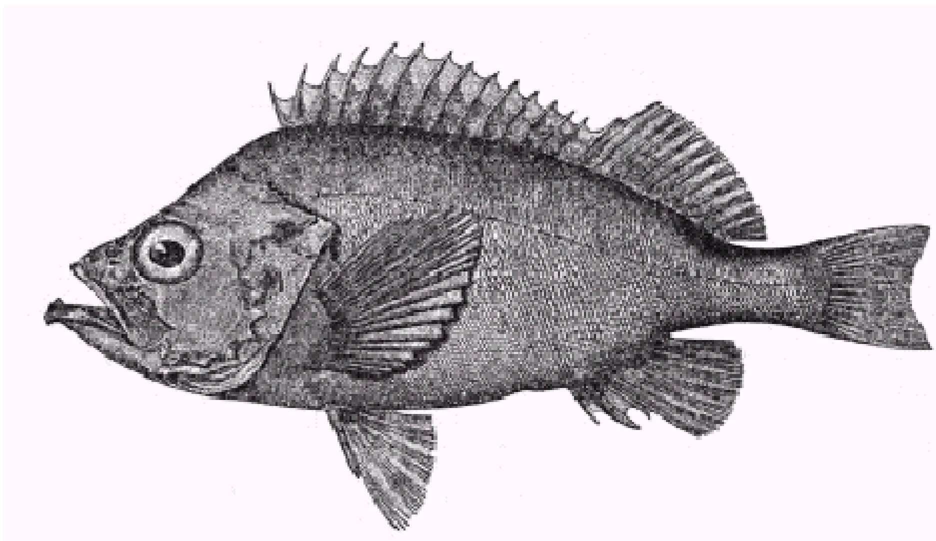

Figure 1. Acadian Redfish (*Sebastes fasciatus).* Note: It is impossible to visually distinguish it from Deepwater Redfish.

Golden Redfish (*S. norvegicus*) differs in certain morphological characteristics from Deepwater Redfish and Acadian Redfish. It is generally more orange in colour. Its eyes are also smaller than those of its congeners, and the small bony protrusion on its lower jaw is rounded and less pronounced. Moreover, this species is only abundant in the region of Flemish Cap (outside Canadian waters). Elsewhere in the Northwest Atlantic, its presence is marginal (Ni and McKone 1983).

A subspecies of the Acadian Redfish, *S. fasciatus kellyi*, has also been described (Litvinenko 1974). It lives in the shallow coastal waters of the Eastport region of Maine (United States), so is not found in Canadian waters. It is distinguished by, among other things, its colour, which ranges from dark green to black.

Distinguishing species

Given their morphological resemblance and the major overlap in their distribution, several criteria have been used to distinguish between Deepwater Redfish and Acadian Redfish. Three characters described by acronyms are currently used: 1) AFC: soft anal fin ray counts (≥ 8 for Deepwater Redfish and ≤ 7 for Acadian Redfish (Ni 1981a; Kenchington, 1986; Rubec *et al*. 1991)); 2) GBM: gas bladder muscle insertion pattern (between the second and third ribs for Deepwater Redfish and between the third and fourth ribs for Acadian Redfish (Ni 1981a,1981b; Kenchington 1986)); 3) MDH, the genotype of the malate dehydrogenase locus (MDH-A*; Payne and Ni 1982; McGlade *et al*. 1983; Rubec *et al*. 1991; Sévigny and de Lafontaine 1992). Two alleles characterize the MDH-A* locus. A homozygote genotype for MDH-A*1 is most common in Deepwater Redfish, whereas a homozygote genotype for MDH-A*2 is typical of Acadian Redfish. Redfish with a heterozygote genotype (MDH-A* 12) could be interpreted as hybrids.

Genetic studies using ribosomal DNA (Desrosiers *et al*. 1999) and microsatellites (Roques *et al*. 2001) have demonstrated asymmetrical introgressive hybridization[1] between these two species. Hybridization, however, does not occur in the entire area of sympatry, but is limited to the Gulf of St. Lawrence and the Laurentian Channel (Roques *et al*. 2001; Valentin 2006).

An overlap exists between Deepwater Redfish and Acadian Redfish regarding AFCs. A certain percentage of Acadian Redfish have eight or more fin rays and, conversely, a proportion of Deepwater Redfish have seven or fewer fin rays (Valentin 2006). As for the GBM criterion, there are sometimes several branches to the gas bladder muscle, which are inserted between several ribs, making use of this criterion difficult. Of the usual identification criteria, MDH is considered to be the most reliable.

The congruence between the different identification criteria is high in the areas of allopatry, but lower in the areas of sympatry (Gulf of St. Lawrence and Laurentian Channel) where hybridization and introgression occur (Valentin 2006; Valentin *et al*. 2006). Moreover, intermediary characteristics such as a MDH-A*12 genotype or a GBM that is uncertain because of bifurcations between several ribs, are found in strong concentrations only in the Gulf of St. Lawrence and Laurentian Channel.

Certain meristic characteristics, such as the number of vertebrae and the dorsal fin ray count, have also been used along with the anal fin ray count to distinguish between the two Redfish species (Ni 1982; Morin *et al*. 2004).

[1] Introgression: incorporation of a gene from one species into another species. It occurs in the Redfish when a fertile hybrid mates with an individual from the parental species.

Using these identification criteria on a large scale is difficult, given the associated costs and the time required. “Redfish” is therefore treated as a single species by the fishing industry. Development of a management strategy for each species has recently been recommended (DFO 2008) and feasibility of developing such a strategy is being examined.

Genetic description

Genetic studies of redfish populations in the Northwestern Atlantic are relatively recent, but population structure of the two species has been relatively well documented.

Studies have shown that genetic structure was relatively weak in Northwestern Atlantic redfishes (Roques *et al*. 2001, 2002; Schmidt 2005; Valentin 2006). This is common in marine organisms, and is due to absence of effective barriers to larval drift or migration (Ward *et al*. 1994; Shaklee and Bentzen 1998; Ward 2000).

Roques *et al*. (2001, 2002) using microsatellite tags were the first to describe the genetic structure of redfish populations in the Northwestern Atlantic. Genotypes from eight loci were compared in 17 samples from regions ranging from the Gulf of Maine to the Labrador Sea, including the Gulf of St. Lawrence and the Laurentian Channel. Other samples taken further east as far as the Barents Sea were also included (Roques *et al*. 2002).

A second study also used microsatellites to describe the redfish populations in the Northwestern Atlantic (Valentin 2006), and combined genetic analyses with morphometric analyses. The number of microsatellites (13) and samples (36), as well as the type of statistical analyses, were revised to increase the accuracy of the comparisons. The samples for this study were taken in summer when redfish dispersion is considered to be highest, and in fall, during the mating season, when populations are considered to be well structured.

In addition to genetic studies, other types of analyses have been conducted to differentiate between redfish populations. One study examined parasites in Deepwater Redfish in five regions (Gulf of St. Lawrence, Laurentian Channel, Labrador Sea, Cabot Strait, Flemish Cap) in order to determine the population structure (Marcogliese *et al*. 2003). An analysis using trace elements of otoliths was also recently published (Campana *et al*. 2007).

Lastly, biological characteristics such as age or size at maturity can be compared between areas to differentiate populations.

Deepwater Redfish

The results of the genetic analyses conducted by Roques *et al*. (2002) showed that Deepwater Redfish in the Gulf of St. Lawrence and the Laurentian Channel (GSL/LC) are homogeneous with respect to genetic diversity. The large majority of comparisons between pairs of samples in this region did not show any significant difference (Table 1) (origin of samples used by Roques *et al*. (2002) are found in Table 2). The average unbiased F_{ST} (θ) was 0.00028. There was also homogeneity seen within a group called “pan-oceanic" by the authors (average θ = -0.0004). It contained Deepwater Redfish from the Grand Banks to the Faroe Islands. A third group was identified during this study made up of individuals from the Norwegian and Barents seas. Each sample from the Gulf of St. Lawrence/Laurentian Channel was statistically different from those in other areas (average θ = 0.0127).

Table 1. Pairwise index of genetic differentiation between each of the 17 samples of Redfish. Dotted lines mark comparisons between Deepwater Redfish and Acadian Redfish. The degree of genetic exchange between samples was estimated using the unbiased Fst (θ) index (from Roques *et al*. 2001).

Sample	FAA1	FAA2	FAS1	FAS2	FAS3	FAS4	MEA1	MEA2	MEA3	MEA4	MES5	MES6	MES7	MES1	MES2	MES3	MES4
FAA1																	
FAA2	0.0132*																
FAS1	0.0091*	0.0196															
FAS2	0.0185	0.0235	(-0.0050*)														
FAS3	0.0196	0.0274	(-0.0003*)	(-0.0058*)													
FAS4	0.0093*	0.0152	(-0.0043*)	(-0.0013*)	(0.0040*)												
MEA1	0.1355	0.1636	0.1354	0.1219	0.1178	0.1255											
MEA2	0.1154	0.1412	0.1113	0.1042	0.0991	0.1067	(-0.0039*)										
MEA3	0.1189	0.1504	0.1145	0.1101	0.1023	0.1105	(-0.0008*)	(0.0026*)									
MEA4	0.1085	0.1424	0.1125	0.1032	0.0974	0.1059	(0.0062*)	0.0014*	(-0.0006*)								
MES5	0.0830	0.1118	0.0817	0.0777	0.0741	0.0743	0.0063*	0.0153	0.0082	0.0044*							
MES6	0.0778	0.1095	0.0883	0.0846	0.0819	0.0792	0.0103	0.0154	0.0096	0.0090	(0.0002*)						
MES7	0.1009	0.1313	0.1015	0.0977	0.0941	0.0927	0.0109	0.0167	0.0156	0.0181	(0.0011*)	(-0.0005*)					
MES1	0.0794	0.1135	0.0829	0.0829	0.0794	0.0766	0.0052*	0.0149	0.0125	0.0103	(0.0020*)	(0.0020*)	(-0.0030*)				
MES2	0.1035	0.1349	0.1016	0.1005	0.0962	0.0933	0.0077	0.0181	0.0117	0.0146	(0.0003*)	(0.0017*)	(-0.0046*)	(0.0000*)			
MES3	0.1065	0.1410	0.1035	0.1070	0.1027	0.0987	0.0078*	0.0224	0.0158	0.0163	0.0093	0.0043*	0.0038*	0.0101	0.0045*		
MES4	0.0817	0.1143	0.0836	0.0865	0.0839	0.0793	0.0169	0.0274	0.0193	0.0213	0.0095	(0.0036*)	0.0057*	0.0098	-0.0094	0.0186	

( ) Indicates the absence of significant heterogeneity in the frequency of alleles based on the Fisher method (α=0.001).
* No significant difference in the estimate θ based on Bonferroni corrections (k=120, α=0.05/120=0.0004).

Table 2. Origin of samples used by Roques *et al*. (2001).			
Sample	**Geographic Origin**	**Sample**	**Geographic Origin**
Acadian Redfish		***Deepwater Redfish***	
FAA1	Gulf of Maine	MEA1, MEA2	Grand Banks
FAA2	Nova Scotia	MEA3	2G
FAS1	South of Newfoundland	MEA4	2H
FAS2, FAS3, FAS4	Gulf of St. Lawrence	MES1, MES2, MES3	Gulf of St. Lawrence
		MES4, MES5, MES6, MES7	South of Newfoundland

Valentin (2006) identified two groups of Deepwater Redfish in the Canadian Atlantic (Figs. 2, 3): a Unit 1/Unit 2 (Figure 4) group (Gulf of St. Lawrence/Laurentian Channel) and a northern group consisting of individuals outside the former group. The F_{ST} varied from -0.003 to 0.008 in the comparison among the GSL/LC samples and no statistical test was significant (Table 3). The Deepwater Redfish in this region, however, were different from those in the Grand Banks region, Labrador Sea and Southern Greenland, as Roques *et al*. had observed (2002). All significant differences observed during this study were for comparisons of samples from the GSL/LC with samples from further north (Table 3). Moreover, statistics based on genetic distances (multi-dimensional statistical analyses and the Neighbour-Joining method), and cluster analyses also demonstrated homogeneity within the GSL/LC samples, and differences between GSL/LC and the Grand Banks and the northern part of the distribution (Figures 2, 3). Valentin's (2006) genetic results were corroborated by morphometric analyses.

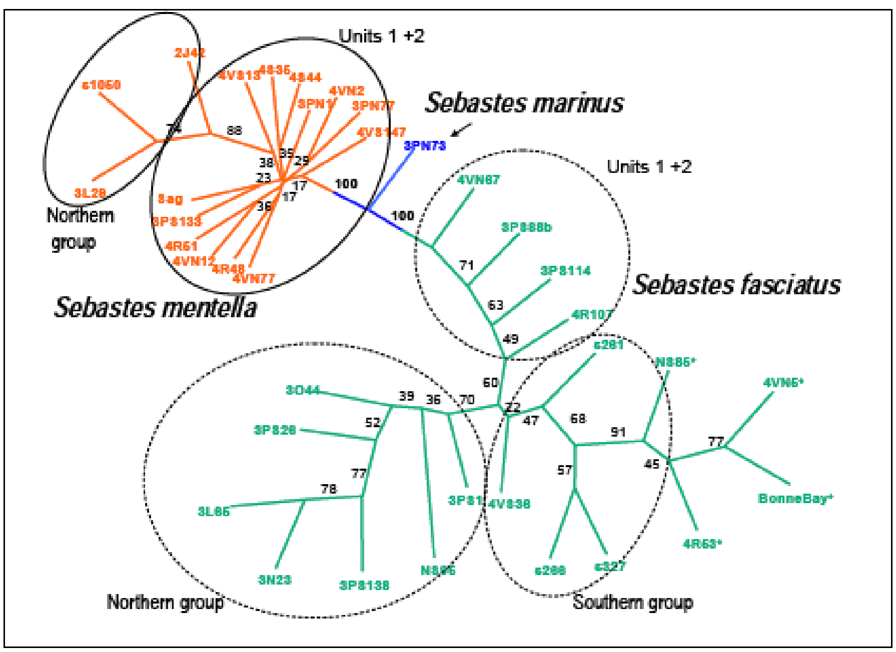

Figure 2. Neighbour-joining tree illustrating the relationship between different samples of Acadian Redfish (*Sebastes fasciatus*), Deepwater Redfish (*S. mentella*) and *S. norvegicus.* Source: DFO (2008) (modified from Valentin 2006).

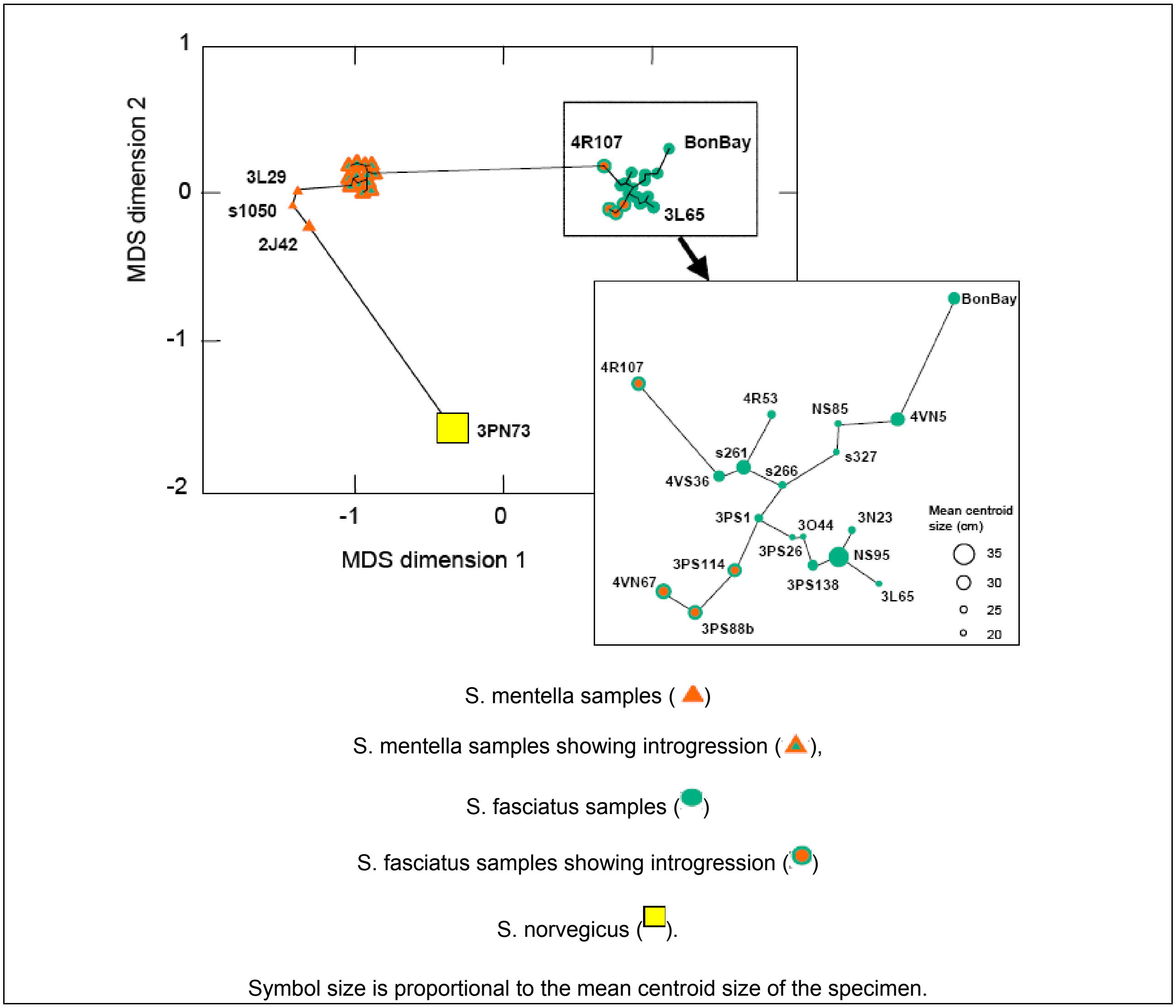

Figure 3. Graphical representation (stress value = 0.031) of the distances between the 36 samples after the MD analysis on the pairwise Cavalli-Sforza and Edwards (1967) chord distances.

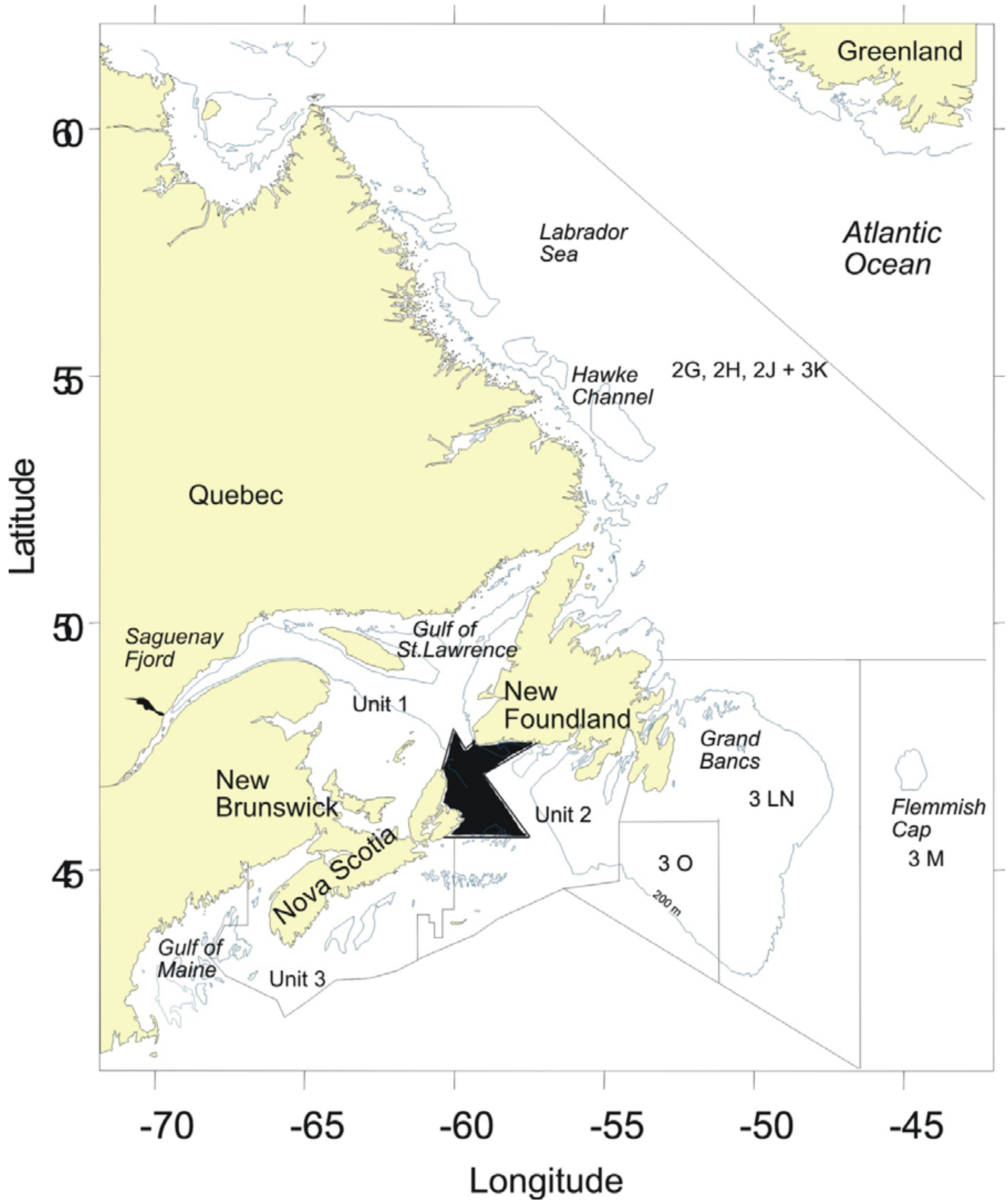

Figure 4. DFO Redfish management units (modified from Morin *et al*. 2004). The black zone is included in Unit 1 from January to May, and in Unit 2 from June to December.

Table 3. Pairwise index of genetic differentiation between Deepwater Redfish samples. The F_{st} value is found above the diagonal, and test significance below the diagonal. (-) non-significant, (+) significant before correction, + significant after sequential Bonferroni correction (from Valentin 2006).

Sample	2J42	3L29	s1050	3PN1	3PN77	3PS133	4R48	4R51	4S35	4S44	4VN12	4VN2	4VN77	4VS13	4VS147	Sag
2J42		**0.012**	**0.027**	**0.039**	**0.033**	**0.043**	**0.041**	**0.041**	**0.040**	**0.037**	**0.039**	**0.034**	**0.043**	**0.040**	**0.033**	**0.042**
3L29	(+)		0.007	**0.025**	**0.018**	**0.027**	**0.027**	**0.025**	**0.022**	**0.02**	**0.025**	**0.021**	**0.024**	**0.022**	**0.019**	**0.025**
s1050	+	-		**0.016**	**0.012**	**0.014**	**0.016**	**0.018**	**0.012**	**0.012**	**0.016**	**0.015**	**0.014**	**0.013**	**0.013**	**0.015**
3PN1	+	+	+		-0.001	-0.003	0.001	0.007	-0.003	0.000	0.000	-0.002	-0.003	-0.001	-0.001	-0.001
3PN77	+	+	+	-		0.003	0.003	-0.001	0.001	0.000	0.001	-0.003	-0.001	0.001	-0.002	0.002
3PS133	+	+	+	-	-		0.004	0.007	0.002	0.003	0.004	0.003	0.002	0.000	0.005	-0.001
4R48	+	+	+	-	-	-		0.004	0.007	0.001	0.005	0.005	0.001	0.004	0.006	0.004
4R51	+	+	+	(+)	-	(+)	-		0.008	-0.001	0.003	0.004	0.005	0.006	0.006	0.004
4S35	+	+	+	-	-	-	(+)	(+)		-0.002	0.001	-0.002	-0.002	0.005	-0.001	-0.003
4S44	+	+	+	-	-	-	-	-	-		0.000	-0.002	-0.002	0.003	0.001	-0.001
4VN12	+	+	+	-	-	-	-	-	-	-		0.001	0.000	0.004	-0.001	0.001
4VN2	+	+	+	-	-	-	(+)	-	-	-	-		-0.001	0.003	0.001	0.003
4VN77	+	+	+	-	-	-	-	-	-	-	-	-		0.000	0.002	-0.002
4VS13	+	+	+	-	-	-	-	(+)	-	-	-	-	-		0.005	0.005
4VS147	+	+	+	-	-	-	(+)	(+)	-	-	-	-	-	-		0.002
Sag	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	

The genetic differences observed between the Deepwater Redfish of the GSL/LC and the rest of the distribution were in large part due to introgressive hybridization (Roques *et al*. 2001; Valentin 2006). According to Valentin (2006), other factors could, however, be responsible for these differences. In order for hybridization alone to explain the genetic differences, the loci causing the difference between the populations should be the same as those responsible for the differences between species, which is only partially true. Moreover, analyses excluding individuals showing signs of introgression also demonstrated the same genetic heterogeneity (Valentin 2006). Introgression therefore was not the only factor causing genetic differentiation.

