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DISTRIBUTION PATTERNS OF THE DEMERSAL FISH ASSEMBLAGE OFF CENTRAL CHILE

PATRONES DE DISTRIBUCION DE LA ASOCIACION DE PECES DEMERSALES FRENTE A CHILE CENTRAL

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ABSTRACT

The spatial and temporal distribution of the fish fauna in the fishing area of *Pleuroncodes monodon*, off Central Chile, is analysed. Haul-by-haul information from four surveys was taken into account (April 1982 and 1983, and March and November 1984). The demersal fish fauna exhibits two boundaries, one at depths of around 250 ± 50 m and the other one at depths of around 100 m. Consequently, three fish assemblages are recognized: inshore over the continental shelf, offshore over the continental shelf, and over the upper continental slope. Temporal and spatial changes in the fish assemblage are clearly recognized with *M. gayi* as the dominant species, being replaced in depth mainly by the grenadier fish *Coelorinchus aconcagua*.

Key words: Demersal fish assemblage, distribution patterns, Central Chile.

RESUMEN

Se analiza la distribución temporal y espacial de la ictiofauna en el área de la pesquería de *Pleuroncodes monodon*, a partir de la información lance a lance de cuatro cruceros de investigación (abril 1982 y 1983, y marzo y noviembre de 1984). La ictiofauna demersal exhibe dos "fronteras", la primera a una profundidad de 250 ± 50 m y la otra a los 100 m. En consecuencia, se reconoce tres asociaciones de peces: una sobre la plataforma continental interior, otra sobre la plataforma continental exterior y otra sobre la parte superior del talud continental. Se reconoce claramente cambios temporales y espaciales en estas asociaciones de peces, aunque *M. gayi* es la especie dominante, siendo reemplazada en profundidad por *C. aconcagua*.

Palabras claves: Asociación de peses demensales. Patrones de distribución. Chile Central.

INTRODUCTION

Over both the continental shelf and the upper slope off Central Chile (30° S-39° S) an important trawl fishery is concentrated, focussing mainly on the Chilean hake (*Merluccius gayi:* Gadiformes), the kingklip (*Genypterus maculatus*: Ophidiiformes) and the red crab (*Pleuroncodes monodon*: Galatheidae, Anomura).

The fishing area of *P. monodon* is reduced (Fig. 1) but demersal fish species are harvested too as by-catch (Henríquez *et al.*, 1982, 1983; Bahamonde *et al.*, 1984). However, investigations on demersal fish of this area have been done only in a circumstantial fashion (e.g. Ojeda & Camus, 1977; Bahamonde & Zavala, 1981; Meléndez, 1983; Bahamonde *et al.*, 1984; Arancibia *et al.*, 1986), but not aiming specifically at a community analysis.

Specific investigations about the distribution of commercial species are scarce. Yáñez & Barbieri (1983) studied the distribution of the benthodemersal fauna in the area off Valparaiso (32° 50′ S; 33° 10′ W). Periodical and seasonal investigations on the demersal fish fauna have, however, not been undertaken.

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In this study, the spatial (bathymetric) and temporal (seasonal) distribution of the demersal ichthyofauna in the fishing area of *P. monodon*, in Central Chile, is analysed.

MATERIAL AND METHODS

On the origin of the information, samples, raw-and standardized data

The raw data was obtained from recorded captures of four bottom trawl surveys performed by the Instituto de Fomento Pesquero de Chile (IFOP; Fisheries Development Institute; Table 1). The objective of these surveys was to estimate the standing stock of *Pleuroncodes monodon*.

On board, the catch was sorted by species and weighted. Tow time, velocity, depth and position were also registered. All surveys were performed with the R/V ITZUMI of the Subsecretaría de Pesca de Chile (Undersecretariat of Fischeries). A shrimp trawl with a 3 cm mesh cod-end, a 30 m head-line equipped with floats, a 34.5 m footrope armed with 14 cm diameter and 14.8 cm width rubber bobbins, "lucketa" type doors, and 15 m long bridles was used as sampling gear. Vertical opening varied between 2.8 and 3.4 m, while average horizontal opening between wing tips was 11.75 m.

All capture data was standardized per species and per tow, because both trawling velocity and time were not constant (mean velocity: 4.1 km/h; mean actual trawling time: 30 min).

The standardization of the capture has the form of

$$C_{st} = C / d$$

where C_{st} = standardized capture, in kg/km; C = actual capture, in kg; d = trawling distance, in km, calculated from

$$d = v * t$$

where v = trawling velocity, in km/h; t = actual trawling time, in h.

