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Meristic variation in beaked redfishes, *Sebastes mentella* and *S. fasciatus*, in the Northwest Atlantic [1]

by

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Abstract

The distribution of Northwest Atlantic beaked redfishes, Sebastes mentella and S. fasciatus, has been confused for the past several decades. S. fasciatus has been reported as having lower meristic counts than S. mentella. Meristic elements of 33,301 vertebrae, 22,622 anal fin ray and 16,290 dorsal fin ray counts were utilized to examine the yearly, depth and geographic variation of meristics in beaked redfishes. Data collected from specimens caught off West Greenland, Baffin Island, Labrador, Newfoundland, Quebec and Nova Scotia were analyzed by 100 m depth intervals. Temporal and depth variation were examined by the χ^2-test of independence on meristic frequencies. Geographic variation was evaluated using the modes and mean values in the meristic frequency histograms. Cluster analysis of meristic frequencies displayed the dendrographic affinities and the distance matrix among division-depth blocks.

Temporal variation indicated a mixture of vertebral frequency patterns which varied with depth and area. Depth variation and geographic clines were found for each of these meristic characters; the shallow and southern waters were dominated by counts of 29, 14-13, and 7 for vertebrae, dorsal fin rays, and anal fin rays respectively, while deep and northern waters were dominated by 30, 15-14, and 8-9. These results suggested that S. fasciatus occurs on the Nova Scotian shelf and Grand Bank whereas S. mentella is largely found in Baffin Bay, Labrador waters and the Gulf of St. Lawrence. The common names of S. mentella and S. fasciatus are discussed. Additionally, five hypothetical stocks of beaked redfishes based on meristic patterns are proposed for management purposes.

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STOCK DISCRIMINATION SYMPOSIUM

Introduction

An understanding of the distribution of beaked redfishes, Sebastes mentella and S. fasciatus, is important for the appropriate design of life history studies of each species and for determining component stocks. However, in past decades this was hampered by the uncertainties of redfish systematics and species identification. This study examines the yearly, depth and geographic variation in meristic characters, which are used to discriminate between S. mentella and S. fasciatus, and explores the distribution of these species in the Northwest Atlantic.

Although morphological differences between these two species were discussed by Barsukov (1972), Barsukov and Zakharov (1972), Litvinenko (1974), and Templeman (1980), the overlapping of morphological characters has made it very hard to distinguish beaked redfishes in field studies. From studies of extrinsic gasbladder musculature, Litvinenko (1980) and Ni (1981a) supported the validity of S. fasciatus. From the discriminant analysis of morphological characters, Ni (1981b) concluded that anal fin rays and vertebrae were good discriminators between S. mentella and S. fasciatus. This has been elucidated by numerous researchers (Table 1) who found that S. mentella had 30 vertebrae, 8 or 9 anal fin rays, and 14 or 15 dorsal fin rays, whereas S. fasciatus had most commonly 29 vertebrae, 7 anal fin rays, and 14 dorsal fin rays.

In this report, vertebrae, anal fin rays and dorsal fin rays of beaked redfishes were examined individually and collectively. I assumed that vertebrae and anal fin ray frequency distributions dominated by 30 and by 8 or 9 respectively indicated S. mentella while vertebrae 29 and anal fin rays 7 indicated S. fasciatus. Thus, a preliminary understanding of the distribution for S. mentella and S. fasciatus could be acquired from meristic variation.

Materials and Methods

We collected 33,301 vertebrae, 16,315 anal fin ray, and 16,290 dorsal fin ray counts between 1957 and 1968. An additional 6,307 anal fin ray counts were gathered between 1974 and 1981 during Canadian research survey cruises. The areas sampled, covering the whole Northwest Atlantic, were NAFO Div. 0-4X (Fig. 1). Sample sites were along the continental slope at bottom depths of 100 m to 750 m. Data were broken down into 100 m depth intervals, since Barsukov (1972) and Templeman (1976) suggested that S. mentella was distributed in deeper waters than S. fasciatus. As beaked redfishes were rarely found in shallow waters, data from waters <200 m were combined into one depth zone.

The temporal variation was analyzed for the vertebrae data only, because of the relatively large sample sizes. Vertebral counts excluded the urostyle, in conformity with Templeman and Pitt's (1961) redfish vertebral studies based on data collected from 1947 to 1954.

Particular attention was given to counting the last ray of the anal fin. This ray consists of two elements separated at the very base of the fin which seated on one basal (pterygiophore). The last two fin elements were counted as one ray.

Yearly and depth variation in meristic frequencies were examined separately using a χ^2-test of independence to identify cells (in the frequency table) or patterns of cells that contributed to a departure from independence. The BMDP2F program (Dixon and Brown 1979) was calculated in a stepwise manner. Stepping stops if the probability of the test-of-fit is greater than 0.05. The cells which contributed most to a significant difference could be deduced from the sequence of cells eliminated.

Geographic variation deduced from the patterns of modes and means in the meristic frequency histograms. I also applied cluster analysis (the BMDP2M program) to describe the dendrographic affinities and the distance matrix among division-depth blocks. The criterion to join clusters is defined as the distance between two cases in the χ^2-test of equality of the two sets of frequencies. Amalgamation uses the distances between centroids as defined by the average values with the clusters.

Results

Vertebrae

Vertebral frequencies for division-depth blocks were first broken down by year to study temporal variation. A summary of the results of the χ^2-tests, for influence of year, is shown in Table 2. Frequencies from Div. 2G and 2H were excluded from the table because insufficient data were available. The vertebral frequencies were stable over time in the waters between Greenland and Baffin Island (Subarea 0 and 1). Vertebral frequencies varied yearly in the shallow waters of southern Labrador (<400 m in Div. 2J), but they were stable in deep waters. In northeastern Newfoundland (Div. 3K), a stable pattern was seen only at the 500-599 m depth zone. On the Flemish Cap (Div. 3M), the unstable depth zone was 300-399 m. On the Grand Bank, vertebral frequencies fluctuated yearly in <500 m waters of Div. 3L, in medium depth zones of Div. 3N (200-299 m and 400-499 m) and in deep waters of Div. 30 (>500 m). On St. Pierre Bank (Div. 3P), vertebral frequencies varied annually in the waters deeper than 200 m. In the Gulf of St. Lawrence (Div. 4RST), vertebral frequencies varied yearly in the 200-299 m depth zone. There were occasional fluctuations in the < 200 m and the 300-399 m depth zones as no significant differences were found by eliminating one year's data for both depth zones. On the Nova Scotian shelf, the frequencies in Div. 4V showed no yearly variations in the shallow waters (< 400 m) while they varied in the deeper waters; Div. 4W and Div. 4X displayed slight differences in yearly vertebral frequencies in the shallow waters and in the deep waters, but they were stable in the medium depth zones (around 200-500 m). In summary, temporal variation varied with different depth zones for different areas. However, a mixture of different types of vertebral frequencies was clearly indicated.

In order to assess variation by depth for each division, data collected from different years were combined and vertebral percentage frequency distributions were evaluated (Fig. 2). The χ^2-tests of the independence of vertebral frequencies with depth for each NAFO Division are listed in Table 3. Only the specimens collected from Baffin Bay (Subarea 0 and 1) and northern Labrador (Div. 2G) showed no significant differences of their vertebral frequencies with depth. They consistently had a high frequency of 30 vertebrae. The significant variation with depth in Div. 2H was due to the high percentage of samples with 31 vertebrae from the shallow waters. In the other areas (Div. 2J, Subarea 3 and 4), χ^2-statistics showed significant differences in the vertebral frequencies with depth. In Div. 4X, excluding specimens from deep water (>600 m) reduced the χ^2 to a non-significant level. In general, vertebral number increased with depth except in Baffin Bay and Labrador waters.

The geographic variation of vertebral frequencies could be appraised from area to area by examining the frequency distributions (Fig. 2). In Baffin Bay (Subarea 0, 1) and northern Labrador (Div. 2G, and 2H) vertebral counts of 30 were dominant at all depths, and so *S. mentella* was determined to be the predominant species. However, 35.2% of the redfish collected from the 200-299 m in 2J and 41% of the redfish collected from <300 m in 3K had 29 vertebra (Fig. 2-1), indicating the presence of *S. fasciatus* at these depths. A mixture of redfishes was observed on Flemish Cap (Div. 3M): the two species intermingled in shallow waters (<300 m) but *S. mentella* dominated in deep waters (Fig. 2-2).

On Grand Bank (Div. 3LNO), S. fasciatus was predominant in shallow waters and S. mentella was predominant in deep waters. The two species probably mixed at a depth of 400-499 m in Div. 3L and 3N, and in deeper waters (> 500 m) in Div. 3O (Fig. 2-2). On St. Pierre Bank (Div. 3P), S. fasciatus was predominant in very shallow water (<200 m) whereas S. mentella was predominant in deep waters. They mixed at a wide range of depth zones (Fig. 2-2). In the Gulf of St. Lawrence (Div. 4RST), S. fasciatus was found to dominate only in water shallower than 200 m; S. mentella dominated at deeper than 200 m (Fig. 2-2 and Fig. 2-3). On the Nova Scotia Shelf (Div. 4VWX), S. fasciatus was the predominant species. S. mentella might be present in higher proportions in waters deeper than 500 m in these areas (Fig. 2-3).

The statistics for vertebrae in each NAFO Division are listed in Table 3. These were calculated by excluding all the abnormal vertebrae (fused vertebrae). A clear geographic cline of vertebrae of beaked redfishes, from a high mean value in the north to a gradual reduction toward the south, was noted, exceptions being Flemish Cap (Div. 3M) and the Gulf of St. Lawrence (Div. 4RST) (Fig. 3). No particular characteristics of abnormal verterbae rate among areas were noted, except a peculiarly high rate (1.36%) in Div. 3K. The overall percentage of abnormal vertebrae for all areas was 0.52%.

Anal fin rays

The anal fin ray statistics for each NAFO Division are listed in Table 4. The χ^2-test of the independence of anal fin ray frequencies with depth in each NAFO Division is listed to show the homogeniety of beaked redfishes. Only the specimens from Baffin Bay (Subarea 0 and 1) and northern Labrador (Div. 2G) showed the same anal fin ray frequencies throughout all depths. Strong depth variation was indicated in all other areas. However, in Div. 2H, 4S and 4T, no significant differences of anal fin ray frequencies were found by excluding specimens from shallow waters.

