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A Review of the Population Structure and Ecology of Redfish in the Irminger Sea and Adjacent Waters

by

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Abstract

Three types of *Sebastes mentella* in the Irminger Sea and adjacent waters have been described and there is a strong controversy about whether these types are more than one stock. Preliminary genetic studies have shown the existence of three different groups, characterised by genetic differences. The biological or ecological significance of these between-group differences, however, has not been evaluated yet.

In the present paper, we review the *S. mentella* life cycle in the area from published data. Spawning of *S. mentella* in the Irminger Sea takes place in a single area above Reykjanes Ridge. The larvae drift towards East Greenland and from there they are carried to West Greenland (NAFO Subareas 0+1). Afterwards, they return to East Greenland where the main nursery area has been identified. There is an evident migration of juvenile fish from the nursery area into the open Irminger Sea, where many different cohorts are involved in the spawning fraction of the population.

We also compare these data of the ecology of the species with the genetic results and we conclude that the observed genetic differences can be derived from possible genetic drift, selection or mostly from temporal variation (age dependency) which has been reported in other species with as high longevity as *S. mentella*. We conclude that *S. mentella* in the Irminger Sea and adjacent waters comprises one single stock.

Introduction

In ICES Divisions V, VI, XII and XIV there are at least 3 species of redfish, *S. marinus*, *S. mentella* and *S. viviparus*.

During last years the existence of more than one stock of *S. mentella* in the area was discussed (ICES, 2000). Historically *S. mentella* was fished on the shelves and banks of the Faroe Islands, Iceland and East Greenland and was considered as one stock. With the start of a new pelagic fishery in the open Irminger Sea in 1982, a new stock was defined for management purposes for *S. mentella* inhabit in this area. In 1992, the Study Group on Redfish Stocks distinguished between these types as deep-sea *S. mentella* and oceanic *S. mentella* (ICES, 1992). In the early 1990's, the pelagic fishery in the open Irminger Sea moved to deeper layers beyond 500 m and some researchers considered that some of the fish caught below 500 m were different to those living above 500 m but resembling more the deep-sea *S. mentella* living on the shelves. This new type of *S. mentella* living below 500 m has been called "pelagic deep-sea *S. mentella*" (ICES, 1998).

There has been a strong controversy about whether these types are more than one stock and different hypotheses have been put forward (ICES, 1999):

The **single stock hypothesis** suggests that all redfish from the Faroe Islands to Greenland segregated according to age/size.

The **two stock hypotheses** suggests that the *S. mentella* living on the shelves (deep-sea *S. mentella*) and that living in deeper pelagic waters of Irminger Sea (pelagic deep-sea *S. mentella*) constitute one stock unit which is separated from the oceanic *S. mentella* living in upper layers of the Irminger Sea.

The **three stock hypotheses** supports the idea that each of the described types constitutes a distinct stock.

Preliminary genetic studies indicate that deep sea and oceanic *S. mentella* types in the Irminger Sea do not share a common gene pool. Nevertheless, heterogeneity among samples of these two types in the Irminger Sea could indicate even a sub-structuring within each group and awaits further study. Only minor differences were observed between deep-sea *S. mentella* in the Irminger Sea and on the Icelandic Continental shelf, indicating that they could share a common gene pool. (Johansen *et al.*, 2000).

In the present paper, we introduce an overview of the existing knowledge on the ecology of redfish species inhabiting the Irminger Sea and adjacent waters (Faroe Islands, Iceland and Greenland), i.e. life cycle description, spawning behaviour and different life stages distribution and drift and/or migration patterns. The population structure of the redfish is discussed with respect to new observations on migration of juveniles (from the East Greenland shelf into the Irminger Sea).

Redfish spawning areas and time

Spawning of redfish in the Irminger Sea takes place in a wide area southwest of Iceland and above of the Reykjanes ridge with extension in a southwesterly direction (Figure 1). It has been recognised that in this wide area both *S. marinus* and *S. mentella* (all stocks) are spawning.

Separate spawning areas for the different species cannot be identified with certainty although there are some indications that the main spawning area for *S. marinus* might be situated in the north-eastern part, i.e. west and southwest of Iceland (Magnússon and Magnússon, 1977; Magnússon, 1980; ICES, 1983) and the spawning area for *S. mentella* in the south-western part of the whole region with a large overlap between them (ICES, 1983; 1998). The stock allocation of *S. mentella* larvae extruded in this area has not been possible yet, and only has been hypothesized (Magnússon and Magnússon, 1995) that the larvae extruded north-eastwards are more likely deep-sea *S. mentella* on the shelf and the larvae extruded southwesterly belonging to the other two stocks (pelagic deep-sea and oceanic *S. mentella*). But this hypothesis is only based on the proximity of each spawning area with the distribution area of each stock.

The stocks of *S. mentella* release their larvae in April to June, overlapping to a great extent in both time and space (Kotthaus, 1961; Magnússon, 1962; Magnússon *et al.*, 1965; Noskov *et al.*, 1984; Shibanov *et al.*, 1984, 1995; Pavlov *et al.*, 1989a; Magnússon and Jóhannesson, 1997). In ICES (1983), it was mentioned that deep-sea *S. mentella* on the shelf spawns later in the year from July to August. However, the Icelandic 0-group surveys (August) have reported no *S. mentella* larvae around Iceland, or the presence of such larvae were scarce (Magnússon and Sveinbjörnsson, 1991; Sigurðsson *et al.*, 1997; ICES, 1998) and, moreover, the size of those few larvae was over 50 mm, even bigger than those reported from the open Irminger Sea at the same time. So it is unlikely that these larvae had been released so late in the year and probably they were born in April-May. Magnússon and Magnússon (1995) are of the same opinion, stating that larvae from both stocks are extruded at the same time. In addition, it has been reported that the main peak of larval extrusion vary year by year both in time and space in relation with oceanographic conditions (Pavlov *et al.*, 1989a; Magnússon and Magnússon, 1995; Shibanov *et al.*, 1995).

The main difference reported between the deep-sea *S. mentella* on the shelf and oceanic *S. mentella* are the depth at which spawning occur. While the oceanic stock spawns at depths of about 200 to 500 m, the deep-sea on the shelf stock spawns approximately at 500 m depth (ICES, 1983; Magnússon and Magnússon, 1995; Shibanov *et*

al., 1995). There are no reports, however, about the spawning depth of the pelagic deep-sea stock, which is thought to live in greater depths (below 500 m) than the oceanic stock. A possible migration of this stock in upward direction for a spawning in shallower waters has not been reported yet, so it is likely that there is a continuous range in spawning depth between 200 and 500 m, representing the adults distribution rather than spawning preferences. Spawning depth can be more related with size distribution and oceanographic conditions than with spawning behaviour. In addition, it is a strong assumption to believe that released larvae will live in the same depths where they have been released. Although it has been not studied in redfish, we rather assume that neutral buoyancy of redfish larvae is similar irrespective of the species/stock origin and, therefore, as for most other marine fish species spawning pelagic eggs/larvae, redfish larvae will drift to shallower and more productive waters irrespective of the depth where they have been released. Thus, the distribution of redfish larvae in the Irminger Sea is more restricted than the distribution area of the mature redfish (Pavlov *et al.*, 1989b), suggesting that larvae drift immediately after spawning to the central and eastern area of the Irminger Sea, probably in relation with the cyclonic gyre of the current present in the area (Figure 2). The densest larvae abundance was recorded at depths of 0-50 m or 0-150 m, as ichthyoplankton surveys usually reveal (Noskov *et al.*, 1984; Pavlov *et al.*, 1989a; Shibanov *et al.*, 1984; Herra *et al.*, 1987; Wieland, 1991; Shibanov *et al.*, 1995). Therefore it is very clear that spawning depth is not relevant in the ecology of the larvae since all of them will follow the same drift pattern independently of their origin.

