Living Resources Committee

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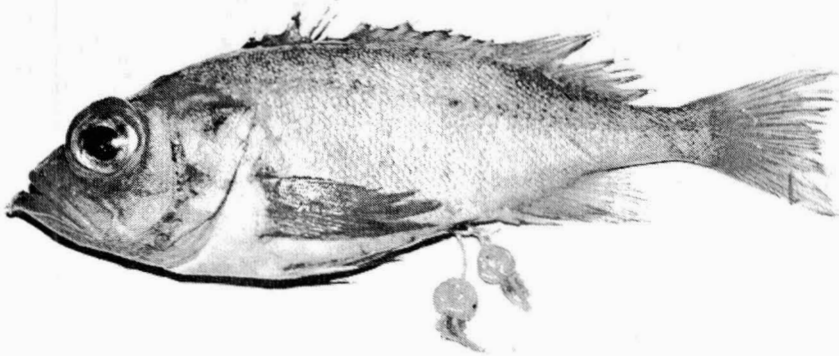
REPORT OF THE

# STUDY GROUP ON REDFISH STOCKS

Hamburg, Germany
28–30 January 1998





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# 1. Introduction

## 1.1 Participants

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## 1.2 Terms of Reference

At the 85th ICES Statutory Meeting it was decided (C.Res.1997/2:62) that

> "the **Study Group on Redfish Stocks** [SGRS] (Chairman: Mr. T. Sigurdsson, Iceland) will be re-established and meet in Hamburg, Germany 28-30 January 1998 to:
>
> a) identify, discuss and coordinate present and future redfish research;
>
> b) plan an international acoustic survey of oceanic redfish in the Irminger Sea and adjacent waters to be conducted in June/July 1999.
>
> SGRS will report to NWWG and to the Living Resources and Baltic Committees at the 1998 Annual Science Conference."

# 2. Redfish in the North Atlantic

The genus *Sebastes* is very common and widely distributed in the North Atlantic. It is found off the coast of Britain, along Norway in the Barents Sea and Spitzbergen, off the Faroe Islands, Iceland, East - Greenland, West - Greenland, and along the east coast of North America from Baffin Island South to Cape Cod (Magnússon and Magnússon, 1995). All *Sebastes* species are viviparous. The extrusion of the larvae takes place in late winter - late spring/early summer but copulation occurs in autumn-early winter. Due to lack of time during this meeting the group decided to deal mostly with the species dealt with by the North-Western Working Group (NWWG). However, a short chapter on the *Sebastes* stocks dealt with at the Arctic Working Group and in the North Western Atlantic (NAFO areas) is presented in order to give an overview of the most important redfish stocks in the North Atlantic.

## 2.1 Stocks in the Northeast Arctic and the North Sea (ICES Sub-areas I, II, III and IV).

### 2.1.1 *Sebastes mentella.*

Figure 2.1.1 shows an outline of the geographical distribution of the Northeast Arctic stock of *S.mentella.* The south-western Barents Sea and the Spitsbergen areas are primarily nursery areas. Although some adult fish may be found in smaller areas, the main behaviour for the fish is to migrate westwards and south-westwards towards the continental slope as it grows and becomes adult. South of 70°N only few specimens less than 28 cm are observed, and south of this latitude *S.mentella* are only found along the slope from about 450 m down to about 650 m. The southern limit of its distribution is not well defined but is believed to be somewhere on the slope northwest of Shetland. The main larval extrusion grounds are along the slope from north of Shetland to west of Bear Island. The peak in larval extrusion takes place during the first half to the middle of April.

The stock is considered to be **outside** safe biological limits. Low recruitment has been observed in the recent surveys and this gives cause for concern about the spawning stock and future recruitment.

This is the only redfish stock in the North Atlantic where an analytical assessment (XSA) is conducted. A rather well defined nursery area makes it possible to survey the juvenile part of the stock, and a time series for a Russian survey covering this part of the stock goes back to 1978. For many years also a Russian commercial trawl CPUE-series (back to 1982) has been used in the XSA-tuning and more recently Norwegian juveniles survey results (back to 1992) have been added. However, ACFM consider the assessment only indicative of the relative trends in stock size, showing that the spawning stock is close to its historically low level.

### 2.1.2 *Sebastes marinus*

Also for *S.marinus* the Barents Sea is a nursery area (Figure 2.1.2). The extension of the distribution area northwards is, however, more restricted than for *S.mentella*, and the Spitsbergen area is thus of minor importance. While for *S.mentella* the Barents Sea and the Spitsbergen areas are considered to contain nearly all the juveniles, juveniles of *S.marinus* are also found on the shelf and along the coast further south. Aggregations of adult *S.marinus* are found all over the continental shelf shallower than 500 m but mainly close to the coast and also to some extent within the fjords. The southernmost observations of this species are outside Bretagne in France, and *S.marinus* are also found spread in the northern North Sea. Known areas of larval extrusions are outside Lofoten/Vesterålen, the Halten Bank and Storegga outside Møre. The peak in

larval extrusion takes place about four weeks later than for *S.mentella*, i.e., middle of May.

An assessment of the stock is not available. Indices from surveys in young fish areas, which only cover part of the nursery area, show a decrease in recruitment to the stock. Data from both surveys and commercial CPUE on larger fish do not indicate any large changes in the adult stock during recent years.

The otoliths of *S.marinus* are considered easier to read than *S.mentella* otoliths. Commercial catch-at-age data together with Norwegian youngfish survey indices (back to 1992) have lead to recent attempts to evaluate the status of this stock by an analytical XSA assessment. However, too many inconsistencies in the input values have so far made it difficult to rely on the results.

### 2.1.3 *Sebastes viviparus*

Although *S. viviparus* may be found down to 400 m it is generally found in shallower waters than the other two stocks, and it also penetrates farther into the fjords where it is the most common redfish species (Figure 2.1.3). Although it is not abundant, it is the most common redfish species in the North Sea and the Skagerrak. The spawning areas have not been properly defined. The peak in larval extrusion is in June. Because of its slow growth and that the size seldom exceeds 30 cm it has not been of commercial interest.

No information exists about the status of this stock. Basic data for assessment or evaluation of the stock are lacking.

## 2.2 Stocks in the North Western Atlantic

There are 3 species of the Genus *Sebastes,* all of them commercially exploited, at Atlantic shelves and continental slopes off West Greenland and Canada, namely golden redfish (*S.marinus* L.), deep sea redfish (*S.mentella* Travin), and Acadian redfish (*S. fasciatus* Kroyer). Acandian redfish is not commonly found off West Greenland (NAFO Subarea 1) where only very few records exist. At the Canadian shelves and slopes, its northern limit of distribution is found at northern Grand Banks NAFO Divisions 2J, 3K while it extends southwards to Georges Bank (NAFO Subarea 5). Golden and deep sea redfish are distributed all over the Davis Strait down to the Nova Scotian shelf (NAFO Divisions 4VWX). In general, deep sea redfish is more dominant at greater depths (200-1000 m) as compared with golden redfish (Saborido-Rey, 1994).

Information on stock composition and status is available from various groundfish surveys. The most important management units (Anon., 1997) are defined as Redfish in NAFO Subarea 1 (West Greenland), Redfish in NAFO Division 3M (Flemish Cap), and Redfish in NAFO Divisions 3L and 3N (Grand Bank). Both golden and deep sea redfish in NAFO Subarea 1 are considered severely depleted (Rätz, 1997a). NAFO Scientific Council recommended a closure of the directed redfish fishery on the Grand Bank for 1998 due to the poor status of the stocks with little or no sign of good recruitment since late 80s (Power, 1997). Biomass and abundance indices from Flemish Cap suggest stability for golden and Acadian redfish while deep sea redfish showed a continuous increase since 1993 from a lower level (Avila de Melo et al., 1997). For redfish off West Greenland and Flemish Cap, a recommendation was given to keep the by-catch of juveniles in the shrimp fishery at the lowest possible level.

## 2.3 Species and stocks in ICES Divisions V and XIV

In ICES Divisions V and XIV there are at least 3 species of redfish, *S.marinus*, *S.mentella* and *S. viviparus*. The last one is not of any significance as a fishery resource and due to lack of time during the meeting it was not discussed further. It should however be noticed that Iceland has started to fish *S. viviparus* in 2 small areas South of Iceland at depths of 150 - 250 m. The catches in 1997 were less than 100 tonnes.

Figure 2.3.1 shows schematically some possible relationships between different stocks of redfish in the Irminger Sea and along the continental slope of E-Greenland-Iceland-Faroe Islands. The question marks indicate lack of knowledge regarding relationships between stocks or components of redfish in the different areas. Furthermore, it remains unclear whether redfish in the Irminger Sea constitute a single stock or whether two or more stocks may be involved. Data indicate that redfish in upper ocean layers differ from those in deeper layers in some respects (cf. ICES C.M. 1997/Assess:13). Fishermen thus prefer to fish in deeper layers as this generally yields larger fish with a lower incidence of parasites. Acoustic studies, (presented in WD7), give abundance data separately for depths above and below 500m. The results indicate that peak abundance in the upper layer (above 500m) occurs far to the Southwest from locations of peak abundance in the lower layer (below 500m). This is in agreement with the horizontal and vertical distribution of catches in the fishery.

Two hypotheses have been put forward to describe redfish in the Irminger Sea:

1. The single-stock hypothesis, suggesting that the mature individuals of a single stock segregate according to age/size;
2. The two-stock hypothesis, suggesting that there is a distinct deep-sea stock, separate from the oceanic stock proper, occupying deeper layers. On this hypothesis, it is an open question whether or not the deep-sea stock in the Irminger Sea is separate from the deep-sea stock on the continental slope.

These questions and hypotheses and methods for their evaluation are discussed in chapter 2.4.

### 2.3.1 *S. marinus*

Adult stock

The status of *S.marinus* in ICES Divisions V and XIV was evaluated in a report of the joint NAFO/ICES study group on biological relationships of the West Greenland and Irminger Sea Redfish stocks, held in 1983 (Anon, 1983). Since then, little new knowledge of the general biology of the species has been obtained but the stock size has declined drastically during the last 10 years (ICES C.M. 1997/ Assess:13). The bulk of larval extrusion takes place in April - May. The only known areas of larval extrusion are Southwest and West of Iceland (Magnússon and Magnússon, 1977; Magnússon, 1980) and South of the Faroe Islands (ICES C.M. 1983/G3). Larval extrusion has not been observed in other regions.

During the last two or three decades the most important fishing grounds for *S.marinus* have been SW and West of Iceland. From the annual Icelandic groundfish survey in March (Pálsson *et al.* 1989) and also from other surveys (Magnússon and Magnússon, 1975; Magnússon *et al.* 1988; Magnússon *et al.* 1990; Sigurðsson *et al.*,1997), it has been shown that the size of *S.marinus* increases from North to South (Figure 2.3.2). These results indicate a migration from the nursery areas North and East of Iceland towards the fishing grounds in the West and Southwest. Another important fishery area is the "Rosengarten", between Iceland and the Faroe Islands; the fishery extends on to the shelf of the Faroe Islands (Reinert, 1990). The catches in these areas have, however, declined drastically in recent years. Although larval extrusion has not been observed in these areas and no evidence of a self-sustaining stock, some ideas have been put forward (Reinert, 1990) concerning the origin of the redfish in these areas.

At East Greenland, catches have declined drastically during the last three decades and less than 100 tonnes were caught in 1996, compared to almost 60 thousand tonnes in 1976 and between 15 and 31 thousand tonnes in the period from 1978-1983. During the last few years there have been only negligible quantities of both juvenile and adult ($\geq$ 17 cm.) *S.marinus* in Greenland waters (Rätz, 1997 also in ICES C.M. 1997/Assess:13). The stock size at East Greenland 15 years ago has been estimated as approx. 400-450 thousand tonnes, about 100 - 150 000 tonnes in 1987-1988 (Rätz, 1997b, Yatsu and Jörgensen, 1988) but during the most recent years the stock at East Greenland has declined down to only a few thousand tonnes (Rätz, 1997b).

Fry and larval drift

From the 0-group part of the NORWESTLANT surveys in 1963 (Anon, 1968) a general trend in the drift of larvae was indicated from the central and eastern Irminger Sea towards the slopes along the East Greenland shelf and to some extent around Cape Farewell. That is in accordance with the general direction of currents in the area (Figure 2.3.3).

Redfish fry off West Greenland was only observed in rather small quantities both prior to and after 1983 (Anon, 1983, ICES C. M. 1997/Assess:13). German annual surveys West and East of Greenland have shown that only very small quantities of small redfish (<17 cm) are found West of Cape Farwell.