This type of standardization has been used by IFOP, as reported by Henríquez *et al.* (1982, 1983), Bahamonde *et al.* (1984) and Anonymous (1984), following Paloheimo & Dickie (1964) and Alverson & Pereyra (1969).

Area of study, division by zones and bathymetry

In the area of study, three discrete zones with catchable biomass of *P. monodon* can be recognized: A = Achira; B = Bio Bio; E = Exterior (Fig. 1); each zone was arbitrarily divided into the following six depth strata: (1) ≤ 100 m; (2) 101-150 m; (3) 151-200 m; (4) 201-250 m; (5) 251-300 m; and (6) ≥ 301 m depth, according to

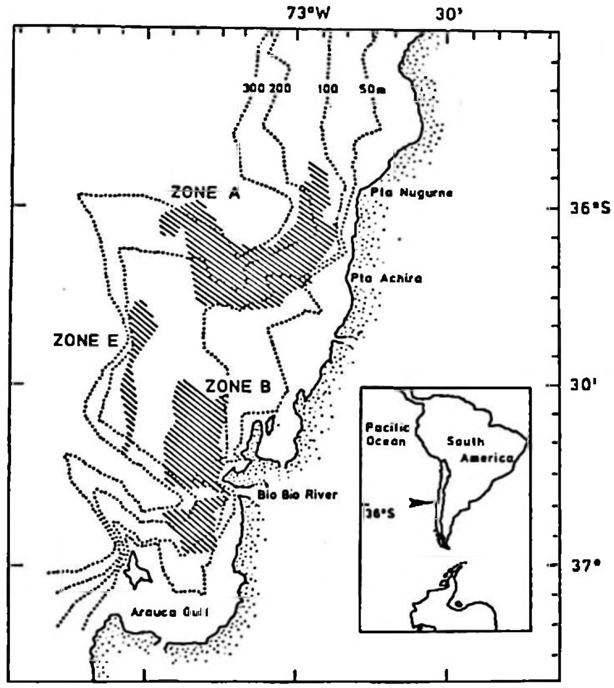

Figura 1. **Geographic distribution of the stock of *Pleuroncodes monodon* on the continental shelf and the upper slope off central Chile (ARANCIBIA, 1988).**

Arancibia (1988) and Yáñez & Barbieri (1983), who also used 50 m depth strata. The number of samples per survey and zone are shown in Table 2.

Each zone was independently analysed per cruise. Previous analysis without this separation did not show any clear patterns. In all analyses, fish species that occurred in more than 1% of the catches were not considered. This reduced the number of 0-values that might have appeared as "noise" in the results (*sensu* Haedrich & Krefft, 1978).

Table 1. *"Pleuroncodes monodon surveys"* carried out over the continental shelf and the upper slope off central Chile from 1982 to 1984 by IFOP.

Year	Area intervals	Depth range (m)	Period
1982	35°47' S 37°05' S	42-300	April 4-30
1983	35°50' S 37°01' S	52-350	April 15- May 8
1984	35°45' S 37°10' S	40-355	March 14- April 4
1984	36°00' S 36°55' S	33-300	Novem- 4-23 ver

Descriptive parameters of the demersal fish community

In order to describe characteristics and distributional patterns of the demersal icthyofauna, several classical community parameters were determined and the multivariate technique of cluster analysis was used.

In this study, the following statistics and indices are used: number of species (S), Shannon-Wiener Diversity Index (H'; Shannon and Weaver, 1949) and evenness (J'; Pielou, 1975).

The formulas are:

$$H' = -\sum_{i=1}^{S} (P_i * \log_2 P_i)$$

where: P_i is the proportion of biomass in the i th species.

$$J' = H' / H'_{max}$$

The evenness is near 0 when the dominance is high and is 1.0 when all species are present in equal quantities.

$$H'_{max} = \log_2 S$$

These statistics and indices were selected because the number of species and biomass are obvious measures to describe a community (Pielou 1969). The Shannon-Wiener index (H') combines the variety and evenness components as one overall index of diversity (Odum, 1971). It seems to be the most consistent and useful method for obtaining significant diversity indices which are relatively independent of sample size (Stirn, 1981). These statistics and indices were calculated with the computational program ACOM (Navarro, 1984).

Cluster analysis

The aim of this technique is to produce a number of discrete groups of patterns of occurrences (Clifford & Stephenson, 1975). The objects are more homogenous within groups, while at the same time the groups are heterogenous among themselves as much as possible (Zupan, 1982).

In these cluster analyses, the sampling units are bottom trawl hauls (Table 2), the objects are depths and their attributes are the mean biomass of each fish species per zone, expressed as percentages.

