SOME CHARACTERISTICS OF THE PELAGIC REDFISH (*SEBASTES MENTELLA* TRAVIN) FROM WEATHER STATION ALFA

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The existence of a permanent pelagic population of the redfish *Sebastes mentella* Travin in the Irminger Sea has been confirmed as a result of successful angling trials carried out by ships occupying Weather Station Alfa (62° N, 33° W) during the years 1962 to 1965. No specimens of *S. marinus* or 'intermediate' forms were found amongst the 207 specimens returned to the laboratory. The sample was predominantly female (7:1) although males were found in equal or greater numbers in the period late December to March. All females were sexually mature and all males were approaching or had reached full sexual maturity.

Captures were made at depths ranging from 50 to 350 m but chiefly between 100 and 150 m in the summer. Fishing was most successful during the periods May to August and December to March.

There was considerable but continuous variation in body proportions and age/length relationships. Much less variation occurred in the numbers of vertebrae and of pyloric caeca.

Allowing one pair of growth rings to one year's growth, it is thought that the ages ranged from approximately 15 to 57 years, with a mean age of 31 years and it is believed that sexual maturity in females occurs between 15 and 25 years of age. Fecundity, which varies according to size (length), ranges from approximately 20,000 to 150,000.

No evidence was obtained to show the relationship of this population to any other redfish population nor is there any clear evidence to demonstrate migration or movement. The seasonal variation in the number of males caught at Station Alfa may possibly be due to either horizontal or vertical migration.

INTRODUCTION

Nansen (1886) was the first to suggest the possible existence of shoals of pelagic redfish over deep water. His suggestion was confirmed by Hjort (1909) who carried out successful long-lining trials in the Norwegian Sea at 100 fathoms, over a depth of 1400 fathoms, but in the North Atlantic the existence of similar stocks of redfish was not confirmed for many years. Dannevig (1919) believed that pelagic redfish could be found over deep water in the northern seas between America and Europe, although he gave no evidence for the capture of such fish, and it was Tåning (1949) who eventually recorded that a specimen had been captured in 1931, (53° 38′ N, 29° 41′ W). Because of his knowledge of the extensive distribution of larval redfish and of the temperature conditions in the North Atlantic, Tåning believed that there was a similarly extensive distribution of a permanent adult population. Kotthaus (see Templeman, 1959) held a different view, believing that adult redfish were present over deep waters of the open ocean for only a short time during the spawning period. However, a programme of sampling for these adult redfish

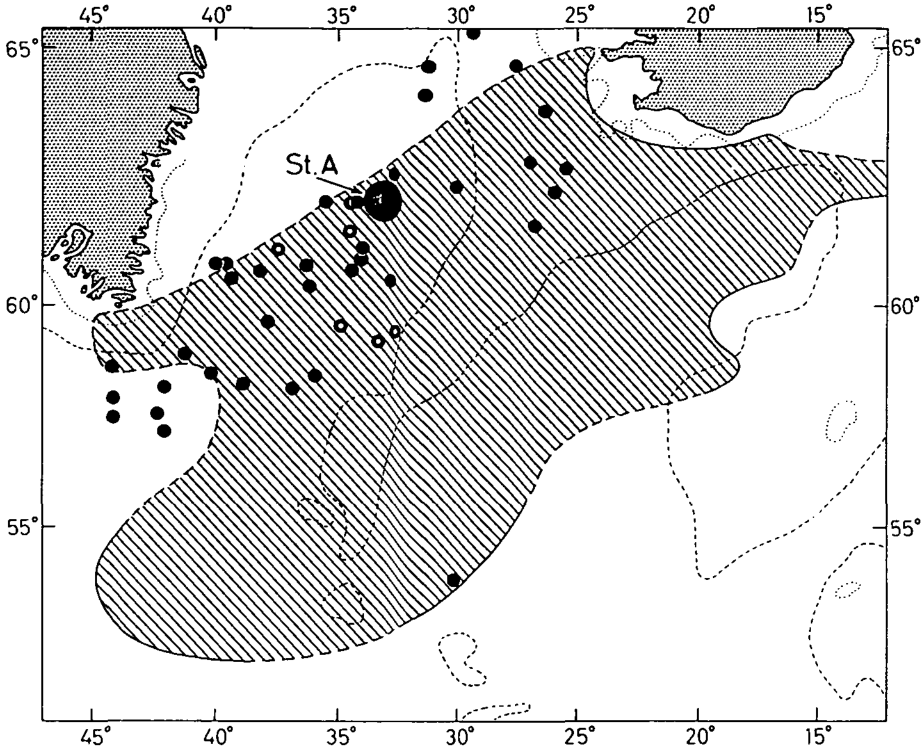


Figure 1. The distribution of *Sebastes* larvae in May (shaded area) based on material obtained by the Continuous Plankton Recorder (after HENDERSON, 1964). The broken parts of the line bordering the shaded area indicate that sampling was insufficient to determine the boundaries with precision. Captures of adult fish are recorded by solid circles (*S. mentella*) and circles with a white centre ('intermediate' forms). Data were obtained from TÅNING (1949), ZAKHAROV (1964), JONES (in press) and the trials at Station Alfa, (St. A.), 62° N, 33° W, 1962–1965. Dotted contour line = 200 m. Dashed contour line = 2,000 m.

had not been undertaken at this time and the two points of view remained unreconciled.

The extension of the Continuous Plankton Recorder Survey (GLOVER, 1962) westward across the North Atlantic and into the Irminger Sea led to the regular sampling of larval redfish throughout the summer months. The distribution of these larvae (see Figure 1) and the seasonal and annual fluctuations in their numbers were first reported by HENDERSON (1961). In that paper (p. 190) he records the capture, during the early summer of 1961, of "plenty of (adult) redfish" at Weather Station Alfa (62° N, 33° W). These fish were presumed to be part of the parent stock and had been caught by rod and line from a Dutch weather ship. As a result of this success, a series of angling trials was planned by the Oceanographic Laboratory and carried out from the weather ships at Station Alfa. The chief objects of the trials were to identify the parent stock, to clarify some problems of larval identification, and to determine the permanency or impermanency of the adult population over deep waters. In addition, various measurements of the size and shape of the fish were made in order to assess the variation within the sampled stock and, if possible, to determine the relationship of these fish to the commercially caught redfish from the adjacent, shallower waters.