From Icelandic 0-group surveys, drift of redfish fry from the areas of larval extrusion to areas West and North of Iceland has also been observed (Einarsson, 1960; Magnússon and Jóhannesson, 1997; Magnússon and Sveinbjörnsson, 1995; Sveinbjörnsson, 1996; Sveinbjörnsson and Jónsson, 1997). These consist almost entirely of *S.marinus* (see i.e. Pálsson *et al.* 1989, Pálsson *et al.* 1997; Sigurdsson *et al.* 1997). It is very rare to find small (juveniles) *S.mentella* around Iceland.

In the 1983 Redfish Study Group report (ICES C.M. 1983/G:3) and in Magnússon and Jóhannesson (1997) the distribution of *S.marinus* 0-group at East Greenland was evaluated, showing that there are considerable amounts of *S.marinus* at East Greenland and that it is mixed with *S.mentella* in variable proportions in different subareas and periods (WD1).

Juveniles – nursery areas

There are only available data on nursery grounds of *S.marinus* in Icelandic and Greenlandic waters but no nursery grounds are known in the Faroe Islands area.

In Icelandic waters, nursery areas for *S.marinus* are found mostly West and North of Iceland at depths between 50 and approximately 350 m, but also in the South and East (ICES C.M. 1983/G:3; Einarsson, 1960; Magnússon and Magnússon 1975; Pálsson *et al.* 1997). As the length (age) increases, migration of young *S.marinus* along the North coast to the West coast takes place towards the most important fishing areas around Iceland. During the period since the Icelandic groundfish survey started in 1985 there seem to have been two relatively strong yearclasses (Stefánsson and Sigurðsson, 1997) growing up North and Northwest of Iceland, most probably the 1985 and 1990 yearclasses. The former have begun to reach the fishery at the fishing banks west and Southwest of Iceland.

Nursery grounds of *S.marinus* off East and West Greenland are found on the continental shelf are mixed with *S.mentella*. In recent years the abundance of *S.marinus* at West and East Greenland has been extremely low and there are no indications of recruitment according to German investigations (Rätz, 1997b). Earlier investigations have shown much larger quantities of juvenile *S.marinus* on the continental shelf and slope of Greenland (i.e. Anon, 1961).

"Giant" redfish

Already in 1960, Kotthaus (In: Anon, 1961) came up with the idea that there might be a new stock or even a

new species of *Sebastes*. New information presented in Johansen *et al.* (1996) and information later presented in Johansen *et al.* (1997) were briefly discussed during 1997 NWWG meeting (ICES C.M. 1997/Assess:13). At that time, it was concluded that, due to the size, the genetic difference and the morphological resemblance with *S.marinus*, these large redfish most likely belong to the so called "giant" *S.marinus* observed and described from waters outside Greenland and Iceland (e.g., Altukhov and Nefyodov 1968, Kotthaus 1960b,c, Kosswig 1974). Therefore it was concluded that there was "sufficient biological evidence to keep these "giants" as a separate management unit not included in the catch statistics or assessment of common *S.marinus* at East-Greenland, Iceland and the Faroe Islands".

A fishery on the "giant" redfish with longliners and gillnets started on the Reykjanes ridge in 1996 outside the Icelandic 200 miles EEZ. The highest catchrates of redfish were at depths between 500 and 800 m (WD2). According to Faroe-Norwegian investigations (Hareide and Thomsen, 1997) one of the main species in this fishery was a *Sebastes* type morphologically similar to *S.marinus*. Most of these fishes were above 65 cm (length distribution between 46 and 89 cm) and 5 kg. Independent Icelandic and Norwegian otolith readings using the same method showed that the age of these fishes were in the range of 15-50 years old (WD 2).

New information presented (WD2) could indicate that the "giants" do mature at much greater lengths than *S.marinus* (50-65 cm for females and 46-60 cm for males, Table 2.3.1). Samples taken widely in ICES Divisions V and XIV as well as in the Arctic areas have shown that nearly 100% of the *S.marinus* of lengths greater than 40-45 cm are mature; this applies to both males and females. Therefore, these new maturity data support the indications from genetic and morphological work (e.g., Altukhov and Nefyodov 1968, Kotthaus 1960b,c, Kosswig 1974, Johansen *et al.* 1996, Johansen *et al.* 1997) that the "giant" redfish might be a separate stock.

The limits of the distribution area of giant redfish is unknown. It is found along the shelves both off Iceland and Greenland. (Jakob Magnússon. Pers. inf.). Along the Reykjanes Ridge the species is distributed South to 52°N (Hareide & Thompson 1997, Langedal & Hareide 1997). "Giant" *S.marinus* caught by fishermen back to the 1930-ies in Icelandic and Greenland waters show that the geographical distribution may have been wider in former days. "Giant" *S.marinus* are still occasionally caught in demersal trawl in Division V. The young fish and nursery areas for these large redfish have not yet been found.

### 2.3.2 *S. mentella*

As described above there are different views on the stock structure of *S.mentella* in the ICES Sub-areas V and XIV(Figure 2.3.1). In order to be consistent with these different views, this overview of *S.mentella* deals with the following 3 groups: Deep-sea *S.mentella* on the shelf, oceanic *S.mentella* and "pelagic deep-sea *S.mentella*".

#### 2.3.2.1 Deep-sea *S.mentella* on the shelf

Traditionally, the *S.mentella* on the shelves and banks around the Faroe Islands, Iceland and at East Greenland are treated as one stock unit, with a common area of larval extrusion to the SW of Iceland, a drift of the pelagic fry towards the nursery areas on relatively shallow waters at East Greenland, and feeding and copulation areas on the shelves and banks around Faroe Islands, Iceland and at East Greenland. This implies extensive migrations of the mature fish (mainly females) between the feeding and the spawning areas and of the immature fish between nursery and feeding areas (see i.e. Anon, 1983).

This definition of a stock unit has been questioned. In Faroese waters spawning has been observed in some years to the south and west of the islands, implying that there could be a local component in the area; no nursery areas have, however, been found so far (Reinert, 1990). A relationship to other ICES areas (II and IV) have also been suggested (Reinert et al., 1992, Reinert and Lastein, 1992). The question of a possible relationship between this stock unit and the two pelagic types in the Irminger Sea has been raised several times, for example in many reports of the North Western Working Group.

Although the annual catches of *S.mentella* have varied considerably, the general pattern has been increasing catches during the past two decades with reduced catches in the most recent years. The bulk of the catches have usually been taken in Division Va but in some years total catches in Division Vb and Sub-area XIV have exceeded the ones in Va. In summary, compared to the average catch level in the 1980s of about 42 000 tonnes, the catch increased from 67 000 tonnes in 1991 to 83 000 tonnes in 1994. The catches have since declined and were at the 1980 level in 1996.

The development in the catches seems to reflect the level of the stock as well. The main reason for the most recent trend has been a considerable increase in effort; a heavy fishery on small redfish in East Greenland has also taken place in recent years. According to German survey data there is a depletion of the adult stock in Sub-area XIV but the same surveys have shown very high numbers of young fish in the most recent years. The peak in the length distribution is now between 28-30 cm. And it seems that the fish have been growing by approx. 2 cm per year during the last years. Despite recent effort reductions in Division V the fishable stock seems, at present, to be at a very low level.

#### 2.3.2.2 Oceanic *S. mentella*

A pelagic stock of *S.mentella* with main distribution of adult fish in the open Irminger Sea (Fig. 2.3.4) was defined by the ICES Study Group on Redfish Stocks in 1992 and named oceanic *S.mentella* compared with the

above mentioned *S.mentella* on the shelves which then was named deep-sea *S.mentella* (ICES C.M. 1992/G:14). The spawning area of this redfish is to the west of the Reykjanes Ridge in the Irminger Sea, geographically partly overlapping the spawning areas of the deep-sea *S.mentella*. The nursery areas are not known but the pelagic fry drift towards Greenland and it is believed that nursery areas are along the coast of East- and West Greenland. Feeding and copulation areas are both in the international parts of the Irminger Sea as well as in the national EEZ's of Greenland and Iceland.

As stated above the status of this fish assemblage as a separate stock unit has been debated for many years. Central in this debate has been the possible relationships to the other pelagic *S.mentella* type in the Irminger Sea and to the shelf deep-sea *S.mentella*. In section 2.4 of this report a list of criteria used to separate the oceanic and the deep-sea redfish can be found. One of these criteria is the heavy infestation rate of the ectoparasite *Sphyrion lumpii*. This parasite is also found on the deep-sea *S.mentella* from the shelves although the infestation rate is much smaller; however, from many sources it can be found that this infestation rate was higher in the past. A careful monitoring of the infestation rate is therefore necessary and several nations have already implemented registration of infestation rates and parasite distribution patterns in their routine sampling schemes of this fishery.

Fishery on this stock started in 1982 when Russian vessels caught more than 60 000 t. In the following years more nations entered the fishery and the catches rose correspondingly to over 105 000 tonnes in 1986, but declined thereafter to only 25 000 tonnes in 1991, mainly due to a reduction in fishing effort. The main fishing period was April-August in depths shallower than 500 m. From 1992 the catches have increased dramatically to 171 000 tonnes and 163 000 tonnes in 1995 and 1996, respectively. Catch figures for 1997 were not available to the meeting.

Reasons for this increase in the catches are participation of more nations/vessels in the fishery, technical improvements (larger and lighter trawls) and an expansion of the fishery both horizontally and vertically. In fact most of the catches in the latest years have been taken deeper than 500 m. Despite the increase in total catches, CPUE has been declining.

The stock has been estimated by acoustics down to approx. 500 m depth since 1991. The investigated area and number of participating vessels have varied so it is difficult to compare results from different years, but the stock seems to have been stable on a level of more than 2.2 million tonnes up to 1996. The estimated value in 1996 was only 1.6 million tonnes, but this was presumably an underestimate due to a deeper distribution of the stock caused by changed hydrographical conditions (Magnússon *et al.*, 1996). There are, however, concerns about the development in the stock, as the commercial CPUE has been decreasing in recent years, and this is supported by the Russian 1997 acoustic survey giving a stock size on same level as the 1996 value (WD7).

The fishery on this stock is now regulated through TAC's agreed upon in North-East Atlantic Fisheries Commission (NEAFC). The TAC level is based on the acoustical estimates which only apply to depths shallower than 500 m. And, as stated above, most of the fishery takes place below 500 m. The problem is magnified considerably by the finding of another type of *S.mentella* deeper than 500 m (see below) and of the fact that the oceanic *S.mentella* also has been distributed deeper than 500 m in recent years.

Given these uncertainties, the above mentioned development in the catches must be described as uncertain because it is at present not known how much of the oceanic *S.mentella* is actually caught in recent years. An attempt to improve the situation has been made by the NEAFC in trying to have the nations report the catches on a depth base. Not all nations have, so far, followed this instruction.

#### 2.3.2.3 "Pelagic deep-sea *S. mentella*"

During the late 1980s a second type of *S.mentella*, resembling the deep-sea *S.mentella*, was found pelagic in the Irminger Sea, at that time distributed below the oceanic *S.mentella* (Reinert, 1987 and Magnússon, 1983). The status of this redfish is not known at present but due to difficulties in separating the catches in the area into the two types, the North Western Working Group at the 1997 meeting – for practical reasons – decided to treat all pelagic *S.mentella* in the Irminger Sea as one management unit. Biologically, however, there are indications of two types, and consequently this redfish in principle should be treated separately as pelagic deep-sea *S.mentella* until more is known on this matter.

For the same reasons as for the oceanic *S.mentella*, it is not known how large a proportion of the catches this pelagic deep-sea type *S.mentella* constitute, but due to the changed behaviour of the fishing fleet and to the higher marked value of this fish, the majority of the catches in recent years could be from this type.

The Russian 1997 acoustic survey in the area estimated the biomass of redfish below 500 m to be in the order of 500 000 t. This value must be treated with caution, however, due to the mixing with the other pelagic redfish in the area and due to the fact that this is the first attempt to use acoustics below 500 m in the Irminger Sea.

It can not be excluded that this redfish might be related to the shelf deep-sea *S.mentella*. If this is the case and the precautionary approach is applied in the management of this stock, than the catches of redfish in the Irminger Sea below 500 m should be reduced considerably (or even stopped) until a recovery has been observed on the shelves.

