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Zonation and Associations of Dominant Fish Fauna in Flemish Cap

by

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SUMMARY

Data from 682 demersal trawls between 126 and 738 m were made on Flemish Cap in summer during the research surveys in the years 1989-1994. Despite the fact that the depth range for all species was not completely covered, analysis of the vertical distribution of the 25 most representative species showed that the fauna is zoned with depth. Distinct faunal assemblages with characteristic catch rates, diversity, and dominant species are found on the shelf (126-300 m), upper continental slope (300-600 m) and middle continental slope (> 600 m). Catch rates are greatest on the shelf and upper continental slope, as while as diversity is greatest on the middle continental slope. Dominance of the commercial species (Cod, Redfish, American plaice, Greenland halibut) is an important aspect of the community structure. Diversity patterns may be understood in terms of the relationships with predation, competition, environmental heterogeneity, and trophic level. Also the influence of the fisheries in the area can modify this structure.

Only *Synaphobranchus kaupy*, *Urophycis chestery*, *Gadus morhua*, *Sebastes mentella*, *Sebastes marinus* and *Reinhardtius hippoglossoides* showed a significant bigger-deeper relation, while *Anarhichas minor* and *Glyptocephalus cynoglossus* has a smaller-deeper relation.

INTRODUCTION

Flemish Cap is a bank located in international waters where fishing is regulated by the NAFO. This bank was the target of an international research programme, but study was discontinuous. A Canadian survey series covered the 1977-1985 period, and Russia has supported an annual survey since 1977. The UE developed demersal surveys on Flemish Cap from 1988 to 1994. The initial purpose of the surveys was to assess the distribution and abundance of main commercial species: Cod, American plaice and Redfish but the sampling data provides an opportunity to describe more generally the abundance, species composition and spatial distribution of other demersal and mesopelagic fish in the region.

To date, because of the scarce information on the species which are not fished commercially in Flemish Cap, the community structure of fish fauna is not really known. Fisheries ecosystems are complex and growing international concern has called for alternative multispecies management based on a better understanding of marine communities as a whole (Gomes et al., 1992).

The deep demersal fish fauna structure on Northwest Atlantic has been studied by other authors (Haedrich et al. 1980, Perry and Smith. 1994) but there are no studies on Flemish Cap. This paper prresents an initial approach to the study of the homogeneity or heterogeneity of the dominant fish fauna distribution, establishing the possible "fish assemblage areas" on Flemish Cap. Such a study has implications for a general understanding of the bioenergetics, biogeography and community structure of fish fauna in this area.

MATERIALS AND METHODS

The data presented here were gathered from standard groundfish research trawl surveys made in summer between 1989 and 1994 in NAFO Div. 3M conducted by the UE. Table 1 shows the cruises carried out in the period studied, number of hauls and species number included in this study.

The survey used a stratified random design, with strata based on depth boundaries of 145, 183, 255, 364, 546 and 728 m (80, 100, 140, 200, 300 and 400 fathoms) (Fig. 1). The survey sample unit was defined as the bottom area fished by a Lofoten trawl towed at a constant speed (3.5 kn.) for 30 min.

Sets were allocated to strata according to area, with all strata containing at least two sets. Trawl tows with unsatisfactory gear conditions were eliminated; the effect of this elimination was small since only a small percentage (< 7%) of the stations in the surveys fell into this category. More details of survey methodology are described by Vazquez (1990).

The problems associated with net samples are well known. Trawling consistently underestimates absolute abundance (Snelgrove and Haedrich, 1985). No adjustments in catch data were made for differences in catchability among species.

All species caught were identified, counted, weighed and expressed as catch per standard sample unit. Set depth was taken as the mean from initial and final depth of the trawl tow.

Twenty two demersal and three mesopelagic species were included in the analysis

(Table 2). They consisted of commercial species and non-commercial but potentially dominant species on a given region or potential forage for other species. These 25 species constituted more than 95% of the biomass estimated in the area. All species were present in at least 4 % of the total observed tows. All strata were sampled with sufficient intensity to assess their composition. The median number of samples per stratum was greater than 35 (Koslow, 1993).

In each sample, whenever the total weight of one determined species was less than 15 gr. or the specimen numbers was one, this species was not considered in the sample. For the smaller, less frequent mesopelagic species (*Serrivomer beani*, *Chauliodius sloani*, *Stomias boa*), these criterion were not applied.

