ICES Advisory Committee on Fishery Management
ICES CM 2005/ACFM:10

Report of the
Study Group on Stock Identity and Management Units of Redfishes (SGSIMUR)

31 August – 3 September 2004
Bergen, Norway

International Council for the Exploration of the Sea

Conseil International pour l'Exploration de la Mer

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1 Executive summary

The Study Group on Stock Identity and Management Units of Redfishes [SGSIMUR] has reviewed all reported material on the stock identity of the various redfish units *(S. mentella*) in the Irminger Sea and adjacent waters, and identified the most likely definition of biological stocks of *S. mentella* as well as suggested practical management units.

The review did especially focus on the reported material relevant for the Terms of Reference, i.e. material on differences in reproductive cycle, spawning areas, drift of larvae, nursery areas and recruitment paths to the fishable stock(s), morphology, parasitology, otolith structure and trace element analysis, age- and growth differences, fatty acid profiles, genetic results, geographical distribution and behaviour (horizontal and vertical) of the fishery and from the scientific surveys.

The Study Group was very concerned about how the sampling of material had been conducted as basis for the analyses, e.g. sorting of individuals according to phenotypes for some of the analyses. Some genetic researchers were concerned about too few analyses on temporal stability, and that the sampling should have been conducted as close to the actual mating time as possible, e.g., in order to avoid that the samples behind the presented results could potentially have been mixed feeding aggregations of fish from various populations. However, it was also argued that this could mask/decrease the real difference rather than increase it, and that despite this possible masking, significant differences were observed. Some of the microsatellite data analyses, considered by the experts to be the most useful genetic tool for stock structure analyses, showed even significant breeding barriers between the suggested stocks. Some geneticians considered isolated taxonomic (sibling?) groups (species level?) as explanation for the differences.

There was a consensus in the Study Group about the existence of some or another kind of structure of the *S. mentella* resource in the Irminger Sea and adjacent waters. The Study Group discussed and exchanged views and arguments related to different hypotheses concerning the most likely number of biological stocks of *S. mentella.*

The majority of the Study Group (~3/4), incl. the outside genetic experts, hold the view that the *S. mentella* in the Irminger Sea and adjacent waters, based on current available knowledge, should be considered as three separate stocks and managed accordingly. These stocks are:

- Oceanic *Sebastes mentella*
- Pelagic deep-sea *S. mentella*
- Shelf deep-sea *S. mentella*

The Greenland shelf is the main nursery area. Observations indicate that juvenile *S. mentella* on the Greenland shelf recruit to both the pelagic stocks and possibly also the shelf stock(s). The nursery areas at Greenland are therefore part of all three suggested stocks. Some observed structure of these nursery areas related to the proposed stocks should be further investigated.

There are also important biological links between *S. mentella* on the shelf of Iceland and Faroes, which need to be taken into consideration. More research is, however, needed around the Faroes to reveal and understand how *S. mentella* in this area e.g., are linked to Iceland and the pelagic Irminger Sea.

The other researchers hold the view that the observed differences and biological structures are either related to growth, age and/or the environment, or at least too small to be used against the one-stock hypothesis. Two of these researchers would, however, as a precautious approach to management in order to avoid disproportional catches of the components, recommend, for the time being, three separate management units in accordance with the majority. Three researchers would, on the other hand, keep today's practice of two management units.

The majority (6/7) of the Study Group recommends three practical management units to be set based on geographical areas and seasons, and have presented their best suggestions. The nursery areas at Greenland should be managed accordingly. Regular scientific surveying of the total area of distribution is necessary for proper monitoring of the stocks and the suggested management units and regulations. Although a full consensus was not possible to reach, the Study Group clearly shows which direction to go from here concerning the management of these resources. Recommendations for future research are given.

2 Introduction

2.1 Participants

Bakay, Yuri	Russia
Carreau, Philippe	EU
Dahle, Geir	Norway
Fevolden, Svein-Erik	Norway
Gíslason, Davíd	Iceland
Gunderson, Donald	USA (invited expert)
Joensen, Horaldur	Faroe Islands
Johansen, Torild	Norway
Jørstad, Knut	Norway
Kristinsson, Kristjan	Iceland
Melnikov, Sergey P.	Russia
Nævdal, Gunnar	Norway
Nedreaas, Kjell H.	Norway (chairman)
Novikov, Georgy	Russia
Reinert, Jákup	Faroe Islands
Saborido-Rey, Fran	Spain
Schmidt, Cathrin	Germany
Sévigny, Jean Marie	Canada (invited expert)
Sigurdsson, Thorsteinn	Iceland
Stefansson, Magnus Ö.	Iceland
Trautner, Jochen	Germany

Member of the ICES Working Group on the Application of Genetics in Fisheries and Mariculture [WGAGFM], Einar Eg Nielsen, Denmark, reviewed and commented by correspondence on the available genetic results before the Study Group (see Working Document no. 8).

2.2 Terms of Reference

At the 91st ICES Statutory Meeting (2003) it was decided (2ACFM29) that **"A Study Group on Stock Identity and Management Units of Redfishes** [SGSIMUR] (Chair: Kjell Nedreaas, Norway) will be established and will meet in Bergen, Norway, from 31 August to 3 September 2004 to:

- review all reported material on the stock identity of the various redfish units *(S. mentella*) in the Irminger Sea and adjacent waters;
- identify the most likely definition of biological stocks of *S. mentella* as well as suggest practical
- management units.

SGSIMUR will report by 8 September 2004 for the attention of RMC and ACFM.

Scientific justification

A prerequisite to sound management is proper definition of stock unit. Uncertainty in the definition of stock units of redfish (*S. mentella*) in the Irminger Sea and adjacent waters has been a matter of continuous debate among assessment scientists for a number of years. Within the NWWG there is a consensus that the group is primarily an assessment group and does not have sufficient expertise to thoroughly review the scientific research of redfish stock identification which has been a part of its ToR for a number of years. The methodological approaches used include genetic differentiation, morphometrics, parasitology, growth patterns, and trace element analyses. This autumn a multinational EU project on the stock identification will conclude in the form of a report that will provide further information on this matter. It is considered essential that a separate group of experts, from the fields of stock identification as well as assessment, review all published information on the stock delineation of the redfish in the Irminger Sea. The objective of the group should be to identify the most likely definition of biological stocks of the *S. mentella* as well as suggest practical management units.

Background

The current stock units assessed and advised on by ICES in the Irminger Sea and adjacent waters comprise the *S. mentella* on the continental shelves and slopes of the Faroe Islands, Iceland, and East Greenland as one stock, and all pelagic *S. mentella* in the Irminger Sea as a single and separate stock.

The existence of more than one stock of *S. mentella* in the Irminger Sea has been discussed in recent years (ICES 2004). Historically, *S. mentella* was fished on the continental shelves and slopes of the Faroe Islands, Iceland, and East Greenland and been considered as one stock. A new pelagic fishery started in the open Irminger Sea in 1982, primarily fishing in waters shallower than 500 m. In 1992, the Study Group on Redfish Stocks distinguished between these types as deep-sea *S. mentella* (shelf redfish) and oceanic *S. mentella* (Irminger Sea redfish). In the early 1990's, the pelagic fishery in the open Irminger Sea moved to layers deeper than 500 m. Some researchers considered that the fish caught pelagically deeper than 500 m differed from the fish caught shallower than 500 m and resembled more to the deep-sea *S. mentella* living on the continental shelves and slopes. *S. mentella* living deeper than 500 m has been called "pelagic deep-sea *S. mentella*". Recently, the distribution of the pelagic *S. mentella* in the upper 500 m has extended significantly more southwest and into the NAFO Convention Areas compared to the early 1990's.

It is not known whether these types represent one stock or several biologically different stocks and different hypotheses have been put forward based on comprehensive studies on growth, maturity, morphometrics, parasites as natural tags, and genetic and fatty acid differentiation of the species (see also Figure 2.1):

- **Single-stock hypothesis:** All *S. mentella* from the Irminger Sea and adjacent waters is one stock and is segregated according to age/size.
- **Two-stock hypothesis:** The *S. mentella* living on the shelves (shelf deep-sea *S. mentella*) and those living in deeper pelagic waters of the Irminger Sea (pelagic deep-sea *S. mentella*) is one stock unit, which is separated from the oceanic *S. mentella* living in the upper layers of the Irminger Sea.
- **Three-stock hypothesis:** The three described components are biologically different stocks.

Despite a lot of effort by different Working Groups and Study Groups within ICES, there has not been a consensus within the ICES regarding which hypothesis is the most likely one. Although the uncertainty regarding stock structure of *S. mentella* is great, extensive research have been done. Several studies have recently been finished to answer important questions regarding the biology, population structure, and abundance and demography of this highly migratory and straddling species. The most comprehensive international work to date has been the EU REDFISH project which was finished this summer, and a draft final report was made available to the Study Group (Anon. 2004). In addition, a Faroes redfish project (WD9) is also available.

The *S. mentella* in the Irminger Sea and adjacent waters have for many years been phenotyped by Icelandic researchers to oceanic phenotype *S. mentella* and deep-sea phenotype *S. mentella*. The reported differentiation of the two *S.mentella* types in the Irminger Sea has been based on the following criteria (e.g., Magnússon & Magnússon 1995, ICES 1998):

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.

Correct phenotyping of *S. mentella* according to the above criteria needs experienced and trained personnel. All data on *S. mentella* that had been phenotyped to either oceanic or deep-sea *S. mentella* in the analyses have therefore been phenotyped by Icelandic personnel. For training personnel in this work, an operational phenotyping key has often been used (Saborido-Rey, pers. comm.):

1. The two most anterior preopercular spines are NOT pointing forward.........*Oceanic*

The spines are pointing forward.. *2*
2. Specimen larger than 32 cm.. *3*
Specimen smaller than 32 cm... *4*

3. Immature fish. Low parasitation infestation rate, without or scarce spots or
mark in the skin. The flesh shows normal colour..*Deep-sea*
Mature fish... *5*

4. Mature fish..*Oceanic*
Immature fish.. *5*

5. High parasitation infestation rate, with black or red spots in the skin.
The flesh shows grey or dark spots...*Oceanic*
Low parasitation infestation rate, without or scarce spots or mark in the skin.
The flesh shows normal colour...*Deep-sea*

Though some results and statistical tests reviewed by the Study Group were based on phenotypes, most of the results and statistical tests reported by the Study Group came from data analyses independent of the phenotyped data, i.e., fish data from different depths and geographical habitats.

The terms ’stock’ and ’population’ were by the Study Group understood as real biological groups of fish, either separated because of breeding barriers or due to other biological and/or hydrographical separation reasons. The term ’management unit’ was by the Study Group understood as the best practical geographical unit (with regards to area and depth) that managers may use to meet the biological terms ’stock’ and ’population’.

3 Review of all reported material on the stock identity of the various redfish units *(S. mentella)* in the Irminger Sea and adjacent waters

3.1 Geographical distribution and behaviour (horizontal and vertical) seen from the surveys.

The distribution of the pelagic *S. mentella* as seen from the joint trawl-acoustic surveys conducted since 1992 have shown that redfish above the deep scattering layer (above 500 m) has been observed further Southwest since 1999 than it was observed in the beginning of the 1990s (Figures 3.1.1-3.1.6). It was also shown that the environmental conditions in the Irminger Sea have changed during this period. In general, there has been observed higher temperature at that depth and the temperature where the highest concentrations of redfish were found (lower than 4°C) in previous years, only small quantities of redfish were observed.

During the surveys from 1992-1997, no attempt was made to measure the redfish that are found at greater depth than 500 m. The reason is that during the first surveys, the existence of any large quantities of redfish below that depth was unknown. As the fishery developed towards larger depth the need for estimating the fish in and below the deep-scattering layer became obvious. Therefore, it was first in 1999 that estimate of fish abundance on fish below 500 m was tried.

The general feature seen from the survey series is that in recent years the highest concentrations of fish found below 500 m is found in the NE part of the surveyed area as highest concentration of fish above 500 m is found in the south-western part (except 2003, where only small amount of fish was found). At depths below 500 m, high proportion of the fish is larger than 40 cm, as the fish observed shallower than 500 m is smaller. During all the surveys conducted, large proportion of both males and females were identified as maturing or postspawners.

The overall proportion of sexes in the survey catches is given below and in detail in Table 3.1.1. It shows that the males are in higher proportion within both depth layers, in all surveys and areas since 1999 and also above 500 m in the 1996 survey.

Year	prop males < 500 m	prop males > 500 m
1996	61%	
1999	63%	60%
2001	66%	59%
2003	64%	61%

In the most recent survey from May-June 2003, the abundance of fish above 500 m was lower than 100 thousand tonnes which is the lowest estimate observed. There were no indications of major biomass portions outside the survey area in horizontal and vertical directions, except for the area close to the Icelandic shelves, below 600 m. The results of the survey series are inconsistent with previous surveys and thus do hardly indicate the actual stock status of pelagic redfish. To which extent biological effects or slight changes in the survey design (RV Walther Herwig III covered the south-western survey area in 2003 about 4 weeks earlier than in 2001) contributed to this inconsistency is unknown. However, strong vertical immigrations from outside the hydro-acoustically surveyed area (deeper than 500 m) are not indicated during June-July considering the contradictions of the low abundance measured and the successful fishing in 2003 (see Figure 3.1.6).

The 2003 survey indicate that redfish distribution area deeper than 500 m might not be entirely covered by the survey as there were high redfish concentrations recorded in the north-eastern part of the survey area and in the vicinity of the continental slope west off Iceland.

Length distribution of fish caught above 500 m range from around 25-42 cm with a peak between 33-37 cm. The fish caught below 500 m is from about 25-50 cm, but often with 2 peaks in the length distribution, one around 35 cm and another between 40-45 cm. The mean length of the redfish measured in the surveys shows that, on average, the fish caught below 500 m in the Northeast area of the distribution is larger (mean length about 41-42 cm) than the fish caught in waters above 500 m in the Southwest area (mean length about 35-36 cm, Figure 3.1.7-3.1.11). The length distribution has not changed in these two depth layers over the time period examined, that is, the length of redfish above 500 m has been between 35 and 36 cm since 1992 and around 40 cm in the lower layer since 1999. However, a sign of recruitment was observed both above and below 500 m in the surveys in 1999 and 2001.

Juveniles of *S.mentella* are very rarely observed in surveys in other areas than along the shelf of West and East Greenland. Germany have conducted demersal surveys in that area since 1982. The results from the Greenland shelf and the absence of juveniles in other areas confirm that Greenland is the most important area for juvenile *S.mentella*. The German results show small redfish (*Sebastes* spp.- mixture of *S.marinus* and *S.mentella*) being both at West and East. *S.mentella* larger than 17 cm was found both East and West, but in higher proportions at the East (Figure 3.1.12).

In summary, the following information can be extracted from the data available.

Abundance of redfish shallower than 500 m has increased in the south-western area since 1996 as fish in the central Irminger Sea has decreased. Fish above 500 has during the recent surveys been observed with highest concentration in the SW part of the surveyed area.

Pelagic redfish deeper than 500 m has been observed through the fishery since 1993 but abundance estimate in joint surveys was first tried in 1999. In the three surveys conducted since 1999, highest concentration was every year observed in the NE part of the Irminger Sea.

The fish observed deeper than 500 m, mostly in the NE part of the area is 25-50 cm, and the average length is around 5-6 cm larger than those observed in the shallower water (25-42 cm) in the SW area.

Survey abundance and fishery during the survey time are consistent in terms of area with highest concentration. Results of the acoustic surveys are in concordance with fishery data, showing highest concentration of fish below 500 m being in the NE part of the survey area and highest concentrations of redfish shallower than 500 m being in the SW area of the area surveyed.

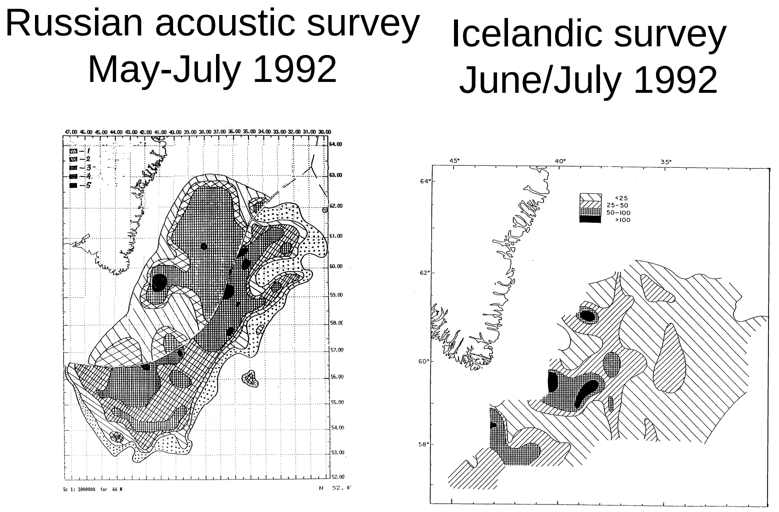
Good recruitment is observed in 1999 and 2001 both below and above 500-m depth but in higher proportion above 500 m. Recruitment was also observed in demersal surveys and catches along the Icelandic slope.

Table 3.1.1. Proportion of males and number of sexed fishes by areas and depth as observed in the joint trawl-acoustic surveys in 1999, 2001 and 2003. The areas codes are shown in figure 3.1.10.

		< 500			> 500		
1999 survey		no males	no females	% males	males	females	% males
Area	A	83	50	62%	712	512	58%
	B	1382	845	62%	801	542	60%
	C				13	11	54%
	D	106	90	54%	86	71	55%
	E	1052	538	66%	290	157	65%
	F						
	Total	2623	1523	63%	1902	1293	60%

		< 500			> 500		
2001 survey		no males	no females	% males	males	females	% males
Area	A	261	136	66%	1238	883	58%
	B	290	174	63%	457	283	62%
	C	26	28	48%	18	15	55%
	D	1156	534	68%	29	20	59%
	E	559	326	63%	66	32	67%
	Total	2292	1198	66%	1808	1233	59%

		< 500			> 500		
2003 survey		no males	no females	% males	males	females	% males
Area	A	36	16	69%	517	352	59%
	B	56	41	58%	201	120	63%
	C	7	3	70%	44	32	58%
	D	5	1	83%	45	9	83%
	E	20	9	69%	48	23	68%
	Total	124	70	64%	855	536	61%


Russian acoustic survey May-July 1992

Icelandic survey June/July 1992

Figure 3.1.1. Distribution and abundance of acoustically detected *S. mentella* in 1992 (shallower than 500 m).

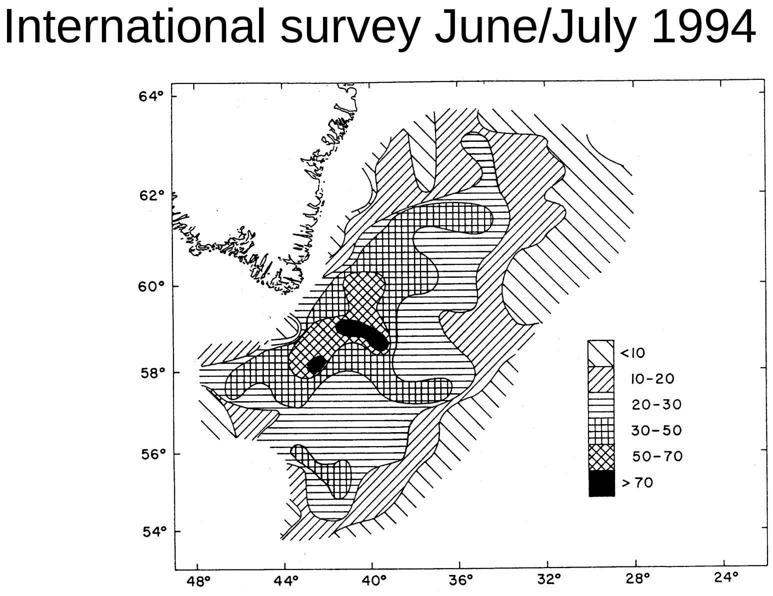

International survey June/July 1994

Figure 3.1.2. Distribution and abundance of acoustically detected *S. mentella* in 1994 (shallower than 500 m).

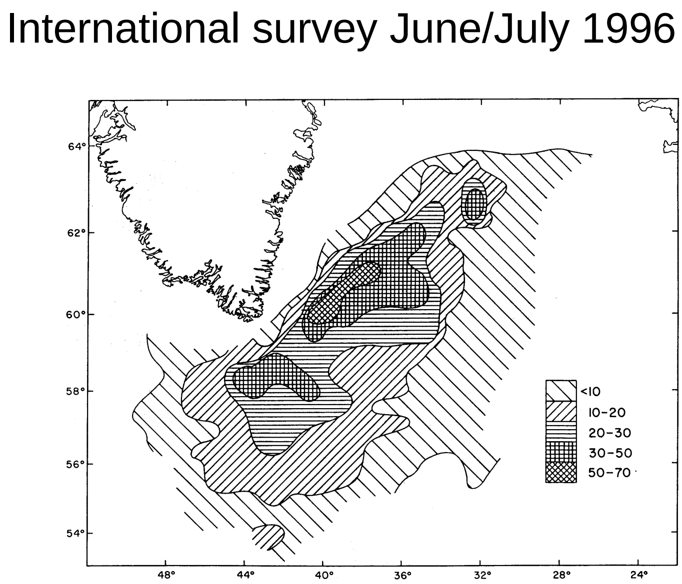


Figure 3.1.3. Distribution and abundance of acoustically detected *S. mentella* in 1996 (shallower than 500 m).

Figure 3.1.4. Distribution and abundance of acoustically detected *S. mentella* in June/July 1999 (shallower than 500 m)

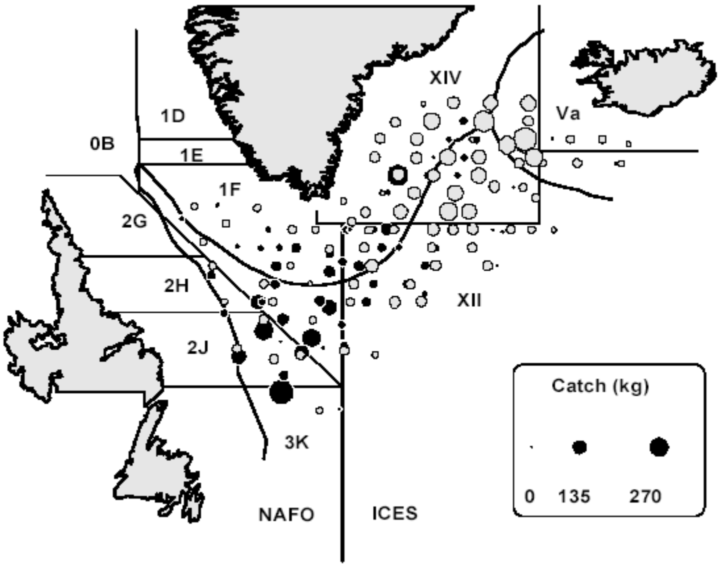


Figure 3.1.5. Distribution and abundance of *S. mentella* below 500 m in June/July 2001 (grey) and shallower than 500 m (black).

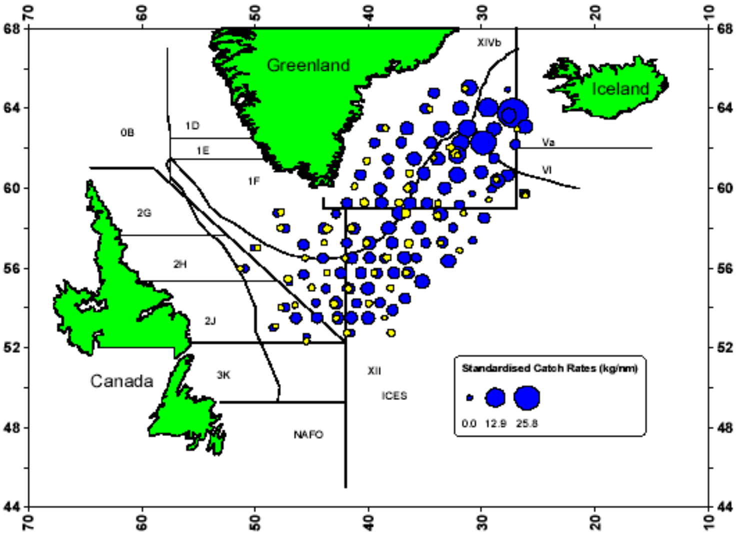


Figure 3.1.6. Positions of stations and scaled catch rates of pelagic *S.mentella* shallower than 500 m depth (bright circles) and deeper than 500 m depth (dark circles) during the international hydro - acoustic survey in May-June 2003.

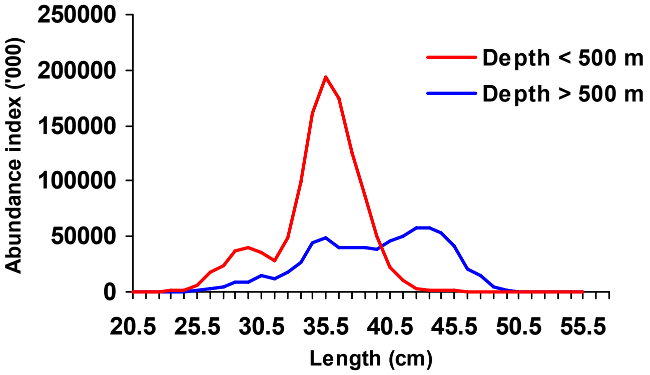


Figure 3.1.7. Length distribution from survey in June- July 1999.

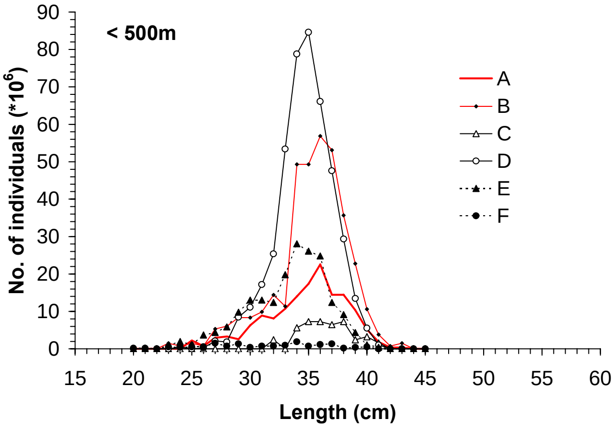


Figure 3.1.8. Length distributions from survey in June - July 2001. Data from depths shallower than 500 m, divided by areas shown on the map.

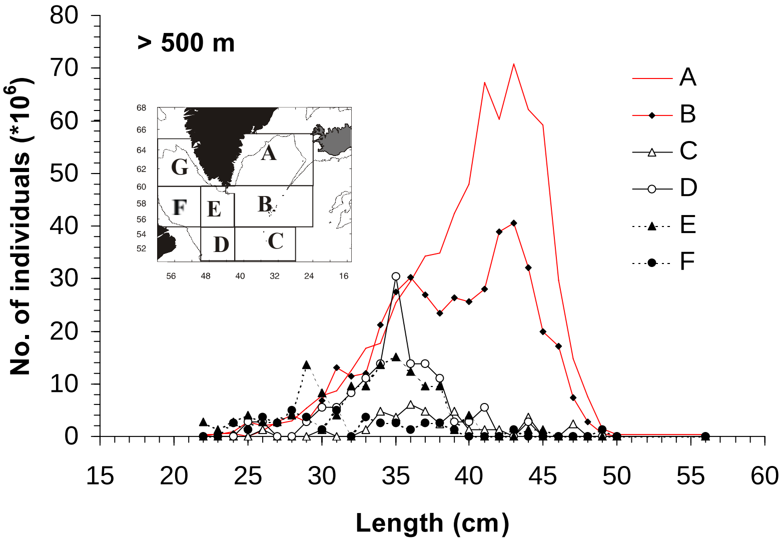


Figure 3.1.9. Length distributions from survey in June - July 2001. Data from depths deeper than 500 m, divided by areas shown on the map.

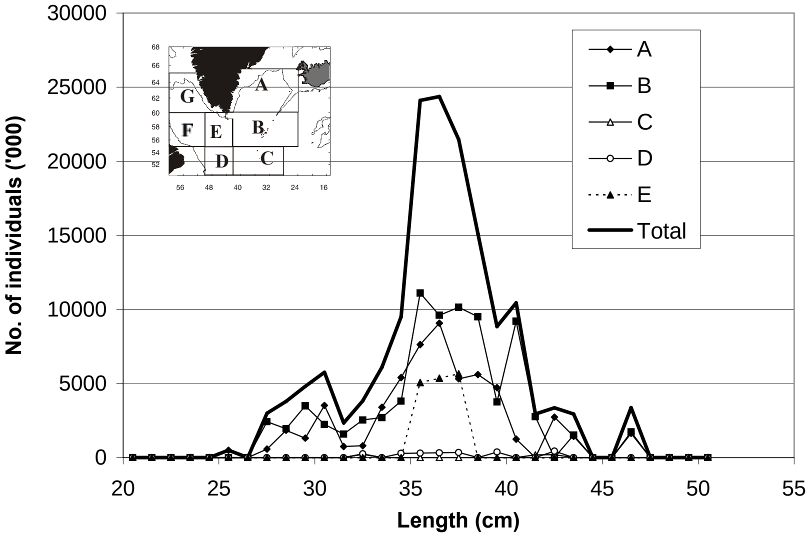


Figure 3.1.10. Length distributions from survey in May-June 2003. Data from depths shallower than 500 m, divided by areas shown on the map.

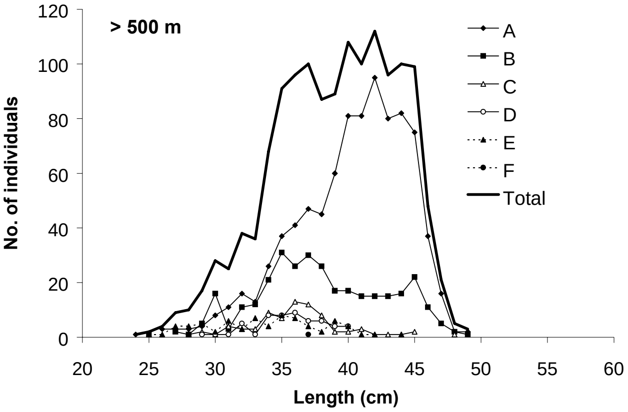


Figure 3.1.11. Length distributions from survey in May-June 2003. Data from depths deeper than 500 m, divided by areas shown on the map.

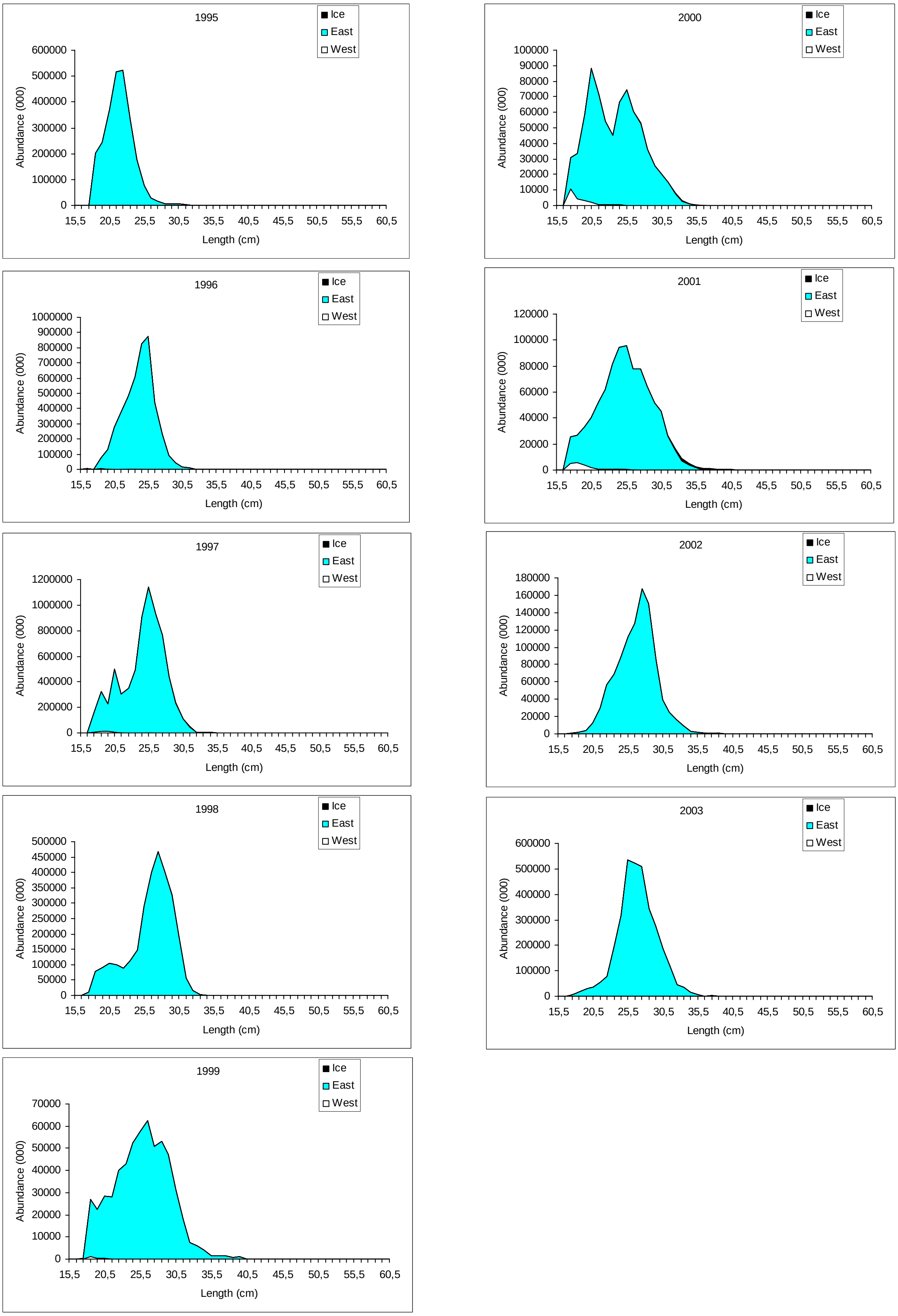


Figure 3.1.12. Abundance of *S.mentella* as observed during the joint German Icelandic groundfish surveys 1995-2003.