Each comparison was carried out between entities per survey. Czkanowski's Quantitative Index, CZ_{ik}, also named Bray Curtis Index

Table 2. Number of samples (bottom trawl hauls) per survey and zone. In brackets: number of species contributing > 1% to the biomase.

Survey	Achira (= A)	Bío Bío (= B)	Exterior (= E)
April 82	83 (11)	51 (3)	23 (5)
April 83	79 (9)	43 (7)	21 (5)
March 84	70 (7)	41 (4)	25 (6)
Nov. 84	74 (8)	49 (8)	13 (7)

(Bloom, 1981) or Percent Similarity Index (Venrick, 1983), was used as a similarity measure because it is not affected by joint absences (Boesch, 1977; Field *et al.*, 1982).

CZ_{ik} may be expressed as

$$CZ_{ik} = \frac{2 \sum_{i=1}^{m} \min(x_{ij}, x_{kj})}{\sum_{i=1}^{m} (x_{ij} + x_{kj})}$$

where x_{ij} is the occurrence of the j[th] attribute in the i[th] object; x_{kj} is the occurrence of the same attribute in the k[th] object.

The unweighted pair-group method using arithmetic averages (UPGMA; also named group-average method) was used for classification (Sneath & Sokal, 1973). It introduces relatively little distortion to the relationships originally expressed in the interentity resemblance matrix (Cunningham & Ogilvie, 1972).

In order to establish a statistical criterium for the identification of groups between entities (depth strata), the similarity within entities was also recorded. Its mean was used as limiting value in the dendrogram.

Following Arancibia (1988), the comparison by pairs of samples (tows) within depth stratum was arranged using a random numbers table. Each sample was compared only once, i.e. the comparison was done without replacement. The significance of difference within and between depth strata of CZ_{ik} was tested by means of the Mann-Whitney U-test. Previous analysis about the distribution of CZ_{ik} did not yield any known probability distribution. The cluster analysis

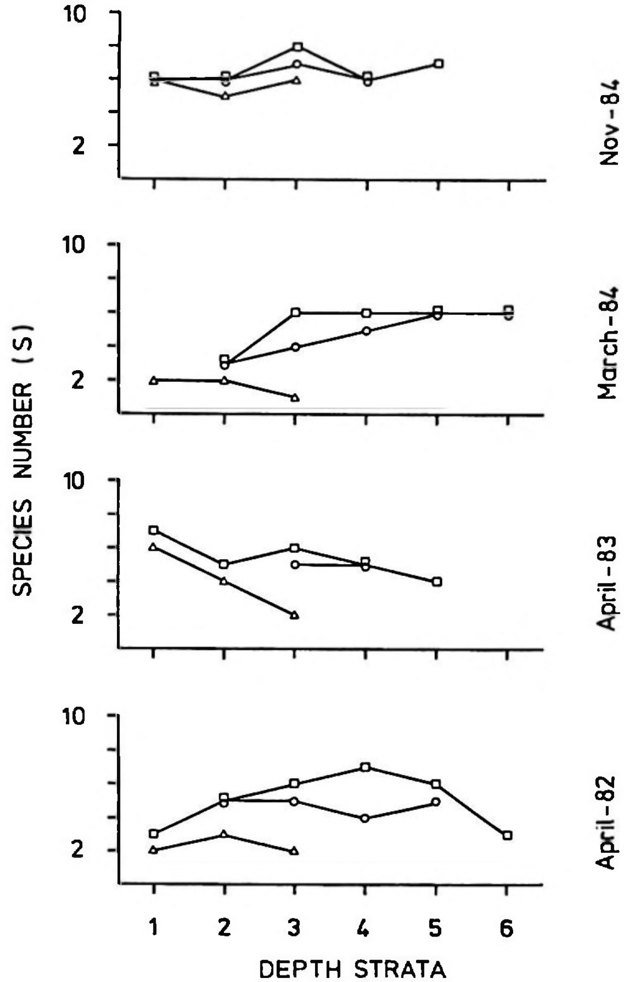

Figura 2. Fish species number per depth stratum and survey (Key: squares = Achira zone; triangles = Bio-Bio zone; circles = Exterior zone).

Table 3. Percent contribution of biomass of the most important fish species caught in surveys for *P. monodon* over the continental shelf and the upper slope off central Chile in 1982, 1983 and 1984 (March and November).

