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Stock identification of *S. marinus* L. and *S. mentella* Travin in the Northeast-Atlantic based on measurements of Cs-137 content in the fish

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Abstract

The paper presents results of a pilot study aimed at analyzing the Cs-137 content in redfish from Norwegian, Faroese and Icelandic waters in order to elucidate the stock distribution of *S. marinus* L. and *S. mentella* Travin in the Northeast Atlantic. Due to the advection of Cs-137 from the Sellafield reprocessing plant sea water from these three areas varies in Cs-137 activity by more than an order of magnitude and the results of the pilot study indicate that the variations in sea water activity are reflected in the activities in redfish from Iceland and Norway to a large extent. Although the data set is too small to evaluate statistical significance the preliminary analysis also indicates, that redfish (especially *S. marinus*) at the Faroes is more related to the Norwegian than to the Icelandic redfish, which is in contradiction to the traditional view of the redfish stock distribution in the Northeast Atlantic.

Introduction

The two redfish species, *Sebastes marinus* L. and *Sebastes mentella* Travin have a very wide distribution in the Central and Northeast Atlantic as can be seen in Templeman 1959 (Fig. 1). At that time it was usual to deal with only one species, *S. marinus*, divided into two subspecies, *S. marinus marinus* and *S. marinus mentella*. Later the existence of two "good species" was accepted based on morphological, morphometric and meristic characters, and recently this has been verified by biochemical analysis (Nedreaas and Nævdal 1989, 1991) using haemoglobin patterns and enzymes (liver IDH, muscle ME) although they state, that generally the two species are very similar in most enzyme patterns. The calculated genetic differences were very small.

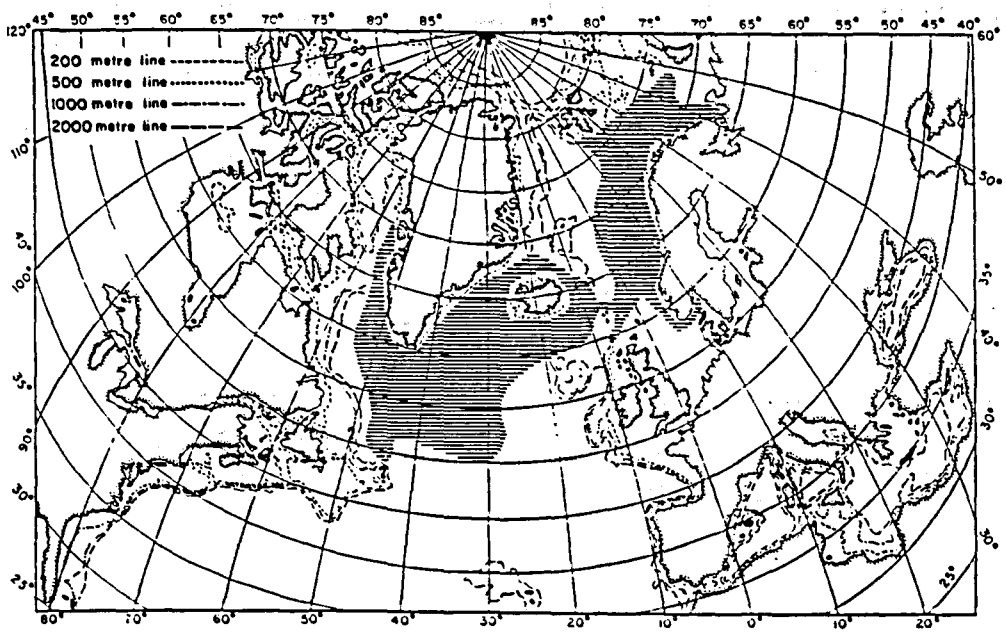

Figure 1. The distribution of S. marinus and S. mentella in the Northeast Atlantic according to Templeman(1959).

The distribution area shown in Figure 1 could today be refined somewhat based on new information but generally it is still valid for the two species taken together. The depth distribution is different for the two species, *S. marinus* being the shallower one. The depth range is somewhat different in different regions, but the main distribution of *S. marinus* is 150-450 m and that of *S. mentella* 300-750 m (Jónsson 1983, Reinert 1990). Due to the overlap in depth distribution there have been many practical problems connected with the split of the commercial catches of redfish into *S. mentella* and *S. marinus* with consequences for a separate management of them.

