ICES STATUTORY MEETING 1993 C.M. 1993/ L:51
Biolog. Oceanogr. Commt.

DIEL VARIATONS IN VERTICAL DISTRIBUTION OF COPEPODS IN THE NORTH IBERIAN COAST

M.L. FERNANDEZ-PUELLES (1)
L. VALDES (2)
M. VARELA (3)
M.T. ALVAREZ-OSSORIO (3)

Instituto Español de Oceanografía

(1) Centro Oceanográfico de Baleares
Apdo. 291 07080 Palma. Spain

(2) Centro Oceanográfico de Santander
Apdo. 240 39080 Santander. Spain

(3) Centro Oceanográfico de La Coruña
Apdo. 130 15080 La Coruña. Spain

ABSTRACT

Included in the framework of the SARP project (Sardine and Anchovy Recruitment Program), a study of copepods vertical distribution has been carried out.

Zooplankton samples were taken at three different stations during a 24 h. period, in the proximity of a drogue buoy using a LHPR sampling net, so that, it is assumed the same water mass was continuously sampled.

Copepods were counted and classified into seven categories according to their size. Development stages and copepodites formed the bulk of copepods population. The vertical distribution of zooplankton in the water column seems to be related to that of chlorophyll. In all the stations the pattern of sardine larvae densities is mainly related to the abundance of nauplii and smaller fractions of copepodites. In general, the three areas reflected differences in the plankton distribution which is discussed.

INTRODUCTION

The Sardine Anchovy Recruitment Project (SARP) form part of a cooperative European programme between Spain, Portugal and Germany on larvae of sprat (Spratus spratus, L.) in the German Bight, sardine (Sardina pilchardus, Walbaum) off the North Coast of Spain and anchovy (Engraulis encrasicholus, L.) along the coast of Portugal. As a contribution towards the SARP project, from April 17 to May 12 1991, a pilot survey along the North Coast of Spain was carried out with the main purpose of Knowing the spawning sardine area, the hydrographic structure and the microzooplankton abundance to identify representative sites for more detailed studies on larval feeding. In this framework, a study on copepods , vertical distribution (fractionated in eggs, nauplii, and five body size classes) was included. (SARP), from April 17 to May 12, 1991 a pilot survey along the North Coast of Spain was carried out.

According to previous observations, unfavorable oceanographic conditions are among the principal determinants of larval survival, and these conditions are reflected in the plankton distribution. On the other hand, food availabitility is considered to be one of the main links between oceanography and larval survival (Hunter, 1976; Bailay and Houde, 1989; Turner, 1984). In this sense, the goal of this paper is to describe the abundance and distribution of the copepods (from eggs to adults) and the diel vertical variation pattern in three sites sampled along the North Coast of Spain where the abundance of the sardine larvae was important and likewise, their main biotic and abiotic parameters in relationship.

As part of the same cruise, studies of the particulate assemblages, distribution of the sardine eggs/larvae, and larval feeding have been published elsewhere (García-Soto, et al., 1991; Robins et al.; 1991; López-Jamar et al., 1991; Conway et al., 1991.)

MATERIAL AND METHODS

Cruise ECOSARP-491 was carried out on the R/V Cornide Saavedra (April 17, May 12, 1991) along the North coast of Spain which was divided in three defined areas: 1) from Santander to Cape Estaca de Bares, 2) from Cape estaca de Bares to Vigo, and 3) from Santander to France: In each area a preliminary mapping of sardine larvae abundance was performed in order to define/select/choose (where the abundance of larvae were higher) the 24 hour stations which situación are showed in Fig 1.

The sampling to determine the diel vertical distribution of the microzooplankton was carried out using a modified version of the Longhurst Hardy Plankton Recorder (LHPR; Williams et al., 1983), The double LHPR, used in the present study, consisted of a fine net (53 µm mesh aperture) for the microzooplankton and a coarse net (200 µm mesh aperture) for the sardine larvae. Each net was attached to a cod-end unit which takes a series of sequential samples with a resolution better than 5 m. Samples were collected in oblique tows

at 2-3 Knots. During the haul the sample depth, and flow rate of the fine net system were monitored and logged to an on-board PC communicating via cored cable separate to the towing cable.

In order to allow sampling to follow the same water mass, a drogued drifting buoy was released at the initial station position. This buoy was then followed for subsequent sampling over the 24 h period. At different times LHPR hauls were taken to give a day/night series at each site (Table I). Valid samples were obtained on all hauls with the exception of the fine mesh samples in the 3rd haul in Asturias which was invalidated due to a split filtering net. On board the plankton samples were preserved in 4% buffered formaldehyde solution for subsequent analysis in the laboratory.

The zooplankton >53 µm was classified in 3 main groups: the copepods, the nauplii and the eggs. Then the copepods were classified into 5 differents sizes according to the cephalotorax length (<0.45; 0.45-0.70; 0.70-0.95; 0.95-1.20 and >1.20 mm for classes C1, C2, C3, C4 and C5 respectively). The size of nauplii was <0.45 mm, and the size of eggs <0.14 mm. Results were converted to standardised plots of vertical distribution profiles.

The sea water temperature and salinity values were taken with the high speed tow net at the same time as the microzooplankton samples. The chlorophyll a and particle size distribution was samples at three standard depths with a 3 l Niskin bottle. Additionally physical and other biological parameters were monitored by CTD profiles and vertical UNDULATOR dips for temperature, salinity and chlorophyll a.

Univariate statistic included ANOVA were performed in order to identify any differences in abundance among stations, time, sizes and depths. For delimiting individual groups of faunal similarities clustering was realized at the three sites taking into account the completed 24 h hauls using the Bray-Curtis similarity index. Finally a no-metric multidimensional scaling (MDS) was employed for delimiting time and depth distribution as described by Field et al. (1982) and Clarke and Green (1988). The statistical calculations were performed using the software package STATGRAPHIC 1 for univariate analysis and the software package PRIMER 2 for multivariate analysis.

RESULTS

Hydrography and chlorophyll distribution

During the first part of the cruise (from April 17 to April 23) winds blowing from NE resulted in drifting of the buoys in St-1 (Asturias) and St-2 (La Coruña) to the W (Fig.1). From April 24 to May 12 the winds shifted to S, SW resulted in the drifting of the buoy in St-3 (Santander) to the E. In Santander, as the winds blew strong the displacement of the buoy in the 24 h period was of 14' in longitude while in Asturias and La Coruña the winds were moderate

and the displacement of the buoys were only of 6' and 2.8' of longitude respectively (Table I). The sea water temperature was uniform in the three 24 h stations ranged from mean values of 11.95 °C (Asturias 19.00 am) abnd 12.27 °C (La Coruña 4.08 a.m.) for the whole water column the warmer temperature was found in Santander, the minimum values were found in La Coruña being 11.3 °C at the surface, the maximum water temperature in Santander went to 13.2 °C. Salinity was higher in La CORUÑA (USP=35.70) than in Asturias (USP=35.65) and Santander (USP=35.20). Nevertheless since differences were so samll, we assume that the physical characteristics of the water mass were the same at the three 24 h stations sampled. Clorophyll distributions were similar in Asturias and La Coruña (Fig.2) showing a stratification pattern with little variations throughout the 24 period of study, however concentrations were slighty higher in La Coruña than in Asturias. In Santander the chlorophyll values were below 0.5 mg Chla/m^3 and the distributions was very uniform not showing any sign of stratification.

Zooplankton abundance and composition

Copepod eggs, nauplii,copepodites and copepod account for more than 90 % of microzooplnakton (>53 um) community. Twenty-one species of adult copepods were identified. Paracalanus parvus, Pseudocalanus elongatus and Clausocalanus spp. made 41-65% of total abundance. Acartia claussi account for 8-31% and Oithona plumifera, O. helgolandica and O. nana made 7-30% of total abundance. According to the cephalotorax length, the group C5 (>1.20 mm) include some copepodites and adults of bigger copepods such as Calanus helgolandicus, Euchaeta hebes, Metridia lucens, Candancia armata and Centropages typicus. The group C4 (0.95-1.20 mm) include copepodites of the former species and adults of P. elongatus.