Species	1982, April	1983 April	1984 March	1984 Nov.
Merluccius gayi	74	82	33	54
Hippoglossina macrops	2	6	52	13
Coelorinchus aconcagua	7	2	7	13
Genypterus maculatus	4	2	2	3
Trachurus murphyi	13	5	2	3
Prolatilus jugularis		1		5
Elasmobranchii (skates and little sharks)	1	1	4	8

was performed with the program CLUST, supplied by Dr. D. Piepenburg from the University of Kiel.

RESULTS

Descriptive parameters of the community

A superficial analysis of the more important species of fish caught in the fishing area of *P. monodon* shows a relatively scarce number of species and only a couple of them dominant (Table 3). The mean number of species (Fig. 2) is very low in the Bio Bio zone although there are differences among years and zones. The biomass diversity (Fig. 3) shows low values with, as expected, relatively high evenness (Fig. 4).

Nevertheless, differences appear when the data is analysed with respect to depth strata

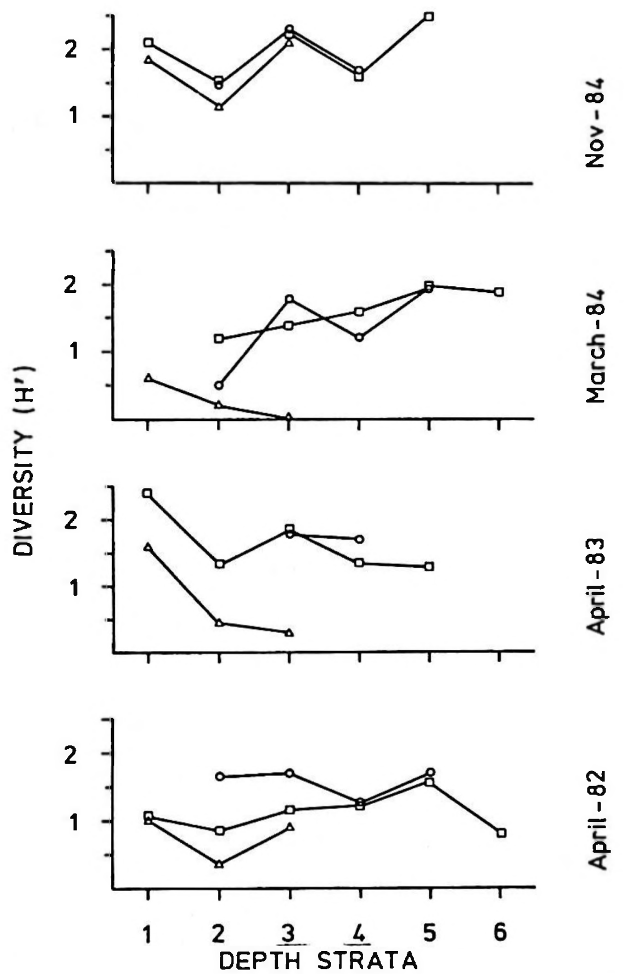

Figura 3. Diversity of fish biomass per depth stratum and survey (Key: squares = Achira zone; triangles = Bio Bio zone; circles = Exterior zone).

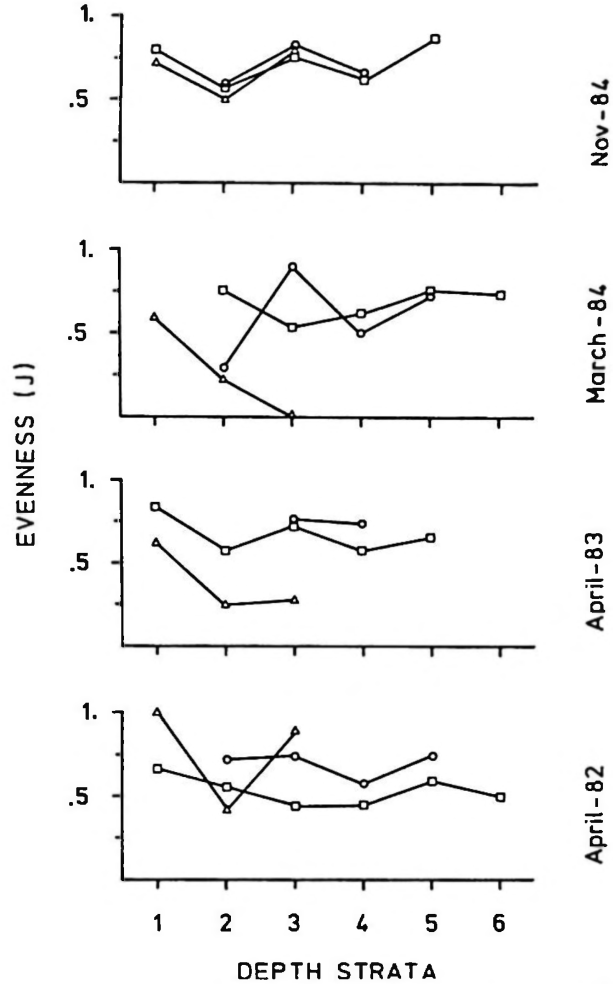

Figura 4. Evenness of fish biomass per depth stratum and survey (Key: squares = Achira zone; triangles = Bio Bio zone; circles = Exterior zone).