Oceanographic conditions found in the Gulf of St. Lawrence and the Laurentian Channel are different from those on the Grand Banks and Labrador Shelf. The GSL/LC is a relatively closed system where the environment is appropriate for all stages of life for the Redfish, including early stages. The Northwestern Atlantic is an open environment with few barriers, unlike the GSL/LC, and Deepwater redfish distribution appears more or less continuous from the Irminger Sea to Labrador/Grand Banks. The member/vagrant hypothesis was suggested to explain the genetic differentiation of Deepwater Redfish (Roques *et al*. 2002; Valentin 2006). Based on this theory, the number of distinct populations in a marine species is primarily determined by retention areas which retain the planktonic larval stages (Îles and Sinclair 1982). This weak genetic structure within the pan-oceanic population could therefore potentially be due to wide larvae dispersion.

No samples of Deepwater Redfish from the southern portion of the Grand Banks have yet been analysed. This region constitutes the southern limit of Deepwater Redfish distribution, where this species is less abundant.

A study of parasites in Deepwater Redfish showed significant differences between samples from the Gulf of St. Lawrence and Laurentian Channel (Marcogliese *et al*. 2003). Conversely, samples from the Gulf of St. Lawrence and Labrador Sea could not be differentiated by parasite rate or occurrence.

Deepwater Redfish females in the Gulf of St. Lawrence (Unit 1) reach sexual maturity at a length and age similar to the females found in the Laurentian Channel (Unit 2) (10.4 and 10.6 yr respectively) (Morin *et al*. 2004; Table 5). However, the values calculated for the Grand Banks are higher (15 yr) than those for GSL/LC.

Campana *et al*. (2007) used otolith trace elements to show that Deepwater Redfish tend to leave the Gulf of St. Lawrence in winter to join aggregations in the Laurentian Channel. The results also indicated that Deepwater Redfish coming from the eastern Scotian Shelf (Unit 2 of DFO) or the southern part of the St. Pierre Bank do not overwinter with these aggregations.

A potentially isolated population is found in the Saguenay fjord (Quebec), but this does not appear to be distinct from the adjoining population. The fjord has a depth of up to 275 m and is separated from the estuary and the Gulf of St. Lawrence by a shallow sill (20 m) that limits exchanges between these two areas. Genetic analyses have not shown any difference between individuals in the Saguenay and those in the Gulf of St. Lawrence. The study of Roques *et al*. (2002) showed a θ of between -0.0005 and 0.0018 and Valentin's study (2006) demonstrated an F_{ST} of between -0.001 and 0.004 during comparisons between Deepwater Redfish in the Saguenay and those in the Gulf of St. Lawrence. According to Fortin *et al*. (2006), there appeared to be Redfish larvae production in the Saguenay, but they only seemed to survive a few days, possibly due to the low salinity in the fjord's surface waters. Therefore, recruitment had to come from the St. Lawrence estuary. The Saguenay Redfish would thus be considered a sink population. Because the sill could prevent adults from the estuary from moving into the Saguenay, it is probable that movements occur when the Redfish are juveniles. There are noticeable differences between the fjord Redfish and those found in the Gulf of St. Lawrence in terms of otolith trace element composition (Campana *et al*. 2007), and the morphometry of Saguenay Redfish is different from that of the Gulf of St. Lawrence (Valentin 2006). However, these characteristics are likely due to growth in distinct environments.

Deepwater Redfish are found as far north as Davis Strait and Baffin Bay off Nunavut (Northwest Atlantic Fisheries Organization (NAFO) Subdivision 0 (Figure 5)) (Treble 2002). Abundance data are limited here, and no quantitative analysis is possible. These fish could be associated with the northern population or with that of western Greenland.

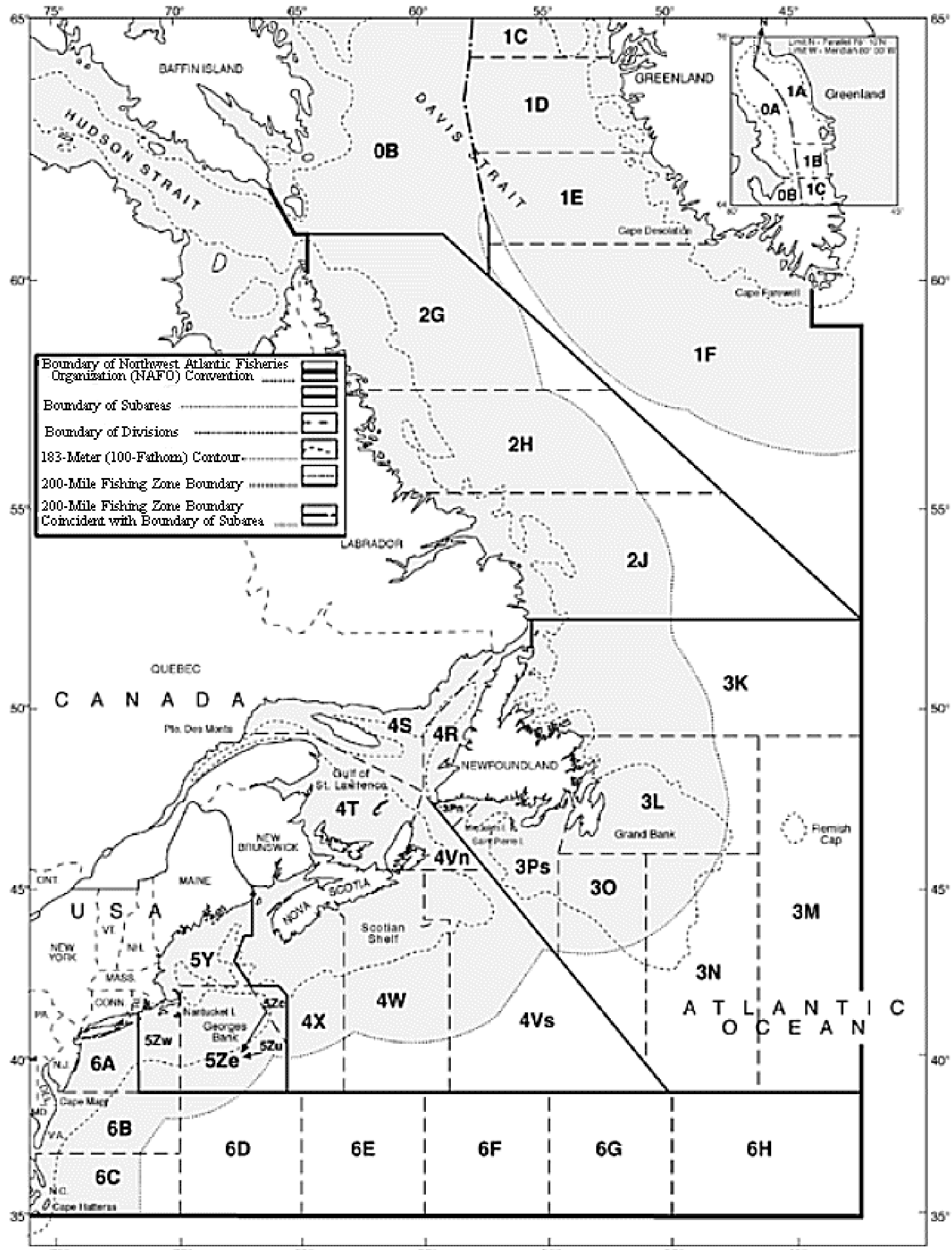

Figure 5. Northwest Atlantic Fisheries Organization (NAFO) zones.

Acadian Redfish

The study of Roques *et al*. (2001) showed genetic homogeneity among samples of Acadian Redfish from the Gulf of St. Lawrence. The θ values varied between -0.005 and 0.004 in the three samples in this region (Table 1). Roques *et al*. (2001) reported a significant difference in the frequency of alleles between a sample from the Gulf of Maine and another from the Scotian Shelf ($p < 0.05$), but as indicated by Roques *et al*. (2003), this result should not be given much weight—only 30 individuals constituted the sample from the Gulf of Maine, and the difference in F_{ST} between the Gulf of Maine and the Scotian Shelf was not significant (Table 1; Roques *et al*. 2001). Further, samples were selected based on the congruence of the different distinguishing criteria (AFC, GBM and MDH) in order to ensure these were Acadian Redfish individuals, which could have led to an underestimation of the genetic variability of the populations (Valentin 2006).

Valentin (2006) identified three groups of Acadian redfish: a Unit 1/Unit 2 (Figure 4) group, a northern group and a southern group (Figures 2, 3). Many of the differences between groups had F_{ST} values which were not significant (Table 4), although structure, MDS analyses and the neighbour-joining method show the various groups as being distinct. The presence of distinct groups is also supported by morphometric analyses. Further, little introgression is seen in samples from the northern region, in contrast to the region of the Gulf of St. Lawrence and the Laurentian Channel. Even the samples from the GSL/LC, which contain few individuals showing signs of introgression, can be differentiated from the northern samples. Therefore, processes other than introgressive hybridization appear to be involved in the population differentiation process. This situation is similar to that of Deepwater Redfish*.* The specific oceanographic conditions of the Gulf of St. Lawrence could cause a certain isolation. Morphometric homogeneity was observed between Acadian Redfish samples in the GSL/LC area. However, the samples exhibited genetic heterogeneity, the source of which remains unexplained.

Table 4. Pairwise index of genetic differentiation between Acadian Redfish samples. The Fst value is found above the diagonal, and test significance below the diagonal. (-) non-significant, (+) significant before correction, + significant after sequential Bonferroni correction (from Valentin 2006).

Sample	3L65	3N23	3O44	3PS1	3PS138	3PS26	3PS114	3PS88b	4R107	4VN67	4VS36	4R53	4VN5	BonBay	NS85	NS95	s261	s266	s327
3L65		-0.002	0.006	0.001	-0.003	0.000	0.003	0.006	0.013	0.007	0.007	0.016	0.019	0.052	0.016	0.005	0.010	0.007	
3N23	–		0.001	0.003	0.000	-0.003	0.004	0.004	0.008	0.006	0.004	0.016	0.017	0.042	0.014	0.002	0.005	0.005	0.011
3O44	–	–		0.001	-0.001	0.000	0.001	0.002	0.008	0.006	0.006	0.014	0.016	0.044	0.017	0.002	0.010	0.008	0.014
3PS1	–	–	–		0.000	-0.002	0.000	-0.003	0.006	0.004	-0.001	0.007	0.014	0.039	0.008	0.001	0.003	-0.001	0.001
3PS138	–	–	–	–		-0.003	-0.001	0.004	0.010	0.006	0.005	0.017	0.017	0.047	0.019	0.004	0.009	0.004	0.007
3PS26	–	–	–	–	–		0.002	0.004	0.010	0.008	0.002	0.012	0.018	0.051	0.016	0.004	0.003	0.001	0.006
3PS114	–	–	–	–	–	–		-0.004	0.002	-0.001	0.001	0.008	0.017	0.038	0.007	0.006	0.003	0.002	0.006
3PS88b	–	–	–	–	–	–	–		0.004	0.000	0.001	0.010	0.023	0.041	0.008	0.003	0.001	0.005	0.007
4R107	(+)	(+)	(+)	(+)	(+)	(+)	–	–		0.005	0.002	0.011	0.014	0.035	0.013	0.005	0.002	0.010	0.010
4VN67	–	(+)	–	–	(+)	(+)	–	–	–		0.001	0.015	0.019	0.044	0.010	0.008	0.005	0.003	0.009
4VS36	(+)	–	(+)	–	–	–	–	–	–	–		0.006	0.009	0.038	0.008	0.002	0.001	0.001	0.007
4R53	+	+	+	(+)	+	(+)	(+)	(+)	(+)	+	(+)		0.010	0.038	0.004	0.015	0.009	0.006	0.010
4VN5	+	+	+	(+)	+	+	+	+	+	+	(+)	(+)		0.029	0.007	0.017	0.019	0.010	0.012
BonBay	+	+	+	+	+	+	+	+	+	+	+	+	+		0.032	0.042	0.046	0.041	0.038
NS85	+	+	+	(+)	+	+	(+)	(+)	+	(+)	(+)	–	(+)	+		0.019	0.006	0.004	0.004
NS95	–	–	–	–	–	–	(+)	–	–	(+)	–	+	+	+	+		0.008	0.009	0.010
s261	(+)	–	(+)	–	(+)	–	–	–	–	–	–	(+)	+	+	–	(+)		0.000	0.001
s266	–	–	(+)	–	–	–	–	–	(+)	–	–	–	(+)	+	–	(+)	–		-0.005
s327	(+)	(+)	(+)	–	(+)	–	(+)	(+)	(+)	(+)	(+)	(+)	(+)	+	–	(+)	–	–	

Table 5. Length (L50) and age (A50) at maturity of females from different stocks (from Morin *et al*. 2004).

			Length			Age		
Species	**DU**	**Stock**	**L50**	**SE**	**N**	**A50**	**SE**	**N**
Acadian Redfish	Atlantic	Unit 1	20.17	0.169	210	7.67	0.126	86
		Unit 2	25.64	0.036	309	10.31	0.029	304
		Unit 3	22.37	0.112	204	8.03	0.147	193
		3O	25.47	0.118	73	10.31	0.110	30
		3LN	23.98	0.298	116			
Deepwater Redfish	GSL/LC	Unit1	24.35	0.169	238	10.36	0.173	93
		Unit 2	24.44	0.133	155	10.60	0.086	143
	Northern	3O	33.13	0.325	25	15.08	0.380	19

Table 6. Length (L50) and age (A50) at maturity of males from different stocks (from Morin *et al*. 2004).

Species	DU	Stock	Length			Age		
			L50	SE	N	A50	SE	N
Acadian Redfish	Atlantic	Unit 1	18.88	0.305	177	6.12	0.189	61
		Unit 2	20.11	0.06	280	7.67	0.046	277
		Unit 3	20.4	0.267	147	6.85	0.191	134
Deepwater Redfish	GSL/LC	Unit1	23.04	0.105	206	8.55	0.104	68
		Unit 2	23.14	0.155	177	8.88	0.18	172

Acadian Redfish in the southern part of the range (Gulf of Maine and Scotian Shelf) seem to be genetically different from those of the GSL/LC and the northern population, suggesting a restriction in the genetic exchange between these zones. Like the Gulf of St. Lawrence, the Gulf of Maine is a productive environment in which all stages of life for Redfish occur in a favourable habitat (Pikanowski *et al*. 1999; Sévigny *et al*. 2000). Immigration from other regions is only episodic in the Gulf of Maine (Valentin 2006).

Acadian Redfish in the Gulf of St. Lawrence (Unit 1) reach sexual maturity at a younger age than those in other areas (Tables 5 and 6; Morin *et al*. 2004): 50% of the females in the Gulf of St. Lawrence are mature at 7.6 years of age, whereas the maturity age is 8.0 in the Scotian Shelf and 10.3 the Laurentian Channel and Grand Banks/Labrador Shelf.

An isolated population is found in the Bonne Bay fjord on the west coast of Newfoundland (Figure 8; Currie *et al*. 2009). Individuals from this fjord showed notable genetic differences when compared with individuals from the Gulf of St. Lawrence as well as from other regions (Figs 2, 3) (Valentin 2006). The difference between the F_{ST} values was also significant for all comparisons involving the Bonne Bay sample (F_{ST} varying between 0.029 and 0.052, Table 4). The morphometric study conducted by Valentin (2006) also showed significant differences between the Bonne Bay Redfish and those in the Gulf of St. Lawrence. These morphological differences are apparent on visual inspection (Valentin 2006). The presence of a distinct population in Bonne Bay is consistent with the observation of limited water exchange between the Fjord and the Gulf of St. Lawrence. It is hypothesized that the population could have been even more isolated during the last deglaciation event that took place between 13,000 and 6,000 years ago.

Designatable units

Deepwater Redfish

Genetic studies, supported by morphometric analyses, strongly suggest that two populations of Deepwater Redfish are found in the Northwestern Atlantic. Only studies on parasite infestations show differences between the Deepwater Redfish in the Gulf of St. Lawrence and those in the Laurentian Channel.

The two genetic populations (Figs 2, 3) of Deepwater Redfish are clearly distinct geographically (Figure 6).

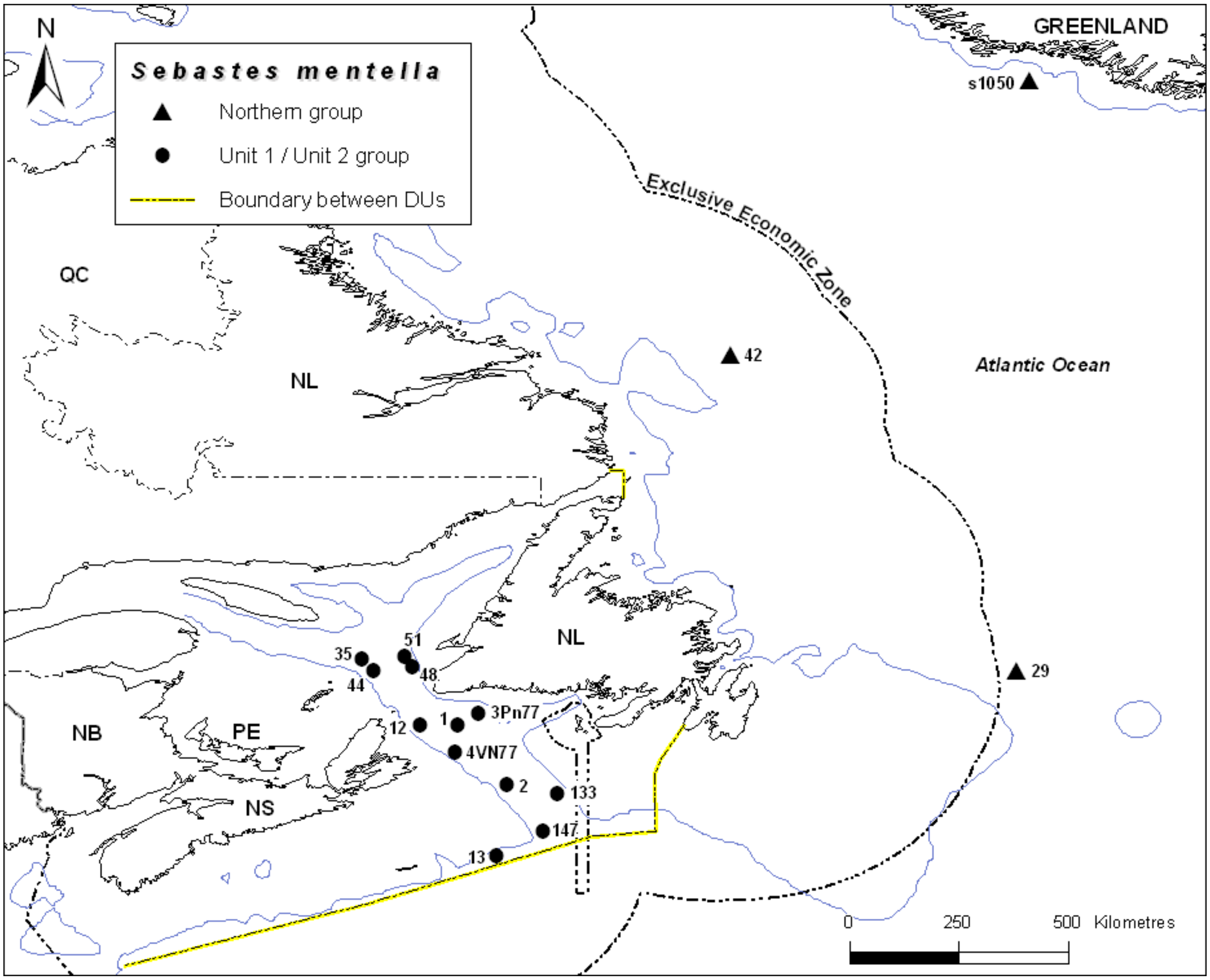

Figure 6. Deepwater Redfish (*Sebastes mentella*) genetic groups (as identified in Figure 2) and proposed boundary between the Northern DU and the Gulf of St. Lawrence/Laurentian Channel DU.

For the purposes of designating status, the report therefore proposes that Deepwater Redfish in Canadian waters be considered as two designatable units: the Northern DU, consisting of individuals of the Grand Banks, Labrador Shelf, Davis Strait and Baffin Bay (NAFO Areas 0 and 2 plus Divisions 3KLNO, Figure 5); and the Gulf of St. Lawrence/Laurentian Channel (GSL/LC) DU (NAFO Divisions 3P4RST).

These DUs meet the “distinctness” criteria of COSEWIC’s DU Guidelines because of the genetic and morphometric differences between them, and because they are clearly geographically separated. They meet the “significance” criteria because elimination of one of these DUs would create a major gap in the distribution of the species.

The proposed boundary between the two DUs (Figure 6) is the boundary between NAFO Divisions 3LO and NAFO Subdivision 3Ps off southern Newfoundland, and between NAFO Divisions 4R and 3K between Newfoundland and Labrador. This is consistent with the genetic data and it conforms with the existing management framework for redfishes.

With respect to the northern boundary of the Northern DU, there is no information to indicate that the Northern DU does not extend to the northern limits of the distribution of the species in Canada; indeed the single sample from southern Greenland is genetically close to samples from Canadian waters on the Grand Banks and Labrador shelf. Accordingly the proposed DU would include all Canadian waters to the north, and its proposed eastern boundary is the boundary between Canadian and Greenland EEzs in the Davis Strait and Baffin Bay.

<u>Acadian Redfish</u>

For the purposes of designating status, this report proposes that the Acadian Redfish be divided into two designatable units: an Atlantic DU covering the Canadian distribution of the species except Bonne Bay and the Bonne Bay DU.

The Bonne Bay DU meets the “distinctness” criterion because its genetic and morphometric characteristics are very different from those of other Acadian Redfish in Canada’s Atlantic. Experienced biologists and fishermen are able to distinguish Bonne Bay redfish from those originating outside the Bay. It meets the “significance” criteria because it has persisted in a unique setting for redfishes, a small fjord-like bay on the west coast of Newfoundland. This DU is separated from the Atlantic DU by the shallow waters of Outer Bonne Bay and the shallow sill (~50 m depth) at the entrance to East Arm, Bonne Bay (Figure 8). The majority of East Arm is greater than 150m in depth and this is where the Acadian Redfish are found.

The genetic differences between the other groups of Acadian redfish are small relative to those identified for Deepwater Redfish (Figs. 2, 3). Further, the three genetic groups identified are not clearly separated geographically (Figure 7). As such, there appears to be no basis for establishing more than one DU for Acadian Redfish outside Bonne Bay.