In Baffin Bay (Subarea 0 and 1) and Labrador (Div. 2G, 2H and 2J) (Fig. 4-1), the anal fin rays of 8 and 9 were both equally observed. Therefore, S. mentella was the predominant species. In Div. 2J, 22.8% of the specimens collected from the 200-299 depth zone had anal fin ray counts of 7, indicating the presence of S. fasciatus. Although the presence of S. fasciatus was also noted in the shallow waters of Div. 3K, S. mentella dominated. S. fasciatus dominated the shallow waters of Div. 3L whereas S. mentella dominated the deep waters of Div. 3K and 3L. On Flemish Cap (Div. 3M), the two species intermingled in shallow waters (<400 m) and S. mentella, with an anal fin ray count of 9, dominated in deeper waters (Fig. 4-2). S. fasciatus was predominant in shallow waters of Div. 3N and probably mixed with S. mentella at a depth of around 400-499 m. In Div. 3O, S. fasciatus was again predominant down to 500 m and a mixture occurred in deeper water. On St. Pierre Bank (Div. 3P), S. fasciatus was predominant in shallow water whereas S. mentella was predominant in deep water. They mixed at the depth zones deeper than 300 m (Fig. 4-2). In the Gulf of St. Lawrence (Div. 4RST), S. fasciatus dominated only in water shallower than 200 m; S. mentella, with 8 anal fin rays, was dominant in waters deeper than 200 m (Fig. 4-2 and 4-3). In Div. 4Vn, S. mentella was still the dominant species. On the Nova Scotia Shelf (Div. 4Vs, 4W and 4X) S. fasciatus was the dominant species. S. mentella may be present in a larger proportion in waters deeper than 500 m in Div. 4W and 4X. A geographic cline, a reduction in anal rays from north to south, was also observed except the Flemish Cap, Banguereau (Div. 4V) and Div. 4T (Fig. 3).

Anal fin ray frequencies were then examined using cluster analysis to display the relatedness of depth and geographic components. A dendrogram (Fig. 5) describes the sequence in which clusters were formed in the amalgamation process. Six groups were observed. 1) The deep water redfish in northeastern Newfoundland had an anal fin ray pattern of 8-9 similar to those of Baffin Bay and Labrador waters. These were determined as S. mentella - the Labrador and Baffin Bay group. 2) On the FLemish Cap, S. mentella, having an anal fin ray count of 9, was dominant. 3) S. mentella, with 8 anal fin rays, was dominant in the Gulf of St. Lawrence. 4) A mixture of anal fin ray 7, 8 and 9 indicated the combination of S. mentella and S. fasciatus. 5) In the shallow waters of Grand Bank and Nova Scotian 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.

In summary, significant depth and geographic variation of anal fin ray frequencies were observed in beaked redfishes. It again indicated that S. fasciatus were distributed in shallower waters and southern areas, whereas S. mentella were dominant in deeper water and northern areas.

Dorsal fin rays

The dorsal fin ray percentage frequency histograms with sample size and mean values were calculated (Fig. 6). Depth and geographic variation were again noted. Beaked redfishes in deep and northern waters had a greater number of dorsal fin rays than those of shallow and southern waters (Table 5 and Fig. 6). The patterns changed from 15-14 in Baffin Bay and Labrador waters, to 14 in deep waters of Grand Bank and in Gulf of St. Lawrence, and then to 14-13 in very shallow waters of Grand Bank and on Nova Scotian Shelf. Exceptions for the geographic cline were Flemish Cap and the St. Pierre Bank (Fig. 3).

Vertebrae, anal fin rays and dorsal fin rays combined

Since significant depth and geographic variation were observed in each meristic frequency, cluster analysis was then conducted by considering all three meristic frequencies to better display the relatedness of depth and geographic components. Cases with sample size less than 20 were excluded from the calculations. As shown by distance matrix in shaded form (Fig. 7). A similar pattern to the results obtained from vertebral frequencies and from anal fin ray frequencies was again obtained to support the distribution of beaked redfishes: S. mentella were shown to be distributed in northern and deep waters whereas S. fasciatus were shown to be distributed in southern and shallow waters. Even the mixing zones for beaked redfishes resembled those derived from anal fin rays and from vertebrae.

Discussion

The distributions of beaked redfishes were proposed on the basis of the assumption that S. mentella has higher meristic counts than S. fasciatus. Although Ni (1981a and b) indicated that 98% of S. fasciatus had anal fin ray counts of 7 and 68.7% had vertebral counts of 29 while S. mentella had 100% anal fin ray counts of 8 or greater and 99% vertebrae counts of 30 or greater, the within species geographic variation of anal fin rays and vertebrae of the two beaked redfishes should be carefully considered in order to confirm their distribution. However, the general pattern of 7 anal fin rays and 29 vertebrae for S. fasciatus and 8 or 9 anal fin rays and 30 vertebrae for S. mentella has been observed throughout most of the northwest Atlantic (Table 1). It is, therefore, reasonable to assume that the intraspecific variability is not likely exceed the interspecies differences.

That the significantly different patterns of vertebral and anal fin ray frequencies are differences between species rather than merely geographic variation of the same species can be substantiated by the following evidence. a) In the temporal variation study, although 47% of the 68 division-depth blocks of vertebral frequencies showed significant differences yearly, only 19.1% showed significant differences after eliminating one or two year's data (Table 2). This supported the hypothesis that different types of vertebral patterns existed for beaked redfishes. It also suggested a certain degree of vertical migration. The inference was drawn because no significant differences were found from the tests of Div. 4R (7 yr data), Div. 4S (4 yr data), and Div. 4T (6 yr data) by eliminating one year's data for both the <200 m and the 300-399 m depth zones. b) From the study of depth variation, I obtained no significant differences by eliminating deep or shallow water data (Table 3 and 4). This also indicated that mixtures of different types of vertebral and anal fin ray frequencies occurred. c) Two clear clusters were obtained from vertebral frequencies, from anal fin ray frequencies and from the three meristic frequencies combined (Fig. 7) to indicate the distribution of beaked redfishes. Even the overlapping of the two clusters, indicating the zones where the two species mixed, are similar. It was understandable that no species-specific pattern could be drawn from dorsal fin ray frequencies, since it was not suggested in the discriminant function (Ni 1981b).

Significant temporal and depth variation of vertebrae and anal fin ray frequencies showed strong division-depth characteristics except for the waters between Greenland and Baffin Island. The geographic cline for vertebrae, observed by Templeman and Pitt (1961), was verified. Vertebral averages decline from 30's in Baffin Bay and Labrador waters southward either along Northeastern Newfoundland waters and Grand Bank or along the Gulf of St. Lawrence to low 29's on the Nova Scotia Shelf. Geographic clines for anal fin rays and dorsal fin rays were also observed, there being a reduced number of rays from north to south. Exceptional area was Flemish Cap (Div. 3M) (Fig. 3).

It was interesting to note that additional meristic patterns could be ascertained especially from anal fin rays (Fig. 5). For management purposes, five hypothetical stocks in Northwest Atlantic are proposed based on these meristic taxa (Table 6). They are the Baffin Bay and Labrador stock, Flemish Cap stock, Gulf of St. Lawrence stock, Grand Bank stock and Nova Scotian Shelf stock. Although there were no significant differences of vertebral and anal fin ray frequencies for _S. fasciatus_ between Grand Bank and Nova Scotian shelf, the deep Laurentian Channel (> 400 m) might possibly act as a barrier and two separate fishery jurisdictional stocks could be considered.

S. mentella were predominant in the waters between Baffin Island and Greenland, in Labrador waters, in deep waters of the Gulf of St. Lawrence (>200 m), and of NAFO Subarea 3 (deeper than around 300-400 m), and in very deep waters of Nova Scotian Shelf (>600 m). S. fasciatus were distributed on the Nova Scotian Banks (<500 m), in shallow waters of NAFO Subarea 3 (<300-400 m) and in the very shallow waters of Gulf of St. Lawrence (<200 m). Therefore, S. fasciatus should not be called the "Labrador redfish" as in the fourth edition of "A List of Common and Scientific Names of Fishes from the United States and Canada" (American Fisheries Society, 1980). I would support Barsukov (1972), W. N. Eschmeyer (pers. comm.) and E. J. Sandeman (pers. comm.) who suggested that the common name "rosefish" be retained for S. fasciatus as first suggested by Taning (1949). "Bank redfish" as proposed by C. R. Robins (pers. comm.), and "shelf redfish", as proposed by T. Kenchington (pers. comm.), are other suitable names by implying shallow water. It is appropriate to use "deepwater redfish" for S. mentella since it is predominant in most of the deep waters of Northwest Atlantic although it can also be found in the shallow waters of Baffin Island, West Greenland and Labrador.

In conclusion, significant depth variation and geographic cline of meristics were observed in beaked redfishes. S. mentella, having 30 vertebrae and 8 or 9 anal fin rays, dominated in northern and deep waters whereas S. fasciatus, having 29 vertebrae and 7 anal fin rays, distributed in southern and shallow waters. A distribution map for beaked redfishes in Northwest Atlantic are proposed (Fig. 8).

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Table 1. Samples sizes, mean values, and modes of vertebrae, anal fin ray and dorsal fin ray frequencies recorded in the literature for (A) Sebates mentella and (B) S. fasciatus. Abbreviations for locality are NAFO Divisions.

Locality	Vertebrae[a]			Anal fin rays			Dorsal fin rays			Author
	N	Mean	Mode	N	Mean	Mode	N	Mean	Mode	
A. S. mentella										
Barents Sea	37	30.14	30	137	8.48	8	80	14.29	14	Barsukov and Zakarov (1972)
Iceland and Greenland	37	30.27	30	42	8.72	9				Barsukov (1972)
Iceland	253	30.17	30	282	8.49	9	34	14.65	15	Barsukov and Zakharov (1972)
West Greenland	146	29.99	30	235	8.53	9	57	14.53	15	Barsukov and Zakharov (1972)
Baffin Island	397	30.02	30	326	8.54	9	153	14.59	15	Barsukov and Zakharov (1972)
2J	202	30.04	30	203	8.61	9				Barsukov and Zakharov (1972)
3K	232	30.03	30	233	8.51	9				Barsukov and Zakharov (1972)
3L	100	30.03	30	100	8.62	8	100	14.67	15	Ni (1981b)
30	109	30.10	30	297	8.94	9	42	14.61	14	Litvinenko (1974)
3M, 3P	49	30.00	30	48	8.37	8				Barsukov and Zakharov (1972)
Flemish Cap and Banquereau	48	30.02	30	48	8.40	8				Barsukov (1972)
B. S. fasciatus										
2J, 3K	228	29.36	29	232[b]	7.63	8	96[b]	13.79	14	Barsukov and Zakharov (1972)
3L	99	29.31	29	100	7.02	7	100	13.62	14	Ni (1981b)
30	124	29.05	29	124	7.22	7	84	13.63	14	Litvinenko (1974)
3M, 3N, 30, 3P	455	29.12	29	455	7.27	7	196[c]	13.67	14	Barsukov and Zakharov (1972)
4W, 5Z	447	29.19	29	489	7.22	7	106[d]	13.73	14	Barsukov and Zakharov (1972)
Flemish Cap, Grand Bank and Banquereau	41	29.19	29	41	7.22	7				Barsukov (1972)

[a] data were ajusted by excluding urostyle

[b] from 3K only

[c] from 30, 3P only

[d] from 4W only

Table 2. Summary of χ^2-test of independence (significant level)[a] for temporal variations of vertebral frequencies in division-depth blocks. Number of years data for calculation are in brackets. Sample sizes are in Figure 2. Abbreviations under geographic areas are NAFO Divisions.