(Figs. 2, 3 and 4). The number of species at all depth strata and zones is higher in November 1984 (beginning of summer) than in other months (beginning of autumn). In general, the Achira zone consistently shows the highest number of species, whereas the Bio Bio zone always exhibits the lowest.

CLUSTER ANALYSIS

April 1982

Six groups can be recognized at a level of similarity within strata equal to 0.657 (Table 4a; Fig. 5a). Moreover, each discrete group has its major species. Group 3 could be an heterogenous unit where a shift in the dominance of *Merluccius gayi* to *Coelorinchus aconcagua* can be recognized.

Table 4. Similarity of biomass of demersal fish within and between depth strata and zones. The significance of diference of within vs. between CZ's was estimated using the Mann-Whitney U-test. The large sample approximation was used (ts; CONOVER, 1971). The statistical signifcance is shown by "*"; α= 0.025.

Period		Mean CZ	s.d.	n	t_s	w(.975)	
a) April '82	within	.657	.148	73	3,468	2,646	*
	between	.512	.207	66			
b) April '83	within	.615	.171	68	1,881	1,591	*
	between	.550	.191	45			
c) March '84	within	.695	.175	64	3,220	2,234	*
	between	.495	.238	66			
d) Nov. '84	within	.581	.127	66	2,230	1,924	*
	between	.480	.216	55			

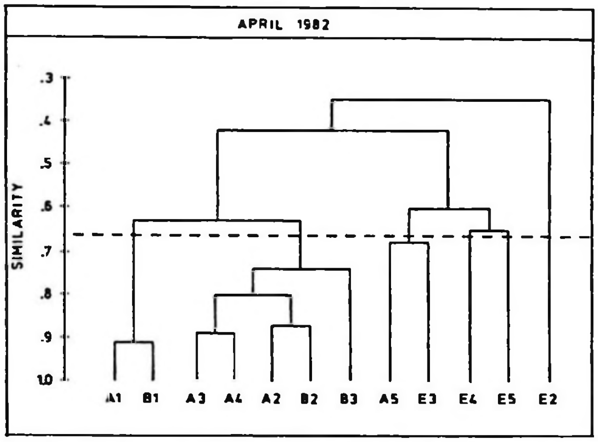

Figura 5 a. Dendrograma showing classification of strata (α = 0.025) based on catch data of demersal fish from bottom trawl survey carried out in April 1982. The broken line shows the mean level of similarity within strata (see Table 2 and text for keys).

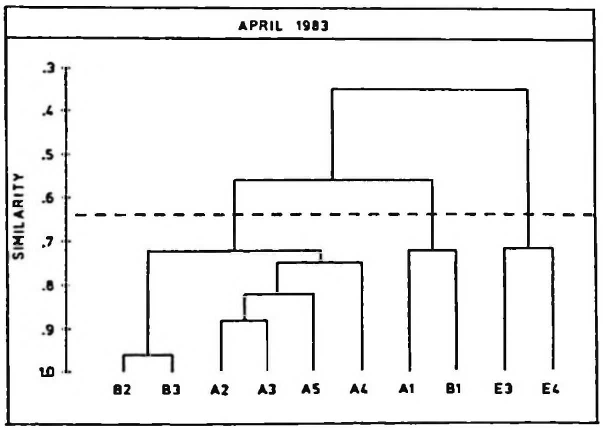

Figura 5 b. Dendrogram showing classification of strata (α = 0.25) based on catch data of demersal fish from bottom trawl survey carried out in April 1983. The broken line shows the mean level of similarity within strata (see Table 2 and text for keys).

April 1983

Three distinct groups can be recognized at a level of similarity within strata equal to 0.615 (Table 4b; Fig. 5b). In group 1, *M. gayi* is the most important species. It is almost the exclusive species at strata B2-B3, with secondary contribution of other species from strata A2 to A5. In group 2, the importance of *M. gayi* is secondarily shared with "Others". In group 3, both *M. gayi* and *C. aconcagua* contribute similarly as major species.