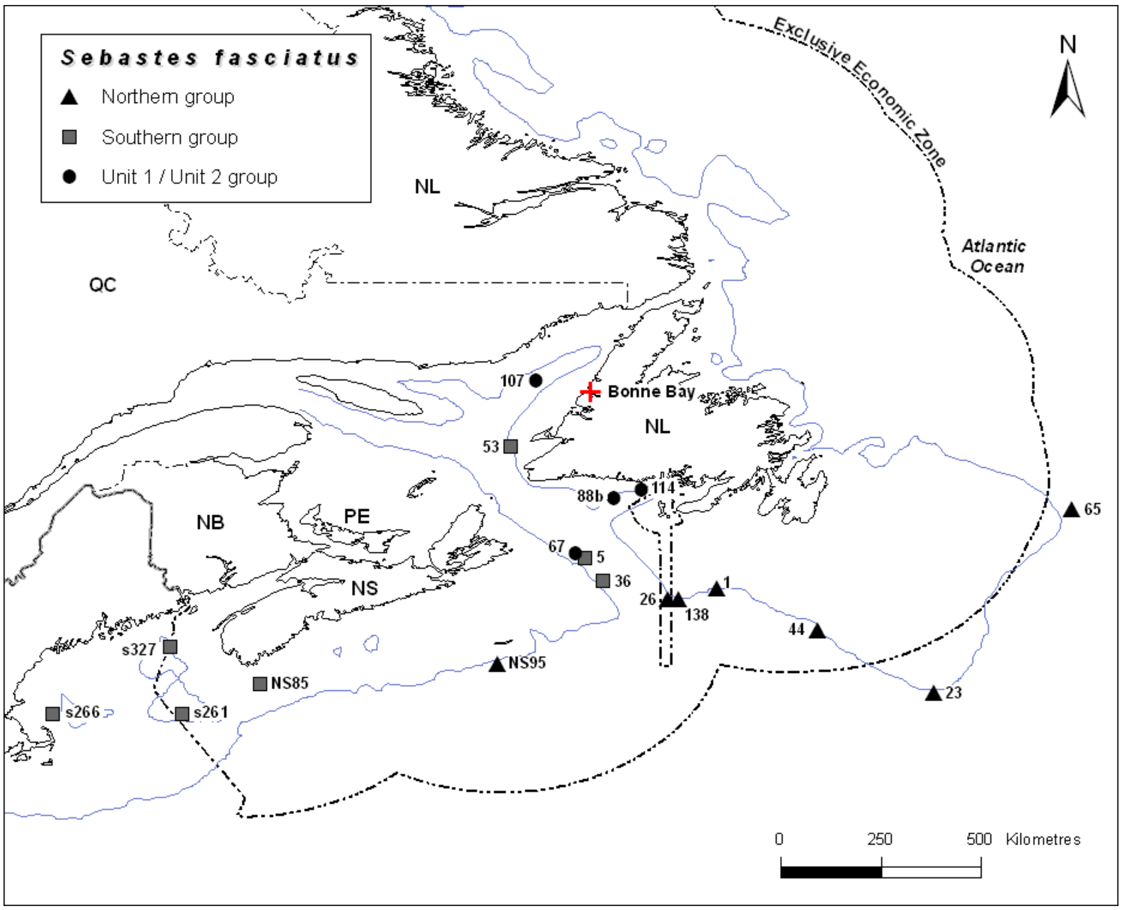

Figure 7. Acadian Redfish (*Sebastes fasciatus*) genetic groups from proposed Atlantic DU (solid symbols) and location of proposed Bonne Bay DU (cross). Genetic groups are as identified in Figure 2.

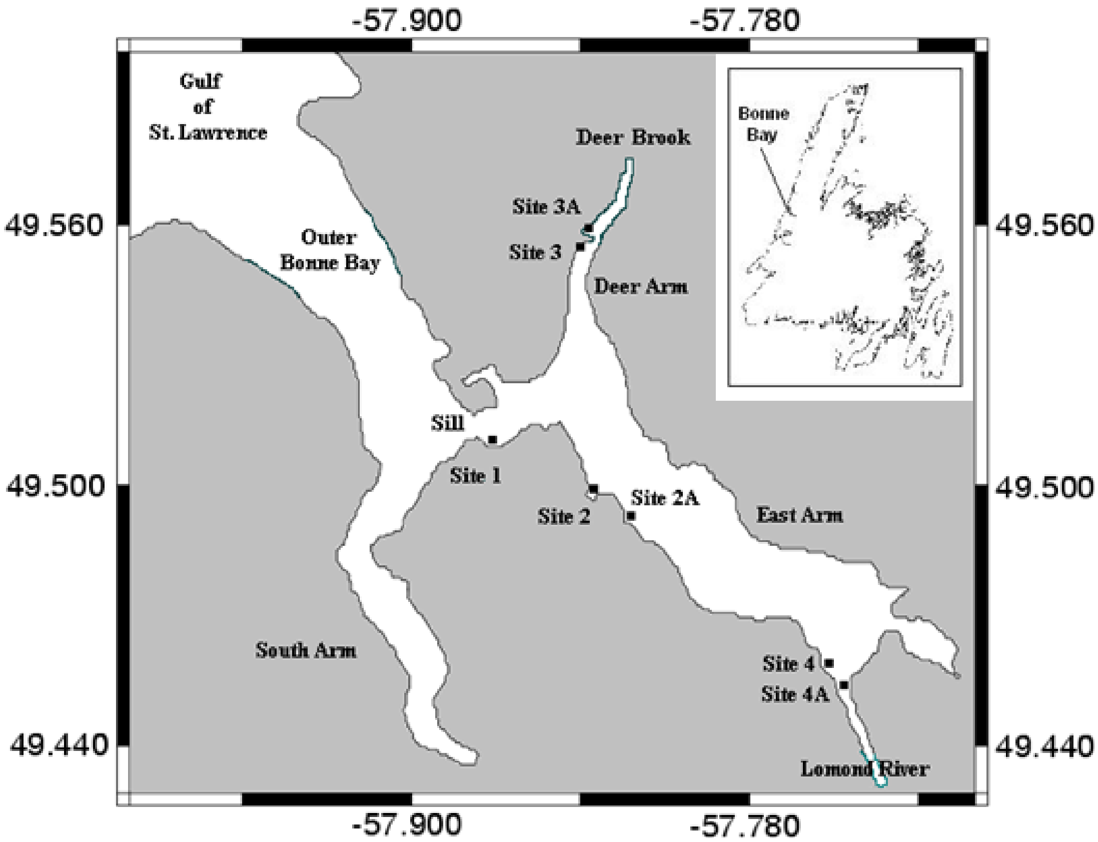

Figure 8. Bonne Bay, Newfoundland. All Redfish were caught in the East Arm, east of the sill. Source: Currie *et al*. 2009.

Because the proposed Atlantic DU covers the entire species distribution (other than Bonne Bay) in Atlantic Canada, the boundaries would be the boundaries of Canada's Atlantic maritime waters and Extended Economic Zone.

DISTRIBUTION

Global range

Deepwater Redfish is found on both sides of the North Atlantic at depths typically varying between 350 and 500 m (Atkinson 1987). However, Deepwater Redfish has been observed at much greater depths (as far down as 910 m) (Whitehead *et al*. 1986). On the western side of the Atlantic, this species is found from the south of Newfoundland north to Baffin Bay (Figure 9). The distribution of this species extends east, from an area south of Greenland and off the coast of Iceland to the northern coast of Europe. In Europe, Deepwater Redfish occurs from the western Barents Sea to the Norway Sea (Whitehead *et al*. 1986).

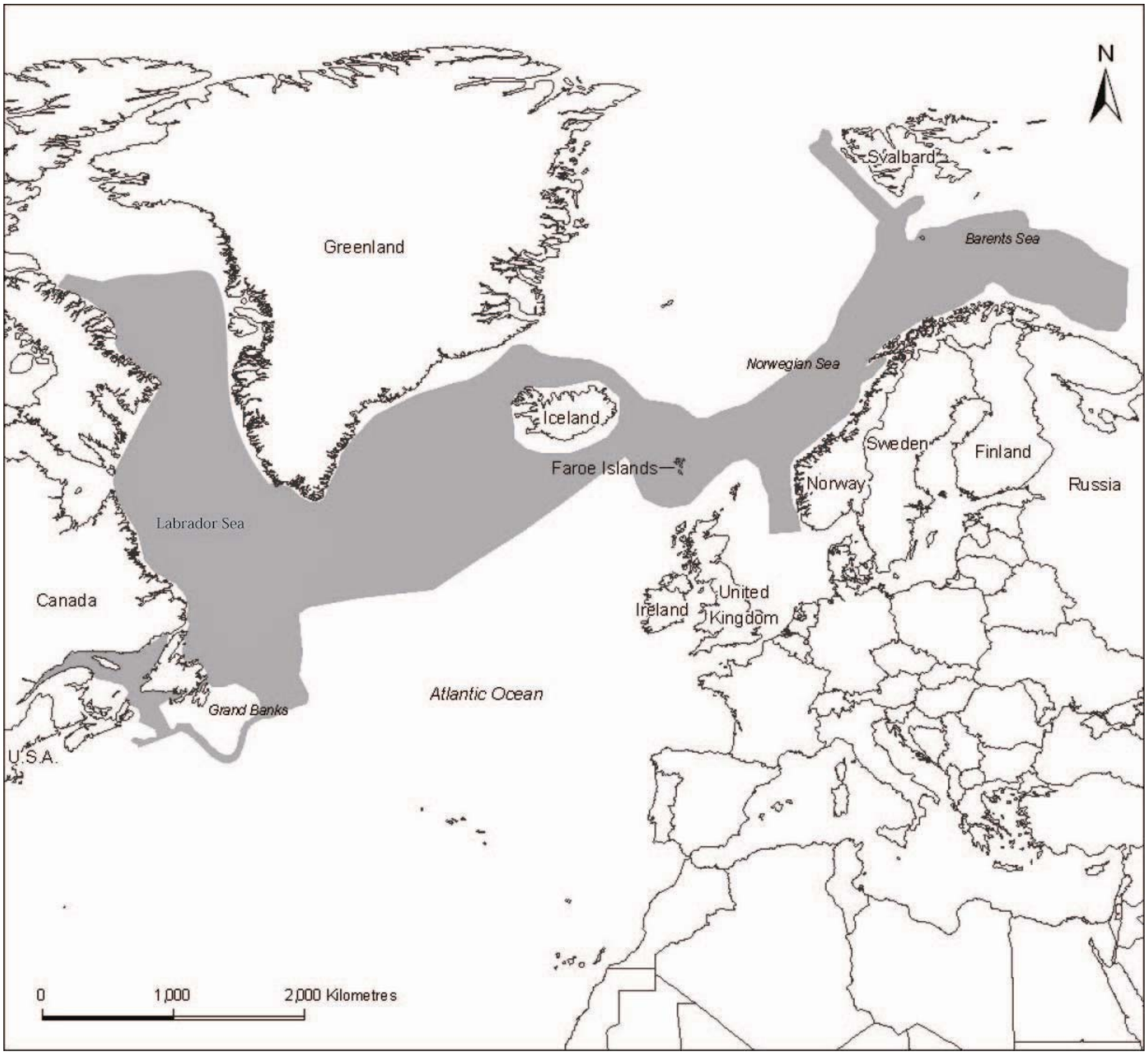

Figure 9. North Atlantic distribution of Deepwater Redfish.

The distribution of Acadian Redfish, which is found only in the Northwestern Atlantic, is more limited than that of Deepwater Redfish. This species occupies shallower depths than Deepwater Redfish, generally between 150 and 300 m (Atkinson 1987). The distribution of the Acadian Redfish extends from the Gulf of Maine to the Labrador Sea (Figure 10). A few individuals (18 in total) of Acadian Redfish have been reported east of Greenland and near Iceland (Whitehead *et al*. 1986).

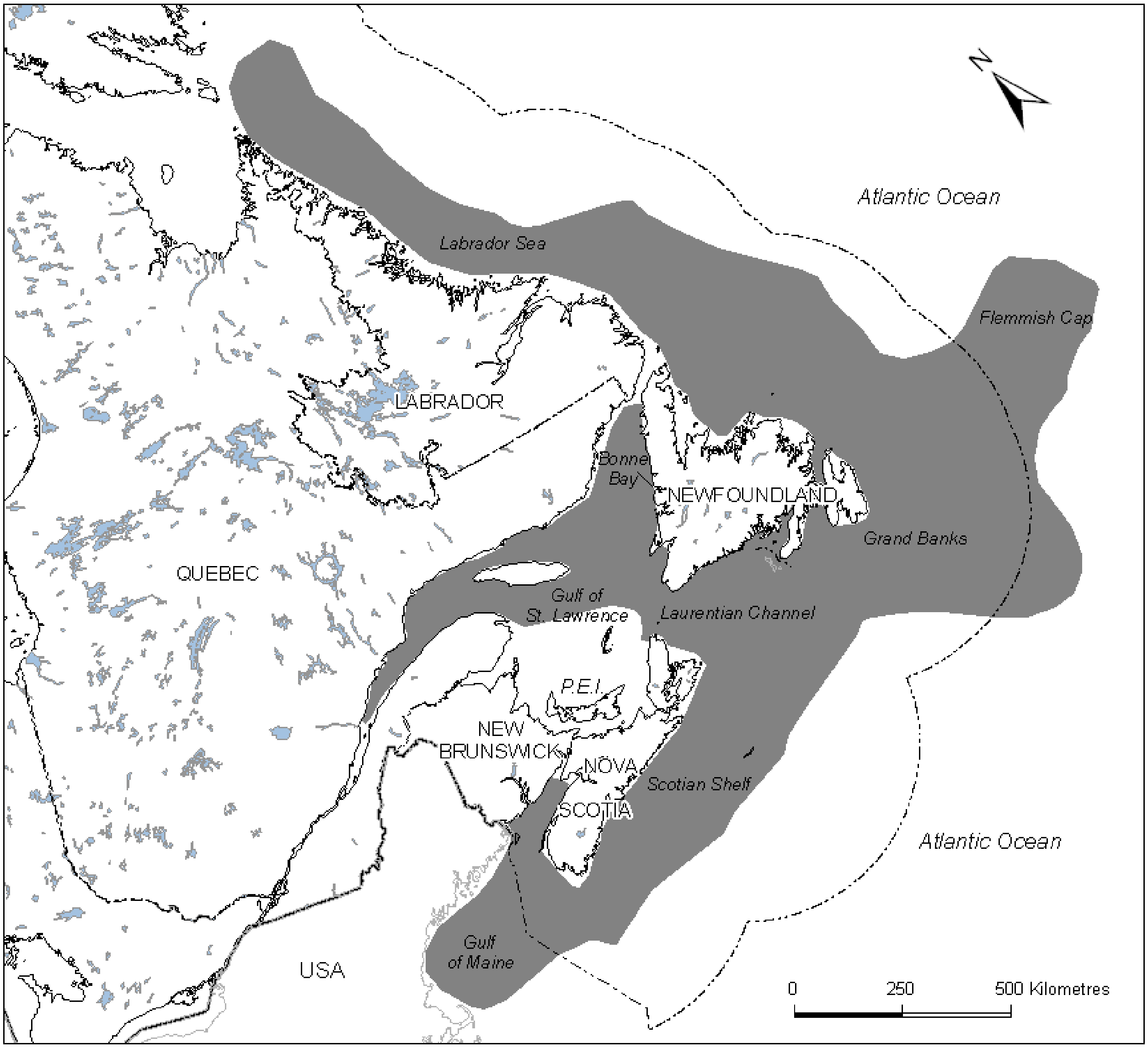

Figure 10. Global distribution of Acadian Redfish.

The distributions of these two redfish species in the Northwestern Atlantic follow a north-south gradient: Deepwater Redfish is more abundant in the north, whereas Acadian Redfish is more prevalent in the south. The vast majority of Redfish occupying the north of the Labrador Sea are Deepwater Redfish, whereas Acadian Redfish is found almost alone in the Gulf of Maine and the Scotian Shelf (Valentin *et al*. 2006). In the intermediate zones, both species are present.

Canadian range

In Canadian waters, Deepwater Redfish is primarily found along the edge of the banks of the continental slope and in deep channels. The Canadian range extends from the area south of Newfoundland to Baffin Bay, and includes the Gulf of St. Lawrence and Labrador Sea (Figure 11). Deepwater Redfish also occurs in the St. Lawrence estuary and can be found as far as the Saguenay fjord.

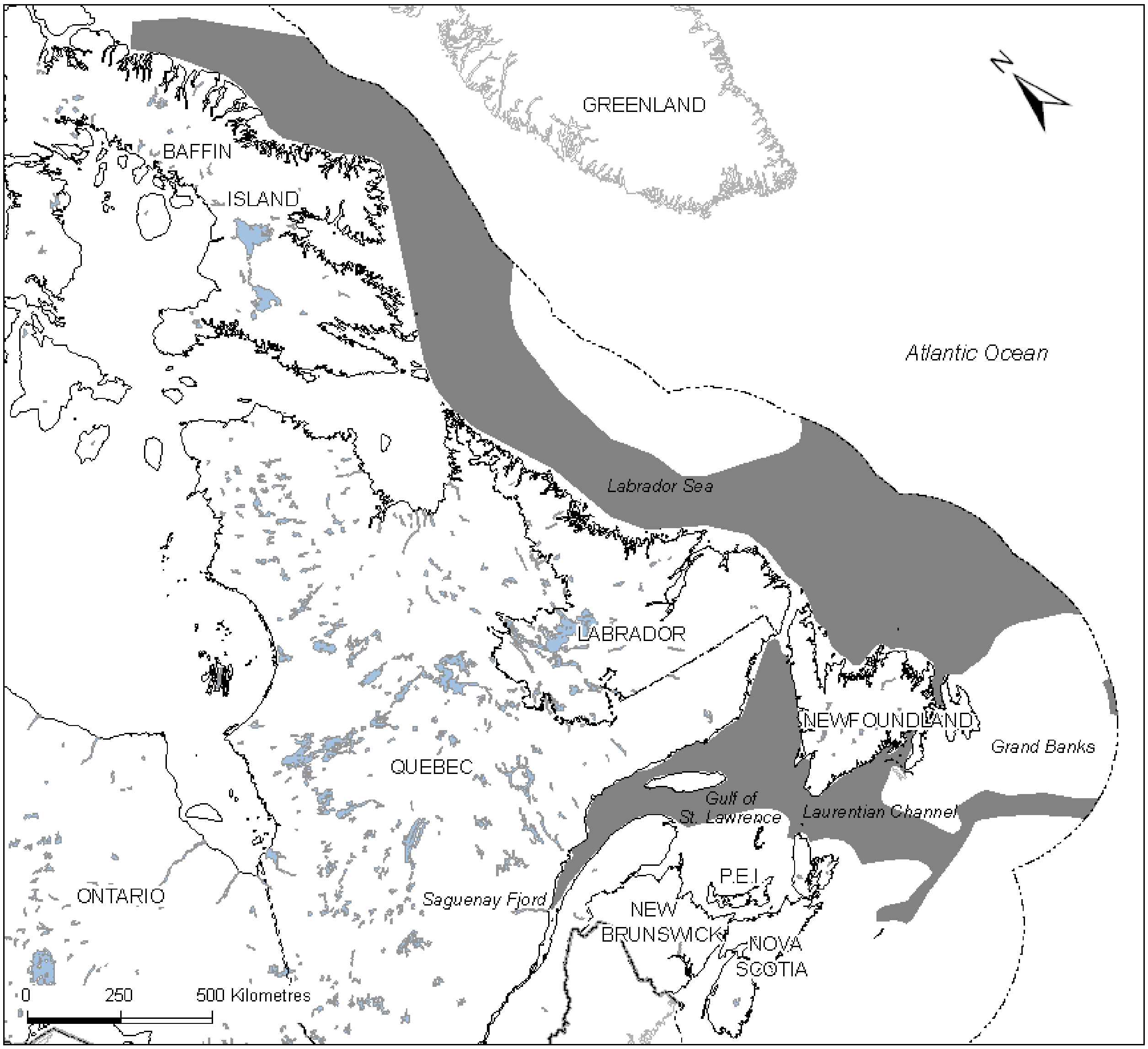

Figure 11. Canadian distribution of Deepwater Redfish.

A large portion of the range for Acadian Redfish is found in Canadian waters. This species is found on the Scotian Shelf, along the continental slope of the Grand Banks of Newfoundland, in the Gulf of St. Lawrence and south of Newfoundland (Figure 12). Acadian Redfish also occurs in the Bonne Bay fjord.

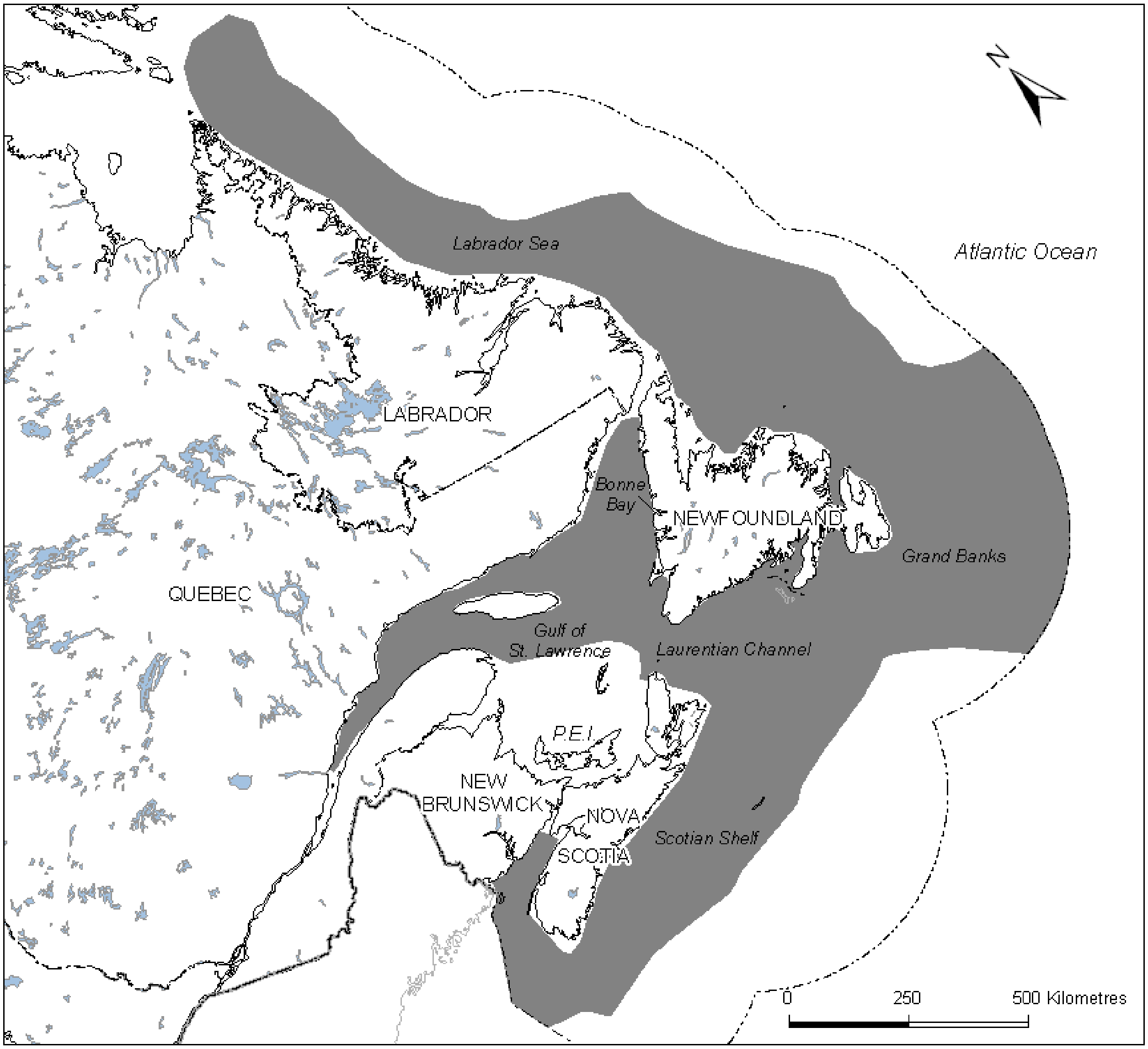

Figure 12. Canadian distribution of Acadian Redfish.

Extent of occurrence and area of occupancy

The area of occupancy was evaluated by DFO using data from scientific surveys (Sévigny *et al*. 2007). Three indices were produced: the design-weighted area of occupancy (DWAO) index, the D95 and the GINI index of aggregation. The DWAO is the area of occupancy (*A*) weighted by sampling:

$$A = \sum_h \sum_i \frac{W_h}{n_h} I_{hi}$$

where W_h is the area of stratum *h*, n_h is the number of tows in stratum *h*, and I_{hi} = 1 if the catch in stratum *h* and set *i* is > 0. I_{hi} = 0 if the catch = 0.

The D95 and GINI are indices of fish concentrations. However, of the three indices presented by DFO, the DWAO is the one that comes closest to the definition of "area of occupancy" as proposed by COSEWIC. This index will therefore be presented for the different areas of occupancy covered by each survey. It should be noted that the DFO surveys used in this analysis do not include NAFO Area 0 where Deepwater Redfish are known to occur.

Using DFO's catch data, the COSEWIC Secretariat has also calculated the area of occupancy of Redfish species. Unlike the DWAO, the calculation method used by COSEWIC is based on presence in 2 km by 2 km grid squares. The two values for the area of occupancy (DWAO and COSEWIC) are presented in this report.

The COSEWIC Secretariat also calculated the extent of occurrence. This index is obtained from the minimum area occupied by a convex polygon covering all sites for the listed catches.

