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Species Proportions and Some Reproductive Aspects of Three Redfish Species (*Sebastes marinus*, *S. fasciatus*, and *S. mentella*) on Flemish Cap, March 1983

by

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ABSTRACT

Gas bladder musculature criteria are used to identify adult redfish, Sebastes sp., from the pre-spawning assemblage in February-March, 1983 on Flemish Cap Bank. The relative proportions of each of three species S. mentella, S. fasciatus, and S. marinus were determined for each of 5 depth zones. S. marinus is the dominant species at depths to 258 meters, S. fasciatus is dominant from 259-369 meters and S. mentella is dominant at depths >369 meters. Weighted by abundance at depth, the overall proportions of each species for the entire area are 11% for S. marinus, 32% for S. fasciatus, and 57% for S. mentella. Anal fin ray, sex ratio and female reproductive maturity data are presented. Estimates of peak extrusion periods from maturity data indicate S. marinus and S. mentella overlap considerably in the late April period but for S. fasciatus, peak extrusion is delayed until mid-May.

INTRODUCTION

In the past, there has been much controversy over the taxonomic status of members of the Sebastes genus in the Northwest Atlantic. Until the early 1970's, the commonly held view was that a single species, S. marinus, existed but that morphological variation warranted separation into two sub-species, S. marinus marinus and S. marinus mentella (Bigelow and Schroeder 1953; Andriyashev 1954; Leim and Scott 1966). More recent work has demonstrated differences, particularly in the configuration of the gas bladder musculature, which suggest the existence of three valid species: S. marinus, S. fasciatus, and S. mentella (Litvinenko 1980; Ni 1981a; Power and Ni 1982; Payne and Ni 1982).

Redfish larval surveys have been carried out as part of the Flemish Cap International Project since 1978. Since the identity of the redfish population and possible differences in species extrusion activity may have a significant impact on the interpretation of these data, the identification scheme based on gas bladder musculature (Ni 1981a; Power and Ni 1982) was utilized to determine the respective proportions of the three species in the pre-spawning adult assemblage on Flemish Cap and as an aid to investigating their reproductive biology and coincidence of extrusion seasons.

METHODS

During February and March 1983, two cruises were made to Flemish Cap Bank. The first was a stratified random trawl survey during which 133 successful 30 minute tows were completed in 5 depth zones (1) 100-184 meters, (2) 185-258 meters, (3) 259-369 meters, (4) 370-554 meters and (5) 555-739 meters. For each set, both weight caught and length frequency distribution were recorded for redfish and other species. The frequency distributions for redfish were later broken down and fish ≥25 cm further analysed (Smith and Somerton MS 1981) to obtain a minimum abundance estimate for each depth zone. The 25 cm cut-off was used so that only adult redfish would be included (Atkinson 1984).

On the second cruise, 14 successful 30 minute trawls were completed in line transects with tows in each of the same depth zones covered in the first cruise. The per zone breakdown is as follows: zone 1, 3 tows; zone 2, 3 tows; zone 3, 2 tows; zone 4, 5 tows; zone 5, 1 tow. In each tow, the first 160 redfish ≥25 cm were selected for identification according to gas bladder musculature (Litvinenko 1980; Ni 1981; Power and Ni 1982). The total number of redfish identified was 1342. Broken down by depth zone, the totals were: zone 1, 92 redfish; zone 2, 140 redfish; zone 3, 169 redfish; zone 4, 776 redfish; zone 5, 165 redfish. The proportion of each of the three species was determined for each depth zone and, using the abundance figures from the previous cruise, the weighted proportion of each species for the entire Flemish Cap Bank was estimated.

Additionally, anal fin ray numbers, sex ratios, and female reproductive maturity stages were determined for each species. Reproductive maturities were recorded as follows:

Stage I. Immature. Ovaries and eggs very small and prior to fertilization.

Stage II. Early egg development. Ovaries enlarged, ovulation has occurred followed by fertilization.

Stage III. Egg developing. Considerable cell division has occurred.

