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Migration of juvenile deep-sea redfish (*Sebastes mentella* Travin) from the East Greenland shelf into the central Irminger Sea

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Abstract

This study investigates the stock structure and recruitment of deep-sea redfish *Sebastes mentella* off East Greenland and in the central Irminger Sea and evaluates current migration theories. Analyses of long-term trends in length distributions from survey data and commercial catches on the East Greenland shelf and in the central Irminger Sea are presented to identify strong year-classes and to track their abundance in these areas. Following the length frequency patterns over the past five years, a sharp decrease in abundance of recruiting *S. mentella* on the East Greenland shelf and a subsequent 'ingrowth' of this length class into the oceanic stock in the Irminger Sea becomes evident. This observation, made for the first time since the regular groundfish surveys off Greenland started in 1982, suggests a migration of juvenile fish from East Greenland into the central Irminger Sea and indicates that the East Greenland shelf could be an important nursery area for oceanic redfish. The phenomenon of large-scale migration and its effect on the management of these stocks is discussed with respect to controversy on stock separation of redfish in the North Atlantic. A short overview on future research needs and objectives of current investigations on the stock structure of *S. mentella* in the Irminger Sea and adjacent areas are given.

Keywords: Redfish, *Sebastes*, migration, recruitment, population structure

Introduction

Three species of redfish inhabit the Northeast Atlantic, *Sebastes marinus* (L.), *S. mentella* Travin and *S. viviparus* Krøyer, the former two species being of major importance for commercial fisheries. In the Irminger Sea and adjacent waters (ICES Divisions V, XII and XIV; NAFO 1), golden and deep-sea redfish are currently separated into three management units (ICES 1998). Demersal *S. marinus* and *S. mentella* are distributed on the continental shelves off Greenland, Iceland and the Faroe Islands (e.g. Whitehead *et al.* 1986, Reinert and Lastein 1992, Rätz and Stransky 1999), while oceanic *S. mentella* mainly occurs in the central Irminger Sea within depths of 50 m to about 1000 m (ICES 1992 and 1998, Magnússon and Magnússon 1995). The population structure and discrimination of these stocks, forming the basis of stock-specific assessment measures, remains unclear.

Various methods have been used to identify, delimit and discriminate fish species and stocks, the most common techniques being based on population genetics (Parker *et al.* 1998) and morphometry (Ihssen *et al.* 1981, ICES 1996 and 1999a). The most promising studies investigating the population structure of marine fish species were carried out using DNA analysis (Morris *et al.* 1996, Desrosiers *et al.* 1999, Ruzzante *et al.* 1999), enzyme electrophoresis (Smith *et al.* 1990), otolith shape analysis (Campana and Casselman 1993, Colura and King 1995) and elemental 'fingerprinting' of otoliths (e.g. Campana *et al.* 1994, Edmonds and Fletcher 1997, Thresher 1999). Tagging studies were successful for some species but generally tend to be very cost consuming and suffer low recapture success (Leaman and Nagtegaal 1987, ICES 1999a). Several studies involved parasites as biological tags, using area-specific parasite inventory of host organisms to track the origin of the sampled specimen (MacKenzie 1983, Williams *et al.* 1992).

The separation of *S. mentella* stocks off Greenland and in the Irminger Sea was repeatedly reported as being difficult and was subject to some controversy over the past (ICES 1992, 1993 and 1998). Phenotypic discrimination of stocks is currently based on differences in the length at maturity, parasite infestation and colouration of the skin and muscle tissue (ICES 1998). Investigations on the genetic structure of these stocks revealed no significant differences between stocks (Nedreaas *et al.* 1994). A preliminary study by Johansen *et al.* 1998, however, applied RAPD (Random Amplified Polymorphic DNA) analysis and pointed to differences between oceanic *S. mentella* and deep-sea *S. mentella* in the Irminger Sea, which are currently treated as one stock (ICES 1998). Morphometric analyses by Reinert and Lastein (1992) suggest significant differences between *S. mentella* in the Irminger Sea and other areas in the Northeast Atlantic. Tagging studies, carried out in the 50's and 60's in the Godthåb fjord, were sparse and resulted in negligible offshore recaptures (ICES 1983).