The extents of occurrence for Deepwater Redfish and Acadian Redfish are evaluated respectively at 511 x 10^3 km^2 and 553 x 10^3 km^2 in the Gulf of St. Lawrence/Laurentian Channel. The area occupied by redfish species in this region has remained constant over the period studied (Figure 13). Although the abundance indices have declined substantially (see later section), the distribution of redfishes has remained the same. Between 1996 and 2002 (years in which sampling was carried out in both units 1 and 2), the surface occupied varied between 144 000 and 149 000 km^2. Note that identification by species was not carried out due to the imprecise methods of differentiation (Morin *et al*. 2004). As well, sampling does not cover the entire redfish range. Based on the 2 km x 2 km COSEWIC method, the areas occupied by Deepwater Redfish and Acadian Redfish in this area are 16 x 10^3 km^2 and 31 x 10^3 km^2 respectively.

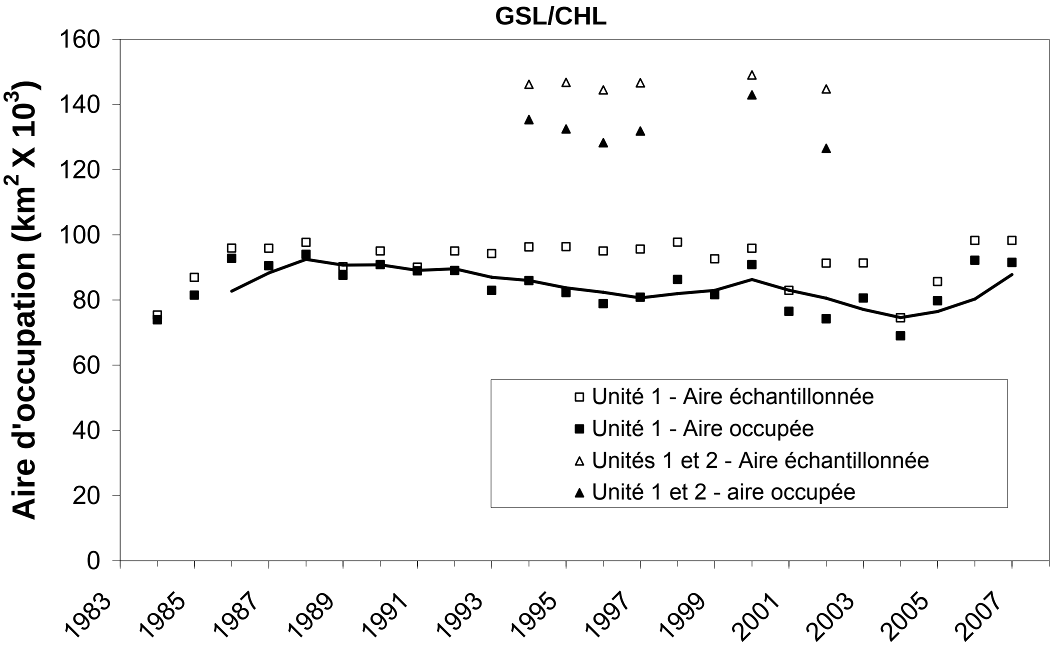

Figure 13. Area of occupancy (DWAO) for redfish populations in the Gulf of St. Lawrence and the Esquiman Channel. Aire échantillonnée = area sampled. Aire d'occupation = area of occupancy. Unité = Unit.

In northern areas (Newfoundland Grand Bank, Labrador Shelf and Sea), the extent of occurrence has been evaluated at 1431 x 10^3 km^2 for Deepwater Redfish and 785 x 10^3 for Acadian Redfish. The area of occupancy (DWAO) was calculated by DFO for each management zone (Sévigny *et al*. 2007). The areas occupied by *Sebastes* sp. in each management unit were added to Figure 14. Note that the area covered by the surveys varied enormously from year to year. Note that the survey season is not the same for all areas between 1973 and 1990. Zones 3O and 3LN were visited in the spring, whereas zones 2J3K and 2GH were seen in the fall. From 1991 to 2006, the values were calculated on the basis of the fall surveys for all zones. Note as well that certain surveys (especially 2GH) were not done for each year. As with the Gulf of St. Lawrence/Laurentian Channel populations, Redfish distribution seems to be relatively stable over time. The DWAO index increased, based on surface sampled. Moreover, the surveys did not cover the entire area occupied by the northern Redfish population. The actual zone occupied is therefore higher than the maximum value of 104 000 km^2 as measured in the surveys. Based on the 2 km x 2 km COSEWIC method, the areas occupied by the northern populations of Deepwater Redfish and Acadian Redfish are 21 x 10^3 km^2 and 20 x 10^3 km^2 respectively.

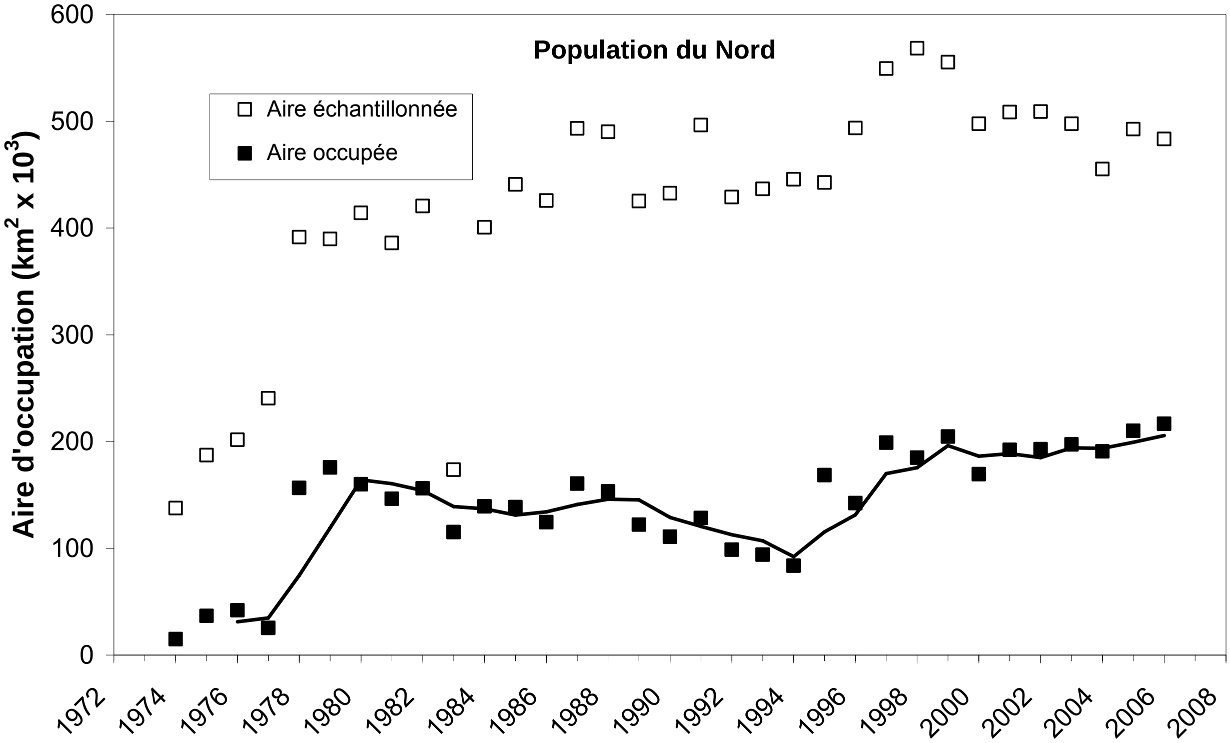

Figure 14. Area of occupancy (DWAO) for redfishes in the northern area (Grand Banks, Labrador Shelf). Aire échantillonnée = area sampled. Aire d'occupation = area of occupancy.

In the southern area, Unit 3 of DFO (Scotian Shelf and Gulf of Maine), the extent of occurrence for Acadian Redfish has been evaluated at 173 x 10^3 km^2. In spite of fluctuations that may be attributed in part to variabilities in sampling, no long-term trend was seen (Figure 15). Based on the 2 km x 2 km COSEWIC method, the area occupied by the southern population of Acadian Redfish is 5.6 x 10^3 km^2.

The east arm of Bonne Bay has a surface area of 26.1 km^2 based on a polygon that encloses the fjord (Joe Wroblewski, pers. comm. 2009). The extent of occurrence is estimated to be 72 km^2 using a 2 km x 2 km grid of the area. Area of occupancy would probably be somewhat less than this since redfish occupy only the deeper fraction of the fjord.

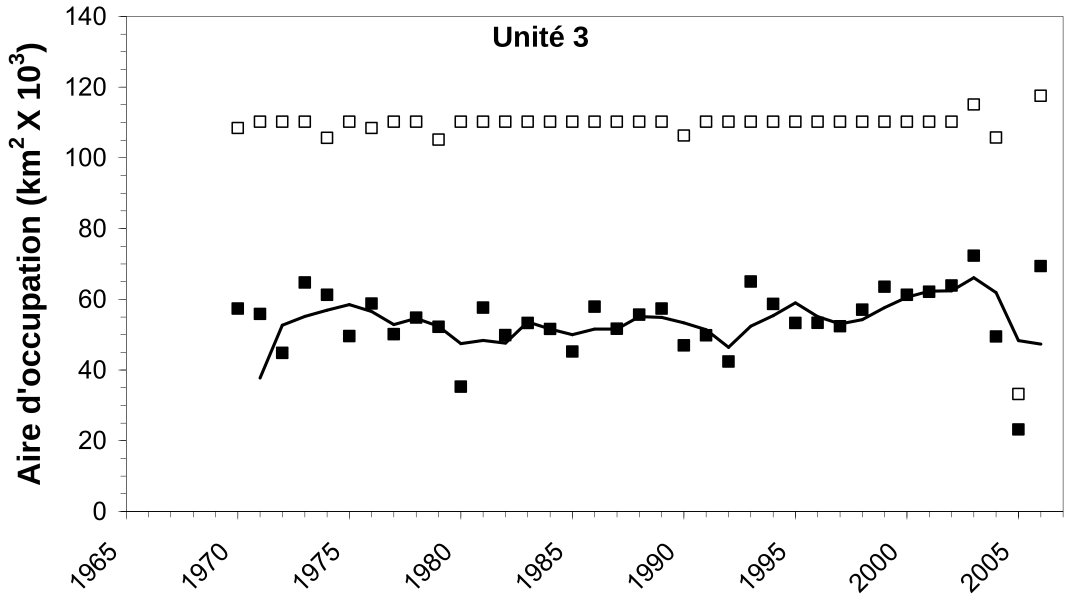

Figure 15. Area of occupancy (DWAO) for Acadian Redfish in Unit 3, the Scotian Shelf. Aire d'occupation = area of occupancy. Unité = Unit.

HABITAT

Habitat requirements

The habitat requirements of Atlantic Redfish species are incompletely known. Knowledge of the requirements of Acadian Redfish in the Gulf of Maine were summarized by Pikanowski *et al*. (1999). Certain aspects of redfish biology and requirements were also described by Gascon (2003).

Redfishes are born as larvae, which are found primarily in surface waters. In the Gulf of Maine, newly released larvae are mainly found in the first 10 m of the water column, whereas larvae measuring between 10 and 25 mm are found in the thermocline (10–30 m) (Pikanowski *et al*. 1999). Unlike larvae in the Gulf of Maine and the Scotian Shelf (Kelly and Barker 1961; Sameoto 1984; cited by Kenchington 1991), larvae in the Gulf of St. Lawrence undertake a marked vertical migration. The preferred depth of Redfish larvae (regardless of the species) was evaluated at between 11 and 30 m by day and 10 metres or less at night (Kenchington 1991). Despite the preference for certain depths larvae were observed throughout the upper 200 m of the water column. Some observations suggest that Deepwater Redfish larvae make larger vertical migrations than Acadian Redfish larvae (Kenchington 1991).

In the Gulf of Maine, Acadian Redfish juveniles move below the thermocline upon reaching a length of approximately 25 mm. The juveniles remain pelagic until they reach 40–50 mm, i.e. for a period of approximately 4 to 5 months (Kelly and Barker 1961). In general, smaller redfishes live in shallower waters, while larger individuals occupy deeper waters. The preferred zone for younger individuals is between 75 and 175 m. Some evidence suggests that redfishes use rocks or anemones as shelter from predators (Shepard *et al*. 1986; Auster *et al*. 2003). Because the smaller redfishes stay in shallower habitats, it is likely that their need for shelter (macro-vegetal or anemone) is greater than that of the adults. Coastal habitats are more commonly occupied by Acadian Redfish than by Deepwater Redfish.

Adults prefer cold waters (approximately 5^{o}C) along the slopes of banks and deep channels. Acadian Redfish generally live at depths varying from 150 to 300 m, whereas Deepwater Redfish are found between 350 and 500 m (Atkinson 1987). Although these are consistent depth preferences, and depth can be used to help separate the two species, overlap in depth distribution is such that depth alone cannot be used to separate species. Redfish are considered to be semi-pelagic species because they make large-scale daily vertical migrations (Gauthier and Rose 2002).

Trends

The proportion of habitat made up of anemones or coral or having an irregular bed may have declined in recent decades due to the increased use of bottom trawling. However, no studies have been carried out to evaluate the effects of trawling on these habitats. If this type of habitat is important for the survival of Redfish, the possible reduction of the habitat could have an adverse impact on the abundance of the species.

BIOLOGY

Information on the biology of Deepwater Redfish and Acadian Redfish is limited. As a result of the multidisciplinary research program on redfishes carried out between 1995 and 1998 by Fisheries and Oceans Canada (DFO) (Gascon 2003), knowledge of redfish biology has improved. Modelling marine ecosystems has also been useful in understanding the different trophic interactions of Redfish (e.g. Savenkoff *et al*. 2006).

Life cycle and reproduction

The redfishes of the Northwestern Atlantic differ from most other marine fishes because females are viviparous. Fertilization is internal, and the female carries the young until they are released as larvae. According to Saint-Pierre and de Lafontaine (1995) and Lambert *et al*. (2003), the absolute fecundity of females varies between 1500 and 107 000 larvae, and fecundity increases as a power function of fish length or mass. According to the results of these studies, Acadian Redfish seems to have greater fecundity than Deepwater Redfish. Breeding (transfer of male gametes to the female) occurs between September and December (Ni and Templeman 1985; Lambert *et al*. 2003). The female carries the embryos until the larvae are released, for a period that varies with region and species. In the Gulf of St. Lawrence, the larvae appear to be released in late spring and early summer, but release seems to take place sooner in the waters south of Newfoundland (Ni and Templeman 1985). Larval release in Deepwater Redfish appears to occur 15 to 25 days earlier than for Acadian Redfish (Sévigny *et al*. 2000). The larvae measure 6 - 9 mm at birth (Penny and Evans 1985).

Recruitment is highly variable in these species. An interval of between 5 and 12 years has been observed between each of the major year classes (Morin *et al*. 2004) during periods when populations were relatively lightly exploited and abundant. Some year classes that appeared particularly strong at young ages have disappeared without reaching larger sizes, for unknown reasons. This phenomenon was observed during the 1990s when the abundant 1988 year class apparently disappeared before reaching commercial size (Lambert *et al*. 2003).

Redfish differ from most other marine fishes in their slow growth and long life expectancy. Specimens at least 75 years old have been reported (Campana *et al*. 1990). The two species have similar growth, although Acadian Redfish grows more slowly starting from age 10 (Morin *et al*. 2004). Further, after age 10 females grow faster than males in both species. Growth is quicker in the southern part of the range than in the northern part (Gascon 2003).

Deepwater Redfish males generally reach a maximum length of 40 to 45 cm, whereas females may grow to between 45 and 60 cm in length. A 58-cm specimen was described by Coad and Reist (2004). Acadian Redfish commonly reaches a size of 45 cm in the Gulf of Maine (Mayo *et al*. 1990).

“Generation time” is defined by COSEWIC as the average age of the parents of the current cohort. The same calculation that is applied to cod was used to determine the generation time for the different species and populations of Redfish (COSEWIC 2003). This was done to take into account the effects of fishing pressures on age at maturity.

$$G_t = A_{female} + 1/M$$

where A_{female} (or A50) is the age at which 50% of adult females are mature, and M is the instantaneous rate of natural mortality. The natural mortality rate used in this report is 0.125, as adopted by Bundy *et al*. (2000). This involves an average of the values estimated by Rikhter (1987). Because redfish have a long life expectancy, this value is considered more appropriate than the 0.2 value used for several marine species (e.g. cod: Smedbol *et al*. 2002). The A50s of the different stocks, based on Morin *et al*. (2004), are found in tables 5 and 6, and generation times are summarized in Table 7.

Table 7. Age at maturity, generation time, and summary of decline rates for the number of mature individuals for Deepwater Redfish and Acadian Redfish in different areas. Age at maturity is for females. For the rates of decline, NA indicates no data, and None indicates there was not a decline.

Species	DU	Stock	Age at Maturity	Generation Time (yr)	Period	Rate of Decline
Deepwater Redfish	GSL/LC	Unit 1	10.4	18.4	1984−2007	- 98.4%
		Unit 2	10.6	18.6	1994−1997; 2000; 2002	NA
	Northern	3O	15.1	23.1	1991−2006	None
		3LN			1991−2006	None
		2J3K			1978−2006	- 98.0 %
		2GH			1987−2006	None
Acadian Redfish	Atlantic	Unit 1	7.7	15.7	1984−2007	- 98.5%
		Unit 2	10.3	18.3	1994−1997; 2000; 2002	NA
		3O	10.3	18.3	1991−2006	None
		3LN			1991−2006	None
		2J3K			1978−2006	- 99.7%
		2GH			1987−2006	None
		Unit 3	8.0	16.0	1984−2006	None

Predators

Redfishes are preyed upon by Harp Seals (*Phoca groenlandica*), Hooded Seals (*Cystophora cristata*), Grey Seals (*Halichoerus grypus*), and large piscivorous fish. These fish include Greenland Halibut (*Reinhardtius hippoglossoides*), Thorny Skate (*Raja radiata*), Atlantic Cod (*Gadus morhua*), Black Dogfish (*Centroscyllium fabricii*), Monkfish (*Lophius americanus*), Pollock (*Pollachius virens*) and Wolffishes (*Anarhichas* sp.) (Konchina 1986; Berestovskiy 1990; Pikanowski *et al*. 1999, Hammil and Stenson 2000).

Based on modelling conducted by Savenkoff *et al*. (2006), the Harp Seal and skates have been the main predators of redfishes over the past few years in the Gulf of St. Lawrence. Before stocks collapsed, Atlantic Cod was the main predator. On the Newfoundland and Labrador Shelf, Greenland Halibut and skates appear to be the main predators of redfishes (Savenkoff *et al*. 2001). In the eastern part of the Scotian Shelf, Pollock, Grey Seals and Haddock are the most common predators of redfishes (Bundy 2004).

Diet

At the larval stage, Acadian Redfish in the Gulf of Maine feed on the eggs of fish and invertebrates. The largest larvae also feed on copepods and euphausiids (Anderson 1994; Pikanowski *et al*. 1999). When redfishes reach juvenile and adult sizes, the prey size increases, and the redfishes may then feed upon copepods, euphausiids and fish. Deepwater Redfish and Acadian Redfish seem to have a similar diet (Dutil *et al*. 2003a).

Physiology

The preferred temperature of Acadian Redfish larvae at the southern limit of their range (Gulf of Maine) was evaluated at between 4 and 11^{o}C (Pikanowski *et al*. 1999). The preliminary results of the laboratory studies carried out as part of the DFO multidisciplinary project on Redfish (Dutil *et al*. 2003b) show that the mortality rate is higher in Acadian Redfish larvae at low temperatures (0.3 to 1.6^{o}C) and at temperatures above 14^{o}C than at temperatures between these values.

The temperature preference of Acadian Redfish juveniles in the Gulf of Maine is between 5 and 10^{o}C (Pikanowski *et al*. 1999). In the Gulf of St. Lawrence and the Laurentian Channel, the temperature preference for adult Redfish is between 4.5 and 6.0^{o}C, whereas it is between 5.5 and 7.0^{o}C off Nova Scotia (Morin *et al*. 2004).

Movements/dispersal

Dispersal in redfish species has not been well documented. Dispersal probably mainly occurs at the larval and juvenile stages. The larvae are extruded in the spring and the juveniles only settle on the bottom at the beginning of the fall (Kenchington 1984), which leaves considerable time for dispersal by currents.

Once redfishes reach the bottom, it is believed that their movements are limited. Given their exceptionally long life, however, the adults could undertake major long-term movements. Redfishes very rarely survive capture due to the gas bladder's rupture (lethal trauma) on being brought to the surface. It is therefore virtually impossible to conduct tagging studies on these species unless tagging is done at depth (and Redfish live too deep to be tagged by divers). For these reasons, redfish movements are not as well documented as for some other species.

Redfish in the Gulf of St. Lawrence move in winter to the Laurentian Channel south of Newfoundland. Analyzing industry catch rates first revealed this movement (Atkinson and Power 1989). A study using the composition of otolith trace elements also supports these conclusions (Campana *et al*. 2007).

Given its more fusiform morphology, it is believed that Deepwater Redfish may move farther than Acadian Redfish (Valentin *et al*. 2002).

POPULATION SIZE AND TRENDS

Search effort

DFO trawl surveys are the main method used to follow changes in redfish abundance. Surveys have been conducted based on management units defined by the Northwest Atlantic Fisheries Organization (NAFO) (Figure 5): 1) West Greenland (Subarea 1); 2) the Labrador Sea (Subarea 2+Division 3K); 3) the Flemish Cap (Division 3M); 4) the eastern and northern Grand Banks (Divisions 3LN); 5) the southwestern Grand Banks (Division 3O); 6) the Gulf of St. Lawrence (an area defined by DFO as Unit 1, comprising NAFO 4RST + 3Pn4Vn, January to May); 7) the Laurentian Channel (an area defined by DFO as Unit 2, comprising NAFO 3Ps4Vs4Wfgj + 3Pn4Vn, June to December); 8) the Scotian Shelf (DFO Unit 3 comprising NAFO 4WdehklX); and 9) the Gulf of Maine (NAFO Subarea 5). Each of the DUs proposed in the present report (other than Bonne Bay for Acadian Redfish) therefore groups together several management areas. The abundance indices presented in this section were calculated by DFO and details are presented in Sévigny *et al*. (2007).

Abundance estimates of *Sebastes* spp. for each management area as well as the related confidence intervals are in Appendices 1 and 2.

Abundance estimates in these surveys are relative. Catchability of redfishes varies depending on the fishing gear used, and the power or speed of the vessel, so abundance estimates from different areas or years cannot be directly compared. Moreover, because redfishes are semi-pelagic species, bottom trawls (as used in DFO surveys) may not sample the entire population, and abundances would therefore be underestimated. Sampling can also only be partial when redfishes occupy areas beyond depths covered by the surveys, so presence of redfishes in deep waters may thus lead to abundance being underestimated. The bed topography may differ between areas, and can also introduce bias. Certain areas have very steep slopes or a rocky bed, which complicates or prevents the use of bottom trawling. Lastly, the data series available are, for the most part, of short duration, and generally do not cover the three generations usually needed for application of the COSEWIC decline criterion.

Given the impossibility of rapidly differentiating between Deepwater Redfish and Acadian Redfish, particularly in commercial catches, redfish stock assessments have always been done for all species combined. However, morphological and genetic characteristics collected during the various surveys permit differentiating the species in trawl survey catches (Morin *et al*. 2004; Méthot *et al*. 2004).

In Units 1 and 2 (Gulf of St. Lawrence and Laurentian Channel), anal fin ray count and MDH analyses were used to evaluate total and mature abundance for each genotype (Deepwater Redfish, Acadian Redfish and heterozygotes). In this report, the heterozygote individuals were treated separately. However, data on these individuals are presented in the sections on Deepwater Redfish*.* Although introgressive hybridization is bidirectional, it is asymmetrical toward Deepwater Redfish (Roques *et al*. 2001). Several characteristics, including fecundity and sexual maturity, show this asymmetry (Gascon 2003), as well as distribution (Morin *et al*. 2004) and depth occupied (Méthot *et al*. 2004). Although some of heterozygotes are closer to Acadian Redfish, the majority are related to Deepwater Redfish*.*

In surveys in NAFO 3O, 3LN and 2+3K (Grand Banks and Labrador Sea), differentiation by species was done by number of vertebrae, and anal and dorsal fin ray counts (Morin *et al*. 2004)). Next, the percentages of Deepwater Redfish and Acadian redfish were estimated by depth zone and applied to the abundance indices of *Sebastes* sp. This assessment by depth is based on data used by Ni (1982), and the estimates therefore do not take into account the potential variations in the percentages of the species by depth over time.