No spawning of redfish has been reported to take place in Greenland waters.

Although *S. marinus* larval extrusion has been observed in the South of the Faroe Islands (ICES, 1983) and *S. mentella* spawning has been observed in some years to the South and West of these islands, implying that there could be a local component in the area; no nursery areas, however, have been found so far (Reinert, 1990). A relationship to the more North-east Atlantic areas has also been suggested (Reinert *et al.*, 1992, Reinert and Lastein, 1992). The question of a possible relationship between this stock unit and the two pelagic types in the Irminger Sea has been raised several times (e.g. ICES, 1999; 2000). In conclusion, the existence of a single and wide spawning area in the main concerned area (Greenland, Irminger Sea and Iceland), with a wide depth distribution and with a single spawning peak in April-June, is very likely. Redfish larvae, irrespective of their origin (stock) are then pooled and drifted towards Greenland, and partially at a lower level to Iceland as laid out below.

Larvae and fry (0-group) distribution and drift patterns

The ichthyoplankton surveys show that redfish larvae are distributed over an extensive area although smaller than the distribution area of adult fish. In fact, the spawning area described above has been inferred mostly from ichthyoplankton surveys, assuming that larvae inhabit the same area than adults in the first days of life, although this has not been proved yet. The early larval distribution area is shown in Figure 1. Redfish larvae are widely distributed across the whole area, but patches of higher density are located in a different position year by year (Henderson, 1961; Pavlov *et al.*, 1989a; Magnússon and Magnússon, 1995; Magnússon and Jóhannesson, 1997).

There is a general agreement among authors about the larval drift. A general trend in the drift of larvae was indicated from the central and eastern Irminger Sea towards the slopes along the East Greenland shelf and to some extent around Cape Farewell (Anon, 1968; ICES, 1983, 1998). That is in accordance with the general direction of currents in the area (Figure 2).

From Icelandic 0-group surveys, drift of redfish fry from the areas of larval extrusion to areas West and North of Iceland has also been observed (Einarsson, 1960; Magnússon and Jóhannesson, 1997; Sveinbjörnsson, 1996; Sveinbjörnsson and Jónsson, 1998). These consist almost entirely of *S. marinus* (see i.e. Pálsson *et al.* 1989, Pálsson *et al.* 1997; Sigurðsson *et al.*, 1997). It is very rare to find small (juvenile) *S. mentella* around Iceland. As said above, it seems that *S. marinus* spawns northeasterly, so it is consistent with the occurrence of *S. marinus* larvae around Iceland. Nevertheless, *S. marinus* larvae also drift towards Greenland as *S. mentella* do. Records of larvae along Greenland shelves strongly suggest that larvae initially drift to Southeast Greenland, passing Cape Farewell and moving northwards. Both *S. marinus* and *S. mentella* larvae and fry have been observed off West Greenland, *S. marinus* being considerable less abundant (ICES, 1983; ICES, 1997). German annual surveys West and East of Greenland have shown that only very small quantities of small redfish (<17 cm) are found West of Cape Farewell (Rätz and Sigurdsson, 2001). In the 1983 Redfish Study Group report (ICES, 1983) and in

Magnússon and Jóhannesson (1997), the distribution of *S. marinus* 0-groups at East Greenland was evaluated, showing that there are considerable amounts of *S. marinus* at East Greenland and that it is mixed with *S. mentella* in variable proportions in different Subareas and periods.

If most of the larvae or only a part of them move to West Greenland is unknown. We suspect that most of the *S. mentella* larvae drift to West Greenland since there is an important nursery area for age 1 redfish as explained in the next chapter.

The distribution area of larvae during summer extends south Cape Farewell far to 55°N (Henderson, 1961). Following several authors (Zakharov, 1966; Magnússon and Sveinbjörnsson, 1991; Wieland, 1991; Wieland, 1992; Pedersen and Kannevorff, 1992), it is obvious that *S. mentella* larvae extruded in the Irminger Sea in April-June drift towards East Greenland, where high densities of 0-group redfish can be found in August/September. Subsequently, most of them are carried southwards with the East Greenland current, passing Southwest Greenland in September/October and continuing with a northward displacement during October and November at West Greenland (Figure 3). In this area, redfish is largely recruited at age 1 which could explain the occurrence of large quantities of small redfish as by-catch in the shrimp fishery in the Davis Strait (Pedersen, 1990, Pedersen and Kannevorff, 1992; ICES, 1990) or in the surveys in NAFO area 1 (Atkinson, 1987; Rätz and Stransky, 1999).

Nevertheless, we should mention that part of the larvae are retained in the Central Irminger Sea since fry of 4-6 cm have been recorded in late summer/early autumn in that area (Noskov and Romanchenko, 1986; Magnússon and Sveinbjörnsson, 1991; Rikhter, 1996).

There is a probability of *S. mentella* fry migration from West Greenland into Canadian waters in the Davis Strait. Templeman (1961) reported small (6-13 cm) *S. mentella* off the East Coast of Canada, from 64°N to 60°N. The source of these small *S. mentella* is supposed to be a West Greenland Water transfer greater than usual (Templeman, 1961).

Juvenile distribution, nursery areas, and migration pattern

There are only data available on nursery grounds of *S. marinus* in Icelandic and Greenland waters but no nursery grounds are known in the Faroe Islands area (ICES, 1998).

In Icelandic waters, nursery areas for *S. marinus* are found mostly West and North of Iceland at depths between 50 and approximately 350 m, but also in the South and East (ICES, 1983; Einarsson, 1960; Magnússon and Magnússon 1975; Pálsson *et al.* 1997).

Nursery grounds of *S. marinus* off East and West Greenland are found on the continental shelf, mixed with *S. mentella*. In recent years, the abundance of *S. marinus* at West and East Greenland has been extremely low and there are no indications of recruitment according to German investigations (Rätz and Stransky, 1999; Rätz and Sigurdsson, 2001). Earlier investigations had shown much larger quantities of juvenile *S. marinus* on the continental shelf and slope of Greenland (*e.g.* Anon, 1961). Since no spawning has been detected on the Greenland shelf, we assume that the juveniles present around Greenland and those in Iceland belong to the same stock, spawning off Southwest Iceland, which is in accordance with other authors (ICES, 1998).

No specific nursery grounds for *S. mentella* have been found in Icelandic and/or Faroes waters and there is also no record of nursery grounds off the south coast of Iceland (ICES, 1983). However, major nursery grounds were found along the coast of West- and East Greenland (Figure 3). The major source of information for this nursery grounds are the German annual surveys off Greenland (see *e.g.* Rätz and Stransky, 1999). Unspecific small redfish (<17 cm) are distributed along both sides of Greenland. Most of the redfish bigger than 17 cm are *S. mentella*, so we assume that most of the small and unidentified redfish are also *S. mentella*. In Figure 4, the length distributions of small redfish since 1982, derived from the German surveys are shown. It can be observed that small redfish is considerably less abundant off West Greenland, but when occurs they are mainly and almost exclusively formed by ages 1 and 2 (6-8 cm and 11-12 cm, respectively). In years of low abundance, these year classes are found mainly in West Greenland, but in years of higher abundance (*i.e.* 1985, 1993, 1995-98) the bulk is almost solely distributed off East Greenland. The size of young redfish increases northwards in East Greenland (Rätz and Stransky, 1999; Jørgensen, 1999). Thus, there is a general migration pattern of young redfish from East to West

Greenland. But in some years, larvae are retained in East Greenland, probably yielding a higher survivor rate and hence a good recruitment. A southward migration presumably takes place along the West coast of Greenland, since the length of small *S. mentella* increases from North to South in the area of the offshore shrimp fishery (Anon, 1983). This is in accordance with the fact that no spawning of redfish has been observed in West Greenland.

