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The use of anal fin ray frequencies to indicate the stock units of deepwater redfish, Sebastes mentella and rosefish, S. fasciatus

by

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Introduction

It is important to have a good perception of redfish population units so as to have better stock assessment and management. Owing to the significant patterns of anal fin ray frequencies this report gives support to the distribution of sharp-beaked redfish proposed by a previous vertebrae frequency study (Ni 1981c). A preliminary understanding of the possible stock components in different depths of the Northwest Atlantic is explored.

Although redfish comprise the third largest groundfish catch in Northwest Atlantic, the understanding of stock units is still at a very primitive stage The perplexity of redfish systematics and species identification in past decades hampered the stock discimination studies.

From the extrinsic gasbladder musculature study, Ni (1981a) supported the existence of S. fasciatus. From the numerical classification study of morphological characters, Ni (1981b) concluded that anal fin ray counts were the best discriminator other than the extrinsic gasbladder musculature. This has been elucidated by the numerous researchers (Barsukov 1972, Barsukov and Zakharov 1972, and Litvinenko 1974), listed in Table 1, who found that anal fin ray count of S. fasciatus was most commonly 7 whereas that of S. mentella was 8 or 9. Therefore, the assumption was made that a) an anal fin ray frequency distribution

dominated by 7 indicated S. fasciatus as the predominant species b) 8 or 9 indicated S. mentella and c) a combination of 7 and 8 or 7 and 9 indicated a mixture of sharp-beaked redfish.

Results obtained from the analysis of anal fin ray frequencies supported the results from a vertebrae frequencies study (Ni 1981c). S. mentella was predominant in the waters between Greenland and Baffin Island, in Labrador waters and in deep waters of the Gulf of St. Lawrence and in all NAFO Subarea 3. S. fasciatus was predominant in Nova Scotia Shelf, in shallow waters of NAFO Subarea 3 and of the Gulf of St. Lawrence. Furthermore, there were four different patterns of anal fin ray frequencies, which implied possibly four or five sharp-beaked redfish stocks in the Northwest Atlantic.

Materials and Method

There were 22622 anal fin ray counts collected during the 1979 and 1980 groundfish survey cruises as well as the morphological data compiled by Sandeman and Templeman. The area sampled, covering the whole Northwest Atlantic, were NAFO Divisions (with sample size) 0(771), 1(591), 2G(825), 2H(1282), 2J(1627), 3K(437), 3L(1850), 3M(1340), 3N(1279), 3O(1993), 3P(2452), 4R(2205), 4S(1588), 4T(522), 4V(1239), 4W(1608), and 4X(1013). An analysis of anal fin ray frequencies was conducted by NAFO Division and by 100-m depth interval, since Barsukov (1972) and Templeman (1976) suggested that S. mentella were distributed in deeper waters than S. fasciatus.

Particular attention was given to the reading of the last ray of the anal fin. It was observed to consist of two elements that were separated at the very base of the fin and connected with only one intermuscular bone (pterygiophore). The last two bases were counted as one ray.

Vertical variations were examined by the method of χ^2-test of independence. Geographic variations were evaluated by the patterns shown from the mode in the anal fin ray frequency histogram as well as by cluster analysis to display the dendrographic relations among division-depth blocks.

Results and Discussion

Table 2 displays the sample sizes by NAFO Divisions and 100 meter depth intervals.