Even more important for management purposes is the division of each of the species into stock units. This has been very difficult due to lack of supporting data and has been done more on a geographical than a biological basis. In the ICES area *S. marinus* and *S mentella* are both divided into two stock complexes, the one in the Northeast Arctic (Sub-areas I and II) with main areas of adult distribution, reproduction and nursery within the Norwegian Economic Zone and the Fishery Zone at Svalbard, the other in the Faroe, Iceland and East Greenland region (Sub-areas V, VI, XII and XIV). In addition to this a pelagic stock of *S. mentella* with main distribution in the open Irminger Sea has been defined by the ICES Study Group on Redfish Stocks and named oceanic *S. mentella* compared with the ordinary bottom living *S. mentella* which is now named deep-sea *S. mentella* (Anon. 1992).

The term "Irminger Sea stock complex" has been applied to the redfish stocks in Sub-areas V, VI, XII and XIV pointing to the very central role of the areas SW of Iceland as common spawning (i.e. extrusion of larvae) places for the redfish from these areas (Anon. 1983). Nursery areas for the juveniles are found at Iceland (*S. marinus*), East Greenland (*S. marinus* and deep-sea *S. mentella*) and East/West Greenland (most probably oceanic *S. mentella*). Feeding and copulation

areas of the adults of this stock complex are assumed to be along the coast of East Greenland, around Iceland and the Faroe Islands. This implies extensive migrations between feeding and spawning areas of the females and between nursery and feeding areas of the young fish.

Observations of the sex composition of the demersal redfish catches in the spring/summer time in all 3 areas have supported spawning migrations of the females, most of the redfish caught in the spring/summer time being males (Reinert 1990). Several O-group surveys have revealed the drift of larvae/fry to the mentioned nursery ground (Anon. several years) and young fish surveys have shown the nursery grounds at Iceland and East Greenland (Magnüsson et al. 1975, 1988).

Spawning has also been observed at the Faroes in some years for both *S. marinus* and *S. mentella*, as well as larvae, but juveniles and young fish have never been recorded in this region, so the fate of this offspring is unsure. The smallest specimen caught in the trawl surveys (40 mm mesh size in the codend) have been 28 cm for *S. marinus* and 22 cm for *S. mentella*; in the commercial catches of *S. marinus* lengths of 40-60 cm are prevailing, whereas those of *S. mentella* are 37-50 cm.

These observations indicate that the adult redfish in Faroese waters is spawned or at least spends its younger years somewhere else and that would support the traditional view that Faroese redfish derives from the Irminger Sea stock complex. Recent studies of redfish from the mentioned areas using biochemical genetic analysis have, however, raised some doubts about this stock division, pointing to a closer relationship between Faroese and Norwegian Waters (Nedreaas & Nævdal 1991, Nedreaas et al. 1992). From Figure 1 it should be obvious, that the redfish at the Faroes could derive from both of the stock complexes as the Faroes are situated on the submerged ridge between Scotland and Greenland via Iceland which separates the two main "redfish regions".

Realizing the problems regarding the stock identification several Institutes have put a lot of work in this matter in recent years. In 1989 an ICES "Study Group on Oceanic-Type *Sebastes mentella*" was established which in 1990 was renamed "Study Group on Redfish Stocks". In 1990 a redfish workshop was held in Iceland sponsored by the Committee for West Nordic Projects. At this meeting several possibilities were discussed for finding some parameter that could help distinguish between stocks. One group of parameters that has potentials in this respect is the content of radioisotopes deriving from the Sellafield nuclear reprocessing plant. Releases from this plant have contaminated the Irish Sea with several isotopes increasing the levels by several orders of magnitude above background. The isotopes which remain in the water phase are advected out of the Irish Sea and prevailing ocean currents transport the contaminated water into the North Sea, towards the north along the Norwegian coast and further into the Northeast Atlantic although dilution along the route decreases the concentrations.