Group C3 (0.70-0.95) include adults of P. parvus, Clausocalanus spp., and A. clausi, copepodites of these species and adults of Oithona sp.. and adults of the smaller species such as Microsetella norvegica, Macrosetella rosea, Oncaea media, etc.

Copepods assemblage and their relative abundance are almost the same in the three 24 h stations. However, in term of numbers, abundances of adult copepods and copepodites were similar only between St-1 and St-3 (mean values of 3805 and 4451 ind.m/ ^{3}, 37 and 59% respectively(while in St-2 mena abundance only made 1945 ind.m/ ^{3} (46%). Eggs abundance in St-1 was tenfold the abundance en St-2 and St-3 with mean values of 967, 96 and 85 eggs m/ ^{3} in each station. Nauplii abundance in St-1 was twofold the abundance of St-2 and St-3 with mean abundance of 5564, 2145 and 2958 ind. m/ ^{3} in Asturias, La Coruña and Santander, 54, 51 and 39% respectively (Fig.3).

Microzooplankton vertical distribution

To ascertain the vertical distribution of the zooplankton in Asturias (Station 1), 4 different hauls from April 24 to April 25 were carried out at 10:00 am, 17:30; 22:20 and 3:30 am. Since

1 - STATGRAPHICS is registered trademark of Stratistical Graphics Corporation.
2 - PRIMER is statistical software package developed in Plymouth Marine Laboratory.

sunrise on that day was at 5h.30' and sunset at 19h.21', we can considerer 2 day/hauls and 2 night/hauls.

The vertical distribution of the 7 groups analysed has been shown in Fig.4 at three different hours sampled.

In the morning haul, the average number of the copepods was 4009 ind/m3 , 5575 nauplii/m3 and 834 eggs/m3. The maximum of the organismes was at 10 m depth where the smaller nauplii and the smaller copepods, at 20 m depth, were the more abundant. Although other peack appeared at 40 m depth, it was less. The bigger copepods showed 2 maximum values at 20 and 45 m depth, as well as the eggs. The smaller nauplii and copepods formed the 79% of the total copepods.

In the afternoon haul the average of the copepods decreased with 2560 ind/m3 , 3286 nauplii/m3 and 768 ind/m3. The copepods distribution, at that moment, seems to be concentrated about 15 - 30 m and again the smaller copepods and nauplii formed the bulk of the zooplankton being 75%.

During the night haul the number of organismes increased with 4847 copepod/m3 , 7830 nauplii/m3 and 1299 eggs/m3. On this ocassion only the maximum was found between 15-25 m depth where the nauplii were very concentrated at 20 m depth and the copepods around them, even the bigger copepods. The smaller organismes (nauplii + copepodites) formed 74% of the total.

In general we could see that during the day they were dispersed in wider layer of water from 10 to 40 m depth, and not so concentrated as in the other hauls. In the afternoon, the organismes move upward, especially the bigger sizes
and at night the bigger copepods wich did not move up earlier went to the upper layers, while the nauplii and the smaller copepodites concentrate themselves close to the 20 m layer.

At Station 2 (Coruña Coast) and from April 28 to April 29- 4 different LHPR hauls were carried out from the bottom (100 m depth) to the surface , now 20 layers were considered. In the analysis,, except the 4:00 am haul the copepods fractions were only two (copepods< 0.7 mm and copepods >0.7 mm). The vertical distribution is shown in Fig 5.

At the 8:00 haul we found the maximum abundance, the average value was 6942 ind/m ^{3} where the copepods formed 45% and the nauplii 53% . On this occasion the nauplii and the copepodites,<0.7 mm , formed the bulk being 86% of the total. In general the maximum number of individuals were at 20 to 40 m depth , all of them at the same layer. Bivalve larvae were also concentrated (2425 ind/m ^{3}) in deaper layer (55 m depth) where the eggs were very abundant.

At the 18:00 haul the average number decreased with 3052 ind/m ^{3} with 51% of copepods and 49% of nauplii. In this occasion the bivalve larvae also decreased being 1146 ind/m ^{3}. All of them went upward to the surface except the eggs.

At the 24:00 haul the organismes value reach the minimum with 1920 ind/m ^{3} where neither the copepods, >0.7 mm, nor the nauplii went to the surface and only the smaller copepods a slightly increased in numbers in the first 5 meters.

At 4:00 am the average was 4848 ind/m ^{3} with a clear increase at the surface, of the nauplii, as well as the copepods.

During the afternoon ,all the groups went upward close to the 20-25 m layers. Except at midnight, in the complete darkness , all the marine microzooplankton went to the surface incresing their abundance.

At Station 3 , From May 10 to May 11 at 75 m depth off Santander Coast, 6 different LHPR hauls have been carried out. On this occasion 15 layers were considered. The vertical distribution is show in Fig 6.

The maximun values were found at the 14:40 pm haul with 11470 ind/m ^{3}, 51% of nauplii and 23 % of smaller copepodites (C1). Copepods from 0.45-0.70 mm were also abundant (19%). The distribution observed was very irregular with a lot of peacks as in the surface, 30 m, 60 m and 75 m depth.

The minimum values were observed just after the sunset (19:40 haul), thus the sunset happened at 19:20 haul, the average layer was 3314 ind/m3, 31% of nauplii, 41 % of smaller copepods (C1) and 20 % of 0.45-0.70 copepods (C2). The surface layer as well as the 40-45 m depth were the most concentrated.

At 20:40 pm haul the average layer increased slightly with 5656 ind/m3, the 0.45-0.7 mm copepods were more important than in the other hauls. Again the nauplii (24%) and the smaller copepods (37%) formed the bulk of the copepods. Irregular distributed peacks appeared with the maximum about the 45 and 55 m depth.

At the 2:05 am haul 7804 ind/m ^{3} were counted with 30% of nauplii and 32% of smaller copepods. The nauplii and the copepods seems to be concentrated about 15-20 m dpeth. The peack about the 55 m depth has still present at this time.

Very early in the morning, 5:55 am haul (5:20 am sunrise time), the average number of zooplankters was 9347 ind/m3 , the bulk of the copepods (N1-C1 and C2) were close to the surface (39, 23 and 27% respectively). The other peacks about 30 and 50 m depth were still there.

At 10:40 am haul the organismes number decreased at 7376 ind/m3, each layer. All the groups went down to medium layers around 30 to 50 m depth.

The nauplii seems to do important diel variation and especially at midday they went to the surface. The C1 do not seem to do any vertical migration and always keep themselves at medium layers. The

medium size copepods (C2 and C3) went upward to the surface at night and even during the sunrise. The bigger copepods (C4 and C5) moved themselves very irregularly, finding them close to the surface during the day.

Vertical distribution of microzooplankton follows a similar pattern to that of chlorophyll. In Asturias and La Coruña, microzooplankton, irrespective of the hour or day, concentrated in the upper layers of the water column, where chlorophyll values are higher. Nevertheless, in Santander where the chlorophyll is evenly distributed vertically, the microzooplankton does not show a clear vertical distribution as it does in Asturias and Sandander.

One way analysis of variance on log (x + 1) transformed abundances for all the stations revealed significant differences between the sizes and organismes but no the depth.

Cluster analysis based on zooplankton abundances at each level sampled show high affinities between groups at the three 24 h stations (Fig.7). Each linkage include size classes that represente consecutive developmental stages, showing that the cluster has a clear biologicla meaning. At a similarity level of 75% the three 24 stations are divides in two groups, in the first, classes C1, C2 (in Coruña) and C3 (in Asutiras and in Santander) appear together with the nauplii (N1); in the second group, the association include big copepods and copepodites of the classes C4 and C5. Copepod eggs do not show a high affinity for any of the groups and their appear with C2, C3 in Asturias but with C4, C5 in La Coruña and Santander.

These results suggest that the classes with a smaller body size, sich as N1, C1, C2 and C3 exibit a similar behavior patrern with respect to their position and movements in the water column. These same trend is observed bewtween C2 and C5, but the behaviour between the samller and the biggers may be disimilar.