Depth range (meters)	Baffin Bay		Southern Labrador	NE Nfld.	Flemish Cap	Grand Bank			St. Pierre Bank	Gulf of St. Lawrence			Nova Scotian Shelf		
	0	1	2J	3K	3M	3L	3N	30	3P	4R	4S	4T	4V	4W	4X
<200							ns (2)	ns (4)	ns (8)	***[b] (8)	*[b] (4)	***[b] (6)	ns (6)	*[b] (6)	*[b] (3)
200-299			***[b] (4)	*[b] (3)	ns (2)	*** (4)	*[b] (3)	ns (2)	***[c] (8)	*** (8)	***[c] (5)	***[c] (6)	ns (3)	*[b] (3)	ns (3)
300-399	ns (2)	ns (2)	**[b] (3)	*** (2)	*** (2)	**[b] (4)	ns (3)	ns (3)	*** (4)	***[b] (7)	*[b] (4)	ns (5)	ns (2)	ns (3)	* (2)
400-499	ns (2)	ns (2)	ns (3)	* (2)	ns (2)	**[b] (3)	*** (2)	ns (3)		ns (3)	ns (2)	ns (2)	** (2)	ns (3)	ns (4)
500-599		ns (2)	ns (3)	ns (2)	ns (2)	ns (4)	ns (2)	**[b] (3)			-[d]	-		**[b] (3)	* (2)
≥600		ns (2)	ns (2)	* (2)		ns (3)		** (2)	-	-	-	-		ns (3)	*[b] (3)

[a] ns: no significant difference; *: significant difference at p = 0.05 level; **:significant difference at p = 0.01 level; ***: significant difference at p = 0.001 level.

[b] no significant difference was found by eliminating only one year data.

[c] no significant difference was found by eliminating two years data.

[d] depth not applicable

Table 3. The vertebrae statistics of beaked redfishes for each NAFO Division. χ^2-test shows the independence of vertebral frequencies with depth zones used in Figure 2.

Statistics	Baffin Bay		Labrador Shelf			NE Nfld.	Flemish Cap	Grand Bank			St. Pierre Bank	Gulf of St. Lawrence			Nova Scotian Shelf			Total
	0	1	2G	2H	2J	3K	3M	3L	3N	3O	3P	4R	4S	4T	4V	4W	4X	
N[a]	599	546	435	948	2377	1809	1204	1743	1229	1885	5838	5335	2465	2053	1061	2598	1176	33,301
$\bar{x}$	30.03	30.06	30.01	30.04	29.94	29.68	30.01	29.53	29.41	29.29	29.46	29.65	29.75	29.82	29.21	29.17	29.15	29.59
Mode[b]	30	30	30	30	30	30	30	29,30	29,30	29	29,30	30,29	30	30	29	29	29	30,29
Range	29-31	29-31	29-31	29-31	29-31	29-31	29-31	29-31	28-31	28-31	28-31	28-32	28-31	28-31	28-31	27-31	28-31	27-32
$SE_{\bar{x}}$	0.0104	0.0116	0.0103	0.0106	0.0082	0.0121	0.0145	0.0133	0.0155	0.0112	0.0071	0.0074	0.0106	0.0109	0,.0129	0.080	0.0110	0.0033
Percentage of abnormal vertebrae	0.83	0.18	0.68	0.73	0.25	1.36	0.50	0.85	0.65	0.37	0.58	0.39	0.48	0.29	0.47	0.35	0.25	0.52
χ^{2}[c]	ns	ns	ns	***	***	***	***	***	***	***	***	***	***	***	***	***	***[d]	***

[a] excluding abnormal vertebrae.

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

[c] ns: no significant difference; ***: significant difference at p = 0.001 level.

[d] No significant difference was obtained by excluding specimens from deep water.

Table 4. Anal fin ray statistics of beaked redfishes for each NAFO Division. χ^2-test indicates the independence of anal fin ray frequencies with depth zones used in Figure 4.

Statistics	Baffin Bay		Labrador Shelf			NE Nfld.	Flemish Cap	Grand Bank			St. Pierre Bank	Gulf of St. Lawrence			Nova Scotian Shelf			Total
	0	1	2G	2H	2J	3K	3M	3L	3N	3O	3P	4R	4S	4T	4V	4W	4X	
N	771	591	825	1282	1627	437	1340	1850	1279	1993	2452	2205	1588	522	1239	1608	1013	22,622
$\bar{x}$	8.51	8.55	8.53	8.57	8.38	8.13	8.60	7.82	7.58	7.32	7.63	7.90	7.93	8.10	7.50	7.27	7.24	7.88
Mode[a]	9 8	9 8	9,8	9,8	8,9	8	9	7,8	7	7	7,8	8	8	8	7	7	7	8,7
Range	7-10	7-11	6-10	7-12	6-10	5-10	6-12	6-11	6-11	6-11	6-11	6-10	6-10	7-10	6-10	6-11	5-9	5-12
$SE_{\bar{x}}$	0.0195	0.0237	0.0192	0.0172	0.0172	0.0306	0.0236	0.0196	0.0226	0.0142	0.0153	0.0153	0.0171	0.0252	0.0189	0.0149	0.0153	0.0055
χ^2[b]	ns	ns	ns	**[c]	***	***	***	***	***	***	***	***	***[c]	**[c]	***	***	***	***

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

[b] ns: no significant difference; **: significant difference at $p = 0.01$ level; ***: significant difference at $p = 0.001$ level.

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

Table 5. Dorsal fin ray statistics of beaked redfishes for each NAFO Division. χ^2-test indicates the independence of dorsal fin ray frequencies with depth zones used in Figure 7.

Statistics	Baffin Bay		Labrador Shelf			Flemish Cap	Grand Bank			St. Pierre Bank	Gulf of St. Lawrence			Nova Scotian Shelf			Total
	0	1	2G	2H	2J	3M	3L	3N	3O	3P	4R	4S	4T	4V	4W	4X	
N	771	591	468	983	1219	664	1658	1274	1693	936	1482	759	219	952	1607	1014	16,290
$\bar{x}$	14.59	14.57	14.56	14.59	14.42	14.56	13.99	13.92	13.76	14.37	13.98	14.06	14.09	13.69	13.69	13.61	14.07
Mode[a]	15,14	15,14	15,14	15,14	14,15	14,15	14	14	14	14,15	14	14	14	14	14,13	14,13	14
Range	12-16	13-16	13-16	12-17	12-17	12-17	12-18	11-18	11-17	12-17	12-19	12-16	12-16	12-16	11-18	12-16	11-19
$SE_{\bar{x}}$	0.0239	0.0259	0.0273	0.0213	0.0208	0.0340	0.0198	0.0213	0.0157	0.0268	0.0186	0.0250	0.0476	0.0195	0.0162	0.0192	0.0063
χ^2 [b]	ns	ns	ns	*	***	***	***	***	***	***	***	***	ns	*	***	***	***

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

[b] ns: no significant difference; *: significant difference at p=0.05 level; ***: significant difference at p=0.001 level.

Table 6. Hypothetical stocks of beaked redfishes in Northwest Atlantic. Abbreviations are NAFO Divisions.

	Hypothetical stocks	Species	Vertebrae	Dorsal fin ray	Anal fin ray	Note
1.	Baffin Bay (Subarea 0 and 1) Labrador Coast (2GHJ) Northeastern Newfoundland waters (>300 m) (3K)	*S. mentella*	30	14,15	8,9	<300 m of 2J and 3K may have *S. fasciatus*
2.	Flemish Cap (3M) (≥ 300-400 m)	*S. mentella*	30	15	9	< 300m are *S. fasciatus* and *S. marinus*
3.	Gulf of St. Lawrence (4RST)	*S. mentella*	30	14	8	< 200m are *S. fasciatus*
4.	Grand Bank (3LNO)	*S. fasciatus*	29	14	7	3LN: > 500 m are *S. mentella*
5.	Nova Scotia Shelf (4VWX)	*S. fasciatus*	29	14,13	7	> 600m may have *S. mentella*

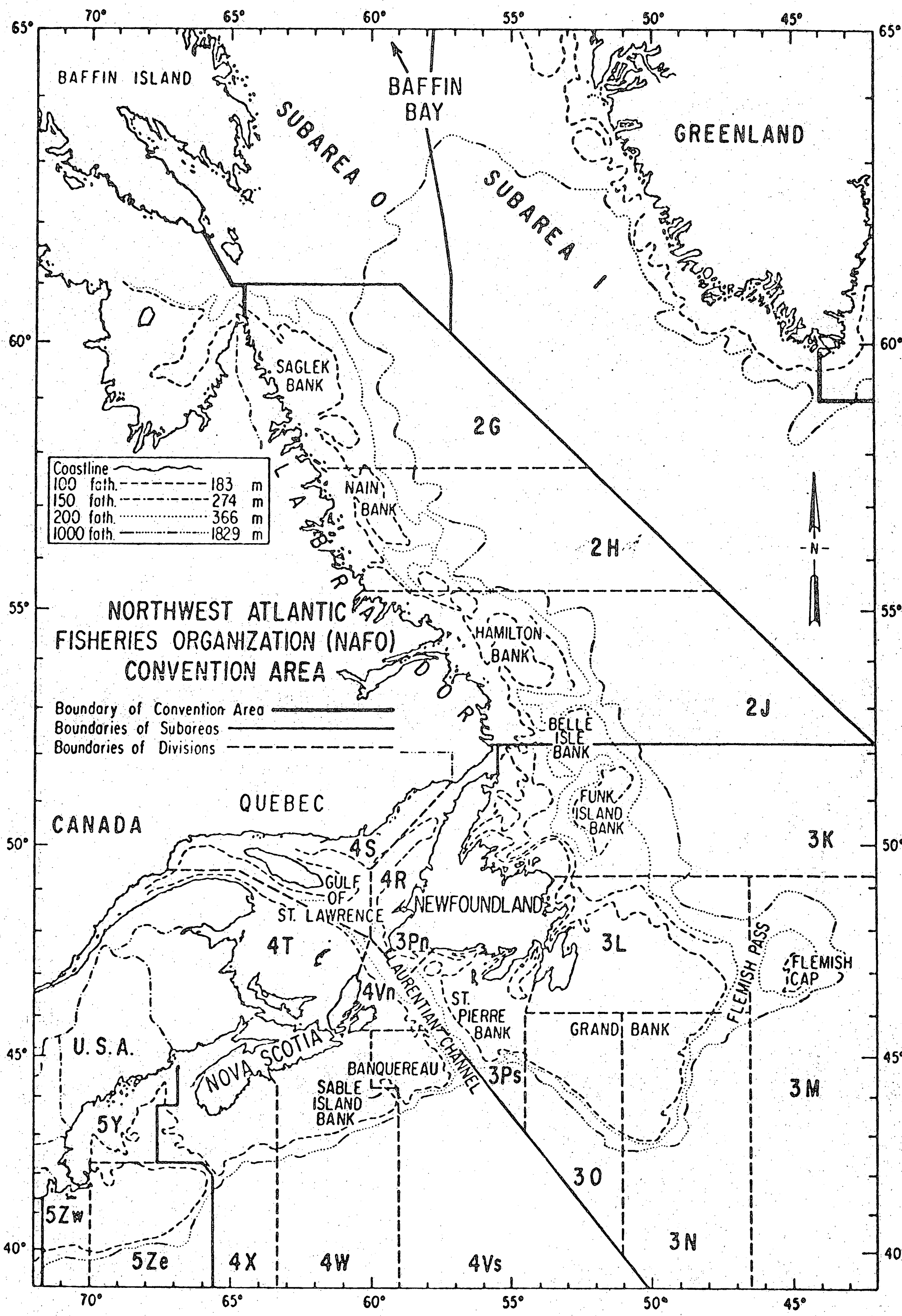

Fig. 1. NAFO Divisions and place names referred to in the text. Sample sites were along the continental slope at bottom depth around 100 m to 750 m.