In recent years (1989-2000), deep-sea *S. mentella* off Greenland were basically smaller than 30 cm, although in previous years, a higher abundance of sizes over 30 cm was observed, mainly off East Greenland (Figure 5). This indicates that redfish over 30 cm “disappear” from the area. *S. mentella* grows in this area until they are close to reach maturity.

Adult distribution

Adult redfish are found all around the studied area: Faroes, Iceland, open Irminger Sea and both East- and West Greenland. However, most of the adult redfish are found around the Faroe Islands, Iceland and the Irminger Sea.

One stock of *S. marinus* exists in the area of East Greenland-Iceland-Faroes. In Iceland, *S. marinus* migrate from the nursery areas in the North and East towards the West and Southwest, growing in size. *S. marinus* adult distribution extends along the Iceland- Faroes Ridge, and the shelf of the Faroes.

Both oceanic and pelagic deep-sea *S. mentella* inhabit pelagic waters of the Irminger Sea, including areas in the Icelandic and Greenland EEZ, rather close to the shelf, while the deep-sea type is restricted to the shelves. However, the distribution areas of the three stocks are overlapped, although patches of densest abundance are easily found, which change seasonally in relation with spawning and feeding behaviour.

Very low abundance of *S. mentella* smaller than 25 cm was found around Iceland and in the Irminger Sea (Sigurðsson, 1998; Alekseev, 1999; Stransky, 2000). As hypothesized by Stransky (2000) and Alekseev (1999), redfish migrate from East Greenland eastwards as they grow (Iceland and/or Irminger Sea). On the international survey on pelagic redfish in the Irminger Sea in June/July 1999, juvenile *S. mentella* of 27-29 cm were observed in the length spectrum above and below 500 m depth (Figure 6). While the length peak of redfish in the Irminger Sea, observed in previous years, varied around 35 cm, a considerable proportion of recruits was appearing in the area during 1999. A migration of a part of the large quantities of juvenile *S. mentella* recorded on the East Greenland shelf in 1995-1998 (Figure 5b) into the Irminger Sea is therefore very likely.

In Figure 7, the size range distribution of redfish is shown. The majority of oceanic *S. mentella* ranges between 30 and 40 cm in length, with a mean of 35-36 cm, rather constant along the years. In Icelandic *S. mentella*, size ranged from 30 to 45 cm, with several modal groups present in different years (35 cm in 1995-1997, 40-42 cm in 1989-1994; Sigurðsson, 1998). Pelagic deep-sea *S. mentella*, however, is known to display a bigger size range, between 36 to 46 cm, with a mode around 42 cm. But there is also a horizontal size gradient, thus for oceanic *S. mentella* the mean length is maximal in the central part of the Irminger Sea and 2-3 cm less in the peripheries (Pedchenko *et al.*, 1997).

A gradient in the depth distribution in relation with size is very well known in many marine fish species. Particularly, in redfish, it has been extensively described that fish move to deeper waters as they grow (Atkinson, 1986). Moreover, the migration to deeper waters is more related with maturity than with size (Saborido-Rey, 1994), but since maturity is correlated with size, the overall picture is that bigger fish migrate to deeper waters. At the same size, the immature fish inhabits shallower waters.

Most of the oceanic and pelagic deep-sea *S. mentella* are mature fish, but deep-sea *S. mentella* reach the maturity at a bigger size. Thus, size at maturity for the oceanic type is around 31 cm but 38 cm for the deep-sea type (Magnússon and Magnússon, 1995). In both cases, size at maturity is rather close to the minimum size recorded in the area for each stock, so it remains not clear if such differences are a statistical artefact of the different size distribution. Immature fish are more common in deep-sea *S. mentella* on Icelandic shelf, and size at maturity is slightly bigger than oceanic *S. mentella*, around 34 cm. Interestingly, if we would pool oceanic and pelagic deep-sea *S. mentella*, the resulting size at maturity between *S. mentella* living in the open Irminger Sea and those living in Icelandic waters will not be much different.

Aging of redfish belonging to these stocks has been made in very few times. But there is an agreement that these redfish are quite old, and older than redfish at the same size from other stocks, *e.g.* Barents Sea, Flemish Cap (Saborido-Rey *et al.*, 1997). As a general overview, it can be said that there could easily be 30-year classes living in the Irminger Sea at the same time (with a length range of 30 to 45 cm). It's reasonable that the life history of a given cohort may be absolutely different than another one that is 30 years older. We cannot assume that distribution, feeding, migration and reproduction of the different cohorts are the same, moreover, we expect to find strong differences between them.

Let us to consider an example: It is known that the resistance to be infested by parasites increase with age, older fish are less susceptible to infestation than younger fish (Kennedy, 1975). On the other hand, no optimum conditions are apparently available at the depths deeper than 500 m for *S. lumpi* existence (Bakay, 1999). If we assume that in East Greenland there is a low infection of *S. lumpi*, due to oceanographic conditions or other considerations and that in the Irminger Sea, above 500 m, a higher possibility to be infected exists, then the next hypothesis can be established: During 1980's, the occurrence of *S. mentella* above 30 cm was common in East Greenland (Figure 5), *i.e.* old fish without parasites, but since 1988, these cohorts moved to the Irminger Sea, but to deep waters due their size. These fish never will be infected. Since 1989, *S. mentella* moves from East Greenland to the Irminger Sea when they are smaller than 30 cm, *i.e.* relatively young fish; due to their size they occupy the shallower waters, and would become infected. This explains why fish living at deeper waters are less infected. In fact it has been observed that infestation rate changes between years (Magnússon and Magnússon, 1995; Jones 1970). Similar explanations can be hypothesized regarding to other observed differences as size at maturity, colour, etc.

Most of the authors agree with the idea that *S. marinus* in Greenland and Iceland are the same stock, being East Greenland a nursery area for the Icelandic stock, although not the only one. Both deep-sea *S. mentella* on the shelf in Greenland and Iceland is believed as belonging to the same stock. Pelagic deep-sea *S. mentella* resembles to deep-sea *S. mentella* on the shelf regarding to colour, morphology, infestation rate and maturity, and many authors believe that they both are the same stock. The life cycles of both species, *S. marinus* and *S. mentella* are similar. No genetic differences have been found between Greenland and Icelandic *S. marinus* (Nedreaas *et al.*, 1994), but significant differences have been described between deep-sea *S. mentella* on the shelf and pelagic deep-sea *S. mentella* although only Icelandic *S. mentella* has been compared (Johansen *et al.*, 2000). From an ecological point of view, it is not possible to explain the existence of different stocks of *S. mentella*. If both *S. mentella* are different stocks, how the adults recognize to which stock they belong if they were born in the same area, at the same time and they have drifted together and recruited in the same place?

Genetic differentiation

In recent years an increasing effort studying genetic discrimination of the redfish stocks has been made. Several techniques have been used (haemoglobin, allozymes, mtDNA, nDNA,...). The results of these preliminary studies show a clear conclusion, the three stocks inhabiting the area are genetically different. The discrimination of the stocks is supported by the different frequency in the heterozygotes (Johansen *et al.*, 1996, 1997; Danfjeldsdottir and Jónsdottir, 1999; Johansen *et al.*, 2000).

As explained above, redfish is a long-lived species with a particular life history in the Irminger Sea. Special attention has to be taken to the fact that many different cohorts, probably more than 20-30, are involved in the spawning fraction of the population. More important is the fact that larvae are pelagic and spread along a wide geographic area. Hedgecock (1994a) suggests that genetic heterogeneity on microgeographic scales results from temporal variation in the genetic composition of recruits. An even more widespread observation is that very slight but significant and persistent heterogeneities of allelic frequencies have frequently been observed on microgeographic scales, embedded within the large regions over which dispersal maintains an otherwise high level of genetic similarity (Hedgecock, 1994a).