3.2 Distribution of the fishing fleet and data from the fisheries relevant for the ToRs

Presentation was given on the pelagic fishery since it commenced in 1982. Both data from the EU REDFISH report (Anon. 2004) as well as information given in WD6 (Shibanov & Melnikov) was evaluated. The fishery can be divided into 3 periods, from 1982-1991, 1992-1996 and from 1997 to present time. During the whole period the fishing season have been from April to October fishing newly spent fish and feeding fish. In addition, information on the demersal fishery for *S.mentella* around Iceland was given.

Pelagic fishery 1982-1991: The main fishing area was in the central Irminger Sea from 58° to 61°N and between 28°-36°W, the NEAFC Regulatory Area beyond Greenland and Icelandic national jurisdictions at depths between 75 and 400 m (Figures 3.2.1-3.2.2). The fish length distributions derived from commercial catches remained very stable, with an average length of between 35 and 37 cm. During this period, there are no indications of changes in the mean fish size over time.

Pelagic fishery 1992-1996: The fishery shifted towards trawling at greater depths (Figure 3.2.2), yielding larger redfish and developing a clear seasonal pattern in the fishery. Both the fishing areas and the depth of trawling changed systematically as the season progressed. The size distribution of the fish caught also changes with depth, yielding about 40-42 cm fish in the deeper waters during the beginning of the fishing season. Around mid June, all fleets moved southwest out to the central Irminger Sea where trawling took place in upper ocean layers yielding relatively smaller redfish of similar sizes compared to the early fishing years 1982-1992.

Pelagic fishery 1997-present: During the first months of the fishing season (April), the fishery is conducted in an area east of 32°W and north of 61°N. In May and June, the fishery is conducted more or less at the same areas, but in July and August, the fleets moved to areas south of 60°N and west of about 32°W, where the fishery continues until October (e.g., WD6, Anon. 2004a). There are very little fishing activities in the period from November until late March or early April when the next fishing season starts. Since 1997, the vessels have operated at a depth range of 200 to 950 m, but mainly deeper than 600 m from April until middle of June but at depths shallower than 500 m from July and until the end of the fishing season (Figure 3.2.3). From the fishery data it is evident that the fishing grounds are separated in 2 almost distinct areas (Figure 3.2.4), though at different months. The fleets start the fishing season in the north-eastern area operating at depths deeper than 500 m and catching larger fish than they catch in the south-western area during in the second half of the year (Figure 3.2.5). The size of the fish caught in the south-western areas during summer and autumn is significantly smaller than the fish caught in the north-eastern area in the spring and early summer (Figure 3.2.6). To what extent the *S. mentella* in these main fishing areas are connected, e.g., through migration, should be further investigated. Estimated catches of pelagic redfish caught by depth is shown in Figure 3.2.7, based on log-book reporting by depth.

Demersal fishery: Fishery for *S.mentella* has been conducted with large factory trawlers and fresh fish trawlers for decades along the shelf of E-Greenland - Iceland - Faroes. Main fishing areas has however been Southwest and West of Iceland (Figure 3.2.8). In Icelandic waters, only fishable stock has been detected, the juveniles are expected to be found along the shelf of East Greenland and the spawning areas are reported SW of Iceland, over the Reykjanes Ridge. Figure 3.2.9 shows the weekly fishing locations of the Icelandic pelagic fleet in May-July 2003. When comparing the pelagic gear fishery with the demersal gear fishery in June-July 2003, there are indications that in June - July, the pelagic fleet did follow a fishable concentration of redfish northward and all the way into the shelf area west of Iceland where, in July 2003 there were relatively high catches of *S.mentella* caught with bottom trawl (Figures 3.2.9-3.2.10).

The chairman wants to add that a migration of pelagic *S. mentella* in this northward direction has later/recently been confirmed by Icelandic tagging results.

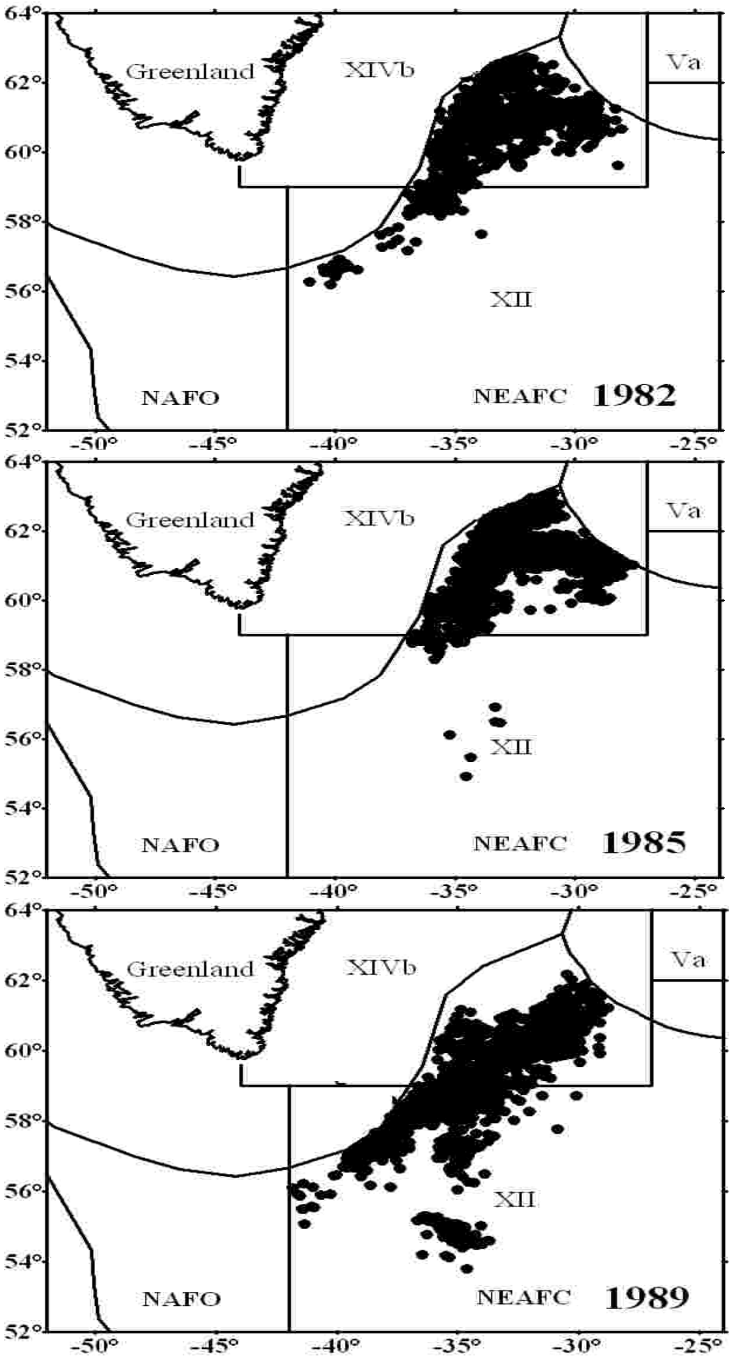


Figure 3.2.1. Distribution of the fishery in 1982, 1985 and 1989 (WD 6, Shibanov & Melnikov).

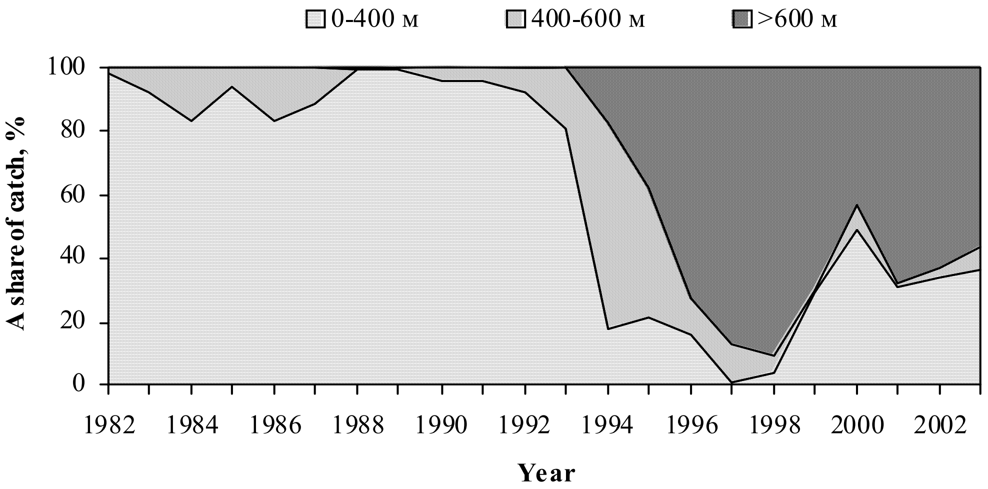


Figure 3.2.2. Depth distribution of catches by the Russian fleet since 1982 (WD 6, Shibanov & Melnikov).

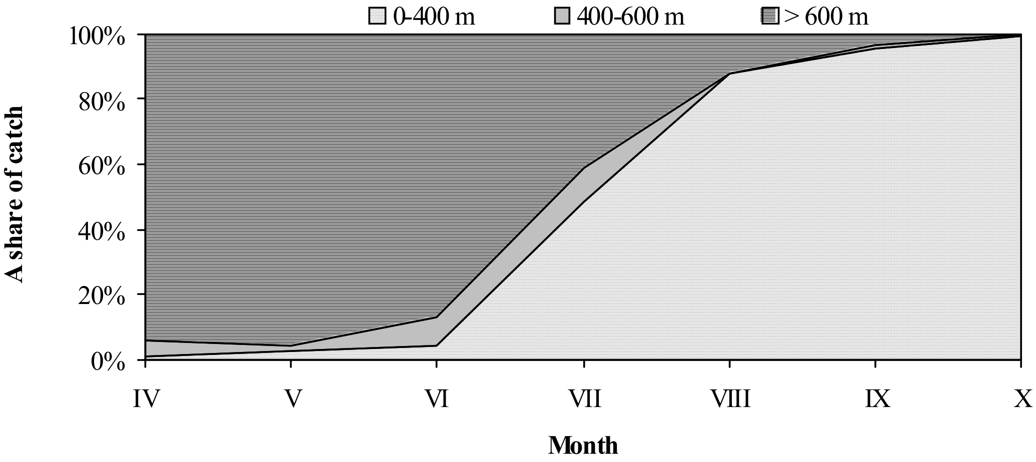


Figure 3.2.3. Depth distribution of Russian catches by month since 1999 (WD 6, Shibanov & Melnikov).

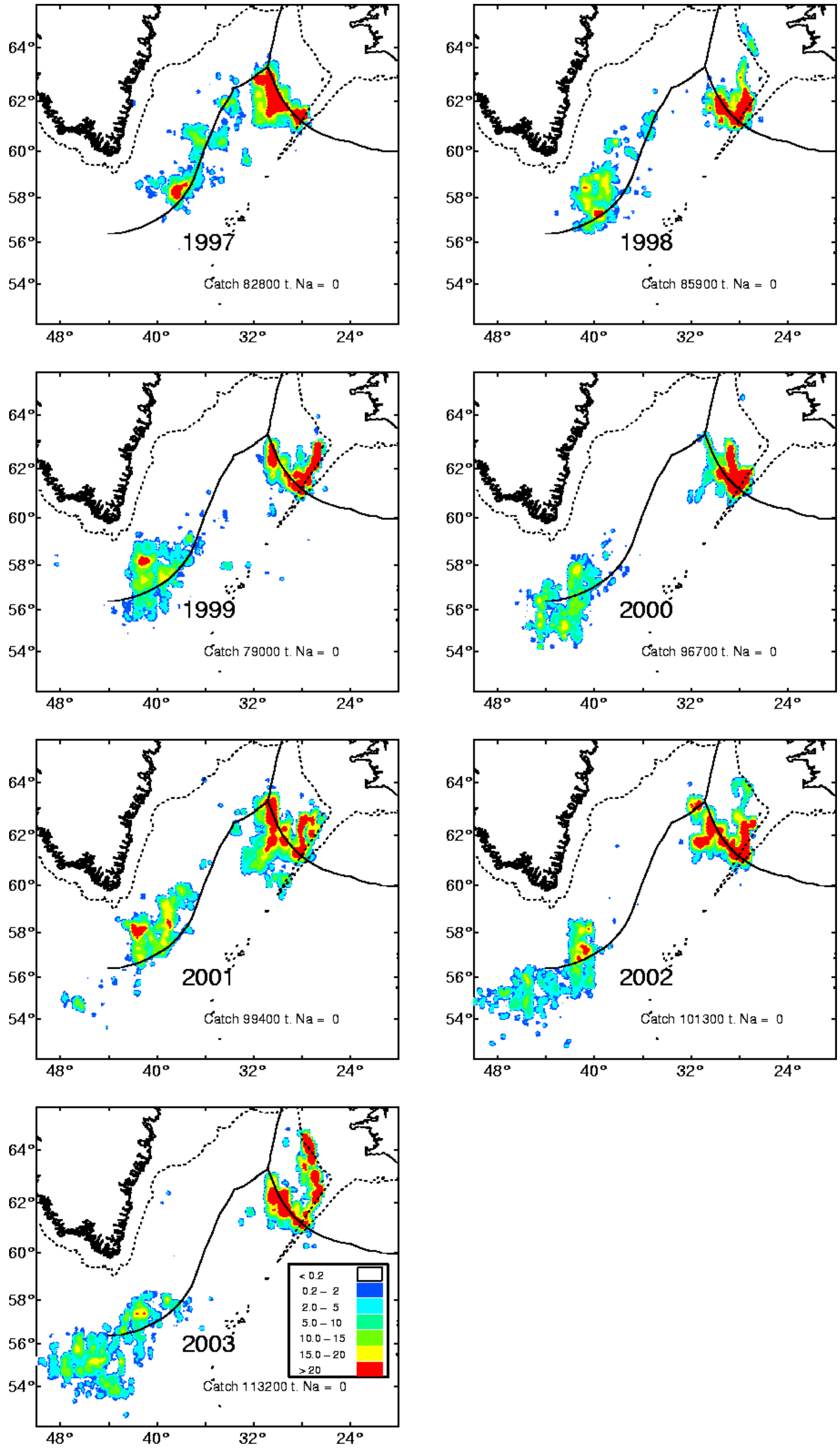


Figure 3.2.4. Geographical overview of the pelagic fishery 1997-2003. The data are from Faroes, Norway, Germany, Iceland, Russia and Greenland and represents more than 75% of reported catches during that period.

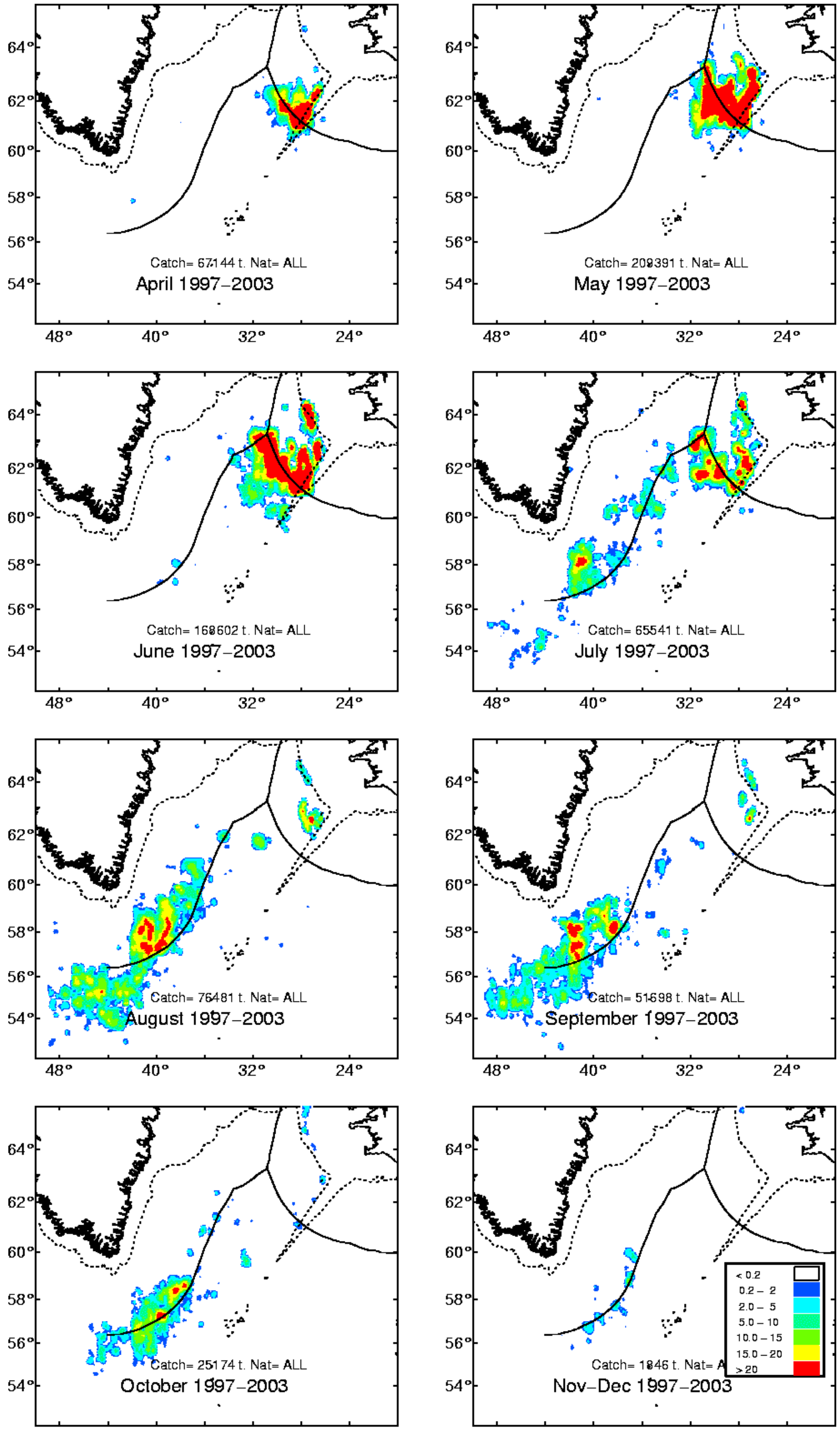


Figure 3.2.5. Summarized distribution of fishing locations for pelagic *S. mentella* from 1997-2003 by month.

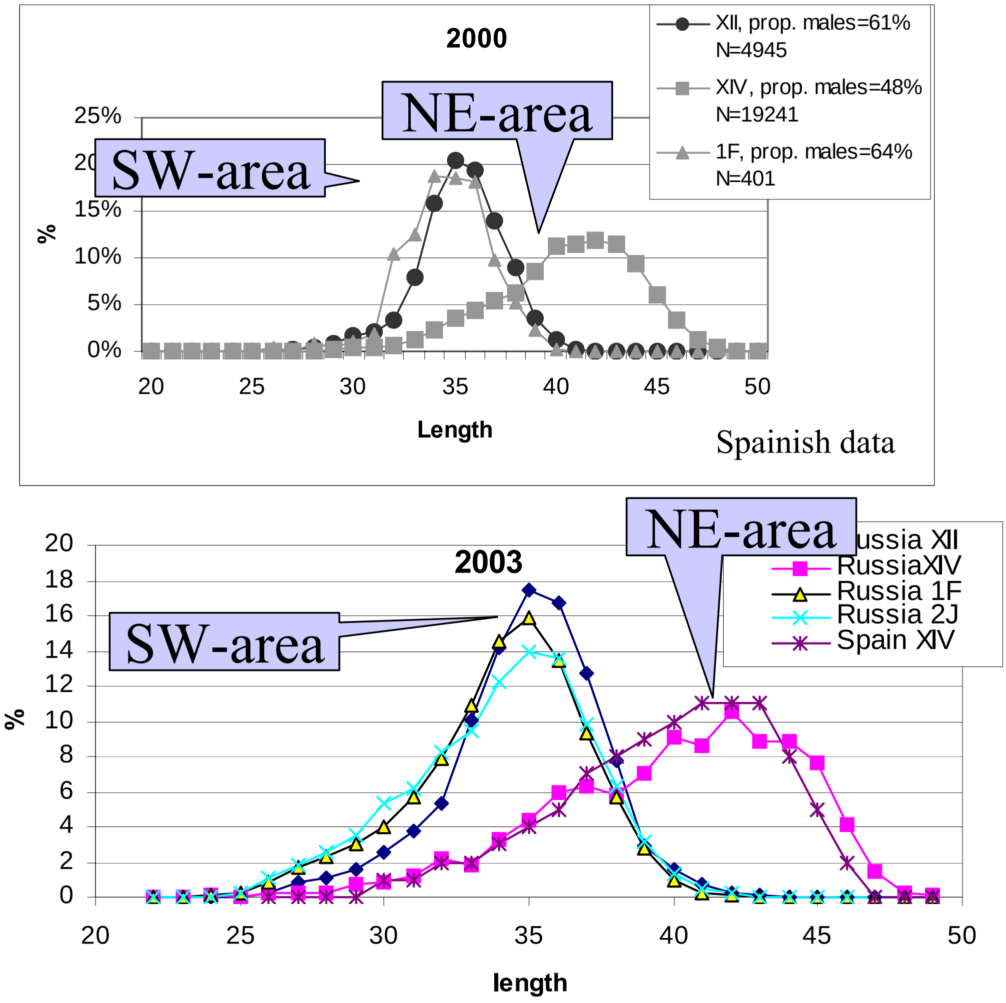


Figure 3.2.6. Length distributions of pelagic *S. mentella* by area in 2000 and 2003 (data from ICES NWWG 2004).

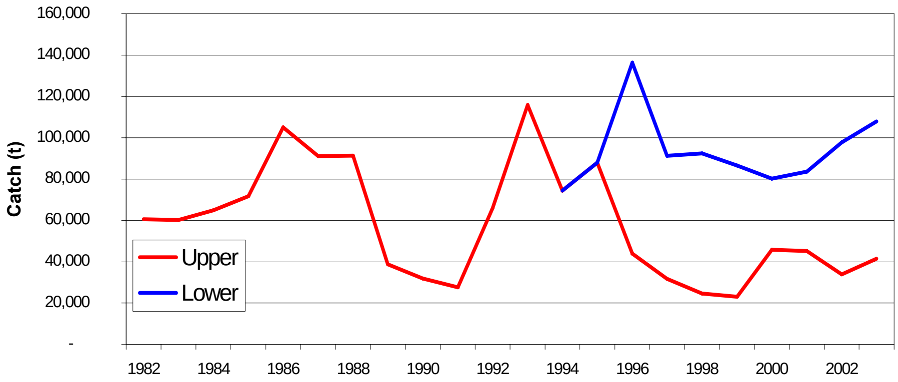


Figure 3.2.7. Approximation on estimated total catch of pelagic *S. mentella* by depth. ‘Upper’ means shallower than 500 m, ‘Lower’ means deeper than 500 m. Note that the curves overlap in 1994 and 1995.

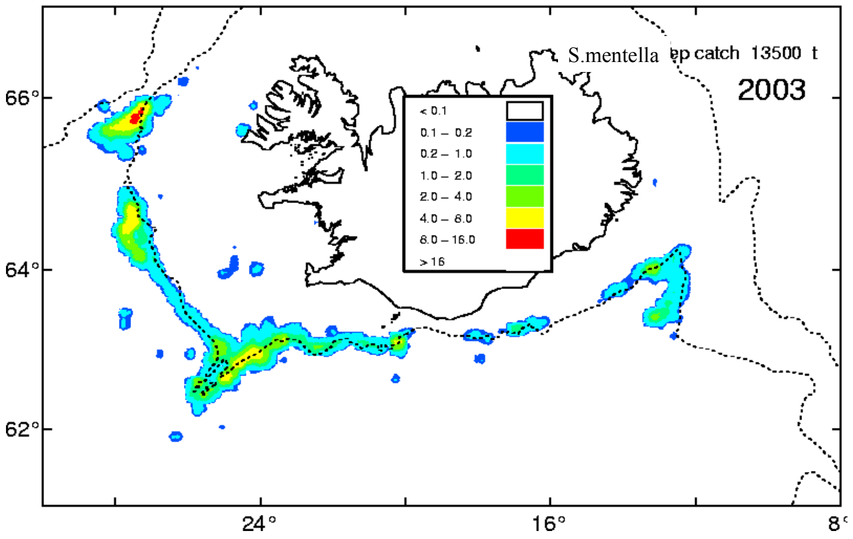


Figure 3.2.8. Demersal fishery for *S.mentella* on the slope of Iceland.

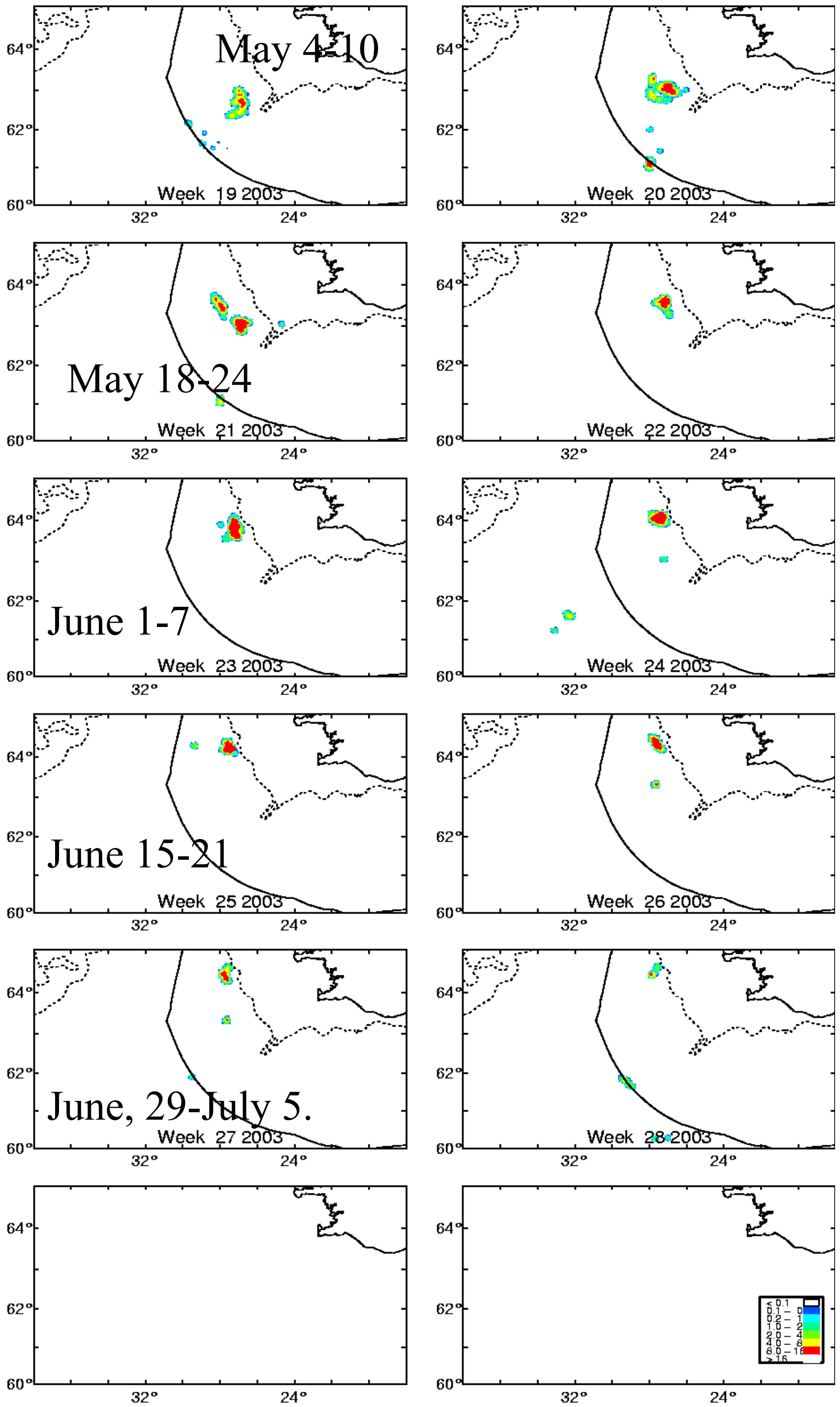


Figure 3.2.9. Icelandic pelagic fishery for *S.mentella* by week in May - July 2003.

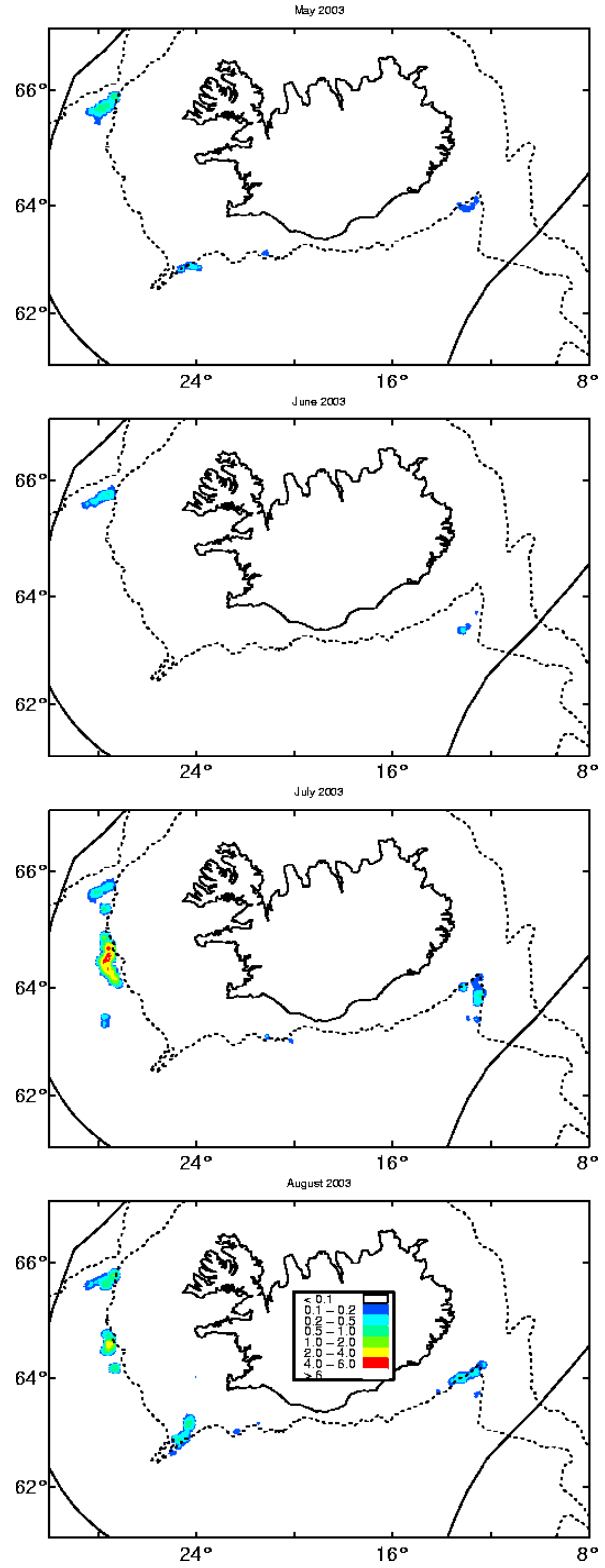


Figure 3.2.10. Icelandic demersal fishery for *S.mentella* in June - August 2003

3.3 Reproductive cycle, mating and breeding areas, drift of larvae, nursery areas and recruitment paths to the fishable stock(s)

Two contributions were presented to the SG:

1. Sergey Melnikov presented the WD4 "Population status and identity of fishable stock of redfish *Sebastes mentella* in the pelagic Irminger Sea and adjacent waters" by V.N. Shibanov and S.P. Melnikov.
2. Fran Saborido-Rey presented Chapter 3 (Workpackage 2) from the EU REDFISH Project Report: "Reproductive strategies" (Anon. 2004).