The species of genus Sebastes was not identified every year. *S. marinus* was identified from 1990 and *S. mentella* and *S. fasciatus* only were identified from 1992. For this reason, the analysis where the specific composition of all species was required was only computed for the years 1992, 1993 and 1994.

As a preliminary analysis to establish whether zonation was present, a variation of the chi-square test was employed. This method (Gardnier & Haedrich, 1978) depends on the presence or absence of the species. For this analysis, the bottom trawls collection made on Flemish Cap was arranged in order of increasing depth, the area studied arbitrarily was divided into six depth regions (< 150 m, 151-250 m, 251-350 m, 351-450 m, 451-550 m, 551-650 m, > 651 m) and the species numbers that appeared for the first time in each region (upslope boundaries) were recorded. This method tests the distribution across the area of upslope boundaries using the formula:

$$\chi^2 = (Q/K) \times (V - [K^2/Q])$$

Where Q= number of regions into which the area is arbitrarily divided; K= total number of species; V= the sum of squares over all regions of the number of upslope boundaries. Values of the index were compared with those in a chi-square table for Q-1 degrees of freedom. If the calculated value exceeds the value obtained from the table, the boundaries are distributed non-randomly, i.e.: they are zoned. For details, Gardnier & Haedrich, (1978) should be consulted.

One approach to identifying associations between catches was made of the twenty five representative species and the depth data from the surveys. Firstly, we characterise the general frequency distribution of the habitat variable (depth) by constructing its empirical cumulative distribution function for observed depths in the stations. Secondly, we associated the catch of the fish (in numbers) of a particular specie in each station with the depth at that station as a weighting factor and constructed the empirical cumulative distribution of depths as weighted by the number of the specimens caught by species. In our case, the allocation of the stations or bottom trawls was strictly proportional to stratum size, so the stratification can be ignored (Perry & Smith, 1994).

If there was no particular association between fish distributions and depth within the area surveyed, e.g. if the fish were randomly distributed with respect to depth, then the cumulative distribution function by each species would be almost identical to the function for observed depths. Conversely, when the fish were associated with a small depth range then these functions would be very different.

These cumulative distribution functions were plotted (Fig. 2) and the potential boundaries were examined by calculating the percentage similarity (PS) between the regions involved. PS, is a commonly-used measure of faunal overlap and was calculated according to the formula of Whitaker & Fairbanks (1958).

$$PS = 100 \times \left(1.0 - 0.5\sum\left|P_{ia} - P_{ib}\right|\right)$$

Where P_{ia} = the proportion assumed by species i in sample a; P_{ib} = the proportion assumed by species i in sample b.

Diversity, H, was calculated using the information function (Shannon & Weaver, 1963):

$$H = -\Sigma p_i \ln p_i$$

Where p_i = the fraction of the total comprised by species i in a region.

PS is an theoretically insensitive index to sample size, but it is in fact highly sensitive to the relative number of species in two strata (Koslow, op. cit.). The dependence of PS on relative species number presents a problem for the interpretation of PS. For this reason, cluster analysis was also employed to assess faunal change with depth and to contrast with the results based on analysis of the PS indices.

We used the commonest type of cluster analysis, normal or q-type analysis, in which samples are arranged into groups where each had a similar biotic composition. The classification and ordination analyses were based upon a matrix of similarity coefficients among depth strata. In calculating the similarity coefficients, we used the number of individuals per sample for each species.

To reduce the large number of samples (334) for the 1992-1994 years, the samples were grouped into class depths of 50 m by each year and the mean values for the specimen numbers by each species were calculated. The data (number of occurrences for each species) were root-root transformed. This transformation has the effect of scaling down the scores of abundant species to avoid swamping the other data (Field et al. 1982; Clifford and Stephenson 1975). Also the root-root transformation has the advantage that, when similarity is assessed by the Bray-Curtis measure, the similarity coefficient is invariant to a scale change (Stephenson and Burges, 1980).

We have adopted the Bray and Curtis measure of similarity because it is not affected by joint absences (Field and McFarlane, 1968) and is, therefore, sufficiently robust for marine survey data where many of the species are absent from a majority of the samples, while giving more weight to abundant species (in comparing samples) than to rare ones.