The anal fin ray percent frequency distribution is shown in Fig. 1. In NAFO Division 0, 1, 2G, 2H and 2J (Fig. 1-1), the anal fin rays of 8 and 9 were both equally observed therefore, S. mentella was the predominant species. In Division 2J, 22.8% of the 254 specimens collected from the 200-299 depth zone had anal fin ray count of 7, indicating the presence of S. fasciatus. In Division 3L, S. fasciatus dominated the shallow water whereas S. mentella, having anal fin ray pattern similar to that of Labrador waters, dominated the deep water. The two sharp-beaked redfish species probably mixed at a depth of around 300-499 meters. The composition of redfish on Flemish Cap (3M) was very complicated and consisted of three redfish species (Ni and Mckone 1981). The sharp-beak redfish intermingled with S. marinus in shallow waters (<400 meters) S. mentella, with an anal fin ray count of 9, was dominant in deeper water (Fig. 1-2). S. fasciatus was predominant in shallow waters of Division 3N (Fig. 1-2), and probably mixed with S. mentella at a depth of around 400-499 meters. In Div. 30, S. fasciatus was again predominant down to 500 meters and a mixture occurred in very deep water. On St. Pierre Bank (3P), S. fasciatus was predominant in shallow water whereas S. mentella was predominant in deep water. They mixed at the depth zone deeper than 300 meters (Fig. 1-2). In the Gulf of St. Lawrence (4RST areas), S. fasciatus could only be found shallower than 200 meters; S. mentella was predominant deeper than 200 meters (Fig. 1-2 and 1-3). The anal fin ray pattern was dominated by 8 instead of 9 or 8-9. In 4Vn area, S. mentella was still the predominant species. On the Nova Scotia Shelf (Division 4Vs, 4W and 4X) S. fasciatus was the predominant species. S. mentella may be present in waters deeper than 500 meters in Divisions 4W and 4X.

The mean values of each division-depth block, summarized in Table 3, offered a general indication of the distribution of sharp-beaked redfish. Anal fin ray means in the low 7's indicated that S. fasciatus was the predominant species whereas 8's indicated that S. mentella was the predominant species. The high 7's suggested that a mixture of the two species occurred.

Since the anal fin ray percentage frequencies showed strong characteristics of either kurtosis or skewness, the modes of the anal fin ray frequency distribution should offer better representation of the data (Table 4). If the second highest mode was more than 35%, it was also included in the table. Again, the presence of S. fasciatus was indicated on the Nova Scotia Shelf, in shallow waters (<400 meters) of NAFO Subarea 3 and in very shallow waters (<200 m) of the Gulf of St. Lawrence. S. mentella was found in between Greenland and Baffin Island, in Labrador waters, in deep waters of NAFO Subarea 3 (>300 meters) and of the Gulf of St. Lawrence (>200 meters) and even in very deep waters of Nova Scotia Shelf (>500 meters).

The anal fin ray statistics for each NAFO Division are listed in Table 5. χ^2 test of the independence of anal fin ray frequencies with depth is also listed to show the homogeniety of redfishes in each NAFO Division. Only the sharp-beaked redfish from the waters between Greenland and Baffin Island as well as from northern Labrador waters showed the same anal fin ray frequencies throughout all depths. In Divisions 2H, 4S and 4T, no significant differences of anal fin ray frequencies were found by excluding specimens from shallow waters.

Anal fin ray frequencies were then examined using cluster analysis to display the closeness of division-depth blocks. Figure 2 shows the distance between cases represented in shaded form. Two clear clusters again demonstrated the distribution of S. mentella and S. fasciatus. An overlapping of the two clusters indicated the zones where the two species mixed. A dendrographic relationship diagram (Fig. 3) also describes the sequence in which clusters were formed in the amalgamation process. Six clusters were observed: 1) Most of the deep water sharp-beaked redfish had an anal fin ray pattern of 8-9 similar to those of Labrador waters. These were identified as the Labrador and deep water stock. 2) On Flemish Cap, the count of 9 was predominant and implied a separate stock. 3) The Gulf of St. Lawrence stock was dominanted by a count of 8. 4) A mixture of 7, 8 and 9 indicated the combination of S. mentella and S. fasciatus. 5) In the shallow waters of Grand Bank and Nova Scotia Shelf, S. fasciatus dominated with 7 anal fin rays. 6) A small portion of 8 or 9 anal fin rays suggested that S. fasciatus was dominant

with occasional occurrence of S. mentella. There were no significant difference of anal fin ray frequencies for S. fasciatus between Grand Bank and Nova Scotia Shelf. However, the deep Laurentian Channel (>400 m) might possibly act as a barrier and two separate jurisdical fishery stocks could be considered.