The trials began in April 1962 and continued, with a short break in the autumn of that year, until the end of March 1965. Sea-angling gear, suitable for fishing to a depth of 400 m, was issued to Dutch, Norwegian, French and British weather ships with a request that they should fish for a few hours during each week on station.

Between May and July 1963 these trials formed part of the ICNAF NORWESTLANT surveys. A report on the fishing that took place on Station Alfa and elsewhere in the North Atlantic during that period is being published separately (JONES, in press) and includes a description of the gear and the methods of fishing.

The present paper deals with the full period of the trials at Station Alfa only and examines the results of the fishing and some of the physical characteristics of the fish. The problem of larval identity has been dealt with elsewhere by HENDERSON (1964).

Special attention has been paid to examining the data for seasonal variation in physical features which could help to distinguish different groups within the sampled population and which could, in extended studies of this type, be compared with data taken elsewhere and at different times.

RESULTS

1. NUMBERS, DEPTH DISTRIBUTION, SIZE AND SEX RATIO

(Tables 1 and 2)

More than 800 hours of line-fishing on Station Alfa have resulted in the capture of approximately 1000 redfish. Some of this fishing was carried out by the crews of the weather ships for sport and to provide fresh fish for the galley. Consequently, only 207 specimens were returned to the laboratory for examination. Fishing was carried out on 232 days, the duration of the attempts varying from less than one to more than twelve hours, and on 83 occasions (35·8 %) some fish were caught. The greatest success was obtained in the summer months and, although the degree of success varied during the rest of the year, consistent failure to catch fish despite considerable fishing effort was only reported for one month, December 1963.

It is impossible to calculate the relationship between the fishing effort and the success of fishing because the number of lines in use and the number of hooks per line varied, but a positive relationship was noted between the success of fishing and an increase in the number of fishermen. This may account for the exceptionally high daily catches in July 1963 and May and August 1964. Catches of up to six fish per line per hour were recorded during

TABLE 1. Details of fishing effort and catches of *S. mentella* from Weather Station Alfa, 1962–65.

	Months	Days fishing attempted	Fish caught	Fish examined in laboratory	Sex ratio ♀ : ♂	Mean standard length cm	Mean body weight kg	Most successful depth of capture m	Range of depth of capture m
1962	April	2	0	–	–	–	–	–	–
	May	9	5	3	2:1	31·0	·83	100	80–200
	June	11	66	14	13:1	31·4	·79	100	80–120
	July	16	34	8	8:0	31·6	·79	120	50–150
	August	13	5	5	4:1	32·0	·90	120	80–120
	September } October }	?	12	0	0	–	–	–	–
	December	?	P	0	0	–	–	–	100–200
1963	January	?	P	7	5:2	32·7	·86	<280	–
	February	1	9	5	4:1	32·2	·84	200+	–
	March	4	P	8	1:1	30·5	·73	250	200–300
	April	3	3	0	–	–	–	>200	–
	May	9	55	10	10:0	31·6	·79	250	200–300
	June	23	69	68	16:1	32·0	·81	120	80–300
	July	10	139	39	37:2	31·9	·84	100	100–150
	August	13	25	5	5:0	31·2	·74	200	–
	September	9	0	0	–	–	–	–	–
	October	9	2	2	2:0	32·4	·9–1·1	–	150–300
	November	11	4	3	3:0	32·4	·8–1·0	150	150–200
	December	10	0	0	–	–	–	–	–
1964	January	6	0	0	–	–	–	–	–
	February	16	12	7	3:4	30·4	·73	200	100–250
	March	10	0	0	–	–	–	–	–
	April	6	0	0	–	–	–	–	–
	May	10	271	8	7:1	30·8	·75	180	150–250
	June	3	0	0	–	–	–	–	–
	July	7	0	0	–	–	–	–	–
	August	3	136	5	4:1	32·0	·84	200	150–350
	September	2	14	3	3:0	33·7	·90	–	200–300
	October	?	0	0	–	–	–	–	–
	November	?	0	0	–	–	–	–	–
	December	?	6+	6	1:5	28·5	·53	?	?
1965	January	0	0	0	–	–	–	–	–
	February	6	0	0	–	–	–	–	–
	March	?	1+	1	1:0	36·0	1.1	150	–
Total & means		232+	868+	207	7:1	31·7	·80	–	–

P reported as 'plentiful' or 'hundreds'

the most successful periods. One report was received of seven fish being taken together on one line and, during good fishing conditions, fish were caught as rapidly as the lines could be hauled and reshot. It is of interest to compare these numbers with the results of mid-water trawling trials for redfish given by ZAKHAROV (1964). He reported that, during a North Atlantic cruise of the "Pobeda" in June 1962, only 76 redfish were caught in 73 one-hour trawls.

Fishing was generally unsuccessful each year in April. This was presumably because it is the time at which spawning begins and it is believed that the ripe females descend below 400 m to spawn (EINARSSON, 1960). This depth is the maximum attained by the fishing gear when the lines hang vertically in the water. The failure of fishing on certain occasions may have been because the drifting of the ship prevented the gear from reaching its maximum depth. Indeed, for this reason, an accurate determination of the depth of capture was sometimes difficult.

An estimate of the most successful depth of capture is given for each month, together with the range of depths from which captures are believed to have been made (Table 1). In general terms the fishing seems to have been most successful between 100 and 150 m in the summer months; fishing at other depths, when tried at the same time, was usually unsuccessful. On most occasions, captures made at other times of the year were from greater depths, down to a maximum of 350 m. No further pattern in the seasonal figures can be seen and depth distribution does not appear to be related either to size or sex so far as can be judged from the available data. The shallowest depths from which redfish have been caught during these trials are 50 m (once) and 80 m (four occasions).

Size has been recorded in three ways: the overall or maximum length, the standard length, both measured in centimetres, and total body weight measured in kilograms.

