

# Incidence of Subcaudal Melanophores in Pre-extrusion Larvae of Redfish Species in the Newfoundland-Labrador Area

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## Abstract

Pre-extrusion larvae of female redfish from the Newfoundland-Labrador area in 1958-66 were examined for the presence or absence of subcaudal melanophores. The larval samples from the sharp-beaked *mentella*-type redfish were readily separated into two groups, one with all or nearly all of the larvae possessing subcaudal melanophores and recognized as *Sebastes fasciatus*, and the other tending to have a small fraction or none of the larvae with these melanophores and recognized as *Sebastes mentella*. Moreover, the larvae of *S. fasciatus* had on the average a greater number of subcaudal melanophores which were also usually larger than those of *S. mentella*. However, the presence of these melanophores in many of the North American *S. mentella* contrasts with the reported absence of subcaudal melanophores in larvae of Icelandic and Northeast Atlantic and of the North Atlantic oceanic populations of *S. mentella*. The female parents of larvae assigned to *S. fasciatus* had significantly lower vertebral, anal fin-ray and dorsal fin-ray numbers than those of larvae assigned to *S. mentella*.

The occurrence of subcaudal melanophores in *Sebastes marinus* larvae generally resembled that in the North American *S. mentella* (as distinct from *S. fasciatus*) except that the former tended to have more larvae with melanophores than the latter. The meristic characteristics of the *S. marinus* parents more closely resembled those of *S. mentella* than those of *S. fasciatus*, but the fin-ray numbers in *S. marinus* tended to be lower than in *S. mentella*.

In the Northwest Atlantic area from Flemish Cap to southern Labrador, the spawning females of *S. mentella* appear to live deeper and extrude larvae earlier in the year than those of *S. fasciatus* and *S. marinus*. These differences in distribution and biology and the occurrence of large immature *S. mentella* in the northern part of Newfoundland-Labrador area have management implications which are discussed.

## Introduction

Tåning (1949) (see also Hansen and Andersen (1961) and Tåning and Bertelsen (1961) for more detail) discovered large quantities of oceanic redfish fry in late June and early July in the area between the south of Iceland and Greenland and north of Flemish Cap. In the area north of Flemish Cap, he also found the young of American redfish which he believed were carried by currents from Flemish Cap. Tåning and Bertelsen (1961) noted the absence in the oceanic form and the presence in the American form of a melanophore in the cleft between the two large hypural plates, the latter larvae thus resembling those of *Sebastes viviparus*. These American larvae noted by Tåning (1949) were larger than, and the caudal melanophore pattern different from, those subsequently described by Templeman and Sandeman (1959), who found, in their examination of pre-extrusion larvae of *Sebastes marinus* and of the sharp-beaked *mentella*-type redfish from the continental slopes of the Newfoundland-Labrador

area, that a much larger proportion of the *mentella*-type larvae had subcaudal melanophores similar to those in *S. viviparus* larvae of Tåning and Bertelsen (1961).

These observations in the Northwest Atlantic stimulated a number of researchers to examine well-developed but unextruded larvae of *S. mentella* from the central and eastern regions of the North Atlantic (Kotthaus, MS 1961; Henderson, 1964; Henderson and Jones, 1964; Raitt, 1964; Jones, 1968). These authors reported that the larvae of *S. mentella* did not possess the group of subcaudal melanophores noted by Templeman and Sandeman (1959). The oceanic redfish population southwest of Iceland and south and southwest of Greenland, and by inference the oceanic redfish larvae extending from these areas to north of Flemish Cap, are *S. mentella* (Henderson and Jones, 1964; Zakharov, 1964; Templeman, 1967).

The presence of subcaudal melanophores in larvae from sharp-beaked redfish of the

Newfoundland-Labrador area (Templeman and Sandeman, 1959) and their absence in larvae of *S. mentella* of the Northeast Atlantic, the researches of Barsukov (1968, 1972) and Barsukov and Zakharov (1972) on body form, depth and other relationships in redfish of the North Atlantic, the differences in the location of attachment of the gasbladder muscles (Hallacher, 1974), and the studies of Litvinenko (1974) on coloration of young redfish, make it evident that there is, in the North American area of the Northwest Atlantic, a sharp-beaked *mentella*-type redfish different from *S. mentella*. Although Storer's (1856) description of *Sebastes fasciatus* from off the American coast was very brief, its meristics were probably those of the typical North American sharp-beaked redfish rather than those of *S. mentella* or *S. marinus*. The use of *S. fasciatus* for the American sharp-beaked redfish was noted by Tåning and Bertelsen (1961) and was introduced by Tåning in data on meristics subsequently noted by Kelly *et al.* (1961). The subject was also mentioned briefly by Tåning (1949) as being a name given by Storer (1856) to the American species, whose larvae were found by Tåning to possess a caudal melanophore not present in the larvae of oceanic *S. marinus* (now known as *S. mentella*). Barsukov (1968) and Barsukov and Zakharov (1972) concluded, and Templeman (1976) agreed, that *S. fasciatus* should be recognized and used where possible to distinguish this redfish which is different from *S. mentella* in its morphological and biological characteristics, in order to stimulate further research. *S. fasciatus* is used in this paper as a working name for this purpose. If proof of biological separation were necessary before a name can be used, very few closely-related fish species, especially those from deep water, could be separated specifically. The above subject is discussed in more detail by Templeman (1976).