Stage IV. Eyed eggs. The embyro is in the early stage of formation, the eyes are pigmented.

Stage V. Fully formed larvae. Eggs not hatched but larvae fully formed and pigmented.

Stage VI. Hatching initiated. Various proportions of eggs hatched and larvae loose in the ovarian cavity.

Stage VII. Hatched larvae. All or nearly all larvae hatched and loose in the ovarian cavity. Yolk sac in various stages of resorption.

Stage VIII. Spent. Ovaries large and reddened, some with old larvae undergoing phagocytosis. Recovering from last year's spawning.

RESULTS

Sebastes spp. on Flemish Cap reach their greatest abundance in relatively deep water. Over 69,000 redfish of all species were caught in the 5 depth zones, the deepest of which included depths to 739 meters. By adjusting the catch figures (Table 1) for each depth zone by the number of fishing units (a measure of the total area per zone) in each zone, the relative abundance of redfish was established. Sebastes spp. were most abundant in depth zone 4 (370-554 meters), followed closely by depth zone 3 (259-369 meters). Depth zone 5 (555-739 meters) had the next highest abundance, approximately 60-70% that of zones 3 and 4. In depth zone 2 (185-259 meters), Sebastes spp. abundance was approximately 20% that of zones 3 and 4 and in depth zone 1 (0-185 meters) redfish were only of negligible importance. The total estimated abundance over all depth zones probably underestimates the true total because redfish are found deeper than 739 meters, the limit of the deepest depth zone fished in this study.

The existence of three redfish species, S. marinus, S. fasciatus, and S. mentella, on Flemish Cap was confirmed from the identification of specimens in 5 depth zones. Their vertical distributions are distinctly different (Table 2). S. marinus is most abundant in depth zone 2 (185-258 meters) but is also abundant in zones 3 and 5. S. marinus is an important constituent of the redfish population in zone 1 as well, but because of the low abundance of all redfishes in that zone, the abundance of S. marinus in relation to its abundance in other zones is not important. No S. marinus were found in zone 4. Proportionally, in descending order of importance, S. marinus comprised 93.4% of all redfish in zone 2, 56.8% of all redfish in zone 1, 12.5% of all redfish in zone 5, 4.2% of redfish in zone 3, and was not found in zone 4.

S. fasciatus is most abundant in depth zone 3 (259-369 meters) but is also abundant in zones 4 and 5 as well. It is incidental in zone 2 and practically non-existent in zone 1. Proportionally, in order of descending importance, S. fasciatus comprised 94.6% of all redfish in zone 3, 5.2% of all redfish in zone 4, 2.2% of all redfish in zone 2 and 1.2% and 1.1% in zones 5 and 1 respectively.

S. mentella is very abundant in depth zone 4, about 50% as abundant in depth zone 5, of incidental importance in zones 2 and 3 and of negligible importance in zone 1.

Proportionally, in descending order of importance, S. mentella comprised 94.8% of all redfish in zone 4, 86.2% of all redfish in zone 5, 42.1% of all redfish in zone 1, 4.4% of all redfish in zone 2, and 1.2% of all redfish in zone 3.

When Flemish Cap is considered in its entirety with the proportions of each species weighted according to the differing total redfish abundance per zone, S. mentella comprises 56.7% of the total redfish population, S. fasciatus comprises 32.3% of all redfish, and S. marinus just 11% of the total redfish population.

Although the data available concerning the anal fin ray frequencies of the three species by depth zone is sparse, some conclusions are possible (Table 3). Approximately 55-71% of all S. marinus have an anal fin ray frequency of 8, 26-40% have a frequency of 9 and 0-8% have a frequency of 7 in all depth zones examined. There is no evidence of vertical differences in anal fin ray frequencies for S. marinus. For all depth zones together, 5.9% of S. marinus has an anal fin ray frequency of 7, 58.5% have a frequency of 8, 33.3% have a frequency of 9, and 2% have a frequency of 10.