It is sometimes difficult to compare published morphometric data from a variety of sources because different measurements have been used and because differences occur between the measurements of freshly-caught fish and of those that have been preserved, for example, in formalin. During these trials a test was carried out to measure the amount of shrinkage that occurred after preservation in a 10% formalin solution (4% formaldehyde). Measurements were taken from 35 freshly-caught redfish and the same fish were remeasured after some weeks preservation in formalin. A reduction in overall length of up to two centimetres had occurred. This reduction, together with differences between standard length (snout to the root of the tail), overall length and fork length means that, for fish in this size range, there may be a discrepancy of 6 to 8 centimetres between the figures given by various authors.

In this survey the standard length of formalin-preserved specimens is considered to be the most suitable measurement of size, because damage to the caudal fin has sometimes invalidated the measurements of overall length and, for body weight, allowance has to be made for the variable weight of the gonads at different seasons of the year. The ovaries may vary from as much as 18% of the total body weight shortly before the larvae are liberated, to 1% or less in the month following spawning.

The standard length of the 207 fish varied from 26 to 37 cm, equivalent to an overall length of 30 to 43 cm; males were significantly smaller than females ($p = 0{\cdot}05$).

Table 2 shows the mean and range of standard lengths and body weights for each sex. No obvious pattern in the monthly distribution of these data was apparent, but such patterns, if present, may have been obscured by the small

TABLE 2. Standard length and body weight of *S. mentella*.

		Standard length (cm)		Total body weight (kg)	
	Number	Mean	Range	Mean	Range
Females	181	32·01	28–37	0·83	0·5–1·2
Males	26	29·73	26–34	0·66	0·4–0·9

size of the samples in some months. The monthly data for female fish were examined carefully for evidence of an annual recruitment period but none was found. Where fishing was successful it was evident that a variety of sizes of fish occurred in the same locality, a day's fishing producing both female and male fish, ranging, for example, from lengths of 20·0 to 35·0 cm or more than 50% of the full range of standard lengths found in all the samples.

It has been reported by other workers that, except at mating time, the sexes tend to be segregated and follow different paths from the breeding grounds to their feeding grounds. SOROKIN (1961), for the Barents Sea and MAGNUSSON (1955), for Icelandic waters, give the times of sexual parity (and mating) as August to October and October to December respectively. In the pelagic population sampled at Station Alfa parity or male dominance was found only from late December to March and in the period September to November no males were taken at all, although this period was poorly sampled in all years. Males were found in each month of the post-spawning period (May to July) although they were few in number. This does suggest that there is not a complete separation of the sexes similar to that recorded for other populations. The overall dominance of the female redfish in this area is shown by the average sex ratio of 7:1 for all times of the year.

2. BODY MEASUREMENTS AND IDENTIFICATION

(Tables 3 and 4 and Figures 2 and 3)

The following external body measurements were recorded from all redfish returned to the laboratory during these trials: overall and standard length, body depth, head length, snout to ventral fin and snout to anal fin, schnabel length (the bony protuberance of the lower jaw), orbit diameters horizontal and vertical and the interorbital distance. In addition, an eleventh measurement, the post-orbital length was measured on 128 specimens. Otolith length and otolith width were measured for each fish. Pyloric caeca were counted in 202 fish and vertebrae in 120. The number of growth rings in the otoliths of 88 specimens was counted and the results of all these measurements will be found in Tables 3 and 4 and Figures 2 to 4.

The morphometric data were collected principally for the purpose of detecting races or stocks within the sampled population but were also used in the first instance to confirm identification at the specific level. All 207 fish conformed to the published criteria for *Sebastes mentella* Travin. Apart from difference in colour and the presence or absence of the schnabel on the lower jaw, the key (ANDRIYASHEV, 1954) for the separation of the two species or subspecies, '*marinus*' and '*mentella*', is based on relative measurements of parts of the head. These are: the proportions of the horizontal orbit diameter (HOD) to the head length (HL) and to the post-orbital length (POL). TRAVIN, (1951) in his original separation of the two forms, expressed these proportions as percentages and found that the levels which separated '*marinus*' from '*mentella*' were 26% for the first measurement and 60% for the second; the higher figures referred specimens to the '*mentella*' type in each case. The mean values that he obtained from 100 specimens of *S. mentella* caught near Bear Island in the Barents Sea were as follows: HOD/HL × 100 = 29·2% (range 23·5–35·5%) and HOD/POL × 100 = 70·0% (range 58·5–90·5%). The

TABLE 3. Body measurements of *S. mentella* from Weather Station Alfa. Mean values for each size group. Ranges of observations are given in parentheses.