Templeman and Sandeman (1957) reported two varieties of redfish from the Newfoundland area, the common sharp-beaked *mentella*-type and the less common *marinus*-type, and Templeman (1957) reported the presence of the latter in shallower water and the former in deeper water of the Flemish Cap area. Templeman (1959) reported the relative distribution of both types in the Newfoundland area, and Templeman (1961a, b) reported the proportions of these types taken during research vessel cruises in 1959 and 1960 off Baffin Island and Labrador. It was concluded that young *mentella*-type redfish taken in 1959 off Baffin Island had drifted from West Greenland. It is now known that female redfish at West Greenland are usually immature (Zakharov, 1962, 1967; Biester *et al.*, MS 1962; Templeman, 1966), so that these *mentella*-type fry had probably drifted from Southwest Iceland or East Greenland by way of West Greenland. Alternatively, they may have been produced by the

oceanic population of *S. mentella*.

Bainbridge and Cooper (1971) summarized the knowledge of larval redfish distribution from the Continuous Plankton Recorder Surveys, which was the subject of a series of papers by Henderson (1961, 1964, 1965a, 1965b, 1968). The oceanic redfish larvae in the region extending from southwest of Iceland and south of Greenland to north of Flemish Cap did not have subcaudal melanophores and were thus likely to have been derived from the oceanic population of adults, previously shown to be of the sharp-beaked variety and hence *S. mentella*. Most of the redfish larvae from southern Labrador and the Northeast Newfoundland Shelf had subcaudal melanophores and thus were mainly *S. fasciatus*. However, because the southern Labrador area was sampled by ships whose passage was through the Strait of Belle Isle, it is probable that this area was not often or usually sampled early in the year due to ice conditions, and that most of the *S. mentella* larvae which are extruded earlier than those of *S. fasciatus*, were missed in the plankton recorder sampling of the area. The redfish larvae from Flemish Cap were almost all without subcaudal melanophores and could have been *S. marinus* or *S. mentella*. However, since sharp-beaked redfish are dominant on Flemish Cap (Templeman, 1976) and *S. mentella* are much more abundant than *S. fasciatus* (from the present data), these larvae were therefore mainly *S. mentella*. Most of the redfish larvae in plankton recorder samples from the Scotian Shelf and the Gulf of Maine possessed subcaudal melanophores, the proportion increasing from north to south. The parents of these larvae were therefore mainly *S. fasciatus*. Barsukov (1968, 1972) and Barsukov and Zakharov (1972) concluded that both *S. mentella* and *S. fasciatus* were present on the North American Shelf, the former more common toward the north in deeper water and the latter more common toward the south in shallower water. Templeman (1973), from the distribution of redfish parasites, concluded that the oceanic *S. mentella* must intermingle with the continental slope populations of North American redfish.

The present investigation was directed especially toward evidence of differences between the larvae of the two varieties of the sharp-beaked *mentella*-type redfish, and incidentally of *S. marinus*, from a study of subcaudal melanophores in unextruded larvae of females from parts of the Newfoundland area.

## Materials and Methods

The materials for this paper were collected during some bottom trawl surveys conducted by research vessels of the St. John's Biological Station in 1958-66.

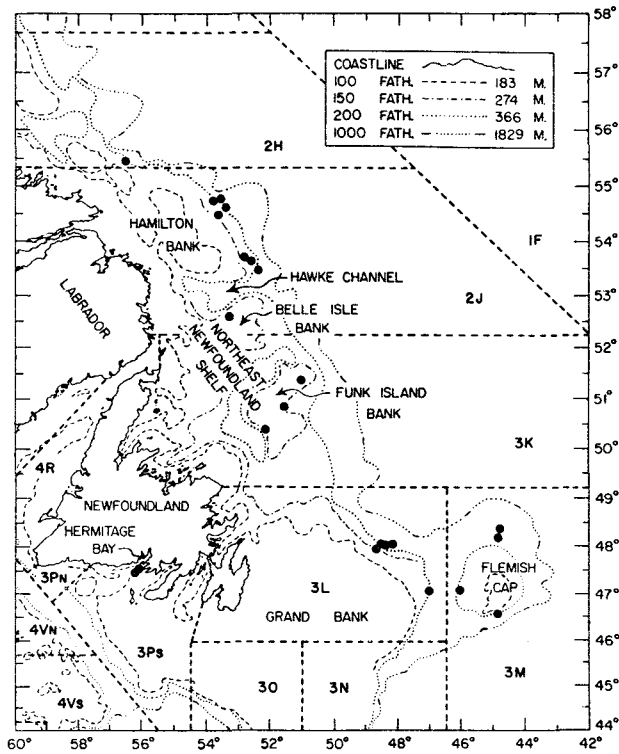


Fig. 1. Map of Newfoundland-Labrador area showing locations of capture of female redfish from which the samples of pre-extrusion larvae were obtained.

Soon after capture, unextruded redfish larvae, with some hatched and as close as possible to extrusion, were obtained in good condition from parent females (from locations noted in Fig. 1 and Table 1), identified individually as *S. marinus* or the sharp-beaked *mentella*-type, and preserved in 5% formalin. For some of the female parents, the vertebral number and the dorsal and anal fin-ray numbers were counted and checked under the author's supervision. The urostylar half-vertebra was included as a vertebra. The posterior 2 dorsal and 2 anal fin-rays with bases located close together and related to a single neural or haemal pterygiophore were counted as one. Counts of skeletons with fused vertebrae were not used in this study.