When studying the population structure of marine fish, large-scale migration patterns are to be considered before any conclusions can be drawn from the analysis of stock-specific features such as different gene pools. Redfish is known to exhibit strong migration between areas in the North Atlantic, related to hydrographic conditions or breeding places (Tåning 1949, Kotthaus 1965, Troyanovsky 1992, Rikhter 1996). Current theories on the origin of the Irminger Sea stock of *S. mentella* suggest either a migration of young redfish from the Icelandic and East Greenland shelves into the Irminger Sea (Magnússon and Magnússon 1995) or a spreading of adult redfish from a common spawning stock in the central Irminger Sea to other areas, forming separate local stocks (Pavlov *et al.* 1989).

The present study uses a 'classic' approach to investigate the stock structure of *S. mentella* off East Greenland and in the central Irminger Sea and evaluates current migration theories. Analyses of long-term trends in length distributions from survey data and commercial catches are presented to identify strong year-classes and track their abundance in these areas. Following the length distribution patterns of *S. mentella* on the East Greenland shelf and in the central Irminger Sea, migration of juvenile fish from East Greenland into the pelagic Irminger Sea stock is discussed with regard to fisheries management.

Materials and Methods

Abundance estimates and length distributions of *S. mentella* have been derived using annual groundfish surveys covering shelf areas and the continental slope off West and East Greenland, data from commercial catches of the German fisheries and the 1999 international hydro-acoustic survey in the Irminger Sea. A map of the distribution area of demersal and oceanic *S. mentella* is given in Figure 1.