Standard length cm	No	Body depth mm	Head length mm	Snout/ventral fin mm	Snout/anal fin mm	Schnabel mm	Orbit diameter (vertical) mm	Orbit diameter (horizontal) mm	Inter orbital distance mm	Otolith length mm
Females										
28	2	100·5	105·5	112·5	191·5	10·5	35·5	36·6	22·0	15·3
		(100–101)	(103–108)	(111–114)	(191–192)	(10–11)	(34–37)	(34–39)	(20–24)	(15·0–15·5)
29	13	103·8	104·8	113·8	190·5	11·3	33·7	34·7	20·7	14·6
		(99–110)	(99–110)	(106–125)	(183–200)	(10–14)	(30–38)	(32–40)	(17–23)	(13·5–16·0)
30	20	109·8	110·3	119·2	200·4	12·4	36·5	38·5	24·2	15·3
		(96–119)	(103–118)	(109–131)	(195–209)	(10–14)	(32–41)	(34–46)	(18–24)	(14·0–16·0)
31	42	111·9	112·8	120·0	206·1	12·7	37·2	39·0	22·4	15·8
		(98–126)	(106–120)	(109–131)	(187–220)	(12–14)	(31–42)	(33–44)	(18–25)	(13·5–18·0)
32	39	116·5	116·2	125·0	212·0	13·1	37·7	41·0	22·6	16·0
		(105–130)	(105–126)	(106–142)	(189–227)	(12–15)	(32–42)	(34–45)	(18–26)	(14·0–17·5)
33	26	119·1	118·8	129·7	218·3	13·3	38·5	40·1	23·7	16·3
		(109–128)	(110–126)	(116–139)	(210–230)	(12–14)	(34–43)	(36–45)	(20–26)	(14·5–17·5)
34	25	121·6	120·7	130·2	226·2	14·0	38·9	40·8	24·7	16·5
		(110–132)	(110–127)	(110–142)	(210–245)	(13–15)	(32–43)	(35–45)	(21–25)	(15·0–18·0)
35	5	122·8	124·8	136·2	230·6	15·2	40·6	42·2	24·2	17·0
		(111–130)	(117–130)	(132–148)	(222–237)	(14–16)	(36–44)	(38–45)	(22–26)	(16·0–18·0)
36	6	125·5	125·5	134·0	221·7	14·0	40·0	42·0	25·5	16·9
		(116–135)	(116–137)	(113–146)	(189–237)	(12–16)	(38–43)	(40–46)	(22–30)	(16·0–18·0)
37	3	129·3	130·3	142·7	236·3	15·0	41·0	43·7	25·7	17·0
		(123–135)	(127–133)	(140–144)	(231–243)	(14–16)	(41)	(43–44)	(25–26)	(16·0–18·0)
Males										
26	2	91·5	94·5	108·0	174·0	9·5	27·0	28·5	21·0	13·0
		(88–95)	(94–95)	(105–111)	(170–178)	(9–10)	(25–29)	(27–30)	(20–22)	(12·5–13·5)
28	4	99·3	102·0	114·8	188·3	11·5	35·0	26·0	21·0	14·4
		(93–104)	(98–106)	(112–116)	(180–202)	(9–13)	(32–39)	(33–40)	(20–22)	(13·5–14·5)
29	4	100·5	106·7	118·0	191·0	11·5	34·5	36·5	21·0	14·8
		(99–104)	(105–109)	(116–120)	(186–194)	(11–13)	(33–35)	(35–37)	(20–22)	(14·0–15·5)
30	9	106·7	110·7	120·0	194·9	12·6	36·9	38·6	21·3	15·7
		(101–112)	(107–117)	(112–132)	(192–205)	(11–14)	(32–41)	(34–43)	(19–23)	(14·0–17·5)
31	3	107·3	113·7	122·7	201·7	13·0	38·3	40·3	21·0	15·7
		(105–112)	(113–115)	(120–123)	(190–215)	(12–14)	(37–39)	(40–41)	(21)	(15·0–16·5)
32	3	113·3	119·0	128·0	201·0	13·7	39·0	41·0	23·7	16·2
		(110–115)	(115–124)	(122–135)	(195–206)	(13–14)	(38–40)	(40–43)	(23–24)	(16·0–16·5)
34	1	107·0	114·0	114·0	180·0	13·0	37·0	39·0	25·0	16·5

specimens from Station Alfa had a mean value for HOD/HL × 100 of 34·2% (range 28·7–40·1%) and for HOD/POL the mean value was 78·7% (range 66·0–93·2%). The frequency distribution of the individual figures is given in Figure 2 together with some comparative data from TRAVIN (1951).

There are two striking points associated with the figures for the specimens from Station Alfa. Firstly, both by the measurements and by observation, there do not appear to be any 'intermediate' forms, resembling a hybrid between *S. marinus* and *S. mentella*, although ZAKHAROV (1964) has recorded this form from the vicinity of Station Alfa (Figure 1). Secondly, the figures suggest that the converse is true and these fish show the characters of '*mentella*' in a more extreme form than the type material from the Barents Sea. The mean values for both these measurements are noticeably higher than those obtained by TRAVIN (1951).

It should be noted however that no data are available for *S. marinus* from waters adjacent to the Irminger Sea and it is possible that this species may provide higher figures for HOD/HL × 100 and HOD/POL × 100 than are obtained from *S. marinus* from the Barents Sea.

Within this sample of *Sebastes mentella* it was thought that certain differences in the body proportions of some specimens were distinguishable by eye. However, these were not sufficiently clear-cut to separate any group of fish from the remainder. To determine whether such apparent differences were genuine, or merely part of a wide general variation, a statistical method of examining the morphometric data was employed.

Standard length was selected as the basic criterion of size and the relationship to this of all other external body measurements was determined. In all eight cases the relationship was found to be linear for the range of size classes sampled. All the data were therefore transformed to figures based on the approximate mean standard length of the sample which was 32 cm.

For a preliminary test, a random selection was made of five female fish from each of the eight size groups that were best represented. The method of analysis used was Principal Component Analysis (KENDALL, 1961) which provided a means of examining, first, the relationship between various body measurements and second, differences in the measurement of maximum variation of body form for each fish.

The relationship between the various body measurements of the fish is given in the correlation matrix (Figure 3). This method of representing body form, if applied to other populations, could be used as a comparative method of study. The value of the method is that wide individual variations are reduced and differences in correlation values will represent different proportional relationships in the body measurements of each population.

A measurement of differences of body form in individual fish was obtained by finding the first component. This accounted for 50% of the total variability and a plot of the values of the component on a linear scale is also shown in Figure 3.

The set of points represent the maximum possible linear discrimination between the fish, based on seven characters. The eighth, vertical orbit diameter, showed complete correlation with horizontal orbit diameter (6 and 7 in Figure 3) and was discarded because it had no further value in the analysis.

The Principal Component Analysis was carried out to discover whether the values obtained for individual fish would fall into two or more groups. The