The presence or absence of subcaudal melanophores in the larvae were observed through a binocular dissecting microscope at a magnification of 20X, but additionally at higher magnifications when unusually small melanophores were present. A subsample of 20 larvae taken at random from the container in which the sample was preserved was examined for melanophores. Information on redfish larvae examined by Templeman and Sandeman (1959) from collections in 1958 was utilized by taking the results of observations on the last 20 of the 120 larvae

initially examined from each parent. Comparison of sample frequencies of larvae with subcaudal melanophores from 44 *mentella*-type female parents (table 3 of Templeman and Sandeman, 1959), when 120 larvae per sample were used, with those from the same parents (1958 data in Table 1 of this paper), when the last 20 larvae examined were used (and similarly for 37 *S. marinus* specimens of the 1958 data), indicated that the frequency spread was not seriously changed by using the smaller sample size.

The data obtained on subcaudal melanophores in larvae of the sharp-beaked *mentella*-type were used to nominally identify *S. fasciatus* and *S. mentella*. Meristic characteristics of the female parents, thus identified, were used, in relation to the stage of egg and larval development in other mature females of *mentella*-type redfish whose larvae were not examined for melanophores, to estimate the relative numbers of *S. fasciatus* and *S. mentella* at different depths and stages of egg development, hatching and larval extrusion, and thus obtain information on the approximate spawning times in these species. Redfish lengths mentioned in this paper are fork lengths from chin with mouth closed to mid-fork of the caudal fin.

## Results

### Subcaudal melanophores and redfish species

Data on the incidence of subcaudal melanophores in the larvae of sharp-beaked *mentella*-type and *S. marinus* females in various parts of the Newfoundland-Labrador area are listed in Table 1.

***Mentella*-type redfish.** The frequency of occurrence of subcaudal melanophores in samples of 20 larvae from each female parent indicates two fairly distinct groups of redfish (Table 1). One group usually had all 20 larvae, and occasionally 19–13 larvae in samples of 20, with melanophores. These larvae usually had 1–3 and occasionally 4 or 5 subcaudal melanophores which when expanded were quite large with much black pigment. In the other group of *mentella*-type redfish, the subcaudal melanophores were either absent, or present only in very small numbers of larvae, the frequency of occurrence being usually 0–4 and occasionally up to 8 larvae in samples of 20 larvae per female parent. (The two redfish each with subcaudal melanophores in 11 larvae of 20 examined are dealt with below.) In the second group of redfish, the larvae with subcaudal melanophores had typically 1 and occasionally 2 very small melanophores, some of which were so tiny when contracted that they were barely visible under 20× magnification. Examination under higher magnification indicated that they had typical black



1.88 melanophores for the remaining 43 *mentella*-type redfish (now ascribed to *S. fasciatus*) of Templeman and Sandeman (1959) and with an average of 1.11 for the more recent *S. mentella* samples reported in this paper. The melanophores in the larvae of this specimen were tiny and faint (resembling those of *S. marinus*) and contained a smaller amount of pigment than was usual for *S. fasciatus*. A subcaudal melanophore in a larva of this fish is illustrated by Templeman and Sandeman (1959, fig. 4A) in comparison with melanophores in larvae of other *mentella*-type specimens (fig. 4C, D, F) which have now been called *S. fasciatus*. This specimen was therefore presumed to be *S. mentella*.

The other *mentella*-type redfish with subcaudal melanophores in 11 larvae (of 20 examined) was taken on the northeast slope of Grand Bank (Div. 3L) at 501-521 m in March 1961, together with 3 specimens assigned to *S. fasciatus* in which subcaudal melanophores were present in all 20 larvae examined from each fish and 23 specimens assigned to *S. mentella* with melanophores in 0-8 larvae of 20 examined from each fish. In this specimen, each larva with melanophores had 1 and sometimes 2 tiny melanophores, the average being 1.3 per larva in 19 larvae (8 from another subsample additional to the 11 larvae examined routinely) with melanophores. This specimen was likewise presumed to be *S. mentella*.

In studies of this type where occasionally the number of larvae with subcaudal melanophores falls intermediate between those which can definitely be assigned to *S. fasciatus* on the one hand and to *S. mentella* on the other, the specimens should be omitted from the comparisons or the melanophores in more larvae examined carefully for their affinities with typical larvae of *S. fasciatus* and *S. mentella* before they are assigned to species. The latter procedure was followed in this paper.

***S. marinus*.** In redfish identified as *S. marinus* (Table 1), the most common numbers of larvae with subcaudal melanophores per sample of 20 examined from each female parent were from 0 to 6 but there were as many as 12-13 larvae in some samples. These subcaudal melanophores, when present, were, as in *S. mentella*, fewer in number and fainter with less pigment than in *S. fasciatus*, formerly described and illustrated by Templeman and Sandeman (1959) as North American *mentella*-type redfish. The depths of capture of *S. marinus* were typically shallower than for *S. mentella* in areas where both species were found.