Abundance indices for mature individuals for each population were based on size class. Individuals equalling or exceeding L50 females in size (Table 5) were considered mature in each region.

The decline rate was determined using the following equation:

$G_{decline} = 1 - \exp(T*b)$

where *T* is the number of survey years and *b* the slope of linear regression for abundance in $\log_e$.

Redfishes have an exceptionally long lifespan, and surveys covered only a short period relative to this. Thus, recruitment variability must be considered when evaluating the status and rate of decline in this species.

Abundance

All decline rates presented in this section, along with generation time and age at maturity for each population are summarized in Table 7. Abundance indices by species and population are shown in table form in Appendix 1.

Deepwater redfish

Gulf of St. Lawrence/Laurentian Channel DU

The proposed Gulf of St. Lawrence/Laurentian Channel DU includes two management units, Units 1 and 2 (Figure 4), which were put in place in 1993 (Atkinson and Power 1991). Unit 1 corresponds to NAFO Divisions 4RST, and has been covered by a DFO summer scientific survey since 1984. Two changes were made to the vessel and fishing gear during this series. Correction factors had to be determined to allow comparisons among the different survey years.

Before 1993, Unit 2 was made up of more than one management unit, and no survey fully covered Unit 2. Complete surveys of the area were carried out between 1994 and 1997, in 2000 and in 2002. Partial surveys have been done over a longer period of time: since 1972 in Subdivision 3Ps, and since 1970 in Subdivision 4V. These surveys were carried out using different gear and for a different period, and thus the data obtained from these surveys cannot be compared with data from directed Redfish surveys. Further, no identification information was collected during these surveys so abundance indices by species are not available from these surveys (see “Pooled Species” section below).

In Unit 1, abundance indices of mature Deepwater Redfish were stable until the end of the 1980s, after which they declined between 1989 and 1994 (Figure 16). The estimate went from 2293 million mature individuals to a minimum of 34 million in 2004. The Deepwater Redfish abundance index in 2007 is an all-time low (36 million). The rate of decline between 1984 and 2007 was assessed at 98.6%. Abundance indices for heterozygotes follow the same pattern as those for Deepwater Redfish (Figure 16).

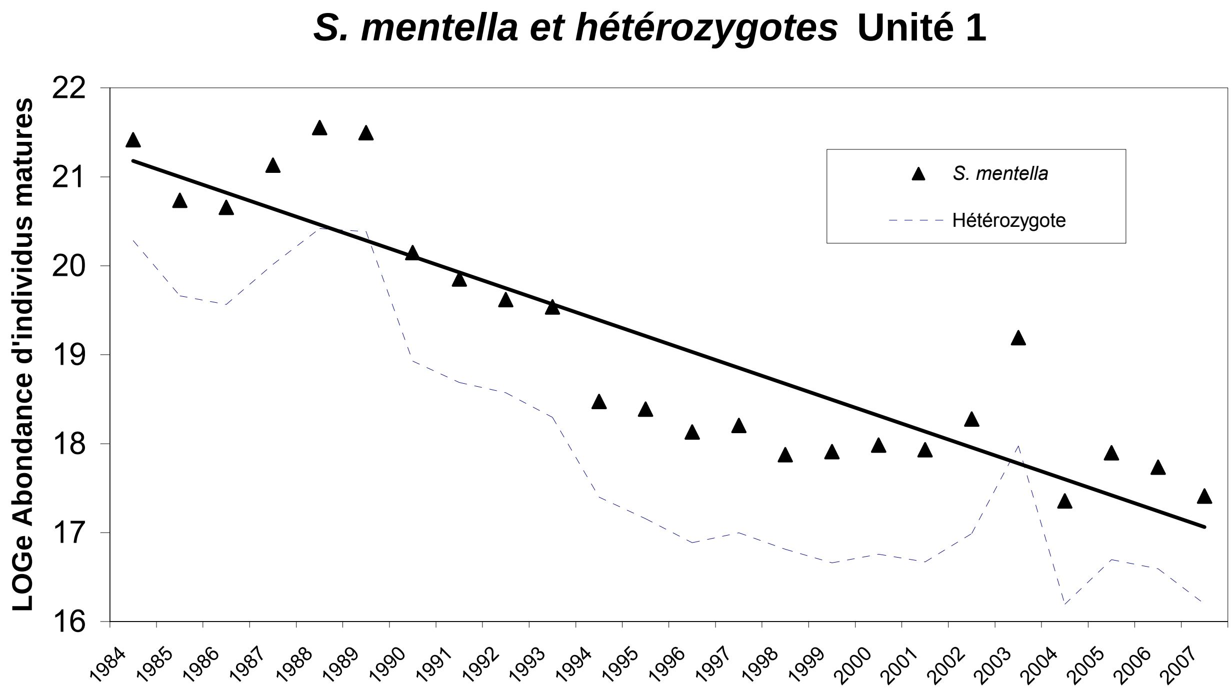

Figure 16. Survey abundance of mature Deepwater Redfish and heterozygotes in Unit 1, proposed Gulf of St Lawrence/Laurentian Channel DU, from 1984 to 2007, ln transformed.

Little information is available for Unit 2. As in Unit 1, the abundance index appeared to remain stable between 1996 and 2002 (Figure 17), varying between 169 and 245 million mature individuals (Morin *et al*. 2004). The abundance index series available for Unit 2 is insufficient for evaluating the changes that have occurred over the past decades.

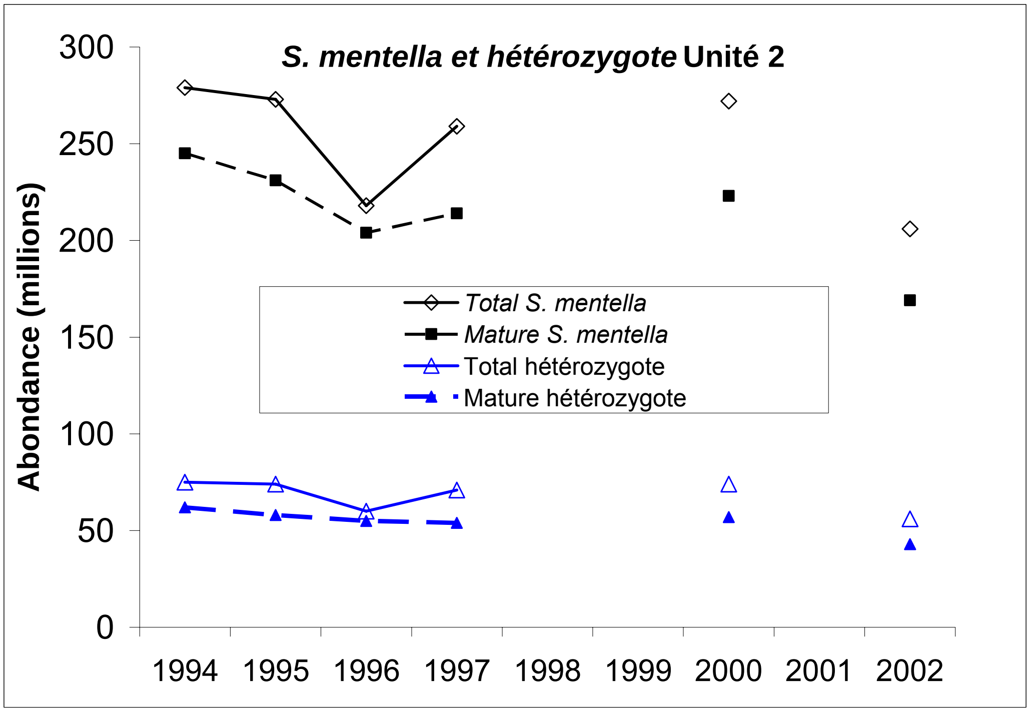

Figure 17. Survey abundance of Deepwater Redfish and heterozygotes in Unit 2, Gulf of St Lawrence/Laurentian Channel DU, from 1994 to 2002.

The lack of significant recruitment of Deepwater Redfish is a concern in the Gulf of St Lawrence/Laurentian Channel population (Figure 18). Redfish populations are characterized by the appearance of strong year classes between 5 and 12 years of age (Morin and Bernier 1994). These populations will thus support fishing activities for many years to come. The last significant year class for Deepwater Redfish may have been produced at the beginning of the 1980s (Sévigny *et al*., in progress). Therefore, there has been no major recruitment of Deepwater Redfish for more than 25 years. Note that, in Unit 1, a year class has appeared for the first time in the 2007 catches (Figure 18). Tests will be carried out to establish to which species this cohort belongs.

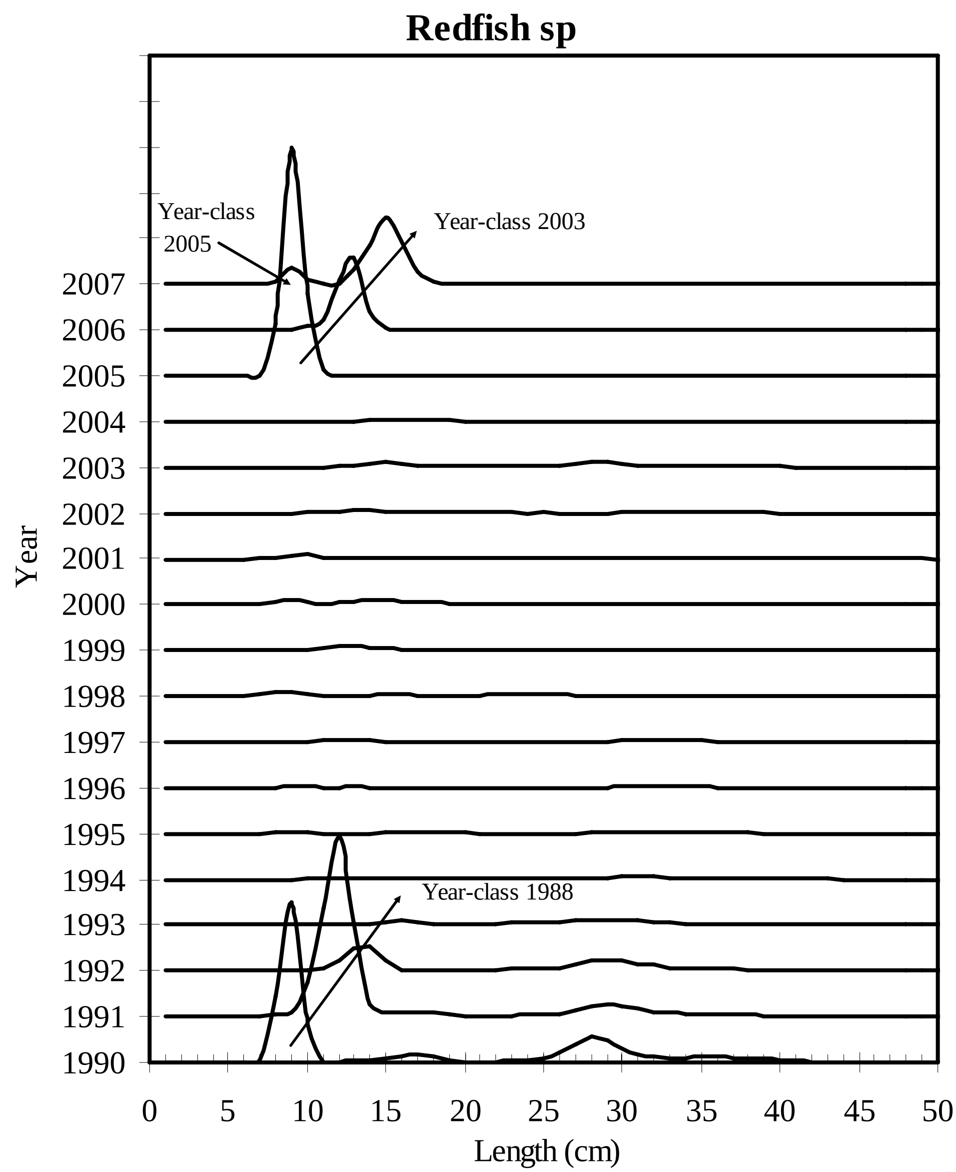

Figure 18. Length frequency of *Sebastes* sp. in Unit 1, Gulf of St. Lawrence/Laurentian Channel DU. From Sévigny *et al*. 2007.

Northern DU

Abundance indices by species are available for NAFO 3O, 3LN and 2+3K (Sévigny *et al*. 2007).

Surveys have been carried out in the spring in divisions 3O and 3LN since 1973 and in the fall since 1991. However, due to the use of different gear and variations in the area covered, only 1991 to 2005 are directly comparable. Note that the 2006 survey in Divisions 3O and 3N did not cover the depths in which redfishes would normally be found. Surveys have been conducted in NAFO 2J3K since 1978. From 1978 to 1991, depths to 1000 m were covered, while maximum depths have been increased to 1500 m since 1996. A survey was also carried out more sporadically in Divisions 2GH, with variable coverage and no survey in 2G in 2001, 2004 or 2006. Since 1996, surveys have been carried out down to a depth of 1500 m.

The difference in areas covered by the surveys adds variability to abundance estimates. However, the additional area that has been fished since 1996 covers deeper areas (1000 to 1500 m) in which Redfish are not abundant. The often rocky bed of a steep slope provides additional variability, because no two hauls have the same catch performance. Species were differentiated based on meristic characteristics (number of vertebrae, anal and dorsal ray fin count (Morin *et al*. 2004,) which adds additional uncertainty.

In Division 3O, abundance indices from 1973 to 1982 were variable without showing any trend (Figure 19). Variability may be explained by the fact that the surveys only cover depths shallower than 200 fathoms (366 m), such that Deepwater Redfish population was not sampled in its entirety. From 1984 to 1990, the estimates were also variable, with a declining trend, decreasing from 2.1 million in 1984 to 0.4 million in 1990. Since 1991, in spite of the wide variability, a generally increasing trend has been observed in the abundance index. The estimated number of mature individuals went from 3.1 million in 1992 to 20.8 million in 2005 during the spring survey, and from 1.2 million in 1992 to 33.5 million in 2006 during the fall survey.

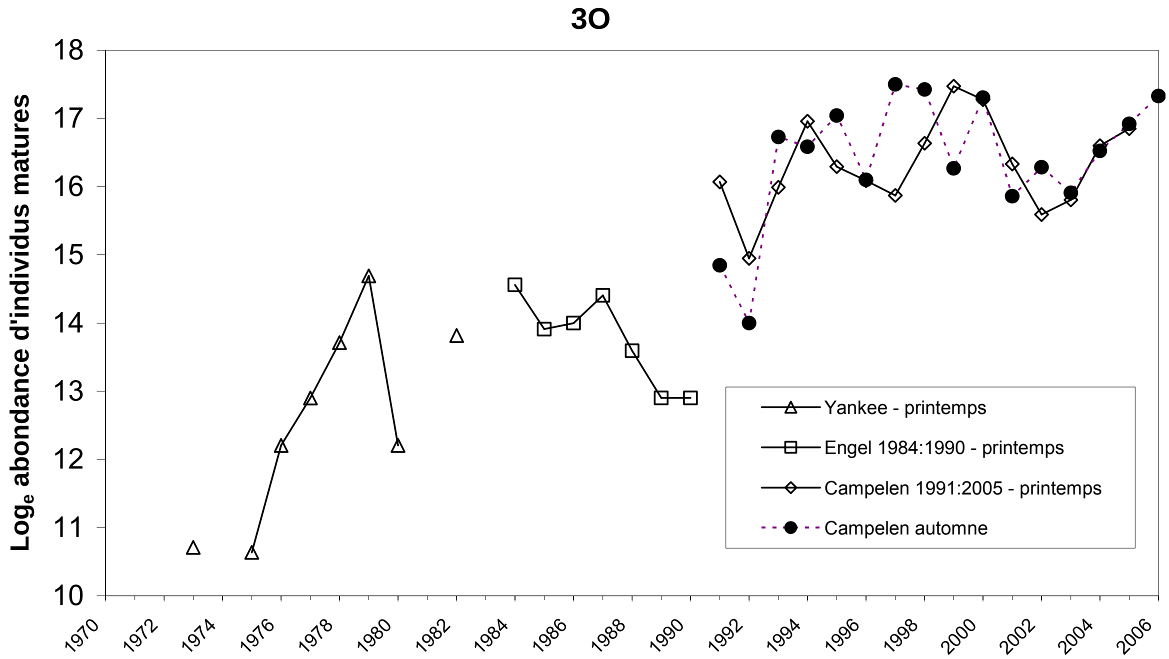

Figure 19. Survey abundance of mature Deepwater Redfish in Division 3O, Northern DU, ln transformed. Printemps = spring; automne – fall.

In Division 3LN, there was considerable variation between 1973 and 1982 (Figure 20). Higher estimates at the end of the period may be attributable to better distribution coverage (Morin *et al*. 2004). Indices for mature Deepwater Redfish declined between 1985 and 1990 (1.9 to 0.5 million). An increase in the abundance index was noted in the spring between 1991 and 2004, followed by a decline. The values calculated in 2006 are similar to those observed in 1991 (10.4 and 8.1 million, respectively). Lastly, a slight increase was seen during the fall survey between 1991 and 2006. Note that this management unit was under a moratorium for Redfish from 1998 but a fishery was recently reopened.

In Division 2J3K, the Deepwater Redfish substantially decreased in numbers between 1983 and 1995 (Figure 21), going from 3752 million to 14 million. The abundance index has dropped by 98.3% since 1978. The abundance estimates, however, have shown a tendency to increase over the past few years.

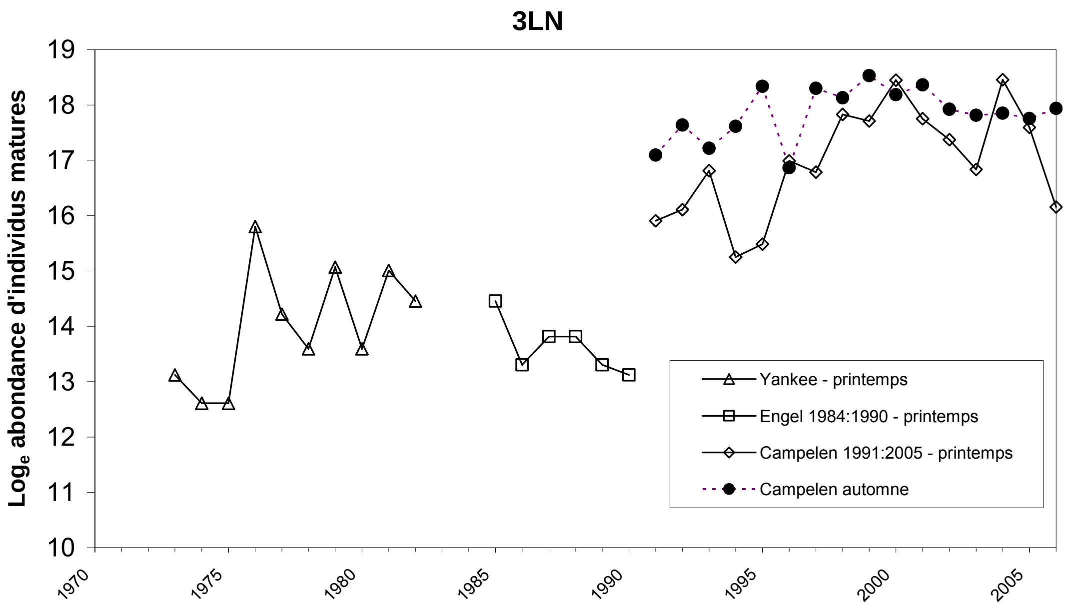

Figure 20. Survey abundance of mature Deepwater Redfish in Division 3LN, Northern DU, ln transformed. Printemps = spring; automne = fall.

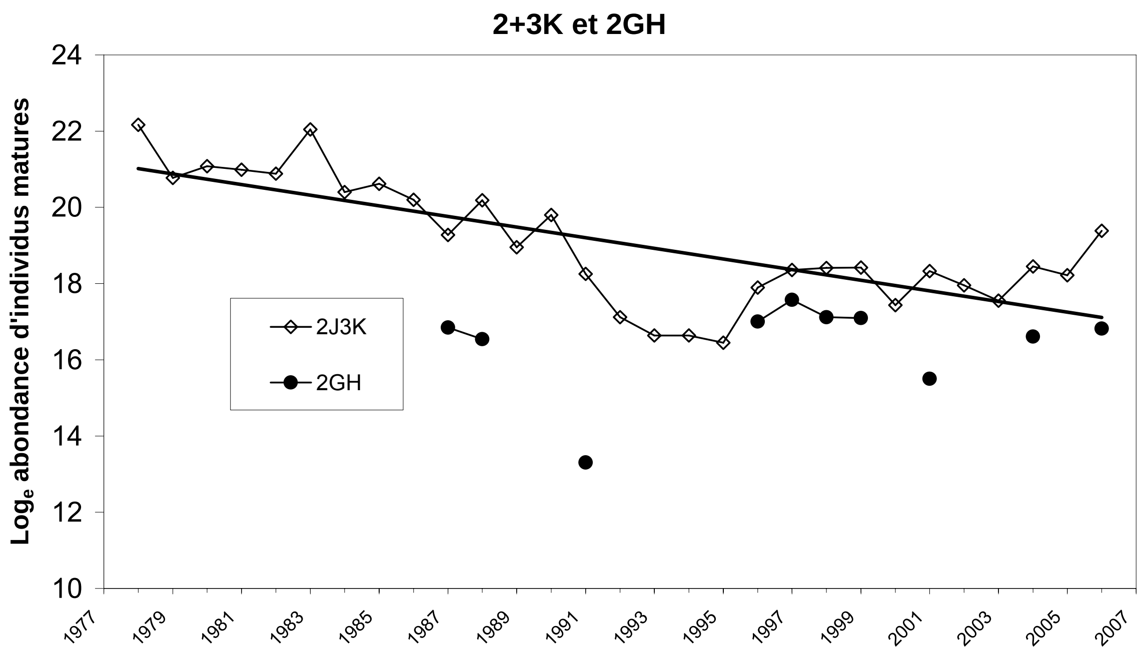

Figure 21. Survey abundance of mature Deepwater Redfish in divisions 2J3K and 2GH, Northern DU, ln transformed. Note: Division 2G was not sampled in 2001, 2004 and 2006.

The surveys conducted in Division 2GH have shown a certain amount of variability without revealing any trends.

In summary, the portion of the population found in Division 2J3K has declined substantially, although an increase has been observed since 2000. The abundance indexes for divisions 3O, 3LN and 2GH do not appear to show similar declines, although changes in gear make long-term index comparisons difficult; in 3LN and 3O an increasing trend has been observed since the early 1990s.

Acadian Redfish

Atlantic DU

Although a single DU is proposed for Acadian Redfish outside of Bonne Bay, abundance indices for this DU are presented by geographical region.

a) Gulf of St. Lawrence/Laurentian Channel

This region includes Management Units 1 and 2. The same surveys as those described for the Deepwater Redfish in the Gulf of St. Lawrence/Laurentian Channel are used for Acadian Redfish.

The Gulf of St. Lawrence (Unit 1) included over 70% of the total abundance in the Atlantic DU in the early 1980s. The abundance index for mature individuals was relatively stable during the 1980s but plummeted between 1988 and 1996 (Figure 22), going from 2500 million to 39 million during this period. Abundance has remained low ever since; the abundance index was 50 million in 2007. The rate of decline in the mature population between 1984 and 2007 was evaluated at 99.5% in the Gulf of St. Lawrence.

Because Unit 2 is a recent management unit, very few data are available for the entire zone. No trends are apparent in this short series (1994 to 2002; Figure 23). Data for 3Ps and 4V for *Sebastes* sp. presented below in the section on pooled species have shown, however, a certain stability in the abundance indices since the 1970s. Moreover, the indices for these last two surveys have been increasing since 2004.