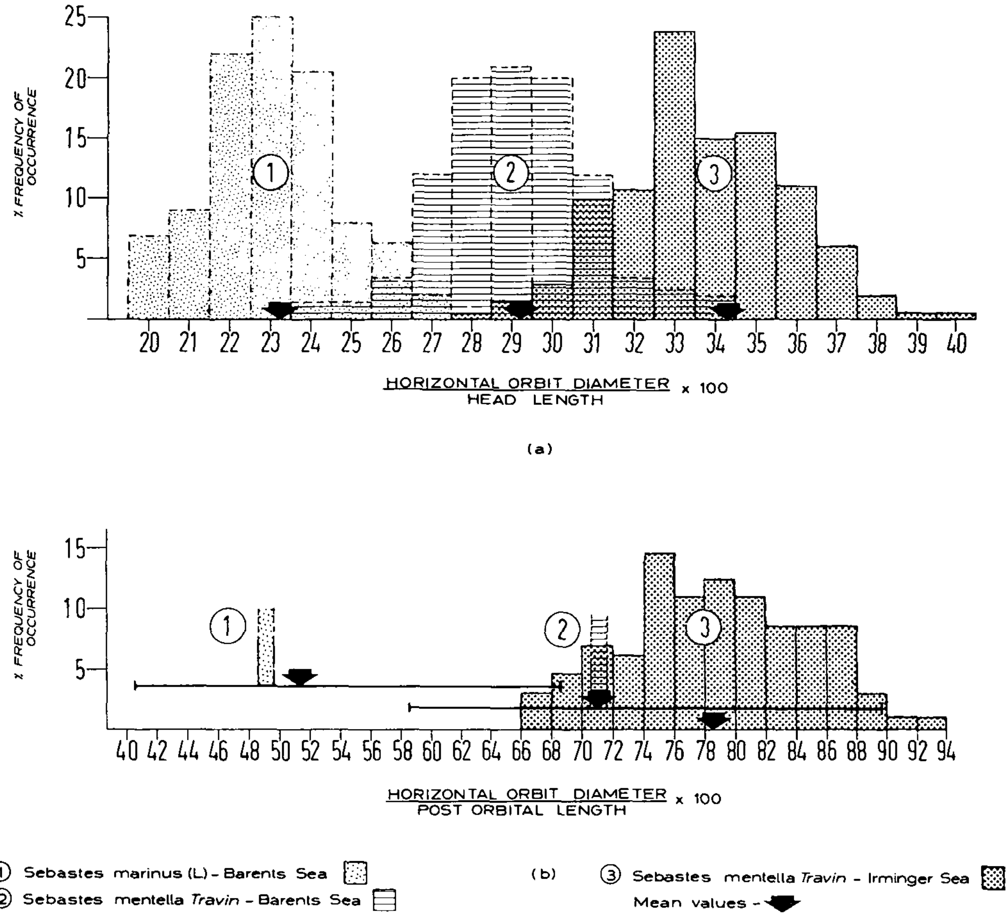


Figure 2. The relationships between (a) horizontal orbit diameter and head length and (b) horizontal orbit diameter and post orbital length. Data for fish from Station Alfa (3) are compared with TRAVIN's (1951) data for *Sebastes marinus* (1) and *S. mentella* (2) from the Barents Sea. Only the modal value and range of observations are given for $\frac{\text{HOD}}{\text{POL}} \times 100$ of the two Barents Sea samples.

presence of such groups would mean that there was an equal number of groups within the sample of fish and that each differed in body form from the others. In this event different origins for such groups would have to be postulated. There was, however, no clear grouping of the first component values and this suggests instead that there is a wide but continuous variation in the body proportions of these fish. The distribution of these values according to time of capture has been examined, but it was found to be random and two fish of widely differing values had been caught, on some occasions, at the same time. This infers that there is no seasonal sequence of variation in body proportions.

Meristic data, in the form of vertebral counts and numbers of pyloric caeca were obtained as measures of variability in conjunction with the morphometric data. Pyloric caeca were counted in all fish in a suitable condition; the number of caeca ranged from 8 to 12; the mean figure for 202 fish was 9·98 and the modal class (42·1 % of the sample) was 10 (Table 4 a). The fish used for vertebral examination were selected to form a sample which was representative of size, sex and date of capture. The vertebral counts, which included the urostyle, ranged between 30 and 32 (Table 4 b) with a mean of 31·13; 85·8 % of the sample had 31 vertebrae. The frequency distributions of both sets of data show normal curves with relatively narrow ranges of observations.

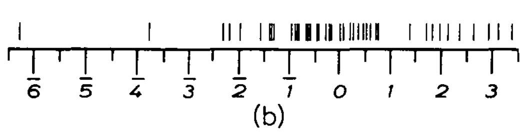
The counts of vertebrae and pyloric caeca did not show any systematic differences, either in the means or ranges, in relation to length class, sex or season.

3. OTOLITHS AND THE AGE/LENGTH RELATIONSHIP

Age determination, growth rates and longevity of redfish have frequently presented difficult problems (ROLLEFSEN, 1961) and there have been disagreements on methods and the interpretation of results. However, it is generally believed that growth is very slow and that the fish may reach a considerable age. Accurate reading of scales or otoliths is made difficult by slow growth and longevity, especially where the higher age-groups are being dealt with, and the data obtained have therefore to be used with considerable care.

	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1)	63	63	51	16	40	42	00
(2)		75	68	35	58	63	$\overline{02}$
(3)			65	14	40	38	$\overline{01}$
(4)				34	39	40	$\overline{03}$
(5)					49	42	$\overline{16}$
(6)						100	$\overline{33}$
(7)							$\overline{32}$

(a)



(b)

Figure 3. A matrix which gives the correlation coefficients (× 100) of 8 body measurements taken from 40 female redfish and, below, the values of the first principal component plotted on a linear scale to show the variation in overall body proportions of the same 40 fish, based on seven of the eight body measurements. Key for body measurements: 1. Body depth. 2. Head length. 3. Snout to ventral fin. 4. Snout to anal fin. 5. Beak (schnabel length). 6. Vertical orbit diameter. 7. Horizontal orbit diameter. 8. Interorbital distance.

TABLE 4. a. Frequency distribution of the number of pyloric caeca

	Number of pyloric caeca									
	8		9		10		11		12	
	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂
Number of fish	8	1	45	7	74	11	43	3	7	3
Percentage	4	4	22	28	42	44	21	2	3	12
Combined figures	9		52		85 (42%)		46		10	

Mean number of pyloric caeca ♀ 9·98
♂ 10·00
Combined 9·98

b. Frequency distribution of the number of vertebrae

	Number of vertebrae					
	30		31		32	
	♀	♂	♀	♂	♀	♂
Number of fish	1	0	92	11	13	3
Percentage	1	0	87	79	12	21
Combined figures	1		103 (86%)		16	

Mean number of vertebrae ♀ 31·11
♂ 31·21
Combined 31·13

The otoliths of all specimens were measured and the pairs of growth rings were counted in the otoliths of 88 fish selected to sample a wide range of size groups. Otolith lengths and standard lengths of the fish were plotted against the number of growth rings; the closest relationship was shown by the former. The distribution of these points and the calculated regression curves are shown in Figure 4, a and b. The mean values demonstrate that, on the whole, increase in age is accompanied by increases both in standard length and otolith length.