**Relative numbers of subcaudal melanophores in redfish larvae**

It is apparent from Table 1 that *S. marinus* had a higher proportion of larvae with subcaudal

melanophores (21%) than *S. mentella* (11%). Only 10% of the 48 samples of 20 larvae from *S. marinus* and 24% of the 68 samples from *S. mentella* had larvae with no melanophores. For *S. fasciatus*, on the other hand, all 20 larvae in 87% of the 159 samples examined possessed melanophores. In the original data of Templeman and Sandeman (1959) where 120 larvae constituted a sample from each specimen, all 120 larvae had melanophores in 67% of the 43 *mentella*-type redfish (now called *S. fasciatus*) examined, whereas none of the 37 *S. marinus* examined had all 120 larvae without subcaudal melanophores, the greatest numbers of larvae without melanophores being 117 in one sample and 113 in another. Increasing the number of larvae per sample for *S. mentella* would similarly reduce the percentage of samples with no subcaudal melanophores in the larvae.

The maximum number of subcaudal melanophores in a larva (of 20 per sample) was greatest in *S. fasciatus*, being usually 3 but often 2 or 4 and occasionally 5 (Table 2). For *S. mentella* and *S. marinus*, the greatest number of melanophores was usually 1 but ranged from 0 to 2, except in *S. marinus* where one larva was noted with 3 melanophores. These results indicate a considerable distinction between *S. mentella* and *S. marinus* on the one hand and *S. fasciatus* on the other but no apparent difference between areas for each species.

Data for comparing the average numbers of subcaudal melanophores per larva were derived from

TABLE 2. Numbers of female redfish with maximum number of subcaudal melanophores per larva in samples of 20 larvae per female parent.

Species	Div.	No. of females with maximum number of melanophores (0-5) per larva					
		0	1	2	3	4	5
<i>S. fasciatus</i>	2H	—	—	2	2	—	—
	2J	—	—	4	8	3	—
	3K	—	—	10	45	13	3
	3L	—	—	3	17	7	—
	3M	—	—	5	4	3	—
	3P	—	—	5	20	4	—
	Total	—	—	29	96	30	3
<i>S. mentella</i>	2J	2	5	—	—	—	—
	3L	7	14	10	—	—	—
	3M	6	17	6	—	—	—
	3P	—	—	1	—	—	—
	Total	15	36	17	—	—	—
<i>S. marinus</i>	2J	1	18	5	1	—	—
	3K	1	5	1	—	—	—
	3L	1	1	1	—	—	—
	3P	2	10	1	—	—	—
	Total	5	34	8	1	—	—

the work of Templeman and Sandeman (1959) for 43 *mentella*-type redfish (now called *S. fasciatus*) and from the counting of melanophores in 170 *S. mentella* larvae and 62 *S. marinus* larvae from the more recent samples. The average number of melanophores per larva was 1.11 for *S. mentella* and 1.05 for *S. marinus*. The latter compares with an average of 1.07 in 1062 *S. marinus* larvae (with melanophores) examined by Templeman and Sandeman (1959). For *S. fasciatus*, on the same basis, the average number of melanophores in 5,098 larvae was 1.89. The melanophores were so much more distinct when contracted that the average increased to 2.11 in *S. fasciatus* larvae noted as possessing contracted melanophores (Templeman and Sandeman, 1959).

#### Larval development and possession of subcaudal melanophores

In female redfish, after the eggs are liberated in the lumen of the ovary and fertilized, larval development proceeds to hatching. The yolk sac, which is rather large after hatching, declines gradually as the larva grows and is very small upon extrusion. Although the objective was to obtain larvae as close as possible to the extrusion stage, it was sometimes necessary to collect larvae in earlier stages of development if samples were to be obtained at all. Only hatched larvae were examined, and it was observed that the larvae were generally better developed and the yolk sac smaller in samples with progressively higher

percentages of hatched larvae. Making allowance for the small numbers of larvae grouped in certain percentage-hatched categories (Table 3), there is no indication that the number of larvae with subcaudal melanophores varied during larval development from hatching to extrusion in *S. fasciatus* and *S. marinus*, and the same is likely to be the case for *S. mentella* although there were no samples in which less than 70% were hatched.

#### Distribution of female parents by depth and area

The Hawke Channel-Hamilton Bank (Div. 2J) and the more northerly (Div. 2H) larval collections from *mentella*-type redfish in May to August at 187–375 and 457–468 m were all from late spawning *S. fasciatus* (Table 4). Also, 24 *S. marinus* were sampled at 457–468 m in June. However, in April at 457 m on Hamilton Bank, the only late stage larvae found were from 7 *S. mentella* and one *S. marinus*. In the area south of Hawke Channel and on Funk Island Bank (Div. 3K), all of the larvae of *mentella*-type redfish from 214 to 232 m in April and May belonged to *S. fasciatus* females. Larvae from *S. marinus* females were also sampled in this area. Along the northeast slope of the Grand Bank (Div. 3L), larvae from *S. fasciatus* and *S. marinus* females were obtained in March at 271–371 m. At greater depths in this area (433–521 m), the larval collections indicated a mixture of *S. fasciatus* and *S. mentella*, the former being more prevalent at 433–457 m and the latter at 501–521 m. In the Flemish Cap area

TABLE 3. Percentage distribution of female parents in relation to the numbers of larvae with subcaudal melanophores, for parents with larvae in 3 stages of hatching.