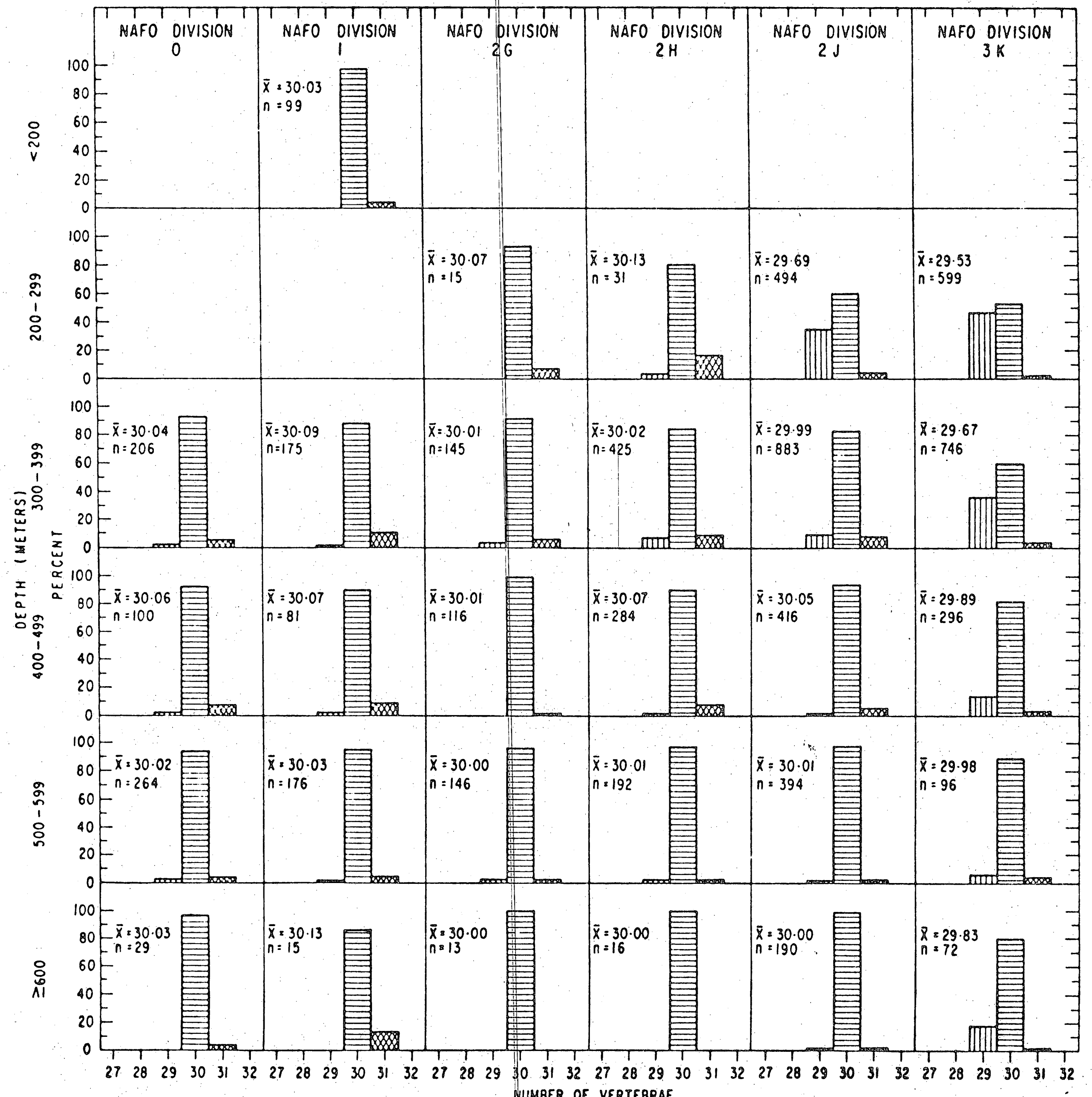

Fig. 2-1. Percentage frequency histograms of vertebrae in NAFO Divisions 0 to 3K by depth.

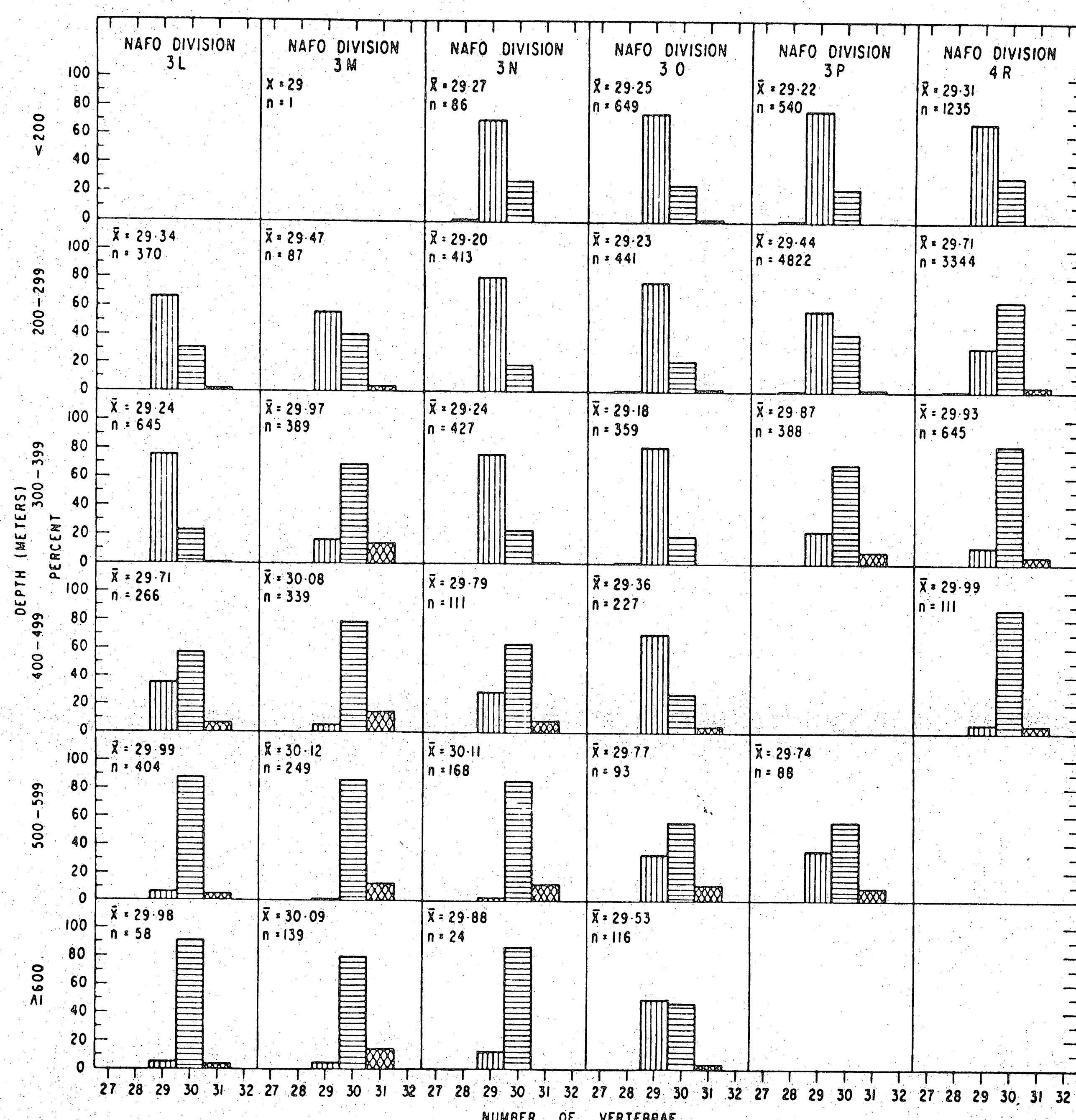

Fig. 2-2. Percentage frequency histograms of vertebrae in NAFO Divisions 3L to 4R by depth.

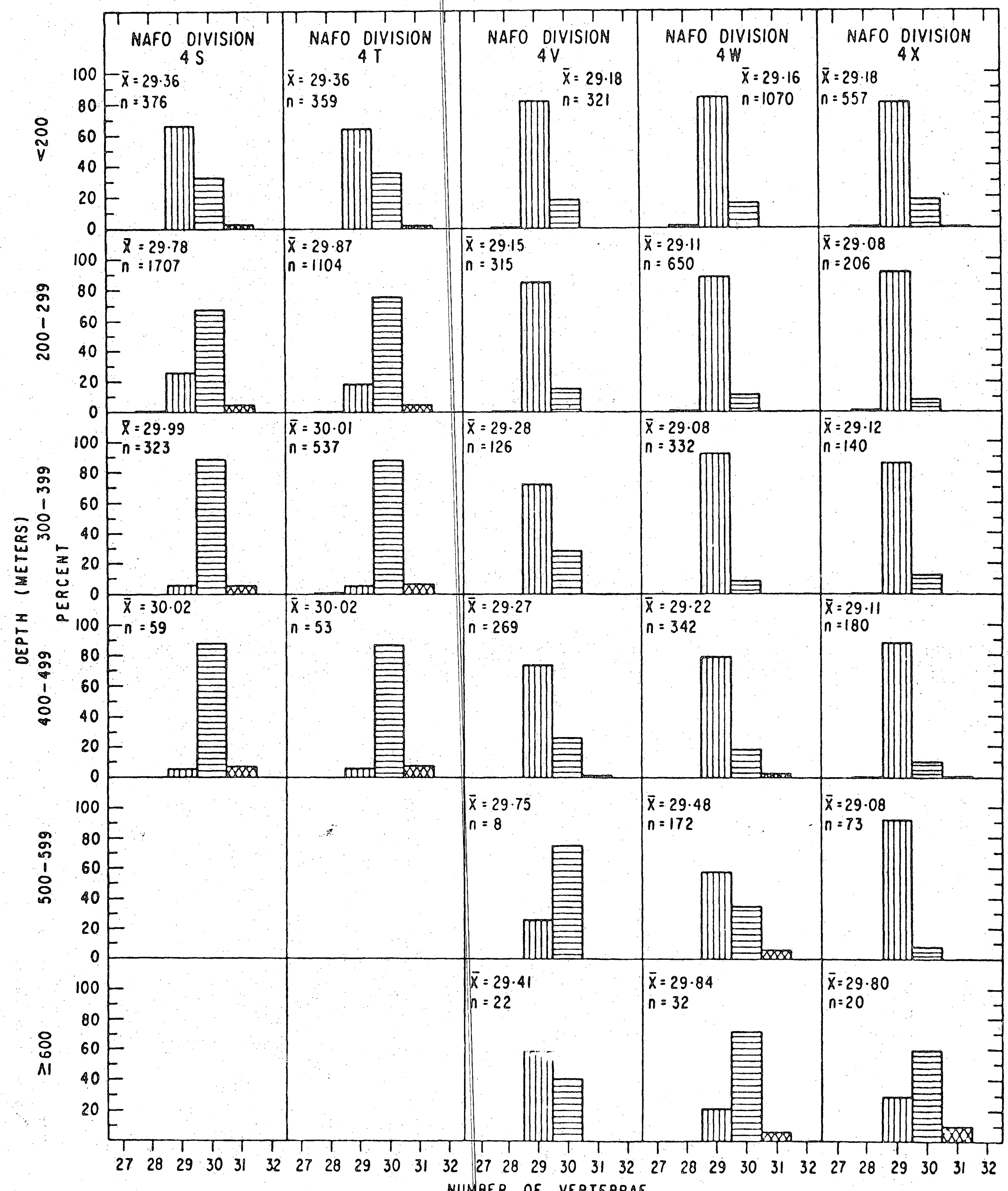

Fig. 2-3. Percentage frequency histograms of vertebrae in NAFO Divisions 4S to 4X by depth.