March 1984

Six distinct groups can be recognized at a level of similarity within strata equal to 0.695 (Table 4c; Fig. 5c). In groups conformed by more than one stratum (groups 1 and 2), *M. gayi* is the main species. In the first, it is almost the exclusive species with presence of *G. maculatus*. This group was arranged with all Bio Bio zone (B) plus E2. In the second group *M. gayi* dominates also, but with a gradually increasing contribution of *Hippoglossina macrops*. The other groups are conformed by single strata -the deepest (E4, E5, A6) and the shallowest (A2)-, also with typical fish assemblages dominated by *C. aconcagua* and *Trachurus murphyi*, respectively.

November 1984

Four discrete, homogenous groups can be recognized at a level of similarity within strata equal to 0.581 (Table 4d; Fig. 5d). But either *M. gayi* (group 1) or *C. aconcagua* (group 4) are most important with partial exceptions in the shallowest strata (group 2). A gradual shift in the contribution of other species becomes apparent.

The strong relationships of the demersal ichthyofauna among strata per zones are evident, as can be seen in several horizontal pictures (Fig. 6a-d).

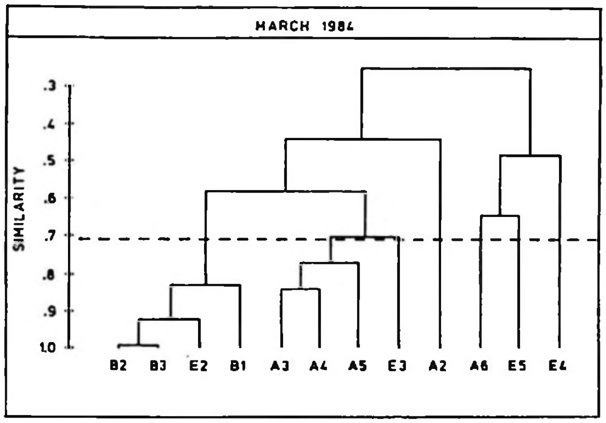

Figura 5 c. Dendrogram showing classification of strata (α = 0.025) based on catch data of demersal fish from bottom trawl survey carried out in March 1984. The broken line shows the mean level of similarity within strata (see Table 2 and text for keys).

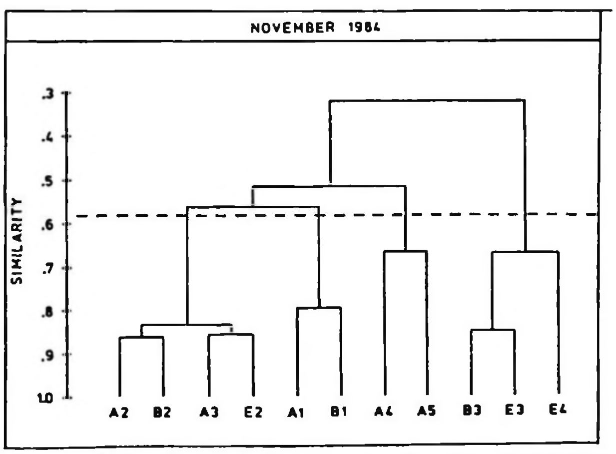

Figura 5 d. Dendrogram showing classification of strata (α = 0.025) based on catch data of demersal fish from bottom trawl survey carried out in November 1984. The broken line shows the mean level of similarity within strata (see Table 2 and text for keys).

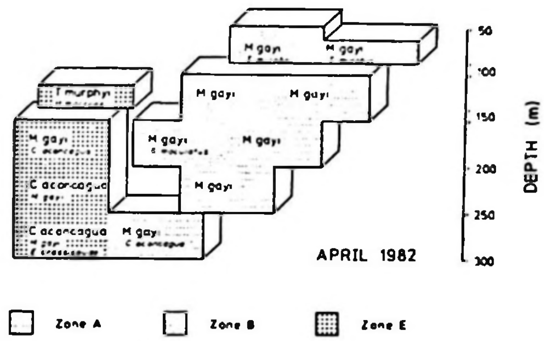

Figura 6 a. Demersal fish assemblage on the contin shelf and the upper slope off central Chile in April 1982. The horizontal axis is an arbitrary distance westwards from the coast line.

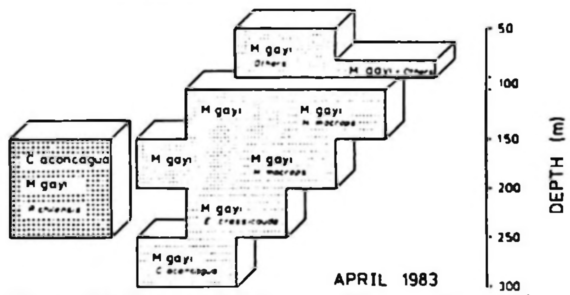

Figura 6 b. Demersal fish assemblage on the continental shelf and the upper slope off central Chile in April 1983. The horizontal axis is an arbitrary distance westwards from the coast line.