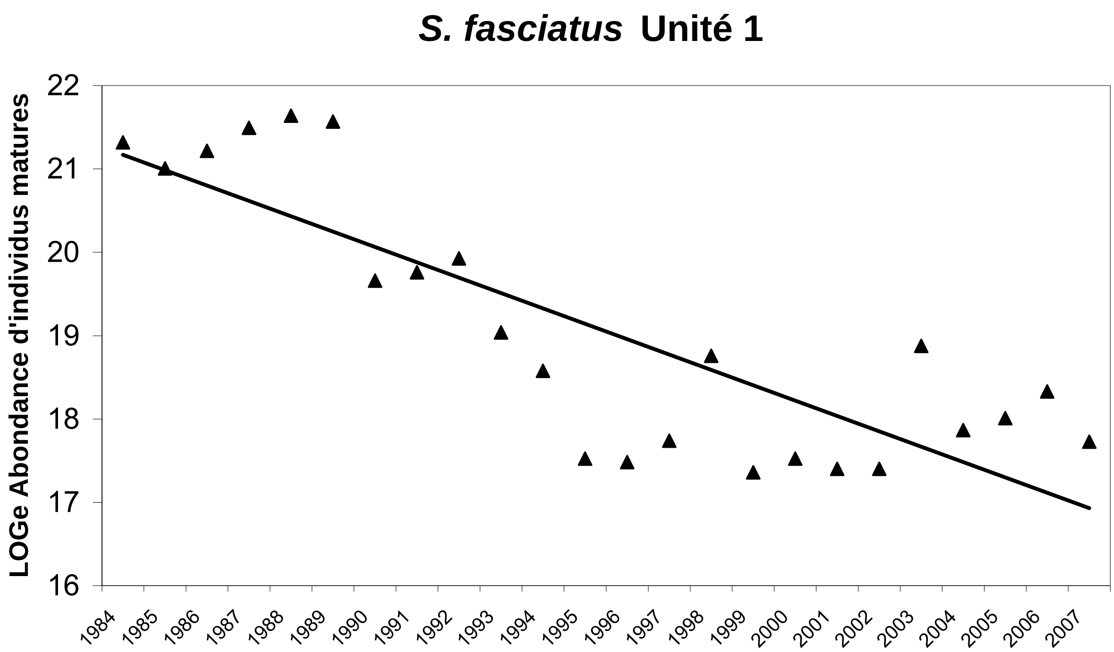

Figure 22. Survey abundance of mature Acadian Redfish in Unit 1, Gulf of St. Lawrence, ln transformed.

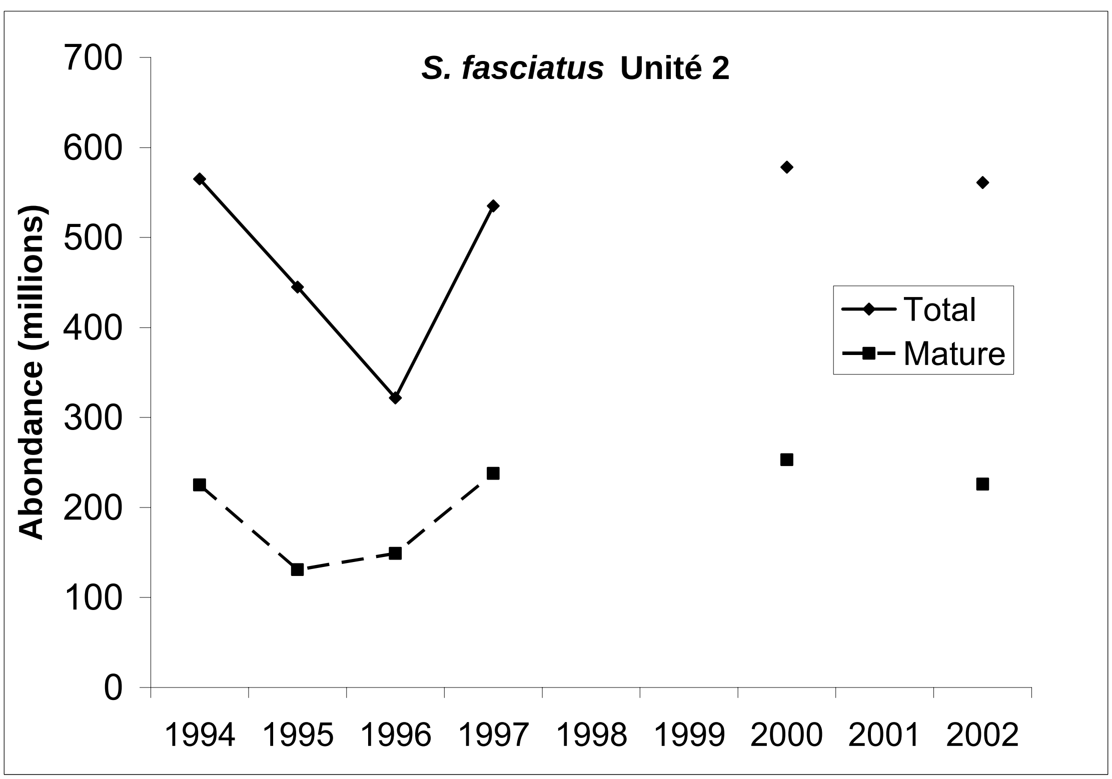

Figure 23. Survey abundance of mature Acadian Redfish in Unit 2, Laurentian Channel, from 1994 to 2002.

Cohorts which appeared to be abundant when they were first observed in surveys have subsequently disappeared before recruiting to the fishery. In Unit 1, the 1988 year class disappeared from survey catches after only a few years (Figure 18). This year class was mainly made up of Acadian Redfish. The most plausible hypothesis for this disappearance is a high mortality rate. The lack of major recruitment over the past few years has kept the population at a low level of abundance. A large new cohort of Acadian Redfish, however, appeared in the 2005 surveys (Figure 18). This cohort was still apparent in the 2007 survey, but preliminary analysis of the 2008 survey shows that it has now disappeared (DFO pers. comm.).

b) Northern area

Surveys in divisions 3O, 3LN, 2J3K and 2GH described for Deepwater Redfish were used to examine abundance trends.

In Division 3O, surveys conducted in the spring from 1973 to 1982 showed considerable variability in the abundance index, without revealing any definite trend (Figure 24). The values varied between 6.4 and 135 million. That variability could be explained by the incomplete coverage of areas occupied by Acadian Redfish. The 1984 to 1990 spring surveys also revealed fluctuations. The values were higher in 1990 (439 million) than at the beginning of the survey in 1984 (41 million). Between 1991 and 2007, two surveys were carried out annually in this area (spring and fall). An increase in the abundance index occurred between 1991 and 1998 in the spring survey. The values thereafter fluctuated without any definite trends. The 1997 spring survey is considered to be an anomaly (Morin *et al*. 2004). The 1991 to 2006 fall surveys showed more stable abundance indices, with the exception of the high values recorded in the late 1990s.

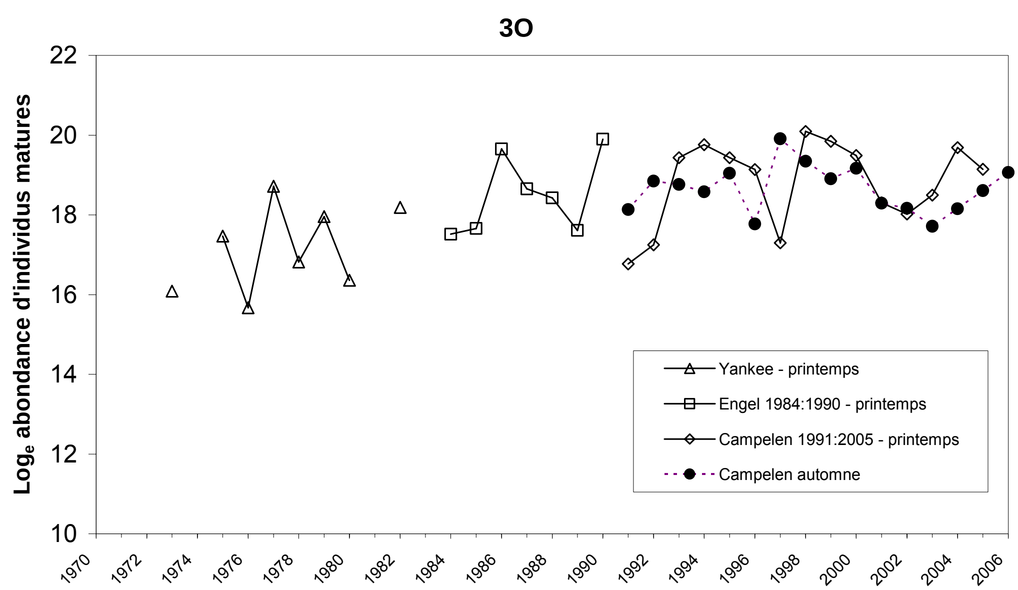

Figure 24. Survey abundance of mature Acadian Redfish in Division 3O, ln transformed. Printemps = spring; automne = fall.

In Division 3LN, the abundance indices varied greatly between 1973 and 1982 (7.5 to 161 million; Figure 25). The variation in the area sampled over the years could explain the higher values over the last few years (Morin *et al*. 2004). From 1985 to 1990, the abundance indices also varied without showing any definite trends. Lastly, the abundance indices seemed to have increased between 1991 and 2006 in the spring and fall surveys. The values in the fall were 33 million in 1991 and 252 million in 2006. In the spring, the abundance index was 17.1 and 95 million for these same years. Directed Redfish fishery has been prohibited in this division since 1998.

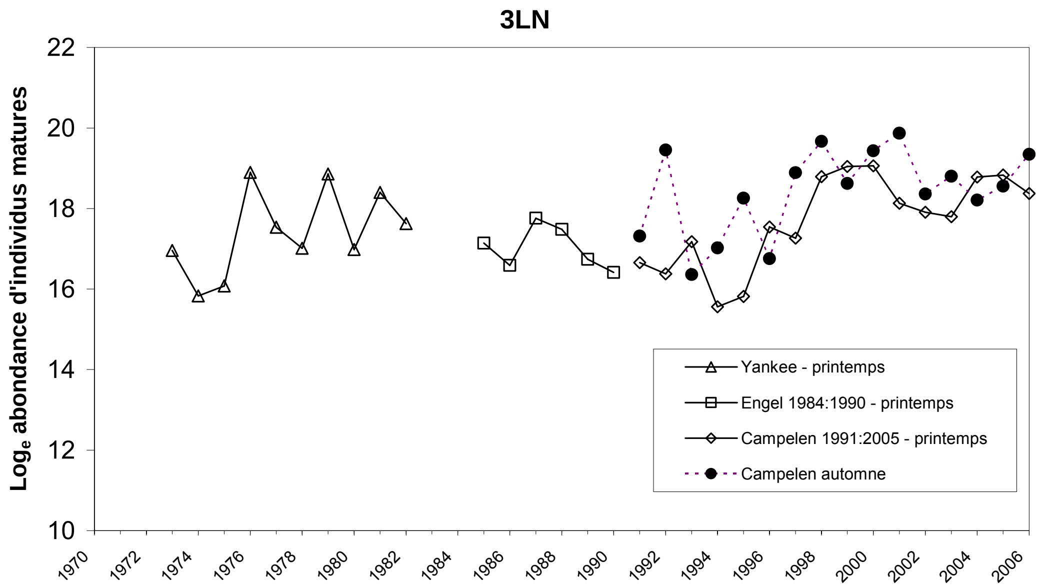

Figure 25. Survey abundance of mature Acadian Redfish in Division 3LN, ln transformed. Printemps = spring, automne = fall.

In 2J3K, the Acadian Redfish population started to decrease in the mid-1980s, and then dropped substantially in the 1990s (Figure 26). From 4001 million in 1983, the abundance index decreased to 1.2 million in 1994. The values remained low until 2004 and increased in 2005 and 2006 to 71 million. The rate of decline between 1978 and 2007 was 99.8%.

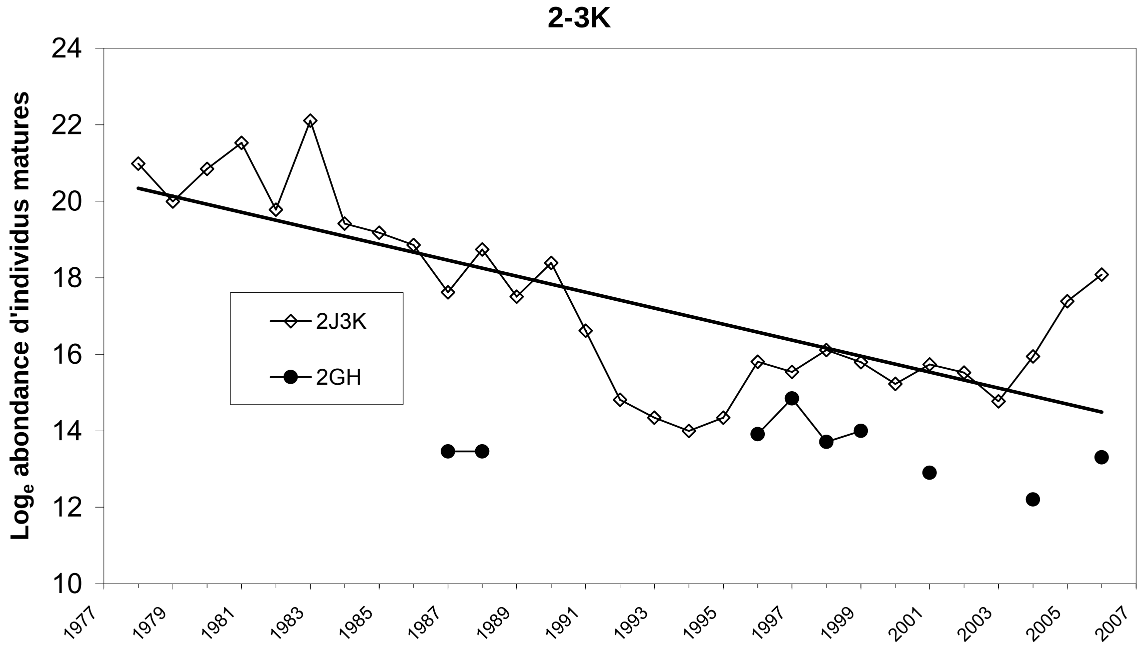

Figure 26. Survey abundance of mature Acadian Redfish in divisions 2J3K and 2GH, ln transformed.

Surveys conducted in 2GH were discontinued and no trend appeared.

To conclude, the Acadian Redfish abundance index dropped substantially in Division 2J3K, but has shown some increase in the most recent years. In other areas, the data between 1991 and 2007 showed no decline. Unfortunately, the complete series cannot be compared given the changes to the fishing gear. The northern area made up less than 20% of the Acadian Redfish abundance in the Atlantic DU in the early 1980s.

c) Southern area

The southern area includes the Scotian Shelf and Gulf of Maine. The Scotian Shelf constitutes Management Unit 3, and is made up of NAFO subdivisions 4X and 4Wdehlk. NAFO Division 5 in the Gulf of Maine is almost entirely located in American territory. Because only Acadian Redfish is found in this zone, no classification by species was necessary to interpret survey results.

A scientific survey has been conducted annually by DFO in Unit 3 since 1970. However, the vessel and fishing gear were changed in 1982 and no conversion factor could be calculated. Consequently, only the data series from 1982 to date are comparable. Large variations in abundance indices were seen in Unit 3 (Figure 27), from 29 to 343 million mature individuals between 1982 and 2006, but with no long-term trend. Therefore, there has been no evidence of decline in Unit 3 and the average abundance between 1970 and 2006 is 207 million.

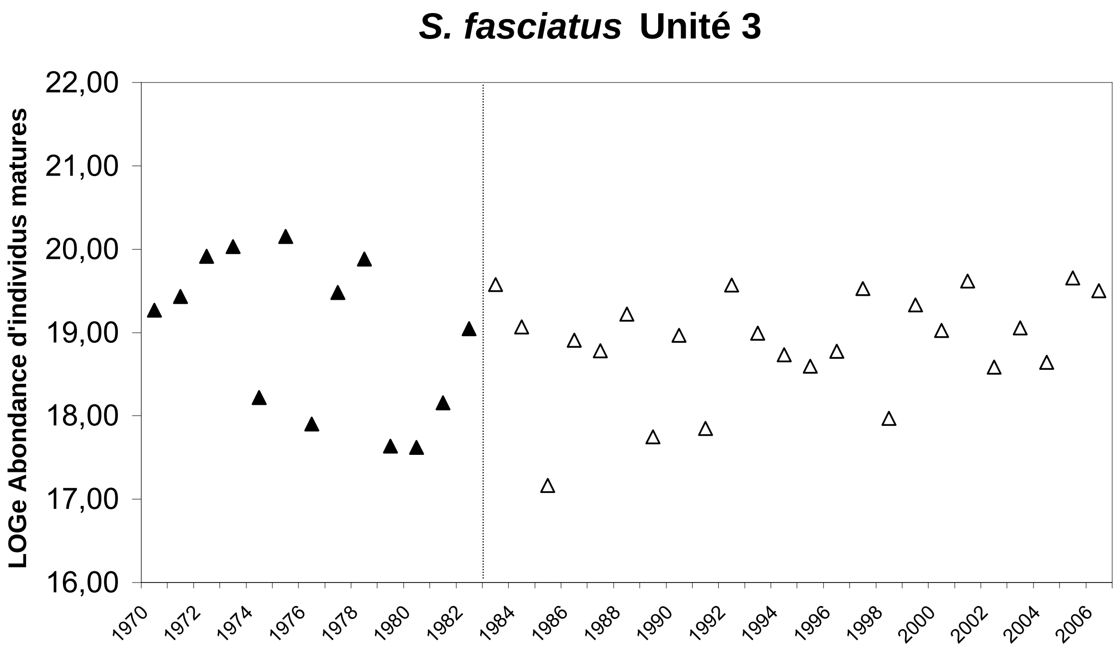

Figure 27. Survey abundance of mature Acadian Redfish in Unit 3, Scotian Shelf, ln transformed.

Scientific surveys have been conducted since 1963 by American authorities in the Gulf of Maine. A decline in the average numbers per tow was recorded in this region until the mid-1990s (Mayo *et al*. 2006). Subsequently, the numbers increased considerably to reach levels in 2005 similar to those seen at the beginning of the historical series of fall surveys. It would seem that several major year classes may have appeared over the past few years (Mayo *et al*. 2002). However, the rate of increase is not consistent with the low growth rate seen in this species (Mayo *et al*. 2002).
In summary, in the southern area there has been no indication of major decline. Abundance indices in Unit 3 fluctuate widely, but without showing any specific trend. In the Gulf of Maine, abundance indices are increasing and several significant year classes have appeared over the past few years. The southern area made up less than 10% of the Acadian Redfish abundance in the Atlantic DU in the early 1980s.

Assessing overall status of Acadian Redfish in the Atlantic DU requires that abundance indices from individual parts of the range be considered in the context of overall abundance trends. There is no easy way of combining indices from surveys using different methods in different areas. Greater weight should be given to indices from the northern and Gulf of St. Lawrence/Laurentian Channel areas than to the southern area, because the former areas have had greater abundance of the species (based on relative fishery catches and relative abundance indices).

Accordingly, it can be concluded that the species has declined substantially over a period of roughly 1.5 generations. A decline of the order of 98% was observed over something greater than one generation in the Gulf of St. Lawrence, the area representing over 70% of the historical abundance. However, in northern and southern areas, abundance indices have been stable or increasing since the 1990s. An overall decline of roughly 75% is evident for the DU.

Bonne Bay DU

Little information is available on the isolated population in the Bonne Bay fjord on the west coast of Newfoundland. Given the small size of the fjord, the population can only be a small one. No abundance data, however, exists on this population.

<u>Pooled species</u>

Gulf of St Lawrence/Laurentian Channel (Unit 2)

The partial survey of Unit 2 conducted by DFO in NAFO 3Ps (Figure 28) did not collect information to separate the two redfish species, so this information is presented for pooled species. Given the similarity in abundance trends in other areas, it is probably valid to consider this information as representing the situation for each species, although uncertainty would be increased by using the information in this way.

Changes were made in vessels and fishing gear during this series, which complicates analysis of the results. In 1983, the vessel *A.T. Cameron*, equipped with a Yankee trawl, was replaced by the vessels *Wilfred Templeman* and *Alfred Needler*, equipped with an Engel trawl and, since 1996, the Campelen trawl has been used on these two last vessels. It was noted regarding cod that the Campelen trawl was more effective for catching small individuals, while being just as efficient with the larger fish (DFO 1998). Determining abundance trends during the period covered by these surveys is difficult (Figure 5); each vessel-gear combination can be considered a single series (1973-83, 1984-1995, 1996-2007) but the relative abundance between these three series is unknown. There is some indication of an increasing trend in the most recent years. In 1991, a strong year class of Redfish probably appeared, consistent with this increase in the abundance index.

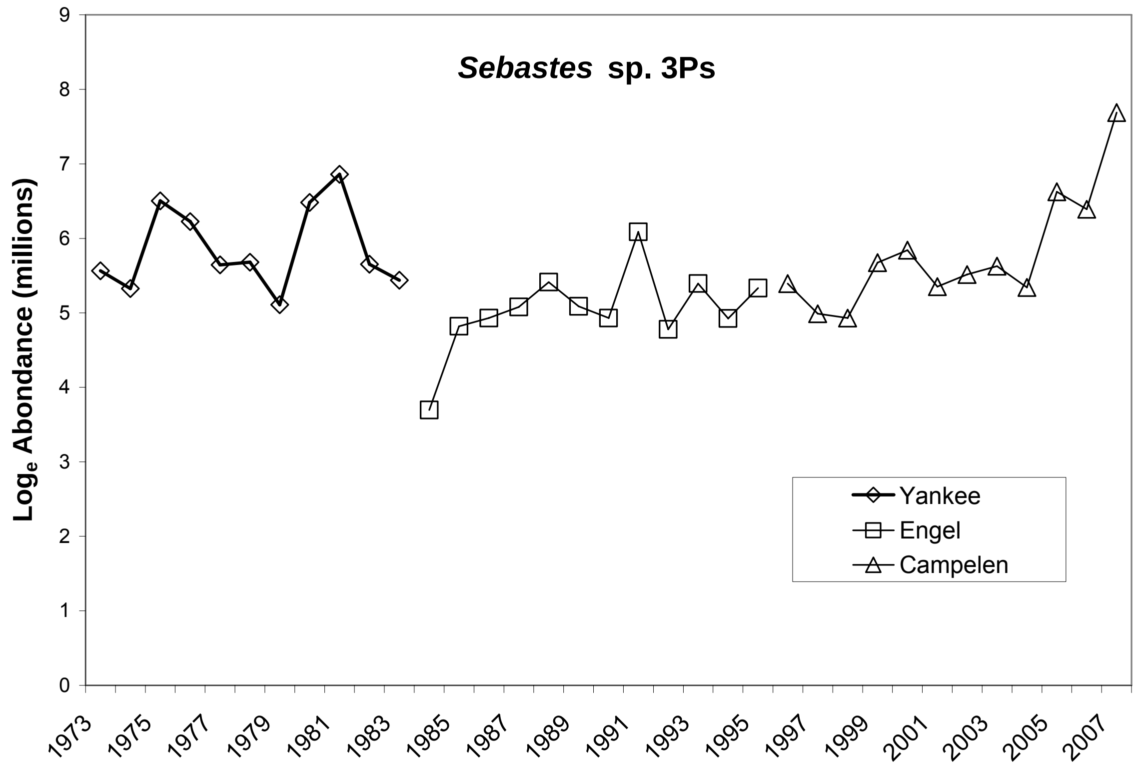

Figure 28. Survey abundance of *Sebastes* sp. in Division 3Ps, Gulf of St. Lawrence/Laurentian Channel DU, ln transformed. The type of gear used is indicated in the legend.

As with the partial survey for NAFO 3Ps, no identifying criteria were available to classify the abundance indices by species in the survey of NAFO 4V (Figure 29). This survey was conducted using a Western IIA trawl, and the vessel *Alfred Needler* was used during most of these surveys. However, between 2004 and 2007, the survey was carried out by the vessel *Teleost*, and no comparative information has been collected in order to take vessel changes into account. There appears to be no decline throughout the entire period (Figure 29). The indices were especially high during the 1980s, but comparable between 1970 and 1990. Note that the indices increased between 2004 and 2007.