The depth clustering analysis (not represented) reveals the concentration of the bulk of copepods in the upper 50 m. Differences in depth abundances are also evidenced by other ordinatio ntechniques as MDS (Fif.8, 9, 10). When depth-time abundances are plotted over sardine abundances, it is noted that microzooplankton abundances and sardine abundance are related in both, depth and day/night distribution. Nevertheless, maximu, numbers of organism appear during night in layers 35, 30 and 25 m depth. This relationship is particularly evident in Asturias when multiple correlation between the sardine larvae and nauplli was 0.8539 and with the copepods 0.6573 (both at the depth of maximum abundances, 30 m).

DISCUSSION

Although one of the purposes of this paper was to know the behavior pattern of the microzooplankton common to the three areas studied, the greater diversity of ecological factor involved in the stations

sampled does not allow us to explain completely the differences between their diel verticla variation. During decades of investigations on zooplankton migration have found a lot of causes which can explain together the plankton movement, including vertical as well as horizontal migration, chanbes in feeding behavior and algernating reproductive states (Haney, 1988).

On the basis of luctuations in environmental factors, zooplankton exhibit a variety of daily cycles and any region has peculiar features where the plankton respond th these differences (Bayly, 1986). Moreover there are many mechanismes controlling the diel verticla movement as light, temperature, food and predator avoidance. Many authors considerer that the food base for the sardine larvae are the samller developmental stage copepods and their egss (Last, 1980; Conway et al., 1991). On this sense the bulk of the community studied was forme by the nauplii and the smaller copepods size (C1) never below 70%.

If we considerer the three stations studied were different in their hydrographic conditions (Cabanas et al., 1991; Lavin et al. 1992) we can understand that the diel vertical variaiton will be differente.

Observing those diel variaitons between Asturias and La Coruña is possible to appreciate clear vertical migrations at night in the more abundnat groups, except the smaller copepods, but in Santander they were very irregularly distributed throughout the period, where the maximu, number of individual appared during mdday instead of durign the night. Nevertheless this could be understood by the study of the vertical composition structure, because different species show different behavior with nocturnal or reversal migrations going to the upper layers (Harris, 1988).

This migrations, is very confused specially for smaller size ranges (lower than 250 µm), thus depending of the period of time, their movement to the surface can nont be clear, althougt the bigger copepods always seems to go upward (Magnessen, 1989). In our study the size claseed analysed were considering the sardine larvae feeding objetive, so that it was not in smaller sizes.

In Norway (Lie et al, 1983) during May was observed a clear migration for bigger copepods, >250 µm, but not during June, likewise it occured in Santander. Probably the period of time sampled among the three stations can be other factor of variability very important.

If we considerer appart of the temporal and spatial variation between the, the long buoy desplacement, in the case of Santnader, should be considered as other factors involved (as water masses movement, advection) to understand that irregular distribution. It is very complex to study the diel verticla migration in one fix location but in a movement systems seems to be really impossible to understand (Margalef, 1980).

Even when the drogge was followed continuosly in any station does not seem to be the same water masse from surface to bottom. Although the abundance was very different between day and night hauls in La Coruña and in Asturias, the proportion of their components was similar, but in the case of Santander was more different (Fig.11).

In Asturias we found a relation between the sardine and the microzooplankton, the copepods as well as the nauplii in the upper 30 m depth. The vertical migration for the sardine larvae seems to start in the late afternoon earlier than the bigger copepods, keeping their maximum during night.

In La Coruña the night vertical migration to the upper layer was also clear for the microzooplankton, even when their maximum abundance was early in the morning at 30 m depth during the day. The sardine larvae appeared in deeper water, and again in late afternoon they went up presenting their maximum abundance. The eggs distribution was maximum at deeper layers specially during the day. Seems to be that the development of the eggs took place below 60 m depth as other places in the Celtic Sea (Williams et al, 1987). These eggs distribution does not appear in the other stations. Some correlation among the plankton and the sardine was found in the upper layers.

In Santander the microzooplankton distribution was very irregular along the water column. The maxiumum microzooplankton abundance was found in the afternoon for all the size classes, thus seems to be in relation to the chlorophyll and to the sardine larvae distribution. Nevertheless no correlations were found. Only some nocturnal migration in upper layers was found to the bigger sizes of the copepods.

The simultaneous use of univariate and multivariate techniques permitted the interpretation and confirmation of the results observed.

REFERENCES

BAILY, I.A.E. (1986).- Aspects of died vertical migration and its enigma variations in Limnology in Australia. Monographiae biological. Vol. 61: 349-368.

BAILEY, K.M. and HOUDE, E.D. (1989).- Predation as eggs and larvae of marine fishes and the recruitment problem. Adv. Mar. Biol., 25. 1-83.

CABANAS, J.M., G. DIAZ DEL RIO, A. LAVIN and T. NUMS, 1992.- Hydorgraphic conditions off the galician coast NW of Spain, during an upwelling event. Bol. Inst. Esp. Oceanogr. 8/1):27-40.

CLARKE, K.R. and GREEN, B.H. (1988).- Statistical desing and analysis for a biological effects study. mar. Ecol. Prog. Ser. 46:213-226.

CONWAY, D.V.P., TRANTER, P.R.G., FERNANDEZ DE PUELLES, M.L. and S.H. COOMBS, 1991.- Feeding of larval sprat (Sprattus sprattus L.) and sardine (Sardina pilchardus Walbaum). ICES, 1991/L:76.

FIELD, J.G., K.R. CLARKE and R.M. WARWICK (1982).- A practical strategy for analyzing multispeies distribution patterns. Marine Ecol. Progr. Ser. 8:37-52.

GARCIA SOTO, C., N.I.H. HALLIDAY, S.B. GROOM, A. LAVIN and S.H. COOMBS (1991).- Slope current and upwelling off the NW coast of Spain, satellite imaginery and plankton distribution ECOSARP project. ICES 91 C:17.

HANEY, J. (1988).- Diel patterns of zooplankton behavior. Bull. of marine Science 43(3) 583-603.

HUNTER, J.R. 1976.- Report of a colloquium on larval fish mortality studies and their relation to fisheries research, january 1975. NOAA Tech. rep. NMFS Circ. 395: 5pp.

LAST, J.M. (1980).- The food of twenty species of fish larvae in the west-central North Sea. Fish Res. Tech. Rep. MAFF Direct. Fish Res. Lowestoft, 60 44 pp.

LAVIN, A., 1991.- Condiciones hidrográficas de la zona Galicia-Cantábrico. Abril-Mayo 1990. Inf. Técn. Inst. Esp. Oceanogr. nº 109, 57 pp.

LAVIN, A. G. DIAZ DEL RIO, J.M. CABANAS and R. CARBALLO, 1992.- SARP-AREA cruise. Hydrography and nutrients. Bol. Inst. Esp. Oceanogr. 8(1);7-26.

LIE, V., T. MEGNESEN, B. TUNBERG and D.L. AKSNESS (1983).- preliminary studies an the vertical distribution of size fractions in the zooplankton communities in Western Norway Sasia 68,65-80.

LOPEZ-JAMAR, S.H. COOMBS, F. ALEMANY, J. ALONSO, F. ALVAREZ, BANET (1991).- A Sarp pilot study for sardine (Sardina pilchardus) off north and northwest Spain in April-May 1991 ICES C.M. 1991/L:69.

MAGNESEN, T. (1980).- Vertical distribution of size fractions in the zooplankton community in Lindaspollene. Western Norway 2. Diel variations. Sarsia 74:69-77. Bergen ISSN 4827.

MARGALEF, R. (1980).- Perspectivas de la teoria ecologica. Blume, Barcelona: 110 pp.

ROBINS, D.B., M. VARELA, B. CASAS, N.C.H. HALLIDAY (1991).- Characterization to natural particulate assemblages around the northern coast of Spain in relation to a SARP study of sardine spawning ICES, C.H. 1991/L.81.

TURNER, J.T. (1984).- The feeding ecology of some zooplankters that are importante prey items of larval fish. NOAA Tech. Rep. NMFS 7, 28 pp.

WILLIAMS, R., D.V.P. CONWAY and N. COLLINS (1987).- Vertical distribution of eggs, nauplii and copepodits of Calanus helgolandicus in the Celtic Sea. Marine Biology 96, 247-252.

WILLIAMS, R., N. COLLINS and D.V.P. CONWAY (1983).- The double LHPR system, a hilgh spedd micro and macroplankton sampler. Deep Sec. Res. 30, 331-342.