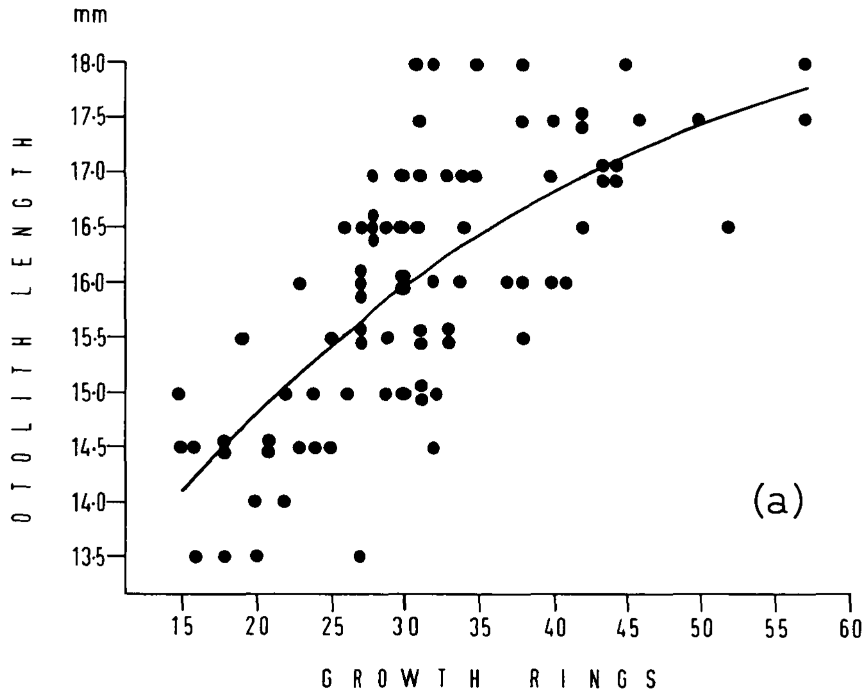
The wide range in the number of growth rings found at any one otolith length indicates that the population is far from homogeneous in the age/length relationship, a finding which is in agreement with the previously recorded variation in relative body proportions.

A comparison of the data for growth rings with those for gonad maturity suggests that the population sampled at Station Alfa consists only of sexually mature fish and that their ages range from approximately 15 to nearly 60 years.

A sample of the otoliths (27) was read by Mr E. J. SANDEMAN of the Biological Station, St. John's, Newfoundland. In general there was a good agreement between the two sets of figures and where there were differences, they were unimportant with the exception of two fish whose otoliths I read as 15 and 16 and SANDEMAN read as 11 and 9. It may, therefore, be necessary to allow for an extension of the age range and an earlier first maturity.

4. FECUNDITY

BAXTER (1959) and BAGENAL (1966) have demonstrated for herring and plaice respectively, that variations in fecundity can be used as a method of distinguishing races of fish. It is likely that such methods will eventually be of value in racial studies of *Sebastes* spp. although at present few data are available



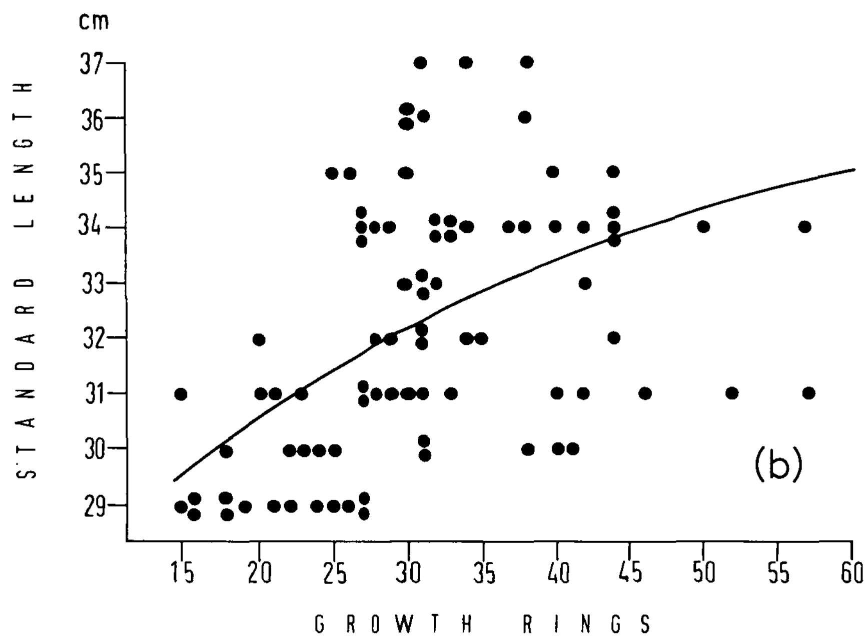


Figure 4. The relationships between (a) the number of growth rings (GR) and otolith length (OL) and (b) between the number of growth rings and standard length (SL). Regression equations ($Y = ax^b$) are (a) $\log_{10}$ GR = 2·8382 $\log_{10}$ OL − 1·9330. r = 0·71, significant at the 0·1% level. (b) $\log_{10}$ GR = ·1207 $\log_{10}$ SL + 1·3292. r = 0·33, significant at the 1% level.

and none which compare the fecundities of *S. mentella* from different areas.

RAITT and HALL (1967) have carried out such studies on *Sebastes marinus* from both Icelandic and Faroese waters and conclude that there are significant regional and annual differences. BAGENAL (1966) points out that there are year-to-year variations in the length/fecundity relationship and such variations must be considered when attempting to attach a value to a particular geographically-defined population. Unfortunately, there are insufficient data to determine annual variations in the sample from Station Alfa. During the three-year period of the trials, 69 fish were found to be suitable for estimations of fecundity. These estimates were carried out by a sub-sampling technique (see JONES, in press), which was found to be accurate by checks made with the egg-counting machine at the Marine Laboratory, Aberdeen.