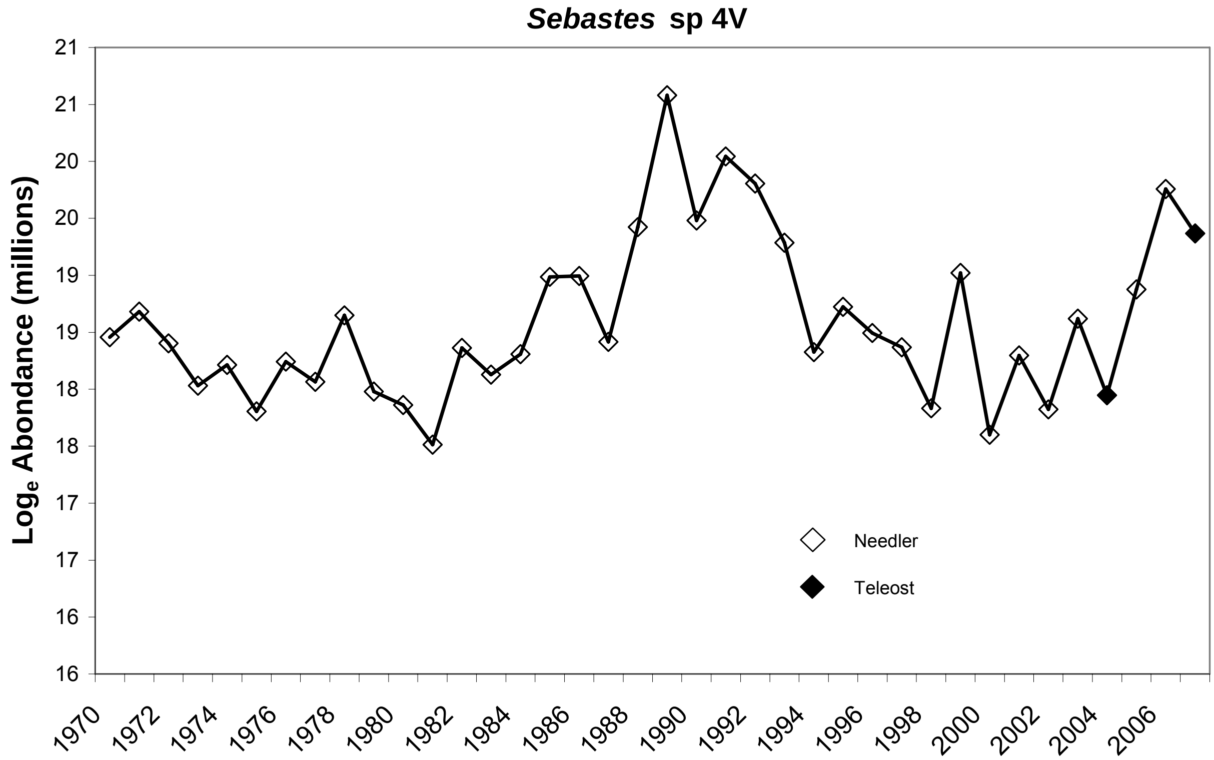

Figure 29. Survey abundance of *Sebastes* sp. in Division 4V, Gulf of St. Lawrence/Laurentian Channel, ln transformed. The vessel used is indicated in the legend.

Rescue effect (immigration from an outside source)

As described in the section on Distribution, Deepwater Redfish is distributed continuously along both sides of the Atlantic. There appear to be no genetic differences in the Deepwater Redfish from the Grand Banks to the Faroe Islands according to Roques *et al*. (2002). The distribution of Acadian Redfish, however, is more limited, and this species tends to travel less and stay in a more coastal habitat. The main zones from which potential contributions to Canadian Redfish populations could come include the region of Flemish Cap to the east of the Grand Banks for both species, the region of Greenland to the north for Deepwater Redfish alone, and the Gulf of Maine for Acadian Redfish.

Roques *et al*. (2002) suggested that the middle of the North Atlantic could form a single larval retention area. The arguments put forth are the lack of genetic differentiation between samples from the different regions, as well as ocean current patterns that may disperse the larvae over a greater distance. As Valentin (2006) mentioned, there is remarkable environmental continuity throughout the distribution of Deepwater Redfish in this region. However, Schmidt (2005) showed genetic heterogeneity between the Irminger Sea, Greenland and Iceland.

Migrations could also be made by adult individuals. Because Redfish have a very long lifespan, movements may happen over a long period. Potential migrations remain speculative because no study to date has dealt with this issue.

Flemish Cap (NAFO Div. 3M) is located entirely outside Canadian waters. Schmidt (2005), based on microsatellites, indicated that Deepwater Redfish in the Flemish Cap region could represent a distinct population. For example, samples from the Flemish Cap were genetically different from those in Division 2J (F_{st} = 0.00989). Moreover, only two of the samples from the different regions of the Northern Atlantic (Irminger Sea, Greenland, Iceland, Division 1F) were not significantly different from the samples of Flemish Cap (F_{st} between 0.00521 and 0.01839). As the author pointed out, these results are in line with the hypotheses already formulated that the Flemish Cap populations are relatively isolated from those of the Grand Banks (Templeman 1976). Note that, according to surveys done by the European Union (de Melo *et al*. 2007), the abundance indices for Deepwater Redfish and Acadian Redfish (combined) seem to have remained stable from the late 1980s to the beginning of 2000. However, abundance estimates appear to have risen considerably since 2003.

Exchanges between the Deepwater Redfish of west Greenland (NAFO Subarea 1) and those of western Davis Strait (NAFO Subarea 0) and the Labrador Sea are possible. However, no study has quantified the potential exchanges between these areas. Abundance evaluated by surveys conducted on the west Greenland shelf since 1982 show greater variation in indices without revealing any definite trends (Fock *et al*. 2006).

In US waters of the Gulf of Maine, Acadian Redfish were at low abundance from the early 1980s to the mid-1990s but biomass per tow increased substantially in the late 1990s and has remained high relative to earlier periods in the time series since then (Miller *et al*. 2008). Variability in annual abundance estimates is high. Redfish in this area since the increase in abundance have been smaller than those seen historically, most at lengths below those taken by the fishery (Miller *et al*. 2008).

LIMITING FACTORS AND THREATS

Limiting factors

Given their long lifespan, slow growth and late maturity, Redfishes are considered to have very low resilience. As well, recruitment is highly variable in this species, with good year classes only appearing every five to 12 years (Morin and Bernier 1994) under normal conditions. Reduction of spawning abundance could have the effect of decreasing the frequency of strong year classes on which the persistence of populations may depend.

The difficulty in differentiating between the two species complicates stock assessments and management. Changes in abundance for each species are not necessarily the same and managing Redfish as a single species could result in fishing pressures that are excessive for a particular species. Discussions are under way in DFO on how to set up management by species.

Certain environmental factors have been cited to explain the declines in abundance and lack of increase in certain Redfish stocks. It has been suggested that the particularly cold conditions observed in the Gulf of St. Lawrence since the end of the 1980s could have had an adverse effect on the survival of Deepwater Redfish larvae (DFO 2000), through adverse impacts on the physical condition of larvae, and the abundance and quality of their prey.

Threats

Directed fisheries

Directed fisheries have been and are the principal threat.

In the Gulf of St. Lawrence/Laurentian Channel, two periods of heavy fishing occurred, coinciding with recruitment of strong year classes: one at the beginning of the 1970s and the other during the 1990s (Figure 30). Interest in harvesting Redfish increased in the 1990s following collapse of other groundfish populations. Average annual catches were 123,000 tonnes between 1970 and 1976. In 1992, more than 90,000 tonnes were landed in these same areas, 78,000 of which came from Unit 1. Catches then fell to under 10,000 tonnes, coming primarily from Unit 2, following the moratorium imposed in the Gulf of St. Lawrence.

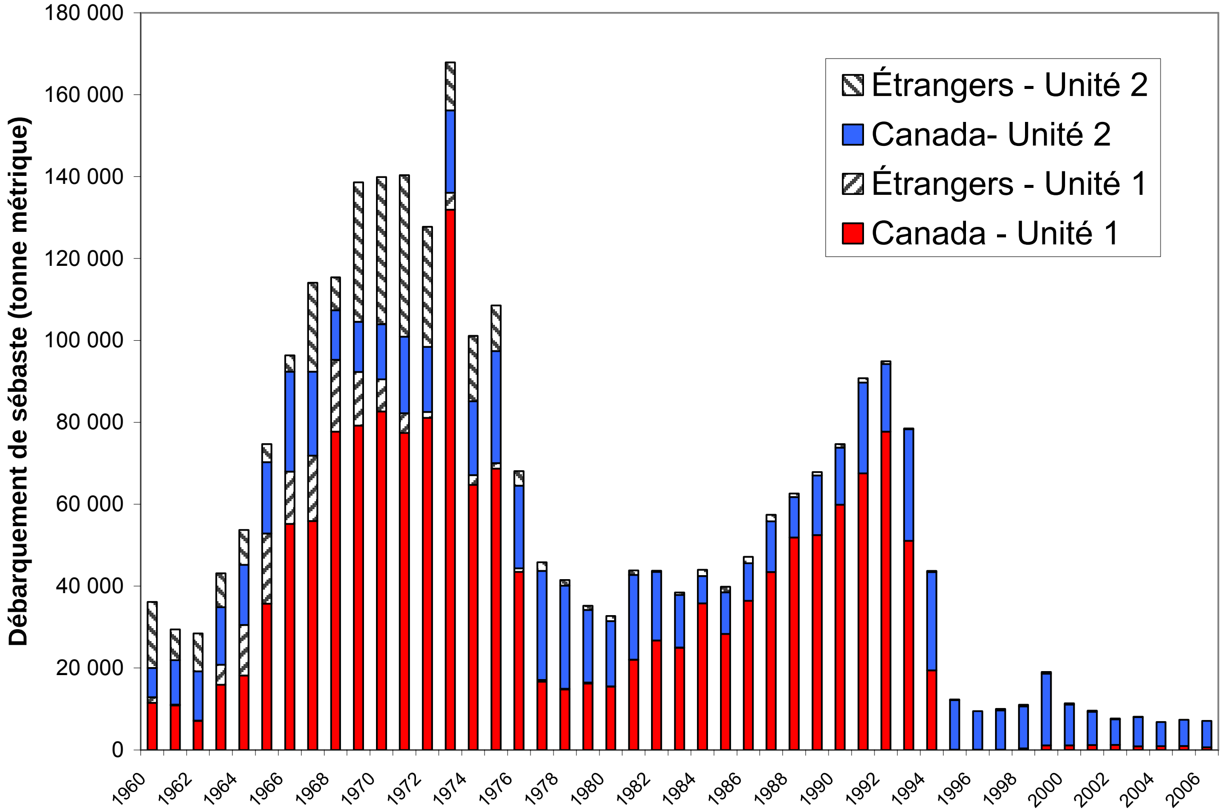

Figure 30. Redfish (*Sebastes* sp.) landings (metric tons) in the Gulf of St. Lawrence (Unit 1) and the Laurentian Channel (Unit 2). Étrangers = foreign. Unité = Unit.

In the northern area, the largest landings occurred at the end of the 1980s and the beginning of the 1990s (Figure 31). Only Division 2+3K had larger catches before this period, with heavy fishing occurring from 1950 to 1960. In 1959, 187,000 tonnes were caught in this sector. Catches dropped considerably in divisions 3LN and 2+3K starting at the beginning of the 1990s, whereas they remained high in Division 3O. Divisions 3LN and 2+3K have been under a moratorium but the Redfish fishery was reopened in 3LN in 2010. Note that a large proportion of landings in these regions have been by countries other than Canada.

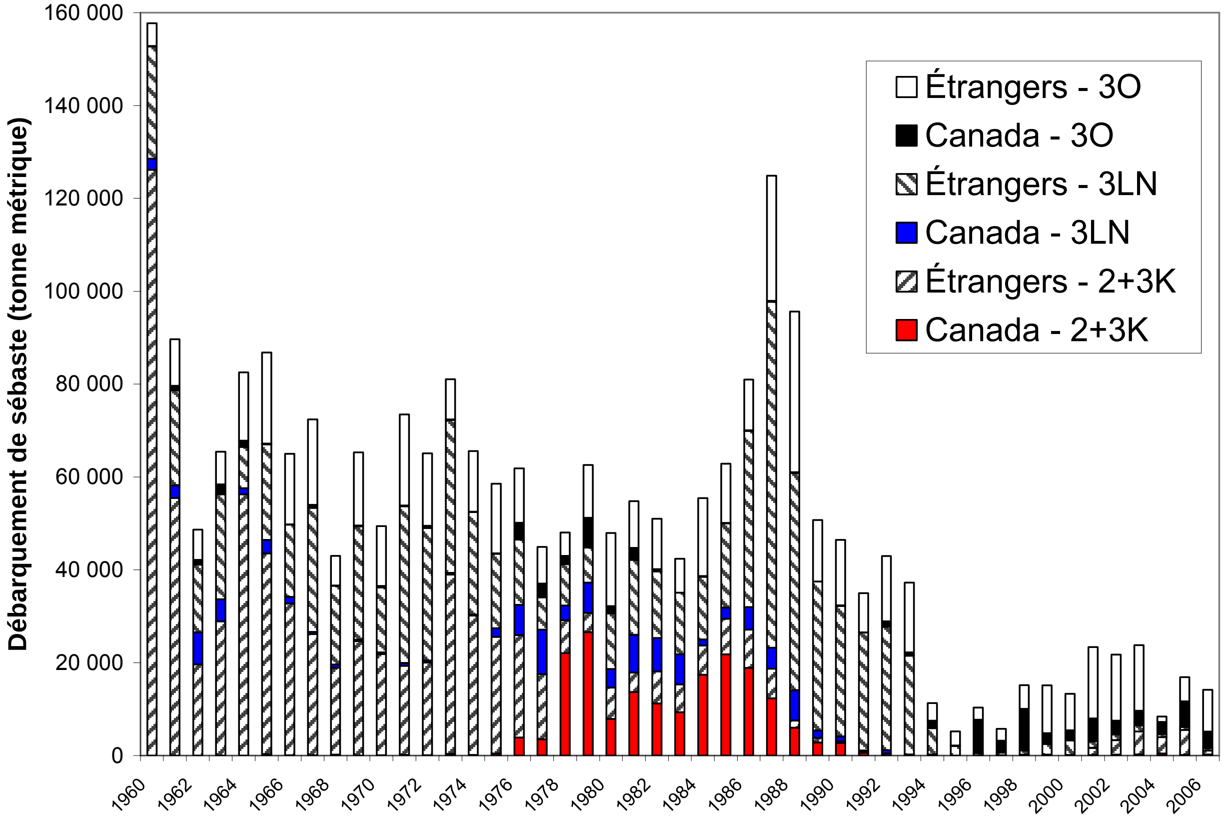

Figure 31. Redfish (*Sebastes* sp.) landings (metric tons) in the Grand Banks and the Labrador Sea. Étrangers = foreign.

In the southern area for Acadian Redfish, catches have been more modest in Unit 3 than in areas further north, varying between 1,900 and 6,700 tonnes between 1977 and 2006 (Figure 32). As well, no decline was recorded in this area. Since 1994, the landings have been limited to 500 tonnes in the Gulf of Maine (Mayo *et al*. 2002).

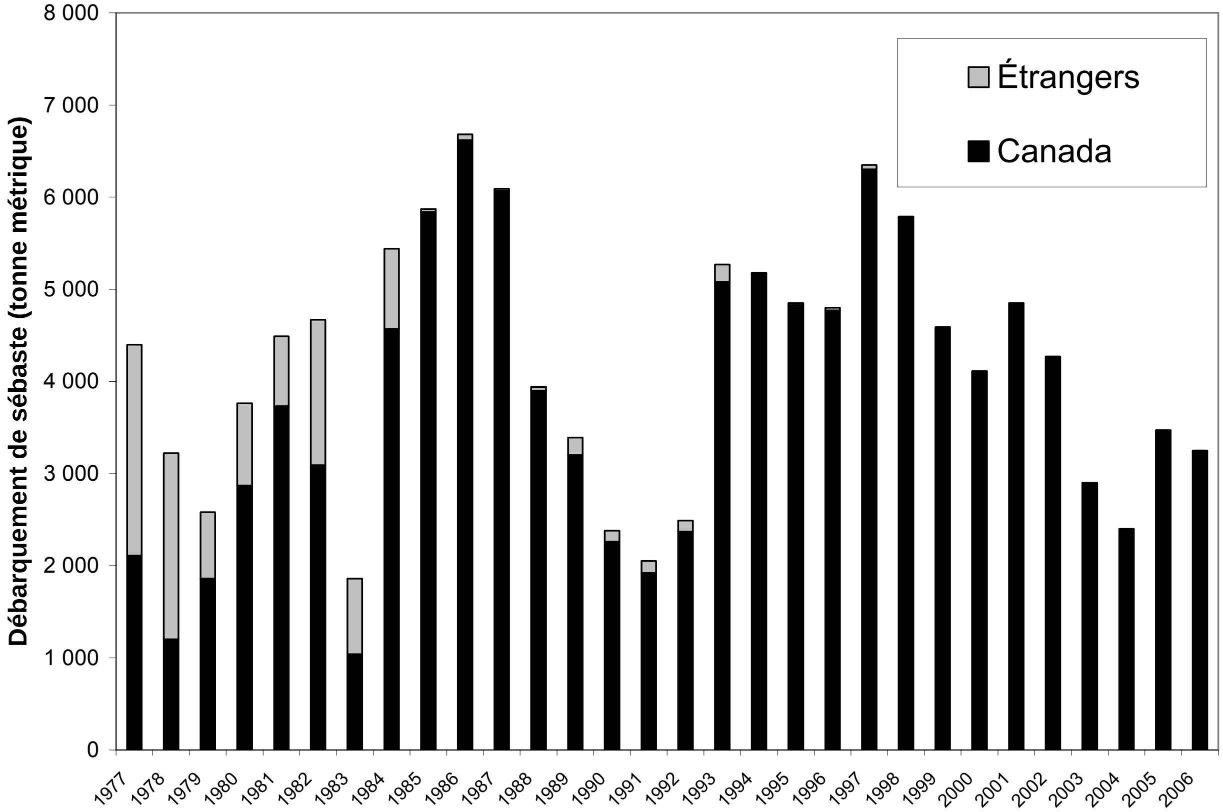

Figure 32. Acadian Redfish landings (metric tons) on the Scotian Shelf (Unit 3). Although landings are classified as "redfish" (*Sebastes* sp.), essentially all would be Acadian Redfish in this area. Étrangers = foreign.

Fishing may have contributed to the disappearance of apparently strong year classes. In the Gulf of St. Lawrence; no major year class has reached a fishable size for more than 30 years. An apparently strong year class, which first appeared in 1988 (assumed to be primarily composed of Acadian Redfish) disappeared in 1992-3 when individuals would have been 14-16 cm in length, below the size taken by gear with current mesh size limits. A similar phenomenon was reported in 1966 and 1974 in the Gulf of St. Lawrence (Morin *et al*. 2004). The disappearance of the 1974 year class coincided with periods of high fishing pressure and a drop in catches (the same is true for the 1988 year class but this disappeared before reaching fishable size, so the fishery is unlikely to have been the principal cause).

The fishery could also affect recruitment by reducing the average size of females and their fecundity, which increases with length (Saint-Pierre and de Lafontaine 1995). In the Gulf of St. Lawrence, the size at maturity of 50% of females decreased from 29 cm from 1957 to 1969 (Ni and Sandeman 1984) to 25 cm in 1990 (Saint-Pierre and de Lafontaine 1995), similar to the decline in size at age observed in cod following great fishing pressure (Dutil *et al*. 1999). Moreover, it has hypothesized that stress from fishing on Redfish females before expulsion could affect larvae survival (DFO 2000).

Incidental and unreported catch

Bycatch from other fisheries may also contribute to mortality, in particular the shrimp fishery, because distributions of Redfishes and the northern shrimp *Pandalus borealis* overlap. Since the introduction of the Nordmore grate in the 1990s, which limits fish bycatches in shrimp trawl gear, the impact of this fishery on Redfish has declined substantially (DFO 2006). Removals due to shrimp bycatch were estimated at less than 1% of the directed fishery removals of Redfish in 2J3K in 2000 (Power 2001). The low recent bycatches may in part be due to the depleted state of Redfish in shrimp fishing areas, and the potential impact of the shrimp fishery should Redfish begin to recover is not well known.

Undeclared catches in fisheries for Redfish and other groundfish species may also represent a major source of mortality in Redfish. This factor is obviously difficult to quantify, although the general decline in trawl fisheries off Canada's Atlantic may have acted to reduce this threat in recent years.

Bonne Bay Acadian Redfish are taken as bycatch in mackerel and other fisheries which are prosecuted in the Bay.

Seal consumption

Redfish consumption by seals could be a major cause of mortality. The northern populations (2J3KL) are preyed upon by both Harp and Hooded Seals. These two species were estimated to have consumed 35,000 t of redfish in 1996 with approximately equal proportions by both species (Hammil and Stenson 2000). The abundance of the Harp Seals has probably increased since then and is considered to be very high. The Harp Seal is also a major predator of redfish in the Gulf of St. Lawrence where the consumption in 1996 was estimated to be 95,000 t. Most of the redfish consumed were thought to be juvenile fish less than 25 cm in length (Hammil and Stenson 2000).

Other threats

The Bonne Bay population could be subject to environmental threats such as oil or effluent spills from a highway along the north shore of the fjord.

SPECIAL SIGNIFICANCE OF THE SPECIES

Deepwater Redfish and Acadian Redfish are (or have been) major commercial species. In 2006, Redfish species generated revenues of $9,431,000 in the Atlantic region (DFO Statistical Services 2007). Revenues were $28,062,000 in 1992, when quotas were high in most areas. The current depleted status of Redfish populations has thus had major negative economic impacts on some fishing fleets.

Given their high abundance (at least in unstressed conditions), these species have an important place in the trophic ecosystem of the Northwestern Atlantic. When abundant in the mid-1980s, redfish were both dominant predators and prey. According to the ecosystem models of Savenkoff *et al*. (2006), redfishes represented 8% of the prey consumed in the northern Gulf of St. Lawrence. As well, after Atlantic Cod, redfishes were the most prevalent predator. The situation has changed since the collapse in populations in the northern Gulf, where the ecological role of redfishes has diminished greatly.

EXISTING PROTECTION OR OTHER STATUS DESIGNATIONS

The Acadian Redfish is on the IUCN's Red List of Threatened Species (Sobel 1996). Its status is qualified as EN A1bd.

Redfish fisheries in the Northwestern Atlantic are managed by DFO, NAFO or the US government and American states. Gulf of St. Lawrence/Laurentian Channel populations are located in exclusively Canadian waters and are therefore managed by DFO. To the north, stocks in NAFO Div. 3O and Divs. 3LN are managed by NAFO, while the remainder, SA2+Div3K, is managed by DFO. The Acadian Redfish population of the southern Scotian Shelf/Gulf of Maine is jointly managed by the United States and Canada.

Moratoria on directed fishing for redfishes are in place for Unit 1 since 1995 and in NAFO 2J3K since 1998. The fishery in NAFO 3LN reopened in 2010 following a moratorium in 1998. Redfish fisheries continue under quota limits in Unit 3 and in NAFO 3O.

In addition to catch limits, minimum legal catch sizes and minimum mesh sizes are in place to reduce fishing pressure on immature redfish populations. The minimum legal catch size for redfish is 22 cm in stocks managed by DFO. Minimum mesh size is 130 mm in areas managed by NAFO, and 90 mm (Unit 1, Unit 2, DFO-managed parts of NAFO 3M and 3O) or 110 mm (Unit 3) for stocks managed by DFO. To protect spawners, fishing is prohibited in May and June in Unit 2 of DFO and the season opens June 15 in Unit 1. There is also a protected area for juvenile redfish to protect the Acadian Redfish southern population (Browns Bank).

Use of the Nordmore grate, which has been mandatory since 1994 in the northern shrimp fishery, allows fish to escape the trawl and has considerably reduced incidental catches of redfishes.

Commercial fishing for groundfish species is currently not permitted in Bonne Bay. Recreational fishing is permitted but it is not directed at redfish.