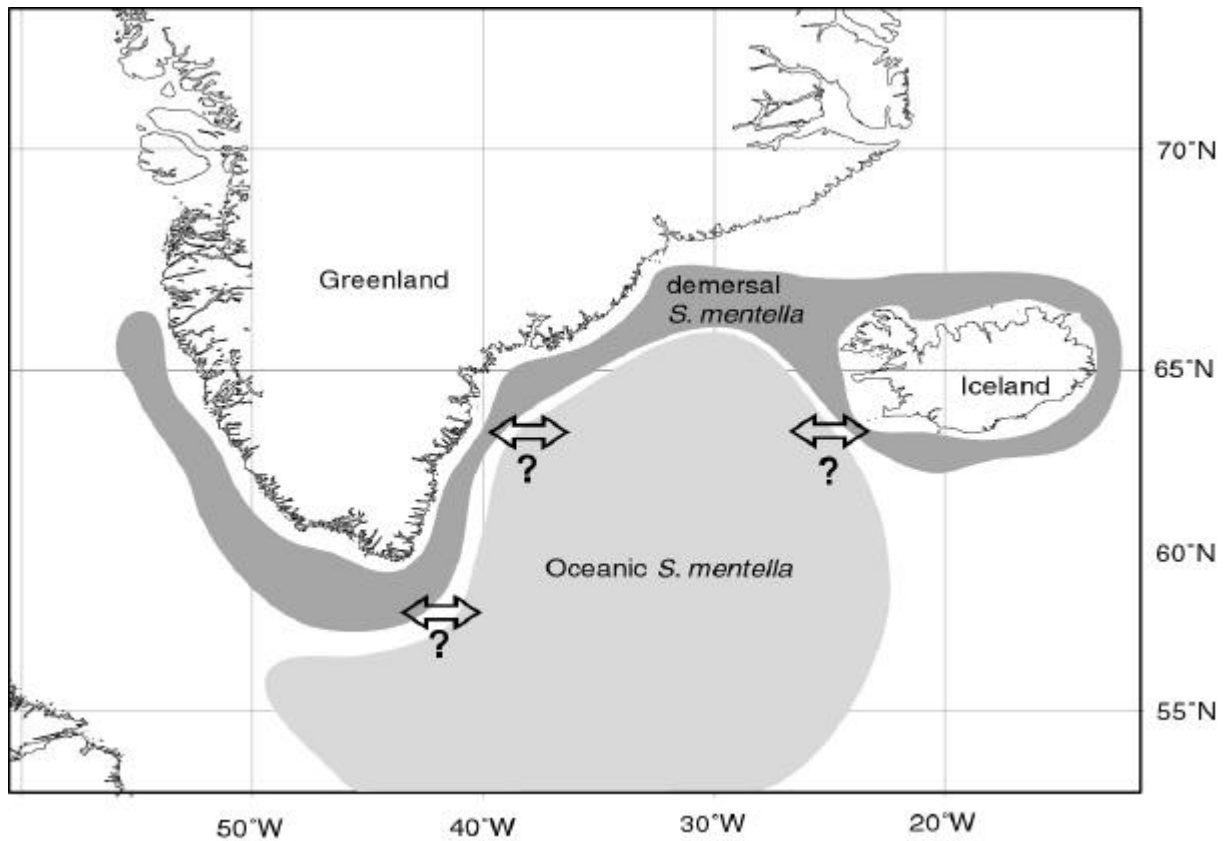


Fig. 1: Distribution of *S. mentella* in the Irminger Sea and adjacent waters. Arrows indicate possible migration between the stocks.

Table 1. Definitions of East Greenland strata applied during the German research surveys.

Stratum	Geographic boundaries				Depth (m)	Area (nm ²)
	South	North	East	West		
5.1	59°00'N	63°00'N	40°00'W	44°00'W	1-200	2468
5.2	59°00'N	63°00'N	40°00'W	44°00'W	201-400	3126
6.1	63°00'N	66°00'N	35°00'W	41°00'W	1-200	1120
6.2	63°00'N	66°00'N	35°00'W	41°00'W	201-400	7795
7.1	64°45'N	66°00'N	29°00'W	35°00'W	1-200	92
7.2	64°45'N	66°00'N	29°00'W	35°00'W	201-400	4589

Research surveys off Greenland

The groundfish surveys commenced in 1982 and were primarily designed for the assessment of cod. In order to reduce the error of abundance estimates, the subdivision of shelf areas and the continental slope into different geographic and depth strata was required due to a pronounced heterogeneity of cod distribution. The survey area off East Greenland was split into three geographic strata. Each stratum was itself subdivided into two depth strata covering the 0-200 m and 201-400 m zones. Table 1 indicates the names of the strata, their geographic boundaries, depth ranges and areas in nautical square miles (nm^2). The inner limit of all strata was the three mile offshore line. The applied strategy was to distribute the sampling effort according both to the stratum areas and to cod abundance. Consequently, 50% of the hauls were allocated proportionally to strata by stratum area while the other 50% were apportioned on the basis of a review of the historical mean cod abundance/ nm^2 , all hauls being randomly distributed within trawlable areas of the various strata. Non-trawlable areas are mainly located inshore. Because of favourable weather and ice conditions and to avoid spawning concentrations, autumn was chosen for the time of the surveys. These were carried out on the fisheries research vessel (FRV) Walther Herwig (II) throughout most of the time period. In 1984 and since 1994, she was replaced by FRV Anton Dohrn and the new FRV Walther Herwig III, respectively.

The fishing gear used in all surveys was a standardised 140-foot bottom trawl, its net frame rigged with heavy ground gear because of the rough nature of the fishing grounds. A small mesh liner (10 mm) was used inside the cod end. The horizontal distance between wing-ends was 25 m at 300 m depth, the vertical net opening being four m. Calculations of abundance and biomass indices were based on the 'swept area' method using 22 m horizontal net opening as trawl parameter, i. e. the constructional width specified by the manufacturer. The towing time was normally 30 minutes at a speed of 4.5 knots. Hauls which received net damage or became hung-up after less than 15 minutes were rejected.