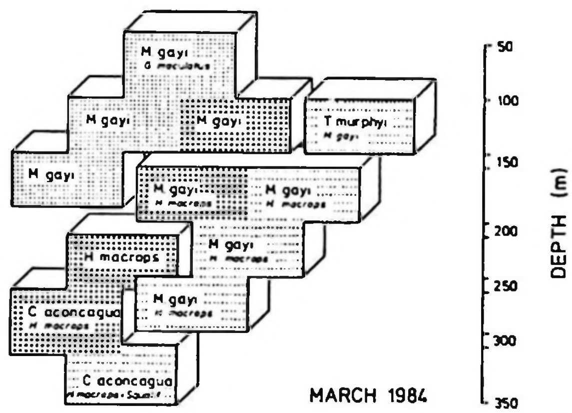

Figura 6 c. Demersal fish assemblage on the continental shelf and the upper slope off central Chile in March 1984. The horizontal axis is an arbitrary distance westwards from the coast line.

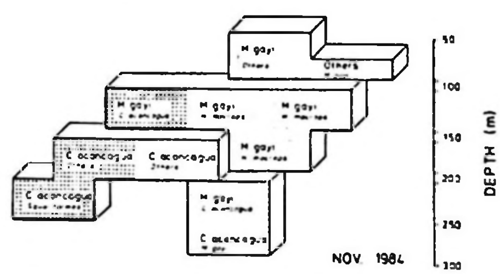

Figura 6 d. Demersal fish assemblage on the continental shelf and the upper slope off central Chile in November 1984. The horizontal axis is an arbitrary distance westwards from the coast line.

DISCUSSION AND CONCLUSIONS

Wihlm (1968) has proposed to use biomass units in the Shannon-Wiener index (H'), as performed by Lyons (1981) and Yáñez-Arancibia *et al.* (1985), in demersal ichthyofauna studies, because the number of individuals in the different species have been used with no consideration of weight among species. This means that individuals of different species of unequal weight would have an equal influence on a diversity index when the basic data is number of individuals, but would not have the same influence if data is in biomass units. H' is dimensionless and thus the choice of biomass units will not influence the results.

In this study, the mean of H' reveals that this demersal fish guild (H' = 1.6) is more heterogenous than a coastal Antarctic fish guild (H' less than 1.3; Targett, 1981) and it is less heterogenous than those of tropical fish communities (H' between 2 and 3 or higher than 3; Smith & Tyler, 1972 *fide* Targett *op. cit.*).

The results allow to conclude that the demersal fish fauna on both the continental shelf and the upper slope off Central Chile exhibits two important boundaries: one at depths of around 250 ± 50 m and one at depths of around 100 m. These two boundaries separate three distinguishable assemblages: one inshore over the continental shelf (above 100 m), one offshore over the continental shelf (between 100 and 250 ± 50 m, aprox.), and one in the upper part of the continental slope.

Each fish assemblage is dominated only by few species, therefore the total number of species is relatively low. *M. gayi* is most important offshore associated with *H. macrops*. Inshore, *M. gayi* is also the dominant species, but associated with pelagic and/or coastal fishes (e.g. *T. murphyi* and *Prolatilus jugularis*, respectively). On the upper slope *C. aconcagua* progressively replaces *M. gayi*, associated with the bathypelagic fish *Epigonus crassicauda*, skates or little sharks.

Despite the relatively clear separation by depth, the demersal ichthyofauna seems to be temporally and spatially dynamic. The results of the present study show that the demersal ichthyofauna exhibits fluctuations during the year, and between years for the same season. Comparable results were reported by Overholtz & Tyler (1985), in their study of the demersal fish assemblages of Georges Bank.

The causes of the zonation found off Central Chile are not clear but both important ichthyofaunal boundaries can be correlated with physical changes in the substrate and in the water column. In the area of study, one boundary coincides with both the edge of the continental shelf and the presence of the Günther Current, formed by the Equatorial Subsurface Water (ESSW; Silva & Neshyba,1979). At this boundary, the largest concentrations of *M. gayi* are found.

Avilés *et al.* (1979) proposed a strong relationship between the Günther Current and the presence of *M. gayi* in Chile; its seasonal migrations could be a consequence of the seasonal fluctuations of this current. The oxygen depletion in the ESSW is seemingly not a limiting factor for *M. gayi* (Avilés *et al.*, op. cit.), contrary to what was postulated by Brandhorst (1959).