In conclusion, significant geographic and vertical variations of anal fin ray frequencies were observed in sharp-beaked redfish. It again indicated that S. fasciatus were distributed in shallower waters and southern areas, whereas S. mentella were predominant in deeper water and northern areas. Five hypothetical stocks were proposed based on anal fin ray patterns (Table 6). They are Labrador and deep water stock, Flemish Cap stock, Gulf of St. Lawrence stock, Grand Bank stock and Nova Scotian Shelf stock.

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Table 1. Mean values, modes of frequency distributions, and sample sizes of anal fin rays recorded in the literature for Sebastes mentella and S. fasciatus.

Species	$\bar{x}$	mode	N	Location	Author
S. mentella	8.40	8	48	Banquereau and Flemish Cap	Barsukov (1972)
	8.51	9	233	3K	Barsukov and Zakharov (1972)
	8.61	9	203	2J	Barsukov and Zakharov (1972)
	8.54	9	326	Baffin Island	Barsukov and Zakharov (1972)
	8.94	9	297	3O	Litvinenko (1974)
	8.62	8	100	3L	Ni (1981b)
S. fasciatus	6.83	7	106	Eastport of Maine	Baruskov (1972)
	7.22	7	41	Banquereau, Grand Bank, Flemish Cap, and Iceland	Barsukov (1972)
	7.22	7	489	4W, 5Z	Barsukov and Zakharov (1972)
	7.27	7	455	3O, 3P, 3N, 3M	Barsukov and Zakharov (1972)
	7.63	7	232	3K	Barsukov and Zakharov (1972)
	7.22	7	124	3O	Litvinenko (1974)
	7.22	7	100	3L	Ni (1981b)

Table 2. Sample size of anal fin rays of sharp-beaked redfish by NAFO Division and depth zone.

Depth range (meters)	NAFO Divisions																	Subtotal
	0	1	2G	2H	2J	3K	3L	3M	3N	3O	3P	4R	4S	4T	4V	4W	4X	
<200		100						1	74	526	293	339	372	135	296	600	485	3221
200-299			15	1	254	200	426	197	431	544	1385	1313	882	215	282	453	176	6774
300-399	281	183	250	555	631	100	747	261	434	471	325	306	205	172	182	198	95	5396
400-499	155	101	220	399	356	100	251	409	120	237	324	148	129		457	228	165	3799
500-599	299	190	268	309	236		401	234	192	95	125	99	-[a]	-		106	72	2626
≥600	36	17	72	18	150	37	25	238	28	120	-	-	-	-	22	23	20	806
Subtotal	771	591	825	1282	1627	437	1850	1340	1279	1993	2452	2205	1588	522	1239	1608	1013	22622

[a] Depth not applicable

Table 3. Mean value of anal fin rays of sharp-beaked redfish by NAFO Division and depth zone.

Depth range (meters)	NAFO Divisions																
	0	1	2G	2H	2J	3K	3L	3M	3N	3O	3P	4R	4S	4T	4V	4W	4X
<200		8.63						(7.0)[a]	7.24	7.23	7.33	7.31	7.34	7.98	7.26	7.20	7.24
200-299			(8.60)	(9.0)	7.96	7.88	7.49	(7.94)	7.25	7.18	7.41	7.93	8.11	8.12	7.26	7.15	7.11
300-399	8.52	8.51	8.52	8.56	8.34	8.42	7.49	7.94	7.25	7.20	7.84	8.13	8.08	8.18	7.86	7.17	7.18
400-499	8.49	8.57	8.53	8.57	8.51	8.24	8.16	8.70	8.26	7.48	8.35	8.22	8.18		7.67	7.39	7.30
500-599	8.51	8.54	8.52	8.59	8.64		8.54	8.81	8.68	8.21	8.30	8.25	-[b]	-		7.81	7.29
≥600	8.56	(8.41)	8.53	(8.56)	8.51	8.43	(8.48)	8.83	(8.29)	7.76	-	-	-	-	(7.27)	(8.48)	(8.20)

[a] Sample size less than 30 indicated in parenthesis.

[b] Depth not applicable

Table 4. The mode of the frequency distribution of anal fin rays of sharp-beaked redfish by NAFO Division and depth zone.