Fish were identified to species or lowest taxonomic level and the catch in number and weight was recorded. Redfish inhabiting the survey area close to the bottom are believed to belong to the traditional stocks off Greenland, Iceland and Faeroes (ICES 1995). Fish (≥ 17 cm) were separated to *Sebastes marinus* L. or deep-sea *Sebastes mentella* Travin, whereas juvenile redfish (<17 cm) were classified as *Sebastes spp.* due to time-consuming and difficult species identification. Total fish lengths were measured to cm below.

Stratified abundance estimates were calculated from catch-per-tow data using the stratum areas as weighting factor (Cochran, 1977; Saville, 1977). Strata with less than five valid sets were rejected from the calculation. The coefficient of catchability was set arbitrarily at 1.0, implying that estimates are merely indices of abundance and biomass. Respective confidence intervals (CI) were set at the 5% significance level of the stratified mean. Mean lengths were calculated for each species in each year and stratum.

Sampling of commercial catches of the German fleet in the Irminger Sea

For the period 1995-99, data on commercial catches, effort (hauls and hours fished) and positions were derived from official logbook statistics. The data were aggregated by quarter, year, ICES Divisions as well as international waters and the Greenland Exclusive Economic Zone. Unstandardised mean CPUE (kg/h) and accompanied standard deviations were calculated on a haul-by-haul basis. The majority of vessels were equipped with Gloria-type pelagic trawls with a vertical net opening of 120 m and a mesh size of 140 mm in the cod end. Towing speed varied between 2.8 and 3.8 knots.

Length frequencies of the catches were derived from fish market samplings or measurements conducted directly on board of commercial trawlers. The total body length was measured to cm below. Length compositions of the catches by year and quarter were determined by aggregation of samples being raised to catches or landings according to sample weights. The biological data collection covered the size composition of the catches by sex and sex ratio, maturity and parasite infestation. Maturity stages were noted according to the agreed description given by the ICES Study Group on Redfish Stocks (ICES 1993).

International hydro-acoustic surveys in the Irminger Sea

From the onset of the commercial fishery on oceanic redfish in the early 1980's, the former Soviet Union (later Russia) conducted acoustic surveys in the Irminger Sea until 1993 (Pedchenko *et al.* 1995). Iceland started with a pilot acoustic survey in 1991 (Magnússon *et al.* 1992a) and participated in a survey together with Russia in 1992 (Magnússon *et al.* 1992b). The 1992 survey showed the need for a wider area coverage (ICES 1994), thus Iceland and Norway carried out a survey in 1994 (Magnússon *et al.* 1994), followed by surveys in 1996 (Magnússon *et al.* 1996) and 1999 (Sigurdsson *et al.* 1999) with participation of Iceland, Russia and Germany. The most recent international hydro-acoustic survey in June/July 1999 provided an expanded vertical coverage of the survey area, i.e. redfish below 500 m depth were assessed by an experimental trawl-acoustic method. Details of the survey settings and methods are given in ICES 1999b and Sigurdsson *et al.* 1999.

Results

During the annual German groundfish surveys on the Greenland shelves, a strong recruiting year-class of deep-sea *S. mentella* was observed to dominate the length distributions in 1995-1998 (Fig. 2). The mean lengths of *S. mentella* off East Greenland during this period were 21.9, 24.1, 24.7, and 26.4 cm, respectively. These shifts in length peaks provide an indication of the annual growth rate of these fish which ranges from a few mm to well above 2 cm per year. Abundance indices for these years show a sharp increase in 1995-1997 and a decrease to less than 50% in 1998. In 1999, however, the quantity of *S. mentella* covering the 25-30 cm length range was comparatively negligible.