Fig.1.- 24 h Stations position and microzooplankton biomass (> 53 um) during April 1991 in the North Coast of Spain.

Table.I.- LHPR hauls information in the three Stations sampled in the North Coast of Spain.

Fig.2.- Chlorophyll a distribution in the three 24 h stations.

Fig.3.- Copepods spatial variation (abundance) in the North Coast of Spain.

Fig.4.- Microzooplankton vertical distribution at Station 1.

Fig.5.- Microzooplankton vertical distribution at Station 2.

Fig.6a.- Microzooplankton vertical distribution at Station 3.

Fig.6b.- (Cont.) Microzooplankton vertical distribution at Station 3.

Fig.7.- Clustering size-classes at the three stations analysed.

Fig.8.- MDS plot's resulting from the microzooplankton data in Station 1 and the superimposed sardine larvae abundance.

Fig.9.- MDS plot's resulting from the microzooplankton data in Station 2 and the superimposed sardine larvae abundance.

Fig.10.- MDS plot's resulting from the microzooplankton data in Station 3 and superimposed sardine larvae abundance.

Fig.11.- Microzooplankton temporal variation during 24 h period in the North of Spain.

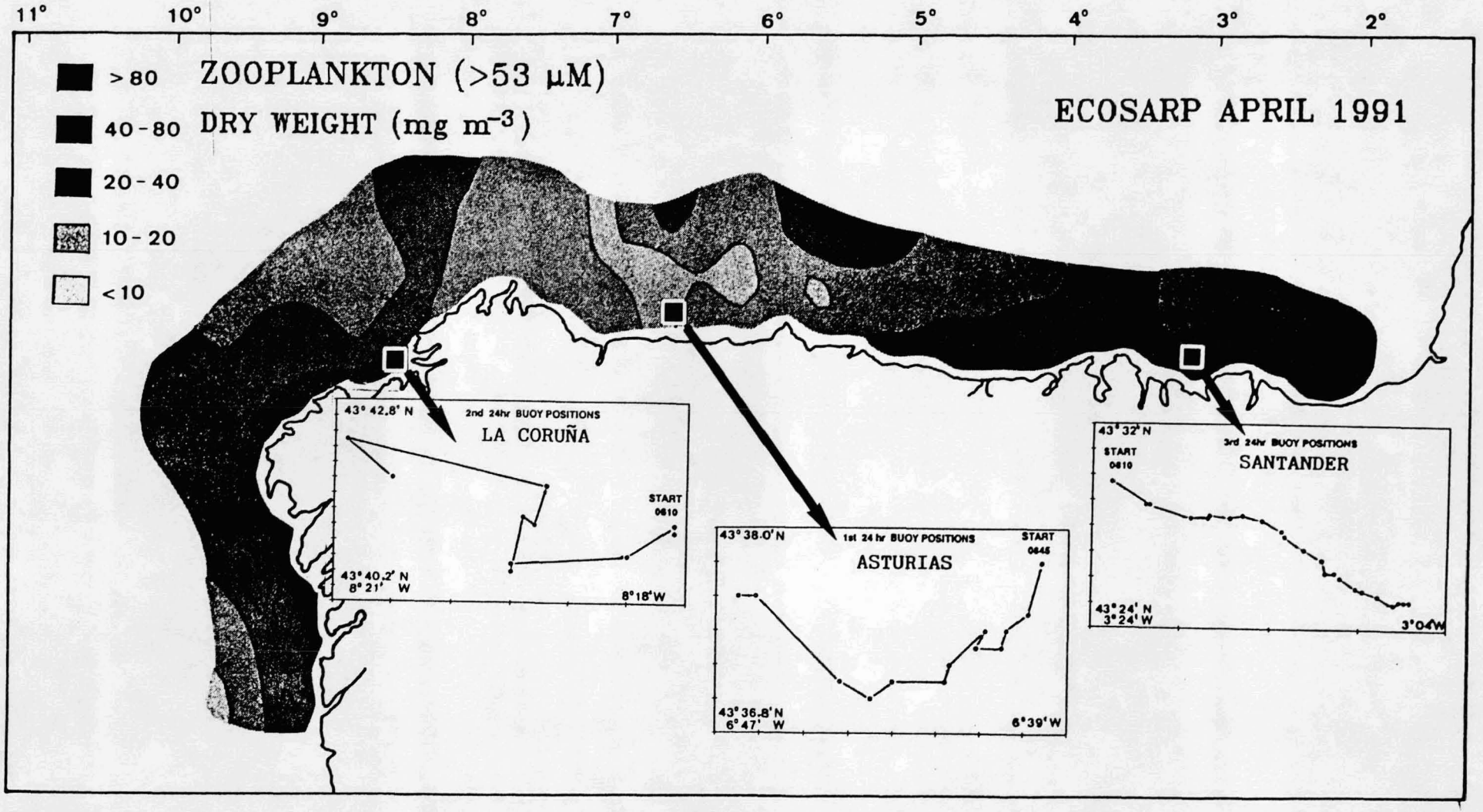

11°
10°
9°
8°
7°
6°
5°
4°
3°
2°
> 80
40 - 80
20 - 40
10 - 20
< 10
ZOOPLANKTON (>53 µM)
DRY WEIGHT (mg m-3)
ECOSARP APRIL 1991
43° 42.8' N
2nd 24hr BUOY POSITIONS
LA CORUÑA
START
0610
43° 40.2' N
8° 21' W
8° 18' W
43° 38.0' N
1st 24 hr BUOY POSITIONS
START
0645
ASTURIAS
43° 36.8' N
6° 47' W
6° 39' W
43° 32' N
START
0610
3rd 24hr BUOY POSITIONS
SANTANDER
43° 24' N
3° 24' W
3° 04' W

Fig. 1

Station	Date	Time Start	Latitude	Longitude	Depth Sampled m	53 µm Samples No.	Mean/std Water column Temperature °C	Mean/std Water column Salinity ‰
ASTURIAS	22/4/91	10.00	43 38.0	06 39.6	89	25	11.95/0.14	35.63/0.04
	22/4/91	17.30	43 37.2	06 41.4	79	21	12.08/0.33	35.66/0.03
	22/4/91	22.39	43 37.2	06 42.1	92	--	12.06/0.20	35.64/0.04
	23/4/91	03.30	43 37.2	06 45.0	86	22	12.02/0.20	35.64/0.03
LA CORUÑA	28/4/91	08.00	43 41.2	08 18.1	109	35	12.14/0.09	35.70/0.01
	28/4/91	18.00	43 41.7	08 19.8	108	31	12.15/0.07	35.69/0.02
	28/4/91	23.57	43 41.7	08 20.0	131	21	12.16/0.14	35.71/0.02
	29/4/91	04.08	43 42.3	08 20.9	115	24	12.27/0.18	35.71/0.02
SANTANDER	10/5/91	10.40	43 28.5	03 20.8	74	16	12.17/0.03	35.33/0.11
	10/5/91	15.00	43 28.2	03 14.4	75	18	12.27/0.07	35.42/0.05
	10/5/91	19.40	43 27.6	03 13.2	88	18	12.18/0.01	35.30/0.20
	10/5/91	23.00	43 26.5	03 10.5	79	18	12.27/0.06	35.26/0.18
	11/5/91	02.30	43 25.5	03 08.0	69	17	12.22/0.02	35.25/0.13
	11/5/91	06.15	43 25.1	03 06.3	65	17	12.22/0.02	35.17/0.10

