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Quebec and Newfoundland and Labrador Regions

Canadian Science Advisory Secretariat
Science Advisory Report 2008/026

ADVICE ON THE STOCK DEFINITION OF REDFISH (*SEBASTES FASCIATUS* AND *S. MENTELLA*) IN UNITS 1 AND 2

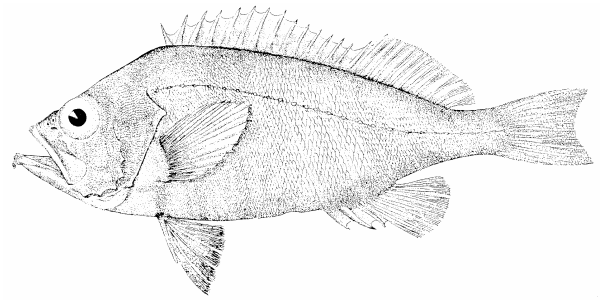

Figure 1. Schematic representation of redfish

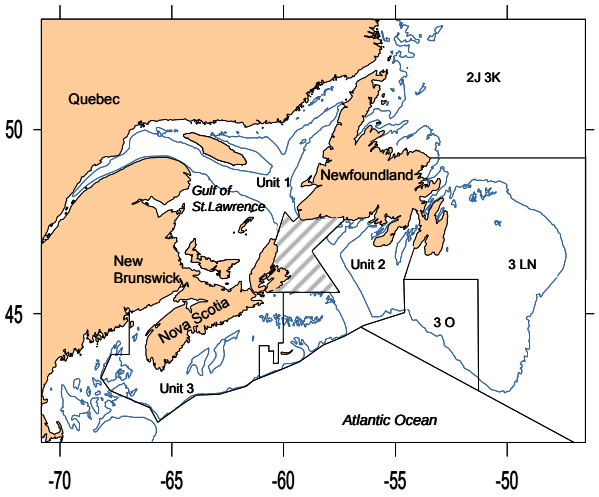

Figure 2. Map of the Northwest Atlantic showing the boundaries of current redfish management units within NAFO Divisions. The area corresponding to NAFO subdivisions 3Pn and 4Vn (hatched) indicates the area of seasonal overlap between Units 1 and 2.

Context

The Northwest Atlantic redfish consists of a complex of three species identified as Sebastes mentella, S. fasciatus and S. marinus. The redfish distribution ranges from the Gulf of Maine, northwards off Nova Scotia and southern Newfoundland Banks, in the Gulf of St. Lawrence and along the continental slope and deep channels from the southwestern Grand Bank to areas as far north as Baffin Island. Redfish are also present in the area of Flemish Cap and west of Greenland.

Sebastes mentella and S. fasciatus, the two commercially most important species, are distributed according to a gradient in the Northwest Atlantic. Sebastes mentella is the dominant species in Baffin Bay and in the Labrador waters while S. fasciatus dominates in the Gulf of Maine and the basins and continental slope of the western Scotian Shelf (UNIT 3). Their distribution overlaps in the Gulf of St. Lawrence (Unit 1), the Laurentian Channel (Unit 2), off Newfoundland (3LN, 3M, 3O), and south of the Labrador Sea (2J, 3K). Sebastes fasciatus and S. mentella distribution is also characterized by the presence of an area of introgressive hybridization which is geographically circumscribed to the Gulf of St. Lawrence – Laurentian Channel area (management units 1 and 2) and to a lesser extent to the Flemish Cap area.

Because redfish species are very similar and very difficult to distinguish by their appearance, they are usually not categorized by species in the fishery and have been managed as one group. The biological relevance of separate management for Units 1 and 2 has been questioned after implementation in 1993. At that time, it was considered that the revised management structure was biologically more tenable and an improvement over the previous framework but it was also recognized that further investigations were

necessary. A moratorium was implemented on Unit 1 in 1995 and a special program of study was initiated to understand redfish stock structure and their inter-relation, particularly in Units 1 and 2. The moratorium continues to the present-day for Unit 1 whereas Unit 2 continues to support a fishery.

