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On Population Structure of Beaked Redfish (*Sebastes Mentella* Travin) in the Irminger Sea as Related to Larval Drift

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Abstract

The biological features of adult beaked redfish (*Sebastes mentella* Travin) of the Irminger Sea, distributed within pelagic depths (outside 200-mile zone) and on the slopes of Iceland and Eastern Greenland Shelf are discussed in the paper, as well as the data on the latter larvae and 0-group distribution. The results of comparisons carried out supported the hypothesis of a lack of close relation between adult redfish in the two areas.

The results also allows to assume the existence of 2 populations *Sebastes mentella* in the Irminger Sea, one in the area of Iceland and East Greenland shelf slopes (coastal stock) and another in pelagic zone over significantly deeper areas (ocean stock). Concerning the early stages, the redfish larvae, drifting towards Western Greenland, seems to originate from a spawning area located at the shelf edge southwest off Iceland, while the larvae hatched in the central sea area were found to be developing within the closed eddy generated by surface currents. No data revealed a possible mass entrance of larvae into the flow of Irminger Current. It was also unlikely that young redfish originating from the ocean spawning grounds would from the major source of the coastal stock recruitment.

Key words: currents, Irminger Sea, larvae, population, redfish

Introduction

It is known, there is an extensive redfish (*Sebastes* sp.) spawning ground (locations where the redfish larvae are hatched) in the Irminger Sea center southwestward of Iceland. According to Troyanovsky (1992), part of the larvae from this spawning ground drifts to Western Greenland and further to Labrador, reaching the Newfoundland Grand Bank. The proposed drift is shown in Troyanovsky paper. This hypothesis is very interesting from both the theoretical and practical points of view, particularly with reference to the problems of population differentiation and fishery management. To address these issues, NAFO and ICES agreed to convene a joint Working Group in 1983 to study biological relation between the redfish stocks of the Western Greenland and Irminger Sea.

In this regard, scientists of AtlantNIRO during the first half of the 1980s were also intensively researching the so called "ocean stock" of redfish outside the 200-mile zone and collected extensive information. The data collected were suitable to derive some considerations on the structure of the redfish population from the Irminger Sea, and the possible relationship of the Irminger Sea redfish to those from the North-Western Atlantic. In this study, the population structure of the Irminger Sea redfish is considered and an attempt is made to relate them to distribution patterns of larvae and 0-group stages.

Materials and Methods

The biological materials utilized in the work were collected during a USSR 1980–85 research surveys carried out in the area outside 200-mile zone between 55–62°N and 29–35°W. The data included the lengths, weights, ages and sexual maturity stage estimation, and a record of redfish infected with parasitic Crustacea *Sphyrion lumpi* Krøyer. The total number of length and weight measurements amounted to 568 000 specimens and age was estimated on 46 000 specimens.

The materials collected in the adult redfish surveys were treated with the standard methods adopted in AtlantNIRO and PINRO, particularly noting that age data were obtained from scales. Besides the adult redfish surveys, during the period 1981–85, surveys of redfish larvae and 0-group were carried out at 757 stations. These surveys were carried out with the methods described in detail by Noskov *et al*. (1985), and Noskov and Romanchenko (1986). One hundred specimens of these were sampled at each station to perform the morphometric analysis. In total, 145 000 specimens were analyzed.

In addition, biological data of redfish from the slopes of the Iceland and East Greenland shelf were obtained from the Zakharov (1969) dissertation, by a kind consent of the author[1] (Ecology and Fishery of Marine Redfishes *Sebastes marinus* L. and *Sebastes mentella* Travin of Iceland and Greenland, dissertation, 1969).

Length measurements and biological analyses of redfish were carried out in pelagic layer of the Irminger Sea during April–July 1996 from R/V of AtlantNIRO. However, taking in account experimental nature of the fishing (control hauls were performed irrespective of fishing aggregations), a direct comparison of data for 1995 and for previous years seemed incorrect, though the new data were found to be of certain interest that should be discussed briefly.