Ongoing research on redfish in ICES areas V and XIV

The following research work is in progress:

- Icelandic groundfish survey since 1985 (4-5 vessels for 2-3 weeks in March). 580 stations on Icelandic shelf down to 500 m depth (*S.marinus* and partly deep sea *S.mentella*).
- Icelandic autumn survey since 1996 (2 vessels in October). 300 stations on Icelandic shelf (excluding the South coast) down to 1500 m depth (*S.marinus* and deep sea *S.mentella*).
- Icelandic 0-group survey (2 vessels in August) 1970–1995. 2–4 weeks with different degree of coverage from west Iceland to east Greenland South to cape Farwell (all stocks).
- German groundfish survey since 1982 (1 vessel in Sept - Oct). Around 200 stations on the shelf of West and East Greenland down to 400 m depth (*S.marinus* and *S.mentella*).
- Greenland trawl survey since 1992 (1 vessel in July-October). Around 80 hauls on East Greenland and 160 on West at depths down to 600 m (*S.marinus* and *S.mentella*).
- Faroes groundfish survey since 1980 (1 vessel in February - March). Around 150 stations taken on the shelf of Faroes Islands down to 500 m depth (*S.marinus*).
- Genetic - Stock identificaton of *S.mentella*. Work is ongoing both in Norway and Iceland. Material sampled mostly with pwlagic- and bottom trawl.
- Genetic - "giants" work ongoing both in Norway and Iceland. Material sampled from longliners and trawl.
- Morphological work on redfish stocks has been going on in Spain for several years (in ICES areas I, II and NAFO areas) but will be started in 1998 on *S.mentella* in the Irminger Sea.

In addition, biological information is collected from numerous other surveys and information from fishery related data is also collected.

2.3.2.4 Further research - recommendations

Stock identification of *S.mentella* and *S.marinus*. It is important to work further on genetic methods and morphological methods should also be applied

Reproductive biology – both spawning and larval drift—of *S.marinus* in the area between Iceland and the Faroe Islands needs to be studied in order to determine whether these fish might constitute a separate stock element.

Age readings. In order to assess the redfish stocks successfully, it is important to investigate further the possibility of developing a reliable age reading technique. Iceland has just started to investigate the otoliths of *S.marinus* collected in recent years and Norway, Russia and Spain has worked further on the matter since the last age reading workshop held in Germany in 1995 (see chapter 2.5).

Iceland has planned a survey on oceanic redfish in May 1998, where the main purpose will be to define the distribution area of the deep-sea component of *S.mentella*. The survey area will extend from the shelf SW of Iceland to south of the areas where the commercial fleet usually trawls on the deeper component.

## 2.4 Stock identification

Several methods have been used to identify, delimit and discriminate stocks, such as analysis of populational, physiological, behavioural, meristic, morphometric (external shape and osteology) biochemical and genetic parameters (Ihssen *et al.*, 1981; ICES C.M. 1996/M:1). The most used have been morphometric analysis, protein electrophoresis and more recently DNA analysis.

In the Northeast Atlantic, two stocks of *S.marinus* are considered to exist (Northeast Arctic and East Greenland-Iceland-Faroes stock) and three *S.mentella* stocks (Northeast Arctic, Greenland-Iceland-Faroe Island deep-sea stock and Irminger Sea oceanic stock). Large redfish, named "giant" redfish, have been found in different areas of the Reykjanes Ridge, on the continental slopes of Iceland and Greenland and Faroe Islands (see section 2.3.1). Although they are morphologically similar to *S.marinus*, some evidence (mainly genetic and size at maturity) shows differences.

In the Northwest Atlantic there are considered to exist nine redfish management units (Davis Strait and West Greenland (NAFO Subarea 0+1), Labrador and North of Newfoundland (SA2 + Div 3K), Great Bank of Newfoundland (Div 3LN), Flemish Cap (Div 3M), Southwest (Tail) of the Great Bank (Div 3NO), St Pierre Bank (Div 3P), Gulf of St Lawrence (Div 4RST), Nova Scotia (Div 4VWX), Gulf of Maine-Georges Bank (Div 5).

In the Irminger Sea *S.mentella* is considered to exist as two types. The mature part of the oceanic type *S.mentella*, is pelagic and inhabits depths from about 50 m to 1,000 m in the Irminger Sea. In 1983 another mature *S.mentella* type resembling the deep-sea *S.mentella* was discovered in the Irminger Sea in pelagic waters mainly deeper than 500 meters, far from the continental shelves (Magnússon, 1983). Until then, deep-sea *S.mentella* was considered to be restricted along the continental. The reported differentiation of the two *S.mentella* types in the Irminger Sea has been based on the following criteria (e.g., Magnússon *et al.* 1994, Magnússon *et al.* 1995):

*Colour*..... the deep-sea type is redder, while the

| | |
|---|---|
| | oceanic type is more greyish red |
| *Length-weight relationship*..... | the deep-sea type being more stout and heavier at a certain length |
| *Length at first maturity*..... | The deep-sea type being longer when first mature |
| *Parasite infestation*..... | The deep-sea type being less infested by the *Sphyrion lumpi* ectoparasite |

In addition, the following criteria are used to aid in the identification of types (Magnússon, 1991):

- The general appearance is different: the oceanic redfish does usually not have the uniform, bright colour as the deep-sea redfish. It is somewhat darker on the back and the colour in general gives an impression of not being "clean".
- The oceanic redfish is very frequently with black and red spots or a mixture of both on the skin. Such spots are sometimes observed on the deep-sea redfish but rather seldom.
- Dark or grey spots are frequently in the fillet of the oceanic redfish but are hardly seen in the fillet of the deep-sea redfish.
- The oceanic redfish is often slightly thinner (just behind the head) than the deep-sea redfish.

**An operational manual for the identification of different *S.mentella* types is urgently required.**

Iceland has discriminated between the two types in the fisheries since 1995. ICES has however, to date, treated them as one stock unit. It is thought that the nursery grounds for the oceanic redfish could be in the Davis Strait, off West and East Greenland, Baffin Island and Labrador and the distribution of the deep-sea redfish is more restricted to east Greenland (Magnússon and Magnússon 1995). Bakay (1988) used *S. lumpi* along with other parasites to study samples of *S.mentella* from different areas in the Irminger Sea and Flemish Cap Bank. He concluded that there is isolation between fish from the two locations, but indication of interrelation between oceanic and deep-sea *S.mentella* from the north-east, central and southern areas of the Irminger Sea.

The general view has been that infestation rate decreased with increased depth (see i.e. Magnússon et al, 1995; Magnússon and Magnússon, 1995). Studies from 1995 and 1996 based on infestation rates and parasites distribution pattern (Del Rio *et al.*, 1996; Sarralde *et al.*, 1997) have, however, showed the oppoiside. According to the 1996 study (Sarralde et al,1997), the results must be taken with caution because the samples from different depths were taken at differnt seasons and the seasonality in the infestation rates has been shown to be significant (Bakay, 1988).

NEAFC has requested ICES to provide information on the relationship between deep-sea *S.mentella* of the Irminger Sea and the deep-sea *S.mentella* fished in demersal fisheries on the continental shelf and slope. Work is currently being done to gain more knowledge about what is believed to be pelagic deep-sea *S.mentella* in the Irminger Sea (e.g., genetic analyses).

Usually two groups of fish are considered as two different stocks when evidence (i.e. biological parameters, genetic and morphometric) shows clear differences; meanwhile both groups are considered as a single stock. However, it is common to consider two groups of fish, well geographically separated as two stocks (or at least as a separate management unit) based on the distribution patterns of the adult fishes. Regarding the two types of *S.mentella* in the Irminger Sea (oceanic and deep-sea) it is known that they live in the same area with a considerable overlap in distribution, at least during the extrusion of the larvae, and the two types are not completely separated bathymetrically during the feeding period.

Although there are some indications of difference between different types of *S.mentella* (section 2.4.1), there is, **at the present time, no sufficient conclusive evidence to allow us to determine whether there are one or two stocks of pelagic *S.mentella* in the Irminger Sea.**

### 2.4.1 *Genetic work*

Following chapter deals with genetic work – past and present – in North-eastern Atlantic (ICES areas). Review of other areas (Northwestern Atlantic and Pacific Ocean); see Annex 3.

#### 2.4.1.1 Molecular genetic markers

The population genetic studies are hoped to help in determining how many separate stocks there are of *S.marinus* and *S.mentella* over their distribution range in the North Atlantic. Does the redfish caught at great depth in the Irminger Sea interbreed with the deep-sea redfish in adjacent waters around Iceland, Greenland, Faroe ISlands and Norway?

The different molecular genetic markers used in population genetic studies can be grouped into three main classes: I. Protein and isozyme analyses. II. Mitochondrial DNA (mtDNA) analyses and III. Nuclear DNA (nDNA) analyses (**ANNEX 3**).

Lewontin and Hubby (1966) and Harris (1966) were among the first to show the usefulness of isozyme data for population genetic studies. Since then, this method has been used to study systematics, sociobiology, genomic organisation and population genetics. Population genetic data today are mainly based on isozymes and other nuclear DNA (nDNA) and mitochondrial DNA (mtDNA) markers, such as VNTR DNA sequences (multilocus DNA fingerprinting), mini- and microsatellites, cDNA RFLP (copyDNA restriction fragment length polymorphism), RAPD (random amplified polymorphic DNA), AFLP analyses (amplified fragment length polymorphism), nDNA and mtDNA PCR (polymerase chain reaction) amplification

and sequencing, mtDNA RFLP and mtDNA PCR and RFLP. The isozyme method is relatively inexpensive, fast (screening of large part of the genome) and easy to use. The use of nDNA and mtDNA primers in PCR in conjugation with RFLP's and sequencing is a fast and easy approach and has now made it possible to detect highly polymorphic loci for use in population genetic studies.

The different genetic markers differ in discrimination power. Choosing which genetic method and markers to use depends on the question being addressed, i.e. paternity, population or evolutionary studies. DNA fingerprinting, RAPD's and mtDNA RFLP s have certain drawbacks in population genetic studies since they are based on presence and absence of DNA fragments of which Mendelian inheritance isn't known, making it impossible to test if the population fits the Hardy-Weinberg equilibrium (homogeneity of a population) and allele frequency differences between populations (divergence) (ICES C.M 1996/M:1).

### 2.4.1.2 Past genetic redfish studies in the Northeast Atlantic

The genetic methods that have been used to study North Atlantic *Sebastes* species and stocks have mainly focused on species discrimination with the use of genetic markers, such as proteins (haemoglobins, haptoglobins, sarcoplasmic, serum & general proteins) and isozymes (Altukhov & Nefyodov, 1968; Johansen *et al.*, 1993; Johnson *et al.*, 1971; McGlade *et al.*, 1983; Nævdal, 1978; Nedreaas & Nævdal, 1989; 1991a; 1991b; Nedreaas *et al.*, 1994; Nefyodov, 1971; Payne & Ni, 1982; Rehbein 1983; 1996; Rubec *et al.*, 1991; Trottier *et al.*, 1988; Tsuyuki *et al.*, 1968).

Population structures of Northeastern Atlantic redfish species have been analysed by Nedreaas & Nævdal (1989; 1991a); Nedreaas *et al.* (1994) and Dushchenko (1987) and of the Pacific Ocean by Seeb & Gunderson (1988), using haemoglobins and isozyme analyses.

In those studies, the genetic variation and differentiation within and between the redfish species were found to be low and lowest in *S. mentella*. A need for genetic markers with higher resolution power such as nDNA markers is evident.

**Species identification:**

Rehbein (1983) used sarcoplasmic protein to separate *Helicolenus dactylopterus* and *S. viviparus* from each other and from *S.marinus* and *S.mentella*. Rehbein (1996) used RAPD to separate *S.mentella* and *S.marinus*. The haemoglobin (HB) protein and the malate dehydrogenase (MDH) isozyme in combination, can be used to discriminate between *S.mentella, S.marinus* and *S. viviparus*, but the *HB* marker could, however, not be used on larvae and juveniles less than 7cm long, making it only possible to separate *S. viviparus* from the *S.marinus* and *S.mentella* at those life stages (Nedreaas & Nævdal 1991b; Nævdal, 1978). Johansen *et al.* (1993) used HB and eight isozymes to separate *Helicolenus dactylopterus, S.marinus, S.mentella* and *S. viviparus*. In their study, the haemoglobins for *H. dactylopterus* was diagnostic when compared to *S. mentella* and the isozymes: ALP, CPK, EST, IDHP, LDH, MDH, PGI and PGM for *H. dactylopterus* were diagnostic when compared with the *S. marinus, S. mentella* and *S. viviparus*. Serum proteins and some of the variable isozymes were not diagnostic for species identification and differed in allele frequencies between species (Altukhov & Nefyodov, 1968; Johansen *et al.*, 1993; Nefyodov, 1971). Suggestions that the "giants" are hybrids of *S.marinus* and *S.mentella*, have been made by Altukhov and Nefyodov (1968) based on blood serum protein variation.