Sufficient specimens of S. fasciatus for anal fin ray analysis were only obtained in zones 3 and 4. The frequencies for both these zones are similar. Overall, 1% of S. fasciatus have an anal fin ray frequency of 6, 58.8% have a frequency of 7, 35.3% have a frequency of 8, and 4.9% have a frequency of 9.

Insufficient S. mentella specimens were obtained for anal fin ray analysis from zones 2 and 3. In the other zones, approximately 27-36% of S. mentella have an anal fin ray frequency of 8, 55-63% have a frequency of 9, and 7-14% have a frequency of 10. The frequency distribution of anal fin rays for S. mentella was similar over all depth zones analysed. Overall, 1% of S. mentella have an anal fin ray frequency of 7, 28.8% have a frequency of 8, 56.9% have a frequency of 9, 12.9% have a frequency of 10, and 0.3% have a frequency of 11 anal fin rays.

Comparatively, S. marinus usually has 8-9 anal fin rays, modal at 8, while S. fasciatus usually has 7-8 anal fin rays, modal at 7, and S. mentella usually has 8-9 anal fin rays, modal at 9. S. mentella has the most variable anal fin ray frequency distribution, extending from 7 to 11 while S. marinus extends from 7 to 10 and S. fasciatus from 6 to 9. A χ^2 test for differences in frequency distribution was carried out on the anal fin ray distribution comparing the frequencies for the three species over all depth zones combined. The differences in anal fin ray frequencies were significant ($\chi^2 = 737.0$, Prob > $\chi^2 = 0.0001$).

Sex ratios were determined for each of the three redfish species (Table 4). Insufficient specimens of S. marinus were obtained in zones 3, 4 and 5, of S. fasciatus in zones 1, 2, and 5, and of S. mentella in zones 2 and 3 to allow a conclusive determination of sex ratios at depth. Thus, all data were pooled for each species. Distinctly different patterns were found for the three species. For S. marinus, males outnumbered females by approximately a 2:1 margin. The actual frequency was 66.2% males and 33.8% females. For S. fasciatus, the sex ratio was quite the reverse with females outnumbering males of approximately a 3:1 margin. The actual frequency was 26.5% males and 73.5% females. In contrast with both these species, S. mentella was approximately evenly divided between males and females. The actual frequency was 50.3% males and 49.7% females. The differences, tested by χ^2 test for frequency distributions, were significant ($\chi^2 = 66.2$, Prob > $\chi^2 = 0.0001$).

The reproductive maturity data for each of the three redfish species also could not be broken down by depth zone due to scarcity of specimens, particularly for S. marinus. Thus, the available data from all 5 depth zones were pooled. The majority of S. marinus were immature (stage I) but the frequency distribution (Table 5) is bi-modal showing a second mode in the advanced stage V with large ovarian cavities filled with eggs containing fully formed embryos. Only a few individuals of S. marinus were in intermediate stages II-IV, containing eggs in various stages of development. Bi-modality in the frequency distribution of S. fasciatus is suggested but the data are less conclusive. Although a few individuals (2.0%) were in the advanced stage VI with eggs containing fully formed embryos and some larvae already hatched, the major mode centred around stages I-III, with stage III being most abundant. The S. mentella maturity frequency distribution is strongly bi-modal or even tri-modal if one includes the stage VIII.

S. mentella was the only species in which stage VIII, spent and recovering from spawning in the previous year, was observed. The strongest mode appeared around stage V and VI with fully developed eggs and some hatched larvae present. A few individuals were stage VII, with all eggs hatched and larvae in various stages of development. Only a few individuals were in stages II-IV but another strong mode in stage I was observed.

Consideration of the overall pattern for the frequency distributions of each species reveals that individuals of S. mentella are in the most advanced reproductive stages compared to the other two species. Some individuals already contained hatched larvae in various stages of development, some ready for extrusion, and many individuals contained eggs and various proportion of hatched larvae. S. marinus, although not as advanced as S. mentella, did have a strong mode at stage V which is comparable to the most abundant post-fertilization egg stage of S. mentella. On the other hand, although S. fasciatus does have individuals advanced as far as stage VI, the modal developing egg frequency is stage III.