Depth range (meters)	NAFO Divisions																
	0	1	2G	2H	2J	3K	3L	3M	3N	3O	3P	4R	4S	4T	4V	4W	4X
<200		9,8[a]						7	7	7	7	7	7	8[c]	7	7	7
200-299			9,8	9	8	8	7	7,9	7	7	7	8	8	8	7	7	7
300-399	9,8	9,8	8,9	9,8	9,8	8,9	7,8	8,9	7	7	8,7	8	8	8	8	7	7
400-499	8,9	9,8	9,8	9,8	9,8	8,9	7,9	9	9	7	8	8	8		7,8	7	7
500-599	9,8	9,8	9,8	9,8	9,8		9,8	9	9,8	9,7,8[b]	9	8	-	-		7	7
≥600	9,8	9,8	9,8	9,8	8,9	8,9	8,9	9	8,9	7	-	-	-	-	7	9	9

[a] The second figure where shown had a frequency of greater than 35%.

[b] All three figures had a frequency greater than 30%.

[c] Sample were mainly collected from 198-201 meters.

[d] Depth not applicable

Table 5. Anal fin ray statistics for NAFO Divisions. χ^2-test indicates the independence of anal fin ray frequencies with depth.

Depth range (meters)	NAFO Divisions																
	0	1	2G	2H	2J	3K	3L	3M	3N	3O	3P	4R	4S	4T	4V	4W	4X
n	771	591	825	1282	1627	437	1850	1340	1279	1993	2452	2205	1588	522	1239	1608	1013
$\bar{x}$	8.51	8.55	8.53	8.57	8.38	8.13	7.82	8.60	7.58	7.32	7.63	7.90	7.93	8.10	7.50	7.27	7.24
range	7-10	7-11	6-10	7-12	6-10	5-10	6-11	6-12	6-11	6-11	6-11	6-10	6-10	7-10	6-10	6-11	5-9
SD	0.5425	0.5769	0.5505	0.6159	0.6918	0.6395	0.8427	0.8621	0.3085	0.6344	0.7544	0.7206	0.6820	0.5753	0.6652	0.5961	0.4867
$SE_{\bar{x}}$	0.0195	0.0237	0.0192	0.0172	0.0172	0.0306	0.0196	0.0236	0.0226	0.0142	0.0153	0.0153	0.0171	0.0252	0.0189	0.0149	0.0153
χ^2	ns	ns	ns	*[a]	***	***	***	***	***	***	***	***	***	***[a]	*[a]	***	***

[a] No significant difference was obtained by excluding specimens from shallow water.

Table 6. Hypothetical stocks of sharp-beaked redfishes in Northwest Atlantic.

	Hypothetical stocks	Species	Vertebrae	Dorsal[a] fin ray	Anal fin ray	Note
1.	Labrador Coast West Greenland East Baffin Island (NAFO 0-2)	S. mentella	30	14,15	8,9	3K ?
2.	Flemish Cap (≥ 300-400 m)	S. mentella	30	15	9	< 300m are S. fasciatus
3.	Gulf of St. Lawrence	S. mentella	30	14	8	< 200m are S. fasciatus
4.	Grand Bank	S. fasciatus	29	14	7	3NO: > 500 m and 3L: > 400m are S. mentella
5.	Nova Scotia Shelf	S. fasciatus	29	14	7	> 600m may have S. mentella

[a] unpublished data based on 15290 dorsal fin ray counts.