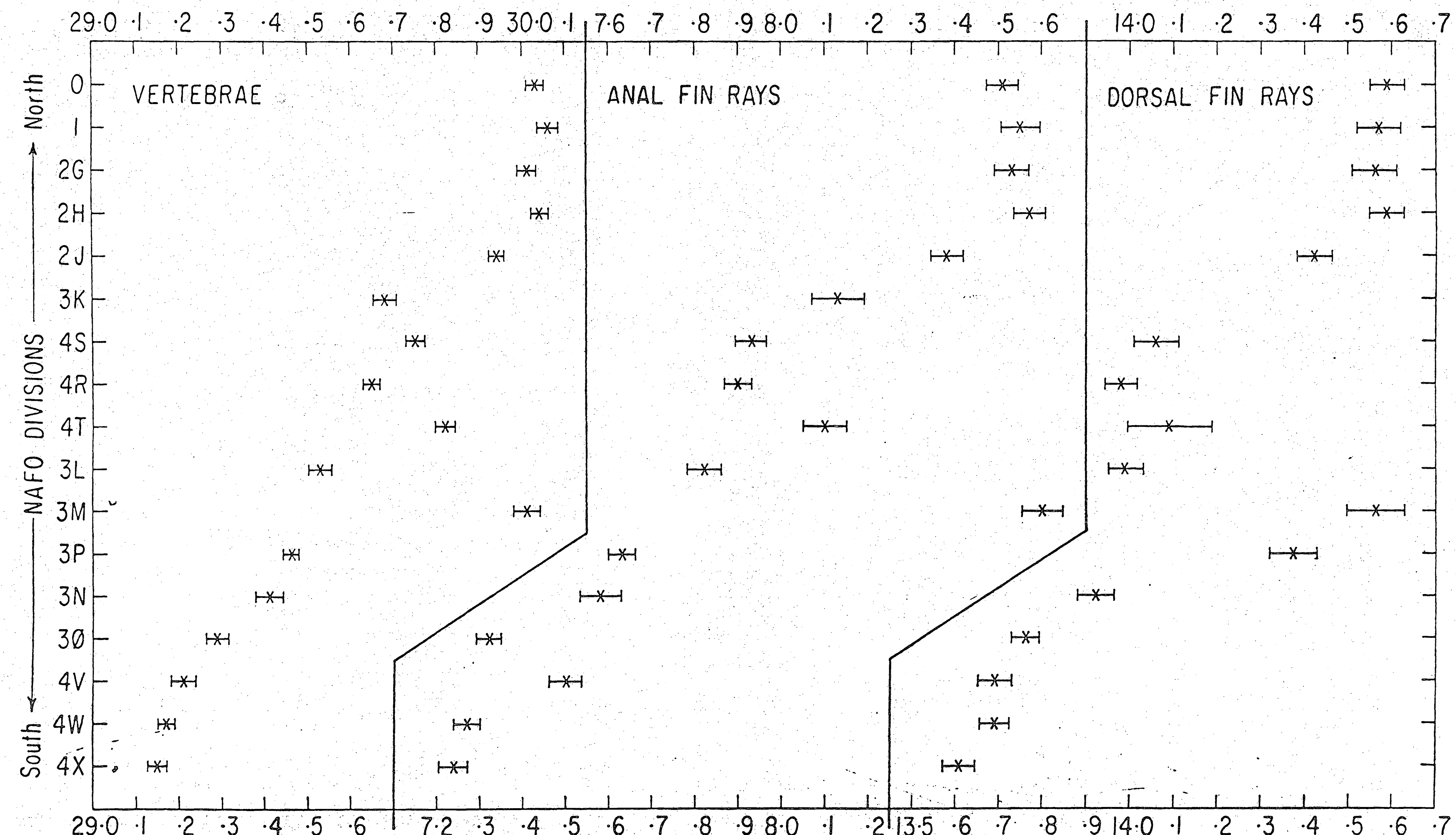

Fig. 3. Geographic clines of meristics in beaked redfishes. NAFO Divisions are in the sequence of north down to south. Horizontal bars are mean values of meristics with 95% confidence limits.

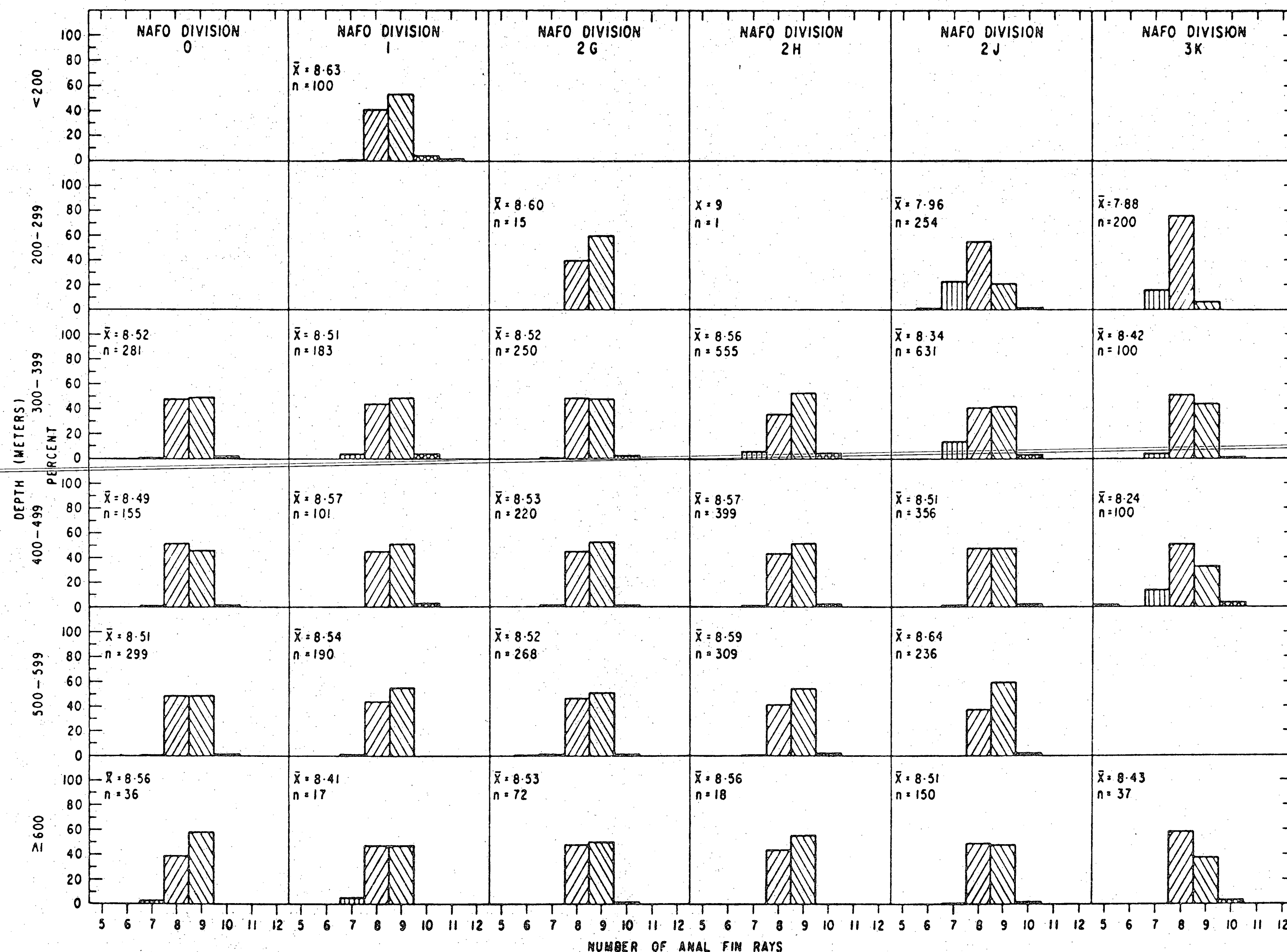

Fig. 4-1. Percentage frequency histograms of anal fin rays in NAFO Divisions 0 to 3K by depth.