The issues of redfish population structure, more specifically the interaction between management Unit 1 and Unit 2, were presented during workshops held at the Maurice Lamontagne Institute in February, 2006 and September, 2007. This Science Advisory Report presents the advice and conclusions from the 2007 workshop.

SUMMARY

- In Unit 1 and 2, there are two commercially important species of redfish: *Sebastes fasciatus* and *S. mentella*.

- Population data indicates that the two species do not have the same life history, particularly in terms of reproduction and recruitment mechanisms. It is therefore recommended that the two species should be assessed separately.

- A review of the biological data (genetics, morphometrics and otolith chemical signature) suggests that Units 1 and 2 corresponds to a single biological population of each species. It is therefore recommended that Unit 1 and 2 be grouped as a single biological unit for each of the two species and assessed as such.

- However, it appears that both species present a complex geographic structuring within biological units, as inferred from differences in abundance, the genetics (*S. fasciatus* only), otolith chemical signatures and corroborated by traditional fisheries knowledge. Seasonal migration patterns are evident. It is recommended that this structuring shall be explicitly taken into consideration in the assessment and in the development of conservation and management strategies.

- The scientific data should be re-analyzed on the new basis of two species, with each species showing population substructure.

- A zonal assessment meeting should be organized to review the scientific data and to define the status of each species in the area presently called Unit 1 and Unit 2.

- These findings may have implications for adjacent management areas.

INTRODUCTION

Redfish species Identification

The Northwest Atlantic redfish consists of a complex of three species currently identified as *S. mentella* and *S. fasciatus*, which dominate the commercial fishery, and *S. marinus*, which occurs at much lower abundance. *Sebastes marinus* can be separated from the other two species by their coloration, eye size and the degree of development of the bony protrusion on the lower jaw. Three characteristics are most commonly used to discriminate *S. mentella* from *S. fasciatus* in the Northwest Atlantic. They are (1) number of soft rays in the anal fin (AFC;

mostly ≥8 for *S. mentella*, mostly ≤7 for *S. fasciatus*), (2) extrinsic gasbladder muscle passage patterns (EGM; primarily between ribs 2 and 3 for *S. mentella*, primarily between ribs 3 and 4 or beyond for *S. fasciatus*), (3) genotype at the liver malate dehydrogenase locus (*MDH-A*; MDH-A*11* for *S. mentella*, *MDH-A*22* for *S. fasciatus*). Although the use of these characteristics have provided most of the information on redfish species distribution in the Northwest Atlantic, their use do not provide information on population structure of the species. Recently, microsatellite DNA markers were developed for redfish. These molecular markers are very powerful for both redfish species identification and description of stock structure.

Redfish distribution

In the Northwest Atlantic, redfish distribution ranges from the Gulf of Maine, northwards off Nova Scotia and southern Newfoundland Banks, in the Gulf of St. Lawrence and along the continental slope and deep channels from the southwestern Grand Bank to areas as far north as Baffin Island. Redfish are also present in the area of Flemish Cap and west of Greenland (Figure 3).