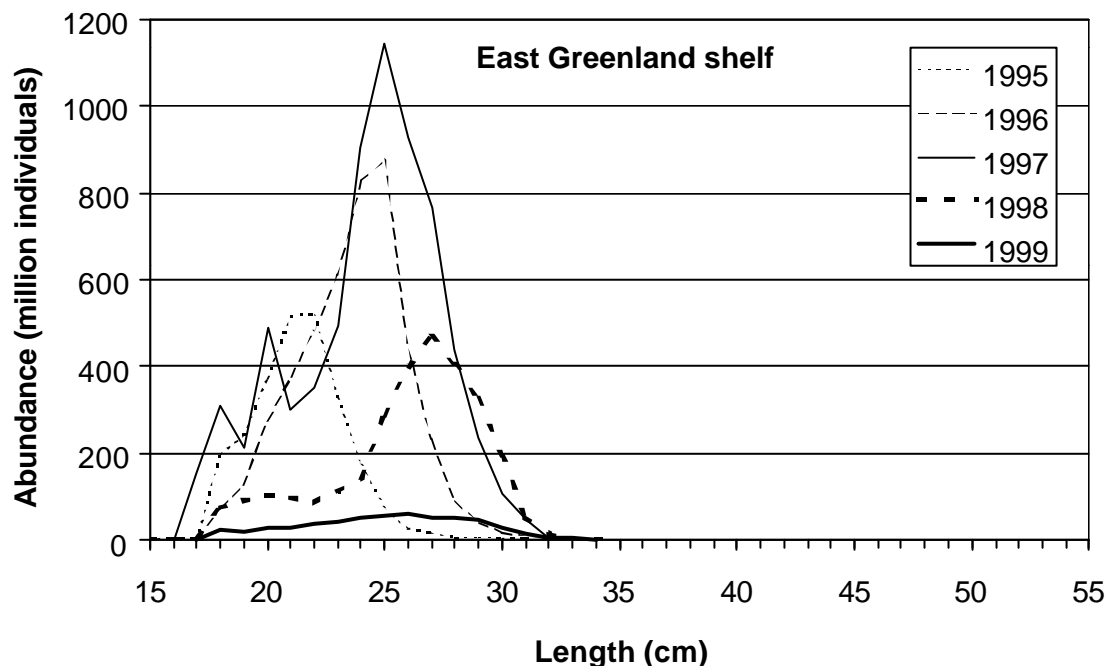


Fig. 2: Length distribution of *S. mentella* on the East Greenland shelf, derived from the German autumn survey 1995-1999.