Results and Discussions

History of the Problem

The first reference to the pelagic population of redfish was made by Nansen (1886). The hypothesis was later supported by Hjort (1901) based on repeated catches of redfish with long-lines at depths of 100–200 m in the open Norwegian Sea. Schmidt (1904) and Jensen (1922) had found aggregations of redfish larvae southwestward of Iceland, hundreds of miles away from the nearest known demersal stock of the redfish. Based on the reports, Tåning (1949) and Templeman (1959) assumed the existence of a pelagic population of Sebastes spp. in the Irminger Sea. However, the fact of abundant occurrence of larvae in the open sea may be interpreted in two ways. They may be a resident population or as Zakharov (1963) supposes, that the larvae in the open ocean are spawned by redfish females which migrated from the Iceland shelf slope and 2–3 months later (in August–September) return back. His point of view is supported by Kotthaus (1965).

In general, by 1981 when the extensive redfish fisheries were performed outside the 200-mile zone, the problem of *S. mentella* population structure was yet uncertain in the Irminger Sea, and the above hypotheses were apparently equally acceptable.

Adults

Let us compare first some biological characteristics of adult beaked redfish in the central part of the Irminger Sea (outside 200-mile zone) and on the Iceland shelf slopes as shown in Table 1. In this regard the data on the length composition, presented in Table 1, are the most abundant. The data presented show that the average length of fish, caught in pelagic zone and at the shelf edge, differs significantly and the difference is observed throughout the year, i.e. there are no reasons to assume migration of various sized redfish from one area to another. In exploration catches of 1995, both males and females of redfish were represented by larger individuals as compared to those sampled from commercial catches in the early-1980s. Besides, at the depths below 600 m, the average fish length was similar to that observed at the slope of the Iceland Shelf (Table 2). However, size of catches obtained in the control hauls was insignificant (mostly 100–300 kg). It should be noted that interpretation of data on redfish size composition in 1995 is difficult due to their experimental nature, therefore it was decided that such data may not be used at present to confirm or reject any hypothesis.

Accordingly, now that other biological characteristics will be discussed. The age composition data were found to differ to a lesser extent. The data in the catches from the open sea areas showed the dominating age was 13–19 years for females and 12–17 for males, while in the shelf zone the dominating ages were 16–22 and 16–21 years, respectively. Taking into account the above-mentioned length and age structure (Table 3), it was found reasonable to pay attention to a growth rate of redfish from the areas considered. The data presented apparently evidence a higher growth rate for fish caught within the Iceland shelf slopes. Magnússon (1972, MS 1983) also observed the lower growth rate of the ocean redfish as compared to that from the shelf areas.

Significant differences were also observed for their maturity rate characteristics. Table 4 shows the data on *S. mentella* maturity rate. Thus, while 90–95% of fish caught from pelagic area were mature at the length of 32 cm, redfish from the coastal areas approached the above percent maturity only at the length of 42 and 44 cm for males and females, respectively. Therefore, a conclusion could be made based on the correlation between *S. mentella* growth rate and maturity in the Irminger Sea, that the redfish found pelagically differ form those found on the shelf slopes. This is also supported by the redfish maturity dynamics research conducted throughout a year, which shows that in the pelagic area the major mating occurs in August–September while in the shelf area it occurs in September–December. As for the sex ratio, females accounted for up to 90% of catches outside 200-mile zone in April–May. Later on, the male proportion increased and approached 50% and over, by winter.

During the 1990s, sex ratios in commercial catches had changed towards significant increases of males by proportion. The same was shown by the controlled hauls. Even during the period when

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TABLE 1. Average length (cm) of redfish caught outside the 200–mile zone of the Irminger Sea and on the Iceland shelf slopes.

			Month											
Area	Year	Sex	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Outside 200–mile zone	1981	Male	–	–	–	33.1	33.2	33.8	34.5	34.9	33.6	33.9	–	–
		Female	–	–	–	35.6	35.6	35.8	36.6	36.6	35.3	35.5	–	–
	1982	Male	35.6	34.6	34.6	32.9	32.8	33.3	33.6	35.3	35.1	35.2	–	–
		Female	38.4	39.2	37.1	35.7	35.2	35.6	35.8	37.0	37.7	36.9	–	–
	1983	Male	–	–	33.5	32.7	33.4	33.6	34.3	34.8	–	–	–	35.1
		Female	–	–	36.4	35.2	35.3	35.5	36.3	36.7	–	–	–	37.1
Shelf slopes	1960s	Male	41.8	40.9	41.6	41.2	42.0	42.1	41.3	42.0	42.0	40.2	41.9	43.0
		Female	43.9	43.4	43.7	42.5	42.3	42.8	42.7	43.2	43.6	42.0	43.0	44.8

TABLE 2. Average length (cm) of redfish in exploration catches from Irminger Sea pelagic zone in April–July 1995.