Table I

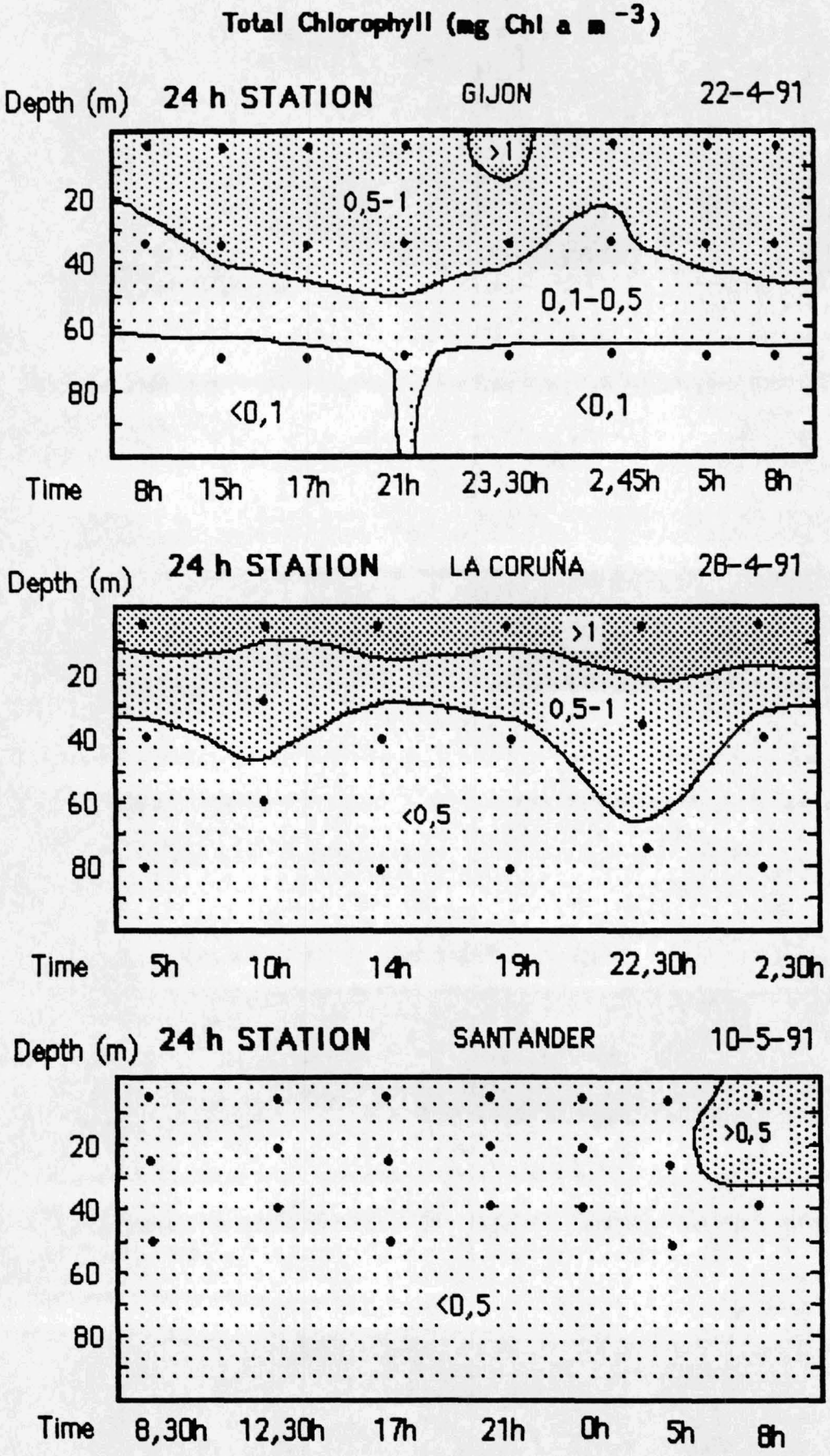
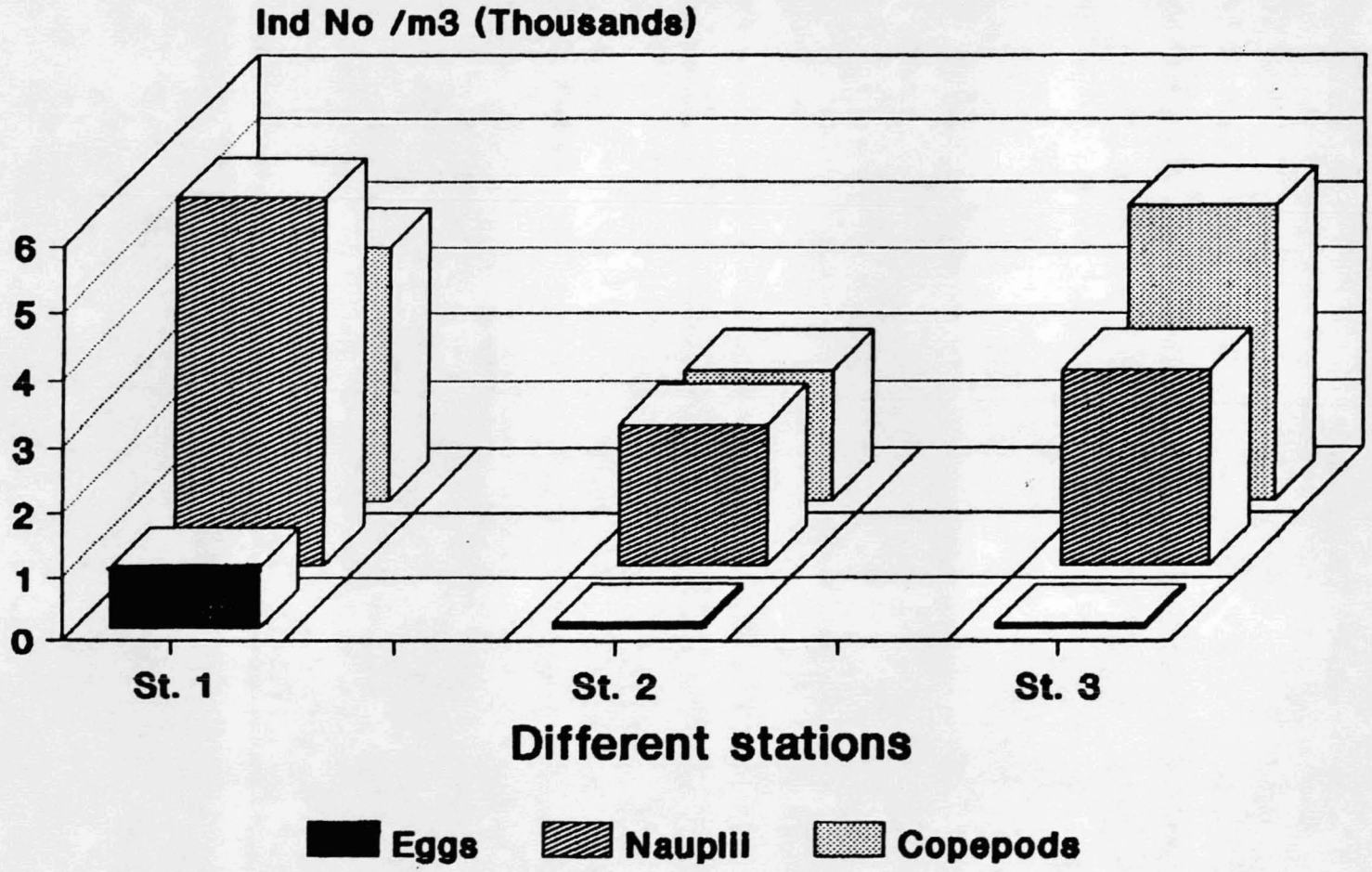

Total Chlorophyll (mg Chl a m -3)
Depth (m)
24 h STATION
GIJON
22-4-91
>1
0,5-1
0,1-0,5
<0,1
<0,1
20
40
60
80
Time
8h
15h
17h
21h
23,30h
2,45h
5h
8h
Depth (m)
24 h STATION
LA CORUÑA
28-4-91
>1
0,5-1
<0,5
20
40
60
80
Time
5h
10h
14h
19h
22,30h
2,30h
Depth (m)
24 h STATION
SANTANDER
10-5-91
>0,5
<0,5
20
40
60
80
Time
8,30h
12,30h
17h
21h
0h
5h
8h