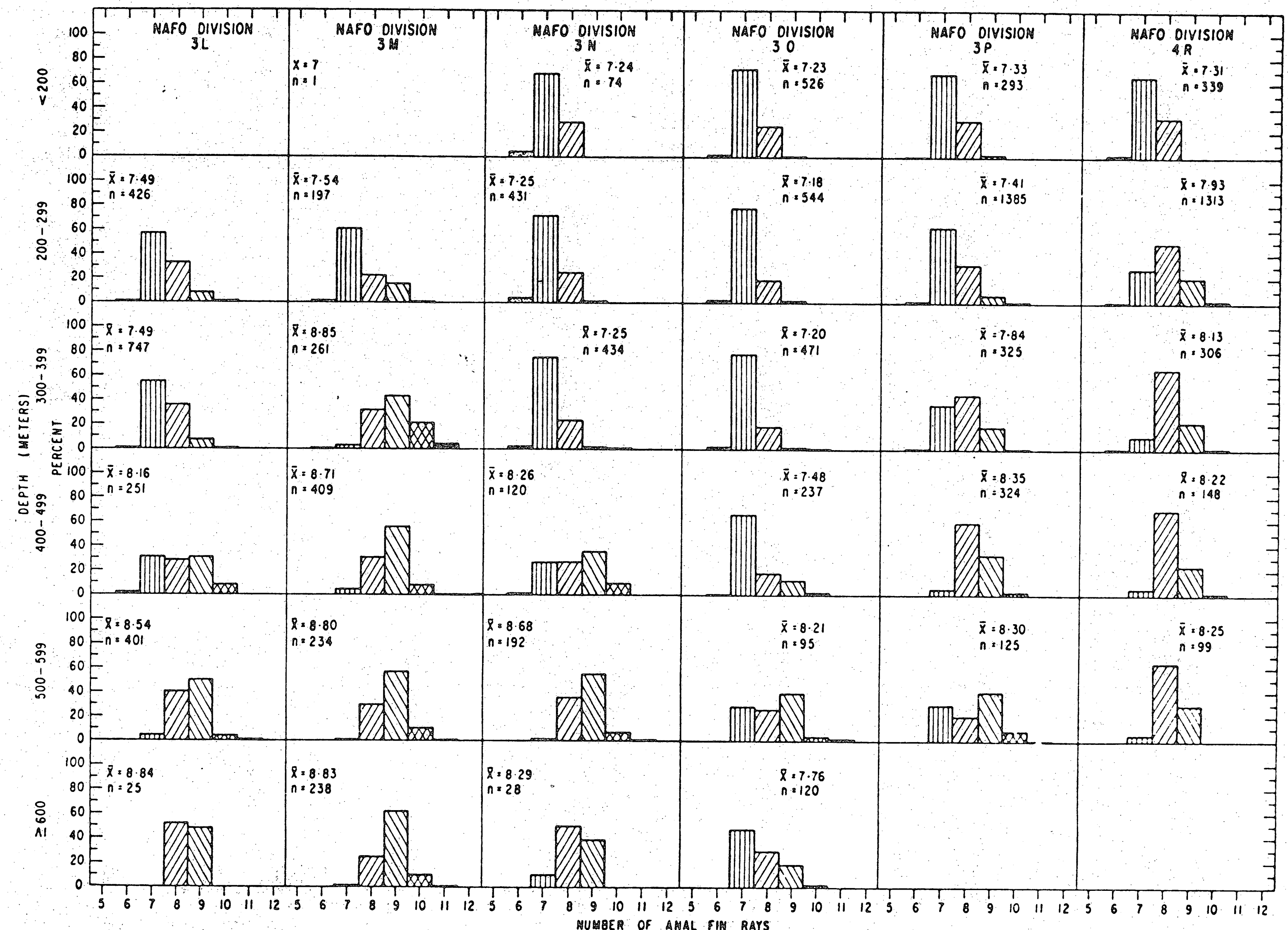

Fig. 4-2. Percentage frequency histograms of anal fin rays in NAFO Divisions 3L to 4R by depth.

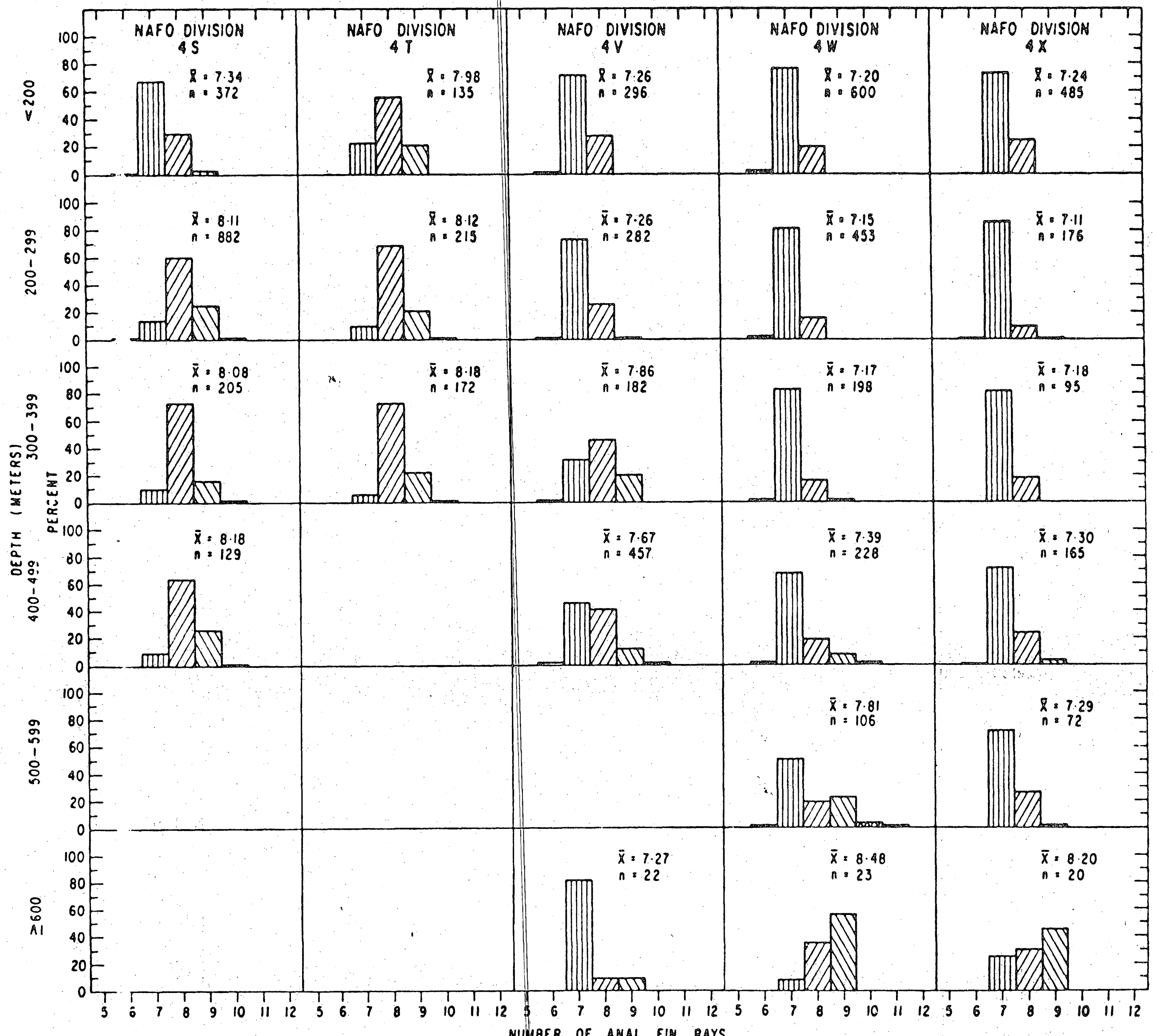

Fig. 4-3. Percentage frequency histograms of anal fin rays in NAFO Divisions 4S to 4X by depth.

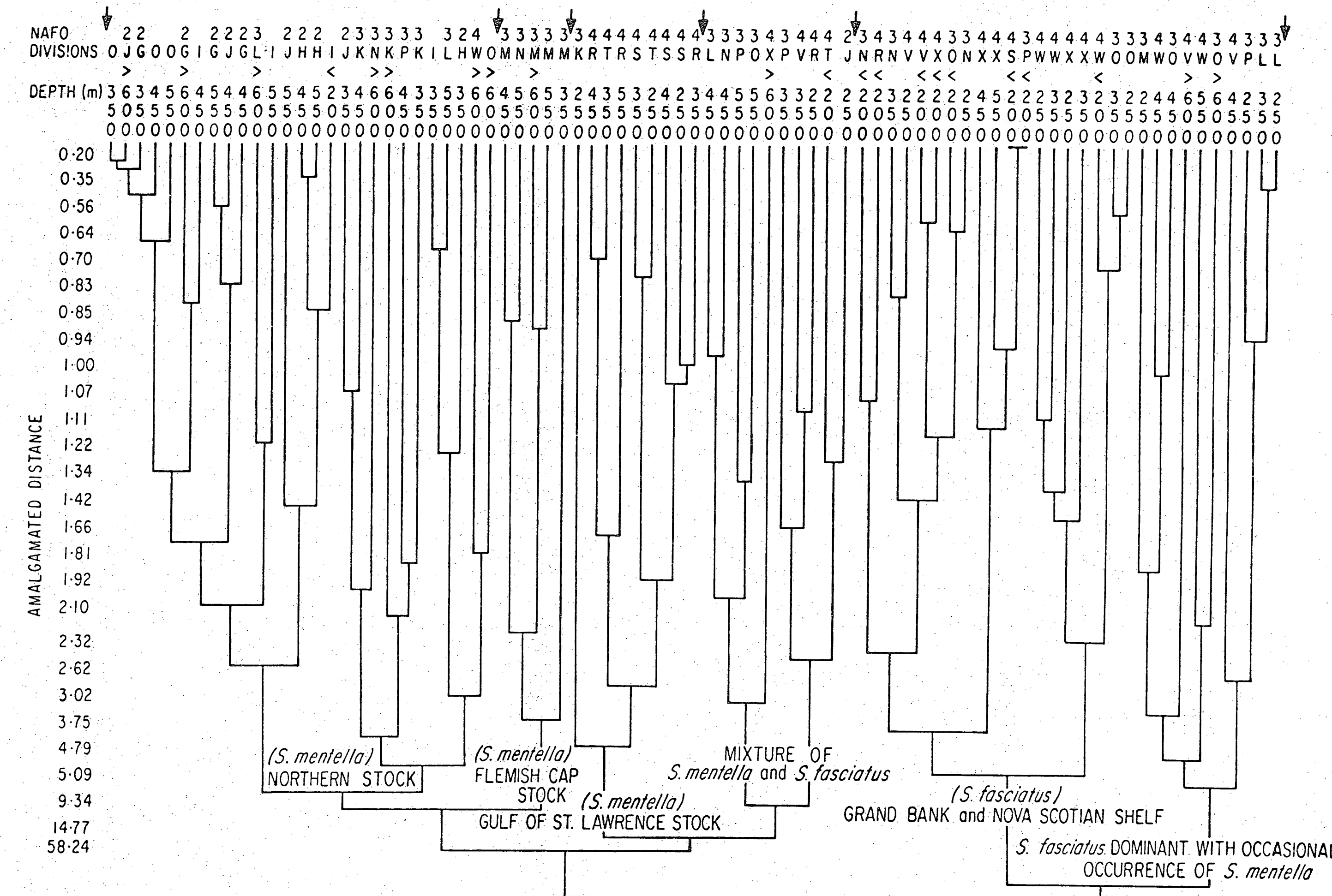

Fig. 5. Dendrographic relationship of anal fin ray frequencies among division-depth blocks. Case labels are NAFO dividion and depth intervals. Depth at 250 represent 200-299 m, same apply to 350, 450 and 500.