Depth of		Month			
catch	Sex	April	May	June	July
up to 600 m	Male	–	37.0	36.1	36.4
	Female	–	39.0	37.4	37.1
600–800 m	Male	40.5	38.8	41.2	40.5
	Female	41.1	40.4	42.0	41.4

TABLE 3. Average length by age (cm) of redfish caught outside the 200-mile zone of the Irminger Sea (1981–82) and on the Iceland shelf slopes (1960s).

Age	Outside 200-mile zone		Shelf slopes	
(years)	Male	Female	Male	Female
9	27.2	27.6	–	–
10	28.8	28.5	–	–
11	29.7	29.4	–	–
12	30.9	30.5	–	–
13	32.0	32.8	38.0	37.0
14	33.1	33.9	39.5	41.5
15	34.6	35.2	41.0	42.2
16	36.1	36.2	42.5	42.5
17	38.0	37.8	43.4	44.7
18	37.9	38.7	43.6	45.2
19	39.0	39.6	44.3	45.2
20	–	40.3	45.0	45.8
21	–	41.1	45.2	46.2
22	–	41.9	45.8	46.5
23	–	42.7	–	–

TABLE 4. Percent of mature redfish by age-groups caught outside the 200-mile zone (1981–82) and on the Iceland shelf slopes (1960s).

	Outside 200-mile zone		Shelf slopes	
Length (cm)	Male June–July	Female March–April	Male 1960s	Female 1960s
25				
26	0	8		
27	5	12		
28	25	33		
29	71	25		
30	88	55		
31	86	87		
32	92	95	12	
33	96	97	20	
34	97	99	15	
35	99	99	21	1
36	99	99	27	3
37	99	99	33	4
38	98	99	44	6
39	96	99	68	10
40	100	98	80	33
41		97	86	52
42		97	92	69
43		88	95	84
44		86	97	92
45		100	98	94
46			96	98
47			98	98
48			97	98
49			95	98
50			100	99
51				100

larvae were hatching, males constituted up to 70% of catch (commercial fishery data) during the latest years.

The results of meristic characteristic analysis of the beaked redfish caught outside 200-mile zone (our data) and on the Iceland shelf slopes (Barsukov and Zakharov, 1972), presented in Table 5, evidence statistically significant variations in three of the four characteristics considered.

Parasitic Crustacea *Sphyrion lumpi* is a good indicator for the redfish population differentiation (Templeman and Squires, 1960; Sinderman, 1961; Yanulov, 1962). It is therefore not surprising that the problem of fish infestation with this parasite in the central Irminger Sea had been carefully studied (Gaevskaya, 1984). The results show that the average infestation level was 16.8% for females, and 14.3% for both sexes. Besides, during some months the infestation level exceeded 35% at some sites. According to data obtained from the research survey of AtlantNIRO and commercial fishery information for 1995, high infestation levels of within 20–50% of redfish have been revealed (the presence of live individuals of *S. lumpi* as well as traces of damage caused by the latter). At depths below 600 m the level of infestation decreased, however, it still remained rather high (20–35%). Thus, it is seen the new data in general are compatible with the results of previous researchers.

In comparison, other data on the beaked redfish infestation in some other areas of the Northern Atlantic showed that in Barents Sea the average infestation amounted to about 1.0%, off the Bear Island at about 2.9%, and in the Iceland shelf area at about 1.4% (Williams, 1963). In general, in the North Western Atlantic, the peak redfish infestation (6.6%) was observed in the Southern Labrador Bank. No *S. lumpi* was found in the northeastern area of the Newfoundland Grand Bank, at the Flemish Cap Bank and Scotian Shelf (Templeman and Squires, 1960). Based on these results, Gaevskaya (1984) concluded that no other area of the Northern Atlantic showed such high level of the deep-sea redfish infestation as the open Irminger Sea, and that the *S. lumpi* invasion center was likely to be located there. It is interpreted here that poor interactions of redfish from the Irminger Sea area

TABLE 5. Comparison of four meristic measurement characteristics for redfish caught outside the 200-mile zone of the Irminger Sea and on the Iceland shelf slopes (number of specimen is shown in brackets).