The Curtis measure has the form:

$$\delta_{jk} = \frac{\sum_{i=1}^{s} \left| Y_{ij} - Y_{ik} \right|}{\sum_{i=1}^{s} (Y_{ij} + Y_{ik})}$$

where Yij= score for the ith species in the jth sample; Yik= score for the ith species in the kth sample; δ_{jk} =dissimilarity between the jth and kth samples summed over all species.

The clustering strategy is the hierarchical group-average sorting. Analyses were carried out with the standard statistical program 2M (BMDP) (Dixon et al. 1990).

Regressions were performed on individual species to establish whether a correlation between size and depth existed. The size was estimated by calculating the mean weight for each species and sample from the total weight of the species and the specimen numbers in the sample.

The BMDP package (Dixon et. al. 1990) was particularly useful for statistical procedures.

RESULTS

A complete list of the species studied is given in Table 2. This table shows the depth range, weight and number of specimens in the total samples by species. Each species has a unique vertical depth range.

Establishment of zones

The chi-square test was run on all stations for the years 1992-1994 grouped into regions of 100 m depth increase. Value of chi-square exceeded the 0.01 significance level for 5 DF (= 16.81).

$$\chi^{2}_{upslope} \quad 18.4 (p < 0.01)$$

This indicates that in the period considered the distribution is zoned between 125-753 m. The fact that the survey sampling did not completely cover the depth range of all species (the maximum depth sampled was 753 m) made it difficult to set up the zonation with certainty.

Figure 2 shows cumulative distribution functions for observed depths and depths as weighted by the number of specimens caught by each species. We constructed three graphs where the species were grouped for similarity behaviour with respect to depth. Basically, we found three groups of species: the first (Fig. 2a) comprises the species with cumulative occurrence percentages higher than 60% in depths less than 300 m; in the second group (Fig 2b), the species presented no particular association between fish distributions and the depth within the area surveyed with a random distribution with respect to depth; the last group (fig. 2c) composed of species with a cumulative occurrence percentage higher than 60% in depths greater than 600 m.

From Figure 2, the potential boundaries appear pointed at 300 and 600 m. These potential boundaries were examined by calculating PS between the regions involved. PS measured across the 300 m level was 21.5% and across the 600 m level was 24.4%. This data thus does not suggest any pronounced pattern of zonation.

To avoid the difficulty of interpretation of PS index, a cluster analysis was also performed. This analysis on all species studied showed groupings with similar biotic composition and comparable depths (Fig. 3).

Figure 3 is a dendrogram showing station affinities based on the mean root-root transformed abundance (number of specimens) of the twenty five species studied, using the Bray-Curtis measure of similarity and group-average sorting. Three main station groups are distinguished at an arbitrary similarity level of 17%. Group 1 comprised the stations with depths lesser than 300 m , Group 2 with transition depths between 300 and 600 m and Group 3 with depths greater than 600 m.

In order to quantify the differences between these three depth strata, table 3 shows the overall community parameters for these strata. Abundance and biomass both declined on the deepest stratum. In this depth range however, the diversity was greater than the other strata. The intermediate depths (301-600 m) presented the largest number of species, biomass and specimen numbers.

No one species was dominant over the whole sampling range (table 4). *Sebastes mentella* was the only species present in all strata, standing out into the intermediate depth zone. The commercial species exploited in the area, such as Cod, Redfish, Greenland halibut and American plaice were the most important species in terms of both number and biomass. Other fish like *Anarhichas lupus*, *Lycodes reticulatus*, *Chaulodius sloani*, *Antimora rostrata* and the macrourids (*Macrourus berglax*, *Nezumia bairdi*) are also important species. In the two shallower strata, *Gadus morhua* and *Sebastes mentella* represented by stratum more than 60% and 70% of the specimen numbers respectively. The representative species of the deepest stratum were more homogeneously represented.

The regression of mean weight per individual for each specie versus depth was calculated (Table 5). Only *Synaphobranchus kaupi*, *Urophycis chesteri*, *Gadus morhua*, *Reinhardtius hippoglossoides*, *Sebastes marinus* and *Sebastes mentella* showed a significant bigger-deeper relation.