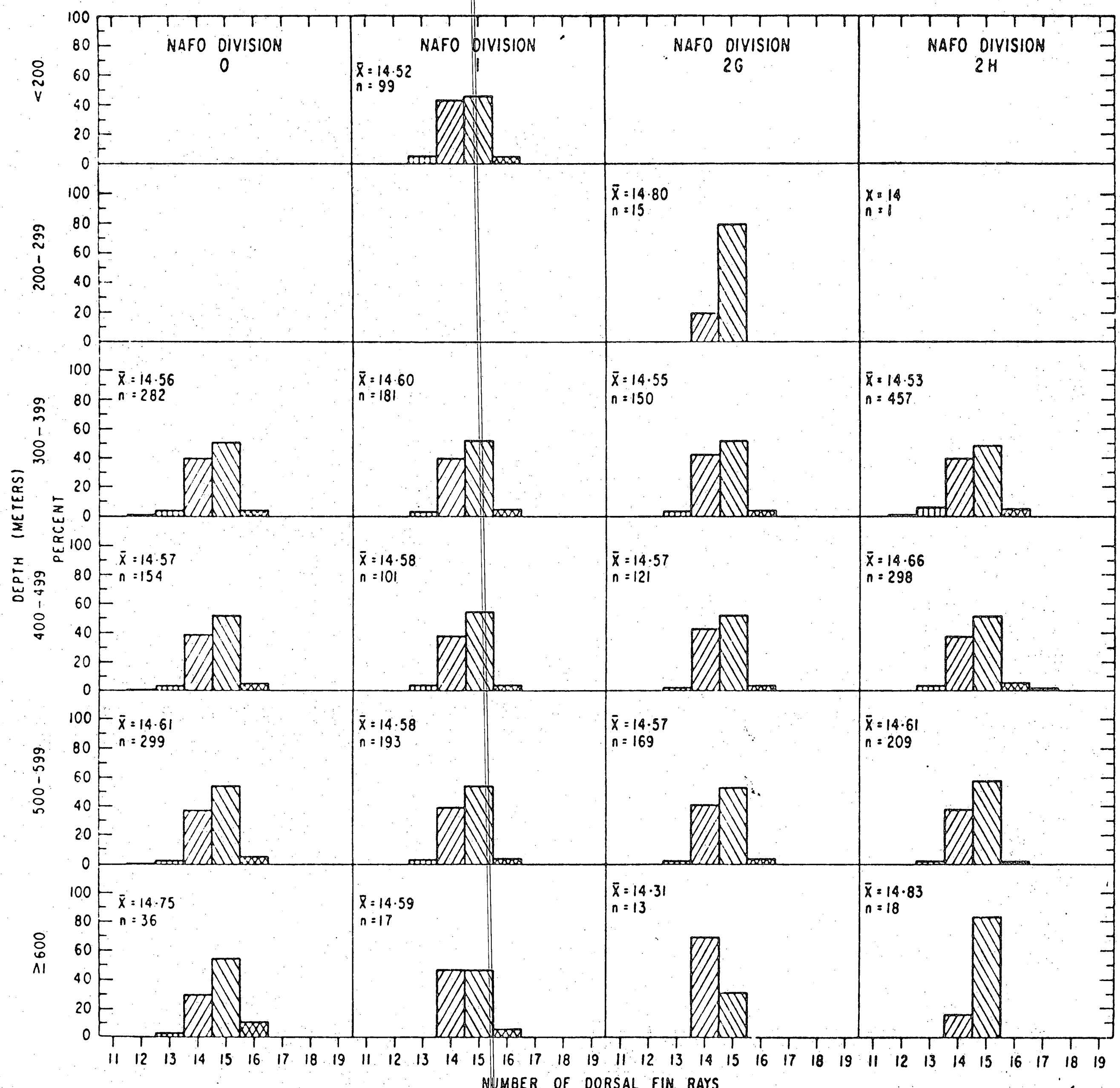

Fig. 6-1. Percentage frequency histograms of dorsal fin rays in NAFO Divisions 0 to 2H by depth.

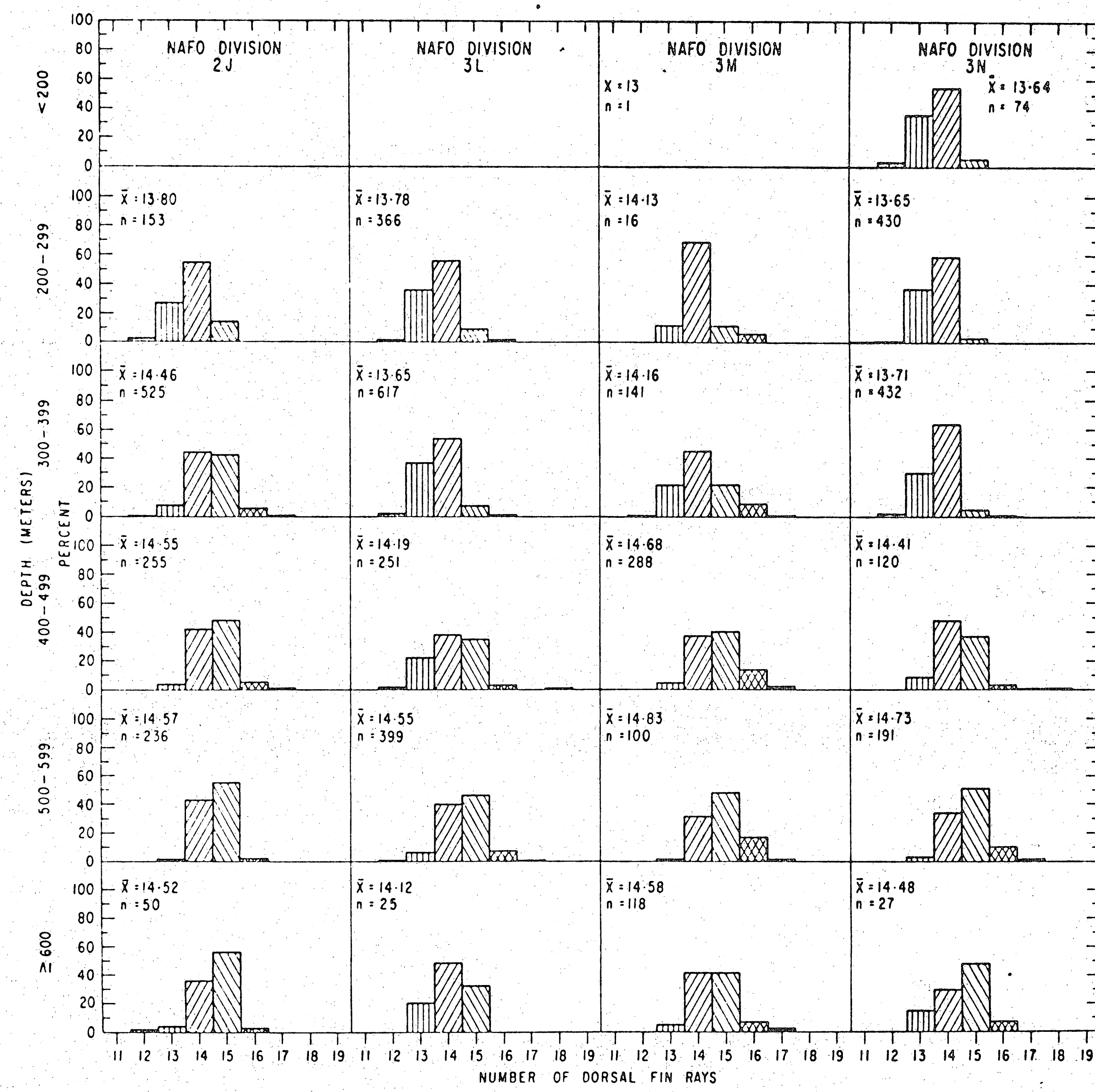

Fig. 6-2. Percentage frequency histograms of dorsal fin rays in NAFO Divisions 2J to 3N by depth.

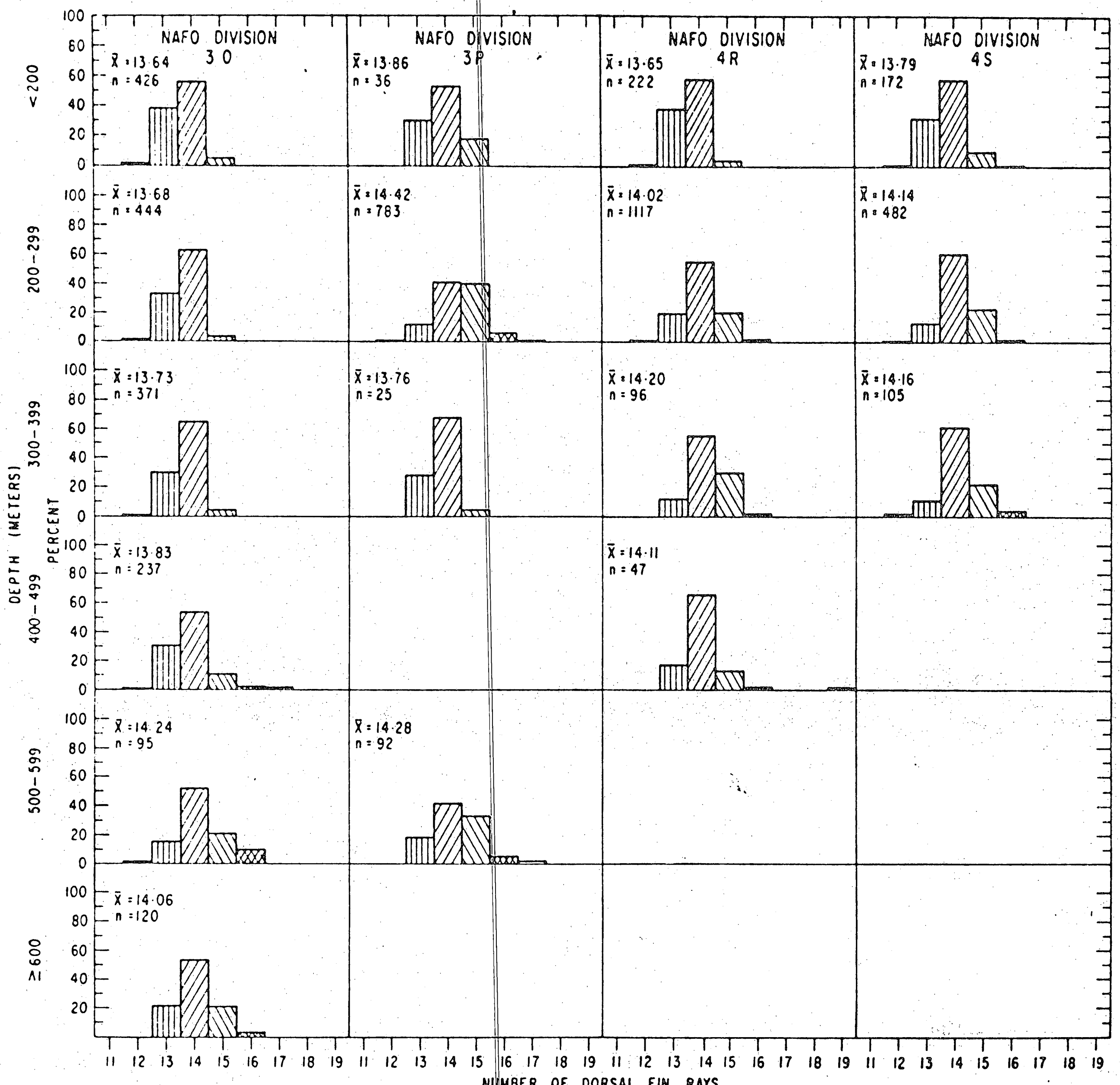

Fig. 6-3. Percentage frequency histograms of dorsal fin rays in NAFO Divisions 3O to 4S by depth.