	Average values			$t_s t$ at
Characteristics	Outside 200-mile zone	Shelf slopes	t%	P = 0.01
Vertebrae number	31.00 (81)	31.17 (253)	12.14	2.58
Number of rays in anal fin	8.76 (78)	8.49 (282)	4.03	2.58
Number of rays in dorsal fin	14.49 (75)	14.65 (34)	1.14	2.62
Number of rays in pectoral fin	18.05 (81)	19.33 (60)	17.07	2.58

with those from other areas, contribute to maintain the high infestation level only in that area.

In the comparison of adult redfish biological characteristics, it also seems useful to consider data on distribution, and their occurrence outside the 200-mile zone, based on the results of the long-term fishery of the former Soviet Union fishermen. Briefly we may summarize that *S. mentella* occurs in the Irminger Sea area throughout a year, concentrating in the most dense aggregations during the period of larval hatching (April–May), during the feeding period (June–July), and sometimes, during the mating period (August–September). During the rest of the year, adult redfish also permanently occur over the vast sea areas outside 200-mile zone, though no dense aggregations are found.

Larvae and 0-group

The data on early stages (larvae and 0-group) of the beaked redfish in the Irminger Sea, Fig. 1 (Noskov *et al*., 1985), showed larval distribution and abundance on the basis of the ichthyoplankton surveys performed from 27 April to 6 June 1982. The most striking feature was the almost entire absence of these stages at peripheral stations, adjacent to the boundary of 200-mile zone. Similar results were obtained in the survey of 1983. Therefore, it can be assumed that during the period discussed, there was no larval drift westwards and northwards. Otherwise, the larval stages should have occurred near the boundary much more frequently. The trawl survey for redfish in August–September 1984 revealed that even in September considerable number of young fish still remained within the central part of the sea (Fig. 2) (Noskov and Romanchenko, 1986), approaching the length of 4–6 cm by this time. In this case it seems appropriate to assume an active movement of young fish, which undoubtedly extended their distribution area as they grow up, and went outside the survey area. It should be noted that Noskov and Romanchenko (1986) refer to the results obtained and conclude definitely that larvae and young fish penetrate the spawning area boundaries in the central part of the sea into the Irminger Current, with further drift to the eastern and western areas of Greenland. It is evident that the above conclusion should be verified with reference to the data on the surface current system in the area of study. Figure 3 shows the large closed eddy in the area within which the spawning area of the "ocean" redfish stock is distributed. It seems unlikely that larvae are able to escape the eddy actively and enter the Irminger Current. Young fish of 0-group also "do not hurry" to do it (Noskov and Romanchenko, 1986).

Overall patterns

In general, the data discussed above evidence the lack of close interrelation between adult beaked redfish, inhabiting a pelagic zone and the slopes of the Iceland and Eastern Greenland shelves. As seen with the changes in the sex ratio during 1990, it seems unlikely that male abundance significantly increased in the Irminger Sea pelagic zone during this period. Probably, they were abundant outside 200-mile zone before. The sharp increase of the male proportion in commercial catches is likely the influence of the considerable extension of fishing area, implementation of new more efficient trawls, and perhaps by an abundance of decrease of females due to selective fishing of the latter during 1980s. The new information here apparently seems to reject the hypothesis on redfish seasonal migrations into pelagic zone to spawning. Thus the assumption of adult pelagic redfish migrating into the northwestern Atlantic areas and returning, also seems unlikely. Magnússon (1981) clearly supported the idea of the existence of the ocean spawning stock of redfish *S. mentella*.

Undoubtedly, the great differences observed in the data compared to the time of sampling (up to 20 years), is a disadvantage to the analysis above. However, if we accept the hypothesis of a single beaked redfish population in the Irminger Sea, it is hard to be convinced that in the period from 1960 to 1980, the biological characteristics of the species may have changed so significantly due to some