Other authors (Polloni et al. 1979, Snelgrove et al. 1985) also observed this bigger-deeper relation in other areas for several of the species studied here. For some of these species, such as *Antimora rostrata,* this article does not report on the bigger-deeper relation. The insufficient depth range sampled (to 753 m) and the wide depth range where this species is distributed, between 499 and 2325 m (Snelgrove et al. op.cit.), may be the reason for the absence of a bigger-deeper relation.

Two species, *Glyptocephalus cynoglossus* and *Anarhichas minor* showed a significant negative correlation.

Burnett, et al.(1992) found significant differences in distribution by depth for juveniles and adults of *G. cynoglossus* in the Gulf of Maine-Georges Bank Region and, while the adults maintained a mean depth constant, the juveniles were found at shallower depths than adults in winter and spring, and at greater depths in summer and autumn. If these situations were reproduced in Flemish Cap, this could be the reason for the negative size-depth correlation.

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Table 1.- Information on the bottom-trawl surveys on Flemish Cap 1989-1994.

SHIP	CRUISE	DATES	N° STATIONS	N° SPECIES
Cryos	Flemish Cap 89	12/7 - 1/8	118	21
Ignat Pavlyuchenkov	Flemish Cap 90	18/7 - 6/8	113	22
Cornide Saavedra	Flemish Cap 91	24/6 - 11/7	117	22
Cornide Saavedra	Flemish Cap 92	29/6 - 18/7	117	25
Cornide Saavedra	Flemish Cap 93	22/6 - 8/7	101	25
Cornide Saavedra	Flemish Cap 94	29/6 - 29/7	116	25

Table 2.- Vertical depth ranges and catch data for fish species taken in bottom trawls on the Flemish Cap 1989-1994.

MAIN FISH SPECIES	DEPTH RANGE	WEIGHT (Kg)	SPECIMENS NUMBER	STATION NUMBERS
Gadus morhua	126 - 631	48500	119979	459
Anarhichas lupus	130 - 497	4950	100063	498
*Sebastes marinus**	130 - 441	6810	16220	253
Glyptocephalus cynoglossus	130 - 738	540	1242	249
*Sebastes fasciatus***	151 - 660	2340	12675	214
Anarhichas minor	129 - 605	2590	1752	302
Raja radiata	126 - 717	1950	1071	385
*Sebastes mentella***	249 - 738	17100	65618	186
Hippoglossoides platessoides	126 - 519	6910	12412	456
Urophycis chesteri	280 - 638	112	1295	168
Lycodes reticulatus	155 - 683	975	5607	281
Raja spinicauda	149 - 717	853	192	118
Anarhichas denticulatus	130 -738	1130	295	167
Reinhardtius hippoglossoides	221 - 753	5550	6821	383
Lycodes smarky	242 - 738	143	458	73
Nezumia bairdi	249 - 753	460	8991	290
Macrourus berglax	249 - 753	1440	2656	179
Serrivomer beani	249 - 738	13	151	44
Stomias boa	313 - 738	4	151	30
Chaulodius sloani	263 - 753	19	67	60
Notacanthus chemnitzii	424 - 753	311	363	65
Synaphobranchus kaupi	466 - 753	445	351	72
Antimora rostrata	524 - 753	389	3366	69
Gaidropsarus ensis	575 - 738	24	99	29
Lycodes vhali	533 - 738	89	372	38

* The data corresponds to the years 1990-1994.

** The data corresponds to the years 1992-1994.

Table 3.- Community parameters and catch rates for fish assemblages by depth zones on Flemish Cap in the years 1992-1994.

STRATA	126 - 300 m	301 - 600 m	601 - 753 m
N° species	19	25	20
Diversity, "H"	1.4	1.2	2.1
N° of specimens	83611	79053	10761
N° of stations	177	123	34
Specimens 0.5 h-1	472	643	316
Total Biomass (Catch Kg)	31400	2300	4170
Biomass (Kg 0.5 h-1)	177	187	123

Table 4.- The most abundant demersal fish species at the three depth zones considered. Values are percentages of total number and of total biomass in the years 1992-1994.