One parameter of special interest is Cs-137 with a radioactive half-life of about 30 years. Investigations through large areas of the Northeast Atlantic have documented the large horizontal variation in Cs-137 activity (e.g. Dahlgaard et al., 1986). In Figure 2 are shown typical levels of Cs-137 in seawater measured during surveys in the early and mid eighties. Since then the difference between Norwegian waters on the one hand and Icelandic/Faroese waters on the other has decreased due to the decrease of the Sellafield release and arrival of the Sellafield signal in Icelandic waters. In spite of this change there is still a significant difference between the sea water activities in Norwegian waters and the others.

With these large variations in the activity of the water one might expect also significant variations in the activity of the fish. Most useful might this be to clarify the origin of adult Faroese redfish. If the fish is indeed spawned or at least spends its first years in Icelandic waters then the Cs-137 activity in Faroese redfish should not be significantly higher than for the Icelandic redfish. If on the other hand Faroese redfish originates in Norwegian waters then Faroese redfish might have Cs-137 levels in between those of Icelandic and Norwegian redfish.

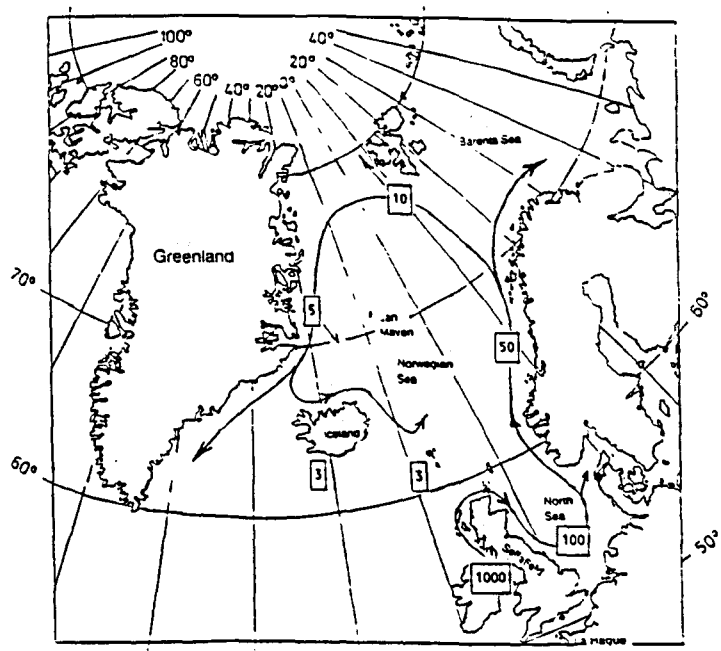

Figure 2. Typical Cs-137 activities in the sea water of the Northeast Atlantic (in Bq/m^3) in the mid-eighties (numbers in boxes) and the transport route from the Sellafield reprocessing plant. Adapted from Dahlgaard et al., 1986.

It was therefore decided to initiate a pilot project, founded by the Committee for West Nordic Projects, to investigate the stock distribution of *S. marinus* in Icelandic, Faroese and Norwegian Waters by measurements of the Cs-137 content in the fish. This paper presents the results of this preliminary work together with measurements on *S. mentella* from Faroese and Norwegian Waters.

Material and methods

Material for the analysis of Cs-137 was collected at the locations shown in Figure 3; Table 1 gives more information about the sampling stations. *S. marinus* was caught in Icelandic, Norwegian and Faroese waters while *S. mentella* samples were from Norwegian and Faroese waters only.

Table 1. Data for the redfish samples analyzed for Cs-137 activity. The sampling stations are denoted by codes shown in Figure 3 and in the column termed location in the table. Position refers to start of haul and number of fish preserved for analysis is split into males (M) and females (F).

Location	Position	Depth (m)	Time of catch	Number of redfish sampled	
				S. marinus	S. mentella
I	63°27'N 24°40'W	257	March 1991	4M + 4F	0
N1	72°27'N 27°40'E	145	Febr. 1991	2M + 2F	0
N2	71°40'N 31°23'E	330	Febr. 1991	0	2M
F1	60°56'N 10°15'W	830	April 1991	0	1M + 1F
F2	62°23'N 09°03'W	480	April 1991	0	1M + 1F
F3	59°53'N 07°57'W	575	April 1991	0	1M + 1F
F4	62°23'N 04°35'W	325	April 1991	1M + 1F	0

The redfish from Iceland (Station I) were collected on board a commercial Icelandic trawler and sent in a frozen state to Tórshavn, Faroe Islands, by a freezer ship. The redfish from Norwegian Waters (Stations N1 and N2) were collected during a trawl survey with the trawler "M/T Anny Kramer" in February 1991 and sent in a frozen state to Tórshavn, Faroe Islands by a freezer ship. The redfish from Faroese Waters (Stations F1-F4) were collected on board the Faroese "R/V

Magnus Heinason" on a redfish survey in April 1991. The fish were frozen whole on board the vessel immediately after being caught and then kept frozen to the embarking at Tórshavn, Faroe Islands.