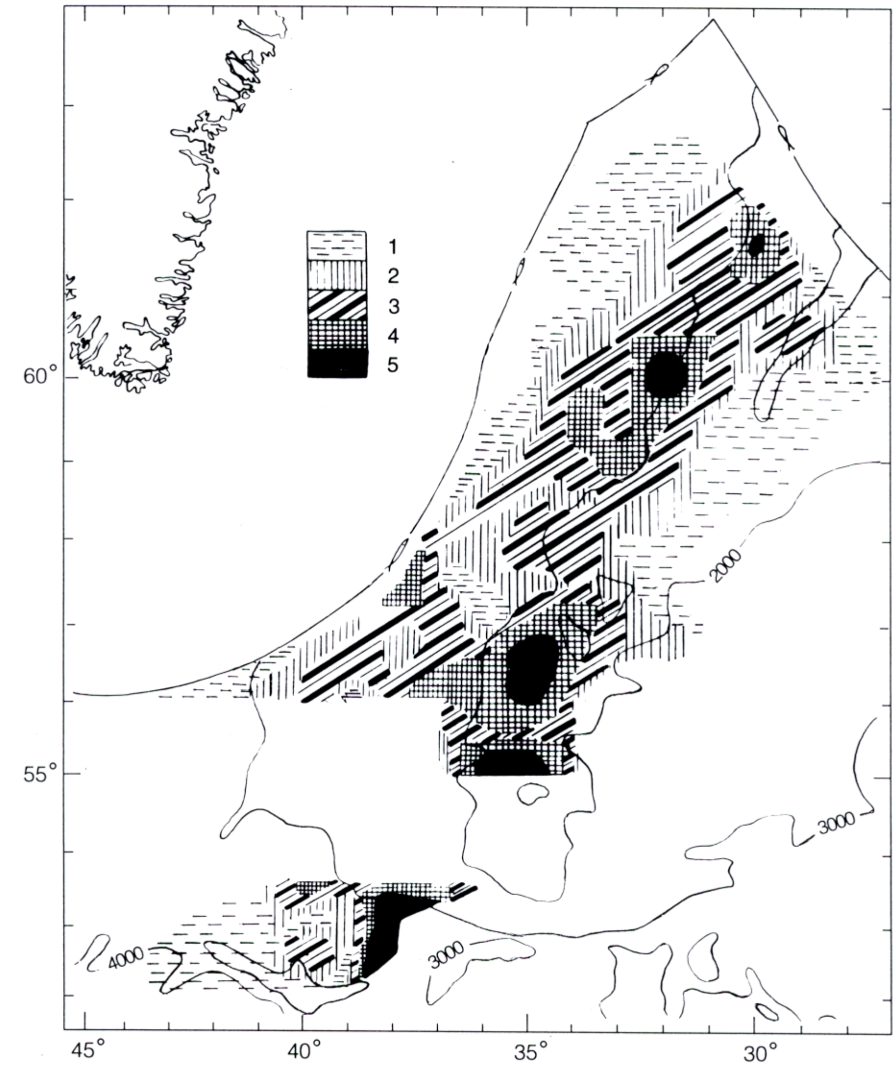

Fig. 1. Distribution and abundance (numbers per m^2) of *S. mentella* larvae in spring 1982 (from Noskov *et al.*, 1985). 1 = 10, 2 = 11–25, 3 = 26–50, 4 = 51–100, 5 = 101 and more.

unknown reasons. Nevertheless, it is also known that the proportion of fish infested by S. lumpi in different areas of the Northwest Atlantic has remained approximately the same as some decades ago.

Interesting information relevant to this problem is discussed in the work by Zakharov (1966). Research of 0-group redfish distribution in July–October 1964 permits the author to reveal large numbers of young fish in the Irminger Current zone (East and West Greenland shelf slopes). These fish were essentially represented by *S. marinus*, while *S. mentella* occurred rarely. This information supports the conclusion that the bulk of beaked redfish larvae which hatched outside the 200-mile zone do not penetrate the Irminger Current flow. Thus the young fish which occurred in the area originate from the spawning ground at the shelf edge southward off Iceland (Magnússon, 1961; Zakharov, 1966), where both larvae of golden and beaked redfish are observed. These fish may easily enter the Irminger Current flow and drift further towards the east and then to West Greenland.