In the discussion, information from other sources were also used.

ad. 1) The aim of the paper was to establish the identity of the fishable pelagic stock of redfish *S. mentella* from the pelagic waters of the Irminger Sea and adjacent areas by identifying all stages in the life cycle, functional role of various areas within the distribution range and specific features of the reproduction of *S. mentella*. Results of this study were also based on Saborido-Rey et al. (2004) and are intended to be used for provision of scientific advice regarding management units for *S.mentella* from the pelagic waters of the Irminger Sea and adjacent areas. In the paper, the principal criteria to distinguish a population are self-reproduction, stability in time, full range of age groups, spatial and/or temporal isolation from analogous groups of the same species and functionally divided population habitat area (reproduction, feeding, wintering and nursery areas).

In order to reach the aim of the paper, the following data were presented by areas and depth: Length and age (scale readings) distributions, maturity, growth, larval distribution, reproduction areas, nursery areas and adult distribution. Also the main currents in the area were related to a single stock hypothesis (Figs. 3.3.1 and 3.3.2). Finally it was concluded by the authors that the current use of types by NWWG is not based on a scientifically sound background (i.e. groundless).

In the discussion it was stated, that although Figure 3.3.3 shows that there is only one area of massive larvae extrusion, this area is very large ranging from about 54 ºN to about 63ºN. Although larvae are found in the whole area, separate patches of highest concentrations can be identified in some years (Fig. 3.3.4). The latter gave rise to a debate whether this could reflect the existence of different stocks in the area. The available information could not give any conclusive answer to this. Pavlov et al. (1989) based on pigment patterns on the larvae could not find any differences between the larvae whereas Magnússon & Magnússon (1995) observed extruding oceanic and deep-sea *S. mentella* in the same area but at different depths; and based on larvae pigments and size of newly extruded larvae they were able to separate the larvae into the two types. Although overlapping to some degree, the distribution of females (stage 3 a-c) from the EU Redfish Report (Anon. 2004) indicate that the main extrusion areas are different for oceanic and deep-sea *S. mentella* (Figs. 3.3.5-3.3.7).

It was commented that mating areas are more important than breeding areas in this species when speaking about stock identity. Distribution of stage 3 redfish (from the EU Redfish Report) were shown (Figs. 3.3.8-3.3.10) in order to track possible mating areas (males in autumn). If the distribution of males in maturity stage 3 reliably show the mating area then the distribution maps of this maturity stage show separate mating areas for oceanic phenotyped *S. mentella* and pelagic deep-sea phenotyped *S. mentella*, and to a lesser extent, Icelandic shelf deep-sea phenotyped *S. mentella*. There is, however, overlap between the groups, but areas with high concentrations were more separate, especially between the two pelagic types. This information was based on all available Icelandic data from both fisheries and surveys pooled for many years and further investigations on mating (and breeding) localities and times is needed.

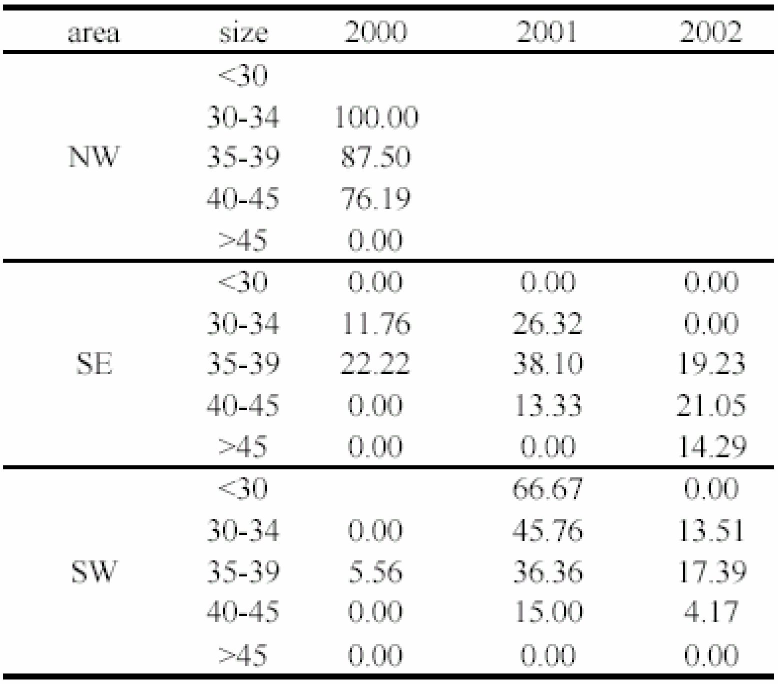
Length, weight, maturity at age in the paper did not show any differences between depths of 0-500 m and depths of 500-1000m but it was commented that age reading by scales is not appropriate for older ages (above ages 15-17) making some of the age related conclusions invalid (Fig. 3.3.11) (see also chapter 9). Scale readings may though be useful for growth studies of younger ages.

It was noted that the eastern boundary of the assumed single stock has not been investigated in this study, but according to Saborido-Rey et al. (in Press) the *S. mentella* in Faroese waters are included.

ad. 2) The fecundity analyses in the report were just briefly mentioned. The main presentation was dealing with the reproductive cycle determined by histological analysis. In the project, the sampling coverage of especially Icelandic waters was good, but also the Irminger Sea and to a less degree Greenland waters were sampled satisfactory; no other areas were sampled. Atresia seems to be a common phenomenon. Redfish often skip spawning, especially small fish, i.e. first spawners Tables 3.3.1, 3.3.2 and 3.3.4). They can look like mature and about to spawn but only with histology it can be stated whether or not this will happen. Older fish show much smaller levels of atresia. Different maturity ogives were estimated for the three potential stocks (i.e. oceanic, pelagic deep-sea and shelf *S. mentella*). When the maturity ogives were estimated following the macroscopic criteria differences were revealed yielding size at maturity similar to those previously reported. However, when using histology, accounting for the proportion of skipped spawners and considering the most appropriate sampling, the maturity ogives were similar between the three stocks. Proportion of skip spawners by area were shown (Tables 3.3.1 and 3.3.3). They support that mature fish migrate to SW Iceland for extrusion of larvae. In the Irminger Sea very few fishes are skipping larvae extrusion. About 95% of the fish in the Irminger Sea are mature, and % immature fish is larger in the SW area than to the NE.

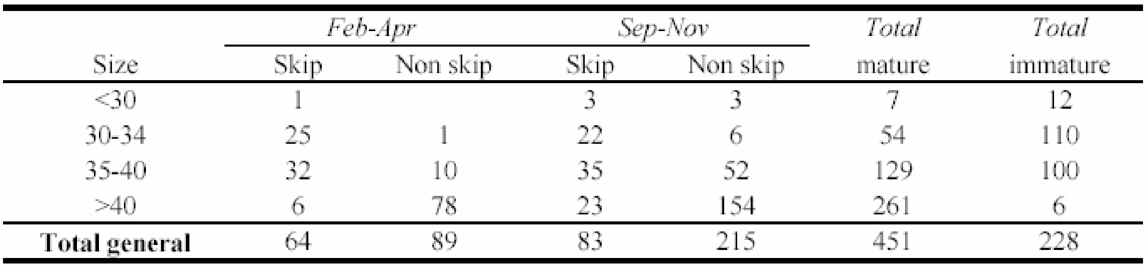
Table 3.3.1

Proportion of skip spawning females by area, size range and year for *S. mentella* around Iceland.



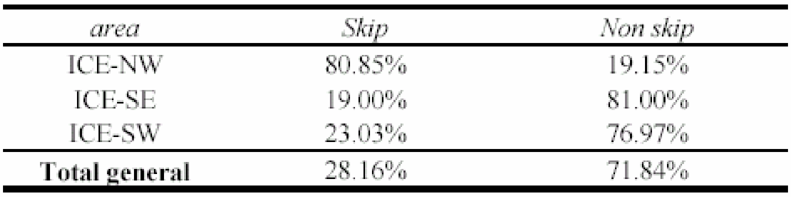
area	size	2000	2001	2002
NW	<30			
	30-34	100.00		
	35-39	87.50		
	40-45	76.19		
	>45	0.00		
SE	<30	0.00	0.00	0.00
	30-34	11.76	26.32	0.00
	35-39	22.22	38.10	19.23
	40-45	0.00	13.33	21.05
	>45	0.00	0.00	14.29
SW	<30		66.67	0.00
	30-34	0.00	45.76	13.51
	35-39	5.56	36.36	17.39
	40-45	0.00	15.00	4.17
	>45	0.00	0.00	0.00

Table 3.3.2 Number of mature fish of *S. mentella* in Iceland that were considered as skip spawners and not skip spawners excluding May and June. The last column indicates also the total number of immature fish for the same period.



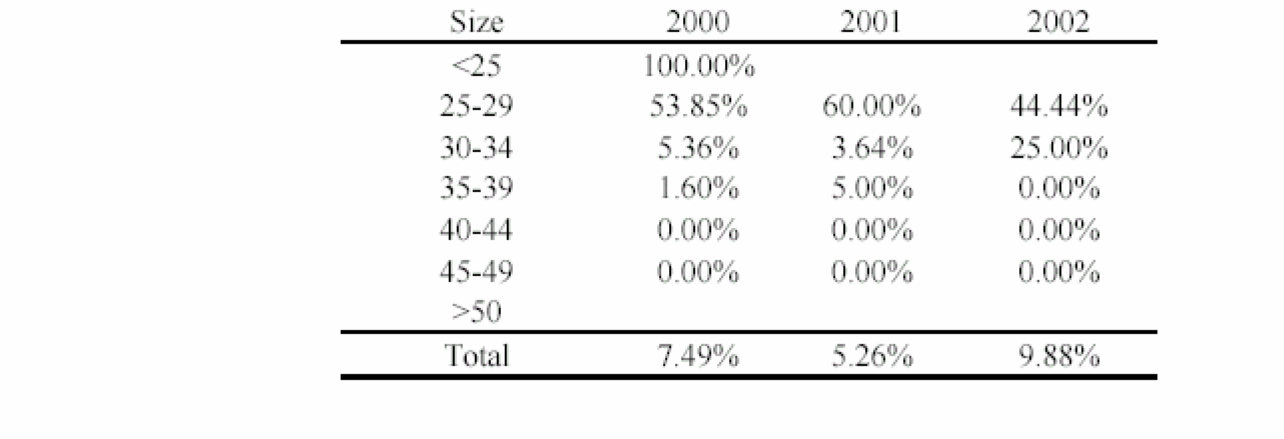
	Feb-Apr		*Sep-Nov*		*Total*	*Total*
Size	Skip	Non skip	Skip	Non skip	mature	immature
<30	1		3	3	7	12
30-34	25	1	22	6	54	110
35-40	32	10	35	52	129	100
>40	6	78	23	154	261	6
Total general	64	89	83	215	451	228

Table 3.3.3. Proportion of mature fish that were considered as skip spawners and not skip spawners excluding May and June.



area	*Skip*	*Non skip*
ICE-NW	80.85%	19.15%
ICE-SE	19.00%	81.00%
ICE-SW	23.03%	76.97%
Total general	28.16%	71.84%

Table 3.3.4



Proportion of skip spawning fish by size and year in *S. mentella* in the Irminger Sea.

Size	2000	2001	2002
<25	100.00%		
25-29	53.85%	60.00%	44.44%
30-34	5.36%	3.64%	25.00%
35-39	1.60%	5.00%	0.00%
40-44	0.00%	0.00%	0.00%
45-49	0.00%	0.00%	0.00%
>50			
Total	7.49%	5.26%	9.88%

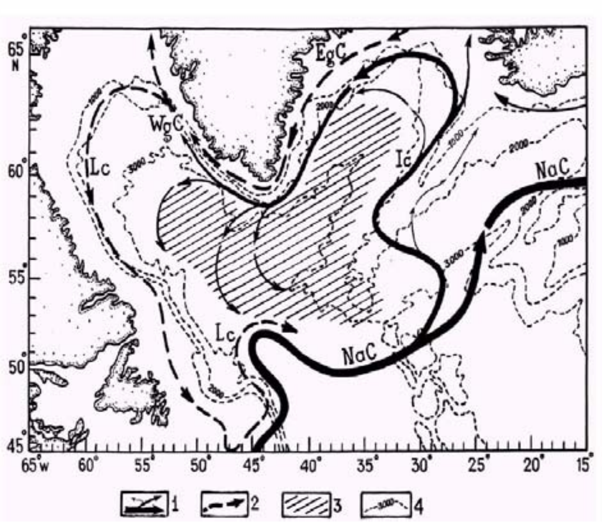


Figure 3.3.1. Scheme of the North Atlantic Currents: *Warm currents* (1): NaC - North Atlantic; IC - Irminger; *Cold currents* (2): EgC - East Greenland; WgC - West Greenland; LC-Labrador; boundary of sub-polar cyclonic gyre (3); isobaths (4).

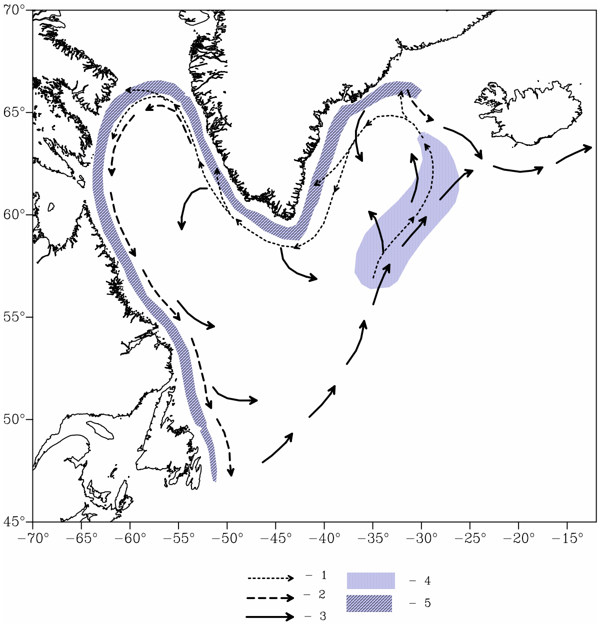


Figure 3.3.2. (1) Direction of larvae and fry drift. (2) Direction of immature individuals migration. (3) Direction of return migration of maturing and mature individuals. (4) Area of reproduction. (5) Distribution area of immature individuals.

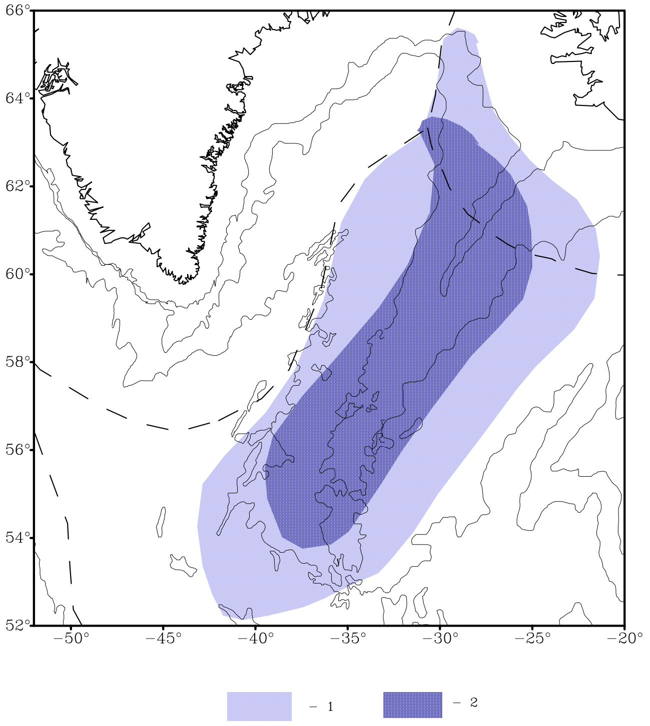


Figure 3.3.3. Typical distribution of larvae (1) and breeding area (2) of *S. mentella* in the pelagic waters of the Irminger Sea from Russian spring ichthyoplankton surveys in 1982-1995.

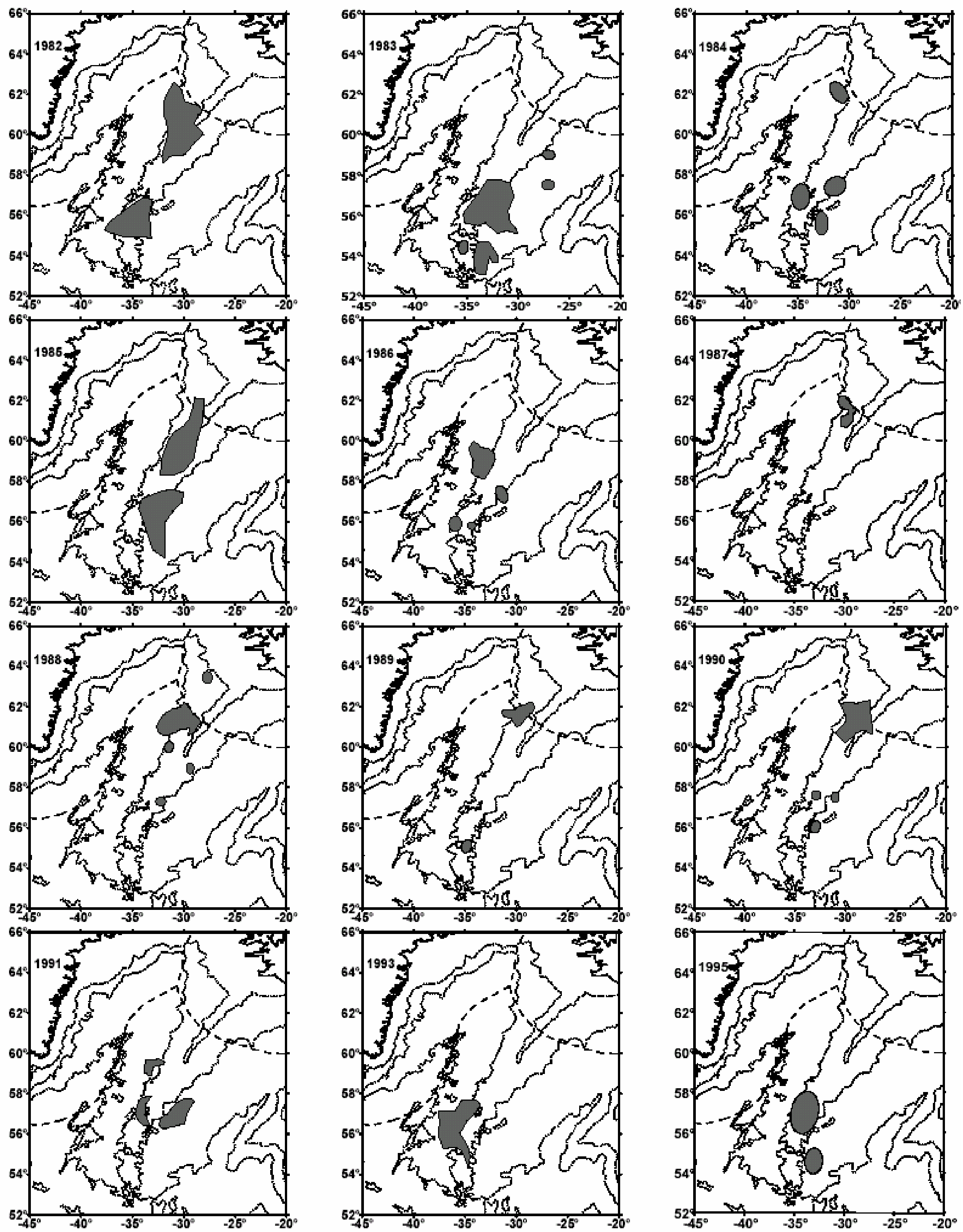


Figure 3.3.4. The must abundant areas of newly extruded redfish larvae in the Irminger Sea according to the Russian spring ichthyoplankton surveys 1982-1995.

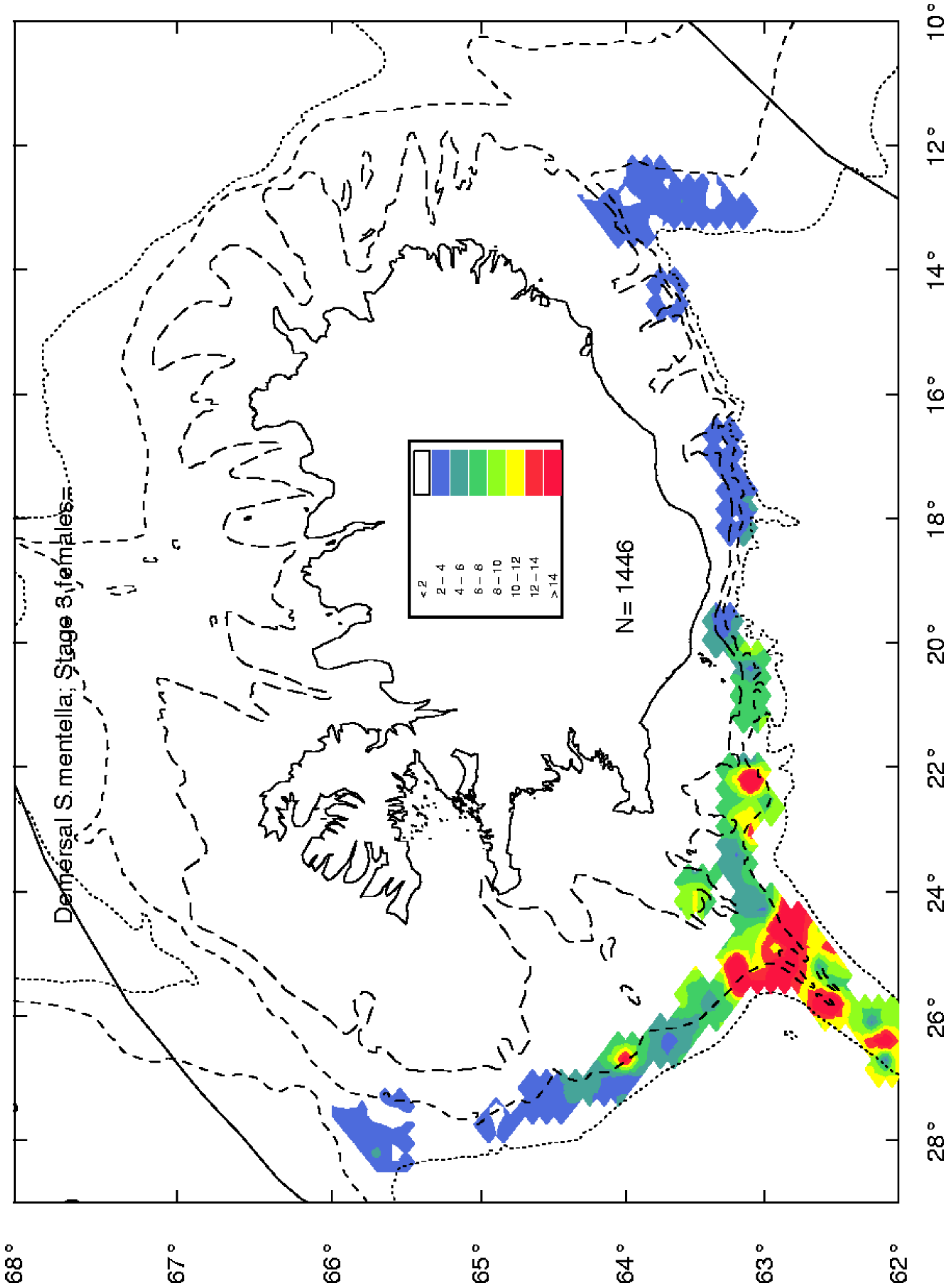


Figure 3.3.5: Distribution of spawning (maturity stage 3a-c) female *S. mentella* in Icelandic waters.

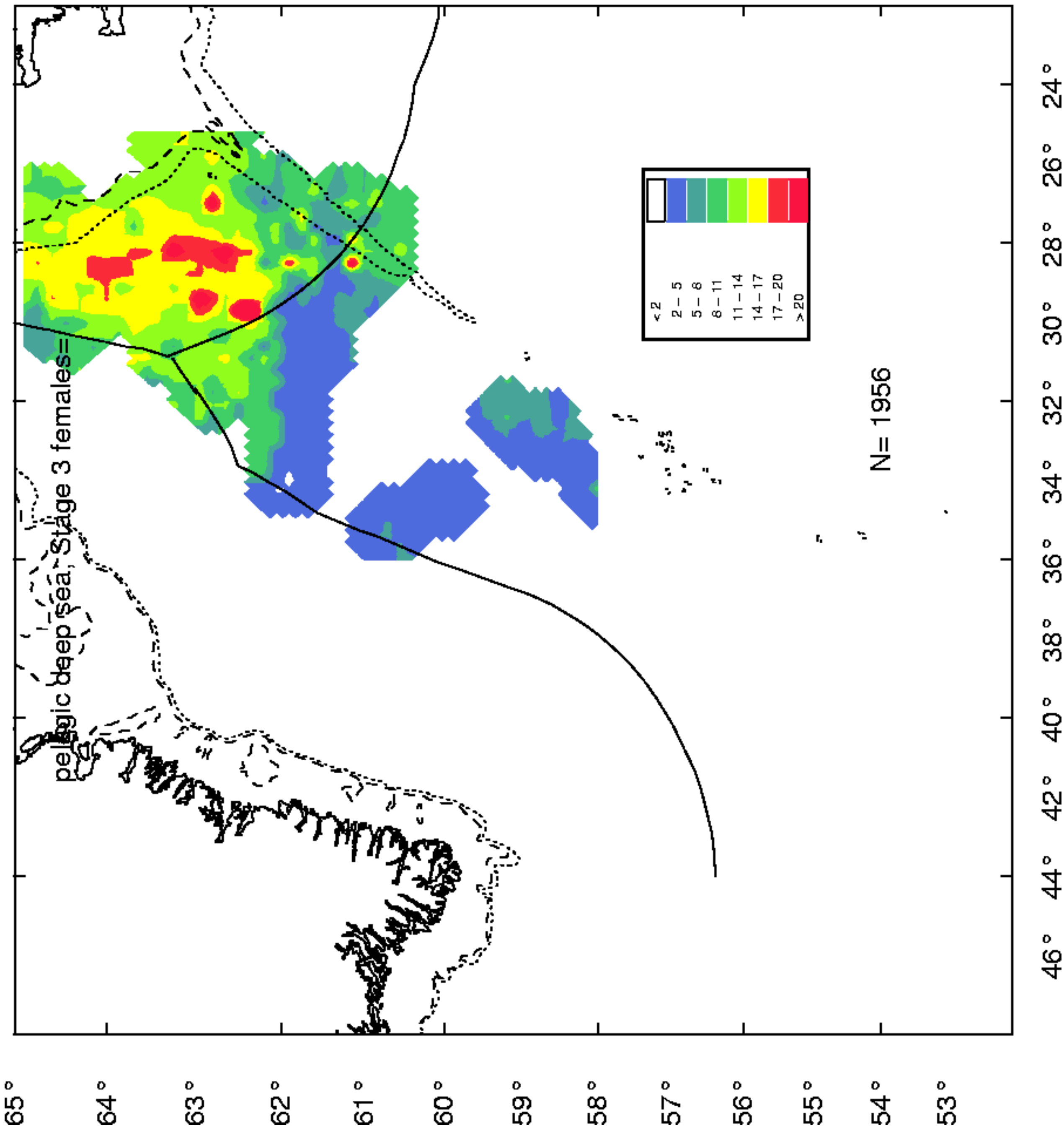


Figure 3.3.6: Distribution of spawning (maturity stage 3a-c) female pelagic - deep sea *S. mentella* in the Irminger Sea and adjacent waters.

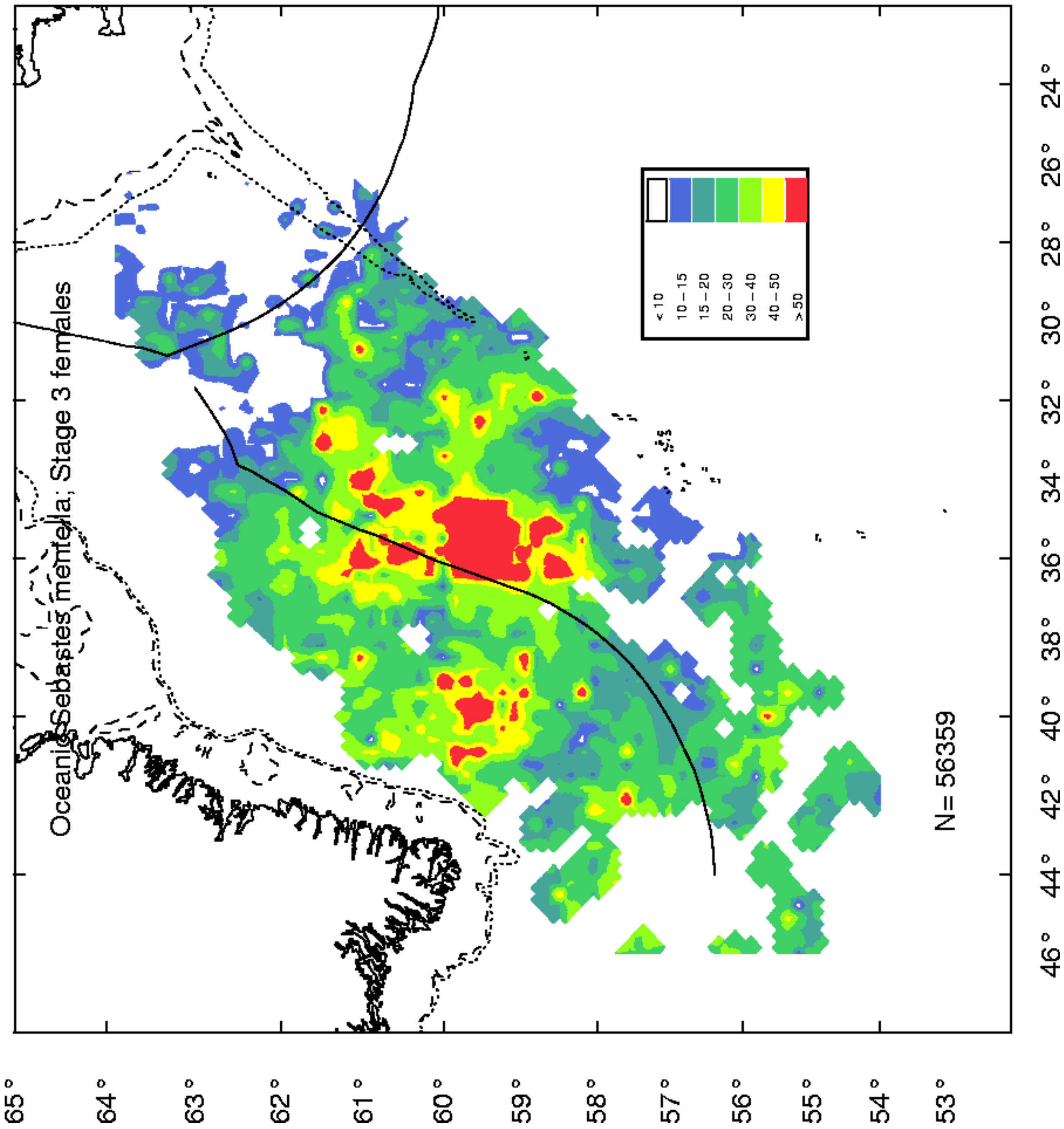


Figure 3.3.7: Distribution of spawning (maturity stage 3a-c) female oceanic *S. mentella*.