SPECIES	NUMBER (%)	BIOMASS (%)
Dominant species in depths <300m		
Gadus morhua	60.5	55.7
Sebastes marinus	14.5	17.2
Sebastes mentella	8	4.8
Sebastes fasciatus	6.1	3.1
Anarhichas lupus	4.5	5.9
Hippoglossoides platessoides	3.9	6.8
Dominant species in depths (301 - 600 m)		
Sebastes mentella	72	63.6
Sebastes fasciatus	9..5	5.9
Nezumia bairdi	3.1	0.5
Reinhardtius hippoglossoides	2.8	6.3
Lycodes reticulatus	2.6	1.7
Anarhichas lupus	2.4	3.3
Dominant species in depths > 601 m		
Nezumia bairdi	25.6	4.4
Sebastes mentella	18.4	24
Antimora rostrata	15.5	5.6
Reinhardtius hippoglossoides	13.8	33.6
Macrourus berglax	10.9	16.2
Chaulodius sloani	3	0.3

Table 5.- Regression parameters of mean weight per individual for each species versus depth

SPECIES	Nº CASES	COEFF. REGRESSION	SIGNIFICANCE	PARAMETERS OF EQUATION $y = ax + b$
Anarhichas minor	302	-0.601	< 0.001	a = 9.4154 b = -0.00701
Synaphobranchus kaupi	72	0.534	< 0.001	a = 3.3544 b = 0.00231
Urophycis chesteri	168	0.64	< 0.001	a = 1.7649 b = 0.00679
Gadus morhua	459	0.56	< 0.001	a = 4.5305 b = 0.007
Sebastes mentella	186	0.56	< 0.001	a = 4.8928 b = 0.00201
Sebastes marinus	253	0.52	< 0.001	a = 4.3948 b = 0.00463
Glyptocephalus cynoglossus	249	-0.673	< 0.001	a = 7.1369 b = -0.00429
Reinhardtius hippoglossoides	383	0.53	< 0.001	a = 4.8408 b = 0.00359

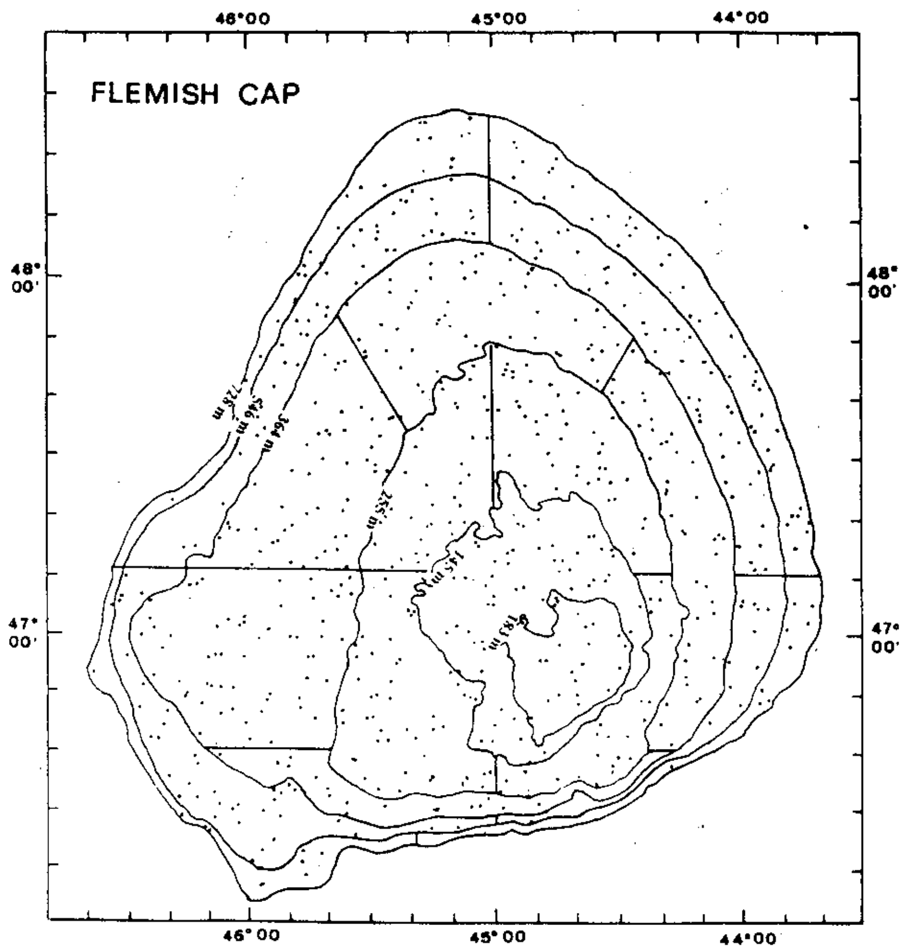

Fig. 1.- Chart showing the positions of bottom trawl stations on Flemish Cap area between the years 1989 and 1994 with the aproximate isobaths.