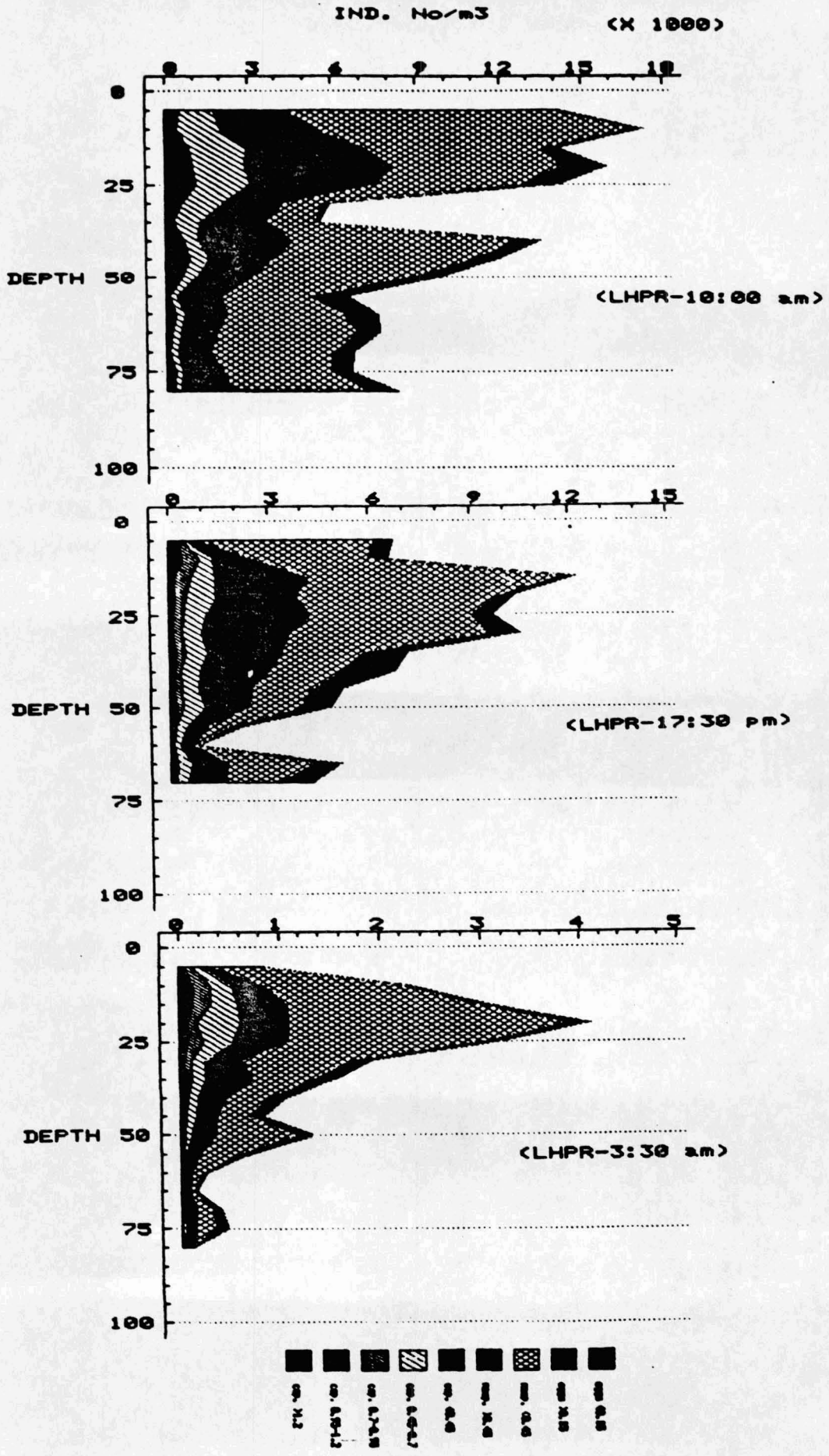
Fig. 2

Copepods abundance in the North of Spain
LHPR > 53 um



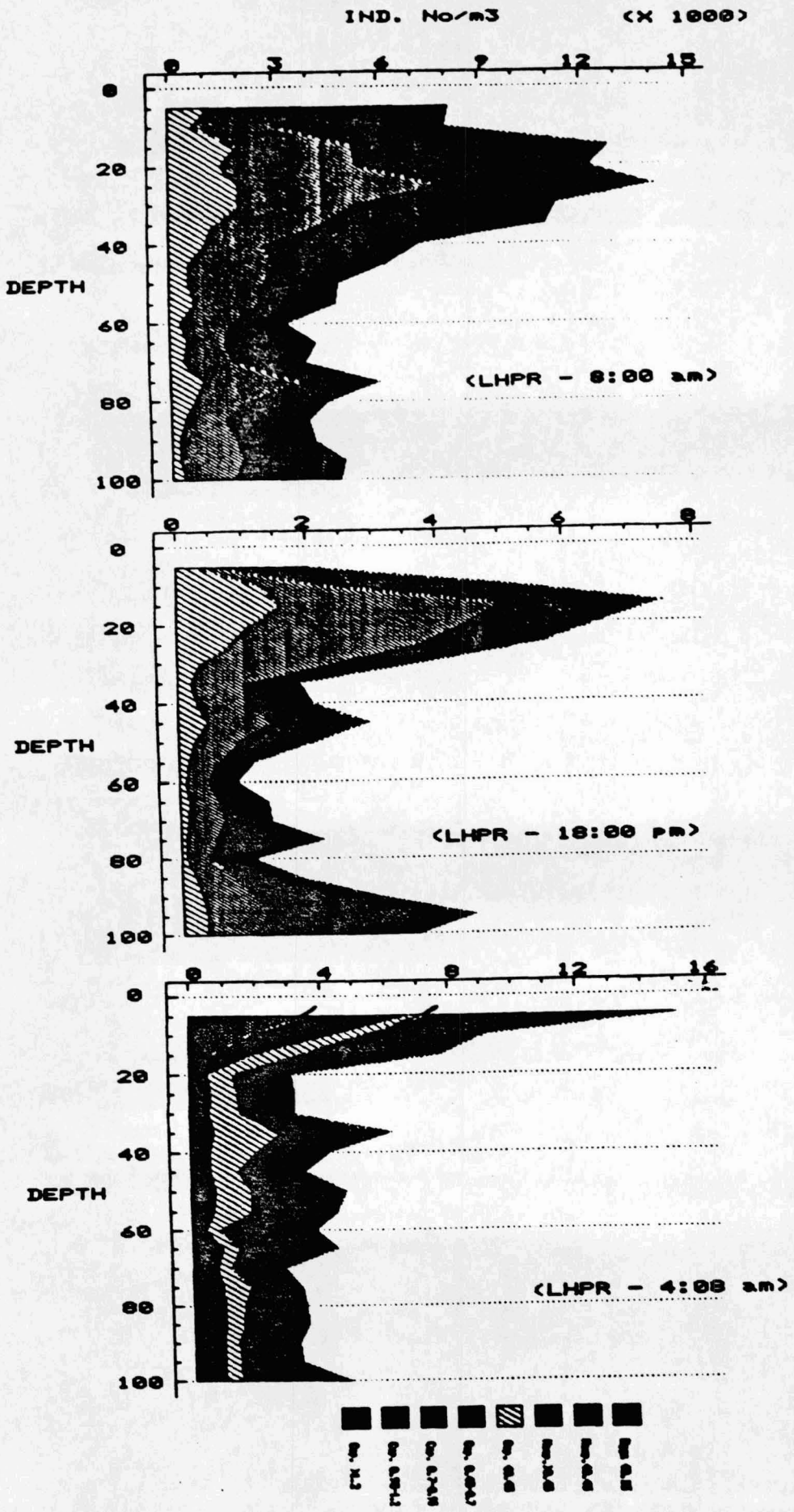
Asturias,Coruña and Santander

Fig. 3



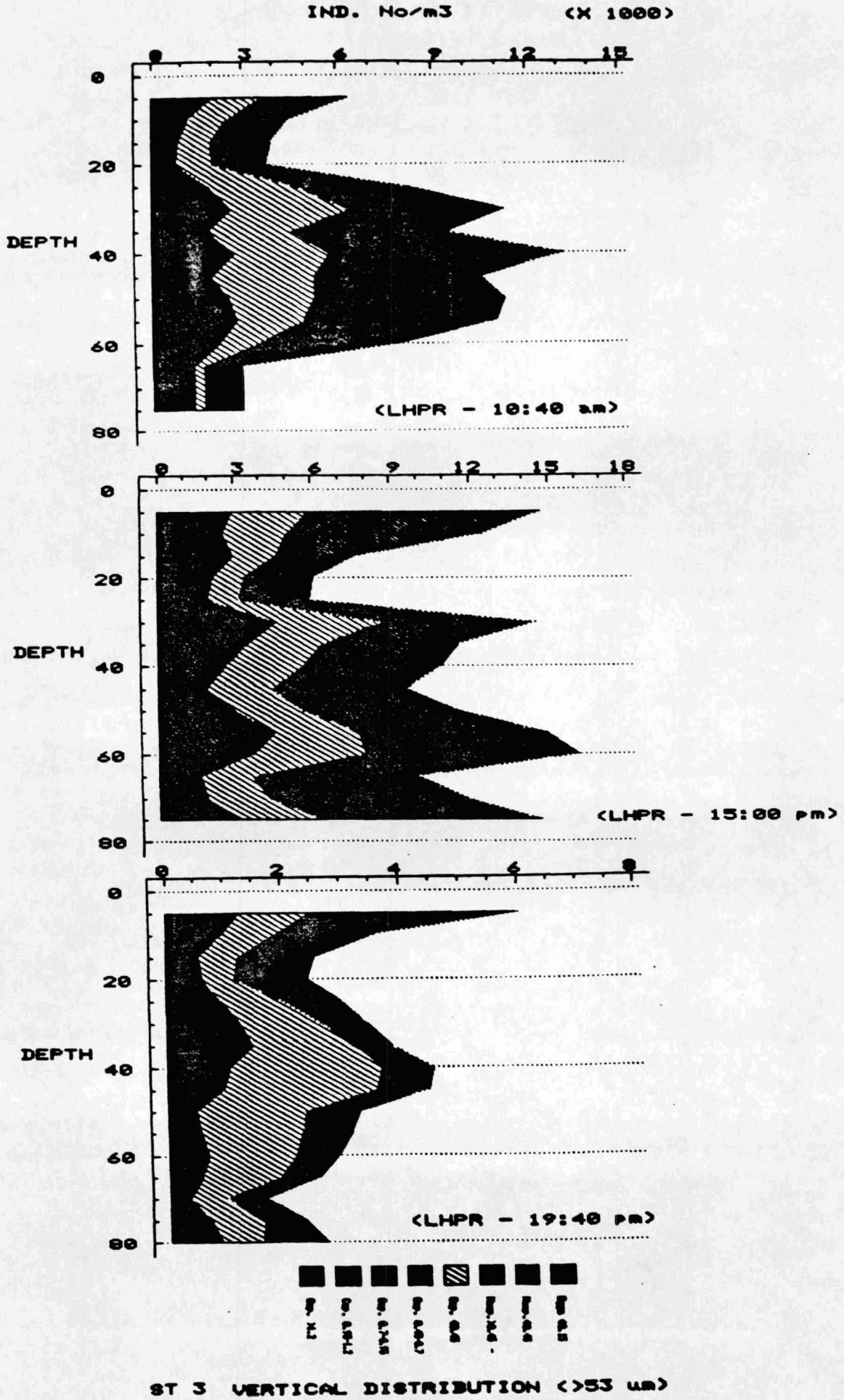