In summary, all three *Sebastes* species can be identified by using the two genetic markers HB and MDH except for larvae and juveniles less than 7 cm. In addition, *S. vivparus* can be separated from *S.marinus* and *S.mentella* by sarcoplasmic proteins. Preliminary work using a nDNA RAPD marker indicate that *S.marinus* and *S.mentella* can be separated, which would make the larvae and juvenile species identification possible, but further development of nDNA markers is most likely needed.

**Stock identification:**

Nedreaas & Nævdal (1991a) examined haemoglobins and 10-15 isozymes and Nedreaas *et al.* (1994), heamoglobin and 5 isozymes in Northeast Atlantic *S.marinus, S.mentella* and *S. viviparus*. The *S.marinus* from Greenland waters differed significantly in the *Hb* and *IDHP* allele frequencies from the frequencies in Icelandic, Faroe Islands and Norwegian coastal *S.marinus* indicating that the *S.marinus* in Greenland waters may be a separate stock. Low isozyme genetic variation was found in *S.mentella* off the Norwegian coast, Faroe Islands, in Davis Strait and off East and West-Greenland. (Nedreaas & Nævdal 1991a, Nedreaas *et al.* 1994). Dushchenko (1986) examined six enzyme systems in 1200 pelagic *S.mentella* from the Irminger Sea (56°-62°N, 1981-1982). He found genetic variation at the *MEP* and *GPDH* loci (malic enzyme and glycerophosphate dehydrogenase) but no difference in allele frequencies between six locations in the Irminger Sea.

### 2.4.1.3 ONGOING Genetic Research.

At present various genetic methods are being employed to study the four North Atlantic redfish species (*S.marinus, S.mentella, S. viviparus* and *S. fasciatus*) by: The Marine Research Institute, Iceland; the University of Bergen and The Institute of Marine Research, Bergen, Norway. The methods applied are: haemoglobins, multilocus isozymes, RAPD, cDNA RFLP, microsatellites, rDNA and mtDNA analyses.

Different genetic markers reveal difference in discrimination power. Using a range of various genetic markers helps to find markers with suitable genetic variation for the redfish population studies. Computer programs designed for the statistical analysis of genetic data, such as: *BIOSYS* (Swofford and Selander, 1989), *PANMIX* (Waples and Smouse, 1990), *HIGHSEAS* (Smouse *et al.*, 1990), *PHYLIP* (Felsenstein, 1990), *REAP* (McElroy *et al.* 1991) and others are and will be used to calculate genetic variability and differences, they can detect mixed stocks and also determine to which stock individuals of the mixed stock most likely belong. Migration/gene flow can also be estimated from the genetic data.

The University in Bergen and the Marine Research Institute, Iceland have written three ICES papers (unpublished) on the progress of the Northeastern Atlantic redfish population genetic work: on *S.marinus* along the Reykjanes Ridge (Johansen *et al.* 1997b) and on the deep-sea and oceanic *S.mentella* in the Irminger Sea and adjacent waters (Johansen *et al.* 1996; 1997a).

**Present status of the projects:**

It is important to identify the population genetic structure of the deep-sea and oceanic *S.mentella* in the Irminger Sea and the degree of their possible reproductive isolation by using various genetic markers. Such work is currently under development. At the moment various genetic markers are being developed and used to study the species and stock identification of redfish. The information on markers that have suitable genetic variation for redfish species (larvae and juvenile) and stock identification should be available in 1998.

***S.marinus:*** Preliminary results on the "giant" *S.marinus* haemoglobin phenotypes showed that they were different from the types seen in the ordinary *S.marinus*, in *S.mentella* and *S. viviparus* and that there were significant differences in allele frequencies at the *IDHP-2* locus between the "giants" and the "ordinary" *S.marinus* suggesting that the "giant" could be a separate stock. Redfish samples from two locations at Reykjanes Ridge (within and outside the 200 mile line around Iceland) consisted of different ratios of the "giant" *S.marinus* and ordinary *S.marinus* haemoglobin types, but it is not yet possible to conclude if the "giants" of the two locations are different stocks or not (*IDHP-2* locus monomorphic). The genetic relationship between "giants" from Reykjanes Ridge and Icelandic continental shelf has not been examined and only few samples have been collected from the latter location.

***S.mentella:*** Preliminary results revealed some phenotypes and alleles of the heamoglobin protein and IDHP isozyme that were unique for the deep-sea *S.mentella* (*Hb* types D & E and *IDHP-2*60* allele). There was a difference in *Hb* and *MEP-2** allele frequencies between the deep-sea and oceanic *S.mentella* in the Irminger Sea which give preliminary indication of population differences. No difference was observed between deep-sea *S.mentella* in the Irminger Sea and Icelandic continental shelf at the *MEP-2* locus. Differences in *MEP-2** allele frequencies were found between the *S.mentella* in the Irminger Sea, Norwegian and Canadian waters. It should be noted that this work is at its very beginning and only based on two loci.

#### 2.4.1.4 Objectives for future genetic research:

To study the population genetic structure and the genetic relationship of redfish stocks and species in the Irminger Sea and at Reykjanes Ridge by:

(i) calibrating a set of molecular genetic markers (haemoglobins, isozymes, RAPD, anonymous cDNA RFLP, microsatellites, AFLP and mtDNA) for use in the detection and characterisation of the redfish at different levels of genetic differentiation, i.e. species (larvae origin) and stocks.

(ii) to use the developed markers to study the relationship and stock structure of the two types of *S.mentella* (deep sea and oceanic) in the Irminger Sea and stocks of *S.marinus* at Reykjanes Ridge and to compare it with redfish from other geographical areas such as Iceland, Greenland, Norway and Canadian waters.

(iii) to use the genetic markers for the identification of the origin of larvae and juveniles sampled in different spawning, drift and nursery areas, i.e. Irminger Sea, Icelandic Slope, East and West Greenland, Canadian coast from Baffin Island to Newfoundland in order to identify nursery areas for the different species and possibly stocks.

(iv) The information gained from the genetic studies on stock structure should be compared with morphometric studies, recruitment studies, life history traits, oceanographic features (temperature, currents, etc.) and stock assessment surveys, with the aim of stock discrimination for assessment of these commercially important fish species.

### 2.4.2 Morphological work

Historically, different anatomic features have been used to identify both species and populations. Several structures and methodologies have been used. At present, multivariate morphometric analysis and, to a lesser extent, meristic analysis are considered to the only valid tool for stock discrimination. Morphometry has been widely used for stock discrimination in several species of fishes and different areas with successful results even where genetics methods have not shown differences between populations (Safford and Booke, 1992; Kinsey *et al.*, 1994). Truss analysis, removing size dependence in the variables, is considered the optimal methodology in morphometric analysis.

In redfish, morphometry has been applied mainly for species identification (Misra and Ni, 1983; Power and Ni, 1985; Kenchington, 1986; Saborido-Rey, 1994), showing the usefulness of this tool. It has, however, been used in very few cases for stock discrimination (Reinert and Lastein, 1992; Saborido-Rey, 1994).

In the Northwest Atlantic, comparison have been made between populations of Flemish Cap, Grand Bank of Newfoundland and Saint Pierre Bank in the three species present there: *S.marinus*, *S.mentella* and *S. fasciatus* (Saborido-Rey, 1994). Results showed that the three areas are clearly separated populations. In the Northeast Atlantic comparisons have been made between Spitsbergen and Lofoten-Møre showing also differences between those groups. The results indicate the possible existence of two distinct populations. Recently, the sampling in the area off North Norway has been improved in order to study, in more detail, the stock structure in the area (Saborido-Rey and Nedreaas, unpublished. data). Though the results show a complex relationship between the groups analysed, it seems that a different morphometric pattern exists between at least three groups of *S.mentella* (Spitsbergen, Barents Sea and Lofoten-Møre). The analysis of the samples taken in summer and autumn shows clear difference, however samples taken in North Lofoten in Spring show that a mixture of the three groups are present in that area. It means that both sampling location as well as time of year is important for discrimination analysis (including genetics) if some kind of migration (spawning, feeding) occurs. If there are different populations, they should be separated at the moment of copulation, and it should be the optimal moment of sampling for discrimination purpoises. However for management migration pattern should be analysed and the degree of overlap studied. More samples should be analysed in order to clarify the complex situation shown by morphometric analysis in Northern Norway.

Differences have also been shown between Irminger Sea, Faroes and Norway, both in *S.marinus* and *S.mentella* (Reinert and Lastein, 1992). However, in the case of Faroese *S.mentella*, some within variation occurs, indicating that there could be a mixture of several populations in that area.Hovewer, the results indicate that the Irminger Sea *S.mentella* stock is a separated stock from Northeast and Faroes stocks.

Morphometric analysis will be started in 1998 by Spanish researchers trying to clarifying the existence or not of two types or populations of *S.mentella* in Irminger Sea and their relation with another possible stocks in adjacent waters such as Iceland and Greenland shelf.

Summarising, morphometric analysis shows clear differences between populations, though in some areas the results are too heterogeneous and further studies are necessary. It is a useful technique to apply in the areas where the population structure has not been clarified.

## 2.5 Age readings

The "Workshop on age reading of *Sebastes* spp." held in Germany in December 1995 (ICES C.M. 1996/G:1) set up some recommendations for further work. Among these were the following:

1. The otolith is the most appropriate structure to be used for age determination of redfish.

2. Requirements for scale/otolith comparisons.

Collections for such comparisons be made for the next two (2) years after which time the necessary analyses are carried out. The examination of material, and analysis of results should be done by small working groups of experts familiar with the stock/species in question.

3. Future activities and timetable.

The time limit for collection of material for comparison of scale and otolith interpretation is two years. During that time period, analyses of existing material should be ongoing. Small working groups of experts, as is appropriate for each stock/species in question should meet during the second half of 1998 to examine results and determine, to the extent possible from the data, possible conversions. These working groups should comment on the usefulness of any such conversions including limitations."

Catch-at-age data and survey indices of redfish based on scale readings exist for many of the stocks in the northeast Atlantic. As a consequence of the recommendations given by the 1995 ICES Workshop, for two of these stocks work has been initiated to examine scales and otoliths from the same fish in order to find possible ways of converting the old scale ages to otolith ages. These stocks are the oceanic *S.mentella* in the Irminger Sea and the deep sea *S.mentella* in the northeast Arctic. Regarding the latter, a small working group of otolith and scale experts from Norway, Russia and Spain met in Bergen in March 1997. The results showed that for the deep-sea *S.mentella* in the northeast Arctic the age readings of scales and otoliths seem to fit rather well within the lengt and age ranges compared (24-36 cm and 7-16 years; OTO=-1.83+1.12 * SCALE, $r^2$= 0.89). However, more comparable readings of younger and older fishes are needed.

Regarding the oceanic *S.mentella* in the Irminger Sea similar work is currently being done at PINRO, Murmansk. It is the aim of both these ongoing works to finish the analyses during 1998. The international symposium on fish otolith research and applications that will be held in Bergen, Norway, 20-25 June 1998, may also give valuable contributions on this issue.

The group was informed that Iceland has resumed conducting age determination of *S. marinus* using otoliths.

# 3. Acoustic survey to be conducted in June/July1999.

## 3.1 Participating nations

Around the table inquiry showed, that at this stage three countries (Iceland, Germany and Russia) were prepared to make commitments for vessel time for a joint survey in June/July, 1999. Other countries are working on that matter.

The group decided upon the survey period beginning around the 15th of June and extending 4-5 weeks ahead. In order for the countries to plan their survey activities and timing in 1999, the Study Group agreed to make the **second week of January 1999** the deadline for the countries to make a final decision about participating or not. The decision, positive or negative, should be reported to the chairman of the Study Group.

## 3.2 Survey strategy.

The survey area for oceanic redfish which had been agreed upon during the meeting is the same as planned for the joint international survey in 1996 and is located between 52°N to 65°N and 28°W to 52°W (Figure 3.2.1). A part of this area between 56°N to 62°N and 34°W to 46°W is considered as the main area of interest for the oceanic stock.

By letting the survey tracks run parallel to lines of latitudes with 30 nm distance between the tracks inside the main area (grey on Figure 3.2.1) and with 45 nm distance between the tracks outside this area, the combined length of the survey tracks will approximately be 12,000 nm. Accounting for station time (2 trawl stations per day of 3 hours duration each) and assuming a speed of 8-10 knots this corresponds to about 63 vessel-days or about 19 days with 4 vessels, or about 25 days with 3 vessels.

For the sampling strategy the Study Group refers to the 1994 Report of the Study Group on Redfish Stocks (ICES C.M. 1994/G:41), with the exception that collection of scales is made optional.

In the light of the recent shift in fishing effort towards deeper water on the Reykjanes Ridge (ICES, C.M. 1997/Assess:13) the Study Group finds the need for further deep-sea hauls (>500) in future surveys.