Coincidently, Samame*et al.* (1983) and Espino *et al.* (1985) communicated that in Northen Peru (5° S - 9° S), during "normal years", i.e. Anti-El Niño events, the largest concentrations of biomass of *M. gayi peruanus* were found at depths where the oxygen values ranged from 0.25 to 1.5 ml/l.

Above the boundary around 100 m depth, the presence of *M. gayi* is gradually reduced, and coastal or epipelagic species (*P. jugularis* and *T. murphyi*, respectively) increase. Yáñez (1974) reported a similar occurrence off Valparaiso, in Central Chile, being *P. jugularis* and *Stromateus stellatus* the most important species above 100 m depth. This shallower zone is affected by subantarctic water (SAAW) of the Humbolt Current.

Below the boundary at 250 ± 50 m depth, the presence of *C. aconcagua* increases. This change between hake *(Merluccius sp.)* and rattail *(Coelorinchus sp.)* correspond to zonations of demersal fish assemblages in comparable ecosystems. for instance, in the northeastern Atlantic, Haedrich *et al.* (1975, 1980) found a similar situation in the area off New England *(Urophycis regius: Coelorinchus carminatus)*; Day & Pearcy (1968), on the continental shelf and slope off Oregon (*Sebastodes spp.*: *Coryphaenoides pectoralis*); Gabriel & Tyler (1980), in the area from Columbia River to Yaquina Bay, Oregon (*Merluccius productus*: "ratfish");

Snelgrove & Haedrich (1985), in the area off Newfoundland, northwestern Atlantic of Canada *(Gadus morhua: Coryphaenoides rupestris)*; Lleonart & Roel (1984), Roel (1987) and Macpherson & Roel (1987), in the southeastern Atlantic off Namibia *(Merluccius capensis: Coelorinchus spp.)*; and Macpherson (1981), along the coast off Catalonia, Spain *(Merluccius merluccius: Coelorinchus coelorinchus)*.

In general, this study coincides with the one by Yáñez y Barbieri (1983), who found a marked discontinuity between the fauna of the continental shelf and of the bathyal zone. Within each zone the faunal composition gradually changed with depth. Their study was carried out in the area off Valparaiso (33° S), Chile, where species of the family Marcrouridae appear also at 220 m depth. The presence of *M. gayi* is also revealed between 150-300 m depth, but with variation in the catch per unit of effort, both seasonally and bathymetrically, probably because of its migrations along Central Chile.

The coastal fauna was also found at depths shallower than 130 m, including *P. jugularis* and the pelagic fish *T. murphyi*. Previously, Yáñez *et al.* (1974), Yáñez (1974) and Yáñez & Barbieri (1974) reported similar results for the sea bottom assemblage off Valparaiso.

There is another interesting generalization in mid latitudes demersal fish assemblages: only a couple of species contribute significantly to the fish catch. The demersal fish assemblage of interest in this study is not an exception. Above 250 m, where trawling is carried out, only three or four commercially important species account for more than 80 per cent of the catch, independent of the season. Despite this, the other, mostly noncommercial species may have essential roles in the ecosystem occupied by the previous economically important fishes. As Horn (1980) pointed out, the noncommercial species may function as predators or competitors of exploited species, or otherwise affect community structure and, thus, indirectly influence economically important populations.

In this study, the characteristics of the "Exterior Zone" must be emphasized. In fall situation, i.e. April, the "axis" of this demersal fish assemblage is located below 150 m depth, but with a characteristic fauna of the upper continental slope and isolated from the other two zones (Achira and Bio Bio). After winter, i.e. November, fish associations are mainly found with the Bio Bio zone.

Before the beginning of the rainy season, i.e. March, these connections change and the association is mainly with the Achira zone. At this time, the demersal fish assemblage moves both upwards and towards the coast. This is likely to be correlated with, and synchronized to, the displacement of the anticyclonic center over the southeastern Pacific that is influencing water masses movements in the region. Arcos (1987) has shown that variation in the alongshore component of the winds induce a response in the hydrographic fields in Central Chile.

Following Arcos (1987), it can be postulated that the spatial and temporal variability of the demersal fish biomass on the continental shelf and upper slope off Central Chile is just a biological response to changes in hydrographic conditions related to the annual meteorological cycle. In spring/summer the trade winds lies southwestly; in fall/winter they lies northly. As a result, superficial waters are transported offshore in spring/summer (mainly between October and March), which causes a compensatory upwelling from subsuperficial waters and, consequently, the displacement upwards of deeper waters.

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