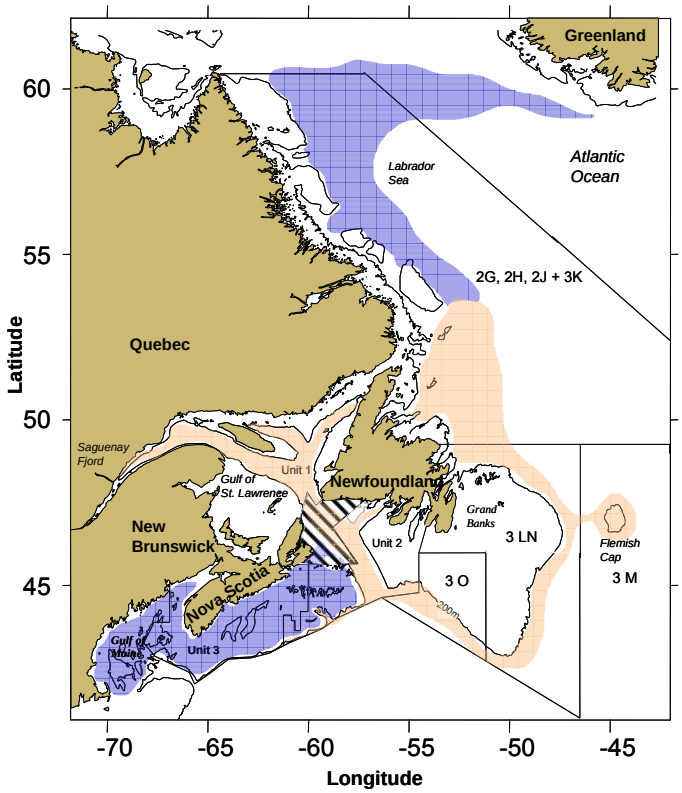

Figure 3. Map of the Northwest Atlantic summarising the general distribution of Sebastes fasciatus and S. mentella based on data of the number of soft rays at the anal fin, extrinsic gasbladder muscle passage patterns and genotype at the liver malate dehydrogenase locus. The approximate location of the areas where the distribution of the two species overlaps (area of sympatry) is represented by the lighter zone. The darker areas are those where only one of the two species is present (areas of allopatry). The boundaries of redfish management units within NAFO Divisions are also indicated. The hatched area (NAFO subdivisions 3Pn and 4Vn) indicates the area of seasonal overlap between Units 1 and 2.

Sebastes mentella and *S. fasciatus* are distributed according to a gradient in the Northwest Atlantic. Indeed, *S. mentella* is the dominant species in Baffin Bay and in the Labrador waters, while *S. fasciatus* dominates in the Gulf of Maine and on the slopes and basins of the Scotian Shelf. The distribution of both species overlaps in the Gulf of St. Lawrence, the Laurentian Channel, the Grand Banks, southern Labrador Sea and the Flemish Cap area. *Sebastes fasciatus* and *S. mentella* distribution is also characterized by the presence of an area of introgressive hybridization (incorporation of genes of one species into another) which is geographically circumscribed to the Gulf of St. Lawrence – Laurentian Channel area (management Units 1 and 2) and to a lesser extent to the Flemish Cap area (3M).

Redfish biology

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

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

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

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

Redfish management

Redfish species are currently managed under nine management areas in the Northwest Atlantic (Figure 3). They are based on NAFO Divisions: West Greenland (Subarea 1), Labrador Shelf (2GHJ-3K), Flemish Cap (3M), North and East Grand Banks (3LN), South Western Grand Bank (3O), Gulf of St. Lawrence ("Unit 1" consisting of 4RST, 3Pn4Vn [Jan. to May]), Laurentian Channel ("Unit 2" consisting of 3Ps4Vs4Wfgj, 3Pn4Vn [June to Dec.]), Scotian Shelf ("Unit 3" consisting of 4WdehklX) and Gulf of Maine (Subarea 5).

Understanding redfish stock structure and their interrelation is a critical issue, more specifically between Unit 1, which is under a moratorium since 1995, and Unit 2, which continues to support a fishery. The importance of addressing the issue of redfish stock definition and boundaries in this area has been repeatedly expressed by the Fisheries Resource Conservation Council (*FRCC Science priorities for 2001*). The industry of the Gulf of St. Lawrence has also expressed concerns regarding the possible impacts of the continuing fishing in Unit 2 on stock recovery in Unit 1.

The issues of redfish population structure, more specifically the interaction between management Unit 1 and Unit 2, were addressed during workshops carried out at the Maurice Lamontagne Institute in 2006 and 2007. However, it is difficult to describe the population structure of Units 1 and 2 redfish without considering the global population structure of these species at the scale of the Northwest Atlantic. The results presented here describe the redfish population structure at the scale of the Northwest Atlantic and also highlight results that are most relevant to the interaction between Units 1 and 2.