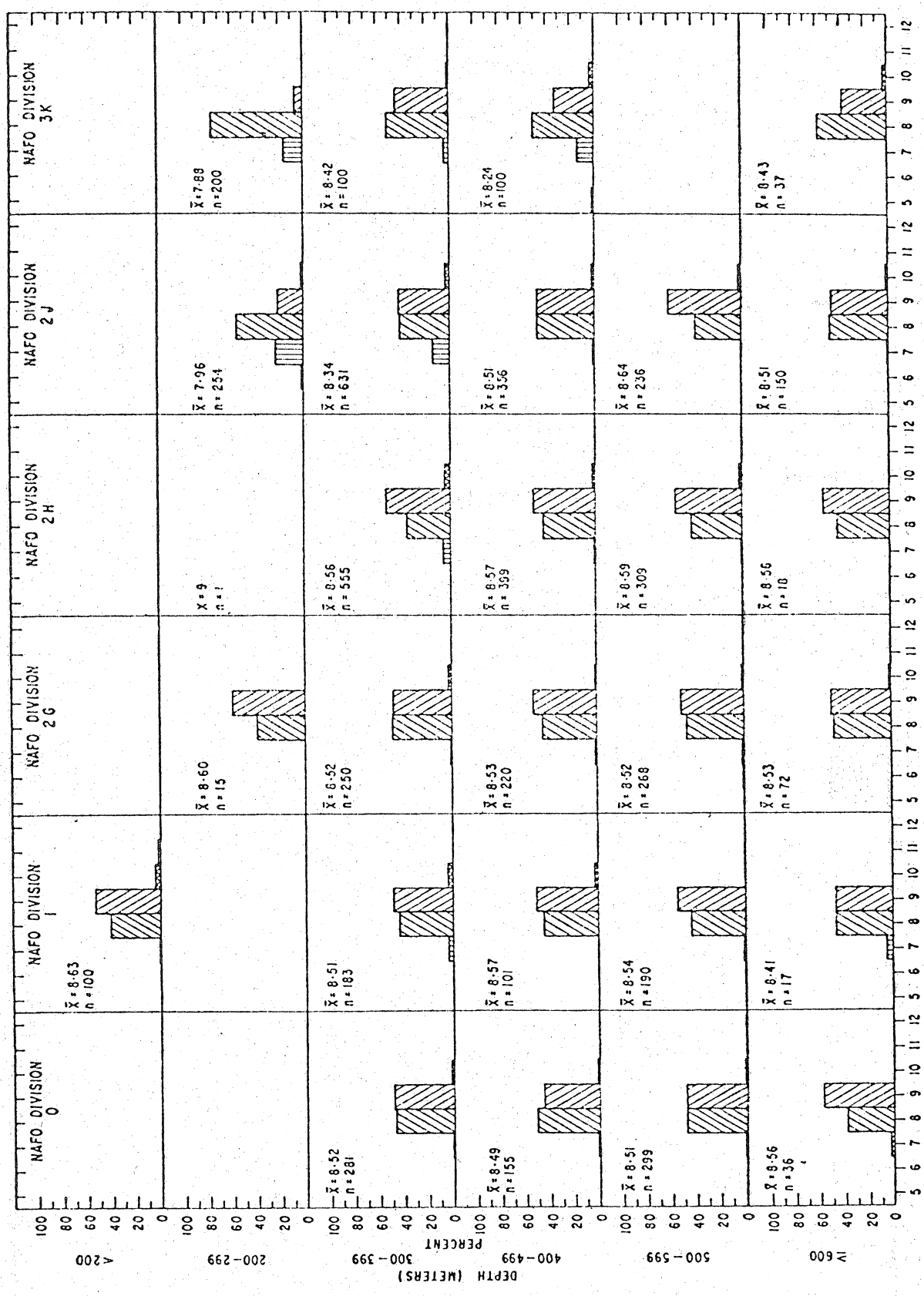


Fig. 1. Anal fin ray frequency distribution by depth zone in NAFO divisions.