DISCUSSION

Although occasionally found in water shallower than 185 m, the depth distribution of Sebastes on Flemish Cap is centred around 259-554 meters. This is consistent with other studies of redfish distribution on Flemish Cap. Templeman (1959) found that on the Grand Bank east of longitude 49° to 50°W, and to the north of the Grand Bank, off eastern Newfoundland and around Flemish Cap, redfish are generally found deeper than 140 fathoms (258 meters).

Templeman (1976) believed the stock of S. marinus on the Cap was relatively small with the majority belonging to the sharp-beaked species, S. mentella and S. fasciatus. In this study, few redfish of any species were found at depths shallower than 185 meters. Those present at these depths were a mixture of mainly S. marinus and S. mentella. S. marinus comprised the bulk of the redfish population down to 258 meters, S. fasciatus predominated from there to 369 meters, and S. mentella was the main constituent in deeper water. The modal depth distribution of S. marinus in March had been previously reported to be deeper than found in this study. Templeman (1976) reported the largest catches of S. marinus in March, 1961 to be 310-375 meters although other surveys in September 1964 and July-August 1968 were modal at 220-295 meters. Chekhova (1972), in a survey during early April 1972 reported S. marinus distribution to be modal around 201-300 meters. Templeman (1976) found S. mentella distribution modal at 520-560 meters in all three years.

Until recently, little was known of the depth distribution of S. fasciatus on Flemish Cap. Ni (1982), on the basis of meristic data collected from sharp-beaked redfishes on Flemish Cap, concluded that S. fasciatus was the main sharp-beaked redfish at depths shallower than 200 meters. From 200-360 meters there was a mixture of both species in unknown proportions and, in deeper water, S. mentella was the main sharp-beaked redfish. In this study, S. fasciatus was a minor constituent of the total redfish population at depths shallower than 258 meters. At depths shallower than 185 meters, S. mentella was much more abundant that S. fasciatus and, from 185-258 meters, S. mentella were approximately twice as abundant as S. fasciatus. However, from 259-269 meters, only negligible numbers of S. mentella compared to S. fasciatus were found. S. fasciatus were more abundant both numerically and proportionally from 370-554 meters than at depths shallower than 259 meters. S. mentella is the dominant species at depths greater than 369 meters. The depth range over which S. fasciatus is proportionally abundant is the narrowest of the three species, with S. marinus being intermediate and S. mentella proportionally abundant over the greatest depth range.

Overall, when the species proportions are weighted for abundance differences in the different depth zones, S. mentella is proportionally and numerically most abundant, followed by S. fasciatus and S. marinus. In this regard, Flemish Cap is different from the adjacent Grand Bank (NAFO Div. 3LNO) where the dominant species is S. fasciatus and is more like northern Newfoundland waters (3K) (Ni 1982). Redfish are known to participate in horizontal and vertical migrations during various stages of their reproductive cycles (Zakharov 1967; Zakharov and Chekhova 1972) so these proportions may not be typical of seasons other than the February-March period.

Anal fin ray frequencies varied somewhat with depth but no significant pattern of different frequencies was found. The anal fin ray frequencies for all species may be characterized as 8 sometimes 9 for S. marinus, 7, sometimes 8 for S. fasciatus, and 9, sometimes 8 for S. mentella. Both the mode and range of the anal fin ray frequency distribution for S. marinus are in agreement with those reported by Ni (MS 1982). The mode for S. mentella agrees with the findings of Ni (1982). No direct comparison of the mode for S. fasciatus on Flemish Cap is available but it appears that the proportion of S. fasciatus with 8 anal fin rays on Flemish Cap is much higher than the adjacent northeastern Grand Bank where Ni (1981b) reported only 2% of S. fasciatus had 8 anal fin rays. It is interesting to note that the anal fin ray frequencies reported here based on species identification by gas bladder musculature are similar to those reported by Templeman (1980) based on species identification by morphological and meristic characters.