In general, the results of the analysis performed leave no doubt concerning the structure of *S. mentella* population in the Irminger Sea. However, the location of the major distribution area of 1–7 year

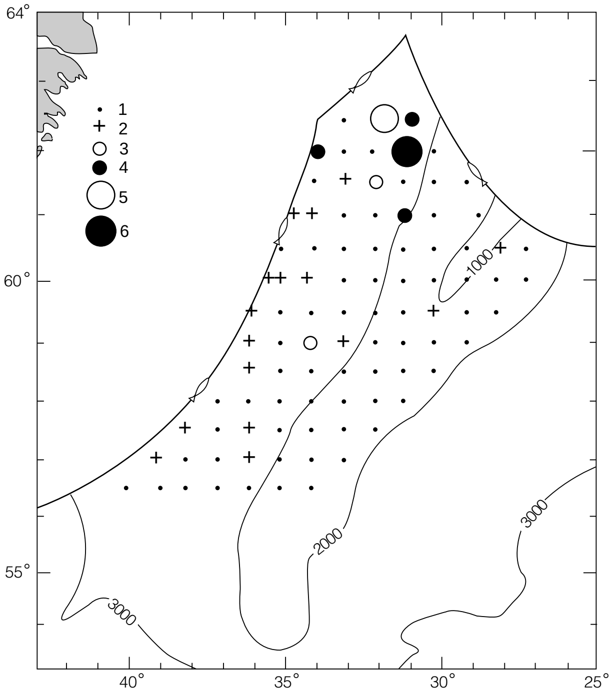

Fig. 2. Distribution and abundance (numbers per m^2) of 0-group *S. mentella* in August–September 1984 (from Noskov and Romanchenko, 1986). 1 = 1, 2 = 1–50, 3 = 50–100, 4 = 101–500, 5 = 501–1 000, 6 = 1 001 and more.

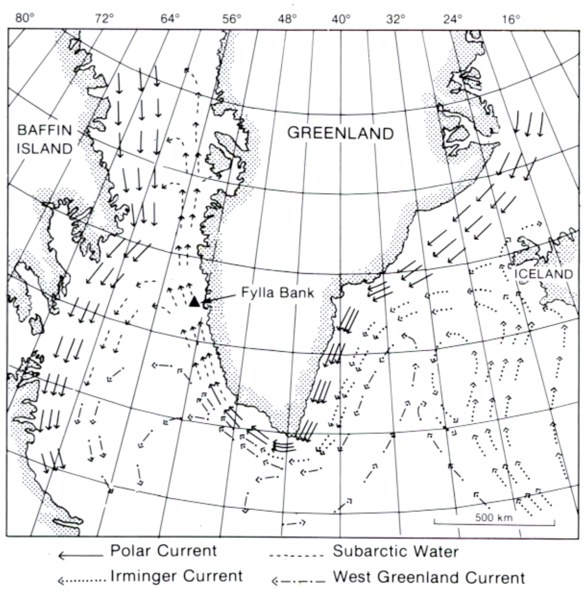

Fig. 3. Surface current system in the Iceland–Greenland area (from Hansen and Germann) (1 = Polar current, 2 = Irminger current, 3 = Subarctic water mass, and 4 = West Greenland current). (Source: NAFO, MS 1983).

old fish which hatched in the pelagic layer remains uncertain. These age groups were actually absent in commercial catches from outside the 200-mile zone. However, the Report of the Joint Working Group ICES/NAFO (Anon., MS 1984) noted that the beaked redfish stock of the Iceland shelf slopes and East Greenland seems only slightly recruited from the pelagic stock of the species. Data studied in the present work supports the above conclusion. These 1–7 year olds seem essentially to distribute within the eddy, approximately between 55–62°N and 32–38°W. However, is likely that these fish penetrate in small numbers into the eastern Greenland shelf, where it mixes with the local population and never returns into the open sea. In these particular pelagic areas of distribution of 1–7 age-group redfish population, the abundance seems to be very high.

Conclusion

There is strong evidence of the existence of 2 beaked redfish populations in the Irminger Sea, the first one (coastal) inhabits the Iceland and eastern Greenland shelf slopes, and the second one (pelagic) occurs in the open sea and spends almost all its life cycle within the water column over big depths. Concerning the relation to the northwestern Atlantic *S. mentella* larvae drifting towards West Greenland and further, the present data supports the view that they seem to originate from the spawning grounds located at the shelf edge south-westwards off Iceland (coastal population), while larvae hatched in the central area of the Irminger Sea develop entirely within the closed eddy.

It is therefore quite evident that such kind of research is directly related to the problem of redfish fishery management in the area concerned, since the results of such analyses have not settled all problems relevant to the population structure of *S. mentella* in the Irminger Sea. Under the circumstances it is recommended that a special research study of the latter should be performed in the area, preferably within the NAFO international forum, which undoubtedly will promote the final decision.

Acknowledgements

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