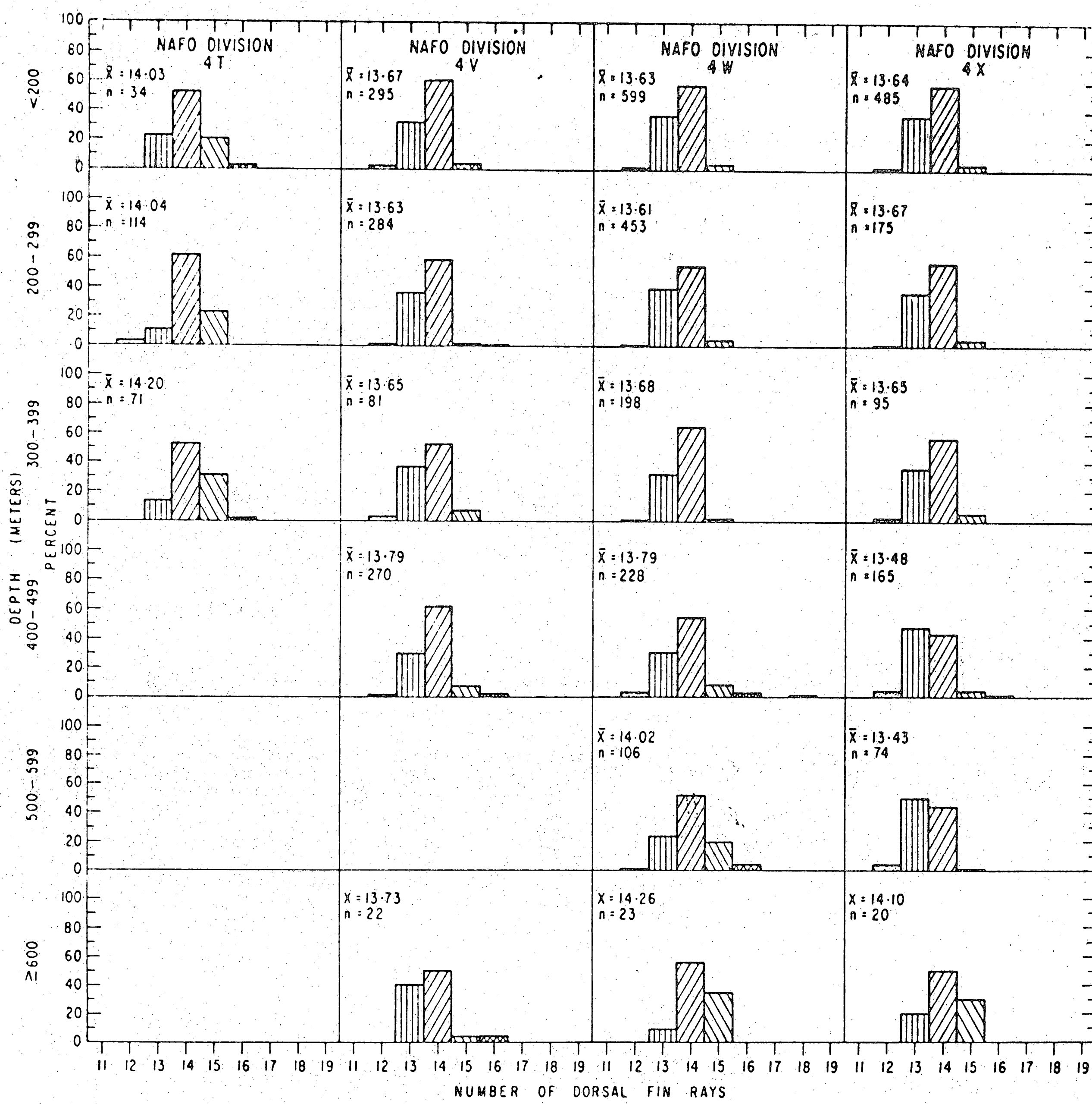

Fig. 6-4. Percentage frequency histograms of dorsal fin rays in NAFO Divisions 4T to 4X by depth.

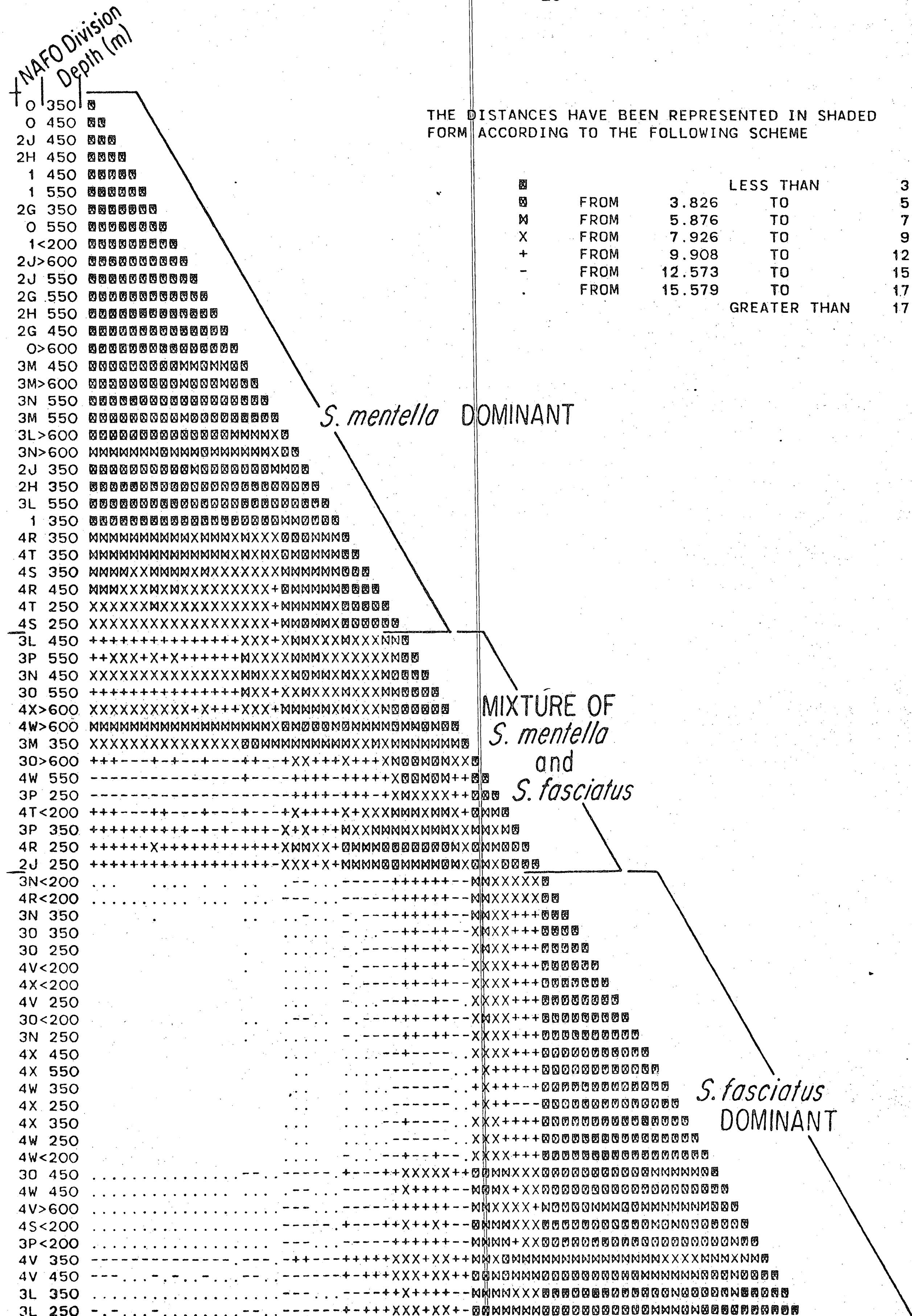

Fig. 7. Cluster analysis of vertebrae, anal fin ray and dorsal fin ray frequencies. Case labels are NAFO division and depth intervals. Depth at 250 represent 200-299 m, same apply to 350, 450, and 550.

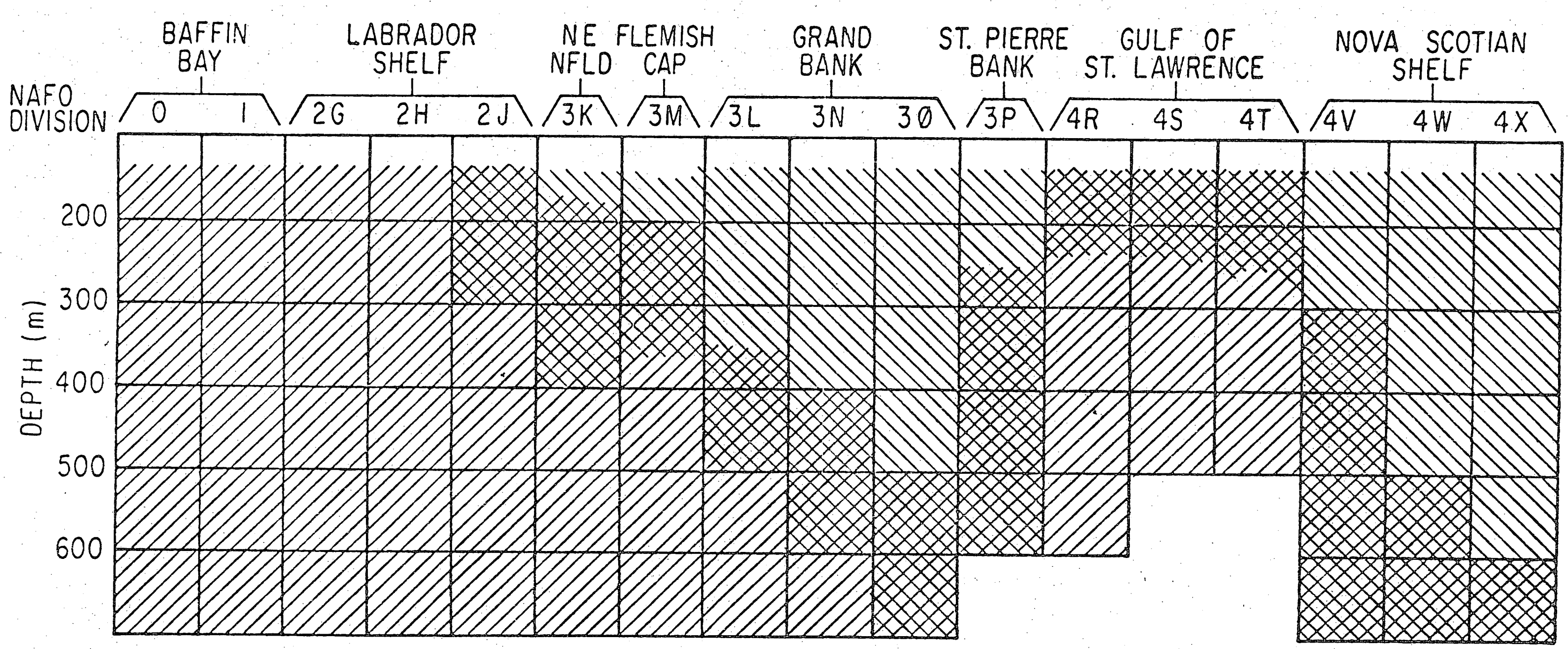

Fig. 8. The distribution of S. mentella and S. fasciatus in division-depth blocks. ▨ : S. mentella ▧ : S. fasciatus ▩ :mixture of S. mentella and S. fasciatus.