ANALYSIS

The redfish stock structure and the assessment of the interaction between redfish from Units 1 and 2 presented in this document are largely based on two types of data: the otolith elemental fingerprint and microsatellite DNA markers. It is worth mentioning that Valentin (2006) also used morphometry for redfish species and stock discrimination.

Redfish seasonal movement based on otolith elemental fingerprint

The elemental composition of the whole otolith (fingerprint) is determined by the habitat where fish spend a large proportion of their life. The otolith elemental fingerprints therefore behave as natural tags and are very useful for stock discrimination and determination of migration patterns.

The otolith elemental fingerprints of redfish were used to study seasonal migration between Units 1 and 2. These analyses reveal significant differences between redfish aggregations. The comparisons between elemental fingerprints of samples collected in summer and fall-winter show that the 3Pn4Vn region is occupied by redfish from Unit 2 in summer and by redfish from Unit 1 in winter. These results are in agreement with the current redfish management practices. However, the results also indicate that redfish from the Gulf of St. Lawrence can migrate further south into the 3Ps area during the winter. These results suggest that mixing between Units 1 and 2 can be extensive. Redfish from the Saguenay Fjord were elementally distinct yet genetically similar from those from other areas, indicating that they represented a sink population, colonized at a relatively young age from one of the existing source populations.

A combined Bayesian analysis of both the otolith elemental fingerprints and the genetic results was also carried out for *S. fasciatus* and *S. mentella*. There were too few sampling sites available for *S. fasciatus* to be able to reconstruct seasonal movements. However, the combined Bayesian analysis for *S. mentella* reinforced the conclusions based on the elemental fingerprints, that the redfish moved towards the entrance of the Gulf (southeast) during the fall/winter and returned (moved to the northwest) in the spring/summer (see red arrows on Figure 4).

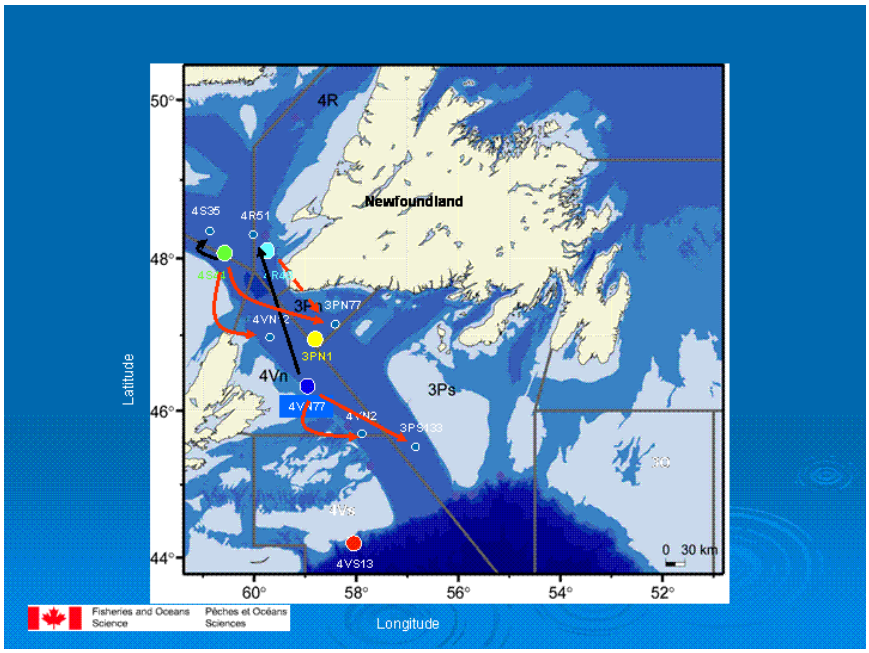

Figure 4. Winter migration of Sebastes mentella reconstructed from a Bayesian analysis of otolith elemental fingerprint and genetics data (see also Figure 5 for the geographic location of S. mentella samples).