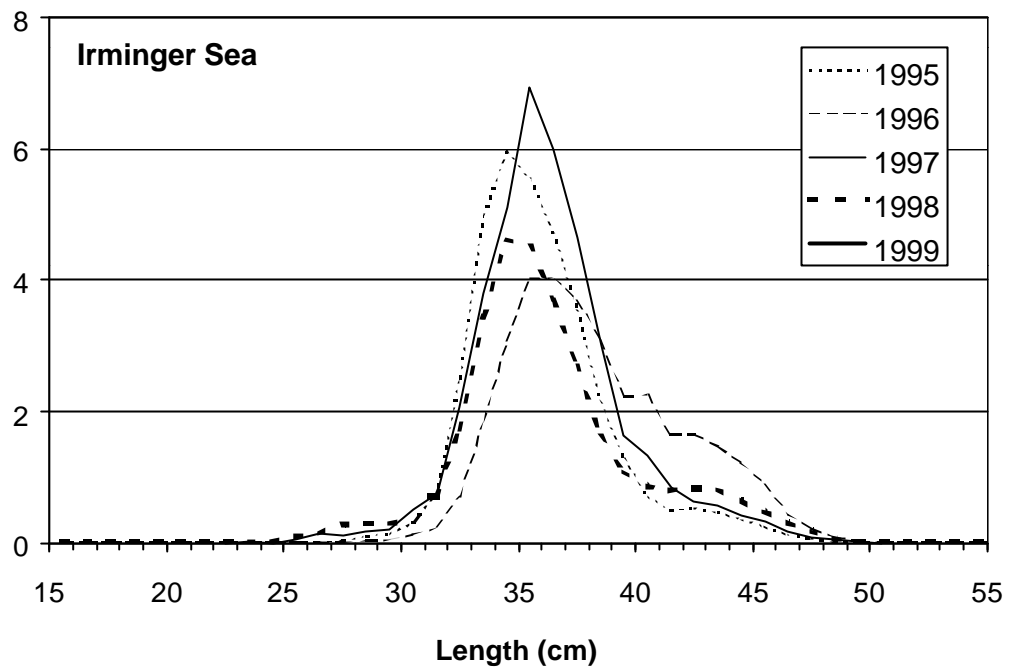


Fig. 3: Length distribution of *S. mentella* in the Irminger Sea, derived from the German commercial fishery 1995-1999.

By contrast, length distributions extracted from data of the German commercial fisheries on *S. mentella* in the Irminger Sea during 1995-1999, exhibit mean lengths around 34-36 cm (Fig. 3). In 1998, and more apparent in 1999, a small peak around 27 to 28 cm formed in addition to the length distribution pattern observed in previous years. This 'ingrowth' of a new length peak into the usual size spectrum of Irminger Sea redfish was also observed during the international hydro-acoustic survey in summer 1999: Figure 4 shows the length distribution of *S. mentella* in the Irminger Sea above and below 500 m water depth, compared to the *S. mentella* length composition in demersal trawls on the East Greenland continental shelf in autumn 1998. The main length peak of *S. mentella* from the East Greenland shelf forms at 27 cm, while *S. mentella* in the Irminger Sea exhibited a small length peak around 28 cm in addition to the 34 cm main peak. The shift in length peaks from 27 to 28 cm observed in October 1998 and June/July 1999, respectively, indicates a growth of about 1 cm within three quarters of a year.

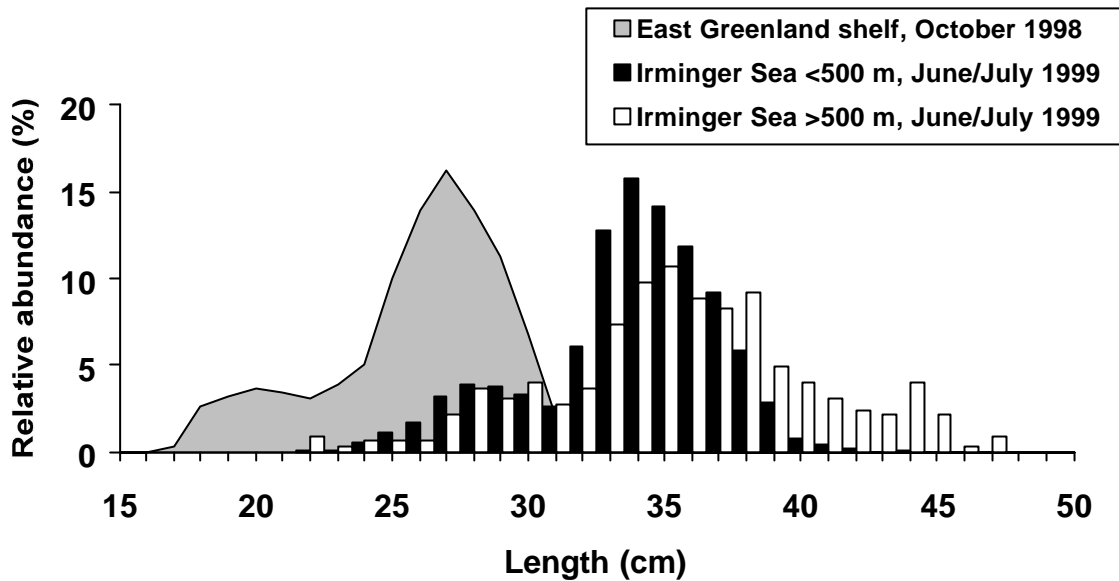


Fig. 4: Length distribution of *S. mentella* on the East Greenland continental shelf in October 1998 and in the Irminger Sea in June/July 1999.