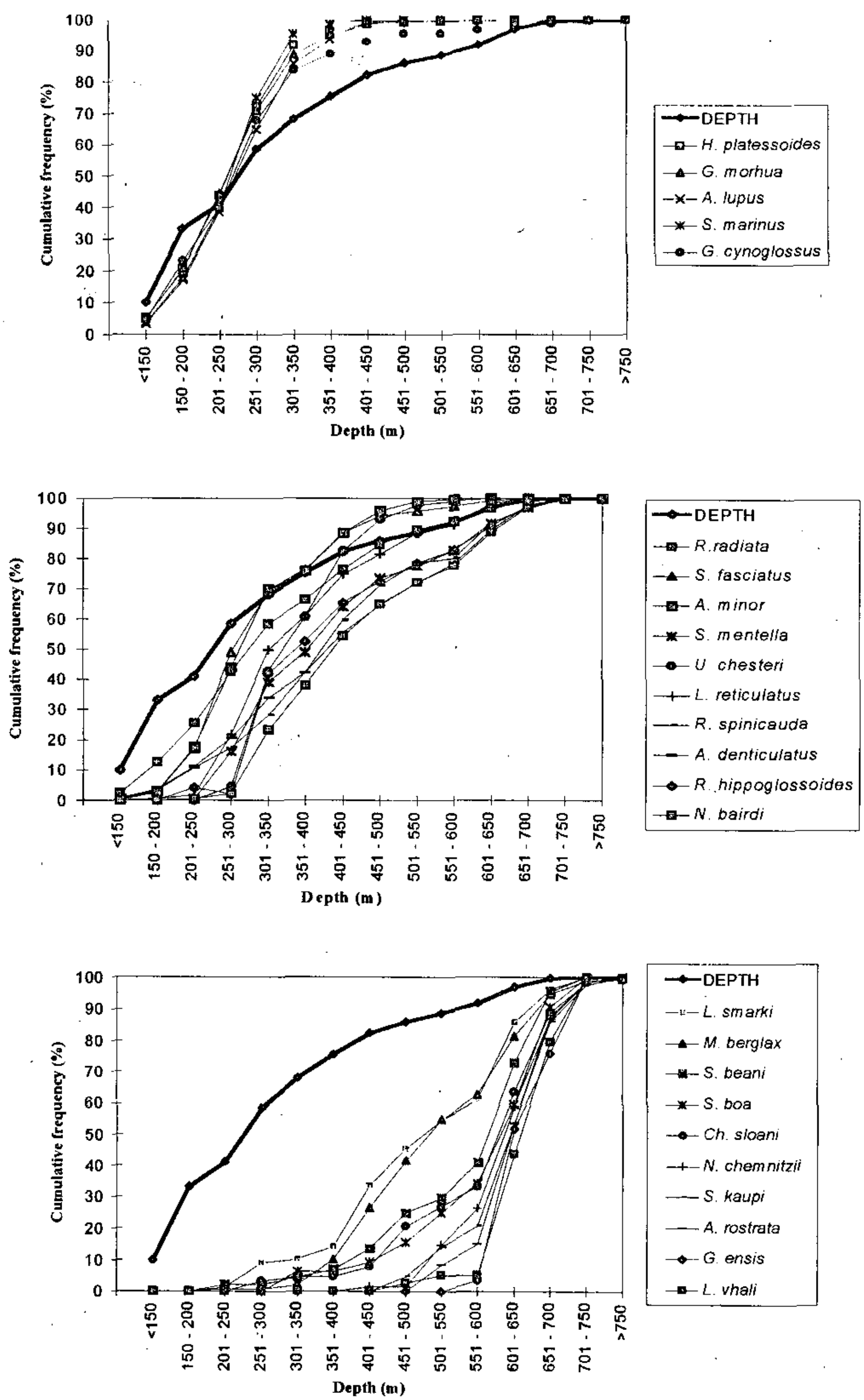

Fig. 2.- Cumulative frequency distributions of depth variable and depths as weighted by the number of the specimens caught for each species on Flemish Cap in Summer 1989-1994.