Stock structure based on population genetic data

The population structure of *S. fasciatus* and *S. mentella* is described in two recent independent studies using molecular markers (Roques *et al*., 2001; 2002; Valentin 2006). Valentin (2006) also used geometric morphometrics to assess the population structure of both species. These studies cover a very large proportion of *S. fasciatus* and *S. mentella* distribution range (Figures 3, 4 and 5; see also illustrations in Roques *et al*., 2001, 2002). The results of both studies are in general agreement and reveal the existence of some stock structure for *S. mentella* as well as for *S. fasciatus* in the Northwest Atlantic.

Two populations are detected for *S. mentella* in the Northwest Atlantic: (1) the Gulf of St. Lawrence - Laurentian Channel (Units 1 and 2) and (2) the Southern and Northern Grand Banks and Labrador Sea (NAFO Divisions 3LN, 3O, 2GHJ-3K). The studies of Roques *et al.* (2002) and Valentin (2006) do not reveal significant genetic differences between *S. mentella* from Units 1 and 2. The phylogenetic tree (Figure 6) clearly shows that all samples from Units 1 and 2 are closely related to each other. Other indices of genetic differentiation (such as *F*st) also do not indicate differentiation between *S. mentella* samples collected in these two management units. Furthermore, the strong genetic homogeneity for *S. mentella* within the Gulf of St. Lawrence – Laurentian Channel (Units 1 and 2) is supported by the morphometric data. Considering the good geographical coverage of the two studies, homogeneity seems to be the rule for *S. mentella* in the Gulf of St. Lawrence – Laurentian Channel area.

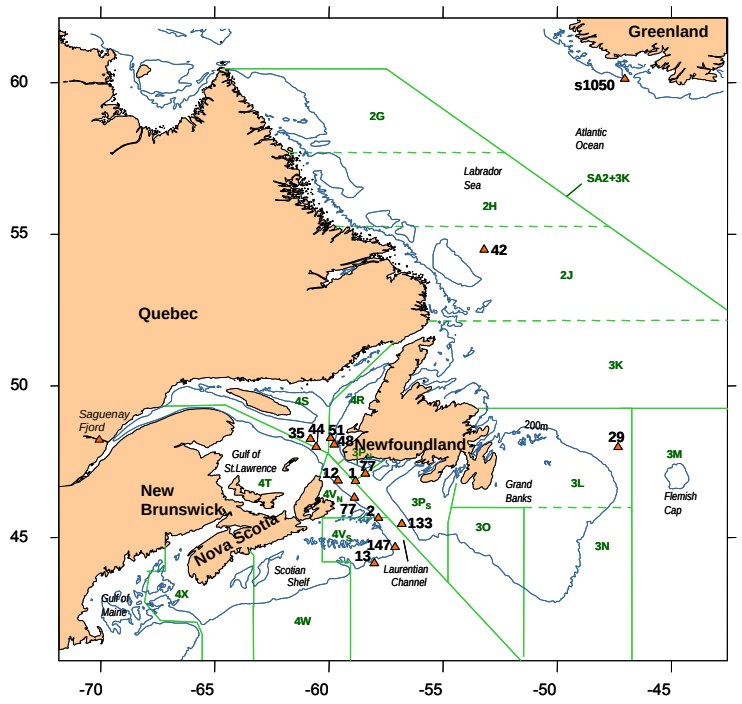

Figure 5. Map of the Northwest Atlantic showing the geographical position of the 16 Sebastes mentella samples used to assess population structure of this species (modified from Valentin 2006). NAFO Divisions are also indicated.