The sex ratio of S. marinus for March was intermediate to that found in February and April in NAFO Div. 3Ps (Ni and Templeman MS 1982). These authors also noted an increase in the male:female sex ratio in S. marinus deeper than 200 meters (2.27) compared to those shallower (0.23). The sex ratio, for S. marinus over all depths on Flemish Cap, was 1.96 which is consistent with the results from 3Ps, given that the majority of S. marinus in this study came from zone 2 (185-258 meters). Ni and Templeman (MS 1982) found the sex ratio for beaked redfishes in March in 3Ps to be 1.21 and observed a steady decrease in sex ratio with increasing depth. In this study, the sex ratio for S. mentella was 1.01. If the sex ratio for beaked redfish in March in 3Ps is similar to Flemish Cap in the same manner that the sex ratios for S. marinus are similar, then this suggests those samples of beaked redfishes observed by Ni and Templeman (MS 1982) in 3Ps are mostly S. mentella.

The female reproductive maturity data indicated S. mentella to be most advanced, followed closely by S. marinus with the majority of S. fasciatus more delayed. The length of time from hatch to extrusion in redfish is probably around 4-5 weeks (Templeman and Sandeman 1959). From data of Sorokin (1961) for S. marinus in the northeast Atlantic, the period from fertilization to hatching is estimated to be approximately 4 weeks. This is consistent with the findings of Eigenmann (1982, cited by Moser 1967) and Fujita (1958, cited by Moser 1967) of a 1 month gestation period for S. rubrivinctus and S. oblongus respectively, two closely related Pacific members of the Sebastes genus. Thus, the total time from fertilization to extrusion may be estimated at 8-9 weeks.

Using these estimates, S. mentella stage VII females would begin extruding larvae from mid- to late March, increase rapidly through early April (stage VI), peak at mid- to late April (stage V) with some residual extrusion through to mid-May (stage II-IV). The stage VIII individuals were regarded as recovering from last year's spawning. S. fasciatus would begin extrusion in early to mid-April (stage VI) continuing at relatively low levels then peaking in early May (stage III) and continuing into mid-May (stage II). S. marinus would begin extrusion and peak from mid- to late April (stage V) with some residual extrusion continuing into May.

Comparing these estimates between species, it becomes apparent that extrusion of both S. mentella and S. marinus will peak during mid- to late April, although some S. mentella start extrusion as early as March. For S. fasciatus, peak extrusion will be in early to mid-May, even though some will start extrusion in early April. In making these estimates, we have assumed that all three species mature through the reported stages at approximately the same rate. It is not possible to determine whether the immature stage I females would not begin maturing at a later date. If they do, then there may be some extrusion, possibly with other peaks, later in the year. Two or more peaks of extrusion within the same year have been reported for several Pacific members of the Sebastes genus (Moser 1967, Westrheim 1975).

The accuracy of these estimates may be supported by comparison with the known extrusion cycles on Flemish Cap. The main extrusion time on Flemish Cap is the April-May period (Bainbridge and Cooper 1971; Templeman 1976). Peak extrusion was estimated from larval length frequency data to be the last week of April in 1980 and 1981 (Anderson MS 1982) and from larval otolith age data to be mid- to late April in both 1980 and 1981 (Penney 1984).

Finally, there has been speculation regarding the nature of the speciation mechanism in the Sebastes genus in Northwest Atlantic waters (Ni and Templeman MS 1982). If the estimated extrusion times reported here are correct, then the separation of periods of peak extrusion activity of S. fasciatus from S. mentella and S. marinus may be contributing to reproductive isolation of S. fasciatus. Inherent in this supposition are the assumptions that the length of the period from copulation to fertilization and from fertilization to extrusion are similar for all three species. On the other hand, the overlap of peak extrusion in S. mentella and S. marinus maybe regarded as an argument supporting the contention these are one and the same species. This contention is further strengthened by the findings of McGlade et al. (1983) that S. fasciatus is electrophoretically distinct from S. mentella, and S. marinus but the later two cannot be differentiated, contrary to the findings of Payne and Ni (1982).