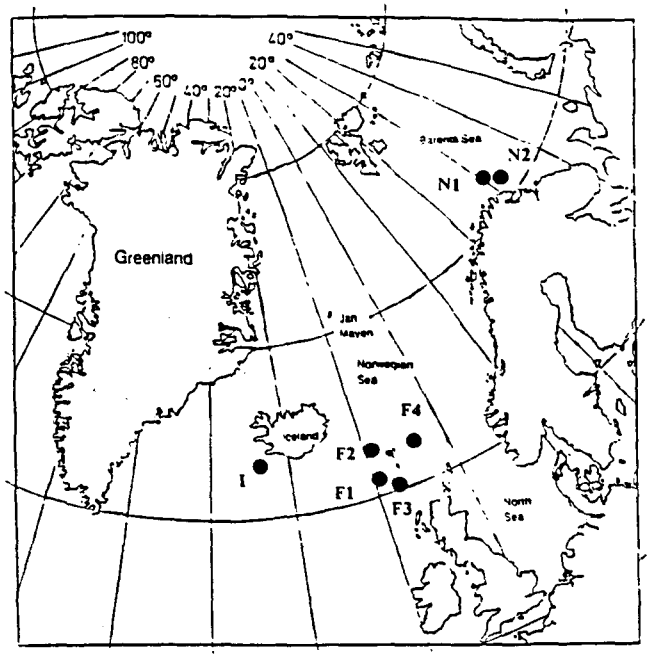

Figure 3. Locations where redfish were caught for analysis of Cs-137 activity.

The Cs-137 analyses were made by gamma spectroscopy using a lead shielded Germanium detector and the software OMNIGAM from EG & G Ortec. For most samples the fish were analyzed separately; but for the Icelandic samples and the Norwegian *S. mentella* sample it was necessary to pool two or more fish in order to obtain sufficient accuracy. Before counting fillets from the fish were stripped of skin and ashed. The ash was then analyzed and concentrations in the fillets were calculated using sample and ash weights. The only exception to this was the *S. mentella* sample from Norwegian waters where the fillets were counted directly without ashing.

Results

The Cs-137 activities in the *S. marinus* analyzed are presented in Table 2 and the *S. mentella* levels are presented in Table 3. The "% error" column in these tables shows the "counting errors" involved in the radioactivity analysis and should be a measure of the uncertainty in the results.

Table 2. Cs-137 activities in S. marinus caught in Icelandic, Norwegian and Faroese waters. Locations are shown in Figure 3. Where more than one fish was in the sample analyzed the table shows ranges of length and weight of single fish.

Location	Fish in sample	Sex	Length cm	Weight g	Cs-137 Activity (Bq/kg)		
					Ash	Fillet	% error
I	4	M	37-38	605-789	7	0.10	30
I	4	F	30-38	380-800	12	0.19	17
N1	1	F	40	1234	53	0.57	10
N1	1	M	47	1490	64	0.72	7
N1	1	F	45	1338	60	0.67	9
N1	1	M	41	910	72	0.81	9
F4	1	F	46	1518	95	1.16	6
F4	1	M	47	1624	28	0.32	18

Table 3. Cs-137 activities in S. mentella caught in Norwegian and Faroese waters. Locations are shown in Figure 3. Where more than one fish was in the sample analyzed the table snows ranges of length and weight of single fish.