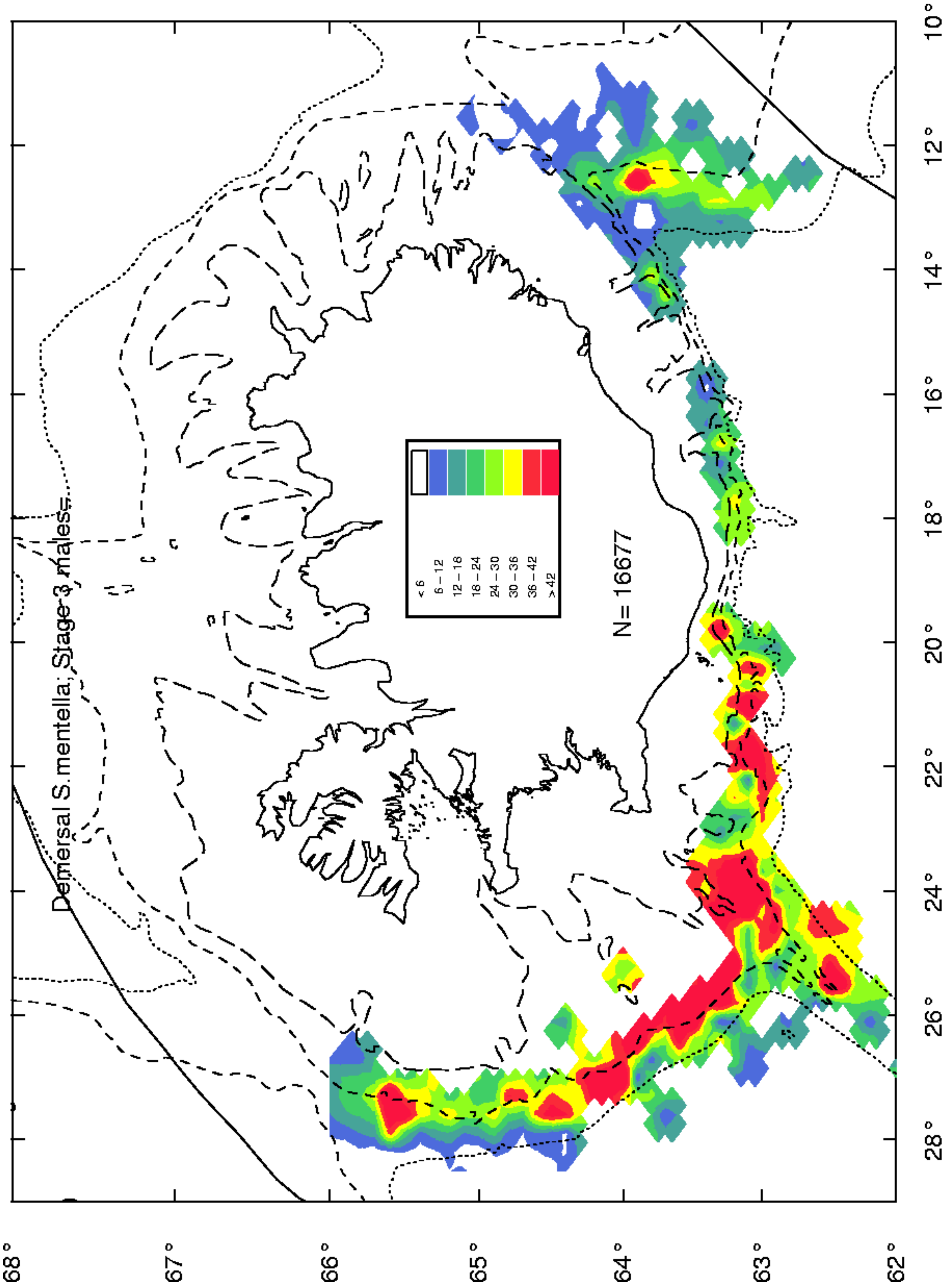


Figure 3.3.8: Distribution of spawning (maturity stage 3) male *S. mentella* in Icelandic waters.

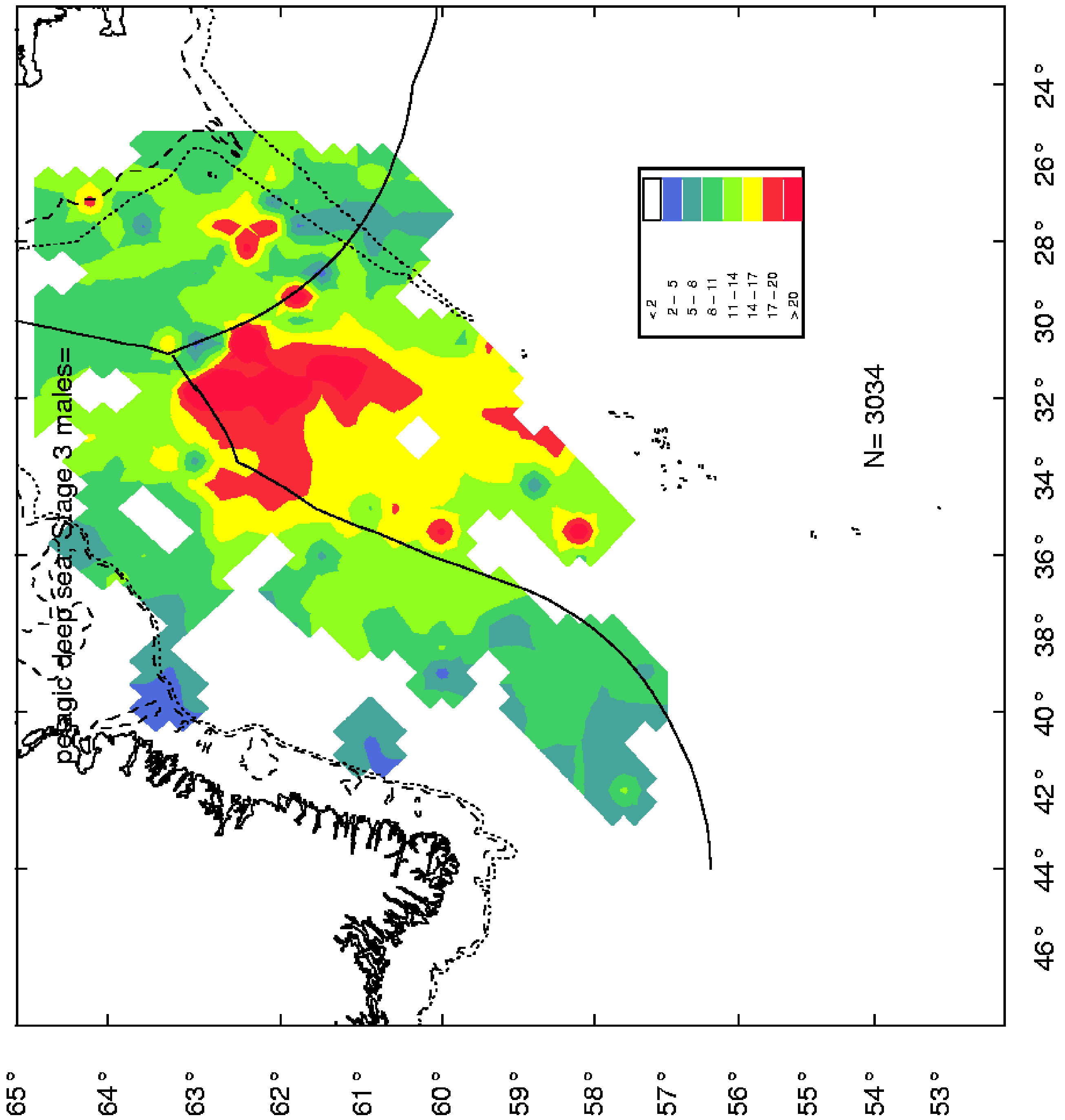


Figure 3.3.9: Distribution of spawning (maturity stage 3) male pelagic - deep sea *S. mentella* in the Irminger Sea and adjacent waters.

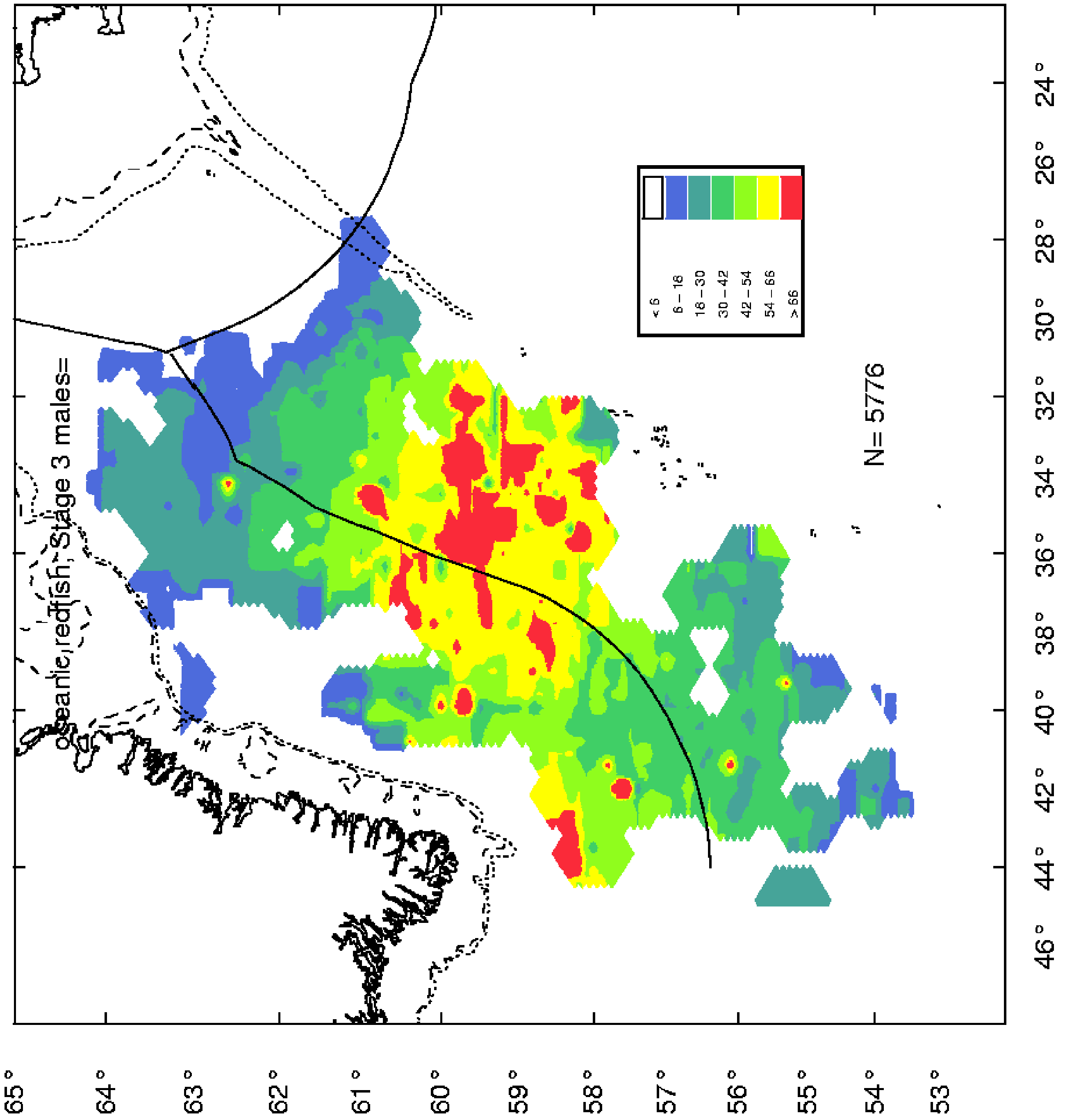


Figure 3.3.10: Distribution of spawning (maturity stage 3) male oceanic *S. mentella*.

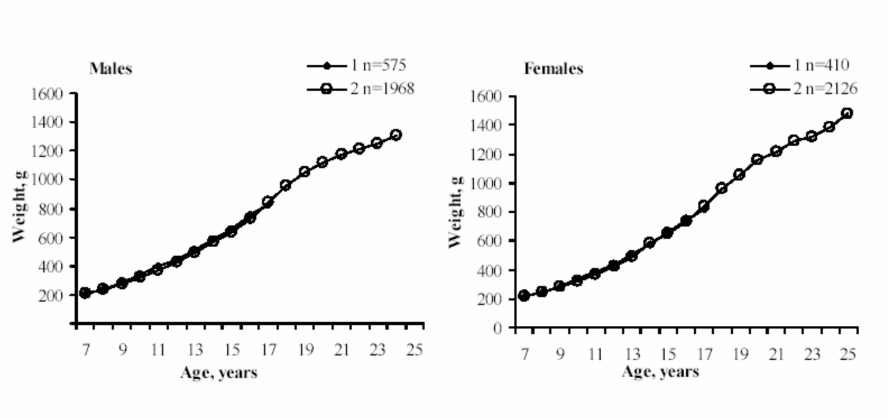


Figure 3.3.11. Weight growth of redfish males and females in the layers 0-500 m (1), 500-1000 m (2) in the Irminger Sea in 1995-2003 from scale readings. Note the unlikely growth development of especially females older than 20 years, which is probably due to a wrong assignment of ages 18-24 to older specimens due to the impossibility to read more ages from scales.

3.4 Morphometric analyses

The major morphometric analyses performed with *S. mentella* in the Irminger Sea and adjacent waters was conducted within the EU REDFISH project. Two different morphometric methodologies have been carried out; the so called traditional morphometry and the geometric morphometry. The results of both approaches are included in the project final report (Anon. 2004). However, during the meeting the results of the traditional morphometric approach were presented. In order to better elucidate the stock structure and the relationships among the different potential components in the area, it was decided to include two reference areas in the analyses, Flemish Cap and Norway from a previous study (Saborido-Rey, 1994). 19 morphometric variables were considered (Figure 3.4.1) that had shown population discrimination even in close areas (Saborido-Rey, 1994). However, a question arose during the meeting on why some morphological features (such as the neck width) used in identifying oceanic and deep-sea types were not included (ICES, 1998; Johansen et al. 2000). Apart from practical and methodological reasons, it was explained that morphometric analyses are based in a multivariate space and thus a single variable should not account for most of the variation, but the multivariate relationship among the variables. Introducing a single variable in the model should not change notably the discrimination power of the multivariate model. On the other hand this could have been recorded as a morphological character.

The proposed phenotypes in the Irminger Sea, oceanic and deep-sea, could not be supported by morphometric analyses (Table 3.4.1 and Figure 3.4.2). In spite of the relative high proportion of deep-sea classified correctly (86 %), half of the oceanic type fish were classified as deep-sea indicating no morphometric discrimination between phenotypes.

The different analyses conducted to study the population structure of *S. mentella* (Table 3.4.2 and Figures 3.4.3 and 3.4.4), showed that Faroes *S. mentella* grouped together with SE Iceland and in minor extent with Central Irminger Sea, but few fishes were grouped with Greenland. *S. mentella* from East Greenland, however, grouped also with SE Iceland and Central Irminger Sea, while most of the fish collected in West Greenland grouped into Central Irminger Sea. SE and SW Iceland fish grouped together and to a lower extent with NE Irminger Sea. Little overlap was observed, however, between Flemish Cap and any of these areas (Faroes, Iceland, Irminger Sea and Greenland). Similarly, Norwegian fish was clearly different from all areas and even from the Faroes waters. These results suggest that Faroes, Iceland, Irminger Sea and Greenland show overlapping morphometry and are distinct from Norway and Flemish Cap. However, Flemish Cap and Norway showed clear morphometric similarities (Table 3.4.2 and Figures 3.4.3 and 3.4.4). The results showed also a geographical cline regarding morphometric similarities, which has been also shown in *S. marinus*, i.e. Faroes was more similar to Iceland than other areas, Iceland overlapped very much with Greenland, while Greenland was similar to Irminger Sea, but little overlap existed between Irminger Sea and Faroes. This could reflect common nursing area in Greenland.

Nevertheless, during the meeting a new hypothesis was put forward regarding the possibility of mixing individuals from different populations during part of the year due to, for example, spawning activity, feeding migration etc. This hypothesis should be tested since enough data exist within the EU project, and it may be an alternative explanation for the morphometric similarities in the Faroes, Iceland and Irminger Sea areas. However, Greenland is known to be the major nursery ground for the rest of the areas where basically small and juvenile fish are found. Thus adult fish seldom return to Greenland once they have migrated to Iceland, Faroes or the Irminger Sea. Potentially, discrete populations could occur in Greenland, partially mixed with others, but no structure specific for the area was observed within Greenland, and overlap with Iceland and Irminger Sea was observed. Nevertheless, more analyses have to be conducted, especially with fishes at similar ages, to ascertain if the observed differences may be derived from a temporal effect; and to examine seasonal variation due to migration among areas.

One of the most interesting outputs of the morphometric analysis was the comparison with the genetic results from the same fishes. This analyses showed a very good concordance between both methodologies, both in Faroes and Greenland in the species level, where the comparisons have been made. Unfortunately, no genetic data from other areas was available to run more comparisons. Another feature revealed from the comparisons is the fact that when the morphometric analyses were conducted on selected genotypes (based in hemoglobin and microsatellites), morphometric differences occurred, but when performed over a random sampling or introducing other genotypes, they were not different at all. This implies that selection of the samples/genotypes may lead to wrong interpretation of the results.

During the Faroes Redfish project, samples from the same individuals of *S. mentella* from 11 locations in the North Atlantic Ocean were analyzed by electrophoretic methods, morphometric method, electrophoretic methods and microsatellite-analyses (WD 9). The morphometric results from this project are given in chapter 3.8. In this analysis, pelagic *S. mentella* from one shallow station in the Irminger Sea and one deep station showed different morphometric characters. The material behind this analysis was, however, much smaller (36 and 50 fish, respectively) than the material included in the EU project which also covered different seasons.

Table 3.4.1. Classification matrix, percentage of total correct classification and Wilks' lambda and Cohen's Kappa resulting to the discriminant analysis of *S. mentella* in the Irminger Sea by phenotype using only partner 3 data.

Wilks' Lambda= 0.76735				
K= 0.3168				
	Correct %	deep-sea	oceanic	undef
deep-sea	85.85	352	58	0
oceanic	51.28	113	120	1
undef	1.23	40	40	1
Total	65.24	505	218	2

Table 3.4.2. Percentage of fish from each sub-area classified into each of the groups resulting from the discriminant analysis of *S. mentella* by sub-area.

Subareas	Faroes		Greenland		Iceland			Irminger			Flemish	Norway
	NW	SE	E	W	SW	NE	SE	NE	CEN	NAFO		
Faroes-NW	29.5	3.6	4.3	0.0	10.1	0.0	41.0	0.7	10.8	0.0	0.0	0.0
Faroes-SE	1.7	62.1	0.0	0.0	5.2	1.7	24.1	1.7	1.7	1.7	0.0	0.0
Greenland-E	1.0	0.0	36.4	3.0	6.1	2.0	26.3	6.1	19.2	0.0	0.0	0.0
Greenland-W	0.0	0.0	20.0	4.4	2.2	4.4	20.0	4.4	42.2	2.2	0.0	0.0
Iceland-SW	5.8	1.4	2.5	0.0	36.6	0.7	33.7	12.7	4.7	0.7	1.1	0.0
Iceland-NE	0.0	0.0	6.0	2.0	0.0	72.0	18.0	0.0	2.0	0.0	0.0	0.0
Iceland-SE	4.7	1.1	1.9	0.4	10.1	1.3	73.4	3.6	2.8	0.4	0.2	0.0
Irminger-NE	0.7	0.0	0.7	0.0	1.2	0.1	2.0	68.0	23.3	3.6	0.2	0.2
Irminger-CEN	0.0	0.0	0.5	0.2	1.0	0.0	0.2	25.0	66.6	6.0	0.4	0.1
Irminger-NAFO	0.0	0.0	0.0	0.0	0.6	0.0	0.3	27.4	49.1	22.6	0.0	0.0
Flemish Cap	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.9	3.6	0.9	87.4	6.3
Norway	0.0	0.0	0.0	0.0	1.3	0.0	0.0	2.7	1.3	0.0	24.0	70.7

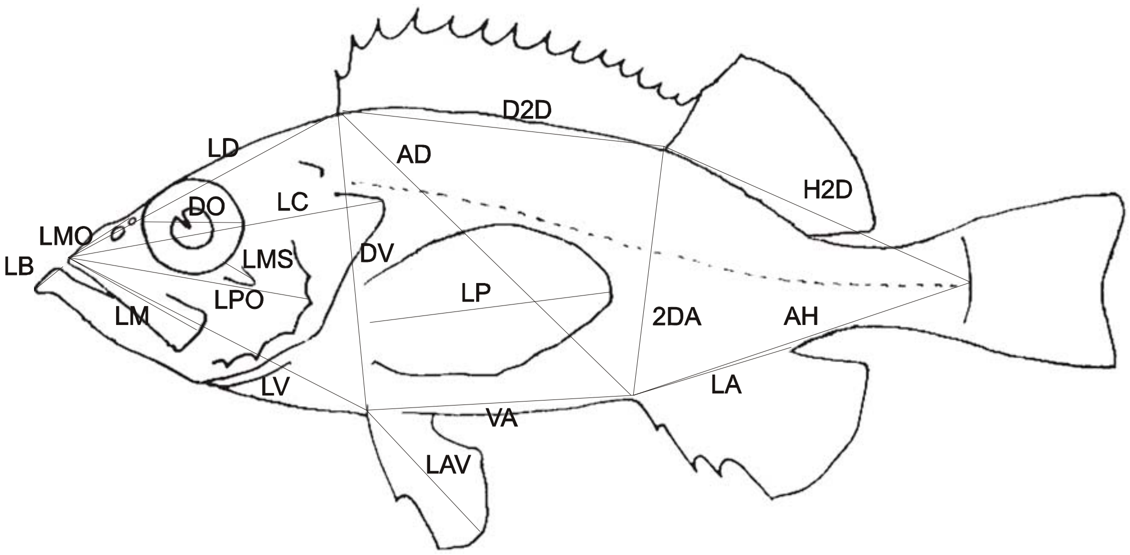


Figure 3.4.1. Interlandmark distances used as variables in traditional morphometry analysis.

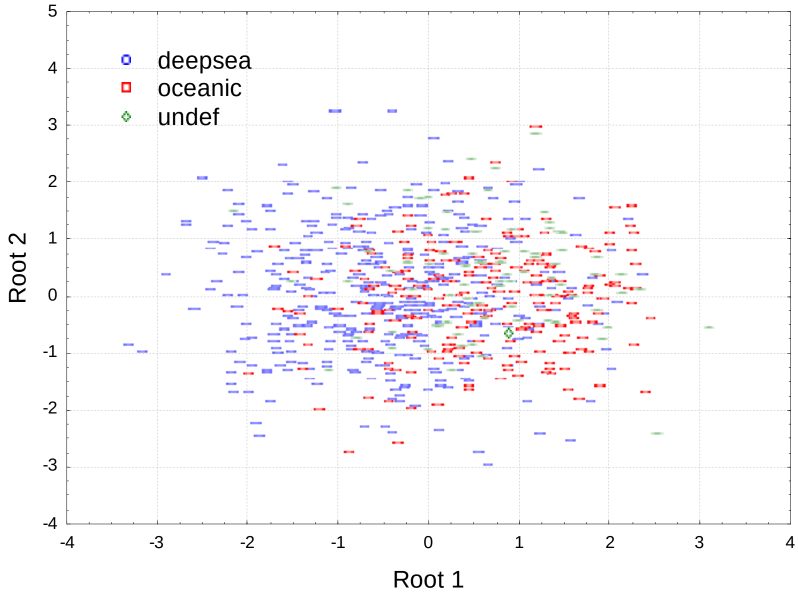


Figure 3.4.2. Plot of canonical scores for each case for the first and second canonical root resulting of the discriminant analysis performed with *S. mentella* in the Irminger Sea by phenotype

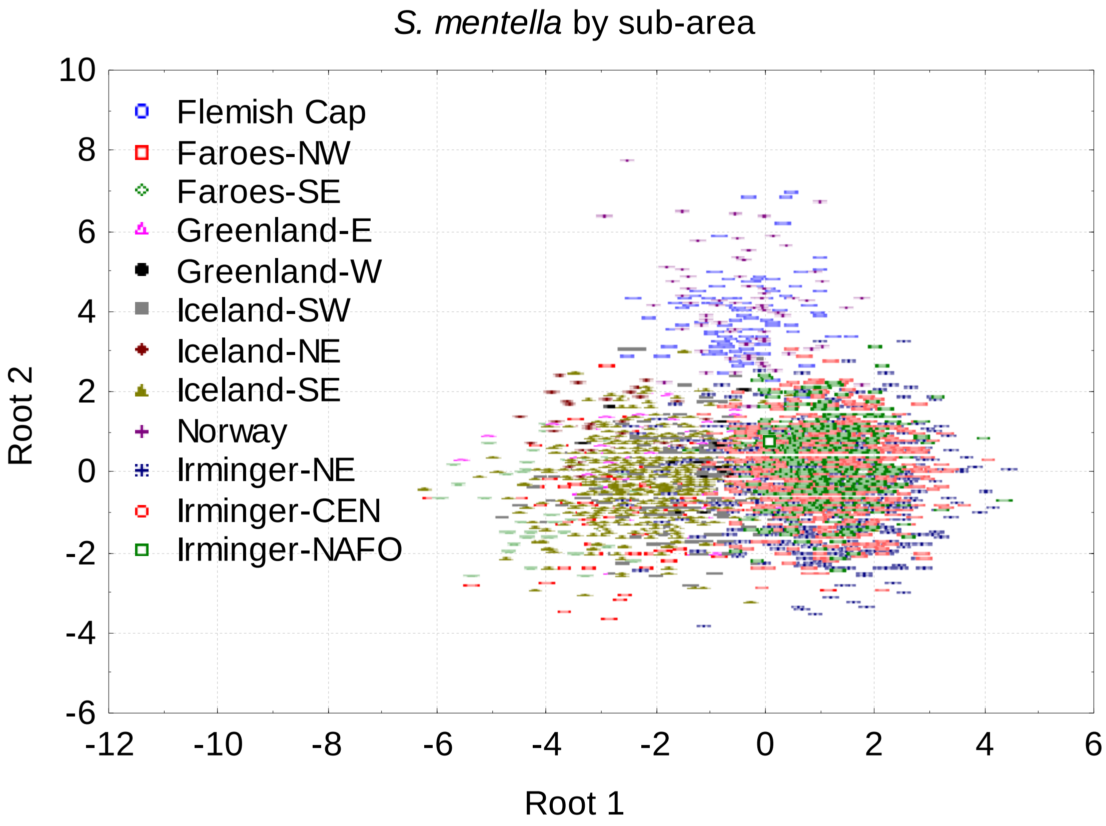


Figure 3.4.3. Plot of canonical scores for each case for the first and second canonical root resulting of the discriminant analysis performed with *S. mentella* by sub-area.

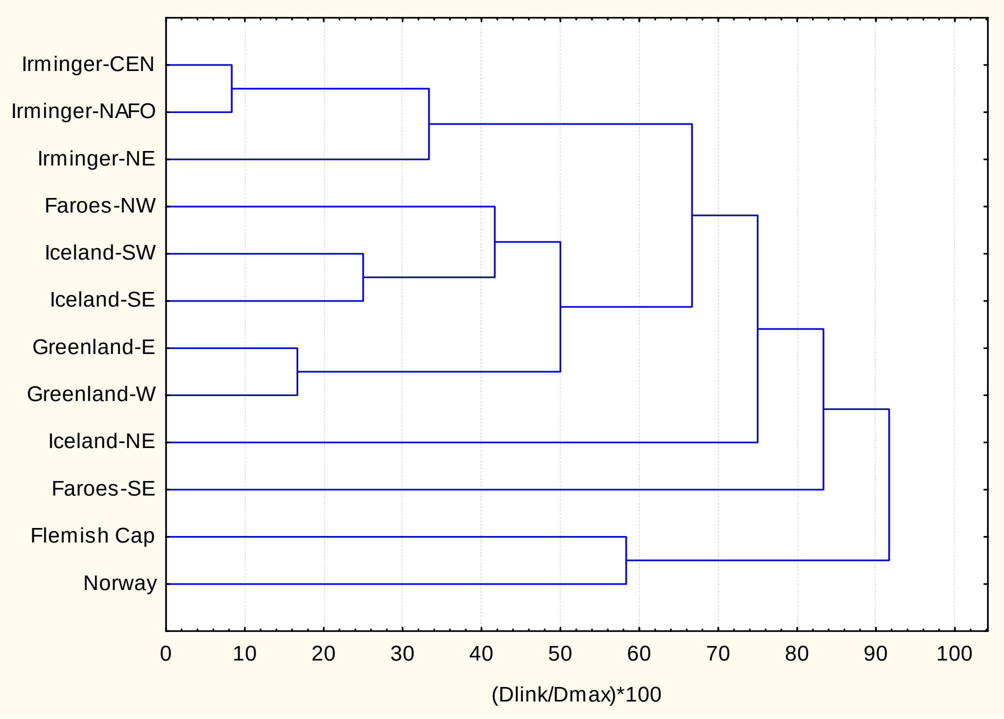


Figure 3.4.4. Tree diagram of an UPGMA Cluster analysis based in Mahalanobis distances resulting from the discriminant analysis performed with *S. mentella* by Sub-area

3.5 Parasites and pigment patches as biological marks on *S. mentella*

The parasite fauna found on and in the *S. mentella* collected from the Irminger Sea and adjacent waters show rather modest geographical differences (Tables 3.5.1-3.5.5; Figures 3.5.1-3.5.2). Some structure is, however, observed. Figure 3.5.2 shows a difference beween shelf *S. mentella* and pelagic *S. mentella*, although only significant for one or two parasite species.

In the occurrence of *S. mentella* individuals with pigment patches on the skin a relative year-to-year constancy, the absence of essential geographic differences and similar peculiarities of localization of pigment patches in both males and females in all the areas was also observed (Tables 3.5.3-3.5.4; Figures 3.5.1, 3.5.2, 3.5.4 and 3.5.8). High similarity (75-96 %) of the parasite fauna (Figure 3.5.2) and the same level of infestation with parasites of the majority of specimens as well as identical and constant during many years (1983-2004) peculiarities of infestation with copepod *S. lumpi* (Table 3.5.2), and pigment patches in males and females of *S. mentella* studied (Table 3.5.3) in all the areas of the pelagic Irminger Sea and adjacent waters were ascertained.

Data from the three most recent international trawl-acoustic surveys (1999-2003) on infestation with copepod *S. lumpi,* known to be the most reliable natural mark, show that the percentage of *S. mentella* with live or remnants *S. lumpi* seems to be lower and more variable among areas in deeper waters than in shallower waters, but in some years in some areas the differences are small:

Survey year	Shallower than 500 m	Deeper than 500 m
1999	39.1	36.2
2001	22.6	17.2
2003*	53.1	29.6

* Relatively low number of studied redfish, especially at depths shallower than 500 m
On the Icelandic shelf during the 2003 demersal survey, the infestation rate was 18.5%

Occurrence of *S. mentella* with pigment patches on the skin at different length caught in the Irminger Sea during the year of 1999 is shown for depths above 500 m and below 500 m in Figure 3.5.5.

The decrease in occurrence of *S. mentella* with pigment patches on the skin among individuals longer than 40 cm being predominant at depths greater than 500 m may be a consequence of age-dependent changes in individuals and apparent pathology of this phenomenon for the redfish (Figures 3.5.5-3.5.6). Hence, such difference cannot be used as the criterion to distinguish the so-called “types” of *S. mentella.*

The decline in occurrence of concretions of melanin in muscular tissue (muscular melanosis) with age and their absence in *S. mentella* longer than 41 cm dominating depths larger than 500 m also pertains to changing of habitat conditions of older individuals (Figure 3.5.7), and thus, cannot be an evidence of belonging of *S. mentella* from older age groups to another “type” or population.

Although some structure and differences are observed, the presented results of the use of natural marks (parasites and pigment patches) to study spatial and vertical structure of *S. mentella* concentrations may not show stable isolated fish groups, spatial and temporal isolation, or isolation by depth of their habitat. The presented results on parasites and pigment patches have thus not necessarily revealed any reliable and stable stock structuring of the resource. On the other hand, the geographical and depth differences of the infestation with copepod *S. lumpi* as e.g. shown in the text table above, as well as the analysis of parasite fauna composition as shown in Figure 3.5.2, show a similar structure as that shown more clearly by other methods as being supportive of a three-stock hypothesis.

Table 3.5.1. Prevalence (%) of *Sebastes mentella* infestation with parasites in different areas of the Irminger Sea and adjacent waters and significance of differences

Parasites, biological tags *	NAFO Regulatory Area (area 1) (n = 199)	Southeastern Greenland Zone (area 2) (n = 107)	Open part of the Irminger Sea			Southwestern Iceland Zone (area 6) (n = 75)	Significance of differences (P)
			south (area 3) (n = 183)	centre (area 4) (n = 218)	north (area 5) (n = 449)		
Myxidium incurvatum *	6,5	8,4	3,3	6,0	5,1	6,6	**> 0,05**
M. obliquelineolatum *	9,5	7,5	4,9	3,2	4,9	4,0	**> 0,05**
Zschokkella sp.	-	-	-	-	-	1,3	< 0,05
Leptotheca macroformis	-	-	-	-	0,5	1,3	**> 0,05**
Leptotheca adeli *	9,0	2,8	1,1	0,9	1,1	4,0	< 0,05
Pseudalataspora sebastei *	5,0	6,5	2,2	2,3	2,0	5,3	**> 0,05**
Bothriocephalus scorpii	12,3	5,6	12,6	8,3	10,1	5,3	**> 0,05**
Hepatoxylon trichiuri pl. *	0,5	1,9	1,6	0,5	0,5	2,6	**> 0,05**
Scolex pleuronectis pl.	8,9	14,9	15,3	13,8	8,8	8,0	**> 0,05**
Phyllobothrium sp. pl.	1,6	1,9	2,2	1,4	0,9	1,3	**> 0,05**
Diphyllobothrium sp. pl. *	0,5	-	0,5	0,5	0,5	1,3	**> 0,05**
Grillotia erinaceus pl. *	1,1	0,9	1,1	0,9	0,9	1,3	**> 0,05**
Derogenes varicus	1,1	0,9	1,6	0,5	0,5	-	**> 0,05**
Podocotyle reflexa	2,8	1,9	2,2	2,8	0,9	2,6	**> 0,05**
Anomalotrema koiae	2,2	1,9	1,1	1,4	0,9	1,3	**> 0,05**
Lecithophyllum botriophorum	2,2	0,9	3,3	0,5	0,7	2,6	**> 0,05**
Anisakis simplex l. *	78,8	78,5	78,7	83,9	79,0	74,7	**> 0,05**
Hysterothylacium aduncum *	7,8	7,5	7,8	8,7	5,5	5,3	**> 0,05**
Acanthocephala gen. sp. 1.	0,5	-	0,5	0,5	-	-	**> 0,05**
Acanthocephala gen. sp. 2.	-	-	-	-	0,7	1,3	**> 0,05**
Sphyrion lumpi [1] *	39,7	34,6	46,2	46,9	42,7	48,0	**> 0,05**
S. lumpi [2] *	11,2	11,8	12,5	7,1	6,5	6,8	**> 0,05**
Pigment patches (spots), % *	20,1	16,8	24,9	23,9	20,2	18,7	**> 0,05**

Note. n – examined fish, [1] - infestation taking into account alive *S. lumpi* and remains of the copepod parasitizing, [2] – infestation by alive *S. lumpi* only.