No. of larvae	Distribution of females by percent-hatched categories								
	<i>S. fasciatus</i>			<i>S. mentella</i>		<i>S. marinus</i>			
	5-50	60-95	100	70-95	100	15-50	60-95	100	
0	—	—	—	27	22	8	17	8	
1	—	—	—	32	26	17	17	8	
2	—	—	—	14	17	25	8	13	
3	—	—	—	9	15	25	—	8	
4	—	—	—	9	4	8	8	21	
5	—	—	—	—	—	—	8	8	
6	—	—	—	5	7	8	17	13	
7	—	—	—	—	4	—	17	—	
8	—	—	—	—	2	—	8	4	
9	—	—	—	—	—	—	—	—	
10	—	—	—	—	—	—	—	4	
11	—	—	—	5	2	—	—	—	
12	—	—	—	—	—	8	—	8	
13	—	—	1	—	—	—	—	4	
14	—	—	1	—	—	—	—	—	
15	3	4	—	—	—	—	—	—	
16	3	—	1	—	—	—	—	—	
17	—	—	2	—	—	—	—	—	
18	—	4	2	—	—	—	—	—	
19	6	7	5	—	—	—	—	—	
20	88	85	88	—	—	—	—	—	
No. of females	32	27	99	22	46	12	12	24	

(Div. 3M), all redfish females sampled in June from 271–373 m were *S. fasciatus*, whereas those sampled in March from 366–640 m were all *S. mentella*. In Hermitage and Connaigre bays on the south coast of

Newfoundland (Div. 3P), all larval samples in May were from *S. marinus*, and the samples from late spawners in July were from *S. fasciatus* (29) and *S. mentella* (1).

**Species designation and meristic characters**

Analysis of meristic characteristics of *S. fasciatus* and *S. mentella* parent females, which were assigned to species on the basis of subcaudal melanophore occurrence in their larvae, indicates highly significant differences ( $P < 0.001$ ) between the average numbers for all 3 characters examined (Table 5), the greatest difference being in anal fin-ray number ( $t = 9.81$ ,  $df = 70$ ) compared with the  $t$ -values for vertebral number (7.53) and dorsal fin-ray number (6.55). The meristic averages for *S. marinus* were also similarly different from those for *S. fasciatus*. Most of the *S. fasciatus* specimens had 30 vertebrae and 7 anal fin-rays whereas the other 2 species had none in these categories. *S. marinus* tended to have fewer dorsal and anal fin-rays than *S. mentella*, the difference being significant ( $P < 0.001$ ) in the case of the latter. Specimens with 32 vertebrae, 16 dorsal fin-rays and more than 8 anal fin-rays were lacking in *S. fasciatus* but present in *S. mentella* and *S. marinus*. Larger numbers of specimens would undoubtedly have produced more overlapping but the general trends

TABLE 4. Numbers of redfish female parents of larval samples by area, depth, dates and species.

Div.	Depth (m)	Time of sampling	Female parents of larval samples		
			<i>S. fasciatus</i>	<i>S. mentella</i>	<i>S. marinus</i>
2H	318–375	Aug	4	—	—
2J	187–276	May–Jun	10	—	—
	320–371	Aug	3	—	—
	457	Apr	—	7	1
	457–468	Jun–Aug	2	—	24
3K	214–232	Apr–May	72	—	7
3L	271–371	Mar	8	—	3
	433–457	Mar–Apr	16	7	—
	501–521	Mar	3	24	—
3M	271–373	Jun	12	—	—
	366–457	Mar	—	12	—
	521–640	Mar	—	17	—
3P	199–232	May	—	—	13
	241–256	Jul	29	1	—

TABLE 5. Frequencies of meristic numbers for female parents of redfish species whose larvae were examined for subcaudal melanophores.

Meristic number	<i>S. fasciatus</i>				<i>S. mentella</i>			<i>S. marinus</i>				
	2J	3K	3L	Total	3L	3M	Total	2J	3L	3P	Total	
<b>Vertebrae</b>												
30	2	1	10	13	—	—	—	—	—	—	—	
31	—	1	3	4	26	24	50	21	1	2	24	
32	—	—	—	—	1	4	5	2	2	—	4	
No.				17				55				28
Mean				30.24				31.09				31.14
S.E.				0.106				0.039				0.067
<b>Dorsal fin-rays</b>												
13	1	—	7	8	—	2	2	—	—	—	—	
14	1	—	5	6	8	9	17	11	1	2	14	
15	—	—	1	1	14	15	29	8	2	—	10	
16	—	—	—	—	6	3	9	4	—	—	4	
No.				15				57				28
Mean				13.53				14.79				14.64
S.E.				0.165				0.099				0.138
<b>Anal fin-rays</b>												
7	2	—	8	10	—	—	—	—	—	—	—	
8	—	—	5	5	7	10	17	15	2	2	19	
9	—	—	—	—	15	17	32	7	1	—	8	
10	—	—	—	—	5	2	7	—	—	—	—	
11	—	—	—	—	1	—	1	—	—	—	—	
No.				15				57				27
Mean				7.33				8.86				8.30
S.E.				0.126				0.092				0.089

appear to be clearly shown.

When the meristic numbers were combined (Table 6), the least overlapping of *S. fasciatus* and the other

TABLE 6. Frequencies of combinations of meristic numbers for female parents of redfish species whose larvae were examined for subcaudal melanophores.