Furthermore, it is important prior to the survey to investigate the possibilities of applying narrow beam transducers, and new development in technology, in order to give an estimate of fish deeper than 500 meters.

Each participating vessel should calibrate its acoustic equipment just before the survey. Intercalibration is highly recommended, and area and timing should also be agreed upon prior to the survey.

Representative of countries participating in the international survey (including technical experts) should meet for more detailed planning in February 1999, when it has been clarified which nations will participate an how many vessels are involved. Also, a meeting of 2-3 days is needed right after the survey to evaluate the results and prepare a joint report of the survey.

## 3.3 Recommendations.

It is the Study Group's opinion, that decreasing catch rates in the fishery on oceanic redfish (ICES C.M. 1997/Assess 13) as well as low biomass estimate in most recent acoustic surveys (ICES C.M. 1996/G:8; WD7) demands a more frequent monitoring of oceanic redfish abundance in the Irminger sea in the future. The Study Group therefore recommends, that the frequency of joint international surveys should be increased and conducted at least every second year.

The Study Group also discussed the possibilities of using deep-towed vehicle transducer. It is important to follow the development of such equipment and if possible it should be tested on redfish during the 1999 acoustic survey.

# 4. Summary of recommendations

1. It is important to get, as soon as possible conclusive results on the identification of redfish stocks.
2. Although genetic work has not – to date – showed conclusive evidence regarding stock identification, it indicates that there might be different stocks of *S.mentella* in the Irminger Sea. Genetic work also indicates that there is a separate stock of redfish, so called "giant redfish". The SGRS recommends that as much effort as possible should be applied in the genetic work in order to work up the already collected data on the different redfish stocks.
3. Morphological analysis on oceanic *S.mentella* will be started in 1998. The Study Group on Redfish Stocks recommend that morphological measurements should be applied on all redfish stocks where population structure has not been clarified.
4. An operational manual for the identification of different types of *S.mentella* in the Irminger Sea is urgently needed.
5. Nursery area of oceanic redfish is not known. Although it is a great task to find the nursery areas and map them, it is very important to start such work. It is of vital importance for assessment purposes to have any evidence of trends in recruitment, before it enters the fishable stock at age about 10 years. It is also important to be able to see as soon as possible the possible effect of the current exploitation rate on the recruitment. This applies also for "giant" redfish.
6. A careful monitoring of parasite infestation rates is necessary.
7. On the "giants" it is important to identify the drift and nursery areas and to decide upon a common maturity scale for the adult specimen.

8. The reproductive biology of redfish needs to be studied, mainly in the Irminger Sea and with special attention in the area from Iceland to Faroes Islands and possible furhter east.

9. Age readings. In order to assess the redfish stocks successfully, it is of importance to investigate further the possibility of developing a reliable age reading technique. The SGRS encourages scientists to continue their work along the lines agreed upon at the last age reading workshop held in Germany in 1995.

10. The Study Group recommends, that the frequency of joint international surveys should be increased and surveys conducted at least every other year.

11. It is important to follow the development of deep-towed vehicle transducer and, if possible, it should be tested on redfish during the 1999 acoustic survey.

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# 6. Tables

**Table 2.3.1.** Maturity at length of the "Giant" redfish on the Reykjanes ridge. Data from May 1996 and July 1997 combined (Working Document no. 2, Hareide et al. 1996, Langedal and Hareide 1997).

| Total length (cm) | FEMALES | | | | | MALES | | | | | Both sexes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Maturity stages | | | | | Maturity stages | | | | | |
| | Immature | Maturing | "Spawning" | Spent | Total | Immature | Maturing | "Spawning" | Spent | Total | Total |
| 42 | | | | | | | | | | | |
| 44 | | | | | | | | | | | |
| 45 | | | | | | | | | | | |
| 46 | | | | | | 1 | | | | | 1 |
| 47 | | | | | | | | | | | |
| 48 | | | | | | | | | | | |
| 49 | | | | | | | | | | | |
| 50 | 1 | | | | 1 | | | | | | 1 |
| 51 | | | | | | 2 | | | | 2 | 2 |
| 52 | 1 | | | | 1 | 1 | 1 | | | 2 | 3 |
| 53 | | | | | | 1 | 1 | | | 2 | 2 |
| 54 | 2 | | | | 2 | 1 | | | | 1 | 3 |
| 55 | 3 | | | | 3 | 2 | 2 | | | 4 | 7 |
| 56 | 3 | | | | 3 | | | | | | 3 |
| 57 | 4 | | | | 4 | | 1 | | 1 | 2 | 6 |
| 58 | 5 | | | | 5 | 1 | 1 | | | 2 | 8 |
| 59 | 4 | | | | 4 | 4 | 1 | | | 5 | 9 |
| 60 | 6 | | | | 6 | 1 | 3 | | | 4 | 10 |
| 61 | 3 | | | 1 | 4 | 2 | 3 | | | 5 | 9 |
| 62 | 3 | | | | 3 | 1 | 5 | | | 6 | 9 |
| 63 | | | | | | | 4 | | | 4 | 4 |
| 64 | 1 | 1 | | 2 | 4 | 2 | 5 | | | 7 | 11 |
| 65 | 4 | 1 | | 4 | 9 | | 7 | | | 7 | 16 |
| 66 | 2 | 3 | | 4 | 9 | | 15 | | | 15 | 24 |
| 67 | 1 | 2 | | 6 | 9 | | 8 | | | 8 | 17 |
| 68 | 1 | 1 | | 10 | 12 | | 12 | | | 12 | 24 |
| 69 | | | | 12 | 12 | | 19 | | | 19 | 31 |
| 70 | | 2 | | 20 | 22 | | 53 | | | 53 | 75 |
| 71 | | 1 | | 13 | 14 | | 30 | | | 30 | 44 |
| 72 | | | | 21 | 21 | | 49 | | 1 | 50 | 71 |
| 73 | | | | 23 | 23 | | 37 | | | 37 | 60 |
| 74 | | | | 23 | 23 | | 32 | | | 32 | 55 |
| 75 | | 1 | | 41 | 42 | | 40 | | | 40 | 82 |
| 76 | | | 2 | 27 | 30 | | 24 | | | 24 | 54 |
| 77 | | | | 16 | 16 | | 23 | | | 23 | 40 |
| 78 | | 3 | | 15 | 18 | | 10 | | | 10 | 28 |
| 79 | | | | 11 | 11 | | 9 | | | 9 | 20 |
| 80 | | | | 6 | 6 | | 4 | | | 4 | 10 |
| 81 | | | | 4 | 4 | | | | | | 4 |
| 82 | | | | 1 | 1 | | | | | | 1 |
| 83 | | | | | | | | | | | |
| 84 | | | | | | | | | | | |
| 85 | | | | 1 | 1 | | | | | | 1 |
| 89 | | | | | | | | | | | |
| Total | 44 | 15 | 2 | 262 | 324 | 18 | 399 | | 2 | 419 | 745 |

# 7. Figures

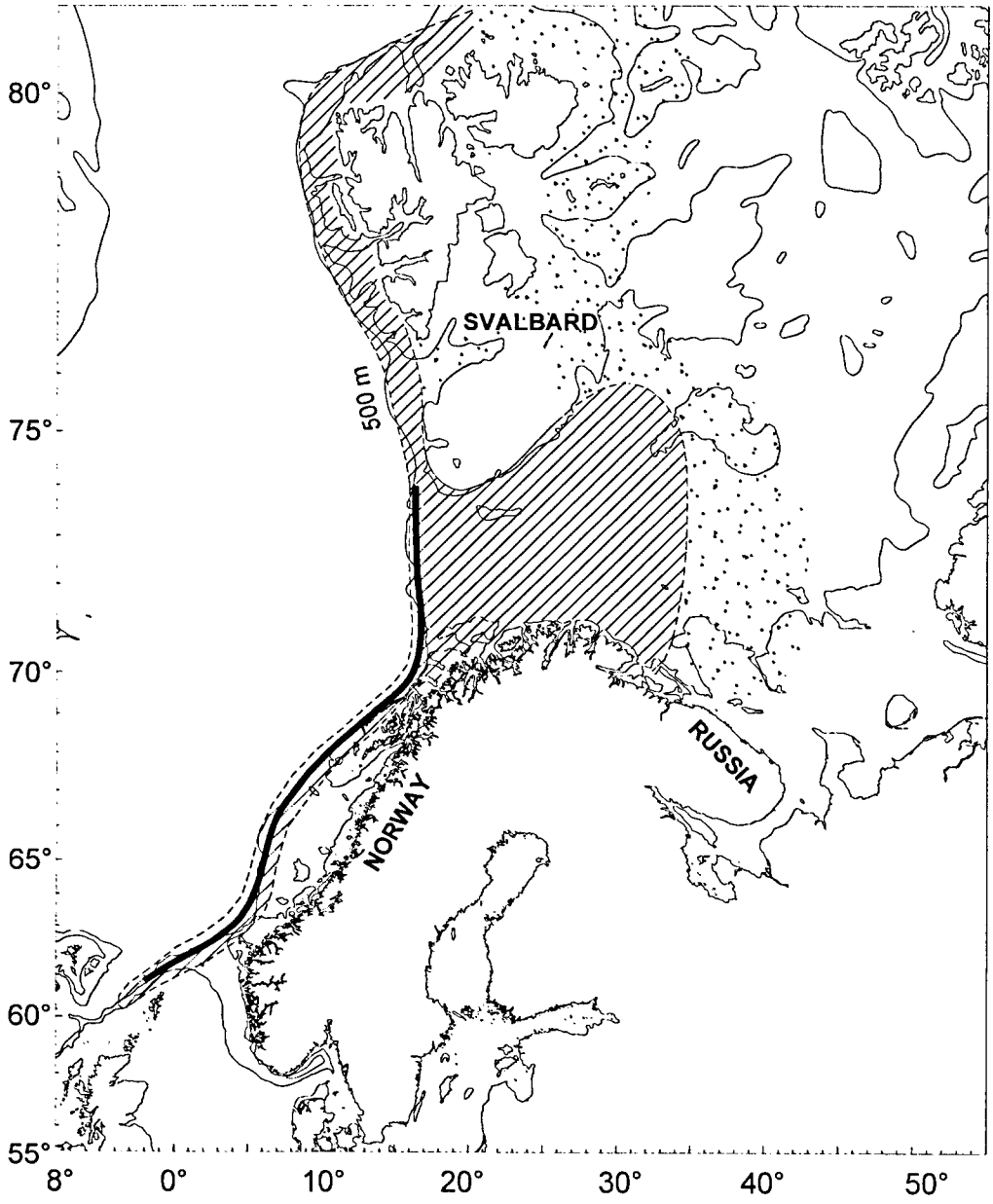


**Figure 2.1.1.** Main distribution area of *Sebastes mentella* in ICES Sub-areas I and II. The hatched area shows the center of abundance. The black area along the slope shows the main area of larvae release.