Table 3.5.2. Average level of infestation of pelagic redfish *Sebastes mentella* with copepod *Sphyrion lumpi* (taking into account the remains of the copepod parasitizing) in the Irminger Sea and adjacent waters in June-July 1983 - 2004

Years	Prevalence, %			Abundance index		
	males	females	males, females	males	females	males, females
1983	24,1	39,8	34,6	0,40	0,92	0,78
1984	22.2	40,5	32,4	0,33	0,90	0,66
1985	26,0	44,9	40,0	0,40	1,14	0,95
1986	23,0	39,7	34,5	0,39	0,96	0,78
1987	20,1	51,1	38,5	0,42	0,91	0,71
1988	23,3	45,4	37,7	0,33	0,98	0,74
1989	24,1	39,5	33,2	0,36	0,85	0,65
1990	25,0	39,3	32,6	0,36	0,80	0,59
1991	31,1	60,9	45,1	0,49	1,57	1,00
1992	19,8	43,7	29,3	0,40	1,10	0,70
1993	21,2	48,0	34,2	0,40	1,20	0,70
1994	29,7	51,1	38,7	0,45	1,38	0,85
1995	23,5	51,1	35,7	0,42	1,37	0,82
1996	25,3	59,3	37,3	0,47	1,50	0,92
1997	22,7	55,1	39,1	0,42	1,28	0,87
1998	27,4	52,7	40,3	0,44	1,33	0,94
1999	33,2	50,6	40,2	0,48	1,22	0,91
2000	28,9	53,3	46,8	0,41	1,35	0,85
2001	32,1	51,3	41,1	0,56	1,20	0,87
2002	30,3	49,6	39,5	0,48	1,27	0,81
2003	35,7	48,2	38,2	0,40	1,14	0,78
2004	29,5	45,4	38,5	0,45	1,04	0,85

Table 3.5.3. Level of *Sebastes mentella* infestation with *Sphyrion lumpi* copepod and occurrence of fish with pigment patches on the skin in different areas of the Irminger Sea and adjacent waters on the example of June-July 2001 (the Russian data)

Infectiousness			NEAFC				NAFO	Significance of differences (P)
			Southwestern Iceland Zone	Open part of the Irminger Sea		Southeastern Greenland Zone		
				north	south			
Level of infestation with *Sphyrion lumpi* copepod *	Prevalence, %	males	43,4	38,2	37,9	28,9	31,2	**> 0,05**
		females	59,9	49,5	58,4	44,1	44,3	**> 0,05**
		males+females	52,3	42,7	46,2	36,6	37,1	**> 0,05**
	Abundance index	males	0,6	0,6	0,6	0,5	0,6	**> 0,05**
		females	1,6	1,3	1,4	1,0	1,2	**> 0,05**
		males+females	1,1	1,0	1,0	0,8	0,9	**> 0,05**
Occurrence of redfish with pigment patches (spots) on the skin, %		males	15,8	15,5	20,1	13,8	15,8	**> 0,05**
		females	22,5	23,8	32,7	23,0	24,6	**> 0,05**
		males+females	19,2	20,2	24,9	18,7	18,8	**> 0,05**

***** - prevalence (%) and abundance index taking into account the remains of the copepod parasitizing (alive *S. lumpi* + old cephalothoraxes of *S. lumpi*).

Table 3.5.4. Degree of infestation on *Sebastes mentella* with copepod *Sphyrion lumpi* by IV zones of redfish investigations in 1999.

Zones investigated (see Fig. 8)	Prevalence, %			Abundance index		
	Males	Females	Total	Males	Females	Total
I	25,3 28,9	34,8 32,8	29,1 30,5	0,4 0,4	0,6 0,6	0,5 0,5
II	6,0 9,5	13,0 11,6	8,8 10,4	0,1 0,1	0,2 0,2	0,1 0,1
III	0,7 0,2	1,8 0,8	1,1 0,4	0,002 0,001	0,018 0,010	0,010 0,005
IV	2,1 1,0	17,1 14,9	8,2 6,7	0,02 0,01	0,3 0,3	0,1 0,1
All the fish examined	31,1 35,4	53,1 47,0	40,3 40,2	0,5 0,5	1,1 1,0	0,7 0,7

Note. Degree of infestation with *S. lumpi* taking into account the remains of *S. lumpi* parasitizing. At the depths shallower than 500 m – over line; at the depths deeper than 500 m – under line.

Table 3.5.5. Parasite fauna of *Sebastes mentella* from different depths of the Irminger Sea by data for 1999, 1986 and 1983

Parasites, biological tags *	27 June 1999				July 1986				April 1983			
	190-290 м		550-805 м		120-200 м		650-700 м		200-400 м		510-600 м	
	n=25, l=30-38 cm L=35,2 cm		n=30, l=40-47 cm L=42,4 cm		n=20, l=29-40 cm L=34,7		n=16, l=36-43 cm L=39,4 cm		n=139, l=28-40 cm L=35,0 cm		n=20, l=35-43 cm L=38,6 cm	
	$57^0$57’ N, $36^0$42’ W				$59^0$18’N, $36^0$14’W		Reykjanes Ridge		$60^0$44’-$62^0$05’ N $29^0$07’-$32^0$55’ W		$61^0$40’N, $29^0$10’W	
	Prevalence, %	Abundance index	Prevalence, %	Abundance index	Prevalence, %	Abundance index	Prevalence, %	Abundance index	Prevalence, %	Abundance index	Prevalence, %	Abundance index
Myxidium incurvatum *	8,0	+	6,7	+	5,0	+	6,25	+	5,0	+	5,0	+
M. obliquelineolatum *	4,0	+	6,7	+	10,0	+	6,25	+	2,2	+	5,0	+
Leptotheca adeli *	8,0	+	6,7	+	-	-	-	-	-	-	-	-
Pseudalataspora sebastei *	4,0	+	3,3	+	-	-	-	-	-	-	-	-
Bothriocephalus scorpii	8,0	0,08	16,7	0,17	15,0	0,15	12,5	0,19	13,7	0,16	10,0	0,10
Hepatoxylon trichiuri pl. *	-	-	-	-	-	-	-	-	1,4	0,01	5,0	0,05
Scolex pleuronectis pl.	8,0	0,08	6,7	0,10	30,0	0,75	12,5	0,25	10,8	0,16	10,0	0,15
Phyllobothrium sp. pl.	8,0	0,20	26,7	0,67	-	-	-	-	3,6	0,06	5,0	0,10
Diphyllobothrium sp. pl. *	4,0	0,04	3,3	0,03	-	-	-	-	-	-	-	-
Grillotia erinaceus pl. *	4,0	0,04	6,7	0,07	5,0	0,05	-	-	1,4	0,01	5,0	0,05
Derogenes varicus	-	-	-	-	-	-	-	-	1,4	0,01	5,0	0,05
Podocotyle reflexa	4,0	0,04	3,3	0,03	5,0	0,05	6,25	0,12	-	-	-	-
Anomalotrema koiae	4,0	0,04	3,3	0,03	-	-	-	-	-	-	-	-
Lecithophyllum botriophorum	4,0	0,04	26,7	0,40	-	-	-	-	4,3	0,06	5,0	0,05
Anisakis simplex l.	100,0	11,00	100,0	12,0	65,0	4,25	93,7	5,69	76,3	5,68	90,0	6,60
Hysterothylacium aduncum *	8,0	0,08	6,7	0,07	15,0	0,15	18,7	0,25	4,3	0,05	10,0	0,10
Sphyrion lumpi [1] *	14,0	0,22	10,1	0,12	15,0	0,20	12,5	0,19	12,2	0,16	10,0	0,15
S. lumpi [2] *	46,0	1,17	51,7	1,00	45,0	0,85	50,0	0,70	47,5	1,00	40,0	0,95

Note: [1] – infestation by alive *S. lumpi* only, [2] infestation taking into account alive *S. lumpi* and remains of the copepod parasitizing.

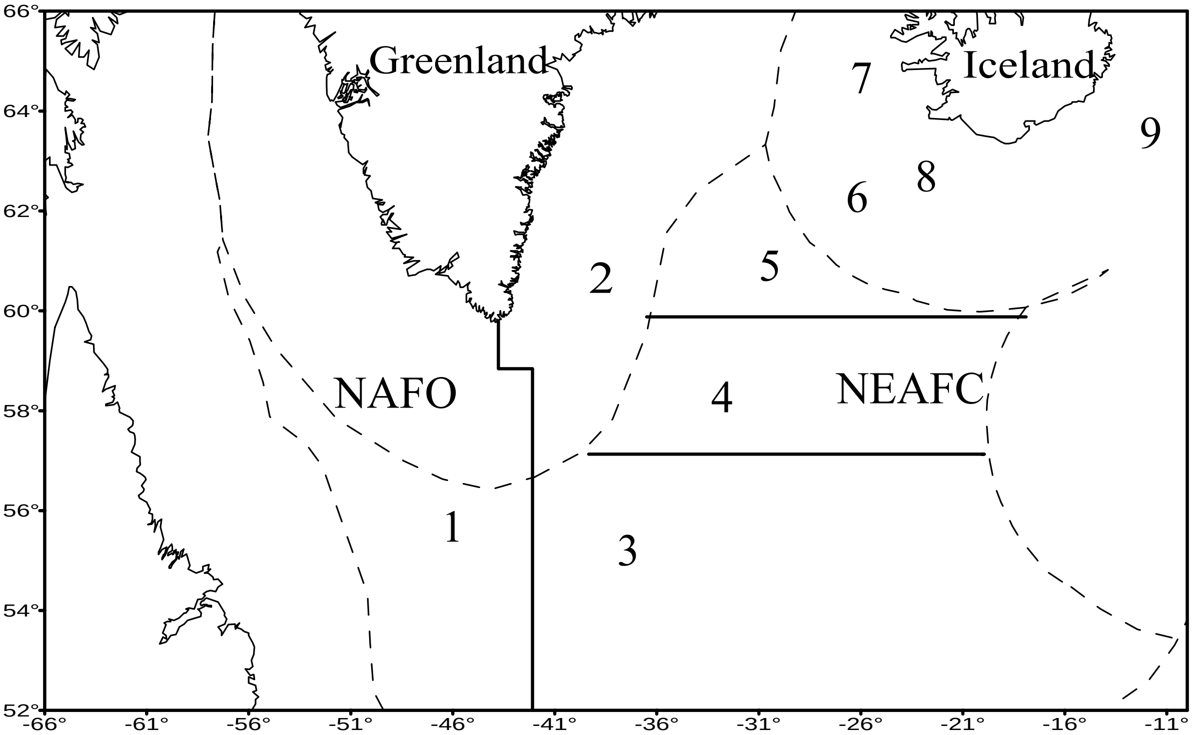


Figure 3.5.1. Areas of *S. mentella* sampling for parasitological data.

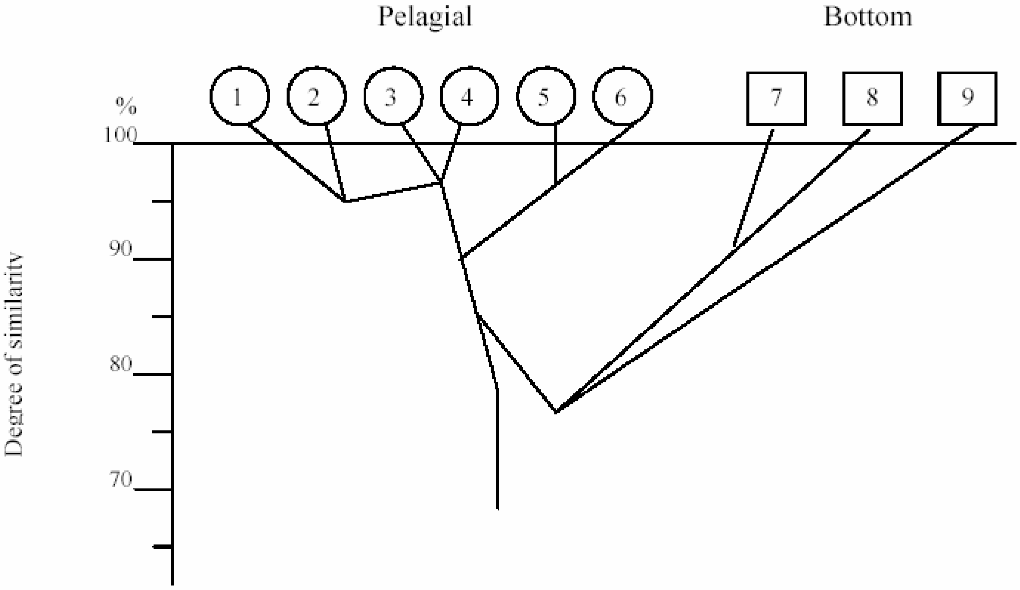


Figure 3.5.2. Dendrogram of degree of similarity of *Sebastes mentella* parasite fauna composition in 9 areas of the Irminger Sea and adjacent waters.

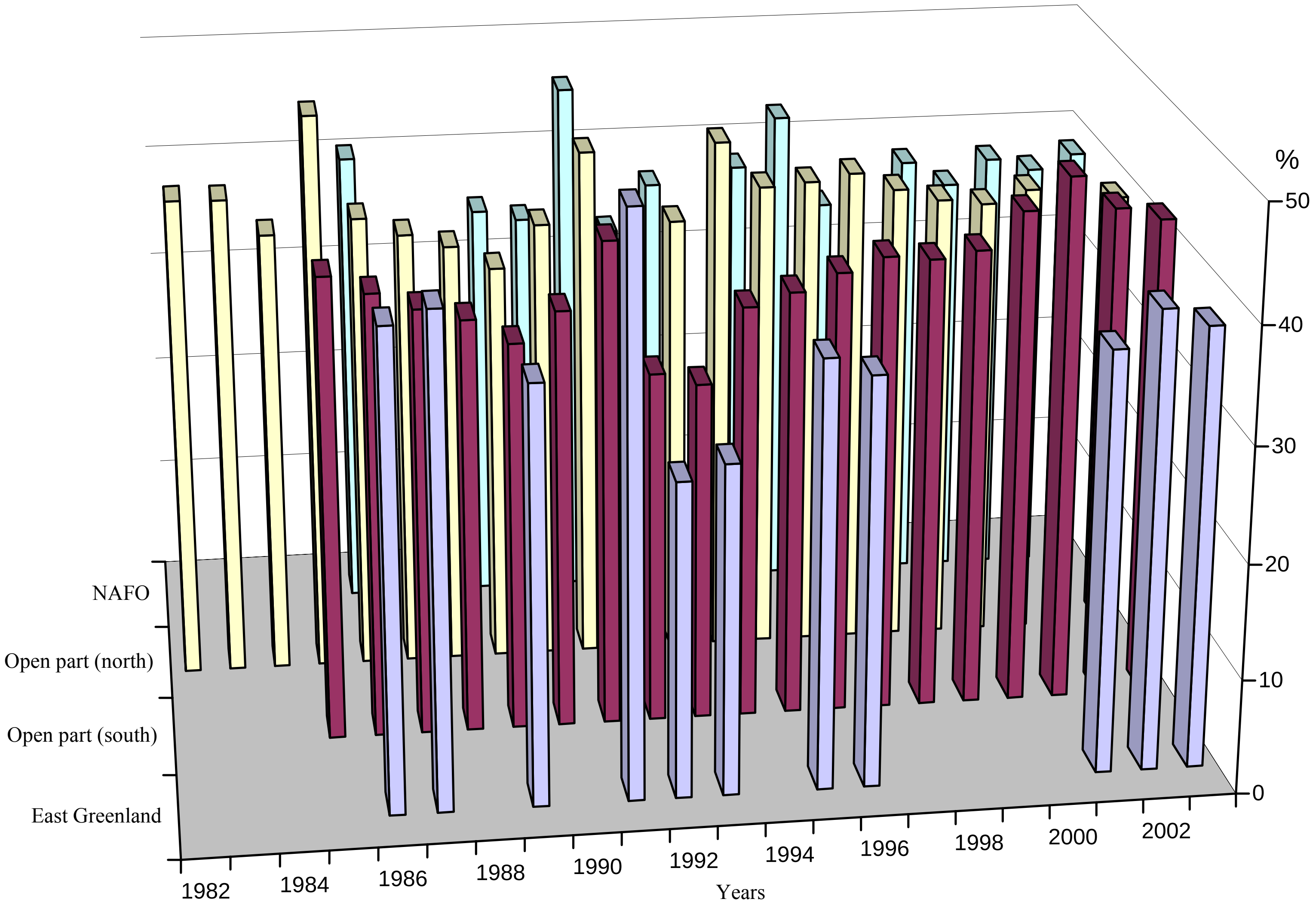


Fig. 3.5.3. Prevalence (%) of copepod *Sphyrion lumpi* in *S. mentella* by areas and years (June-July)

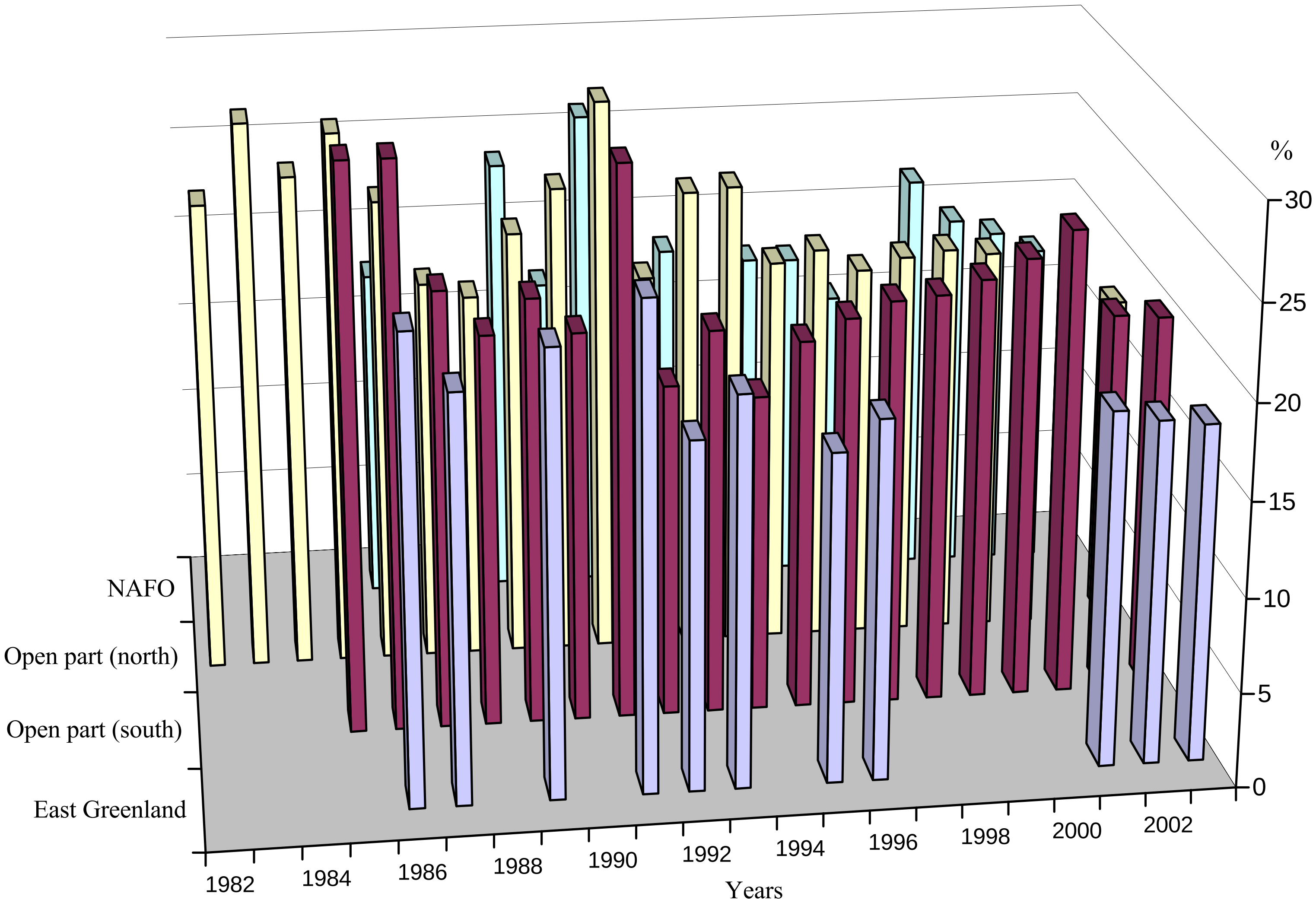


Fig. 3.5.4. Occurrence (%) of *S. mentella* with pigment patches on the skin by areas and years (June-July)

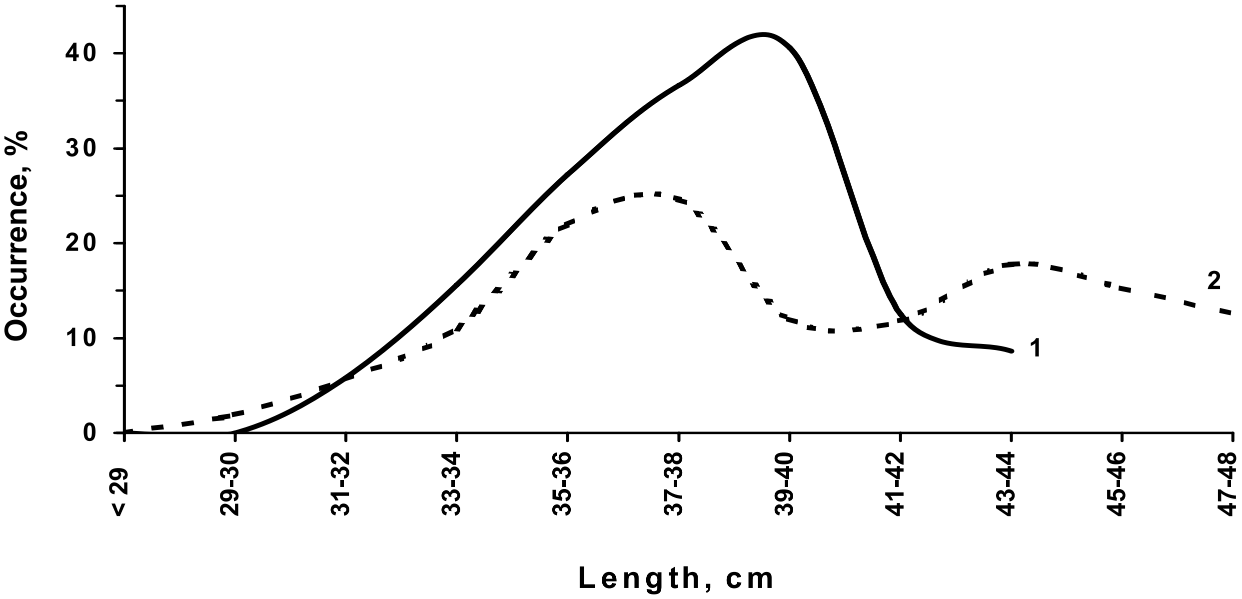


Figure 3.5.5. Occurrence of *S. mentella* with pigment patches on the skin at different length caught at the depths above 500 m (1) and below 500 m (2) in the Irminger Sea during the year of 1999.

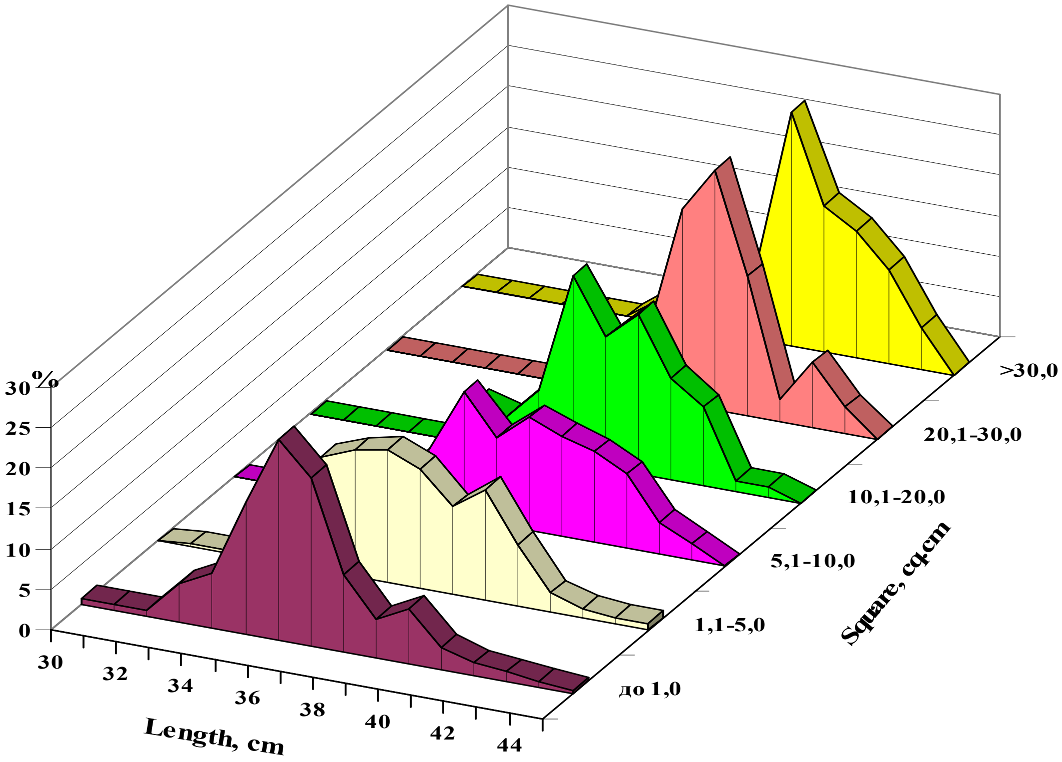


Figure 3.5.6. Occurrence of different-size pigment patches (spots) on the skin of *Sebastes mentella* from the Irminger Sea depending on fish length.

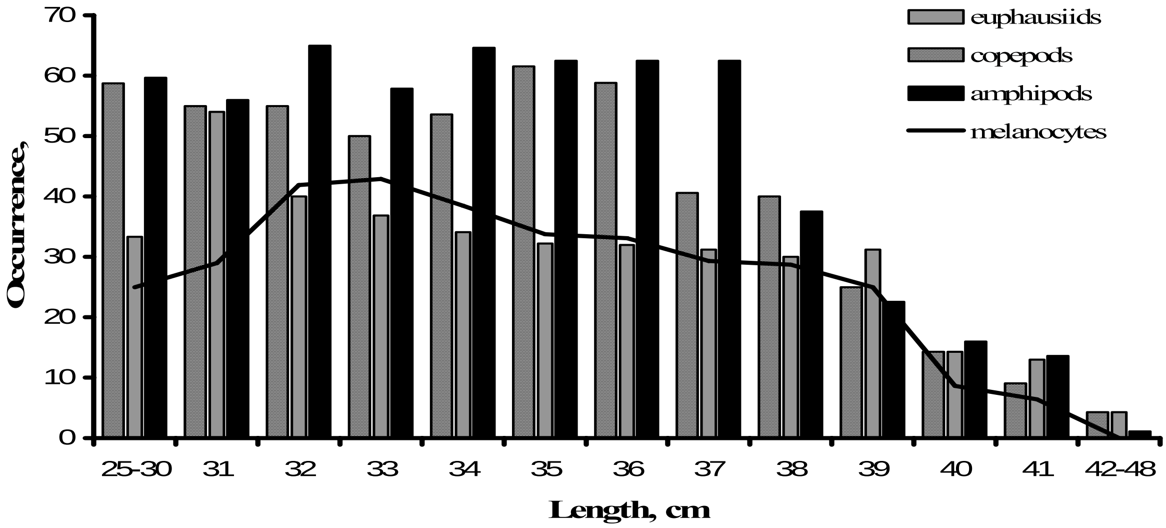


Figure 3.5.7. Occurrence (%) of *S. mentella* with melanocytes in muscular tissue and of some components in its feeding depending on fish length.

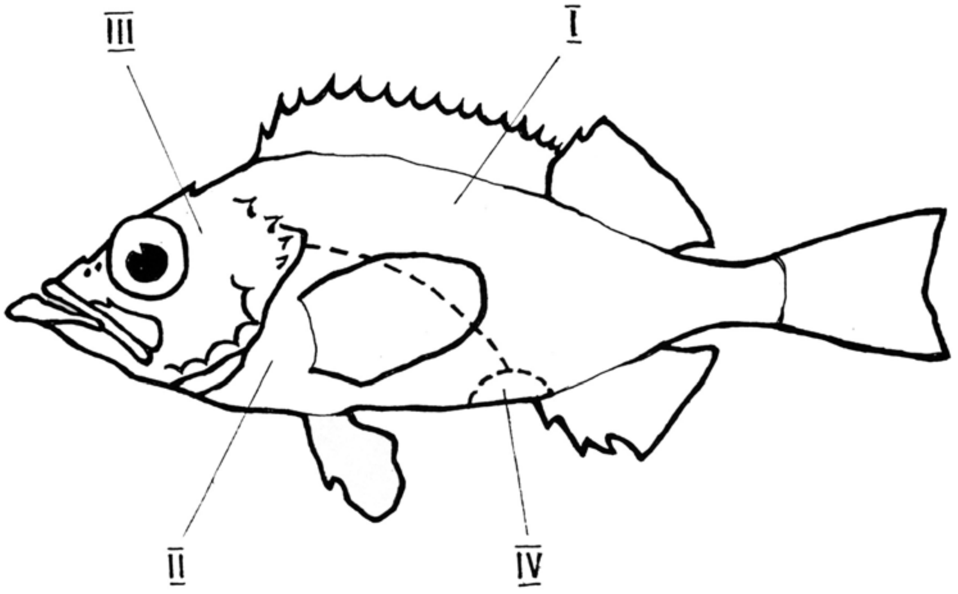


Figure 3.5.8. Parcelling the body surface into of the zones of lesions localization:
I – dorsal ("fillet") and caudal part, II – ventral part, III – head, IV – anal part

3.6 Otolith shape and trace element analyses

Otolith shape analysis

During the EU REDFISH project, material from 586 *S. mentella* specimens, incl. 318 specimens from the Irminger Sea (no info about depth) were analysed and compared for their shape (Anon. 2004). The overall jack-knifed classification success of the discriminant analysis is poor (< 50%), but increases to 72-74% by combining sampling areas to regions (west, central, east Atlantic) (Figure 3.6.1). The observed similarities within the central North Atlantic areas (Greenland, Iceland, Faroe Islands) and weak separation of western and eastern areas did not reveal, or had not the ability to reveal any structuring of the fish resource. The lack of clear geographic otolith shape patterns for *S. mentella* was therefore considered as no basis for any stock separation in the Irminger Sea and adjacent waters based on otolith shape analysis.

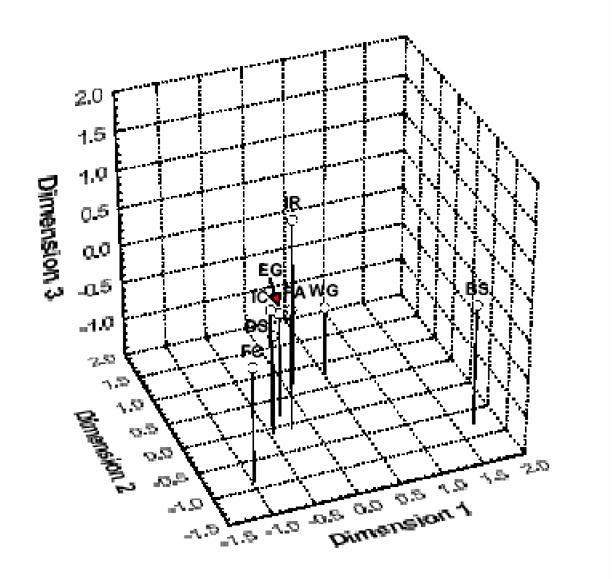


Figure 3.6.1. Three-dimensional ordination plot of the Euclidian distances between average size-corrected Fourier descriptors by area (FC-Flemish Cap, BS-Barents Sea, IR-Irminger Sea, DS-Davis Strait, WG-West Greenland, EG-East Greenland, IC-Iceland) for *S. mentella*.