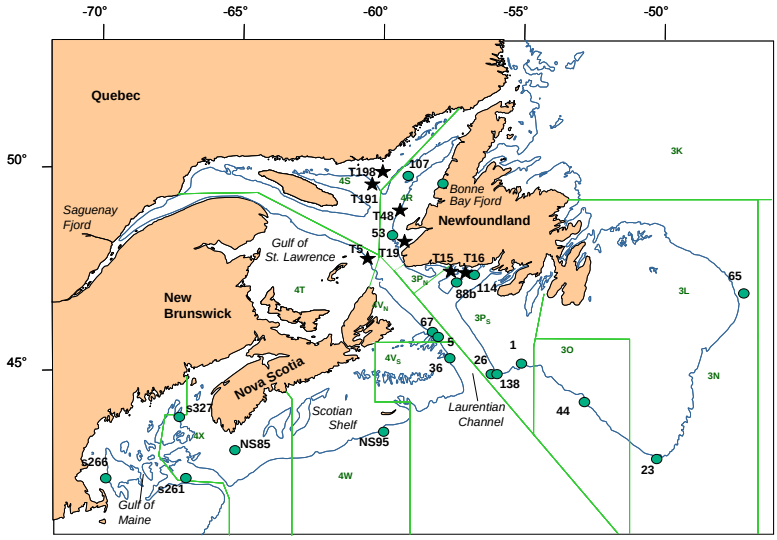

Figure 6. Map of the Gulf of St. Lawrence showing the sampling sites of the 19 Sebastes fasciatus samples analyzed by Valentin (2006) (circle) and of the 7 samples of the 2003 year-class (stars) sampled in 2005. NAFO Divisions are also indicated.

The overall population structure of *S. fasciatus* is more complex. Results of the different studies suggest the existence of local heterogeneity superimposed with larger spatial scale patterns. The population structure of *S. fasciatus* appears to be characterized by the presence of 3 broad groups corresponding to three geographic areas (Figure 7). The first group comprises only samples from the Gulf of St. Lawrence – Laurentian Channel. However, there are indications of genetic heterogeneity within this area. For instance, fish from some samples within this area (see Fig. 5: samples #53 in 4R and #5 in 4VN) are genetically related to the southern group. Furthermore, the population of the Bonne Bay Fjord is genetically differentiated and represents an isolated population within Unit 1. The second group (the northern group) comprises the samples from the slope of the Grand Banks (3LNO) to the southern margin of Unit 2 (southern tip of St. Pierre Bank, with possible ramification on the slope of Nova Scotia Shelf). The third group (southern group) comprises the Gulf of Maine and Nova Scotia Shelf. Overall, this southern group tends to be genetically differentiated from the northern group and from that of the Gulf of St. Lawrence – Laurentian Channel.