Sharp genetic subdivisions can occur in continuously distributed species, particularly those spanning biogeographic boundaries. Examples of the latter from the California Current are presented for the barnacle *Balanus glandula* and the northern anchovy *Engraulis mordax* (Hedgecock, 1994a). Microgeographic heterogeneity holds interest for biological oceanographers and fisheries scientists because it contradicts the logic of population genetics

as well as commonly held notions about the structure of zooplankton and marine fish populations. This temporal variation could be a consequence of either selection on larval populations or large variance in the reproductive success of individuals, owing to chance matching of reproductive activity with windows of oceanographic conditions conducive to fertilization, larval development, retention, and recruitment. In support of the latter hypothesis, effective sizes for natural oyster populations are estimated to be only small fractions of breeding population numbers (Li and Hedgecock, 1998).

In anchovy, genetic variance may be generated by processes governing reproductive success, larval survival, and recruitment to first schools. And it does permit natural selection to act among groups as well as among individuals (Hedgecock *et al.*, 1994). Moreover, differences in genetic composition (in mtDNA) among samples of larvae, produced during a single spawning season by a semi-isolated population of Pacific oysters, have been described (Li and Hedgecock, 1998) and confirm a specific prediction of the hypothesis that marine animals have large variances in reproductive success. Other examples of long term differences have been described in haddock (Purcell *et al.*, 1996), showing an interdecadal heterogeneity in mtDNA from Georges Bank. The temporal aspect of population genetic structure forges a strong interdisciplinary bridge to oceanographic research aimed at elucidating the temporally and spatially varying factors affecting recruitment.

Allele frequencies, when measured over time as either replicate samples, or as different year classes, often show considerable variation (Gauldie, 1984; 1991). Thus, temporal variation in allele frequencies within stocks is often as great as geographical variation in allele frequencies between stocks (Gauldie, 1991). The significance and analysis of temporal and geographic variation in allele frequency depend to a large extent on the underlying assumptions of either selection or genetic drift as cause of variation (Gauldie, 1991; Hedgecock, 1994b).

In cod, growth differences between genotypes at LDH-3* and PGI-1* in fish from the same parents (J. Mork, pers. comm) have been shown. Thus, it is evident that there is a coupling between genotypes and important life parameters as growth. Growth can significantly influence life history of the fish, for example affecting the survival rate. In long lived and slow growing species such as redfish, differences in growth patterns can produce different survival rates, which finally modify the genetic structure of the adult population.

In other studies on genetic structure (Hedgecock, 1994a; Stepien, 1995), most of the genetic diversity was found among individuals within samples and only a few amounts was accounted for by differences among populations. The lack of geographic structure was attributed to high levels of gene flow via larval dispersal. Larval dispersion of Irminger Sea redfish is considerable, as shown above, and much higher than of redfish in other areas such as Flemish Cap, Gulf of Saint Lawrence or Barents Sea.

In the case of Irminger Sea redfish, there are no geographic differences among the suggested genetic stocks, and probably neither a reproductive isolation. These facts, together with a low temporal stability because of year class variation, make it difficult to believe in the existence of different populations.

In a long-lived species such as redfish, with a relatively high fecundity, a population can be sustained by few, abundant and temporally closed, year-classes, which reproduce during many years. Fecundity itself is not high but due to the viviparism, offspring are more likely to survive, so reproductive potential can be high. Even if there is recruitment failure during long time, the population can be sustained if such year-classes produce a series of good new year-classes. Thus, the population can be formed by for example two sets of year-classes largely separated in time.

It is evident from the literature that species exhibiting high longevity also have high levels of mitochondrial DNA mutations, *e.g.* sturgeons (Brown *et al.*, 1988) while species with low longevity also have low levels of mitochondrial DNA variation, *e.g.* albacore tuna (Graves and Dizon 1989). Further research will be necessary to determine the age dependency of mitochondrial DNA before its role in any kind of population analysis can be determined (Gauldie 1991).

Thus, we can assume that pelagic deep-sea *S. mentella* are older cohorts, which have undergone a different life history than younger cohorts, representing oceanic *S. mentella*. Genetic research should be conducted taking into account the age structure of the population. In that sense, age determination and validation will be an important task to be solved.

Conclusions

1. The hypothesis of three different *S. mentella* stocks in the Irminger Sea has been established as the fishery developed.
2. Preliminary genetic studies concluded that the three stocks inhabiting the area are genetically different, but the observed genetic heterogeneity can be explained by other causes than the existence of different stocks.
3. The ecology of *S. mentella* supports that:
 - There is a single spawning area
 - Larvae migrate towards the same area
 - There is only one nursery area
 - There are indications of a migration of *S. mentella* juveniles from the nursery into the adult distribution area.
4. Ecologically seen, the existence of more than one stock of *S. mentella* in the area is unlikely.

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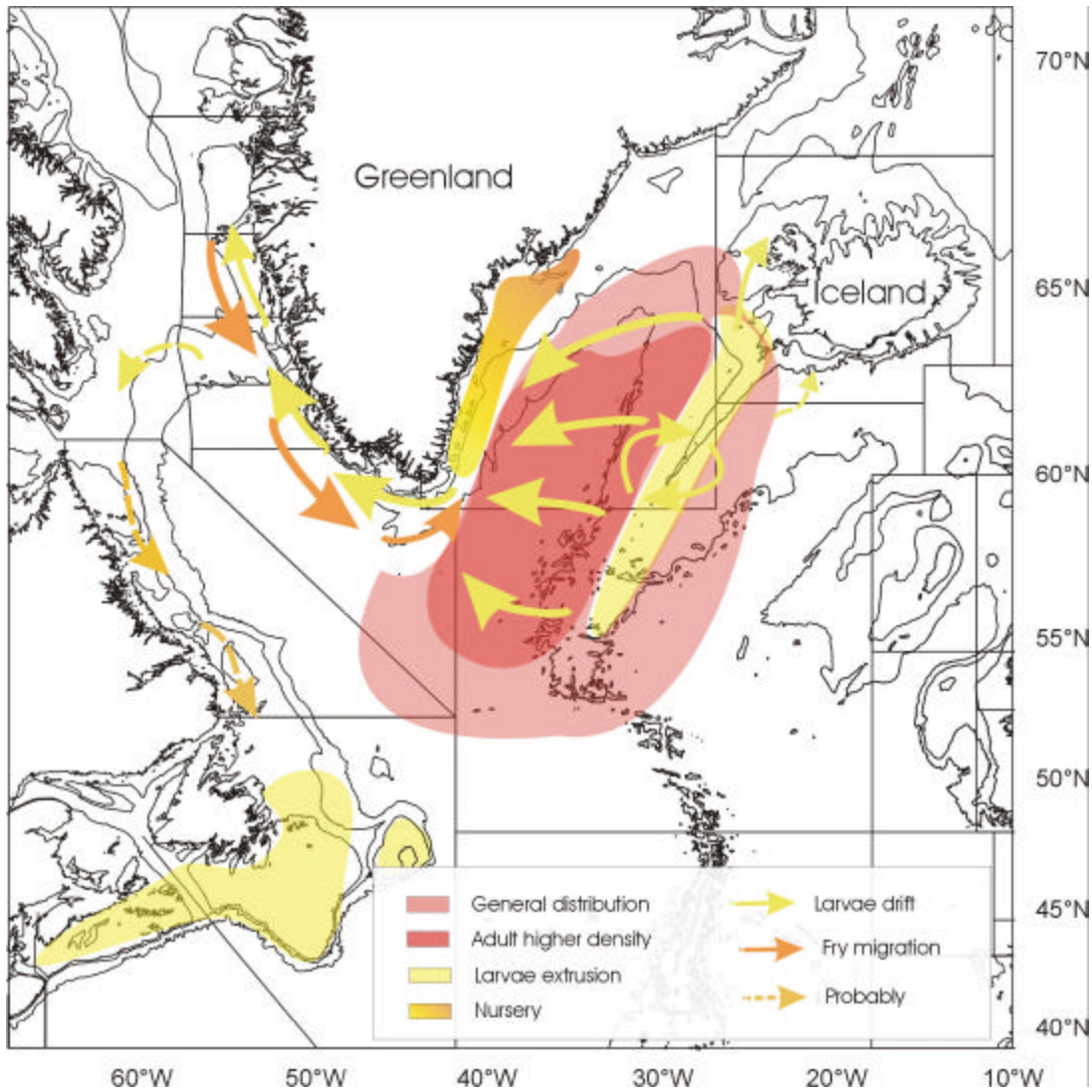