There are differing opinions as to the relative values of estimates of fecundity made before or after internal fertilization or immediately before spawning (e.g. RAITT and HALL, 1967). The specimens examined in this survey showed no apparent change in the fecundity/length relationships at different stages of the ovarian cycle. While there are bound to be losses due to non-fertilization, failure to hatch and failure to release young, these differences are believed to be small compared with those that may occur among individuals of one length-class. Observations made on spent ovaries during the present investigation give the impression that, generally, the numbers of larvae retained and the number of unfertilized eggs undergoing resorption is very low indeed, and only in exceptional circumstances, (e.g. blockage of oviducts by heads of *Sphyrion*) will it reach as much as 1% of the actual value.

Mean fecundity is given in Table 5 for each 1 cm length class based on overall length. The overall mean fecundity of this sample of fish was estimated to be 58,146.

The relationship between overall length and fecundity has been calculated and is expressed by the relationship $F = aL^b$. To bring this to a linear form the figures have been transformed to log values and the resultant equation is $\log_{10} F = 2{\cdot}3831 \log_{10} L + {\cdot}9738$. A correlation coefficient of 0·43 was obtained and this is significant at the 0·1% level. The distribution of the individual points and the trend line provided by the regression equation are given in Figure 5. The use of the expression $F = aL^b$ assumes that the

TABLE 5. Estimated fecundities of *S. mentella* from Weather Station Alfa

Overall length cm	No.	mean fecundity	range of fecundities	calculated fecundity
33	1	42,864	–	39,140
34	4	34,020	24,460 – 40,258	42,040
35	4	48,464	32,776 – 73,550	45,180
36	11	50,003	17,598 – 72,777	48,170
37	10	52,216	37,980 – 69,669	51,410
38	14	62,010	36,515 – 89,000	54,800
39	5	69,749	33,363 – 90,759	58,300
40	6	73,039	39,542 – 109,410	61,930
41	7	76,179	42,206 – 145,637	65,670
42	3	66,612	64,729 – 69,076	69,530
43	4	54,357	41,816 – 71,400	73,590

Sample mean (69 fish) = 59,426
Population mean (179 fish) = 58,146

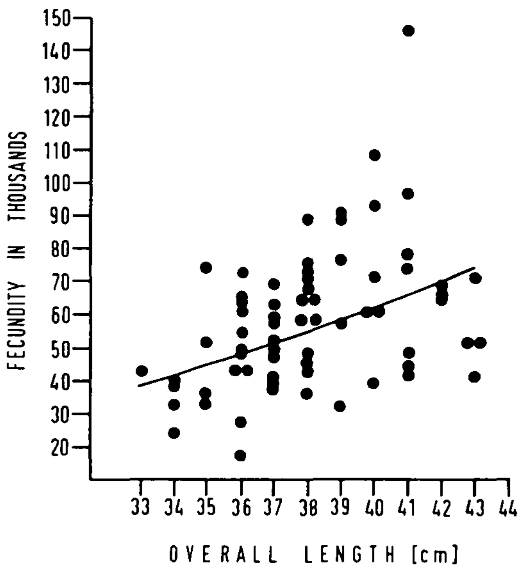


Figure 5. The relationship between overall body length and fecundity. Regression equation ($F = aL^b$) is $\log_{10} F = 2{\cdot}3832 \log_{10} L + {\cdot}9738$. $r = 0{\cdot}43$, significant at the 0·1 % level.

relationship between length and fecundity is of the normal curvilinear shape, fecundity increasing progressively with increasing length, although the upper two length classes show mean fecundity values lower than the three preceding classes.

In his studies on the fecundity of plaice, BAGENAL (1966) found that the relationship between size and fecundity was closer than that between age and fecundity. Where estimates of both parameters had been made for fish from Station Alfa (40 fish) a similar result was found and therefore a lower mean age for the upper length-classes is unlikely to account for their lower mean fecundity values.

Confirmation of the relationship between fecundity and size is obtained, firstly, by comparing the values for the pelagic *S. mentella* from the Irminger Sea with those given for *S. marinus* from Faroese and Icelandic waters by RAITT and HALL (1967). Although there are differences in the length reached at the onset of maturity and in the maximum size, calculated values for fecundity over a comparable size range are very similar. Secondly, the relationship is also confirmed by comparing the ranges for these two species with data that I have obtained for *S. viviparus* from the North Sea. These data, with CORLETT's (1964) results for large *S. marinus* provide the following table:

	Overall length Range (cm)	Range of fecundities x 10^3
S. viviparus	14·5–25·0	2– 54
S. mentella	33·0–43·0	18–145
S. marinus	32·0–73·0	20–337

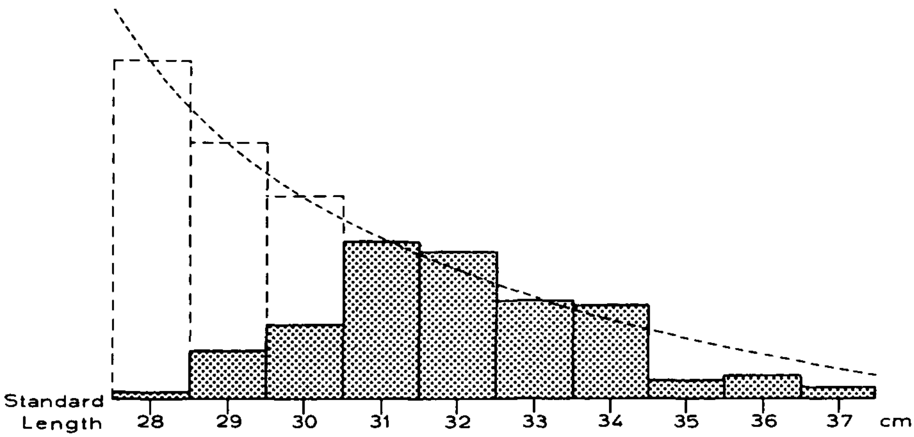


Figure 6. The size composition of the sample of female redfish from Station Alfa. A hypothetical population curve is given to indicate the proportion of well-grown but probably immature fish that are missing.

DISCUSSION

Three of the four main objects of these fishing trials have been achieved. The identity of the parent stock has been confirmed as *Sebastes mentella* Travin. There seems to be little likelihood that either *S. marinus* or intermediate forms occur in significant numbers at any time of the year in the vicinity of Station Alfa, especially within the depth range investigated.