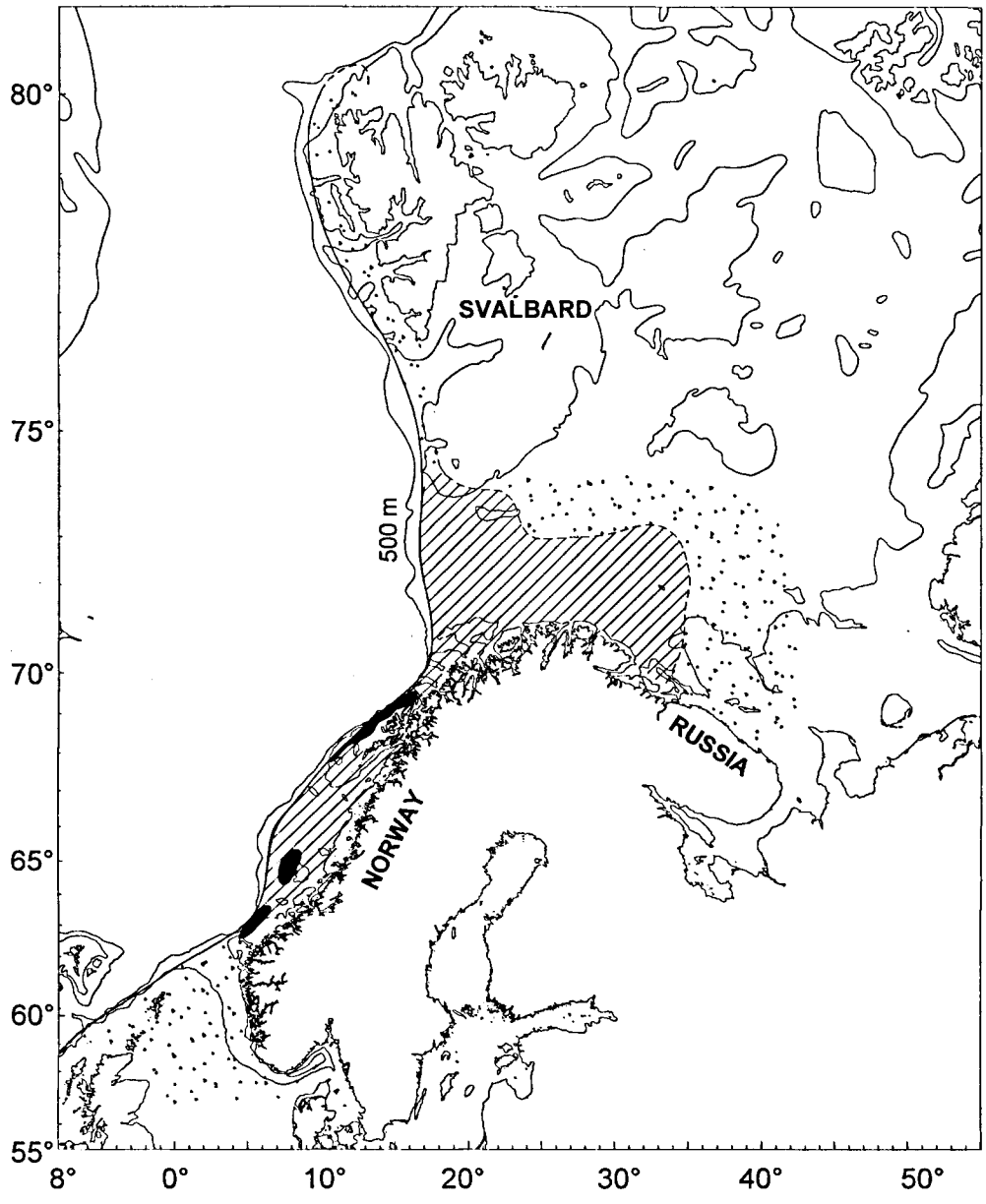


**Figure. 2.1.2.** Main distribution area of *Sebastes marinus* in ICES Sub-areas I and II. The hatched area shows the center of abundance. The black areas show the main area of larvae release.

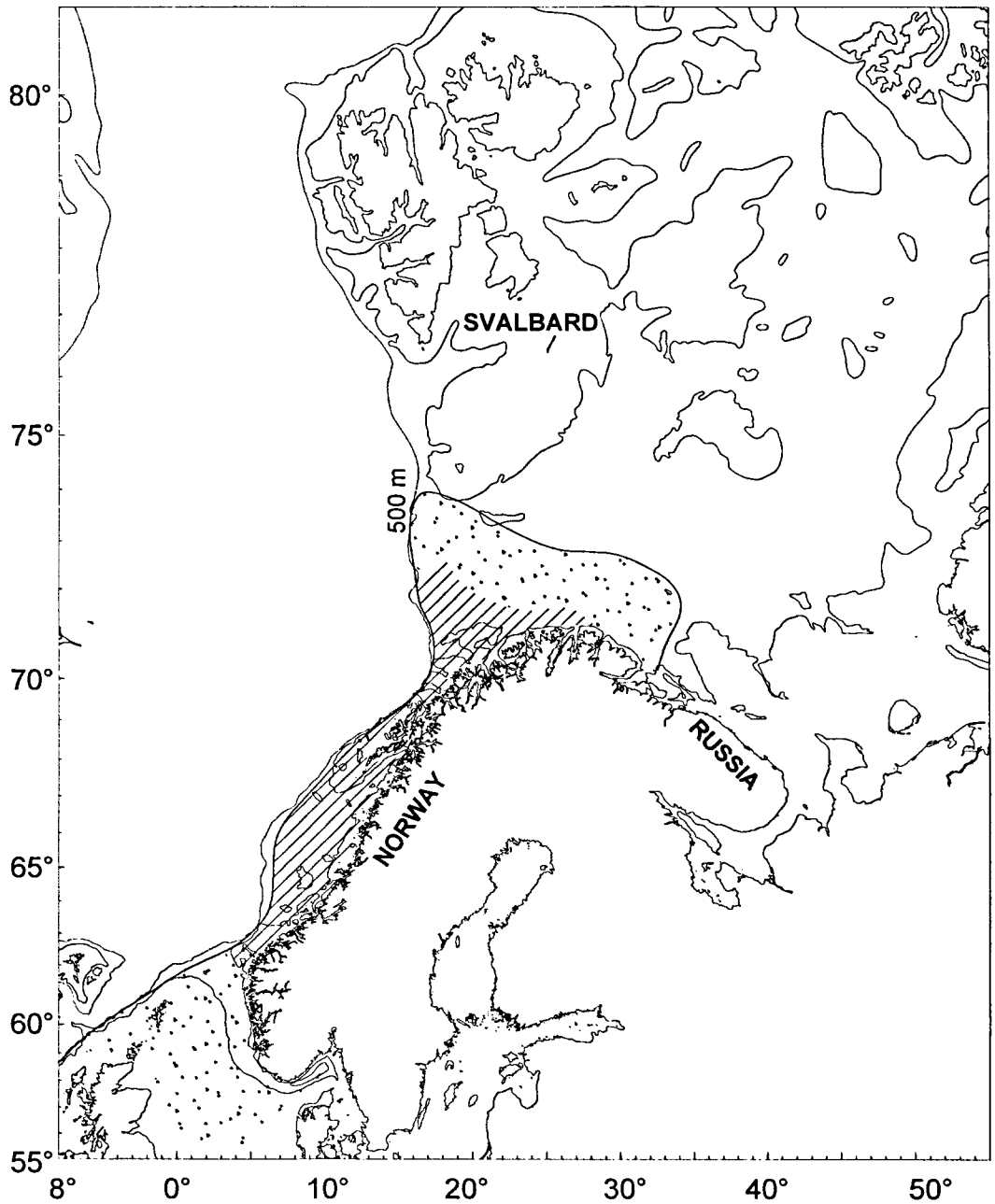


**Figure 2.1.3.** Main distribution area of *Sebastes viviparus* in ICES Sub-areas I and II. The hatched area shows the center of abundance. Areas of larvae release have not been shown due to lack of information

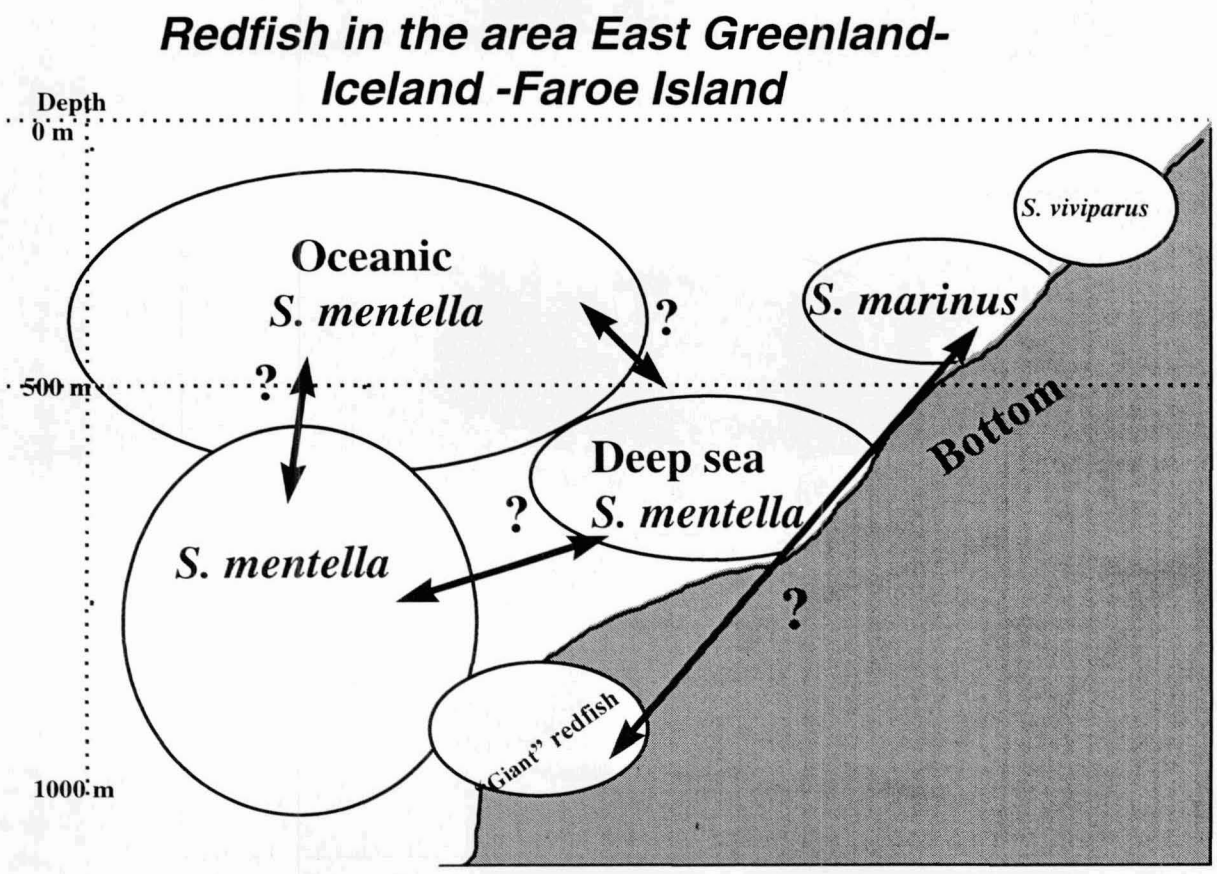


**Figure 2.3.1** Schematically possible relationship between different stocks of redfish in the Irminger Sea and along the continental slope of E-Greenland-Iceland-Faroe Island.

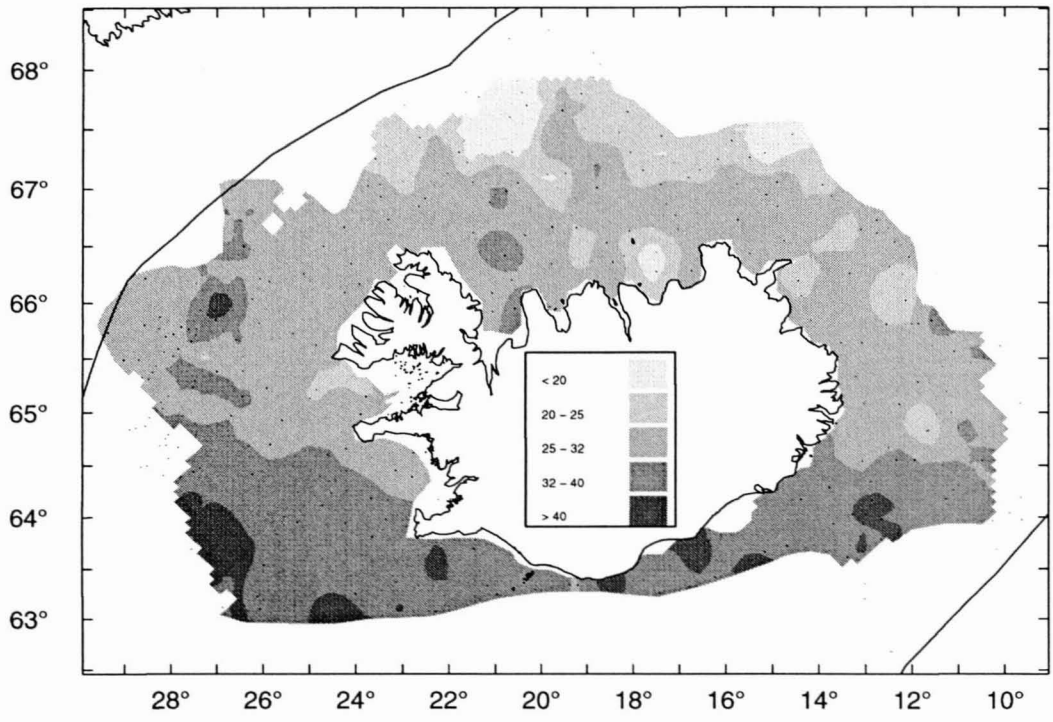


**Figure 2.3.2.**. Mean length of *S.marinus* by station in the Icelandic groundfish survey in October 1996.(from Sigurdsson *et al.*, 1997).