TECHNICAL SUMMARY - Deepwater Redfish Gulf of St. Lawrence - Laurentian Channel Population

Sebastes mentella

Deepwater Redfish	sébaste atlantique
Gulf of St. Lawrence - Laurentian Channel population	population du golfe du Saint-Laurent et du chenal Laurentien

Range of Occurrence in Canada: Atlantic Ocean (Gulf of St. Lawrence, Laurentian Channel)

Demographic Information

Generation time (average age of parents in the population)	18.4-18.6 yrs
Population trend and dynamics	
Observed percentage of reduction in total number of mature individuals over the last 10 years.	-97% in key abundance index since 1984
Projected percentage of reduction in total number of mature individuals over the next 10 years.	Unknown
Observed percentage reduction in total number of mature individuals over any 10 years period, over a time period including both the past and the future.	N/A
Are the causes of the decline clearly reversible?	No
Are the causes of the decline clearly understood?	Yes; fishing and poor recruitment are the likely causes
Are the causes of the decline clearly ceased?	No
Observed trend in number of population	Single population
Are there extreme fluctuations in number of mature individuals?	No
Are there extreme fluctuations in number of populations?	No

Number of mature individuals in population

Population	79m mature individuals in last 5 years

Extent and Area Information

Estimated extent of occurrence (km²)	511 x 10^3 km²
Observed trend in extent of occurrence	Stable
Are there extreme fluctuations in extent of occurrence?	No
Estimated area of occupancy (km²)	144 x 10^3 km² (survey estimate) 16 x 10^3 km² (2x2 km grid)
Observed trend in area of occupancy	Stable
Are there extreme fluctuations in area of occupancy?	No
Is the total population severely fragmented?	No
Number of current locations	N/A
Trend in number of locations	N/A
Are there extreme fluctuations in number of locations?	N/A
Observed trend in area of habitat	Stable

Quantitative Analysis

	Not carried out

Threats (actual or imminent, to populations or habitats)

Fishing (directed and bycatch) and poor recruitment are the principal known threats

Rescue Effect (immigration from an outside source)

Status of outside population(s)? Adjacent DU (Newfoundland-Labrador) is similarly depleted; not found in USA	
Is immigration known or possible?	Possible
Would immigrants be adapted to survive in Canada?	Probably
Is there sufficient habitat for immigrants in Canada?	Yes
Is rescue from outside populations likely?	No

Current Status

COSEWIC: Endangered (April 2010)

Status and Reasons for Designation

Status: Endangered	**Alpha-numeric code:** A2b+4b
Reasons for Designation: As with other members of the family Sebastidae, this species is long-lived (maximum age about 75 yr), late-maturing (generation time 18 yr), and highly vulnerable to mortality from human activities. Recruitment is episodic, with strong year-classes only occurring every 5-12 years. Abundance of mature individuals has declined 98% since 1984, somewhat more than one generation, and the decline has not ceased. Directed fishing and incidental harvest in fisheries for other species (bycatch) are the main known threats. Harvesting in parts of this population (Gulf of St. Lawrence) is currently limited to an index fishery, but commercial fisheries remain open in other areas (Laurentian Channel). Bycatch in shrimp fisheries has been substantially reduced since the 1990s by use of separator grates in trawls, but could still be frequent enough to affect recovery.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Meets Endangered, A2b+4b because abundance has declined more than 50% in less than two generations and the decline has not ceased.
Criterion B (Small Distribution Range and Decline or Fluctuation): Does not apply because the range of occurrence exceeds 20,000 km^2 and the area of occupancy is greater than 2,000 km^2.
Criterion C (Small and Declining Number of Mature Individuals): Does not apply because the estimated population size exceeds 10,000 individuals.
Criterion D (Very Small Population or Restricted Distribution): Does not apply because the number of mature individuals exceeds 1,000 and area of occupancy is greater than 20 km^2.
Criterion E (Quantitative Analysis): Not undertaken.

TECHNICAL SUMMARY - Deepwater Redfish Northern Population

Sebastes mentella
Deepwater Redfish — sébaste atlantique
Northern population — population du Nord
Range of Occurrence in Canada: Atlantic Ocean (Northern Grand Banks of Newfoundland, Labrador Shelf)

Demographic Information

Generation time (average age of parents in the population)	23 yrs
Population trend and dynamics	
Observed percentage of reduction in total number of mature individuals over the last 10 years or 3 generations. ▪ NAFO 2J3K: 98% decline since 1978, given greatest weight because of relative abundance of redfish in this area ▪ NAFO 3O, 3 LN – increasing since 1990s but these stocks had a much lower historical abundance than 2J3K	98% decline in 2J3K abundance index since 1978, but the indices in 3O and 3LN increased since 1991
Projected percentage of reduction in total number of mature individuals over the next 10 years.	Unknown
Observed percentage reduction in total number of mature individuals over any 10 years period, over a time period including both the past and the future.	N/A
Are the causes of the decline clearly reversible?	No
Are the causes of the decline clearly understood?	Yes; fishing and poor recruitment are the likely causes
Are the causes of the decline clearly ceased?	No
Observed trend in number of population	Single population
Are there extreme fluctuations in number of mature individuals?	No
Are there extreme fluctuations in number of populations?	No

Number of mature individuals in population

Population	140 million mature individuals in last 5 years

Extent and Area Information

Estimated extent of occurrence (km²)	1431 x 10^3 km²
Observed trend in extent of occurrence	Stable
Are there extreme fluctuations in extent of occurrence?	No
Estimated area of occupancy (km²)	104 x 10^3 km² (survey estimate) 21 x 10^3 km² (2x2 km grid)
Observed trend in area of occupancy	Stable
Are there extreme fluctuations in area of occupancy?	No
Is the total population severely fragmented?	No
Number of current locations	N/A
Trend in number of locations	N/A
Are there extreme fluctuations in number of locations?	N/A
Observed trend in area of habitat	Stable

Quantitative Analysis

	Not carried out

Threats (actual or imminent, to populations or habitats)

Fishing (directed and bycatch) and poor recruitment are the principal known threats

Rescue Effect (immigration from an outside source)

Status of outside population(s)? No recent trend in Greenland; recent abundance increase on Flemish Cap	
Is immigration known or possible?	Possible
Would immigrants be adapted to survive in Canada?	Probably
Is there sufficient habitat for immigrants in Canada?	Yes
Is rescue from outside populations likely?	Possible but uncertain

Current Status

COSEWIC: Threatened (April 2010)

Status and Reasons for Designation

Status:	**Alpha-numeric code:**
Threatened	Met criterion for Endangered, A2b, but designated Threatened, A2b, because the species is widely distributed, includes several million mature individuals, and has been stable or increasing since the mid-1990s

Reasons for Designation:
As with other members of the family Sebastidae, this species is long-lived (maximum age about 75 yr), late-maturing (generation time 23 yr), and highly vulnerable to mortality from human activities. Recruitment is episodic, with strong year-classes only occurring every 5-12 years. Abundance of mature individuals has declined 98% since 1978, somewhat over one generation. However, declines have stopped since the mid-1990s and increases have been observed in some areas. Directed fishing and incidental harvest in fisheries for other species (bycatch) are the main known threats. Fisheries in parts of this designatable unit are currently closed, but remain open in other areas. Bycatch in shrimp fisheries has been substantially reduced since the 1990s by use of separator grates in trawls, but could still affect population recovery.

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Meets Endangered, A2b because abundance has declined more than 50% in less than two generations.
Criterion B (Small Distribution Range and Decline or Fluctuation): Does not apply because the range of occurrence exceeds 20,000 km^2 and the area of occupancy is greater than 2,000 km^2.
Criterion C (Small and Declining Number of Mature Individuals): Does not apply because the estimated population size exceeds 10,000 individuals.
Criterion D (Very Small Population or Restricted Distribution): Does not apply because the number of mature individuals exceeds 1,000 and area of occupancy is greater than 20 km^2.
Criterion E (Quantitative Analysis): Not undertaken.

TECHNICAL SUMMARY - Acadian Redfish Atlantic Population

Sebastes fasciatus

Acadian Redfish — sébaste d'Acadie

Atlantic population — population de l'Atlantique

Range of Occurrence in Canada: Atlantic Ocean (ocean waters of Atlantic Canada, other than Bonne Bay)

Demographic Information

Generation time (average age of parents in the population)	16 - 18 yrs
Population trend and dynamics	
Observed percentage of reduction in total number of mature individuals over the last 10 years or three generations. ▪ -99.8% since 1978, northern area ▪ -99.5% since 1984, Gulf of St. Lawrence/Laurentian Channel ▪ no trend, Scotian Shelf	greater than 99% over about 2 generations in areas of greatest historical abundance, but some indices are stable or increasing since mid-1990s
Projected percentage of reduction in total number of mature individuals over the next 10 years.	Unknown
Observed percentage reduction in total number of mature individuals over any 10 years period, over a time period including both the past and the future.	N/A
Are the causes of the decline clearly reversible?	No
Are the causes of the decline clearly understood?	Yes; fishing and poor recruitment are the likely causes
Are the causes of the decline clearly ceased?	No
Observed trend in number of population	Single population
Are there extreme fluctuations in number of mature individuals?	No
Are there extreme fluctuations in number of populations?	No

Number of mature individuals in population

Population	565m mature individuals in last 5 years

Extent and Area Information

Estimated extent of occurrence (km²)	1511 x 10^3 km²
Observed trend in extent of occurrence	Stable
Are there extreme fluctuations in extent of occurrence?	No
Estimated area of occupancy (km²)	322 x 10^3 km² (survey estimate) 57 x 10^3 km² (2x2 km grid)
Observed trend in area of occupancy	Stable
Are there extreme fluctuations in area of occupancy?	No
Is the total population severely fragmented?	No
Number of current locations	Not applicable – continuous distribution
Trend in number of locations	Not applicable
Are there extreme fluctuations in number of locations?	Not applicable
Observed trend in area of habitat	Stable

Quantitative Analysis

	Not carried out

Threats (actual or imminent, to populations or habitats)

Fishing (directed and bycatch) and poor recruitment are the principal known threats

Rescue Effect (immigration from an outside source)

Status of outside population(s)? Adjacent population (Gulf of Maine) is not depleted	
Is immigration known or possible?	Possible
Would immigrants be adapted to survive in Canada?	Probably
Is there sufficient habitat for immigrants in Canada?	Yes
Is rescue from outside populations likely?	Possible

Current Status

COSEWIC: Threatened (April 2010)

Status and Reasons for Designation

Status: Threatened	**Alpha-numeric code:** Met criterion for Endangered, A2b, but designated Threatened, A2b, because the species is widely distributed, the population includes several hundred million mature individuals, and abundance indices are stable or increasing since the 1990s in some areas.
Reasons for Designation: As with other members of the family Sebastidae, this species is long-lived (maximum age about 75 yr), late-maturing (generation time 16-18 yr), and highly vulnerable to mortality from human activities. Recruitment is episodic, with strong year-classes only occurring every 5-12 years. Abundance of mature individuals has declined 99% in areas of highest historical abundance over about two generations. However, since the 1990s, there has been no long-term trend in one area, and trends have been stable or increasing in other areas where large declines have been previously observed. Directed fishing and incidental harvest in fisheries for other species (bycatch) are the main known threats. Fisheries in parts of the range of this designatable unit (DU) are currently closed, but remain open in other areas. Bycatch in shrimp fisheries has been substantially reduced since the 1990s by use of separator grates in trawls, but could still be frequent enough to affect population recovery.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Meets Endangered, A2b because abundance has declined more than 50% in less than two generations.
Criterion B (Small Distribution Range and Decline or Fluctuation): Does not apply because the range of occurrence exceeds 20,000 km^2 and the area of occupancy is greater than 2,000 km^2.
Criterion C (Small and Declining Number of Mature Individuals): Does not apply because the estimated population size exceeds 10,000 individuals.
Criterion D (Very Small Population or Restricted Distribution): Does not apply because the number of mature individuals exceeds 1,000 and area of occupancy is greater than 20 km^2.
Criterion E (Quantitative Analysis): Not undertaken.

TECHNICAL SUMMARY - Acadian Redfish Bonne Bay Population

Sebastes fasciatus

Acadian Redfish — sébaste d'Acadie

Bonne Bay population — population de la baie Bonne

Range of Occurrence in Canada: Atlantic Ocean (Bonne Bay fjord, western Newfoundland)

Demographic Information

Generation time (average age of parents in the population)	Unknown
Population trend and dynamics	
Observed percentage of reduction in total number of mature individuals over the last 10 years.	Unknown
Projected percentage of reduction in total number of mature individuals over the next 10 years.	Unknown
Observed percentage reduction in total number of mature individuals over any 10 years period, over a time period including both the past and the future.	N/A
Are the causes of the decline clearly reversible?	N/A
Are the causes of the decline clearly understood?	N/A
Are the causes of the decline clearly ceased?	N/A
Observed trend in number of population	Single population
Are there extreme fluctuations in number of mature individuals?	No
Are there extreme fluctuations in number of populations?	No

Number of mature individuals in population

Population	Unknown

Extent and Area Information

Estimated extent of occurrence (km²)	72 km^2
Observed trend in extent of occurrence	Stable ?
Are there extreme fluctuations in extent of occurrence?	No
Estimated area of occupancy (km²)	Unknown, less than 72 km^2
Observed trend in area of occupancy	Unknown
Are there extreme fluctuations in area of occupancy?	No
Is the total population severely fragmented?	No
Number of current locations	N/A
Trend in number of locations	N/A
Are there extreme fluctuations in number of locations?	N/A
Observed trend in area of habitat	Stable

Quantitative Analysis

	Not carried out

Threats (actual or imminent, to populations or habitats)

This is a relatively small area in an accessible and populated area. Bonne Bay could be subject to environmental threats such as oil or effluent spills from a highway along the north shore of the fjord.

Rescue Effect (immigration from an outside source)

Status of outside population(s)? No rescue possible since this is a distinct designatable unit within Canada	
Is immigration known or possible?	No
Would immigrants be adapted to survive in Canada?	Not applicable
Is there sufficient habitat for immigrants in Canada?	Not applicable
Is rescue from outside populations likely?	Not possible

Current Status

COSEWIC: Special Concern (April 2010)

Status and Reasons for Designation

Status: Special Concern	**Alpha-numeric code:** N/A
Reasons for Designation: As with other members of the family Sebastidae, this species is long-lived (maximum age about 75 yr), late-maturing (females 50% mature at 8-10 yr in the adjacent Gulf of St. Lawrence/Laurentian Channel population), and highly vulnerable to mortality from human activities. Little is known of the biology of this designatable unit (DU). It has a small range of occurrence but there is no indication of decline. The population has been exploited by fishing in the past, but is currently closed to directed fishing. This DU is susceptible to extirpation by random events such as oil spills.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Does not apply, no information on population trends.
Criterion B (Small Distribution Range and Decline or Fluctuation): Does not apply; although extent of occurrence is less than 20,000 km^2 and the area of occupancy is less than 2,000 km^2, there is no information to indicate decline or fluctuation.
Criterion C (Small and Declining Number of Mature Individuals): Does not apply because the population size probably exceeds 10,000 individuals.
Criterion D (Very Small Population or Restricted Distribution): Does not apply because the number of mature individuals exceeds 1,000 and area of occupancy is greater than 20 km^2.
Criterion E (Quantitative Analysis): Not undertaken.

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Red Méthot earned a master’s degree in oceanography from the Institut des Sciences de la Mer (ISMER) in 2002. His thesis was on the spatial and temporal aspects of cod reproduction in stock management. He then worked for Fisheries and Oceans Canada (DFO) on fisheries-related projects. One of his achievements is the development of an analytical method for classifying Redfish catches by species during scientific surveys. He is currently an ichthyologist at Alliance Environnement/Tecsult.

APPENDIX 1. Abundance indices for Redfish populations from Sévigny *et al*. 2007.

Abundance indices for Acadian Redfish, Deepwater Redfish and heterozygotes in Unit 1 of DFO.

Survey Year	Abundance Indices (10^6)					
	Total Population			Mature Population		
	Acadian Redfish	*Deepwater Redfish*	Heterozygote	*Acadian Redfish*	*Deepwater Redfish*	Heterozygote
1984	3162	2826	952	1813	2002	645
1985	3824	1751	670	1327	1013	346
1986	2832	1705	628	1640	935	314
1987	3378	2453	846	2161	1506	492
1988	3256	3103	1031	2500	2293	739
1989	2894	2456	830	2327	2165	713
1990	1633	797	278	345	563	166
1991	1808	649	265	381	418	131
1992	441	224	82	451	332	116
1993	323	361	109	186	306	88
1994	187	136	47	117	106	36
1995	94	119	37	41	97	28
1996	92	99	31	39	75	22
1997	123	106	34	51	81	24
1998	338	111	42	140	58	20
1999	205	113	40	35	60	17
2000	320	142	52	41	65	19
2001	196	111	38	36	61	17
2002	139	119	38	36	87	24
2003	344	287	92	158	216	64
2004	189	68	26	57	34	11
2005	3822	587	304	66	59	18
2006	1662	334	161	91	50	16
2007	1967	437	203	50	36	11

Abundance indices for Acadian Redfish, Deepwater Redfish and heterozygotes in Unit 2 of DFO.

Survey Year	Abundance Index (10^6)					
	Total Population			Mature Population		
	Acadian Redfish	*Deepwater Redfish*	Heterozygote	*Acadian Redfish*	*Deepwater Redfish*	Heterozygote
1994	565	279	75	225	245	62
1995	445	273	74	131	231	58
1996	322	218	60	149	204	55
1997	535	259	71	238	214	54
2000	578	272	74	253	223	57
2002	561	206	56	226	169	43

Abundance indices for Acadian Redfish in Unit 3 of DFO.

Survey Year	Abundance Index (10^6)	
	Total Population	Mature Population
	Acadian Redfish	*Acadian Redfish*
1970	402	233
1971	428	275
1972	521	445
1973	526	499
1974	172	82
1975	572	564
1976	80	59
1977	299	288
1978	434	430
1979	50	46
1980	49	45
1981	81	77
1982	208	186
1983	330	317
1984	244	191
1985	49	29
1986	195	162
1987	157	143
1988	248	222
1989	79	51
1990	222	172
1991	104	56
1992	324	316
1993	206	177
1994	208	137
1995	166	119
1996	217	143
1997	586	302
1998	125	64
1999	329	248
2000	282	183
2001	352	331
2002	151	118
2003	392	189
2004	195	125
2005	446	343
2006	645	294

Abundance indices for Acadian Redfish and Deepwater Redfish in Unit 3O of DFO.

Year	Abundance Index (10^6)							
	Spring				Fall			
	Total Population		Mature Population		Total Population		Mature Population	
	Acadian Redfish	*Deepwater Redfish*	*Acadian Redfish*	*Deepwater Redfish*	*Acadian Redfish*	*Deepwater Redfish*	*Acadian Redfish*	*Deepwater Redfish*
1973	11.8	0.1	9.7	0.0				
1974								
1975	72.9	0.1	38.4	0.0				
1976	33.4	0.6	6.4	0.2				
1977	239.1	0.5	134.8	0.4				
1978	26.7	1.5	20.1	0.9				
1979	86.3	3.9	62.8	2.4				
1980	19.0	0.4	12.7	0.2				
1981								
1982	188.3	1.9	79.4	1.0				
1983								
1984	899.1	10.4	40.5	2.1				
1985	241.0	3.6	46.7	1.1				
1986	925.7	9.4	342.4	1.2				
1987	243.5	4.7	126.1	1.8				
1988	358.9	4.6	100.7	0.8				
1989	84.5	0.6	44.5	0.4				
1990	529.4	0.6	438.9	0.4				
1991	141.3	14.1	19.2	9.5	326.7	9.6	75.1	2.8
1992	123.7	23.1	30.9	3.1	413.3	8.5	153.2	1.2
1993	555.3	13.0	275.9	8.8	262.7	39.5	140.5	18.4
1994	1430.0	29.6	380.8	23.2	296.0	25.4	117.1	15.9
1995	2152.8	44.8	275.4	11.9	955.2	64.9	186.1	25.2
1996	756.4	25.4	204.8	9.7	130.7	22.6	52.2	9.8
1997	81.0	36.2	32.6	7.8	952.8	106.7	442.9	39.8
1998	1008.1	24.7	530.8	16.8	336.5	61.5	252.6	36.9
1999	651.1	67.8	415.1	38.8	249.8	18.5	162.4	11.6
2000	422.4	50.1	291.4	31.8	300.6	58.2	210.8	32.8
2001	148.8	20.5	88.9	12.4	329.4	26.3	87.7	7.7
2002	112.0	11.5	67.0	5.9	232.7	39.9	77.4	11.8
2003	202.9	15.1	107.5	7.3	92.1	21.4	49.2	8.1
2004	485.7	19.4	354.4	16.2	130.4	28.5	76.5	15.0
2005	400.0	26.8	206.2	20.8	190.1	43.7	120.5	22.3
2006	ND	ND	ND	ND	260.1	71.7	190.0	33.5

Abundance indices for Acadian Redfish and Deepwater Redfish in Unit 3LN of DFO.

Year	Abundance Index (10^6)							
	Spring				Fall			
	Total Population		Mature Population		Total Population		Mature Population	
	Acadian Redfish	*Deepwater Redfish*	*Acadian Redfish*	*Deepwater Redfish*	*Acadian Redfish*	*Deepwater Redfish*	*Acadian Redfish*	*Deepwater Redfish*
1973	47.4	1.7	23.1	0.5				
1974	8.9	0.4	7.5	0.3				
1975	16.5	0.7	9.6	0.3				
1976	164.2	7.6	160.9	7.3				
1977	51.0	2.0	41.3	1.5				
1978	29.2	1.1	24.4	0.8				
1979	361.0	12.2	154.4	3.5				
1980	35.3	1.4	23.7	0.8				
1981	130.5	6.3	98.1	3.3				
1982	58.5	2.6	45.2	1.9				
1983								
1984								
1985	113.6	10.8	27.8	1.9				
1986	54.2	2.3	16.0	0.6				
1987	134.6	4.1	51.5	1.0				
1988	89.1	3.5	39.0	1.0				
1989	46.5	2.1	18.6	0.6				
1990	34.3	1.4	13.4	0.5				
1991	41.2	24.9	17.1	8.1	369.5	52.5	33.1	26.5
1992	35.1	19.4	13.0	9.9	1014.7	115.5	280.6	45.6
1993	81.8	28.9	28.7	20.0	30.3	58.3	12.7	30.0
1994	16.2	8.1	5.7	4.2	112.5	62.7	24.7	44.6
1995	19.8	12.2	7.4	5.3	307.9	124.4	84.8	91.8
1996	72.5	51.5	41.5	23.9	34.7	38.8	18.9	21.1
1997	50.5	32.6	31.4	19.5	241.5	113.6	160.1	88.7
1998	185.5	63.6	145.0	55.3	485.9	106.0	346.7	74.7
1999	226.8	58.5	186.3	49.1	159.0	128.0	122.2	111.5
2000	233.8	140.6	189.2	102.9	384.7	102.2	275.3	79.0
2001	111.9	75.2	74.6	51.2	736.3	145.0	425.9	94.4
2002	101.6	58.9	59.7	35.0	159.2	85.7	94.3	60.7
2003	129.0	46.6	53.5	20.5	324.7	88.7	146.2	54.5
2004	200.2	117.8	143.7	103.3	111.5	83.2	80.8	56.6
2005	322.1	62.4	151.0	43.7	216.5	80.0	114.1	51.3
2006	196.0	21.1	95.0	10.4	428.4	97.5	252.1	61.6

Abundance indices for Acadian Redfish and Deepwater Redfish in DFO surveys conducted in the fall in divisions 2J3K, 2GH (1987−1999) and 2H only (2001–2006)

Year	Abundance Index (10^6)							
	2J3KL				Fall			
	Total Population		Mature Population		Total Population		Mature Population	
	Acadian Redfish	*Deepwater Redfish*	*Acadian Redfish*	*Deepwater Redfish*	*Acadian Redfish*	*Deepwater Redfish*	*Acadian Redfish*	*Deepwater Redfish*
1978	3253.1	5386.9	1297.9	4238.2				
1979	817.2	1322.3	481.9	1055.6				
1980	1361.7	1617.1	1130.7	1431.0				
1981	2304.1	1503.7	2224.8	1307.0				
1982	431.0	1469.7	388.9	1172.8				
1983	4024.6	4260.1	4001.2	3751.9				
1984	316.9	799.1	270.3	723.2				
1985	236.5	965.2	213.4	901.3				
1986	186.1	651.9	154.6	593.0	2GH			
1987	61.4	275.1	44.8	234.6	1.4	37.4	0.7	20.7
1988	168.5	689.7	137.7	585.5	7.1	101.6	0.7	15.3
1989	58.6	250.9	40.1	170.2				
1990	106.9	469.1	96.5	398.2				
1991	29.8	134.4	16.5	84.7	1.0	28.9	0.0	0.6
1992	12.9	73.3	2.7	27.2				
1993	6.5	35.7	1.7	16.8				
1994	4.0	32.3	1.2	16.8				
1995	25.0	123.0	1.7	13.9				
1996	62.3	178.0	7.3	59.2	9.1	321.9	1.1	24.2
1997	46.5	178.6	5.6	93.8	13.9	367.9	2.8	42.9
1998	76.3	236.0	9.9	99.0	4.9	150.8	0.9	27.2
1999	56.2	224.6	7.2	100.2	7.5	212.9	1.2	26.6
2000	64.6	160.2	4.1	37.3	2H Only			
2001	145.2	268.8	6.8	91.1	3.0	96.4	0.4	5.4
2002	109.9	265.0	5.5	62.7				
2003	178.2	366.4	2.6	42.0				
2004	325.6	520.3	8.4	103.3	6.0	129.2	0.2	16.4
2005	305.3	559.5	35.4	81.6				
2006	286.6	790.5	71.1	263.0	9.7	148.8	0.6	20.1