Fig. 1. *S. mentella* general drift pattern in the Irminger Sea and adjacent waters. Larvae drift from the extrusion area in Central Irminger Sea towards East Greenland. Later they drift northwards along the West Greenland shelf. A posterior fry migration southwards towards the main nursery area takes place. There is some larvae retention in the Central Irminger Sea. A larvae drift from West Greenland to Canadian waters in the Davis Strait is likely.

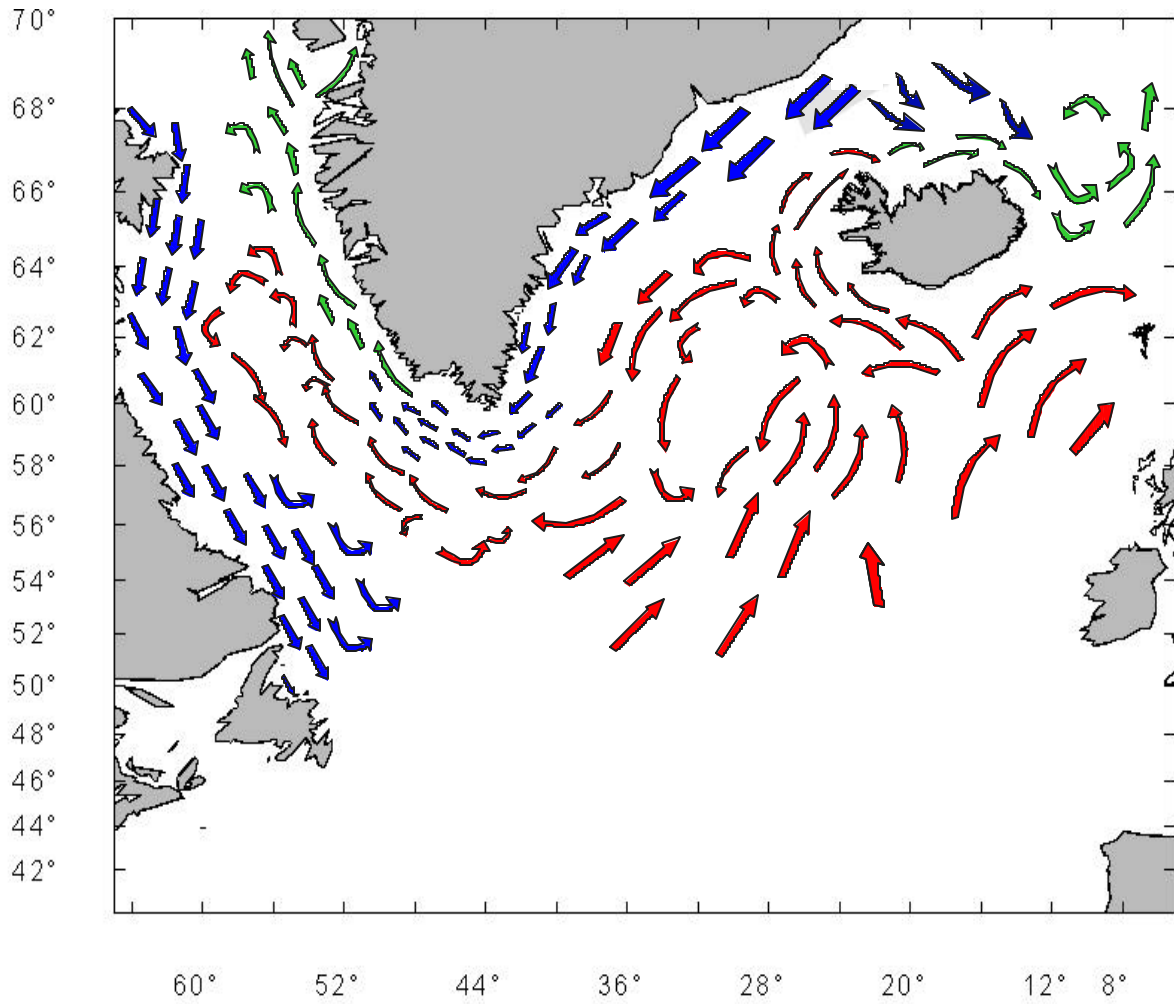


Fig. 2. General trends of currents in the Northwest Atlantic. Figure taken from ICES, 1998.