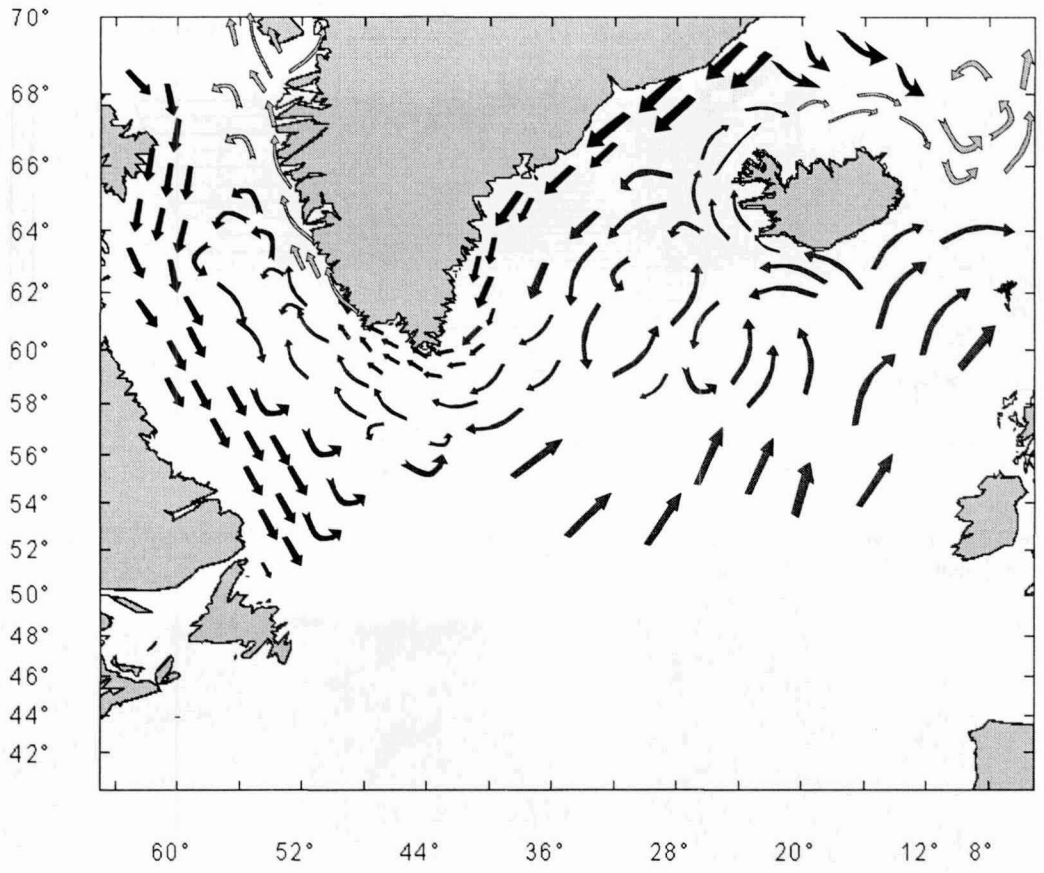


**Figure 2.3.3.** General trends of currents in the Northwest Atlantic.

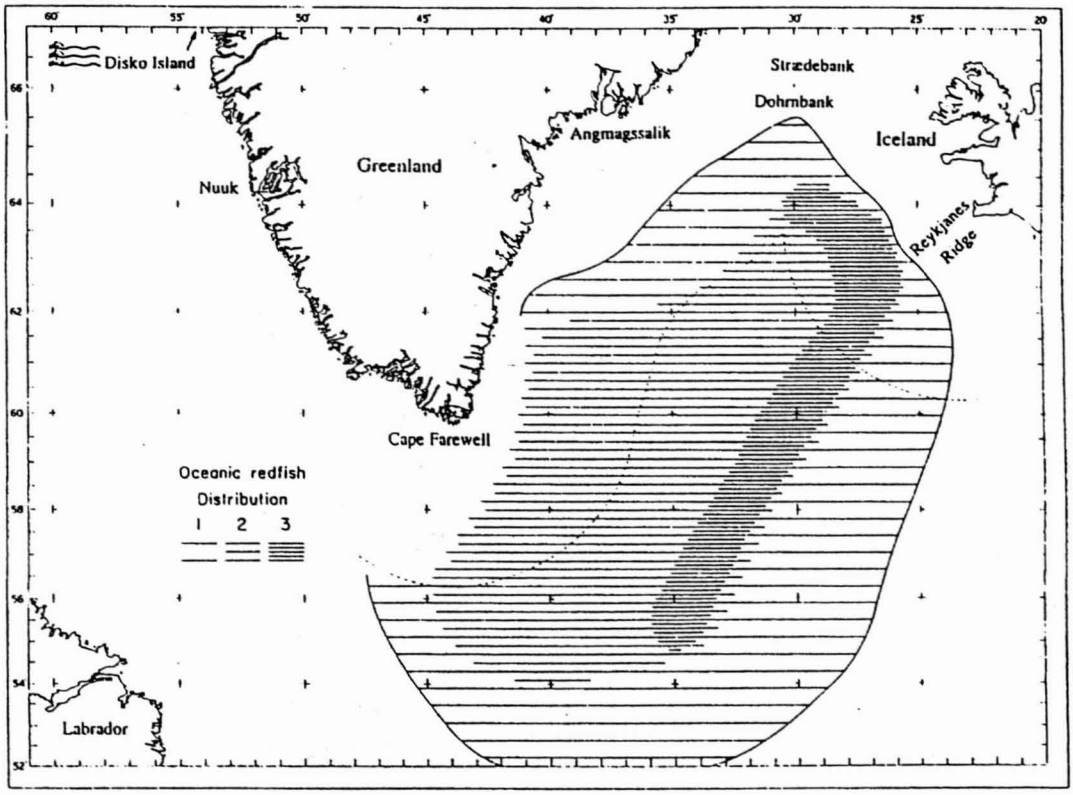


**Figure 2.3.4.** Known distribution area of oceanic redfish. 1= Area of general distribution; 2= area with greater densities; 3= area of larval extrusion.

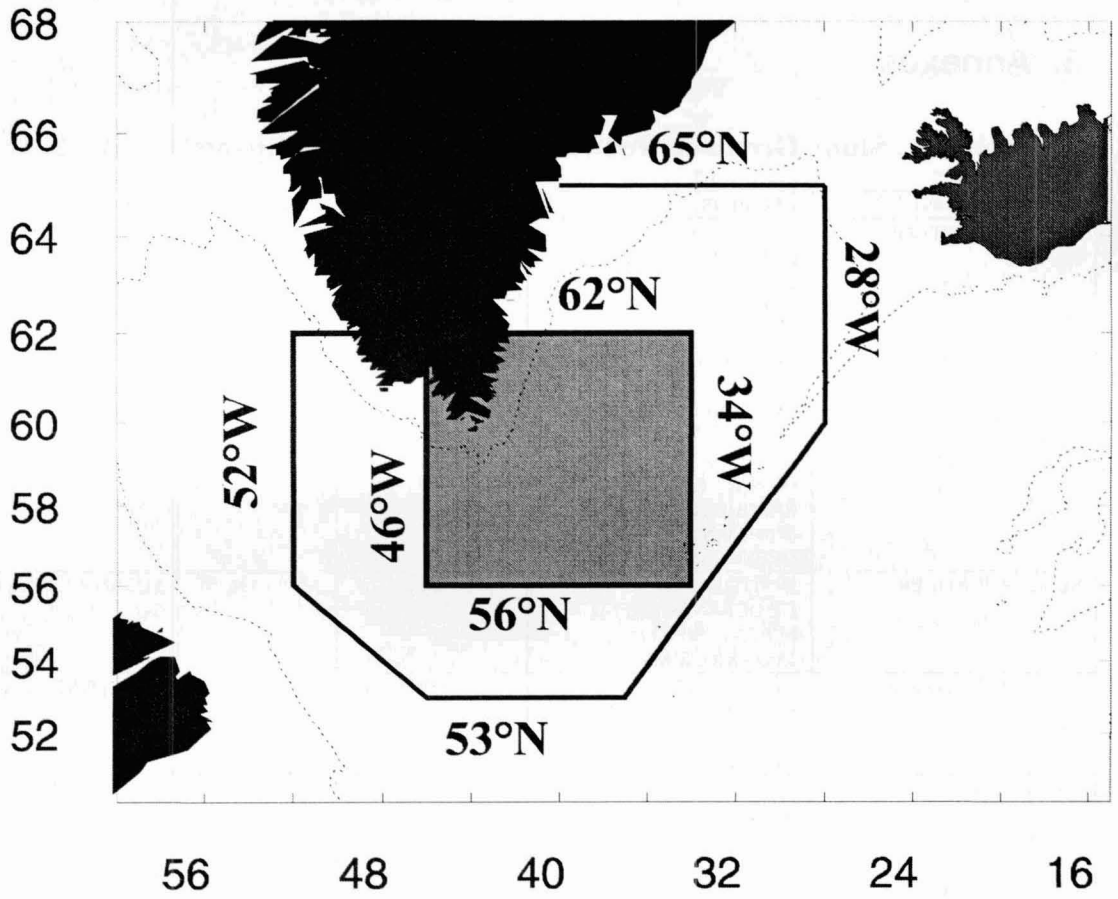


**Figure 3.2.1.** Map showing the agreed total area to be covered during the 1999 international acoustic survey for oceanic *S.mentella*. Within the dark limits (56°N-62°N, 34°W-46°W) the survey tracks should be 30 nautical miles apart, while in the rest of the survey area the distance between the tracks should be 45 nautical miles.

# 8. Annexes

## 8.1 Annex 1. Study Group on Redfish Stocks, list of participants.

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## 8.2 Annex 2. List of working documents

1.Thorsteinn Sigurðsson. Notes on Sebastes marinus in ICES Division Va and XIV (distribution and present research).

2.Nils-Roar Hareide. Data on the biology of giant redfish on the Reykjanes ridge.

3.Anna Kristín Daníelsdóttir. Genetic studies on redfish species and stocks. Past - ongoing - future.

4.Fran Saborido-Rey. Age and growth of redfish (*Sebastes marinus, S.mentella and S. fasciatus*) in Flemish Cap (Northwest Atlantic).

5.Jean-Marie Sévigny and Louis Bernatchez. Redfish Multidisciplinary research programme. Progress report (1997/10/31).

6.V.V Dushchenko. Polymorphism of NADP-dependent malatedehydrogenase in *Sebastes mentella* Travin (Scorpaenidae) from the Irminger Sea (translation of a Russian paper from 1986).

7.Melnikov, S.P., Shibanov V.N., Pedchenko, A.P. Preliminary results of the trawl-acoustic survey of oceanic *Sebastes mentella* conducted by Russia in 1997.

## 8.3 ANNEX 3. Review of molecular methods used in population genetic studies.

### I. Protein and Isozymes:

Electrophoretic analysis of proteins and isozymes has been widely used in order to distinguish between different stocks or populations of animals (Lewontin, 1974; Harris and Hopkinson 1976; Ferguson, 1980; Ayala, 1982; Nevo *et al.*, 1984; Ryman and Utter, 1987; Hoelzel, 1991, to mention only few of many)h analysis is based on the concept that samples of a particular species collected from different areas usually differ significantly in their allele frequencies. The haemoglobins protein have been widely used in population genetic studies, especially in the earlier days and it has shown to be variable in many fish species. The proteins and isozymes are separated by gel electrophores and gels are stained with specific staining. Once suitable protein and/or isozyme variants have been discovered and their genetic bases established with reasonable certainty these variants may form useful markers for the detailed investigation of the population genetics of a species. Comparison of frequencies of a number of polymorphic loci between groups of animals may determine whether they comprise one or more populations.

### II. Nuclear DNA (nDNA) studies:

**1) Anonymous cDNA RFLP's:** is based on random single locus probes made from the transcribed part of the genom. This method has been used successfully in a study of cod populations (Pogson *et al.* 1995) and has some advantages over the multilocus DNA fingerprinting method in both population and family studies. It is more easily used and results are obtained more rapidly than with multilocus probes. The analysis can be done on small samples. Identification of specific loci and alleles is easy and the presence of different level of variable loci allows the choice of loci that suit the problem being tackled. Probes used singly, in succession, or together in a "cocktail" can be as powerful as multilocus analysis using one probe for paternity analysis. The DNA is cut with restriction enzymes and it's fragments are separated by gel electrophoresis. DNA restriction fragments are then hybridised with a cDNA probe which are made from mRNA so each probe represents transcribed functional gene.

**2) rDNA RFLP's (ribosomal):** The DNA is isolated and restricted with a range of restriction enzymes. The products are then hybridised with a rDNA specific probe and the fragments are then separated by gel electrophoresis that give rise to haplotype data and fragment sharing coefficients.