Location	Fish in sample	Sex	Length cm	Weight g	Cs-137 Activity (Bq/kg)		
					Ash	Fillet	% error
N2	2	M	27-28	302-305	-	0.57	30
F1	1	F	50	917	18	0.19	29
F1	1	M	44	1099	14	0.16	36
F2	1	F	41	1208	41	0.45	17
F2	1	M	42	1262	28	0.34	21
F3	1	F	45	1448	28	0.35	13
F3	1	M	42	1107	24	0.28	17

Due to the low activities of the Icelandic redfish they were pooled into two samples, one male and one female, each containing 4 fish. After analysis these two samples were again pooled and analyzed and the result (10 ± 1 Bq/kg in the ash) was consistent with the two original analyses. Also the one exceptional value in Table 2, for the female from Faroese waters, was reanalyzed and the same result was obtained.

Discussion

The activity of Cs-137 in a marine fish will be affected by the activity of the sea water which it inhabits and fish in high-level areas will generally have higher activities than fish in low-level areas. This is supported by the difference in Table 2 between Icelandic and Norwegian *S. marinus*. The results for the two fish from Faroese waters in this table therefore may be used to indicate their origin. According to the traditional concept these fish have been spawned in Icelandic (or possibly Faroese) waters and have spent the first 7-10 years on the same grounds as the Icelandic fish. If this concept was true there should be no reason for the activities of the two fish to be above that of the Icelandic *S. marinus*. If anything, the Faroese redfish might have smaller activities than the Icelandic ones as Faroese waters have about the same activity as South Icelandic waters and smaller activities than North Icelandic and East Greenland waters (Dahlgaard et al. 1991, Ólafsdóttir et al. 1992).

Thus the fact that the two Faroese *S. marinus* have higher activities than the Icelandic samples is an indication that these fish must have spent some time in an area with higher levels and Norwegian waters are the obvious candidate. The activity of the male Faroese *S. marinus* was found to be in between the Icelandic and the Norwegian samples. This may be expected if the fish came to Faroese waters from the Norwegian area. When a fish has spent considerable time in a high-level area and then leaves it for a low-level area the activity in the fish will decrease with time until the fish is in equilibrium with its new environment. For *S. marinus* we have no information on the time required for this equilibration; but the result indicates that it is sufficiently long to have kept the Cs-137 activity of the male Faroese *S. marinus* above the equilibrium for Faroese waters. This is consistent with a Norwegian origin of this male although with just one sample the conclusion is weak.

The conclusion is considerably strengthened, however, by the result for the female Faroese *S. marinus*. With a Norwegian origin female Faroese *S. marinus* might have been expected to have higher activities than the males as the female apparently makes regular (almost annual) migrations to the spawning area. The very high activity of the one female Faroese *S. marinus* analyzed is consistent with this. It may appear confusing that the activity of this fish is well above all the Norwegian samples; but it should be kept in mind that redfish in Norwegian waters cover a large area throughout which sea water activity varies.

Thus the results in Table 2 do indicate a Norwegian rather than Icelandic origin of the Faroese *S. marinus* which were sampled. For *S. mentella* the argument is considerably weakened by the fact that no Icelandic *S. mentella* were analyzed and only one sample from Norway which was not analyzed exactly as the others; but it may be noted that the Norwegian sample of *S. mentella* has about the same Cs-137 activity as the Norwegian *S. marinus* and also for the Faroese samples the levels of the two species seem comparable.

Many questions may be raised to the arguments above: Do differences in age composition account for some of the variation in Tables 2 and 3? Are there geographical variations within each area? How does the recent increase in East Greenland sea water activity affect the conclusions ? etc. It must be stressed, however, that this was only a pilot study and the very small number of samples analyzed does not warrant detailed analyses at the same time as it precludes any definite conclusions. We see indications that some of the *S. marinus* in Faroese waters originates in Norwegian waters; but we can not exclude the possibility that there is an Icelandic input also. Neither can we conclude anything about the origin of *S. mentella* although there is a very weak indication that it behaves like *S. marinus*.

There is, however, a clear conclusion that the method has the potential for clarifying the origin of Faroese redfish and possibly also may give some information about mixing between the Icelandic and the Norwegian redfish. We recommend that resources are allocated for a more thorough study including more statistically representative samples from all three regions from which sexual, geographical and age related variation can be identified so that the basic question of stock division can be addressed more rigorously. It must be kept in mind, however, that the differences in sea water activities between the areas are decreasing and the unique opportunity of utilizing this inadvertent tagging of redfish (and other migratory Northeast Atlantic species) may not exist for much longer.

Acknowledgements

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