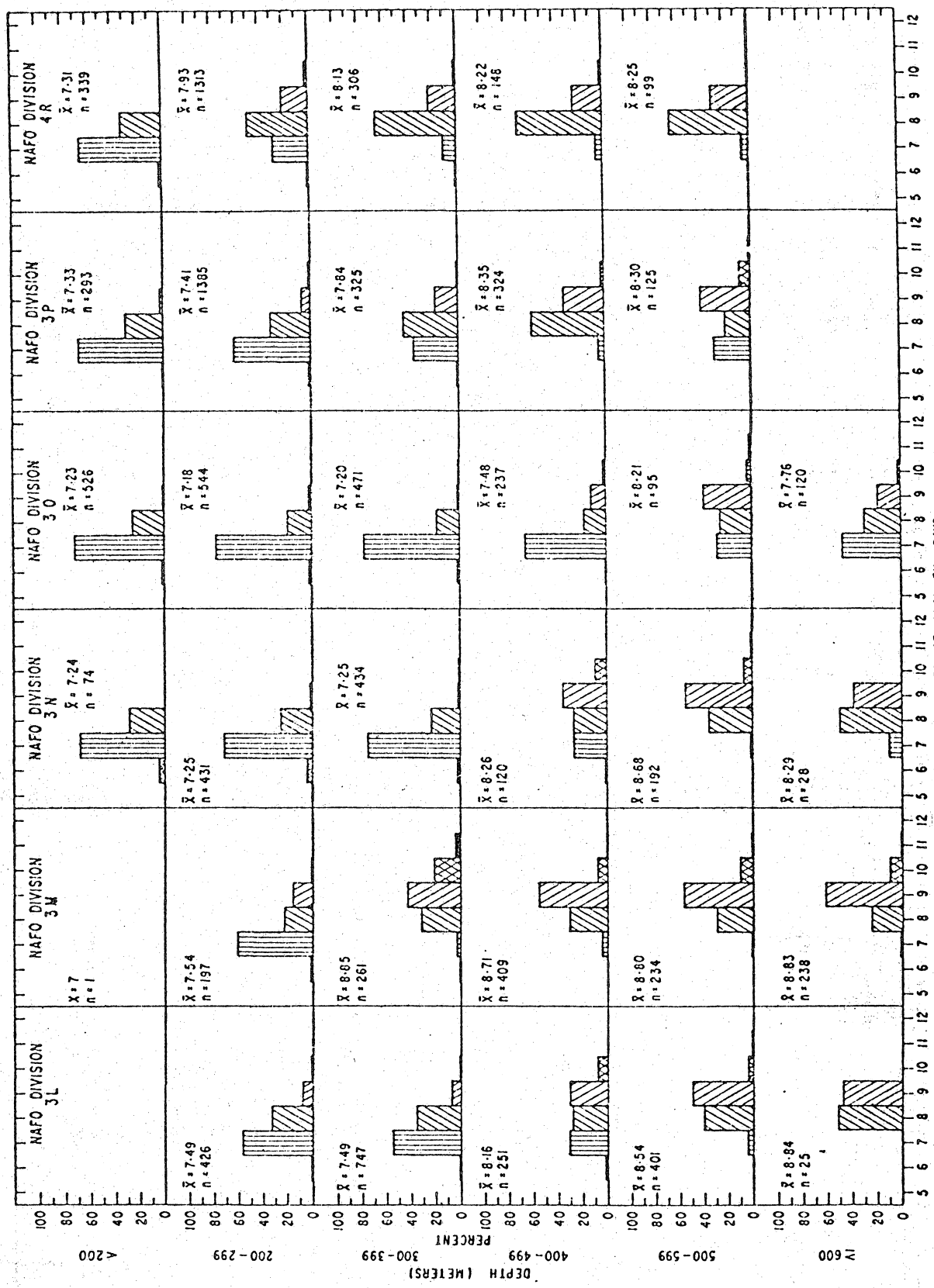

NAFO DIVISION 3L
NAFO DIVISION 3M
NAFO DIVISION 3N
NAFO DIVISION 3O
NAFO DIVISION 3P
NAFO DIVISION 4R
DEPTH (METERS)
PERCENT
NUMBER OF ANAL FIN RAYS
A 200
200 - 299
300 - 399
400 - 499
500 - 599
IV 600

Fig. 1-2.