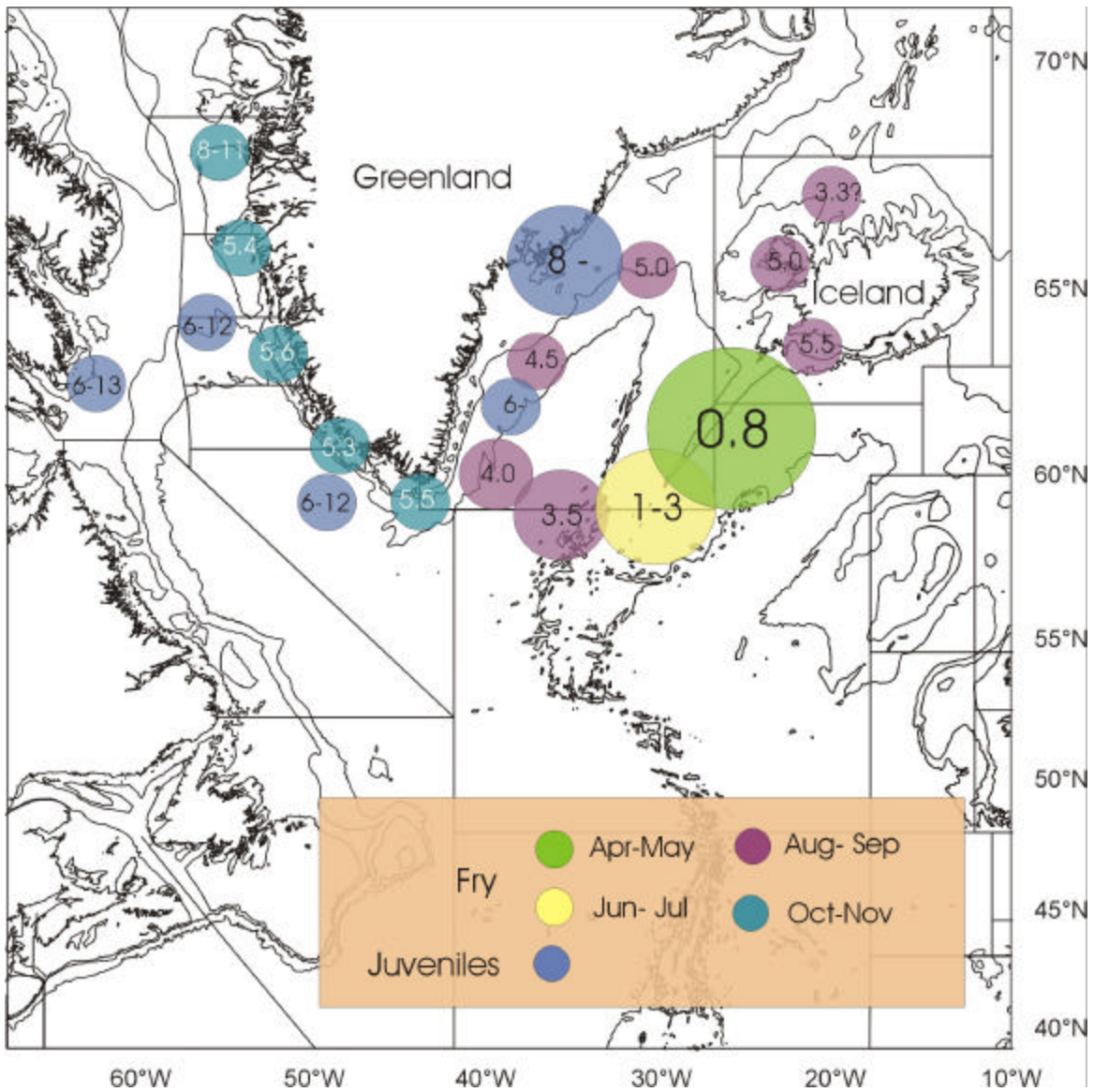


Fig. 3. *S. mentella* fry and juveniles size. *S. mentella* fry is recorded in different positions along the year as it is growing. Juvenile size distributions are shown. The numbers in circles represent the length range (mm) or mean length observed for the fry in the corresponding area, the size of the circles represent reported fry relative density.

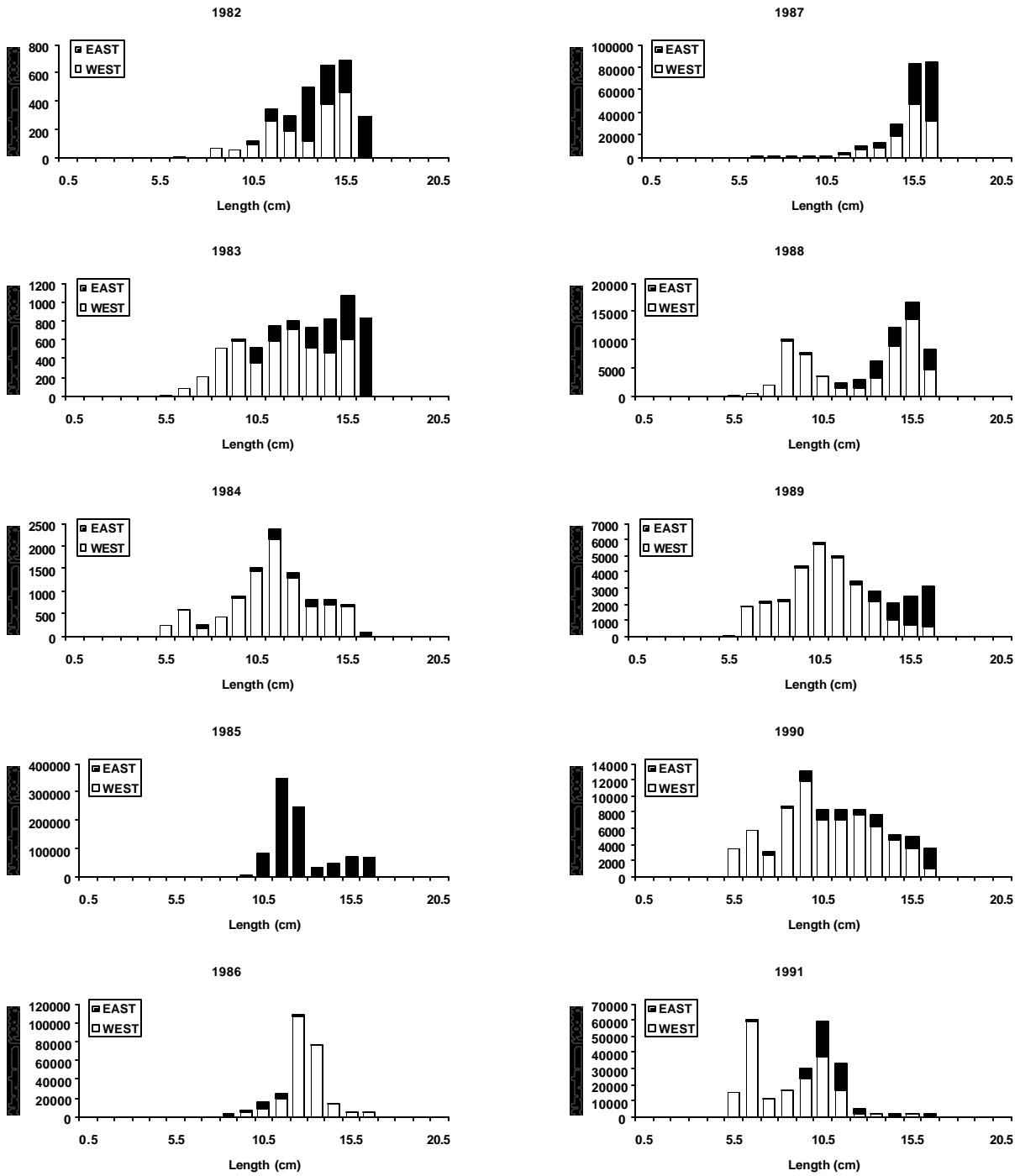


Fig. 4a. *Sebastes spp.* (<17 cm). Length frequencies for East and West Greenland, 1982-91.