Trace element analysis in otoliths

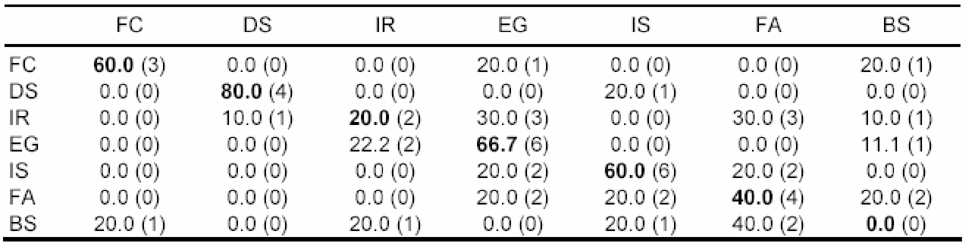
During the EU REDFISH project, material from 75 *S. mentella* specimens from Irminger Sea, Iceland and East-Greenland (no info about depth) were analysed, compared and tested for their otolith microchemistry as a stock separation tool for redfish (Anon. 2004). By determining minor and trace elements in different zones of redfish otoliths from various fisheries regions across the North Atlantic, geographic and temporal variation, as well as migration patterns were investigated.

Relatively high temporal stability in otolith elemental composition was found for juvenile redfish from a major nursery area off East Greenland, collected during five consecutive years.

Elemental concentrations, measured in the nucleus, juvenile and marginal otolith zones, were found to differ significantly between sampling areas and showed consistent longitudinal trends for some elements. Multivariate analysis of element constituents by area, however, revealed poor geographic separation (< 50% classification success) even for species, comparable to recent studies on deep-sea fish in the Northeast Atlantic and to the otolith shape analysis results above. The recently found evidence for migration of juvenile *S. mentella* from the East Greenland shelf into the pelagic habitat of the Irminger Sea could be confirmed by similarity in nucleus chemistry, indicating a common natal origin. But not detecting any difference don't necessarily mean that they came from East-Greenland and had the same origin

The connectivity within the central North Atlantic, inferred from otolith elemental signatures, and the observed weak separation from the Northwest and Northeast Atlantic are in accordance with results from concurrently undertaken body and otolith morphometrics.

Table 3.6.1. Jackknifed classification matrix of the discriminant function analysis of the elemental signatures (log10-transformed concentrations of Li, Mg, Mn, Cu, Zn, Rb, Sr, Sn and Ba relative to Ca) in the nucleus region of *S. mentella* otoliths from seven different areas in the North Atlantic (for area codes, see Fig. 3.6.1., FA-Faroes). The percentages in rows represent the classification into the areas given in columns. Total classification success is 46%. (Source: Anon. 2004)



	FC	DS	IR	EG	IS	FA	BS
FC	**60.0** (3)	0.0 (0)	0.0 (0)	20.0 (1)	0.0 (0)	0.0 (0)	20.0 (1)
DS	0.0 (0)	**80.0** (4)	0.0 (0)	0.0 (0)	20.0 (1)	0.0 (0)	0.0 (0)
IR	0.0 (0)	10.0 (1)	**20.0** (2)	30.0 (3)	0.0 (0)	30.0 (3)	10.0 (1)
EG	0.0 (0)	0.0 (0)	22.2 (2)	**66.7** (6)	0.0 (0)	0.0 (0)	11.1 (1)
IS	0.0 (0)	0.0 (0)	0.0 (0)	20.0 (2)	**60.0** (6)	20.0 (2)	0.0 (0)
FA	0.0 (0)	0.0 (0)	0.0 (0)	20.0 (2)	20.0 (2)	**40.0** (4)	20.0 (2)
BS	20.0 (1)	0.0 (0)	20.0 (1)	0.0 (0)	20.0 (1)	40.0 (2)	**0.0** (0)

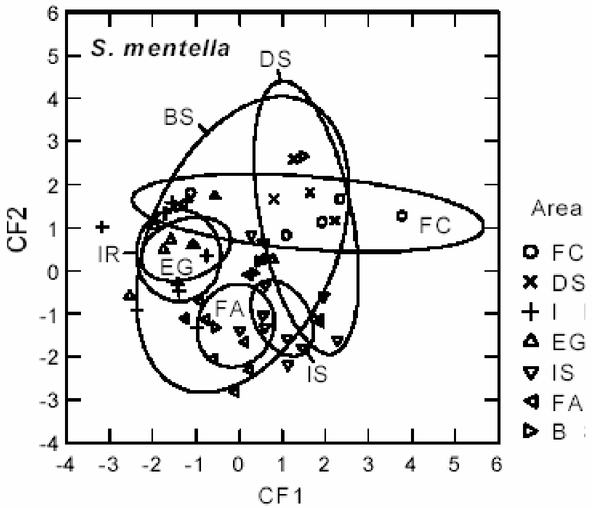


Figure 3.6.2. Discriminant function scores and 95% confidence ellipses for *S. mentella* otoliths from seven different areas in the North Atlantic (for area codes, see Table 3.6.1), based on the log10- transformed concentrations of nine elements (Li, Mg, Mn, Cu, Zn, Rb, Sr, Sn, Ba) in the nucleus region. (Source: Anon. 2004)

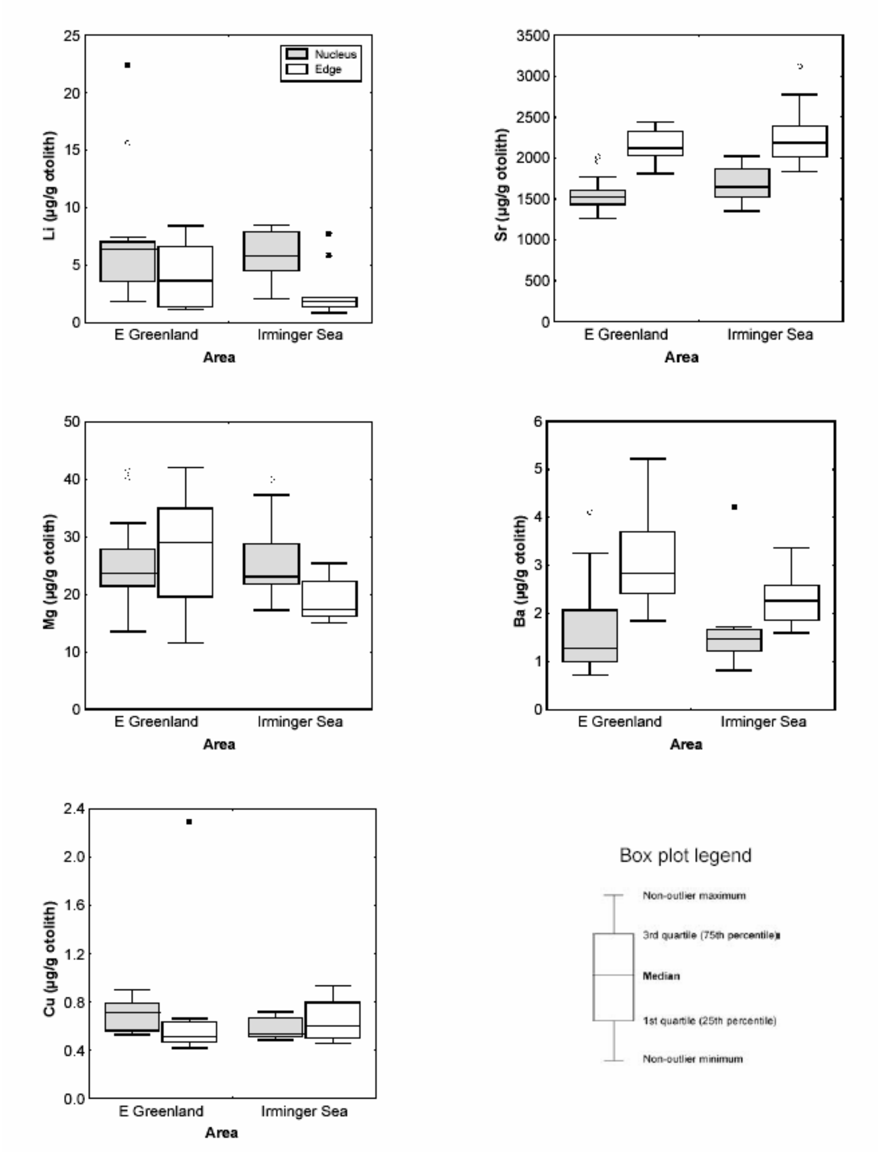


Figure 3.6.3. Concentration (µg g-1 relative to Ca) of the five elements consistently measured in the nucleus and edge regions of *S. mentella* otoliths from fish with total lengths of 25-30 cm, collected on the East Greenland shelf in October 1998 and in the Irminger Sea in July 1999 during a large-scale migration observed for these size groups, areas and period. Outliers are marked by open circles, extreme values are indicated by stars. (Source: Anon. 2004)

3.7 Age and growth of *S. mentella* in the Irminger Sea and adjacent waters

New information on age and growth of *S. mentella* in the Irminger Sea and adjacent waters was available for the Study Group. ICES and the scientific community have previous made an unanimous decision on using otoliths for age determination of redfish in general (Anon. 1996). There was, however, a common view in the Study Group that redfish scales may be used for age determination up to about 15-17 years. The long Russian time series from the Irminger Sea on age composition using scales, may therefore be useful for detecting recruitment patterns, and should be investigated accordingly.

The EU REDFISH project provided us with information on verification of the *S. mentella* age read from otoliths by using radiometric methods. The results which are shown in Figure 3.7.1, confirm ages up to about 40 years (which was the oldest specimen in the analysed sample), and that there is a tendency for the traditional otolith ageing method to underestimate the true age.

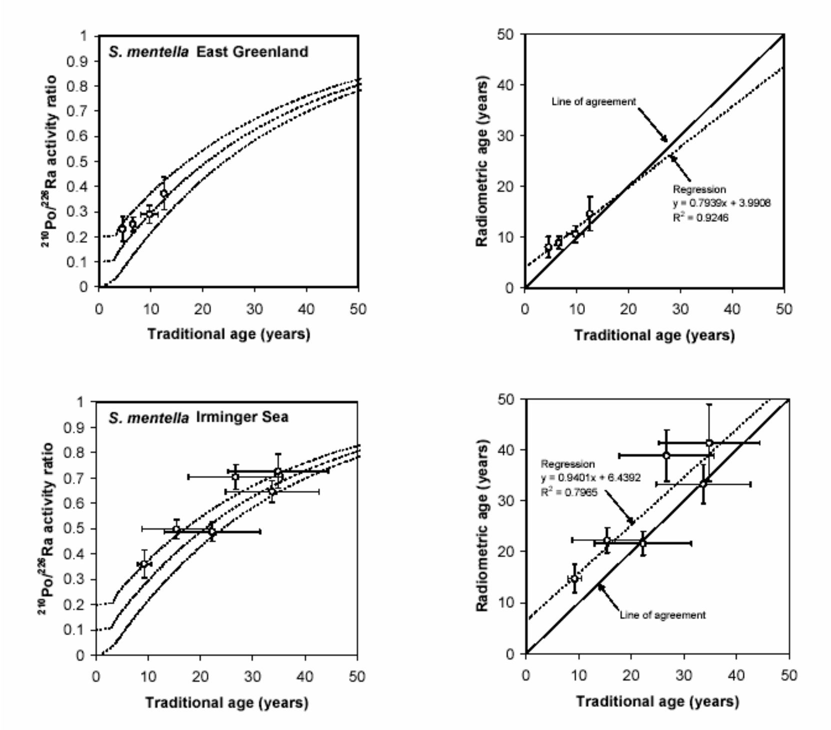


Figure 3.7.1. Validation of otolith age reading of *S. mentella* by radiometric method (Anon. 2004).

During the EU REDFISH project, 213 *S. mentella* otoliths from the Irminger Sea 1999 from 200-350 m depth were exchanged and read by different readers/laboratories (Figs. 3.7.2-3.7.3). The results show that fish were aged up to 50-60 years, and also the degree of harmonization in the age reading between readers. For more information, see Anon. (2004).

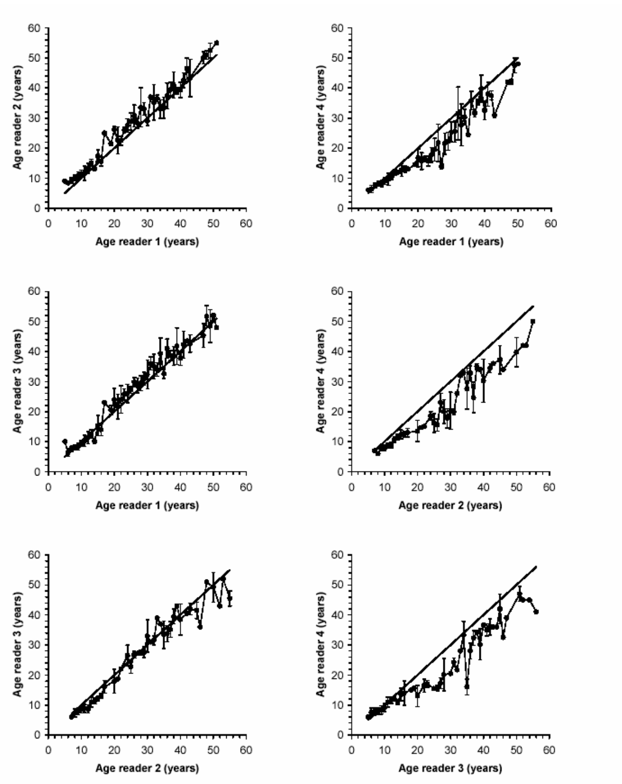


Figure 3.7.2. *S. mentella* from the Irminger Sea in 1999 from 200-350 m depth. 213 otoliths were exchanged (Anon. 2004).

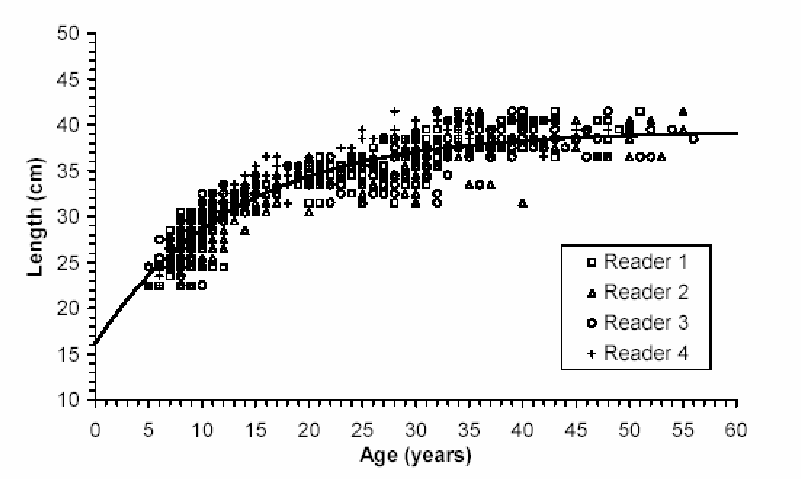


Figure 3.7.3. *S. mentella* from the Irminger Sea in 1999 from 200-350 m depth. Same material as in Figure 3.7.2 (Anon. 2004).

According to Russian scale readings, in 1980-82 the age range of the pelagic *S. mentella* was from 9 to 23 years old (Rikther 1996). At that time the fishery was only for *S. mentella* above 500 m and thereby most likely of Oceanic type. In 1995-1999 the *S. mentella* in the Irminger Sea above 500 m was between 6 to 17 years old while below this depth, from 6 to 25 years old (Bakay & Melnikov 2001). The lower maximum age found above 500 m may be explained by the intense fishery for more than 15 years on this component (Lehman 1991; Merreth & Haedrich 1997; Myers & Worm 2003). The age range in unfished populations above and below 500 m may therefore be similar, and that heavy fishing over time may change this (ref. chapter 3.9).

Of other age reading material from the actual areas available to the Study Group, the following can be mentioned: Norwegian age readings of otoliths from *S. mentella* caught during the fishery in 1993 are shown in the text table and Figure 3.7.4 below.

Date of sampling	Geogr. position	Depth	Nos. of specimens
27 April 1993	N 61°07', W 29°11' (XIVb)	500 m	107 spec.
05 June 1993	N 58°18', W 33°43' (XII)	400 m	100 spec.
24 July 1993	N 60°15', W 33°39' (XIVb)	200-400 m	95 spec.
17 Aug. 1993	N 60°50', W 33°14' (XIVb)	300 m	98 spec.

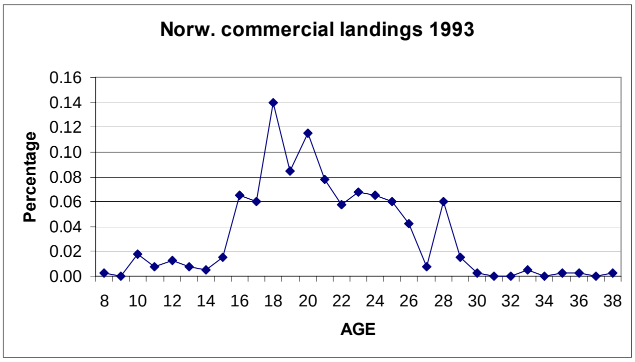


Figure 3.7.4. The age distribution (from otoliths) based on the material in the text table above.

From the otolith material collected and read from the Norwegian fishery in 1999, year-class variation is seen, even for more than 30 years (Figure 3.7.5). The figure also shows new recruits entering the southern area at about age 9-10.

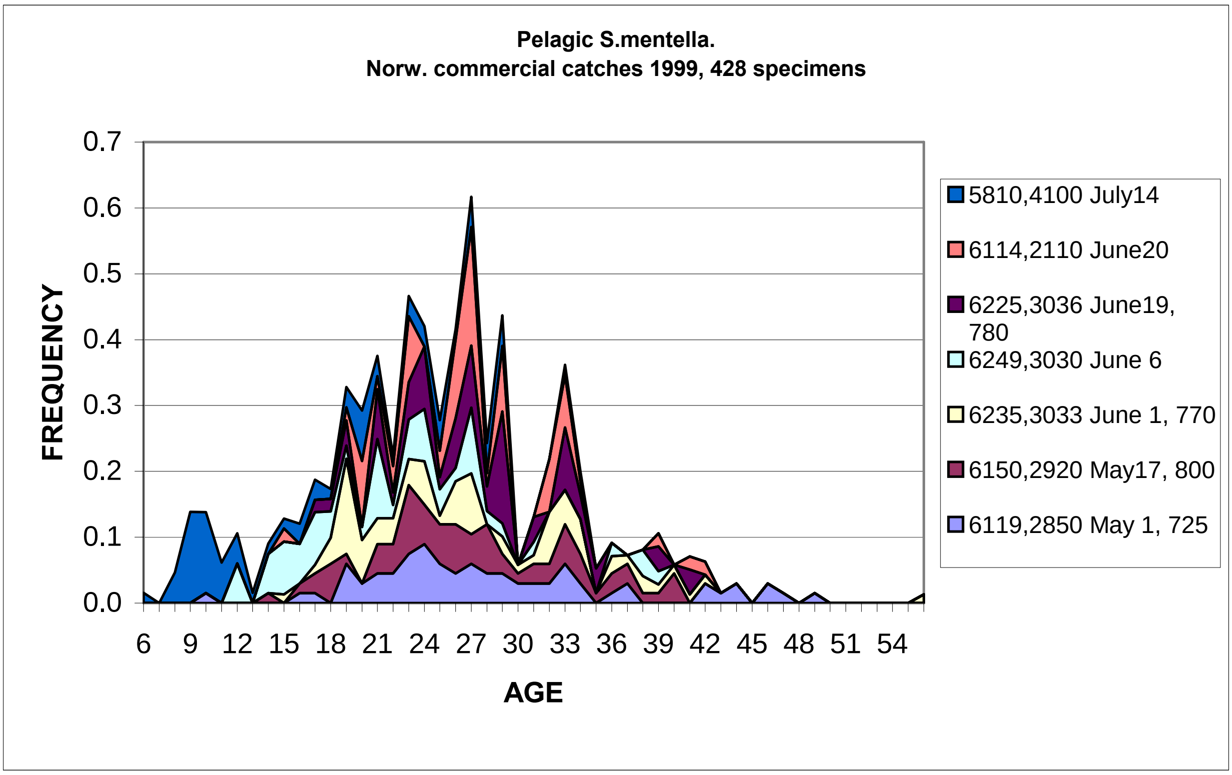


Figure 3.7.5. Norwegian age readings of otoliths from *S. mentella* caught during the fishery in 1999 from seven different locations. The two last samples (20 June and 14 July) are from waters shallower than 500 m, while the other samples were taken at depths greater than 500 m.

Table 3.7.1. Otolith readings by Norway from the 2001 international trawl-acoustic survey.

Depth interval	**Number fish age determined**	**Lowest age**	**Highest age** [year]	**Mean age**	**St. error** [year]
Shallower than 500 m	44	8	38	23	2
Deeper than 500 m	664	10	65	31	0.4

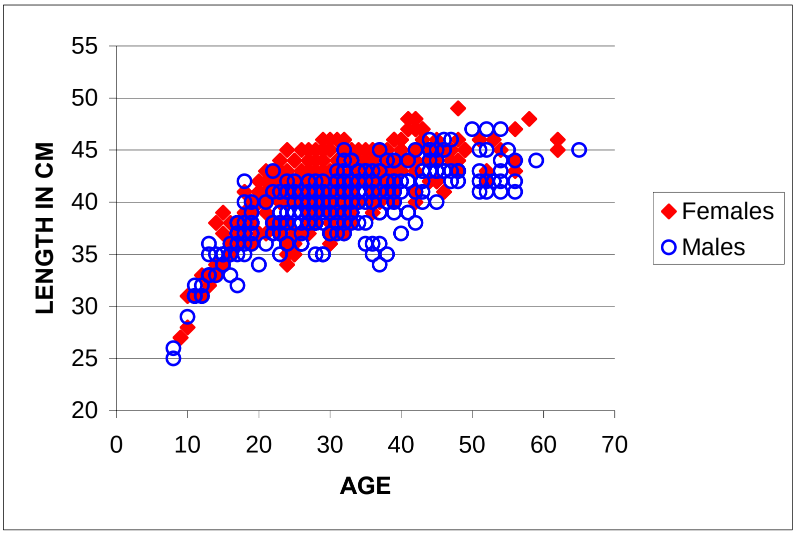
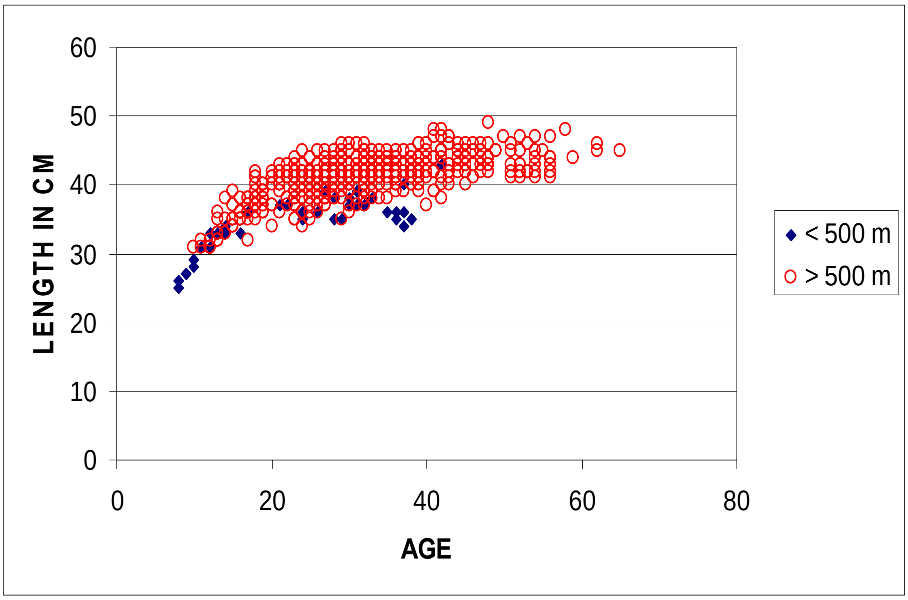


Figure 3.7.6. Otolith readings by Norway from the 2001 international trawl-acoustic survey. Same material as in Table 3.7.1.

A.



B.

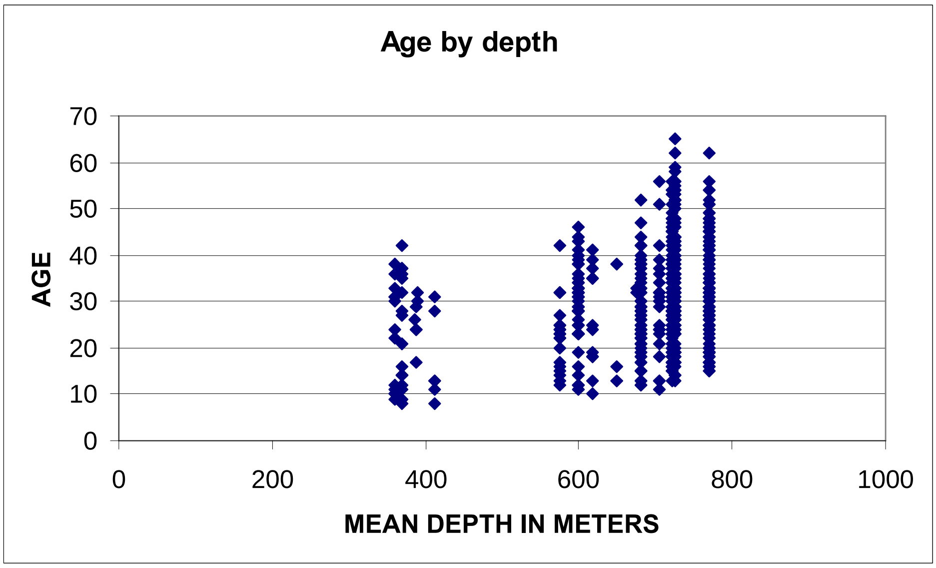


Figure 3.7.7 (A and B). Otolith readings from the 2001 trawl-acoustic survey. Age by depth. Same material as in Table 3.7.1 and Figure 3.7.6.

Table 3.7.1 and Figures 3.7.6-3.7.7 show the otolith age reading conducted by Norwegian specialists during the international trawl-acoustic survey in the Irminger Sea in June-July 2001. A statistical comparison of the growth for specimens shallower than 500 m and deeper than 500 m, showed that the growth rates for fish older than 15 years were fairly constant and equal (p=0.31). However, the deep-water fish were significantly larger at age (on average 4.1 cm, st.error = 0.4) than those caught in water shallower than 500 m.

During 1999 and 2001, Icelandic age readers read the age from otoliths (the same method as used by Norwegian readers) collected from the Icelandic trawl catches of *S. mentella* classified/phenotyped as oceanic *S. mentella*, oceanic deep-sea *S. mentella*, and shelf deep-sea *S. mentella*. The results are shown in Figure 3.7.8.

A statistical comparison show nearly the same results as described for the Norwegian readings of different material, i.e., for ages above 15 years, the growth rates for specimens older than 15 years were constant and equal for the two groups (p=0.56), and the pelagic deep-sea specimens were significantly (on average 5.1 cm, st.error = 0.8) bigger than the oceanic specimens at the same age. On the other hand, the growth rate of the shelf deep-sea *S. mentella* above age 15 were significant different from the growth rates of the two pelagic *S. mentella* groups (p << 0.01).

Concerning specimens younger than age 15, the size of the materials from the three groups were very different, thus making the statistical comparative tests more uncertain. The growth rates for the shelf deep-sea and pelagic deep-sea *S. mentella*, respectively, were, however, not statistically different for ages younger or equal than 15 years (p=0.11).

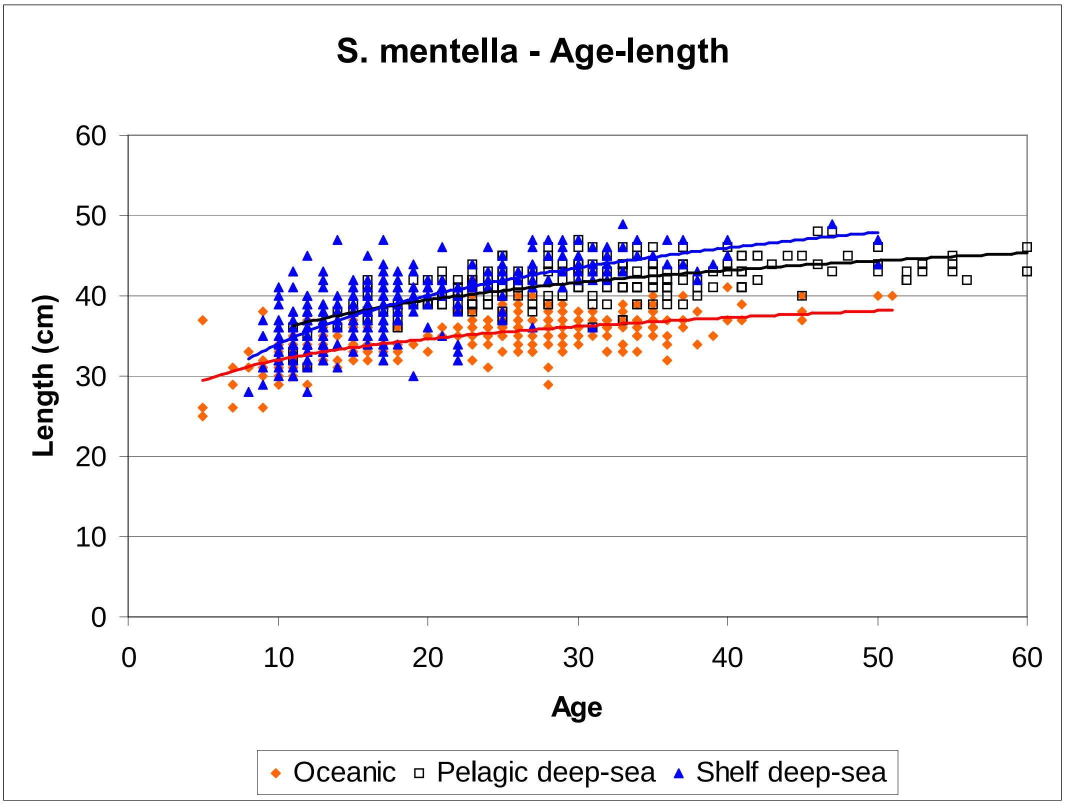


Figure 3.7.8. Age-length distributions of *S. mentella* from the Icelandic commerical catch. The species is classified as oceanic *S. mentella* (data from 1999 and 2001, 261 individuals), pelagic deep-sea *S. mentella* (data from 1999 and 2001 234 individuals) and shelf deep-sea *S. mentella* (data from 1998-2002, 539 individuals), as defined by Icelandic researches.

Comments.

- The available otolith material to the Study Group shows significantly different size at age of *S. mentella* from waters shallower and deeper than 500 m, as well as for *S. mentella* classified/phenotyped as either oceanic *S. mentella* or pelagic deep-sea *S. mentella*. The difference seems to have been established during younger ages since the growth rates for specimens older than age 15 were similar for these two groups. The age material from younger specimens of these two groups was too small to be tested for differences/ similarities.
- A comparison of the growth rates between shelf deep-sea *S. mentella* and the other two pelagic groups show a significant higher growth rate for shelf *S. mentella* for fish older than 15 years, while the growth rate difference at younger ages were not significantly different.
- More ageing of the *S. mentella* should be conducted, both for mortality, growth, morhological, and biochemical (incl. genetic) purpose. The results should be presented as age and length by depth
- Otoliths for age determination of redfish is the international agreed on method (Anon. 1996), but since redfish scales may be used for age determination up to about 15-17 years, the researchers should take advantage of the long Russian time series from the Irminger Sea of age readings from scales for investigating this time series' ability to reveal useful recruitment patterns in the stock(s). The scale readings must be presented on a high season, area and depth resolution.

3.8 Multivariate analysis of fatty acid profiles, and comparisons with enzyme-electrophoresis, microsatellites and morphometrics of the same fish.

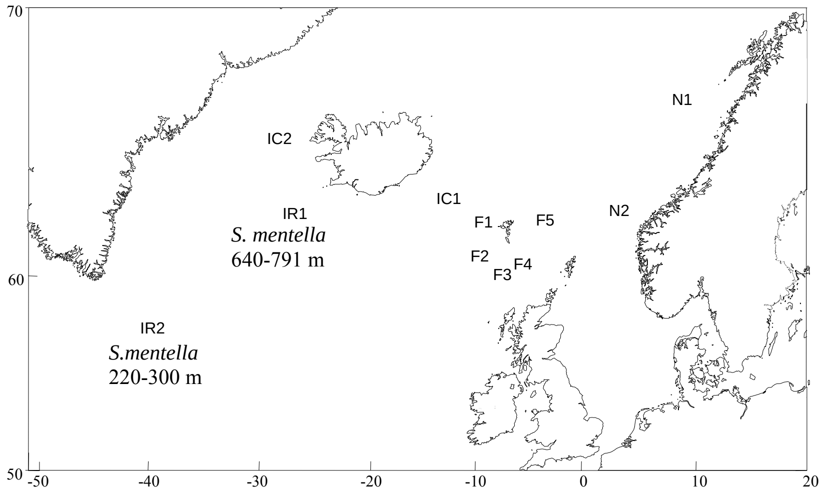


Figure 3.8.1. Northeast Atlantic Ocean and the 11 positions where the sampling of *S. mentella* took place.