**3) rDNA sequencing:** PCR amplification of rDNA regions using specific oligonucleotide primers followed by DNA sequencing.

**3) Variable numbers of tandem repeats (VNTR):** Tandemly repeated nucleotide sequences scattered around the genom. The different number of repeat units give rise to the different alleles.

**a) Minisatellites:** Minisatellites consist of VNTR of 10-100 nucleotides long (Jeffreys *et al.*, 1985).

*DNA fingerprinting:* Multilocus probes that identify hypervariable minisatellite regions, are hybridized with previously restricted DNA. They produce many alleles from number of minisatellite loci and the data is based on present and absent of homologous fragments on an electrophoresis gel (fragment sharing coefficient).

*Minisatellites:* A range of locus specific PCR primers are used to amplify the minisatellites or single locus probes are hybridized with previously restricted DNA. In both cases, the fragments are separated by gel electrophoresis and produce two allele heterozygotes similar to the isozymes and cDNA RFLP methods.

**b) Microsatellites:** Microsatellites consist of short VNTR sequences, two to four nucleotides long (Tautz, 1989). PCR reaction with an oligonucleotide primer is carried out for number of microsatellite loci. After amplification, the PCR products are separated with gel electrophoresis. Alleles may also be revealed as RFLPs followed by PCR using conserved flanking regions. Genetic polymorphism is estimated by the observed allele frequencies. The advantages of this method is that the variability is usually greater than found at isozyme loci and in mtDNA and the alleles are inheritated in a Mendelian way. The drawbacks of this method are the null alleles, which are alleles that fail to amplify in a PCR reaction and cause false heterozygote deficiency departure from the Hardy-Weinberg equilibrium an indication of inbreeding or population mixing.

**c) Repeated DNA sequences:** The repeated DNA sequences can either be sequenced and compared to a consensus sequence or they can be analysed (after the cloning of informative repeated sequences) by combined restriction enzyme and probe patterns that are separated with gel electrophoresis. These repeated DNA sequences behave in a non-Mendelian fashion.

**4) Random Amplified Polymorphic DNA (RAPD):** The RAPD was developed by Williams *et al.* (1990) and has some of the advantages of the isozyme analysis, in that it is inexpensive, fast and easy to use but the genetic inheritance for observed variation in banding patterns is not known. The variations observed are the presence or absence of homologous bands between individuals by using a range of 10-mer (10 nucleotide long) primers to amplify (PCR) DNA. RAPD has been used more for plant than animal genetic studies.

**5) AFLP:** A combination of RAPD- and RFLP- analyses named AFLP-analyses (amplified fragment length polymorphism) has been used to generate genetic markers in recent genetic population studies. Total genomic DNA is cut with two restriction enzymes with recognition sites of six respectively four base pairs and adapters are then ligated to the resulting protruding ends. A preamplification with primers matching to the adapters and possessing an additional selective nucleotide at the 3' end, reduce the amount of restriction fragments. For the final PCR the primer matching to the six base pair restriction site is end-labelled so that only fragments with at least one six-cutter adapter end are detected either in the autoradiography of a PAGE

or by an automated sequencer. By adding selective nucleotides to the 3'end of the primers the amount of bands and to a certain extend the amount of polymorphisms on the gel can be adjusted. AFLP markers have various advantages over RAPD markers. A good reproducibility is given, due to the higher annealing temperatures used in the PCR´s. The method can easily be adjusted to different species and diversity levels.

**III. Mitochondrial DNA (MtDNA) studies:**

The mtDNA molecule is a covalently closed circular duplex, of which the D-loop is the most variable area and the RNA genes the least (Brown, 1983). The characteristics of the mtDNA molecule are: the clonal maternally inheritance nature of it (Lansman *et al.*, 1983) and its rapid evolution (Brown *et al.*, 1979; Brown, 1981; Ferris *et al.*, 1981 and Vawter and Brown, 1986). Gene flow due to male dispersal will not be as likely to affect the geographical variation in mtDNA haplotypes. MtDNA is thought to be more sensitive to bottlenecks and to population subdivisions than the nuclear genes (Wilson *et al.*, 1985). The effective population size of mtDNA is ¼ of that for the nDNA (Nei and Tajima, 1981). The mtDNA smaller effective population size means that genetic drift can cause frequency differences between isolated gene pools more readily in mtDNA than in nuclear DNA (Park and Moran, 1994) since the effect of genetic drift is greater in small populations (subdivision of populations). In rear situations, where sex ration is biased for females or where breeding pattern is such that one male breeds with many females (i.e. herds), the mtDNA can show less subdivision than nDNA (Birky *et al.* 1989). The mtDNA often reveal higher polymorphism than nDNA, but there are evidences where that is not the case and it varies between species. The diversity at nDNA and mtDNA depend on population parameters such as the sex ratio, migrant sex ratio, breeding behavior and female effective populations size (Birky *et al.* 1989).

The authors using mtDNA variation to study natural populations and species have mainly used the enzyme restriction fragment length polymorphism (RFLP) analysis of intact mtDNA (Avise *et al.*, 1979a and 1979b; Brown and Simpson, 1980; Lansman *et al.*, 1981; Moritz *et al.*, 1987; Dowling and Brown 1989, 1993; Smouse *et al.*, 1991; Dahle, 1991 and many more). More recently authors have been studying the mtDNA D-loop area for analysing the population structure of natural populations (Hoelzel, 1991b; Bakke *et al.*, 1996; Hoelzel and Dover, 1991; Hori *et al.*, 1994)The whole mtDNA is isolated and restricted with a range of restriction enzymes. The fragments are separated by gel electrophoresis and give rise to haplotype data and fragment sharing coefficients.

**2) MtDNA RFLP´s and probing:** The whole mtDNA is isolated and restricted with a range of restriction enzymes. The products are then hybridised with a mtDNA gene specific probe and the fragments are then separated by gel electrophoresis that give rise to haplotype data and fragment sharing coefficients.

**3) MtDNA sequencing:** The PCR amplifications of parts of the mtDNA using oligonucleotide primers are sequenced.

## 8.4 ANNEX 4. Genetic studies on Sebastes species from the Northwestern Atlantic and Pacific Ocean.

### *8.4.1 PAST genetic studies*

***Species identification:***

**Northwestern Atlantic *Sebastes* species:** Three (MDH, GAL and SDH) of 16 isozymes analysed, were used to separate the *Sebastes fasciatus* from *S. marinus* and *S. mentella* from the Northwestern Atlantic, non could separate *S. marinus* and *S. mentella* and 12 isozymes were diagnostic for *Helicolenus dactylopterus* (McGlade *et al.*, 1983). Payne & Ni (1982) found frequency differences at the *MDH* and *ESA* loci between Atlantic Canadian (Newfoundland) *S. marinus, S. mentella & S. fasciatus.* The MDH phenotypes were characteristic of 90% of *S. fasciatus* and 95% of *S. mentella* samples from Atlantic Canadian waters (Gulf of St. Lawrence) (Rubec *et al.*, 1991). General protein staining (GPS) was used to separate *S. marinus* and *S. mentella* from the western Atlantic Ocean (Newfoundland) (Trottier *et al.*, 1988), but could not be separated in an earlier study by Tsuyuki *et al.* (1968). Tsuyuki *et al.* (1968), however, found distinct *Hb* pattern between the two species from this location. They found species specific *Hb* patterns (26 patterns) and only four *GPS* patterns in the 26 Pacific Ocean species studied. Johnson *et al.* (1972) could not separate between NE Atlantic *S. marinus* and *S viviparus* at the seven isozyme loci studied (*PGM, SOD, PEPA-I, PEPA-II, LDH, αGPDH* and *IDHP*) or in the general protein pattern (*GPS*), but could separate 10 of the 27 Pacific Ocean *Sebastes* species and *H. dactylopterus* using four isozyme loci (*PGM, SOD, PEP & LDH* ) and *GPS.*

**Pacific Ocean *Sebastes* species:**

Lundstrom (1983) could identify four different protein patterns in nine Pacific Oceanic *Sebastes* species studied by isoelectric focusing (IEF) of muscle proteins. Identification of Pacific *Sebastes* larvae and juveniles to species could be made for 12 of the 72 northeastern Pacific Ocean species by the use of 28 isozyme loci (Seeb & Kendall 1991).

***Stock identification:***

**Northwestern Atlantic *Sebastes* species:**

No references found.

**Pacific Ocean *Sebastes* stocks:**

Seeb & Gunderson (1988) studied the genetic variation and population structure of 1500 Pacific Ocean perch at 25 isozyme loci. They found a slight amount of population differentiation from the Washington coast to the Bering Sea, but no evidence of restricted gene flow between the western Gulf and Alaska and

the Bering Sea. Johnson *et al.* (1973) studied the genetic variation of 25 isozymes in 1662 of the three Pacific Ocean *Sebastes* species: *S. alutus, S. caurinus & S. elongatus.* They found low levels of within and between variation in the three species. Two loci: *αGPDH & PGM* were polymorphic in *S. alutus, PGM &* GPS were polymorphic in *S. elongatus* and only one locus, *αGPDH* was polymorphic in *S. caurinus.* No differences were observed between *S. alutus* samples from two locations (Queen Charlotte Sound, B.C. and Washington) and *S. elongatus* from two locations (Queen Charlotte Sound, B.C. and Anderson Cove, Washington).

### *8.4.2 ONGOING Genetic Research.*

(From the APPENDIX of the ICES Report of the working group on the application of genetics in fisheries and mariculture reports, 1996 (ICES 1996) and email communications.)

**Northwestern *Sebastes* species:**

The two laboratories in Canada, work on the genetic variation of redfish (*Sebastes sp.*) in the Gulf of Saint Lawrence and the Northwest Atlantic. They are: Jean-Marie Sevigny, Maurice-Lamontagne Institute, Fisheries and Oceans, P.O. Box 1000, Mont-Joli (Quebec) and Louis Bernatchez & Severine Roques, Departement de Biologie, Pavillon Vachon, Universite Laval, Sainte-Foy (Quebec). The objectives are to species and population genetic structure of the *S. marinus, S. mentella* and *S. fasciatus.* Jean-Marie Sevigny is the head of the genetic part of the Canadian redfish research program working with allozymes, mtDNA, ribosomal DNA. Other combined redfish studies: species and stock identification (morphology, parasites, otolith shape) and recruitment studies. (WD5).

Jean-Marie Sevigny found low levels of both intraspecific and interspecific variation using mtDNA d-loop sequencing. Louis Bernatchez and Severine Roques are using microsatellites. The aims of their study are: 1) ***-Genetic variability of S. mentella across the North Atlantic:*** In order to assess the importance of historical and geographical factors in shaping *S. mentella* genetic variability, 10 transatlantic samples will be analysed with the 8 microsatellites loci. 2) ***-Population structure of S. fasciatus and S. mentella in the Northwest Atlantic and the Gulf of St. Lawrence:*** 10 samples of each of the two species will be analysed with the 8 loci in order to detect population subdivision in these regions. Defined genetic populations will be compared with the actual managed stocks. The hypothesis of a difference in population richness between *S. fasciatus and S. mentella* will also be tested. 3) ***-Is the hybridization in the Gulf of St. Lawrence from ancient or recent origin?*** Hybrids samples (number to be defined), meaning with intermediate allozymes patterns and morphological characters, will be analysed with the 8 loci. Hardy-Weinberg equilibrium and linkage disequilibrium will be tested in these samples in order to assess the level of hybridization and the time since it has occurred.

**The present status of project:** ***-Development of microsatellites markers:*** Eight microsatellites markers were developed for the four recognized species, *S. fasciatus, S. mentella, S. marinus* and *S. viviparus.* Protocols for PCR reactions and allele scoring were optimized. ***-Genetic variability of microsatellites at the population and species level:*** Two samples of each of the four species, *S. fasciatus, S. mentella, S. marinus S. viviparus*, were analysed with the 8 microsatellites loci. Results confirm high polymorphism of these markers as well as their potential for species and stocks discrimination. Moreover, results showed significant differences among the samples and the differences among species was significantly greater than the differences between populations within species.

**Pacific Ocean *Sebastes* species:**

Three labs in the USA are working on the Pacific redfish species molecular identification using mainly mtDNA sequencing: They are: Southwest Fisheries Science Center, La Jolla; Marine Science Institute, University of California, Santa Barbara and Department of Biology, University of California, Santa Cruz. Whereas population structure is the main aim of redfish genetic studies in the North Atlantic, species identification seem mainly the aim of the studies in the Pacific (i.e. *S. entomelas, S. flavidus, S. melanops, S. miniatus, S.mystinus, S. pinniger, S. serranoides, S. atrovirens, S. carnatus* and *S. chrysomelas*).