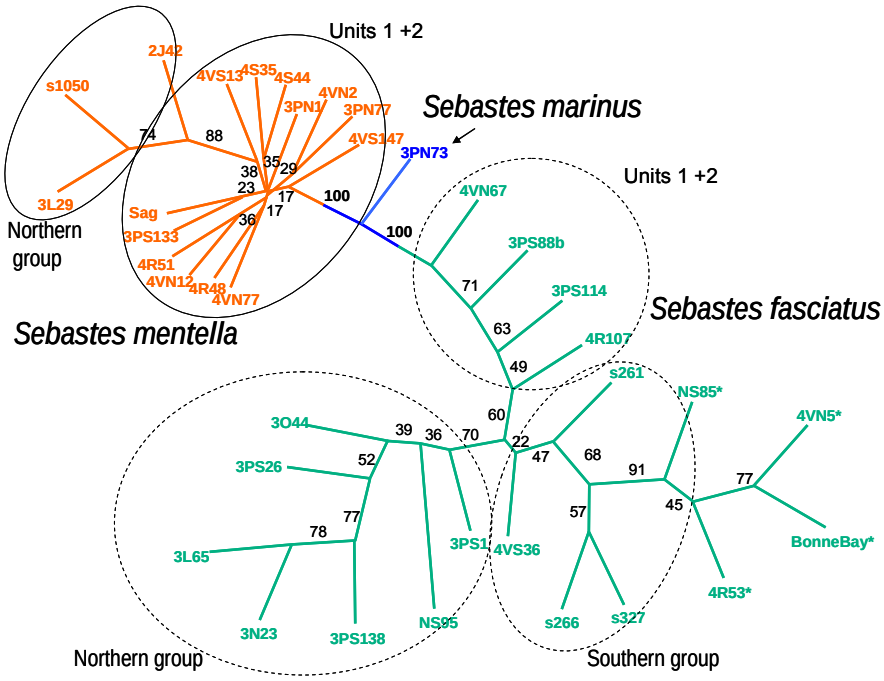

*Figure 7. Neighbour-joining tree illustrating the relationship between different samples of Sebastes fasciatus, S. mentella and S. marinus. The three broad genetic populations observed for S. fasciatus (dotted circles) and the S. mentella genetic populations from Units 1 and 2 (continuous circle) are indicated. The symbol * identifies samples from a given geographic area that are genetically different from the other samples from that area (indication of genetic heterogeneity within S. fasciatus), Modified from Valentin (2006).*

In conclusion, genetic studies on *S. mentella* and *S. fasciatus* show that, within each species, individuals from Units 1 and 2 belong to one population which is differentiated from those outside the Gulf of St. Lawrence – Laurentian Channel area. It seems that redfish movement (adults but most likely juveniles) as well as larval dispersal may explain the absence of differentiation between Units 1 and 2 for the two species. Differentiation between Gulf of St. Lawrence – Laurentian Channel redfish population and those outside this area can largely but not exclusively be attributed to the presence of introgressed individuals in Units 1 and 2. For *S.*

fasciatus, the relevance of the southern limit of Unit 2 is questioned by samples from this area belonging to the northern group.

Analyses of the 2003 year-class

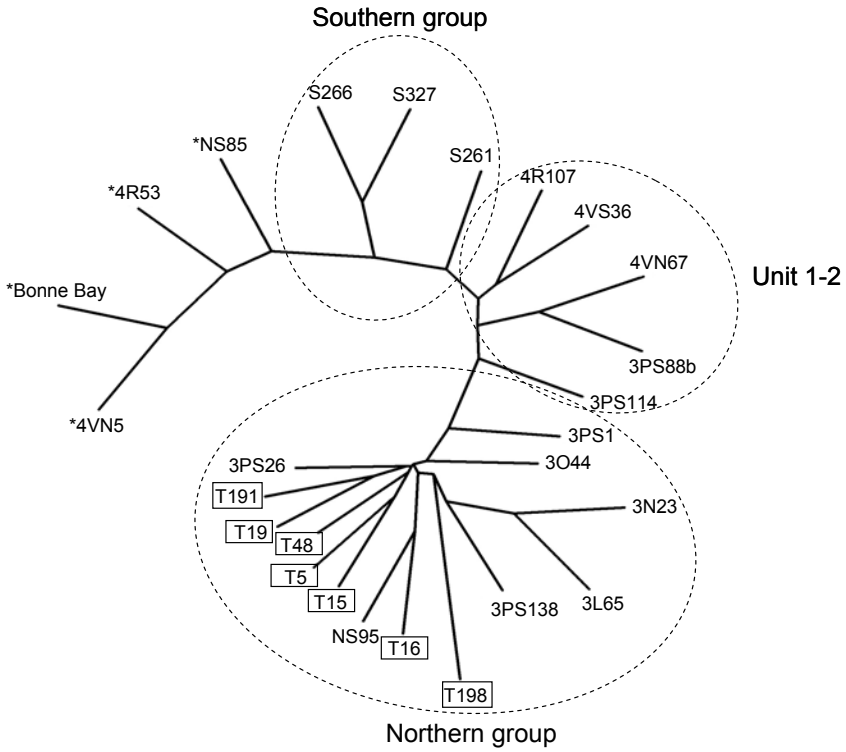

Figure 8. Genetic relationships between the seven samples of the 2003 year-class (in boxes) collected in 2005 in Units 1 and 2 and the samples of adults Sebastes fasciatus analysed in Valentin's study (2006). The 2003 year-class samples group with the adult samples from the southern margin of Unit 2, within the northern group.