Samples from the same individuals of *S. mentella* from 11 locations in the North Atlantic Ocean were also analyzed by electrophoretic methods (Torild Johansen, Department of Fisheries and Marine Biology, Bergen, Norway), morphometric method (Jákup Reinert, The Fisheries Laboratories of the Faroes, Tórshavn, Faroes Islands), electrophoretic methods and microsatellite-analyses (Anna Kristín Daníelsdóttir, Marine Research Institute, Population Genetics Laboratory, Reykjavík, Iceland) and otolith-analyses (Christoph Stransky, Institute for Sea Fisheries, Hamburg, Germany). The results from the otolith method are not presented here.

The material and methods are described in WD9 by Horaldur Joensen, which was presented by him during the Study Group meeting.

Results

Method	Group 1	Group 2	Group 3	Group 4
Fatty acid profile method	F1, F4, F5, N1, N2	F2, F3, Ic1, Ir1	Ic2	Ir2
Enzyme-electrophoretic method	F1, F4, F5, N1, N2, Ic2, Ir2	F2, F3, Ic1, Ir1		
Microsatellite method	F4, F5, N1, N2, Ir2	F2, F3, Ic1, Ir1	Ic2, F1	
Morphometric method	F4, F5, Ic1, Ic2	F2, F3, F1	N2, Ir1, Ir2	N1

The fatty profile method demonstrated that Ic2 and Ir2 resembled Group 1 more than Group 2 even if they were significantly different (Joensen and Grahl-Nielsen 2004). The enzyme-electrophoretic method had not the power to discriminate between Ic2, Ir2 and F1, F4, F5, N1, N2. All of the three independent methods have revealed group 2 as being composed of F2, F3, Ic1, Ir1. This group is therefore very likely a real group and not a fictive one. The classification reached by the morphometric method deviates to a certain degree from the other methods.

The multivariate analysis used in the fatty acid profile method was criticized. One opponent anticipated higher intra-group than inter-group differences if simultaneous analysis of all samples was conducted at an individual specimen level. Multivariate analysis of centroides of fatty acid samples gave a good overview.

3.9 Genetics

Sampling practises:

Samples were collected in two ways. Firstly, some samples were taken without any typing of phenotypes (classified as “undef”). In other surveys, *S. mentella* were classified to three groups, two phenotypes, oceanic and deep-sea and “undef”. Data from all these three groups are represented in current dataset and data from stations were only rejected if numbers were below 20 and pooling with neighbouring stations impossible. This applies to all three groups that the specimens were classified to. An overview of the genetic material behind the genetic results presented to the Study Group is given in Table 3.9.1.

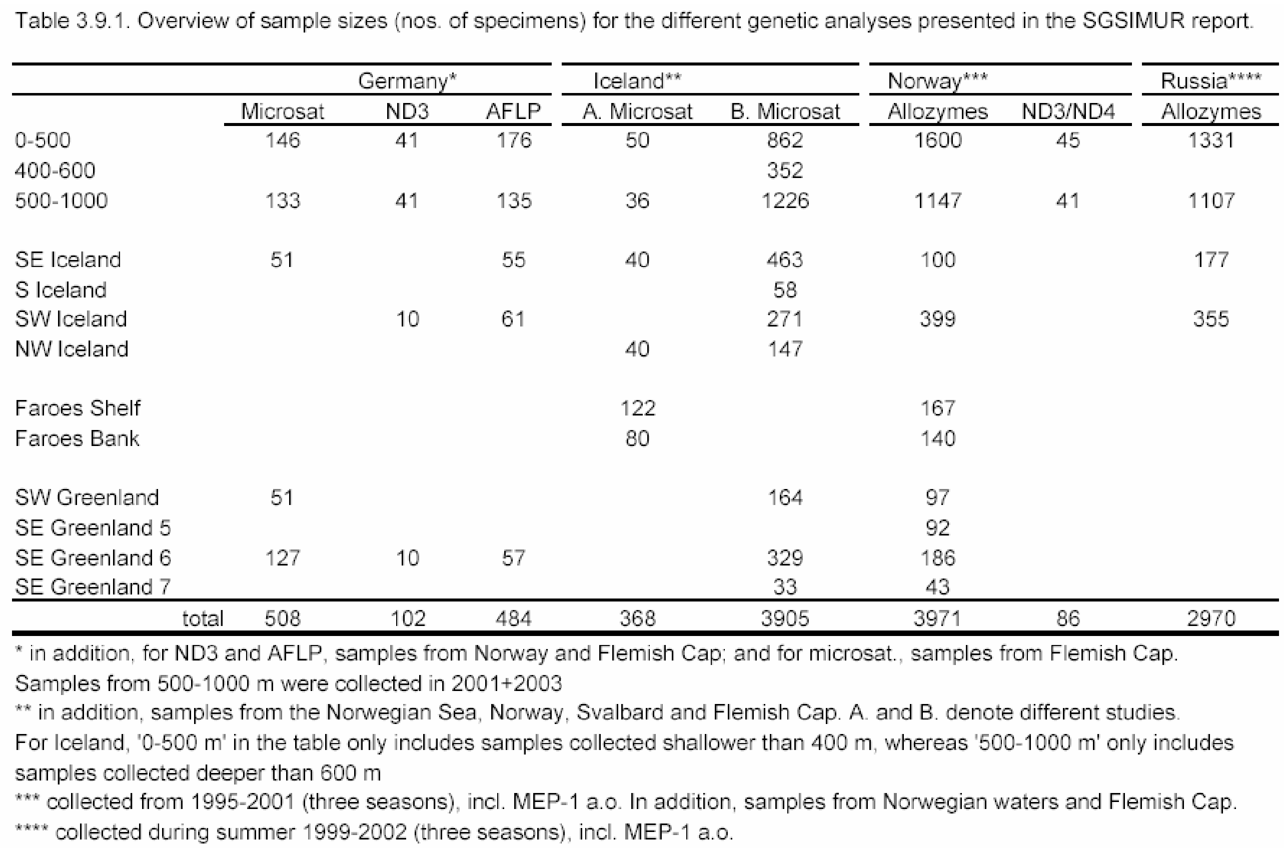


Table 3.9.1. Overview of sample sizes (nos. of specimens) for the different genetic analyses presented in the SGSIMUR report.

	Germany*			Iceland**		Norway***		Russia****
	Microsat	ND3	AFLP	A. Microsat	B. Microsat	Allozymes	ND3/ND4	Allozymes
0-500	146	41	176	50	862	1600	45	1331
400-600					352			
500-1000	133	41	135	36	1226	1147	41	1107
SE Iceland	51		55	40	463	100		177
S Iceland					58			
SW Iceland		10	61		271	399		355
NW Iceland				40	147			
Faroes Shelf				122		167		
Faroes Bank				80		140		
SW Greenland	51				164	97		
SE Greenland 5						92		
SE Greenland 6	127	10	57		329	186		
SE Greenland 7					33	43		
total	508	102	484	368	3905	3971	86	2970

* in addition, for ND3 and AFLP, samples from Norway and Flemish Cap; and for microsat., samples from Flemish Cap. Samples from 500-1000 m were collected in 2001+2003

** in addition, samples from the Norwegian Sea, Norway, Svalbard and Flemish Cap. A. and B. denote different studies. For Iceland, '0-500 m' in the table only includes samples collected shallower than 400 m, whereas '500-1000 m' only includes samples collected deeper than 600 m

*** collected from 1995-2001 (three seasons), incl. MEP-1 a.o. In addition, samples from Norwegian waters and Flemish Cap.

**** collected during summer 1999-2002 (three seasons), incl. MEP-1 a.o.

Four principal documents formed the basis for the Study group’s discussion and conclusions:

Stefansson *et al*.

Nine microsatellite loci (di-, tetra- and pentanucleotides) were used to genotype 4430 specimens sampled in 86 locations throughout the North Atlantic. Principal Components Analysis, reconstruction of phylogenetic tree (Figure 3.9.1) and individual assignment (Table 3.9.2) was used to cluster these. Three main groups were identified. Samples collected from deep (>600 m) and shallow (<600 m) portions of the Irminger Sea clustered separately (Figure 3.9.1, Table 3.9.2) as did those from Iceland. Some of the samples from Southeast Greenland clustered with those from the deep Irminger Sea cluster and some with the Iceland cluster. The samples from Southwest Greenland, however, clustered with the Irminger shallow cluster. One sample fell into a distinct cluster of its own, and this is probably contaminated with *S. marinus* specimens. On average 20 to 25 % of the variation of each sample is assigned to this cluster. Six out of 19 samples from Iceland clustered with the Irminger Sea deep samples but also 4 samples from deepsea habitat from the Irminger Sea clustered with the Irminger Sea shallow samples (here, mixing of specimens from both habitats as the trawl was hauled through the shallow habitat is a plausible explanation).

Within the Irminger Sea, allelic richness was significantly ($p < .001$) higher for fish collected at depths greater than 600 m, than in shallower waters. Additional analysis was carried out on the 37 to 38 cm size class from both depth portions during the SGSIMUR meeting. The results confirm the above results of higher allelic richness ($p < .015$) in the deep portion. Since the largest, and presumably oldest individuals are found deeper than 600 m, this was taken as evidence against any trend in genetic selection with age.

Significant genetic differences ($p < .001$) were found east and west of the “redfish line” used by managers in Iceland to separate demersal and pelagic fisheries there.

Table 3.9.2a. Proportion of individual assignment of *S. mentella* samples caught by pelagic fishing gear into four inferred clusters by the program STRUCTURE defined by Bayesian approach using 9 microsatellite loci.

Habitat	Phenotype	Shallow	Deep	Iceland	Cluster 4	n	Sample
Irminger Sea shallow habitat	oceanic	0.533	0.103	0.169	0.196	100	P1
	oceanic	0.487	0.091	0.202	0.220	100	P2
	oceanic	0.520	0.122	0.156	0.202	38	P3
	oceanic	0.498	0.112	0.215	0.175	31	P4
	oceanic	0.503	0.088	0.214	0.195	27	P5
	oceanic	0.425	0.125	0.223	0.227	20	P6
	oceanic	0.499	0.112	0.193	0.196	65	P7
	oceanic	0.498	0.070	0.215	0.217	37	P8
	oceanic	0.382	0.180	0.174	0.264	30	P9
	oceanic	0.564	0.083	0.141	0.212	36	P10
	deep-sea	0.391	0.136	0.238	0.235	31	P11
	deep-sea	0.521	0.120	0.170	0.190	80	P12
	undef	0.489	0.088	0.197	0.225	55	P13
	undef	0.501	0.108	0.167	0.225	48	P14
	undef	0.492	0.097	0.188	0.222	60	P15
	undef	0.555	0.082	0.169	0.194	60	P16
	undef	0.536	0.082	0.181	0.201	44	P17
Irminger Sea Intermediate habitat	oceanic	0.483	0.086	0.195	0.235	94	P18
	oceanic	0.519	0.098	0.204	0.179	71	P19
	oceanic	0.497	0.145	0.191	0.167	25	P20
	oceanic	0.504	0.107	0.185	0.204	36	P21
	deep-sea	0.506	0.117	0.183	0.194	46	P22
	undef	0.489	0.104	0.191	0.216	33	P23
	undef	0.472	0.086	0.195	0.247	47	P24
Irminger Sea Deep Habitat North	deep-sea	0.109	0.575	0.120	0.196	60	P25
	deep-sea	0.085	0.580	0.113	0.222	50	P26
	deep-sea	0.118	0.546	0.117	0.218	29	P27
	deep-sea	0.337	0.255	0.172	0.237	69	P28
	deep-sea	0.111	0.581	0.116	0.193	50	P29
	deep-sea	0.165	0.482	0.146	0.207	49	P30
	deep-sea	0.112	0.536	0.126	0.226	62	P31
	deep-sea	0.095	0.555	0.094	0.255	72	P32
	deep-sea	0.139	0.623	0.082	0.155	20	P33
	deep-sea	0.141	0.522	0.113	0.223	55	P34
	deep-sea	0.094	0.618	0.095	0.194	67	P35
	deep-sea	0.132	0.499	0.133	0.237	25	P36
	undef	0.071	0.657	0.098	0.174	28	P37
Deep Habitat South	oceanic	0.230	0.376	0.180	0.214	34	P38
	oceanic	0.481	0.151	0.205	0.163	44	P39
	deep-sea	0.298	0.327	0.158	0.217	52	P40
	deep-sea	0.108	0.530	0.109	0.253	22	P41
	deep-sea	0.128	0.522	0.146	0.205	72	P42
	deep-sea	0.417	0.217	0.136	0.230	55	P43
	deep-sea	0.148	0.453	0.130	0.269	53	P44
	deep-sea	0.100	0.605	0.103	0.192	56	P45
	deep-sea	0.231	0.374	0.130	0.265	62	P46
	undef	0.442	0.155	0.182	0.221	87	P47
	undef	0.242	0.453	0.123	0.181	53	P48

Table 3.9.2b. Proportion of individual assignment of *S. mentella* samples caught by demersal fishing gear into four inferred clusters by the program STRUCTURE defined by Bayesian approach using 9 microsatellite loci.

Habitat	Phenotype	Shallow	Deep	Iceland	Cluster 4	N	Sample
Northwest Iceland	deep-sea	0.086	0.182	0.640	0.091	22	D57
	demersal	0.090	0.636	0.105	0.169	91	D58
	undef	0.093	0.612	0.101	0.194	34	D59
South Iceland	undef	0.132	0.122	0.613	0.133	58	D60
Southeast Iceland	undef	0.216	0.083	0.525	0.176	30	D51
	demersal	0.117	0.185	0.534	0.164	80	D61
	undef	0.070	0.079	0.744	0.107	49	D62
	demersal	0.148	0.408	0.274	0.171	100	D63
	undef	0.090	0.620	0.083	0.207	36	D64
	undef	0.102	0.080	0.685	0.133	51	D65
	undef	0.094	0.092	0.690	0.124	34	D66
	undef	0.100	0.321	0.455	0.124	80	D67
	undef	0.103	0.154	0.598	0.145	33	D68
Southwest Iceland	demersal	0.095	0.516	0.222	0.168	63	D69
	demersal	0.097	0.093	0.693	0.116	42	D70
	demersal	0.097	0.128	0.560	0.215	30	D71
	demersal	0.115	0.079	0.649	0.157	34	D72
	undef	0.088	0.354	0.443	0.115	53	D73
	undef	0.115	0.551	0.104	0.230	49	D74
Southeast Greenland	undef	0.137	0.513	0.108	0.242	33	D75
	undef	0.148	0.087	0.481	0.284	114	D76
	undef	0.127	0.034	0.230	0.610	47	D77
	undef	0.161	0.138	0.570	0.131	62	D78
	undef	0.307	0.236	0.228	0.229	57	D79
	undef	0.278	0.272	0.174	0.276	48	D80
Southwest Greenland	undef	0.445	0.149	0.160	0.246	66	D82
	undef	0.492	0.090	0.153	0.265	47	D83
	undef	0.385	0.141	0.222	0.252	51	D84

Shaded cells denote the highest proportions for each sample.

Schmidt and Trautner

Twenty-eight ND-3 mitochondrial haplotypes were identified, and used to genotype specimens collected from throughout the North Atlantic as well as the Pacific. All four *Sebastes* species from the Atlantic were represented, and two Pacific *Sebastes* species, and the genus *Helicolenus* were included for outgroup comparisons. The results showed a relatively recent differentiation of *S. marinus* and *S. mentella*. Eight haplotypes were found in *S. mentella*, but they were not used in population studies because of low numbers analysed.

Microsatellite data showed that genetic heterogeneity was low among *S. mentella* samples (Fst = 0.7-1.7 %). Nevertheless, both microsatellite and AFLP analysis (see below) showed that there was statistically significant genetic variability between locations, and between years at the same locations (Tables 3.9.3-3.9.4).

AFLP data (Table 3.9.5) revealed genetic differences between closely located stations (like SW- and SE Iceland), whereas no significant differences where found between the distant locations Norway and the Southern Irminger Sea. Two samples of *S. mentella* deep sea type taken in different years were genetically similar, but temporal replicates of samples of *S. mentella* oceanic type did not reveal temporal stability. Genetic differences between different geographical regions were observed, but no isolation by distance. The results of the AFLP analysis provide essentially the same pattern as the microsatellite analysis (Table 3.9.6) by Schmidt and Trautner.

Table 3.9.3. Microsatellite analysis by Schmidt and Trautner. Results of the Analysis of Molecular Variance (AMOVA) of the *S. mentella* samples with variance partitioned among locations, among temporal samples from the same locations and within samples (d.f. = degrees of freedom).

Source of variation	**d.f.**	**Variance components**	**Percentages of variation**
Among locations	7	0,01232	0,36
Among temporal samples from the same location	2	0,01745	0,51**
within samples	1078	3,38498	99,13***
Total	1078	3,7219	

** = significant, p < 0,01; *** = highly significant, p < 0,001

Table 3.9.4. AFLP analysis by Schmidt and Trautner. Results of the Analysis of Molecular Variance (AMOVA) of the *S. mentella* samples with variance partitioned among locations, among temporal samples from the same locations and within samples (d.f. = degrees of freedom).

Source of variation	**d.f.**	**Variance components**	**Percentages of variation**
Among locations	7	0,395	5,00*
Among temporal samples from the same location	2	0,238	3,01***
Within samples	594	7,266	91,99***
Total	603	7,899	0

* = significant, p < 0,05; *** = highly significant, p < 0,001

Table 3.9.5. AFLP analysis by Schmidt and Trautner. Genetic differentiation between samples of *Sebastes mentella* based on 85 AFLP loci. Pairwise ΦST values (below diagonal) and probability (P-) values (above diagonal). Sample abbreviations as given in Appendix 3. Probability values were adjusted for multiple tests comparisons using the sequential Bonferroni corrections (Rice 1989): * P value < 0,05; ** P value < 0,01; *** P value < 0,001. Bold numbers: non significant values, n.s. = not significant after Bonferroni corrections.

	VI	FAFC01	MApool	MAFC01	MENO01	MESEIc01	MESWIc01	MEEGr01	MEcIrmds97	MEcIrmds01	MEcIrmoc97	MESIrmoc01	MESIrm01	MEFC01
VI		0,00000***	0,00000***	0,00000***	0,00000***	0,00000***	0,00000***	0,00000***	0,00000***	0,00000***	0,00000***	0,00000***	0,00000***	0,00000***
FAFC01	0,57727		0,00000***	0,00000***	0,00000***	0,00000***	0,00000***	0,00000***	0,00000***	0,00000***	0,00000***	0,00000***	0,00000***	0,00000***
MApool	0,45678	0,47194		0,00000***	0,00000***	0,00000***	0,00000***	0,00000***	0,00000***	0,00000***	0,00000***	0,00000***	0,00000***	0,00000***
MAFC01	0,49067	0,42641	0,09084		0,00000***	0,00000***	0,00000***	0,00000***	0,00000***	0,00000***	0,00000***	0,00000***	0,00000***	0,00000***
MENO01	0,49261	0,46604	0,29983	0,36265		0,00000***	0,00000***	0,00000***	0,00000***	0,00000***	0,00000***	0,00000***	**0,00317n.s.**	0,00000***
MESEIc01	0,49155	0,42922	0,26325	0,30577	0,05693		0,00000***	0,00000***	0,00000***	0,00000***	0,00000***	0,00000***	0,00000***	0,00000***
MESWIc01	0,47680	0,41546	0,26207	0,30607	0,08159	0,03839		0,00000***	0,00000***	0,00000***	0,00000***	0,00000***	0,00000***	0,00000***
MEEGr01	0,45792	0,42744	0,24917	0,31310	0,06989	0,06956	0,09171		0,00000***	0,00000***	0,00000***	0,00000***	0,00000***	0,00000***
MEcIrmds97	0,44434	0,41507	0,25616	0,29871	0,08998	0,05268	0,02100	0,10196		**0,00400 n.s.**	0,00000***	0,00000***	0,00000***	0,00000***
MEcIrmds01	0,46568	0,40801	0,26715	0,31179	0,09500	0,04026	0,02701	0,09559	**0,01516**		0,00000***	0,00000***	0,00000***	0,00000***
MEcIrmoc97	0,51742	0,46095	0,28218	0,33833	0,07969	0,05763	0,08702	0,10161	0,09492	0,09506		0,00000***	0,00000***	0,00000***
MESIrmoc01	0,52058	0,45154	0,29049	0,33614	0,09876	0,05575	0,08903	0,08808	0,11816	0,10307	0,05322		0,00000***	0,00000***
MESIrm01	0,49873	0,48438	0,31532	0,38177	**0,01413**	0,07736	0,10498	0,08213	0,10115	0,11239	0,06979	0,10175		0,00000***
MEFC01	0,47468	0,33664	0,27037	0,28902	0,07660	0,05654	0,07525	0,09385	0,09221	0,08584	0,08039	0,07709	0,08662	

Table 3.9.6. Microsatellite analysis by Schmidt and Trautner. Genetic diffentiation between samples of *Sebastes mentella* based on eight microsatellite loci. Pairwise FST values. Probability values in parenthesis. Sample abbreviations as given in Appendix 3. Probability values were adjusted for multiple tests comparisons using the sequential Bonferroni corrections (Rice 1989): * P value < 0,05; ** P value < 0,01; *** P value < 0,001. Significant values are highlighted in grey.

	MESEIc01	MEcIrmd01	MEcIrmd03	MEEGr00	MEEGr01	MEWGr01	MESIrm01	MENAFO1F01	MENAFO2J01
MEcIrmd01	0,00595 (0,00396)								
MEcIrmd03	0,00867** (0,00010)	0,00099 (0,32106)							
MEEGr00	0,00137 (0,25304)	0,01247*** (0,00000)	0,01411*** (0,00000)						
MEEGr01	0,00563 (0,02109)	0,00515 (0,01634)	0,00836** (0,00040)	0,00921** (0,00079)					
MEWGr01	0,00665 (0,00713)	0,01209*** (0,00000)	0,01579*** (0,00000)	0,01068*** (0,00000)	0,00506 (0,03604)				
MESIrm01	0,00455 (0,02307)	0,00873** (0,00010)	0,0098*** (0,00000)	0,00686* (0,00178)	0,00290 (0,12632)	0,00001 (0,51500)			
MENAFO1F01	0,00816* (0,00198)	0,0118*** (0,00000)	0,01283*** (0,00000)	0,01337*** (0,00000)	0,00600 (0,02030)	0,00057 (0,44332)	0,00254 (0,11811)		
MENAFO2J01	0,0067 (0,00416)	0,01115*** (0,00000)	0,01136** (0,00010)	0,01319*** (0,00000)	0,00563 (0,02297)	0,00112 (0,34165)	0,00152 (0,23909)	-0,00043 (0,65815)	
MEFC01	0,01099*** (0,00000)	0,01673*** (0,00000)	0,01731*** (0,00000)	0,01131*** (0,00000)	0,01408*** (0,00000)	0,00705* (0,00119)	0,00691* (0,00099)	0,00690* (0,00198)	0,00768* (0,00050)

Stroganov and Novikov

According to Stroganov and Novikov, analysis *MEP-2*[1] enzyme system indicated genetic differences with age for samples collected from the Irminger Sea (Figure 3.9.2). Since older fish tend to be found in deeper waters (Figure 3.9.3), this could also be interpreted as a significant genetic difference with depth (Table 3.9.7). However, genetic isolation is only one explanation for this.

The chairman finds it necessary to add that ICES has concluded that otoliths are the only reliable and acceptable structure to be used for age reading of redfish (Anon. 1996). Results based on scale readings of at least 15-17 years and older redfish are doubtful and should not be used.

Table 3.9.7. Frequency of dominant allele in polymorphic loci of *Sebastes mentella* in the Russian allozyme analyses (1999-2002).

Polymorphic systems	Collection areas										Collection years
	Irminger sea				Rosengarten bank	N	Outer-Bailey bank	N	SW slope of Iceland	N	
	0-500 м	N	501-1000 м	N							
*MEP-2**	0,494	170	0,711	200	-	-	-	-	-	-	1999
	0,606	80	0,796	120	-	-	-	-	-	-	2000
	0,574	781	0,687	308	0,548	177	0,716	74	0,610	355	2001
	0,550	300	0,572	479	-	-	-	-	-	-	2002
average	**0,560**	**1331**	**0,653**	**1107**	**0,548**	**177**	**0,716**	**74**	**0,610**	**355**	
*MDH**	1,000	170	0,990	200	-	-	-	-	-	-	1999
	1,000	80	0,975	120	-	-	-	-	-	-	2000
	0,996	781	0,957	308	1,000	177	1,000	74	0,983	355	2001
	0,998	300	0,992	479	-	-	-	-	-	-	2002
average	**0,997**	**1331**	**0,980**	**1107**	**1,000**	**177**	**1,000**	**74**	**0,983**	**355**	
*PGI**	1,000	170	0,992	200	-	-	-	-	-	-	1999
	1,000	80	0,996	120	-	-	-	-	-	-	2000
	0,994	781	0,997	308	0,994	177	1,000	74	0,997	355	2001
	0,998	300	1,000	479	-	-	-	-	-	-	2002
average	**0,996**	**1331**	**0,997**	**1107**	**0,994**	**177**	**1,000**	**74**	**0,997**	**355**	
*PGM-1** (muscle)	1,000	170	0,992	200	-	-	-	-	-	-	1999
	1,000	80	1,000	120	-	-	-	-	-	-	2000
average	**1,000**	**250**	**0,995**	**320**	**-**	**-**	**-**	**-**	**-**	**-**	
*IDH**	0,997	170	1,000	200	-	-	-	-	-	-	1999
	1,000	80	1,000	120	-	-	-	-	-	-	2000
	1,000	781	1,000	308	1,000	177	1,000	74	1,000	355	2001
	0,998	300	1,000	479	-	-	-	-	-	-	2002
average	**0,999**	**1331**	**1,000**	**1107**	**1,000**	**177**	**1,000**	**74**	**1,000**	**355**	

Johansen and Nævdal

The samples from the Irminger Sea during the EU REDFISH project were collected randomly and some were in addition classified into phenotype (oceanic vs. deep-sea during 1995-2001), using criteria described previously by experts (ICES 1998). They were analysed for allozyme and haemoglobin variation. The MEP-1* 1) system indicated significant differences between shallow and deep populations in the Irminger Sea as well as among samples from the Faeroe Islands and Norway (Tables 3.9.8 and 3.9.9), consistent with earlier investigations (Johansen et al. 2000). Aggregating the samples from different depths and phenotypes resulted in a deviation from Hardy-Weinberg equilibrium.

Samples from Greenland suggest recruitment from Greenland to both shallow and deep Irminger Sea, with the possibility that, in some cases, these stocks could be separated geographically both on the nursery area on the shelf and at sea.

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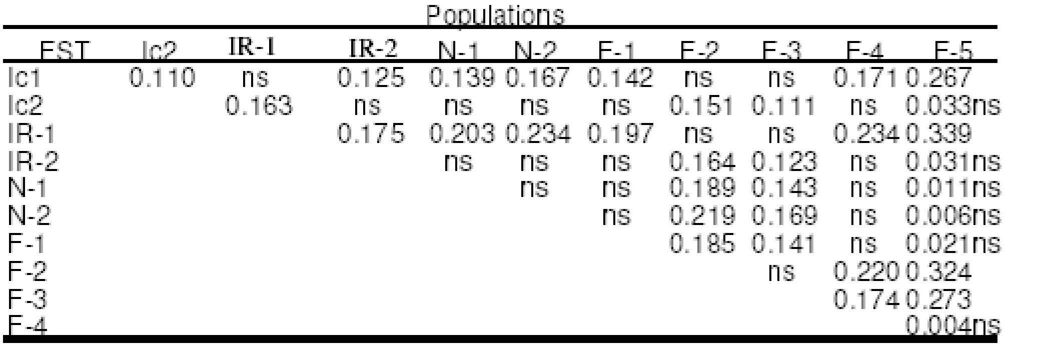
[1] MEP-1 (Norwegian analysis) and MEP-2 (Russian analysis) is assumed to be two different designations of the same locus.

Table 3.9.8. Fst-values (1000 permutation) for prioritised samples (“Vigo samples”) of *S. mentella* analysed for haemoglobin and allozymes. ns=non significant differences

FST	SW Icland	SE Icland	Flem cap	Norway	SE-Irms	oceanic	Grenl609	Green610	Gren611
Deepsea	0.0141ns	0.1803	0.0505	0.3361	0.1214	0.1306	0.1604	0.1082	-0.0077ns
SW Icland		0.0863	0.0097ns	0.2264	0.0416	0.0502	0.0611	0.0272ns	-0.0300ns
SE Icland			0.0367	0.0337	-0.0015ns	-0.003ns-	0.0180ns	-0.0068ns	0.0706
Flemish cap				0.1345	0.0104ns	0.0178	0.0153ns	-0.0031ns	-0.0060ns
Norway					0.0738	0.0661	0.0433ns	0.0778	0.2188
SE-Irminger						-0.0081ns	-0.0156ns	-0.0168ns	0.0274ns
Oceanic							-0.0173ns	-0.0155ns	0.0346ns
Greenland 6 1009								-0.0268ns	0.0406ns
Greenland 6 1010									0.0033ns

Table 3.9.9. Fst-values (1000 permutation) for *S. mentella* analysed for *Mep-1**, *MDH-2** and *IDHP-1**. Ic1: SE Iceland, Ic2: W Iceland, IR1, deep sea Irminger Sea, IR2: shallow Irminger Sea, N: Norway, F1, F4, F5: Faeroe Islands shelf, F2, F3: Faereo Bank.



	Populations									
FST	Ic2	IR-1	IR-2	N-1	N-2	F-1	F-2	F-3	F-4	F-5
Ic1	0.110	ns	0.125	0.139	0.167	0.142	ns	ns	0.171	0.267
Ic2		0.163	ns	ns	ns	ns	0.151	0.111	ns	0.033ns
IR-1			0.175	0.203	0.234	0.197	ns	ns	0.234	0.339
IR-2				ns	ns	ns	0.164	0.123	ns	0.031ns
N-1					ns	ns	0.189	0.143	ns	0.011ns
N-2						ns	0.219	0.169	ns	0.006ns
F-1							0.185	0.141	ns	0.021ns
F-2								ns	0.220	0.324
F-3									0.174	0.273
F-4										0.004ns

Summary of Discussion

There was general agreement that significant genetic structure exists for *S. mentella* within the Irminger Sea and adjacent regions.

Discussion by the group, and a written review by Einar Eg Nielsen, focused on the likelihood that the genetic differences observed between shallow and deep stocks within the Irminger Sea could have arisen through genetic selection (perhaps facilitated by exploitation), or “cohort effects”, rather than reproductive isolation. Genetic (or fishery) selection or a “cohort effect” (= “sweepstakes chance effect”), where offspring from a given year class reflect the genetic contributions of a relatively small part of the parent population would provide alternative explanations for such a result. On the other hand, genetic drift may be one of the factors responsible for differences between marine fish populations, and could be a mechanism to cause a sweepstakes chance effect (Hedgecock 1994; Geiger et al. 1997, Matala et al. 2004) responsible for differences between cohorts. However, “cohort effects” are probably minor in a species which has 20 or more reproductive year classes with high allele richness and composing stock sizes of up to one million tonnes. Significant increasing allele richness by depth also contradicts the effect of selection or genetic drift on microsatellites.

Lack of clear genetic isolation by geographical distance concerned some participants, and further analysis of this phenomenon is suggested.

Some researchers expressed doubt about the sampling design used, and the choice of samples to be analysed (e.g., to what extent not-phenotyped specimens had been included in all the stock structure analyses). The Study Group was informed about collected samples during the EU REDFISH project that not yet had been analysed by some or all methods. The above doubt expressed about the choice of samples to be analysed is therefore hereby addressed to the responsible laboratories.

It was agreed that in a perfect world, samples would have been collected randomly, during the mating season, and over a time period, which allowed analysis of both interannual and decadal effects. The age of each specimen collected would also be determined.