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Table 1. Total catch of redfish (all species) ≥25 cm on Flemish Cap, February 1983.

Depth zone	# of sets	Catch	$\bar{x}$ catch/set	# of Fishing unit (10^{-3})	Abundance/ zone (10^{-3})
1	16	15	0.9	89	83
2	29	5,116	176.4	163	28360
3	48	22,245	463.4	266	122590
4	29	25,838	891.0	164	149470
5	20	15,864	793.2	111	87940
All zones	142	69,078	486.5	793	388440

Table 2. Species proportions (p) of S. marinus, S. fasciatus, and S. mentella, in each of 5 depth zones during March 1983 and the weighted proportions on the entire Flemish Cap Bank.

		S. marinus			S. fasciatus			S. mentella			
Zone #	Depth (m)	p	Std. error	Est. # (10^{-3})	p	Std. error	Est. # (10^{-3})	p	Std. error	Est. # (10^{-3})	Total (10^{-3})
1	0-184	.568	.053	47	.011	.011	1	.421	.053	35	83
2	185-258	.934	.021	2649	.022	.013	620	.044	.017	1250	28360
3	259-369	.042	.015	515	.946	.017	115970	.012	.008	1470	122590
4	370-554	-	-	0	.052	.008	7770	.948	.008	141700	149470
5	555-739	.125	.026	1099	.013	.009	1140	.862	.027	75810	87940
Total		.110		4268	.323		125500	.567		220270	388440

Table 3. Anal fin ray frequencies (%) of S. marinus (1), S. fasciatus (2), and S. mentella (3) in each of 5 depth zones on Flemish Cap Bank, March 1983.

Depth zone	Species	% Anal ray frequencies 6	7	8	9	10	11	N
1	1	-	8.0	66.0	26.0	-	-	50
	2	-	100.0	-	-	-	-	1
	3	-	-	27.8	63.9	8.3	-	36
2	1	-	6.3	55.1	35.4	3.2	-	127
	2	-	33.3	66.7	-	-	-	3
	3	-	-	16.7	50.0	33.3	-	6
3	1	-	-	71.4	30.6	-	-	7
	2	1.3	60.1	38.0	0.6	-	-	158
	3	-	-	-	100.0	-	-	2
4	1	-	-	-	-	-	-	-
	2	-	57.5	25.0	17.5	-	-	40
	3	-	1.1	27.7	56.7	14.1	0.4	730
5	1	-	-	60.0	40.0	-	-	20
	2	-	-	-	100.0	-	-	2
	3	-	0.7	36.2	55.8	7.3	-	138
All zones	1	-	5.9	58.8	33.3	2.0	-	204
	2	1.0	58.8	35.3	4.9	-	-	204
	3	-	1.0	28.8	56.9	12.9	0.3	912

Table 4. Sex ratio of S. marinus, S. fasciatus, and S. mentella pooled over 5 depth zones on Flemish Cap Bank, March 1983. (Numbers in brackets are %.)

	S. marinus	S. fasciatus	S. mentella
Male	135 (66.2)	54 (26.5)	470 (50.3)
Female	69 (33.8)	150 (73.5)	464 (49.7)
Total	204	204	934

Table 5. Adult female reproductive maturity stage frequencies of *S. marinus*, *S. fasciatus*, and *S. mentella* pooled over 5 depth zones on Flemish Cap Bank, March 1983. (Numbers in brackets are %.)

Maturity Stage	*S. marinus*	*S. fasciatus*	*S. mentella*	Totals
I	52 (75.4)	40 26.7)	154 (33.8)	246
II	1 (1.4)	34 (22.7)	4 (0.9)	49
III	3 (4.3)	44 (29.3)	5 (1.1)	52
IV	1 (1.4)	11 (7.3)	3 (0.7)	15
V	12 (17.4)	18 (12.0)	143 (31.4)	173
VI	-	3 (2.0)	89 (19.5)	92
VII	-	-	6 (1.3)	6
VIII	-	-	52 (11.4)	52
Totals	69	150	456	675