ST 1 VERTICAL DISTRIBUTION (>53 µm)

Fig. 4



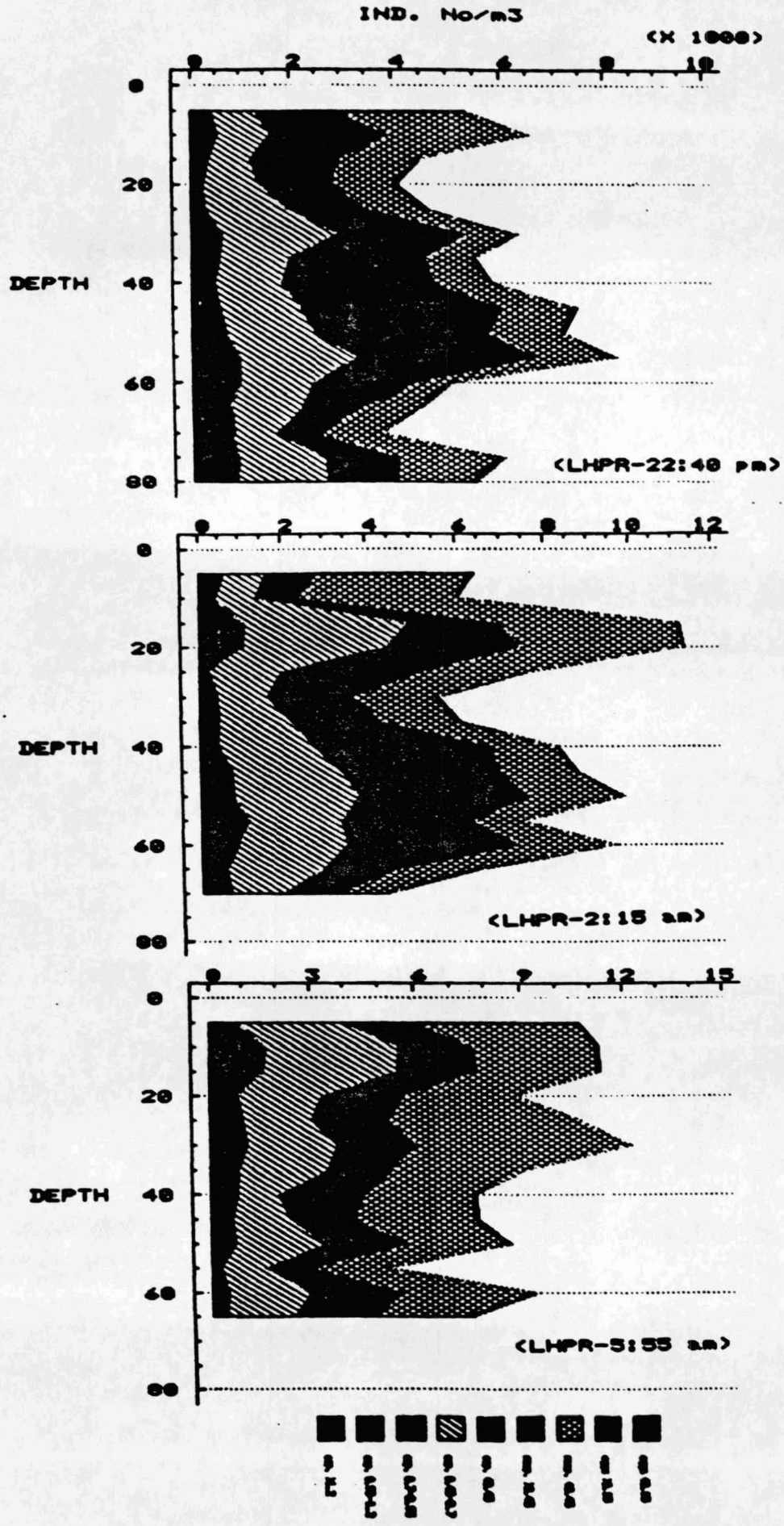
ST 2 VERTICAL DISTRIBUTION (>53 µm)

Fig. 5



ST 3 VERTICAL DISTRIBUTION (>53 um)

Fig. 6a



ST 3 VERTICAL DISTRIBUTION (>53 um)