Meristic number	<i>S. fasciatus</i>	<i>S. mentella</i>	<i>S. marinus</i>
<b>Dorsal + anal fin-rays</b>			
20	6	—	—
21	6	1	—
22	2	4	11
23	1	20	9
24	—	22	5
25	—	7	3
26	—	2	—
No.	15	56	28
Mean	20.87	23.64	23.00
S.E.	0.236	0.131	0.192
<b>Vertebrae + anal fin-rays</b>			
37	10	—	—
38	2	—	—
39	3	14	17
40	—	29	8
41	—	10	2
42	—	1	—
No.	15	54	27
Mean	37.53	39.96	39.44
S.E.	0.215	0.099	0.123
<b>Vertebrae + anal + dorsal fin-rays</b>			
50	6	—	—
51	5	—	—
52	2	1	—
53	1	4	11
54	1	18	7
55	—	19	5
56	—	10	3
57	—	2	1
No.	15	54	27
Mean	51.07	54.72	54.11
S.E.	0.316	0.142	0.229

species occurred for the combinations of vertebrae and anal fin-rays and of all 3 meristic characters. Statistically the differences for the 3 combinations are even more significant and t-values of 10.25–10.55 (df = 67) from comparing *S. fasciatus* and *S. mentella* and of 7.01–7.79 (df = 40) from comparing *S. fasciatus* and *S. marinus*.

In view of the reported lack of subcaudal melanophores in *S. mentella* and the relative lack in *S. marinus* from the east and central North Atlantic, as discussed later, the larger numbers of larvae of these species from the North American Shelf possessing these melanophores indicate the possibility of interbreeding, at least between *S. fasciatus* and the other species. If interbreeding occurs, it could be expected that the larval groups with the highest number of melanophores (19–20) in *S. fasciatus* and those with the lowest number of melanophores (0–1) in *S. mentella* and *S. marinus* would show the least indication of interbreeding. In Table 7, these ideas are examined by applying available meristic data of the female parents to the range of larval groups possessing subcaudal melanophores. It would be expected that any lack of subcaudal melanophores in larvae of female *S. fasciatus* came from the heredity of the female or male parents of this species or, if interbreeding occurs, from a *S. mentella* or *S. marinus* male. Similarly for *S. mentella* or *S. marinus* females possessing larvae with subcaudal melanophores, the presence of melanophores could have come from the heredity of the female and males of the same species or from interbreeding with a male of another redfish species. Of these possibilities, only the effects of the heredity of the female parent can be tested by comparing its meristic characters with the proportion of its larvae with subcaudal melanophores. Few comparative meristic and melanophore data are available for *S. fasciatus*, but there is no indication (Table 7) that the *S. marinus* and *S. mentella* female parents of the larval groups (3–6 and 7–12) with more subcaudal melanophores had meristic numbers closer to those of *S. fasciatus* than the larval groups (0–2) with relatively few melanophores.

TABLE 7. Relation of meristic numbers in female parents of redfish species to numbers of larvae with subcaudal melanophores.

Species	No. of larvae <sup>a</sup>	Vertebrae			Dorsal fin-rays				Anal fin-rays					Sum of 3 meristic characters							
		30	31	32	13	14	15	16	7	8	9	10	11	50	51	52	53	54	55	56	57
<i>S. fasciatus</i>	19–20	13	4	—	8	6	1	—	10	5	—	—	—	6	5	2	1	1	—	—	—
<i>S. mentella</i>	7–11	—	3	1	—	1	1	2	—	—	4	—	—	—	—	—	—	1	—	3	—
	3–6	—	16	—	1	6	6	2	—	3	10	2	—	—	—	—	1	7	5	2	—
	0–2	—	32	3	1	10	22	5	—	14	18	5	1	—	—	1	3	9	15	5	2
<i>S. marinus</i>	7–12	—	5	—	—	3	1	1	—	3	2	—	—	—	—	—	3	—	1	1	—
	3–6	—	15	1	—	9	6	2	—	12	4	—	—	—	—	—	7	4	4	1	—
	0–2	—	4	2	—	2	4	1	—	4	3	—	—	—	—	—	1	3	—	1	1

<sup>a</sup>Number of larvae with subcaudal melanophores per sample of 20 larvae.





proportion of the larvae of *S. marinus* possessed these melanophores, usually only one when present. In this paper, all except one of the *mentella*-type specimens of Templeman and Sandeman (1959) are recognized as *S. fasciatus*.

Kotthaus (MS 1961) did not find subcaudal melanophores in unextruded larvae of *S. marinus* and *S. mentella* taken off Southwest Iceland. Raitt (1964), in redfish from the south coast of Iceland, found no larvae with subcaudal melanophores in a *S. mentella*, 1 larva in a *S. marinus* and 12 larvae in a second *S. marinus*, in samples of 100 larvae from each fish. Henderson (1964), Henderson and Jones (1964), and Jones (1968) found that unextruded larvae of oceanic *S. mentella* caught at Ocean Weather Station A, southwest of Iceland (62°N, 33°W), did not possess subcaudal melanophores. Templeman (1967) obtained similar results from the examination of larvae of 4 oceanic *S. mentella* taken in the Labrador Sea in July. However, because of the late date, only 9 larvae suitable for examination were found. Further examination of unextruded larvae from this area, preferably collected earlier in the year before spawning, is desirable.