Samples of redfish from the relatively strong 2003 year-class were collected in 2005 in the Gulf of St. Lawrence and the Laurentian Channel, i.e. Unit 1 and 2 (Figure 6). These samples were analyzed using the same microsatellite loci as those used in Valentin (2006) and compared to the *S. fasciatus* adults of Valentin's (2006) study. The 2003 redfish year-class belongs to *S. fasciatus.* There are no genetic difference among the seven samples (*F*st not different from 0), suggesting that Units 1 and 2 comprise a single population. However, the genetic characteristics of the 2003 year-class sampled as juveniles differ from those of the adults from Units 1 and 2. Indeed, these juveniles show no sign of introgression. Moreover, they all appear to be more related to the adults from the southern margin of Unit 2 which, as noted previously, shows a stronger relationship with redfish from the northern group (Figure 7).

CONCLUSIONS AND ADVICE

An important conclusion that can be drawn from the genetic and morphometric studies of Roques et al. (2001, 2002) and Valentin (2006) is that there is no genetic difference between redfish from Unit 1 and Unit 2 although some genetic heterogeneity is detected within these management units. For both species, the scale at which genetic differentiation is observed appears to be much larger than the actual management units. The connectivity between Units 1 and 2 is most obvious for *S. mentella*. For this species all samples of the 2 management units are grouped together on the phylogenetic tree based on genetic data. The population structure of *S. fasciatus* is more complex. For this species, three genetic groups are observed (northern group including the southern margin of Unit 2, southern group, and Gulf of St. Lawrence─Laurentian Channel group).

The genetic analyses show that redfish of the 2003 year-class belong to *S. fasciatus* and the characteristics of this cohort differ from those generally found in Units 1 and 2. Indeed, the 2003 year-class show no sign of introgression and is genetically closer to *S. fasciatus* from the southern margin of Unit 2 which is more closely connected with the northern group. These observations suggest that redfish from the northern group also interact with Units 1 and 2. The rationale of such an event and its long-term consequences on the population of Units 1 and 2 should be investigated. The results also suggest that it may be necessary to examine the interrelation between Unit 2 and other management units of the northern group.

The geographic distribution of *S. fasciatus* and *S. mentella* within Units 1 and 2 is patchy rather than continuous. Indeed, the study of otolith chemical signatures shows differences between aggregations suggesting that the aggregations may not mix to a great extent. Some genetic heterogeneity is also observed. It has been suggested that these aggregations can be destroyed if, for example, they are overexploited. Given the fact that redfish reproduction and recruitment dynamics are not well understood, it is recommended that the complexity of the redfish geographic distribution should be taken into consideration in the stock assessment and in the development and application of conservation and management strategies.

Given the difference observed in the biology, distribution, and population structure of *S. mentella* and *S. fasciatus*, it appears that managing redfish as one group as it is done presently may not be the most appropriate strategy. Therefore, it is proposed that the scientific data should be re-analyzed taking into consideration the presence of two species each of which showing population substructure. Finally, and in order to define the status of each species in the Gulf of St. Lawrence-Laurentian Channel area (the area presently called Unit 1 and Unit 2) and to review the relevant scientific data, a zonal assessment meeting should be organized as soon as possible.

OTHER CONSIDERATIONS

The development and application of a management strategy for each redfish species may not be relevant only for Units 1 and 2. Indeed, such strategy may also be applied in other adjacent management areas where *S. fasciatus* and *S. mentella* co-occur and are managed as one group. It may also be necessary to examine the possible interactions between Units 1 and 2 with other management units.

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