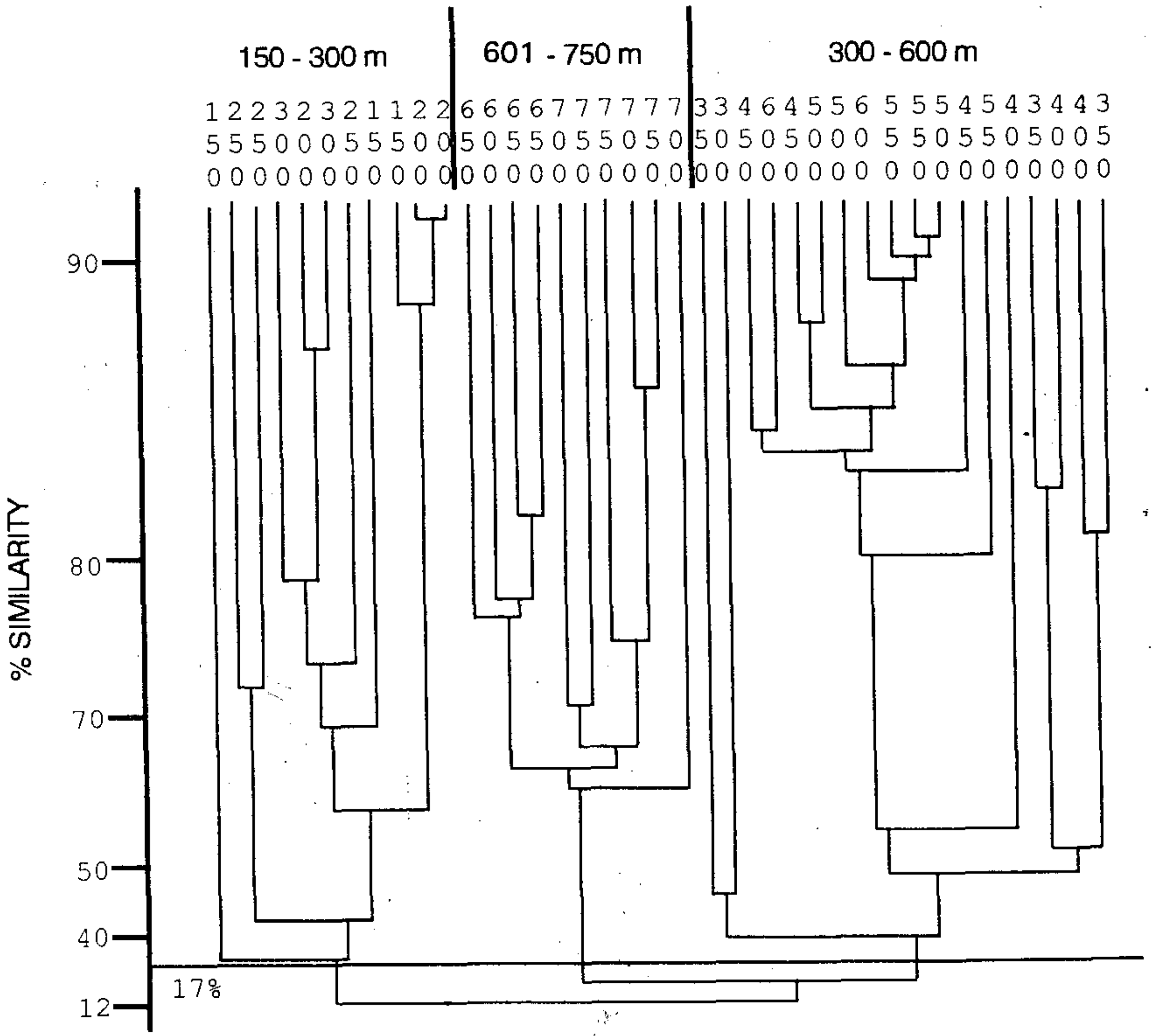

Fig. 3 .- Dendrogram showing classification of 334 stations grouped in 39 depth class of 50 m based on mean abundances of fish fauna species composition by depth class. Abundances were root-root transformed before comparing stations using the Bray-Curtis measure, and the dendrogram formed by group-average sorting. Three main station groups are distinguished at an arbitrary similarity level of 17%.