Corlett (1961b) found that none of 116 redfish larvae, mainly 7–9 mm long, taken in April–May at Ocean Weather Station A had subcaudal melanophores. Einarsson (1960) found that *Sebastes* larvae (except *S. viviparus*) from Iceland waters and the Irminger Sea did not possess subcaudal melanophores. Magnússon *et al.* (1965) examined large numbers of redfish larvae from the Irminger Sea and found none with subcaudal melanophores except a few *S. viviparus*. Bainbridge and Cooper (1971), and referring also to Henderson (1965a, 1965b, 1968), said that, of several thousand redfish larvae examined over a period of more than 10 years from the oceanic area from southwest Iceland and south Greenland to north of Flemish Cap, none possessed subcaudal melanophores. Since the adults in the oceanic area are *S. mentella*, these larvae were the offspring of that species. However, a few of the larvae taken in the vicinity of Flemish Cap and most of the larvae taken in other areas off the North American coast from Labrador to the Gulf of Maine possessed subcaudal melanophores.

#### Identity of *S. fasciatus* and *S. mentella*

In the data presented in this paper, the sharp-beaked *mentella*-type redfish were well separated into two groups, *S. fasciatus*, in which all or nearly all of the unextruded larvae typically possessed subcaudal melanophores, and *S. mentella*, in which the unextruded larvae only occasionally possessed these melanophores. Moreover, the *S. mentella* had smaller melanophores with less pigment, spawned earlier,

were found in deeper water and had higher meristic numbers than *S. fasciatus* from the same area.

The presence of one or more subcaudal melanophores in some of the *S. mentella* larvae from the Labrador-Newfoundland area makes them different in this respect from the basic *S. mentella* stocks off Iceland and in the northeastern and oceanic parts of the North Atlantic, whose larvae were reported to have no subcaudal melanophores. It is possible that the presence of melanophores in some of the *S. mentella* larvae from the North American shelf and slope areas indicates interbreeding, presumably with *S. fasciatus*.

In view of the discrepancy in reports of the presence or absence of subcaudal melanophores in larvae of *S. marinus* by Kotthaus (MS 1961) and Raitt (1964), and the unknown numbers of fish examined by the former and the small number examined by the latter, there is still some doubt regarding the relative proportions of *S. marinus* larvae with subcaudal melanophores in the various regions of the North Atlantic. However, from the data presented by Templeman and Sandeman (1959) and also in this paper, indicating the presence of subcaudal melanophores in up to 50% of the unextruded larvae in some samples from the North American Shelf areas, it seems likely that *S. marinus* larvae from these areas possess more subcaudal melanophores than larvae from other North Atlantic regions. If this is so, interbreeding presumably occurs with *S. fasciatus*.

#### Meristics

Allowing for the small numbers of specimens examined, the meristic frequencies (vertebrae, dorsal fin-rays and anal fin-rays) for *S. fasciatus* and *S. mentella* (Table 5), which were separated in samples of *mentella*-type redfish by subcaudal melanophore differences in unextruded larvae, are generally similar to those of Barsukov and Zakharov (1972). However, these authors did not indicate how their *mentella*-type redfish were assigned to *S. fasciatus* and *S. mentella* preliminary to their study of meristic characters. Additionally, Tåning's vertebral numbers for *S. fasciatus*, listed in Appendix II of Kelly *et al.* (1961), are similar to those for *S. fasciatus* in this paper (Table 5), and the anal fin-ray counts are similar in pattern. The region of origin and methods of selection of Tåning's sample of *S. fasciatus* were not stated, but he regarded all North American Shelf sharp-beaked redfish as *S. fasciatus*.

The meristic frequencies for *S. mentella* (Table 5) are similar to the unpublished data for oceanic *S. mentella* (Templeman, 1967) from the Labrador Sea (in 15 *S. mentella*: vertebral numbers, 30(1), 31(11), 32(1); dorsal fin-ray numbers, 13(1), 14(9), 15(5); and anal

fin-ray numbers, 8(7), 9(8)). The meristic ranges are similar to those of *S. mentella* reported by Travin (1951). The vertebral numbers for *S. mentella* (Table 5) are also similar to those for *S. mentella* from Ocean Weather Station A in the Irminger Sea (Jones, 1969). However, the average number of vertebrae in Taning's sample of *S. mentella* (Kelly *et al.*, 1961, App. II) was lower than that for his *S. fasciatus* and almost as low as that for his *S. viviparus*. It was also 0.77 vertebrae lower than that of his *S. marinus*, whereas it should have been approximately the same or only slightly lower or higher. The locality of capture of these *S. mentella* was not stated but they were probably from the Iceland area. A possible explanation for the low vertebral average in Taning's *S. mentella* is that the urostylar half-vertebra was not included in the counts for that species but was apparently included for the other 3 species.

#### Egg and larval development in relation to depth and species

Inferences on distribution by depth of the two types of sharp-beaked *mentella*-type redfish in March at Flemish Cap and Northeast Grand Bank (Table 8) indicate that *S. fasciatus* occurred at shallower depths and had relatively higher proportions of eggs and larvae in early developmental stages than *S. mentella*. Therefore, since *S. mentella* tend to mature and spawn earlier in the year than *S. fasciatus*, all (except one) of the *mentella*-type redfish taken in June and early July 1958 (Table 1) and examined by Templeman and Sandeman (1959) were *S. fasciatus*. This includes the 12 *S. fasciatus* from Flemish Cap in late June 1958, whereas all specimens collected from this area in March 1961 for examination of larvae were *S. mentella*.