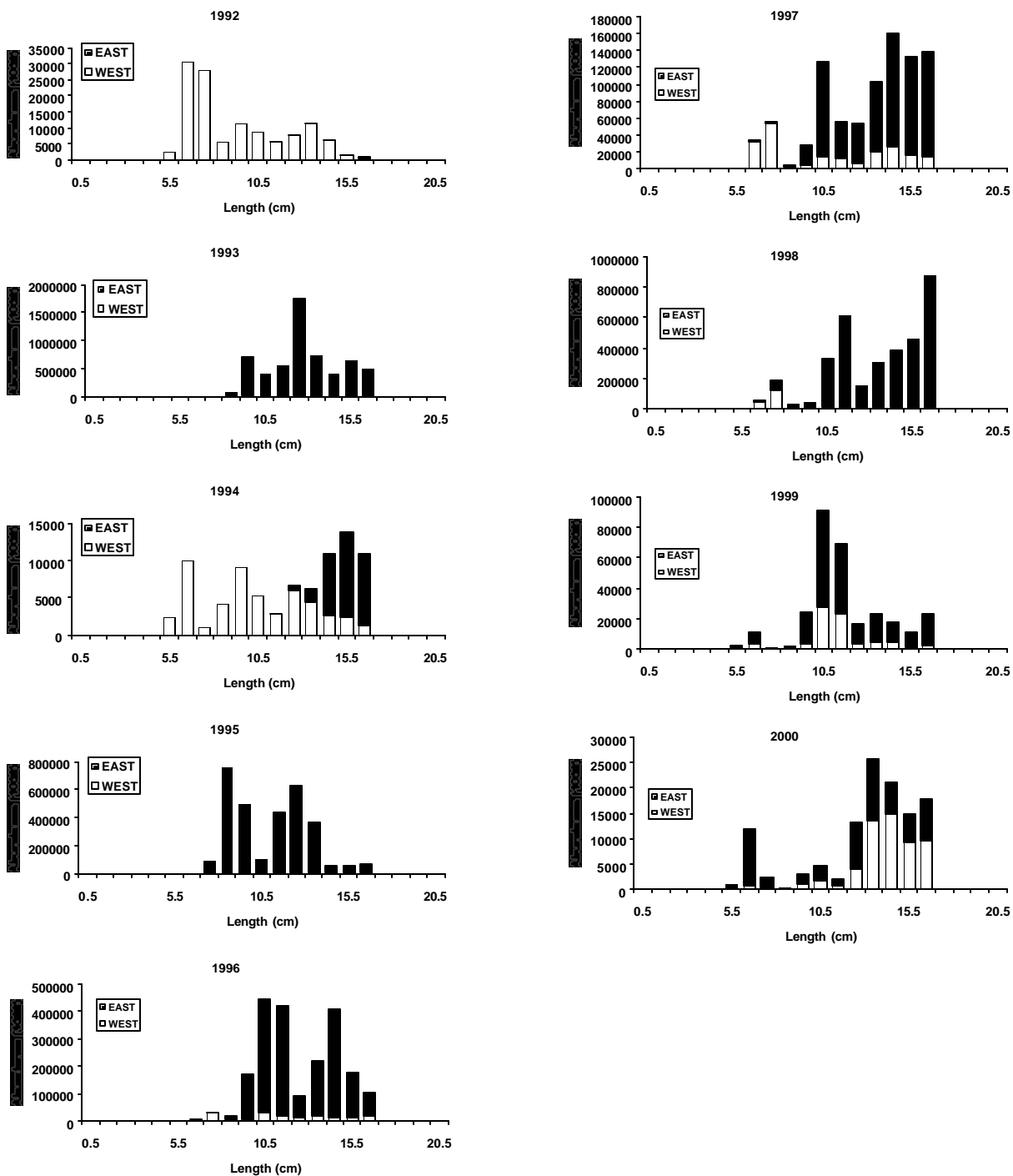


Fig. 4b. *Sebastes spp.* (<17 cm). Length frequencies for East and West Greenland, 1992-2000.

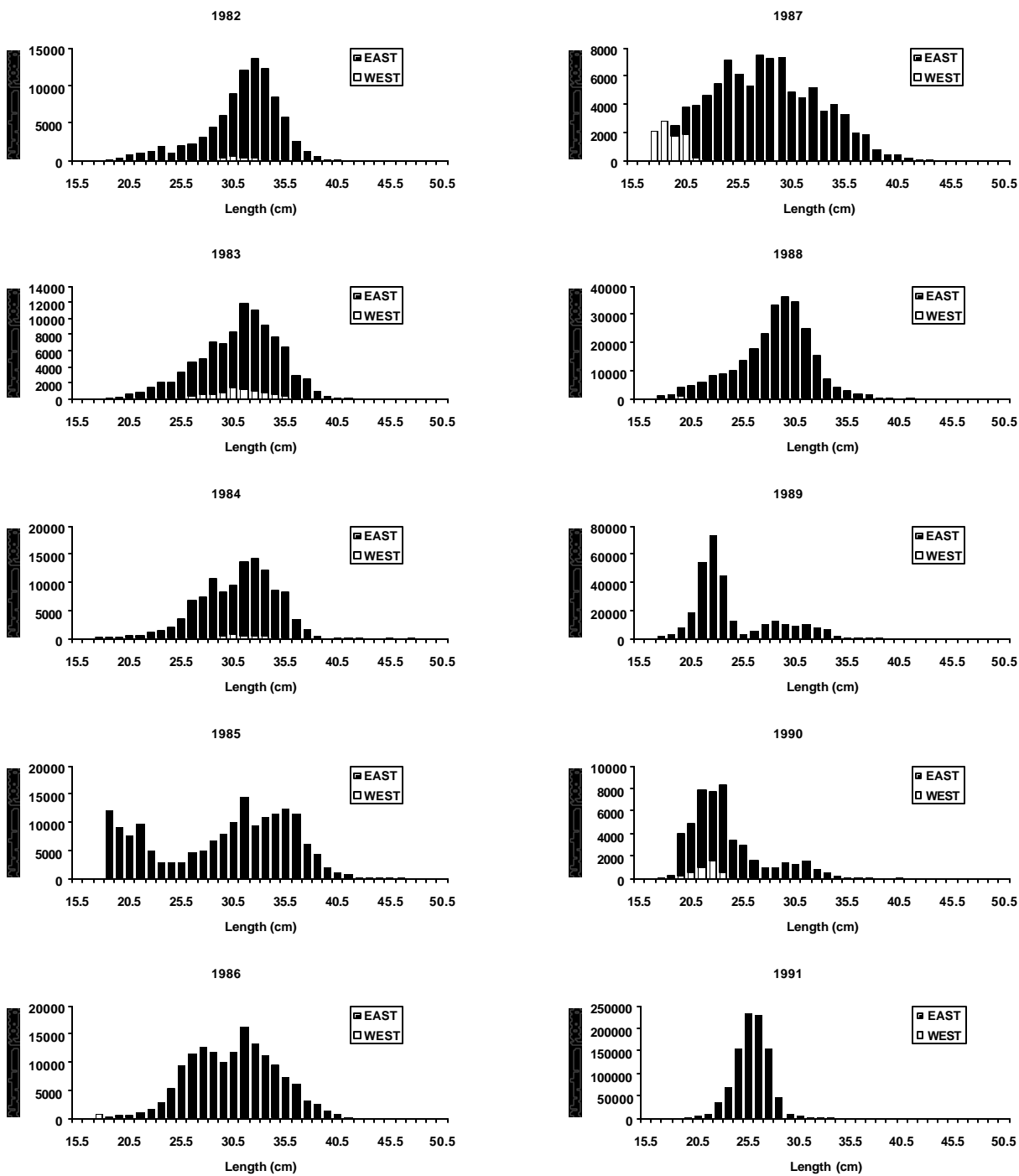


Fig. 5a . Deep sea *S. mentella* (≥ 17 cm). Length frequencies for East and West Greenland, 1982-91.