Material obtained from the ovaries of some fish has provided information on the larval characters and identification. HENDERSON (1964) has demonstrated from this material that no distinction can be made at present between the larvae of *S. mentella* and *S. marinus* in the area to the south and south-west of Iceland.

The suggestion that a population of pelagic redfish exists in this area throughout the year (TÅNING, 1949) has been confirmed, although, because of the limitations of these trials, no conclusions have been reached on the extent or density of the population. These very limitations, however, suggest that it is by no means an insignificant population.

The biological and physical characteristics of the sampled population that have been recorded include depth distribution and seasonal occurrence in general terms, the size and sex composition of the sample and their body proportions. Numerous examinations of the data were made to test, firstly, whether the variations in the latter can be related to age, size or season, and, secondly, whether there were cyclic patterns of variation such as might result from regular movements of the population. No systematic patterns were detected and the results, in particular the Principal Component Analysis, do not suggest regular movements, because they do not divide the fish into any distinct groups. The wide, continuous, variation in body form that occurs is found randomly, at all times of the year, in fish of all ages and in fish caught at one time.

Only one test, based not on body proportions but on the variations in sex ratio, suggests the possibility of horizontal movement within the population.

This refers to the variation in the proportion of male redfish in the populations to the south and west of Station Alfa during the summer months.

If the sample obtained during these trials is fully representative of the pelagic populations of *Sebastes* in the Irminger Sea then it appears to consist only of sexually mature fish. The frequency distribution of the size groups (Figure 6) shows that there is a slow increase in numbers from 28 cm, reaching a maximum in the 31 cm class. The possible explanation for this distribution may be that the onset of sexual maturity in the females of this population occurs over a period of years and the majority have attained maturity when they are about 31 cm. Although considerable variation in the number of growth rings was found in the 31 cm standard length class (Figure 4 b) this length corresponds to a calculated age of approximately 25 years. Evidence of a slow and late onset of maturity occurring at ages comparable with those suggested here, is found in the literature. SANDEMAN (1961), reporting on the age and growth of the Hermitage Bay population of *S. mentella* shows a growth curve for female fish (p. 282) in which the greatest change in the angle of the slope (which will occur at the onset of sexual maturity) is at 20 years of age.

The fourth main object of these trials has not been achieved and further observations must be made to discover whether there is any link, directly in the case of adults, or indirectly through the juvenile stages, with the coastal stock of south-west Iceland or east Greenland. It is also possible that an extension of the pelagic redfish population exists to the south and west of the Irminger Sea. This might provide a link with redfish from the continental slopes of the north-western Atlantic and with the recently reported (TEMPLEMAN, 1967) pelagic adult population of *S. mentella* from the central part of the mouth of the Labrador Sea. Similar pelagic populations are believed to occur in the ocean basin north of Iceland and Norway (HJORT, 1909). If their presence is confirmed a continuous stock of redfish may exist from the Gulf of Maine to the Barents Sea.

The results of various fishing trials for pelagic redfish are shown in Figure 1. Some of the fish were taken due south of Greenland. However, each symbol does little more than record a position where fishing has been carried out and most trials have been of brief duration and have used a variety of gear.

The adult distribution is no doubt directly related to the larval distribution in the immediate post-spawning period (Figure 1), but until there has been adequate sampling over the whole area throughout the year there is no certainty that all this area is occupied permanently.

Despite the lack of information on stock relationships and movements, sufficient information has been collected from pelagic redfish caught at Station Alfa to produce the following summary list of characteristics which may perhaps be considered as a provisional key to help in separating them from, or linking them to, other beaked redfish from the North Atlantic.

1. Depth of occurrence not less than 50 m and generally above 350 m except perhaps at spawning time. In the summer months about 100–150 m.
2. Females predominate (18:1) in the summer months, but during the first three months of the year the sex ratio is about 1:1.
3. Size range 26–37 cm standard length (approx. 30–43 cm overall preserved length) and weight between 0·4 kg and 1·2 kg. Females sexually mature: males either with developing testes or mature.

4. All strongly '*mentella*'-like, according to the key of ANDRIYASHEV. Mean HOD/HL $\times$ 100 = 34·2%. Mean HOD/POL $\times$ 100 = 78·6%.
5. Individual body measurements showing considerable variation in fish caught at the same place and time but conforming to a normal distribution. Having a relationship between body proportions as expressed by the correlation matrix and by the distribution of the first component values (Figure 3).
6. Having an average vertebral count of 31·13 (including the urostyle) and an average number of pyloric caeca of 9·98. Otolith width forming, on average, 61 % of otolith length in the females. Age ranging from 15–57 years: average age approximately 31 years.
7. Potential fecundity, measured throughout the year (except for April/May) of 58,146. The relationship between overall length (L) and fecundity (F) may be expressed by the equation: $\text{Log}_{10} F = 2{\cdot}3832 \text{ Log}_{10} L + {\cdot}9738$.

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SUMMARY

1. Angling trials for redfish (*Sebastes mentella* Travin) were carried out at Weather Station Alfa (62° N, 33° W) in the North Atlantic between April 1962 and March 1965.
2. A thousand redfish were caught. The most successful fishing was either in the summer months (May–August) or in the winter (December–March). In April fishing was unsuccessful and in the autumn only sporadically successful.
3. Depths of capture ranged from 50–350 m; the most successful fishing in the summer was at 100–150 m.
4. Two hundred and seven fish were examined. All the females were sexually mature and the males either mature or approaching full maturity. Females predominated in the sample (average sex ratio 7:1) but from December to March males were as numerous as females.
5. Analysis of eight body measurements suggests that there is continuous variation in the proportions of these, relative to standard length.
6. The standard identification key, plus additional measurements, confirms the identification as *S. mentella* Travin but suggests that the '*mentella*'-like features are stronger than those of the type material from the Barents Sea.
7. Meristic data (vertebral number and number of pyloric caeca) show less variation than morphometric data.
8. Age/Length studies show that there is considerable variation, ages range

from approximately 15 to 57 years with a wide range of ages per length class.

9. Fecundity increases in proportion to body length. A mean fecundity of approximately 58,000 was obtained for the sample.
10. There is no evidence of large-scale migrations of these pelagic redfish nor of any relationships with populations on the continental slopes or shelves.

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