#### Implications for management

Although no *mentella*-type redfish larvae were available for examination from the area extending from Baffin Island southward to the Labrador Shelf (about 57%), it is most likely that all sharp-beaked redfish in the area are *S. mentella*. Some *S. fasciatus* occurred on the Labrador shelf from about 55° 30'N southward, but they were not plentiful relative to *S. mentella*, except from about 53° 40'N southward. In the whole area from Labrador to Flemish Cap the sharp-beaked redfish deeper than about 400 m were *S. mentella*, there being occasional exceptions with area and season (unpublished meristic data, St. John's Station). In March 1961 at Northeast Grand Bank (Div. 3L), all sharp-beaked redfish from 262 to 371 m were *S. fasciatus*, there was a mixture of *S. fasciatus* and *S. mentella* at 433–457 m, and nearly all were *S. mentella* at 501–521 m. These observations agree generally with those of Barsukov and Zakharov (1972). The oceanic

redfish of the Labrador Sea (Templeman, 1967) had the meristic characteristics of *S. mentella*.

Almost all of the female *S. mentella* off Baffin Island and northern Labrador and in depths greater than 550 m from Labrador Shelf and Funk Island Bank were immature, even though some were 46–48 cm in length, close to the maximum size (49–53 cm) for *S. mentella* females of the area, the few mature females at these depths being more usually present in spring than in late summer (Templeman, 1955, 1961a, 1964); Savvatimsky and Sidorenko, 1966; Sandeman, 1969; Zakharov and Chekhova, 1972; Chekhova, 1972). This scarcity of mature females of *S. mentella*, off Baffin Island and northern Labrador and in deep water southward to Div. 3K, greatly reduces the spawning potential of the species in this area. Savvatimsky and Sidorenko (1966) raise the possibility that these immature deepwater redfish are hybrids, but this is very unlikely as their meristics and morphometrics indicate that they are distinctly *S. mentella*. The main explanation for their immaturity is likely to be the depth and consequently the light and temperature relationships throughout their life history, because immaturity of redfish at large sizes from deep water is not evident at Flemish Cap where the three species are present and where temperatures at redfish depths are more uniformly above 3°C than in more northern areas.

The presence, in an area such as Flemish Cap and other parts of the North American Shelf, of two or three redfish species, of which the two sharp-beaked *mentella*-type species are similar in appearance and usually more numerous, offers obvious problems for management, as these three species are now treated as a single group for management purposes. However, these species tend to live at different depths, spawn at different times, differ in spawning sizes and presumably differ in growth rates, with consequent differences in the nursery areas inhabited by the juveniles. The larvae are affected differently by currents, temperature conditions and plankton blooms, with consequent effects on larval growth and mortality. The redfish populations are also undoubtedly affected differently by trawling practices. Redfish may live for 40–50 years or more, and good year-classes are usually not frequent, a large one being known to support a fishery for many years. Also, the different species may have good year-classes in different years. *S. marinus* is often present but usually not plentiful in Subareas 2 and 3, is very uncommon in the northern part of Subarea 4, and is not present (except for rare specimens) in the southern part of Subarea 4 and in Subarea 5. Thus, the two species likely to be numerous enough to have a significant effect on the redfish fisheries of the North American Shelf are *S. fasciatus* and *S. mentella*.

An example of differences in the vertebral frequencies of two size groups of *mentella*-type redfish in Hermitage Bay during 1947-54 was noted by Templeman and Pitt (1961), the larger fish having somewhat higher vertebral counts on the average than the smaller sizes. At the time, for both Hermitage Bay and the Gulf of St. Lawrence, these authors attributed the variation in vertebral numbers to temperature differences during larval development in a single species of sharp-beaked redfish which they considered to be *S. mentella*. Now, in view of more knowledge of redfish species and their meristic characteristics (Barsukov, 1968; Barsukov and Zakharov, 1972; this paper and unpublished records of the Newfoundland Biological Station), it is more likely that the group of larger redfish with predominantly high vertebral numbers (31-32) were *S. mentella*, and that most of the smaller group with predominantly low vertebral numbers (30) were *S. fasciatus*.

If one of these species, in an area where both are important, is overfished to the point where its reproductive ability is severely reduced, the frequency of good year-classes will depend largely on the other species and the overall production of year-classes may then be decreased. Even if regarded as one species, redfish stocks are difficult to assess and manage because of difficulties in ageing, differences in ageing techniques among scientists of different countries, the slow growth rate and the considerable number of years that redfish can be fished before they mature. Their schooling propensities render them easy to catch, with a consequent tendency for the stocks to be overfished. The use of large mid-water trawls in recent years has removed the protection provided by the semi-pelagic nature of these fish and has thus intensified overfishing.

Management of the redfish stocks is further complicated by the problems of the separation of the commercial catches by species, the prevalence of a high proportion of large immature redfish in the north, and possibility of interbreeding between species. If interbreeding occurs, there are the problems of recognizing the hybrids and determining whether they are fertile. Since redfish tend to go deeper as they become larger and the large immatures in the north are close to maximum size, these immature redfish from Funk Island Bank northward at depths greater than 550 m can probably be fished without affecting significantly the production of young redfish. However, Sandeman (1969) noted, for *mentella*-type redfish of the Hamilton Bank area (Div. 2J), that these immature females at 550 m were faster-growing, reaching a greater maximum size but lower maximum age (29 years), than females at 370-460 m, some of which were more than 40 years old. If some of the immature females at the greatest depths become

mature, they do so at such a great age as to be very few in number under heavy fishing pressure.

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