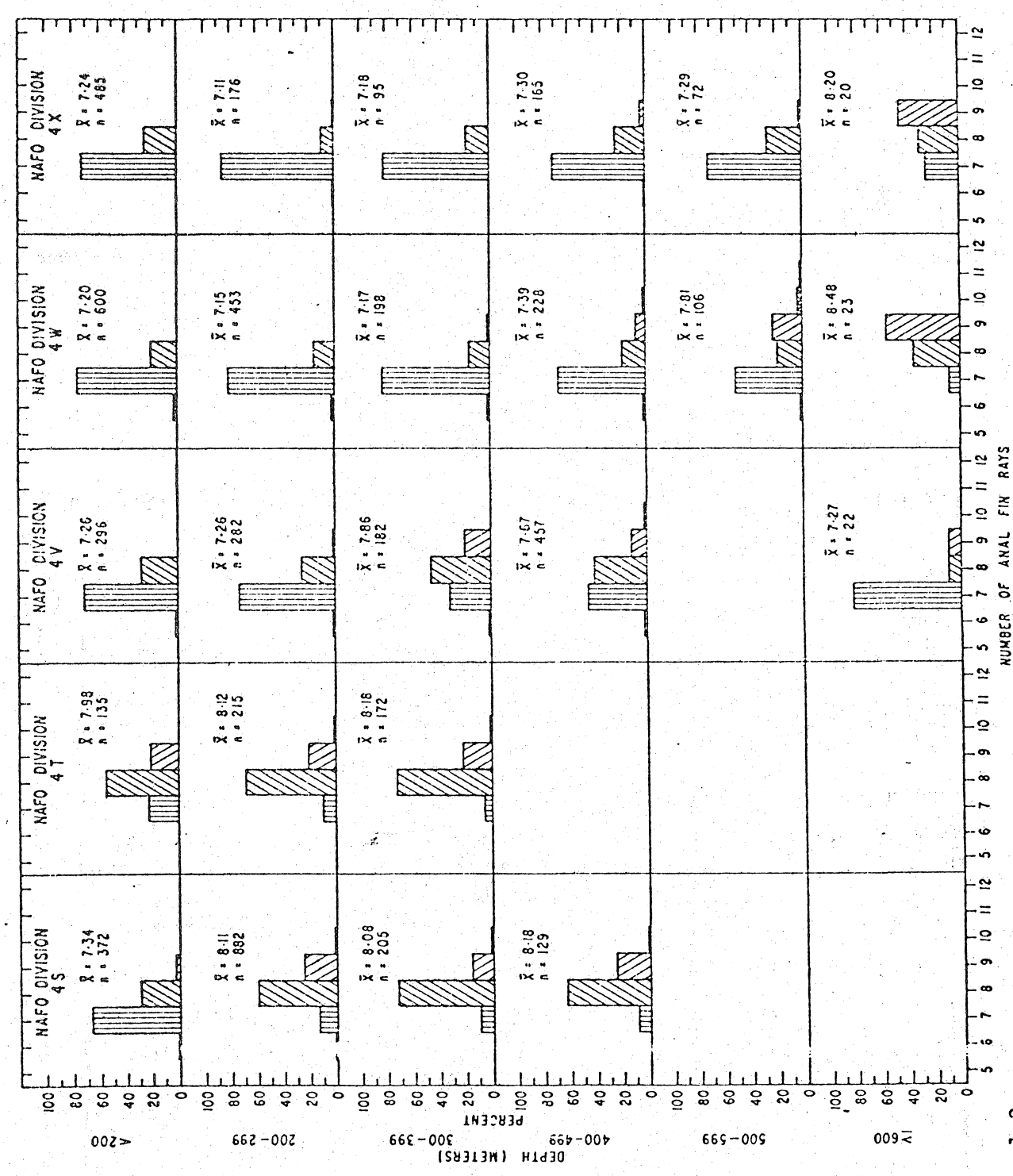
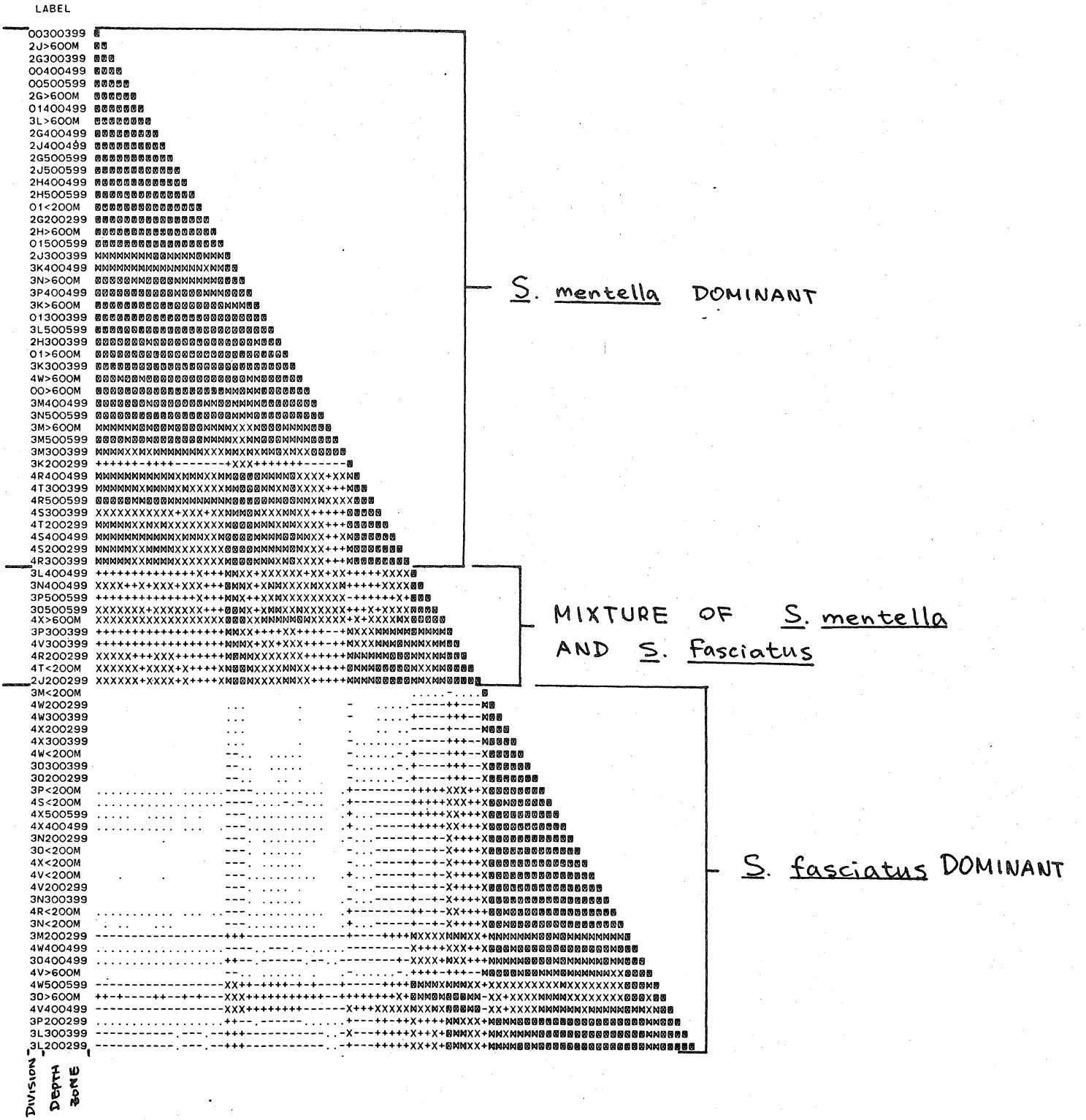

NAFO DIVISION 4S
NAFO DIVISION 4T
NAFO DIVISION 4V
NAFO DIVISION 4W
NAFO DIVISION 4X
DEPTH (METERS)
<200
200-299
300-399
400-499
500-599
>600
PERCENT
NUMBER OF ANAL FIN RAYS

Fig. 1-3.

Fig. 2 CLUSTER ANALYSIS OF REDFISH ANAL RAY FREQUENCIES

DISTANCES BETWEEN CASES REPRESENTED IN SHADED FORM.
HEAVY SHADING INDICATES SMALL DISTANCES.



THE DISTANCES HAVE BEEN REPRESENTED ABOVE IN SHADED FORM ACCORDING TO THE FOLLOWING SCHEME

■			LESS THAN	2.262
▩	FROM	2.262	TO	3.582
M	FROM	3.582	TO	4.901
X	FROM	4.901	TO	6.268
+	FROM	6.268	TO	8.012
-	FROM	8.012	TO	9.850
.	FROM	9.850	TO	11.217
			GREATER THAN	11.217

Fig. 3 CLUSTER ANALYSIS OF REDFISH ANAL RAY FREQUENCIES