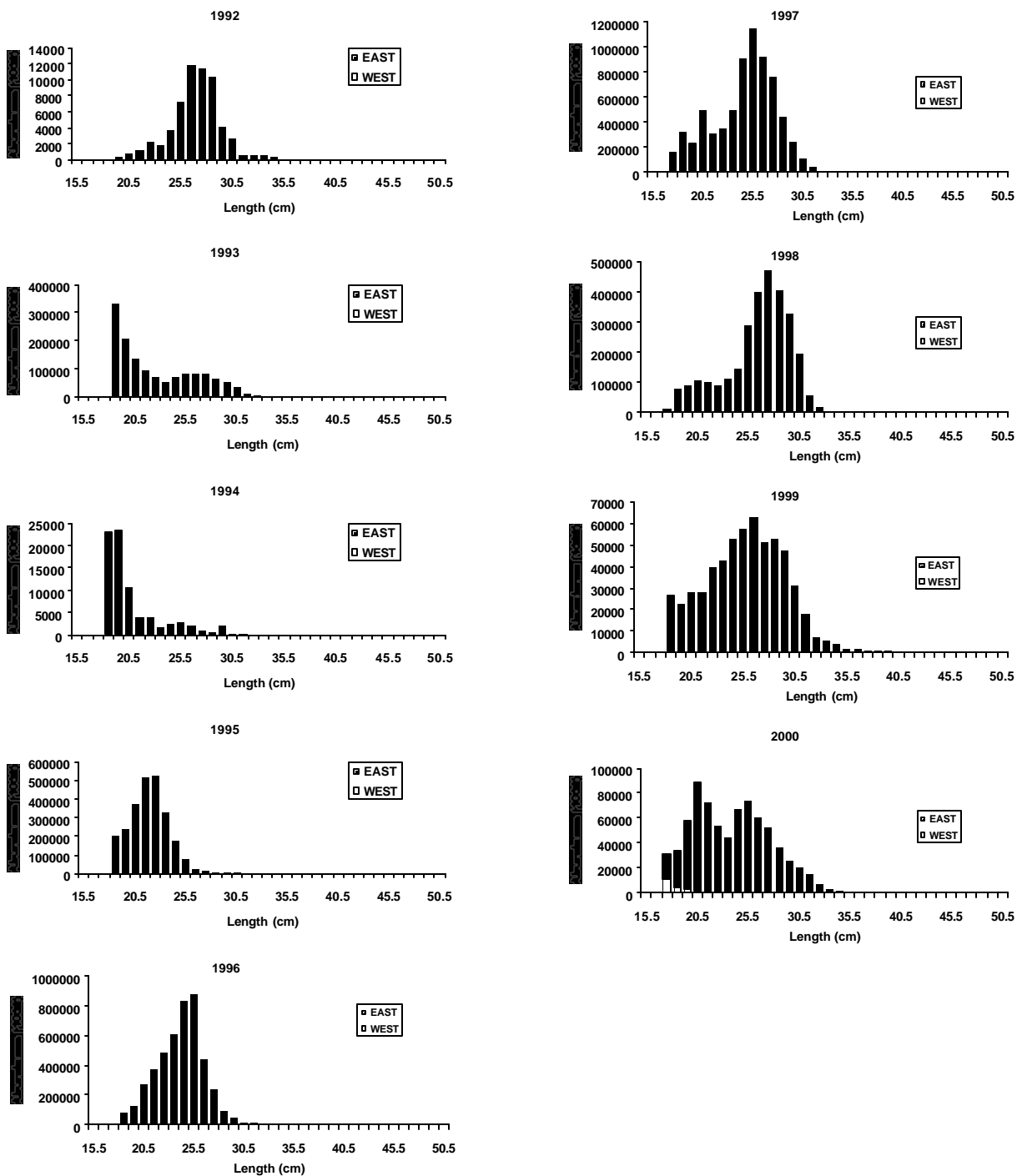


Fig. 5b Deep sea *S. mentella* (≥17 cm). Length frequencies for East and West Greenland, 1992-2000.

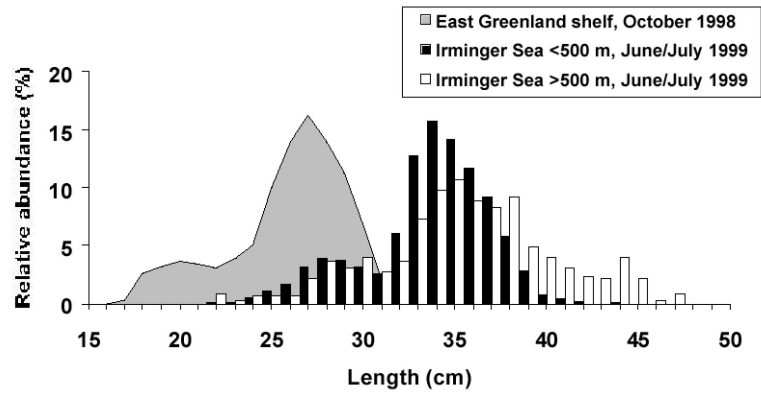


Fig. 6. Length distribution of *S. mentella* on the East Greenland continental shelf in October 1998 and in the Irminger Sea in June/July 1999 (from Stransky, 2000)

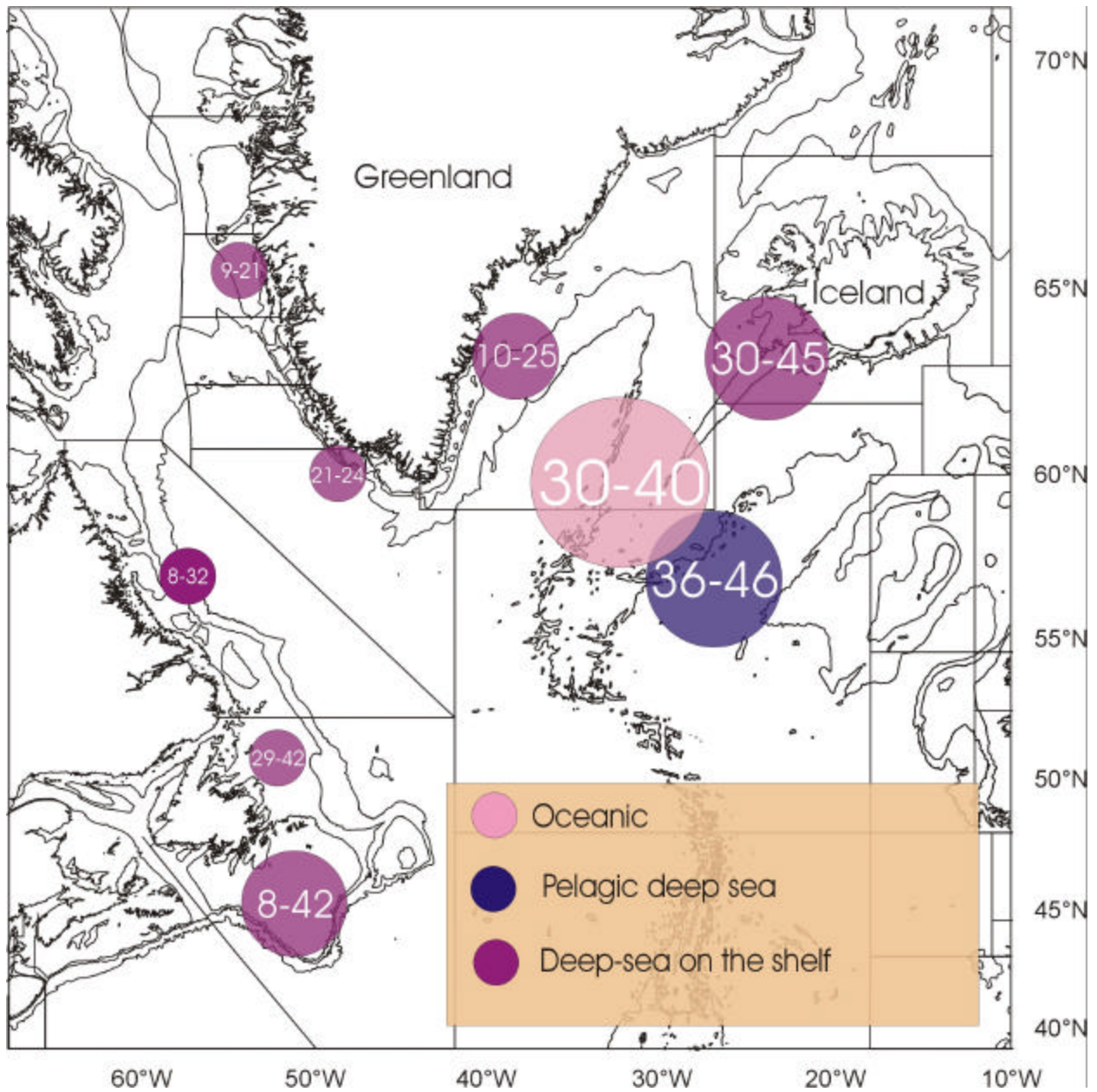


Fig. 7. *S. mentella* adult distribution with the fish length (cm) range for each area (size is referred to the most abundant fish, and do not represent maximum and minimum values). Different stock classifications, according to the three-stock hypothesis, are shown with different colours. The size of the length range circles indicates reported fish relative density in the corresponding areas.