Discussion

After a severe depletion of deep-sea *S. mentella* off East Greenland indicated by the annual German groundfish survey during the 1980's and early 1990's (Rätz 1996, Rätz and Stransky 1999), a sharp increase in abundance was observed in 1995-1997. During the same period, the mean length of these fish showed an upward trend after several years of decreasing mean lengths (Rätz and Stransky 1999). This was mainly due to an individual strong year-class of young fish recruiting into the adult stock. The hope for the a successful recruitment of *S. mentella* in the East Greenland area and the resulting prospects for a rewarding commercial fisheries were set back in 1998 and more dramatically in 1999 when abundance indices diminished to the low level observed before 1995. Since the fishing effort applied to groundfish on the East Greenland shelf remained very low during the past three years (Rätz 1999, Rätz 2000), increased fishing mortality could not be put forward as a reason for the drop in abundance of deep-sea *S. mentella*.

Length composition data from the German commercial fisheries and the international hydroacoustic survey in the Irminger Sea (Sigurdsson *et al.* 1999), however, indicated an 'ingrowth' of young *S. mentella* into the oceanic stock at the same time when these fish disappeared from the East Greenland shelf. A large-scale migration of juvenile fish from the shelf areas into the central Irminger Sea is, therefore, very likely and identifies the East Greenland shelf as a possible nursery area for oceanic redfish occurring above and below 500m depth. Current migration theories, based on few observations (Bakay 1988, Magnússon and Magnússon 1995), suggested a close relationship of *S. mentella* on the East Greenland shelf and in the central Irminger Sea. The phenomenon of significantly high proportions of young deep-sea *S. mentella* contributing to the adult stock of oceanic redfish in the central Irminger Sea was observed for the first time since regular investigations have been carried out in the early 1980's.

From a fisheries management perspective, large-scale migration of marine fish could have major implications regarding stock dimensions and harvesting strategies (Rätz 1994). If the observed migration from the East Greenland shelf to the pelagic fishing areas in the central Irminger Sea occurs frequently, the consistent measure would be to protect young recruiting redfish on the shelf from being exploited and to harvest these as adult stock components in the Irminger Sea at a later stage. In order to evaluate the effects of migration patterns on the stock structure of oceanic redfish, the development of the recruiting redfish in the Irminger Sea will be monitored closely.

With regard to current discussions about stock discrimination of redfish in the North Atlantic (CES 1992, 1993 and 1998), information on stock interrelations like the observed migration plays an

important role in fisheries management, and supplementary studies on the population structure are urgently needed. Further investigations on the population structure of redfish in the Irminger Sea and adjacent waters are currently undertaken within the four-year EU project REDFISH (QLK5-CT1999-01222), using a broad variety of methods including morphometry, otolith structures and genetic analyses. In the scope of this project, otolith shape analyses and assays of the elemental contents in the otoliths will be evaluated as tools for stock separation. These studies will focus on otolith samples taken in 1998 and 1999 in the central Irminger Sea and off East Greenland to compare stock-specific natural markers with the observed migration between these areas. First preliminary results (Stransky, unpublished data) show a high variability in otolith shapes and no indication of a possible classification of *S. mentella* populations based on otolith morphometry. Age determination by otolith readings and age validation by radioisotope ($^{210}\text{Pb}/^{226}\text{Ra}$) ratios will be carried out to investigate if fish of the same length, sampled off East Greenland and in the central Irminger Sea, were of the same age. In addition to the work carried out in the REDFISH project, new possibilities of underwater tagging (Star-Oddi 2000) might allow further insights into migration of redfish.

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