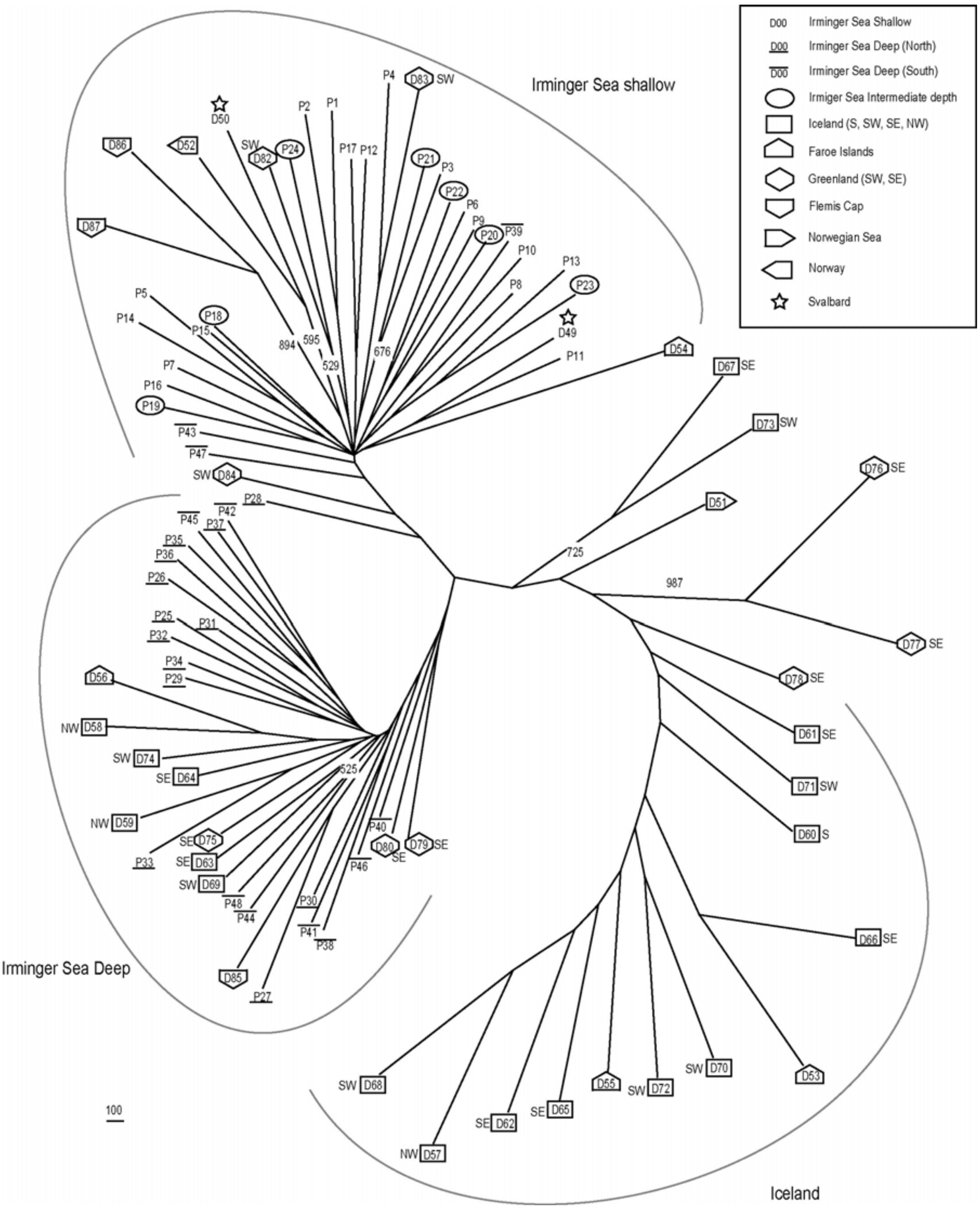


Figure 3.9.1. Consensus neighbour-joining dendrogram based on D_{CE} genetic distances among all *S. mentella* samples in the Northern Hemisphere. The numbers at the forks indicate the number of times the group consisting of the samples occurred among the trees, out of 1000 trees. Bootstrap values are shown for nodes with 50% support or more.

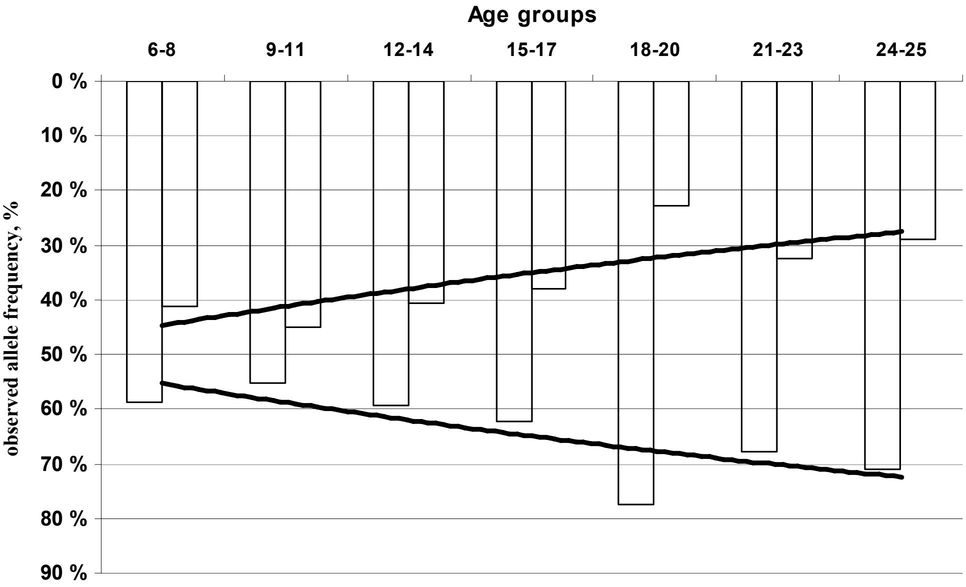


Figure 3.9.2. Observed allele frequency of *MEP-2* (100 and 60)* in different age groups (scale readings) of *Sebastes mentella (1999-2002)*

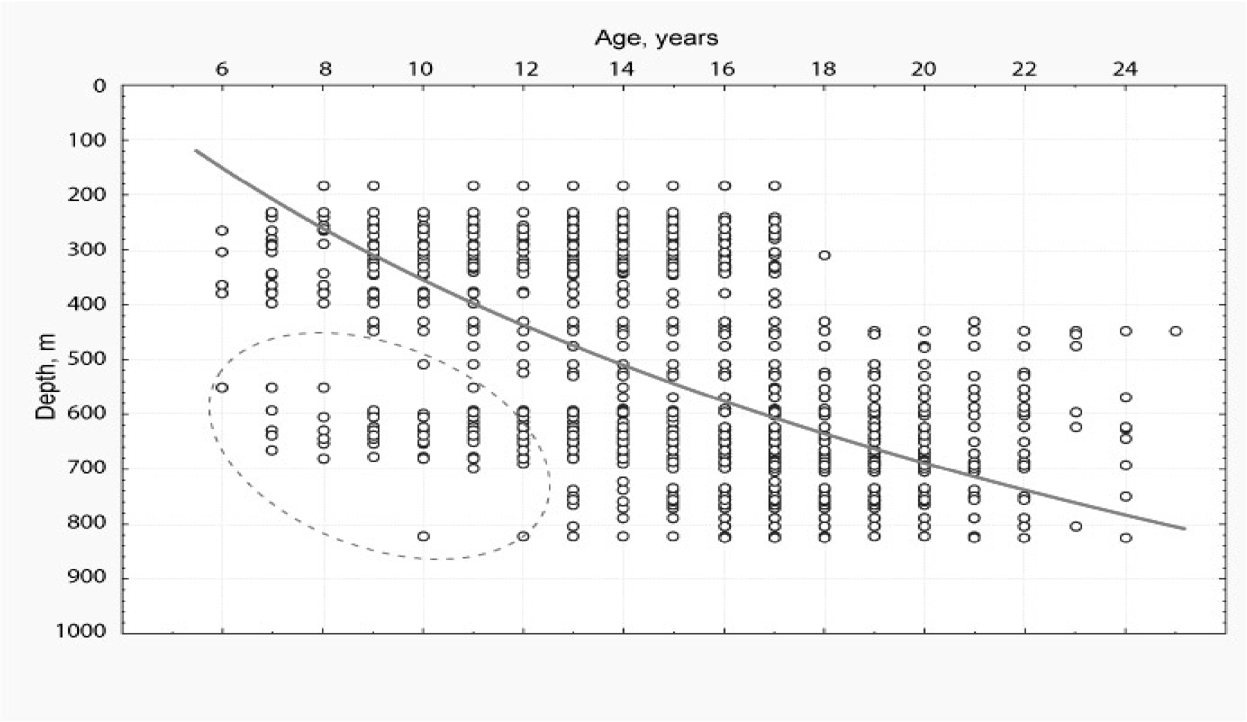
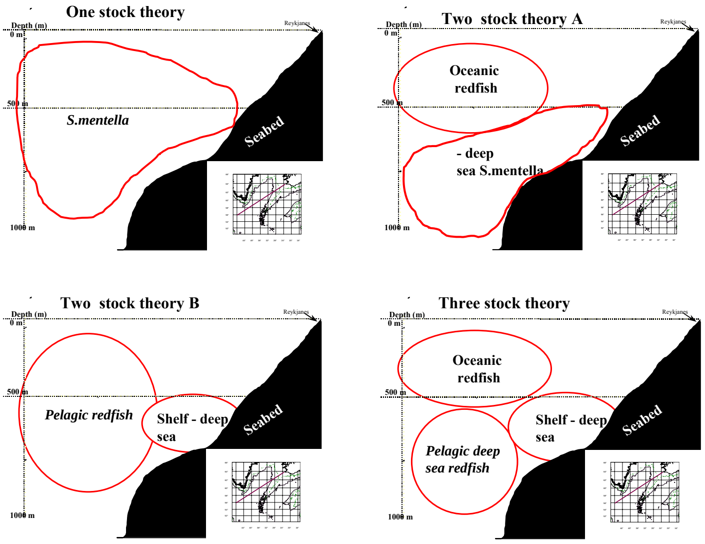


Figure 3.9.3. Distribution of individuals of *Sebastes mentella* by age (scale readings) and depth collected for the Russian allozyme analyses (1999-2003).

4 Identification of the most likely definition of biological stocks of *S. mentella* as well as suggestions for practical management units.

The Study Group discussed and exchanged views and arguments related to different hypotheses concerning the most likely definition of biological stocks of *S. mentella.* These hypotheses are illustrated in the figure below:



Single-stock hypothesis: All *S. mentella* in the Irminger Sea and adjacent waters is one stock and is segregated only according to age/size.

- The extruded larvae are found over one big area. Any possible structure is unknown.
- Main and single nursery area on the shelf of West- and East-Greenland. Geographical structure observed, but needs more research.
- That all the morphological and biological characters used to phenotype the redfish, incl. parasite infestation, are related to growth, age and/or the environment.
- The overall genetic distances are small among locations and depths
- Morpometric data/results (from the EU REDFISH project) did not reveal any clear stock structure in the area (except Flemish Cap)
- Otolith shape and trace element analyses did not reveal any stock structure in the area
- Parasitological data did not reveal any clear stock structure in the area, although a structure in the data is seen (e.g., see Figure 3.5.2). The results may though be supportive for at least the 'two-stock hypothesis B'.
- Consider keeping it a single stock until better (improved) sampling has been conducted and more conclusive evidence has been put forward

Two-stocks hypothesis A: The *S. mentella* living on the shelves of Faroes, Greenland and Iceland (shelf deep-sea *S. mentella*), and those living in deeper pelagic waters of the Irminger Sea (pelagic deep-sea *S. mentella*) is one stock unit, which is separated from the oceanic *S. mentella* living in the upper layers of the Irminger Sea.

- This hypothesis is supported by fatty acid data, microsatelite and allozyme data from SE Iceland (but not W Iceland) and morphometric results (from Faroes redfish project). The morphometric differences between two *S. mentella* samples from the Irminger Sea, one from shallow waters and one from deep waters, as found in the Faroes project, were during the Study Group confirmed by the morphometric method used in the EU REDFISH project
- The main (concentrations) shelf deep-sea and pelagic deep-sea *S. mentella* mating and larvae extrusion sites may be more overlapping than is the case between the two pelagic stocks. [same comment as above. The pertinent evidence here would be a lack of distinct mating and extrusion sites for the deep-sea pelagic and Icelandic shelf stocks]

Two-stocks hypothesis B: The oceanic *S. mentella* living in the upper layers of the Irminger Sea, and those living in deeper pelagic waters of the Irminger Sea (pelagic deep-sea *S. mentella*) represent one stock unit, which is separated from the *S. mentella* living on the Faroes, Greenland and Iceland shelves (shelf deep-sea *S. mentella*)

- Allozyme differences observed between shelf deep-sea *S. mentella* at Iceland and pelagic deep-sea *S. mentella* (WD3, but probably not significant), while it may be argued that the observed genetic structure in the pelagic *S. mentella* resource is related to growth, age and/or the environment.
- The *S. mentella* parasite fauna composition may support this hypothesis (e.g., see Figure 3.5.2)

Two-stocks hypothesis C: The oceanic *S. mentella* living in the upper layers of the Irminger Sea, and the *S. mentella* living on the shelves (shelf deep-sea *S. mentella*) is one stock unit, which is separated from pelagic deep-sea *S. mentella* living in deeper pelagic waters of the Irminger Sea.

- This hypothesis was not considered relevant, and was therefore not further discussed.

Three-stocks hypothesis: The three described components are biologically different stocks.

- Microsatellite data from shelf deep-sea *S. mentella* at Iceland are significantly different from pelagic deep-sea *S. mentella* in the northern Irminger Sea.
- If distribution of females and males in maturity stage 3 (data collected from the fishery) is representative for showing the area of larvae extrusion and mating, respectively, then the distribution maps of this maturity stage show, to a great extent, separate larvae extrusion and mating areas for oceanic phenotyped *S. mentella*, pelagic deep-sea phenotyped *S. mentella*, and Icelandic shelf deep-sea phenotyped *S. mentella*.
- Deviations from Hardy-Weinberg law, statistical tests of microsatelite genetic data (those data sets containing samples from all areas and depths), AFLP genetic data and fatty acid data show up to three different, and statistically significant, groups. Fatty acid results also group the fish significantly into three groups in this area.
- Otolith material (the recommended structure for age reading) show significant different growth and/or length-at-age of shallow and deep living pelagic *S. mentella* in the Irminger Sea (as seen from Norwegian age readings), between oceanic -phenotyped *S. mentella* and pelagic deep-sea phenotyped *S. mentella* (Icelandic readings), and between shelf deep-sea *S. mentella* and the two pelagic groups (Icelandic readings).

More-than-three-stocks hypothesis: In addition to two stocks (oceanic and deeppelagic) in the Irminger Sea, the shelf deep-sea *S. mentella* may be further structured into more than one stock.

- Multivariate analysis of microsatellite data, allozymes, fatty acid profiles and morphometric data (Faroes method) show a further significant grouping/structure of the shelf deep-sea *S. mentella*.

Summary remarks

The Study Group agreed on the arguments used for each hypothesis above. Some of the analyses did not contain data from the Icelandic shelf, and hence can’t support/reject the ’three-stock hypothesis’ of that reason. And, not at least, that no structure or no difference, may be due to the method’s inability to detect structure/ differences.

The Study Group was very concerned about how the sampling of material had been conducted as basis for the analyses. Some sampling was done by sorting of individuals based on phenotypes in order to compare the gene pools of two phenotypically different defined groups. Such sampling may be considered valid for this particular purpose, i.e., for testing the validity of the phenotypes, but is not a recommended sampling procedure for investigating geographical stock structure(s). For such purpose random sampling of individuals, not seeking out any particular phenotype or size, should be adopted. For the analyses of stock structure by area and depth, pre-classified material and material not possible to classify had been pooled together. Some members of the Study Group were, however, not satisfied and confident with the way this had been done.

Some genetic researchers were concerned about too few analyses of temporal stability, and that the sampling should have been conducted as close to the actual mating period as possible. It is a logistic problem of obtaining such samples, but the samples behind the presented results could potentially have been mixed feeding aggregations of fish from various populations. However, it was also argued that this could mask/decrease the real difference rather than increase it, and that despite sub optimal sampling design, significant results were achieved.

Many of the geneticists hold the view that the microsatellite data were most useful when examining the possible existence of population structure(s).

Some geneticists would go as far as, based on the phenotypical differences according to the Icelandic identification key, to say that the pelagic and deep-sea *S. mentella* belong to two taxonomic (sibling?) groups (species level?) that are genetically isolated from each other. And that the differences observed between the two sympatric groups, i.e., most of the morphological, genetic, distribution and life history characteristics are the result of isolation.

Those who argued for the deep-sea and the oceanic *S. mentella* belonging to a single stock were of the opinion that the differences observed between them result from selection of typical specimens when the phenotyping criteria are applied. And that the application of the criteria artificially inflates the difference in characters whose distribution would otherwise be continuous. However, most of the analyses were done irrespective of phenotypes.
E.g., during the meeting, microsatellite results showed significantly more allele richness in deeper living *S. mentella* compared to shallower living *S. mentella*, i.e., irrespective of phenotypes. During the meeting, it was demonstrated that phenotype (shown in the meeting for one allozyme) frequencies may change with age (WD3), and some researchers thought that similar ontogenetic development could explain the differences observed, also in other methods.

There were, however, a consensus in the Study Group about the existence of some or another kind of structure of the *S. mentella* resource in the Irminger Sea and adjacent waters (this is shown by many characters). To what extent the observed structure reflects age/size stock structure or the existence of various stocks was more contentious.

Conclusions

The majority of the Study Group (3/4), incl. the outside genetic experts, hold the view that the *S. mentella* resource in the Irminger Sea and adjacent waters, based on current available knowledge, is composed of three separate stocks. They would give priority to managing the pelagic *S. mentella* in the Irminger Sea as two separate stocks. The evidences for the shelf deep-sea *S. mentella* being separated from the pelagic deep-sea *S. mentella* were not as obvious, but the majority group hold the view that it would be most cautious and conservative to consider the *S. mentella* resource in the Irminger Sea and adjacent waters as three stocks. Future research should give priority to investigating the link between the pelagic deep-sea *S. mentella* in the Irminger Sea and deep-sea *S. mentella* on the surrounding shelf.

The other researchers hold the view that the observed differences and biological structures are either related to growth, age and/or the environment, or at least too small to be used against the one-stock hypothesis. However, when it comes to management units, two of these researchers would, as a precautious approach to management, and to avoid disproportional catches of the components, recommend for the time being, three separate management units. Use of three management units was consequently advised by 85% of the researchers. Three researchers, on the other hand, would keep today’s practice of employing only two management units (see statement below).

Suggestions for practical management units

Since all the management units suggested by the majority (6/7) of the Study Group have an overlapping distribution, the management units need to be defined as a practical tool making it possible for the managers to direct the fishing effort in accordance with their management aims. This means that if the managers want to fish pelagic deep-sea *S. mentella*, and not oceanic *S. mentella*, the scientists should be able to give practical possible advice accordingly, and vice versa, if the managers want to fish oceanic *S. mentella* and/or shelf deep-sea *S. mentella* and not pelagic deep-sea *S. mentella*.

In accordance with this and our current knowledge about the stocks described in this report, the majority (6/7) of the Study Group recommends the practical managemnt units to be set based on geographical areas and seasons.

Concerning how to set the border between the Icelandic shelf deep-sea *S. mentella* and the pelagic Irminger Sea *S. mentella* (both oceanic and pelagic deep-sea), the majority of the Study Group recommends to adopt the current Icelandic ”redfish line” for all fleets, irrespective of pelagic or demersal fishing gears (Figure 4.1.1).

Concerning how to set the border between the oceanic *S. mentella* stock and the pelagic deep-sea *S. mentella* stock, the majority of the Study Group recommends the fishery to be conducted in specific areas and seasons as suggested in Figure 4.1.2. The Study Group considered the pelagic *S. mentella* in NAFO SA2 and Divisions 1F and 3K to be part of the oceanic *S. mentella* stock.

Since we know that the distribution of these stocks at the same time of the year may change over time, it is of vital importance for a successful management that the geographical distribution of the two pelagic stocks is regularly covered and confirmed through scientific surveys.

The Study Group agreed on the Greenland shelf as the main nursery area. Observations indicate that juvenile *S. mentella* on the Greenland shelf recruit to both pelagic stocks and possibly also the shelf stock(s). It is of vital importance for a successful management that juvenile redfish in these areas are given maximum protection.

Statement by a minority of researchers

One researcher holds the view that "since no agreement was reached, and under the light of the opinion of the majority and as precautious approach to management, agrees, for the time being, and with the current level of knowledge, that the *S. mentella* resource may be, if possible, managed as three management units. However, it is requested that, as soon as possible, and with the current dataset, genetic analyses should be conducted to study the relationship of the observed genetic variation and growth of the fish. Especially concerns arise also because the definition of three stocks are based in genetic results suggesting also the existence of more than one stock in areas which currently are managed as one, such as Flemish Cap, Faroes waters and Greenland. Thus the genetic results may be biologically groundless. In addition, it is ignored to what extent the stocks overlaps in their distribution during part of, or all of the year, since considerable shifts and movements have been observed both seasonally and annually since the fishery started. Therefore, as alternative to his (above) proposed management, this researcher is of the opinion that the current management status should be maintained until more research are conducted."

Three researchers presented the following view: "Scientists have identified the fishable stock of redfish, *S. mentella,* by investigating the population status and the basis of studies of structure of pelagic aggregations including analyses of biological data, identifying all stages of the life cycle, functional role of various areas within the distribution range and specific features of reproduction of *S. mentella*. Based on results from Russian investigations, a division of *S. mentella* into "types" within the North Atlantic population currently done by the ICES NWWG for developing management advice is likely to be biologically groundless. In working out management measures for the pelagic fisheries in the NEAFC and NAFO Convention Areas, it is recommended that it is essential that the fishable stock of *S. mentella* in pelagic waters of the Irminger and Labrador Seas is regarded as a single stock and that one TAC continued to be applied as a management measure for this stock. Taking into account strong evidences existing single stock *S. mentella* in the pelagic waters of the Irminger Sea and adjacent areas, and disagreement between SGSIMUR members concerning numbers stock we suggest to keep current management measures and management units *S. mentella*. Before deciding on which and how many stock(s) we should have, it is necessary to clarify the main biological questions related to *S. mentella*, i.e., to determine the areas of overlapping geographical distribution of possible stocks, the level of hybridization of *S. mentella* and *S. marinus*, to create model of life-history and the migration of *S. mentella,* and to unificate age determination by otoliths and scales, in order to determine the criteria which should be used for the definition of management units."

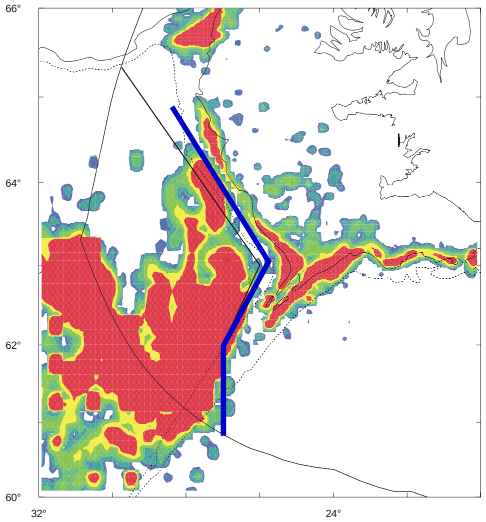


Figure 4.1.1. Total pelagic deep-sea and shelf deep-sea *S. mentella* catch in Icelandic waters 2001-2003 (all years combined). The drawn thick line is suggested by the Study Group to be adopted as the border between the pelagic deep-sea *S. mentella* management unit to the west and south of this line, and the shelf deep-sea *S. mentella* management unit east and north of this line.

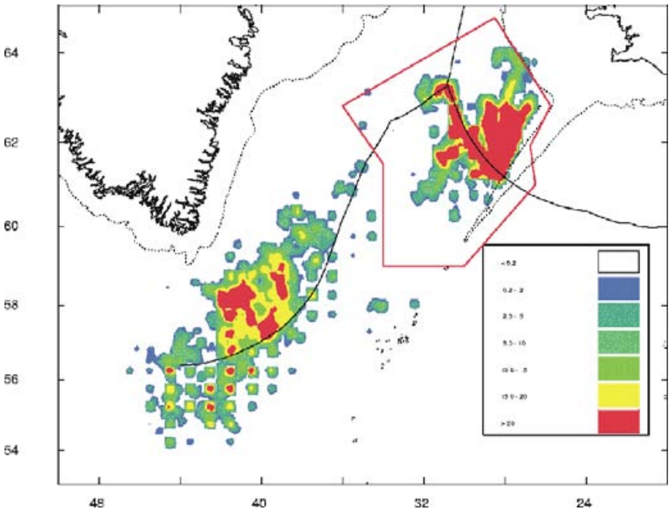


Figure 4.1.2. General distribution of the fishery in recent years, i.e., on mainly pelagic deep-sea *S. mentella* in the north-eastern area on 600-800 m depth in April-July, and on mainly oceanic *S. mentella* in the south-western area on 200-400 m depth in July-October. A ‘box’ has been drawn around the north-eastern area to show the pelagic deep-sea management unit as recommended by the Study Group, among others to prevent a disproportional exploitation rate of the two pelagic stocks.

5 Recommendations for future work

- The link between shelf- and pelagic living *S. mentella* during life-history should be better understood
- Material sampled during the EU REDFISH project should be analysed by all available genetic methods and tests as far as this has not been completely performed. This in order to confirm or reject the objections (e.g., pre-classified, phenotyped sampling) put forward at the Study Group meeting.
- More population genetic theory should be applied to evaluate the likelihood of alternative explanations, incl. better ontogenetic data. Reveal the biological basis of the observed genetic structure, e.g. by confirming the areas of mating/copulation. Likewise, possible selection on proteins should be tested.
- The material collected should be taken care of (tissue bank) for possible future analyses by new methods.
- After a time span, selected areas should be sampled and analysed again to obtain data on temporal stability. To gain more precise knowledge, special attention should be given to the Faroese waters and Greenland shelf to conduct more extensive sampling, analyse "old" and new samples by all available genetic methods and compare in depth genetic and morphological/morphometrical identification of species and populations.
- Use of historical collections (e.g., otoliths, scales) to obtain longer time series of genetic material.
- Age structure has been poorly described and this is of major importance for further understanding of the structure of *Sebastes* spp. in the investigated areas. In order to understand the complete growth- and life-history of *S. mentella* up to an age of 50-60 years, this needs to be done by reading otoliths, a method which e.g., has been validated by independent radiometric methods. The laboratories need to increase their age reading effort.
- Tagging of *S. mentella* by e.g. recently developed underwater tagging equipment to observe migration routes and patterns (ICES 2004b).
- International trawl-acoustic surveys in accordance with the stock structure advised by the majority of the Study Group. Discuss the most suitable timing and area/depth coverage, as well as improved acoustic instruments and methods.

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APPENDIX 1 – LIST OF PARTICIPANTS

STUDY GROUP ON STOCK IDENTITY AND MANAGEMENT UNITS OF REDFISHES

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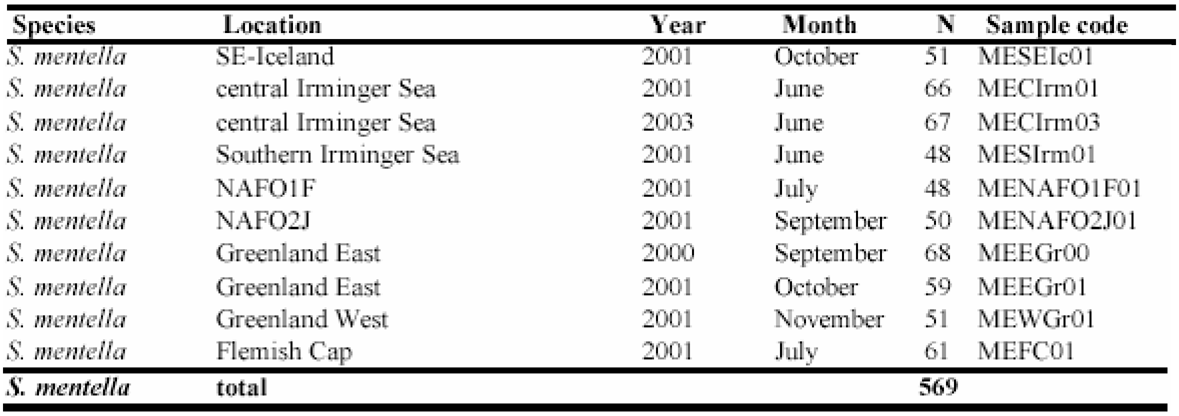
APPENDIX 2 - WORKING DOCUMENTS

WD#	Title	Authors
1.	Population genetic studies of *S. mentella* in the North Atlantic with emphasis on the stock complex in the Irminger Sea	Torild Johansen & Gunnar Nævdal
2.	Molecular genetic studies of species and population structure of North Atlantic redfish (genus *Sebastes*)	Cathrin Schmidt & Jochen Trautner
3.	Study of genetic characteristics of the redfish *Sebastes mentella Travin* from the Irminger Sea and adjacent waters.	A.N. Stroganov & G.G. Novikov
4.	Population status and identity of fishable stock of redfish *Sebastes mentella* in the pelagic Irminger Sea and adjacent waters	V.N. Shibanov & S.P. Melnikov
5.	On the issue of unity of redfish *Sebastes mentella* fishable stock in the Irminger Sea and adjacent waters in the light of parasitologic data	Yu. I. Bakay
6.	Russian fisheries for redfish (*Sebastes mentella* Travin) and biological data from commercial catches in pelagic waters of NEAFC and NAFO Convention Areas in 1982-2003	V.N. Shibanov & S.P. Melnikov
7.	Population structure of *S. mentella* within and around the Irminger Sea	Magnus Stefansson et al.
8.	Review of the genetic data of *S. mentella* in the Irminger Sea and adjacent waters	Einar Eg Nielsen
9.	Stocks of *Sebastes mentella*, Travin 1951, in the North Atlantic discriminated by multivariate analysis of fatty acid profiles, enzyme electrophoresis and microsatellites	Horaldur Joensen

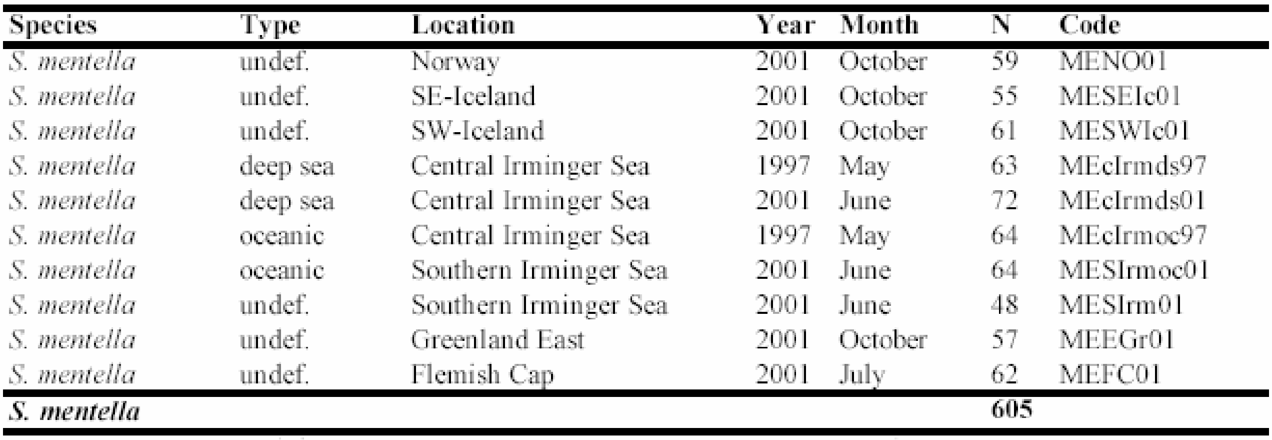
APPENDIX 3 – Sample codes of German genetic material

Microsatellite analysis. Overview of samples analyzed. Summary statistics for redfish samples collected showing species, geographical origins, sampling years, sampling months, sample sizes (N) and sample codes.



Species	Location	Year	Month	N	Sample code
S. mentella	SE-Iceland	2001	October	51	MESEIc01
S. mentella	central Irminger Sea	2001	June	66	MECIrm01
S. mentella	central Irminger Sea	2003	June	67	MECIrm03
S. mentella	Southern Irminger Sea	2001	June	48	MESIrm01
S. mentella	NAFO1F	2001	July	48	MENAFO1F01
S. mentella	NAFO2J	2001	September	50	MENAFO2J01
S. mentella	Greenland East	2000	September	68	MEEGr00
S. mentella	Greenland East	2001	October	59	MEEGr01
S. mentella	Greenland West	2001	November	51	MEWGr01
S. mentella	Flemish Cap	2001	July	61	MEFC01
S. mentella	**total**			**569**	

AFLP analysis. Overview of samples analyzed.



Species	Type	Location	Year	Month	N	Code
S. mentella	undef.	Norway	2001	October	59	MENO01
S. mentella	undef.	SE-Iceland	2001	October	55	MESEIc01
S. mentella	undef.	SW-Iceland	2001	October	61	MESWIc01
S. mentella	deep sea	Central Irminger Sea	1997	May	63	MEcIrmds97
S. mentella	deep sea	Central Irminger Sea	2001	June	72	MEcIrmds01
S. mentella	oceanic	Central Irminger Sea	1997	May	64	MEcIrmoc97
S. mentella	oceanic	Southern Irminger Sea	2001	June	64	MESIrmoc01
S. mentella	undef.	Southern Irminger Sea	2001	June	48	MESIrm01
S. mentella	undef.	Greenland East	2001	October	57	MEEGr01
S. mentella	undef.	Flemish Cap	2001	July	62	MEFC01
S. mentella					**605**	