Fig. 6b

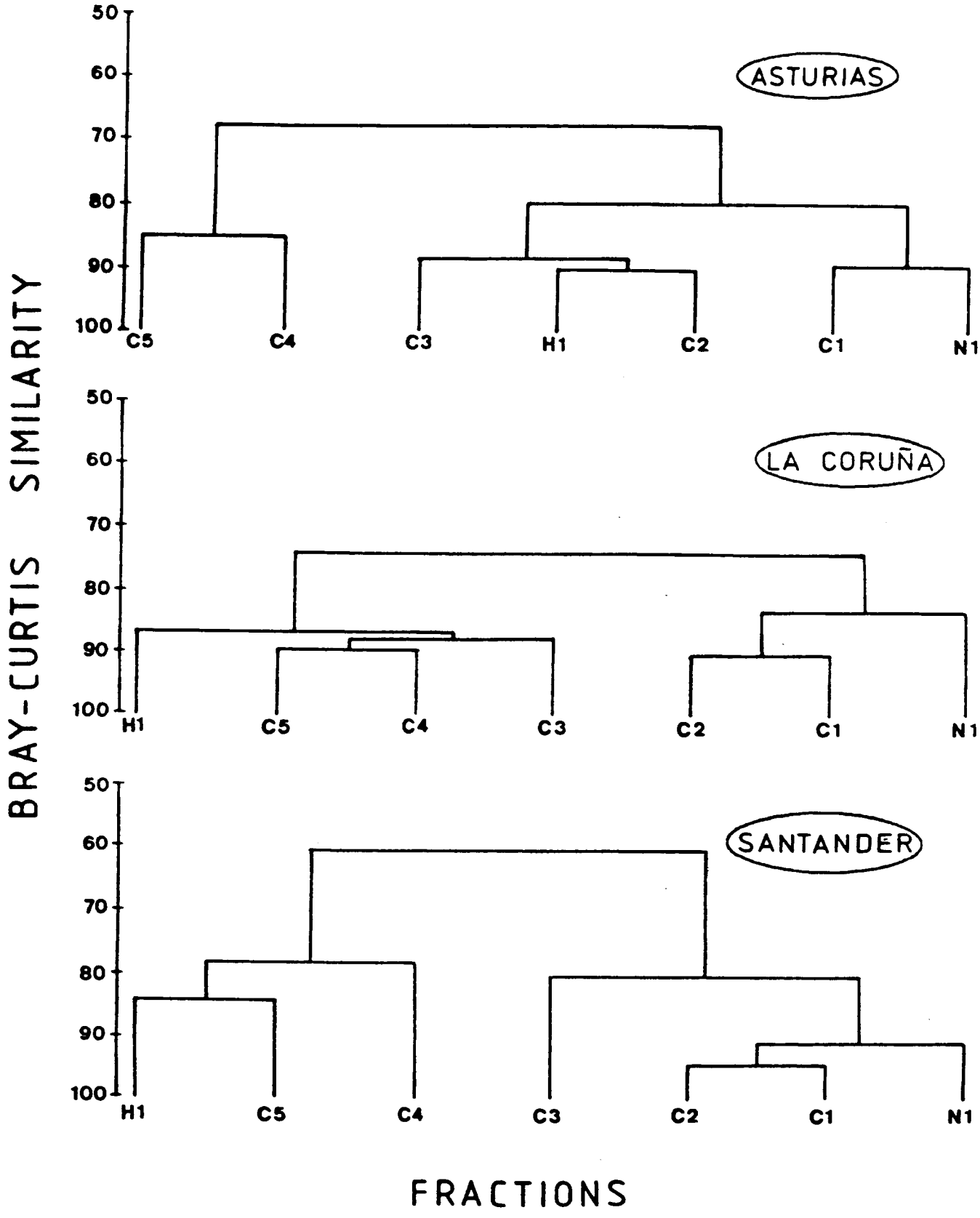
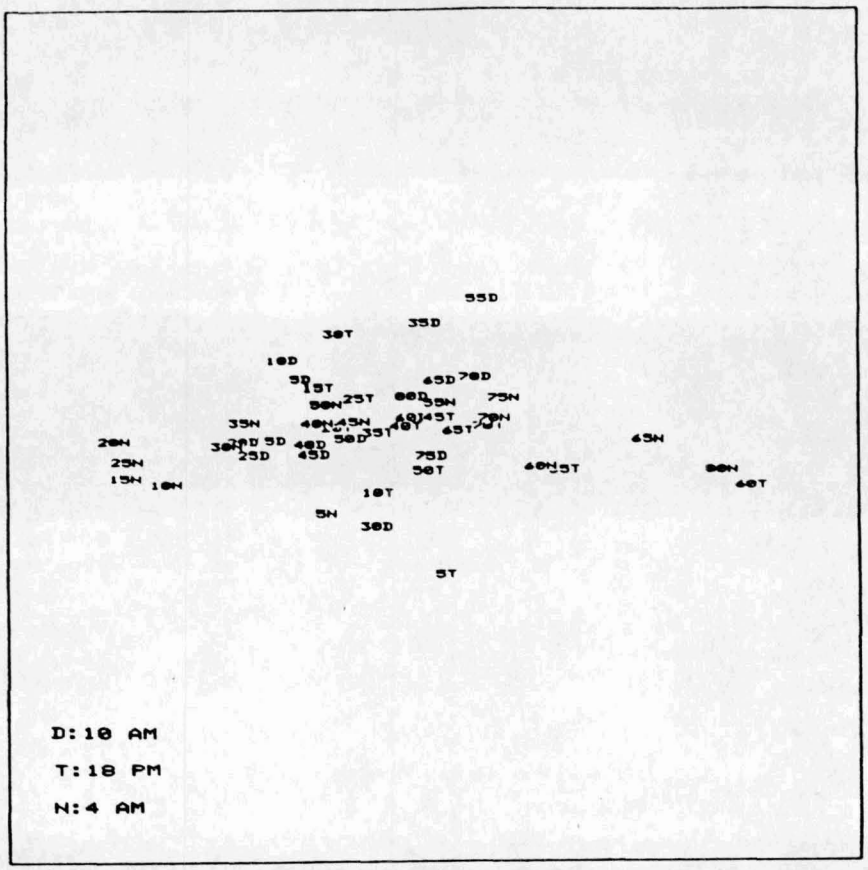

BRAY-CURTIS SIMILARITY
50
60
70
80
90
100
ASTURIAS
C5
C4
C3
H1
C2
C1
N1
LA CORUÑA
H1
C5
C4
C3
C2
C1
N1
SANTANDER
H1
C5
C4
C3
C2
C1
N1
FRACTIONS

Fig. 7

DEPTH-TIME MICROZOOPLANKTON IN ASTURIAS



SARDINE ABUNDANCE

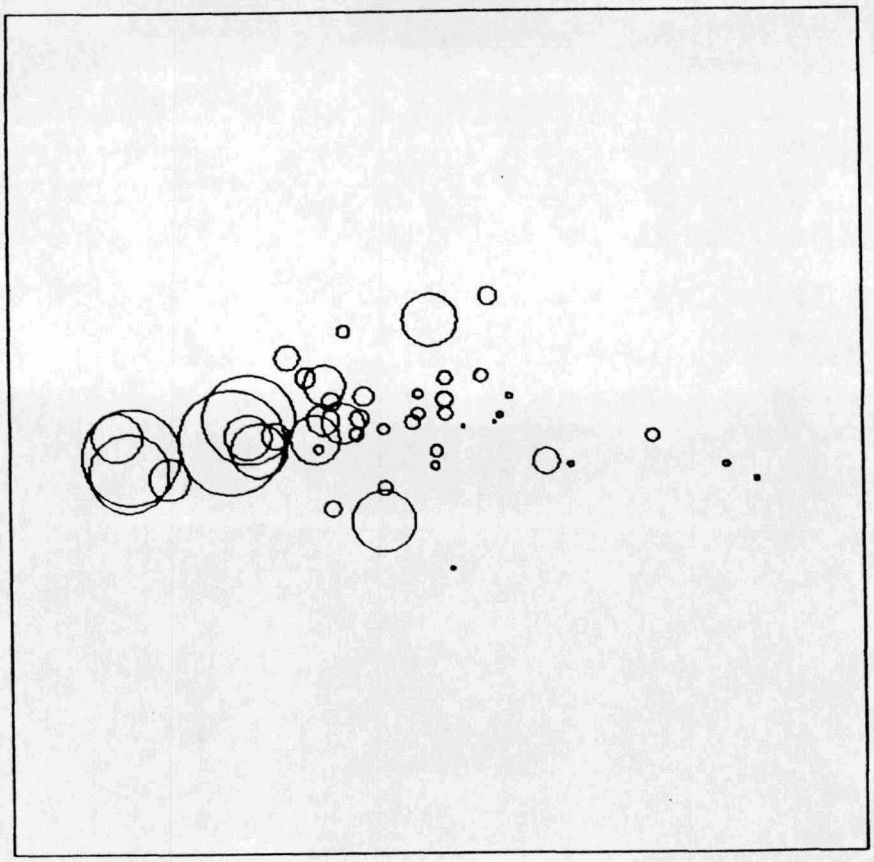
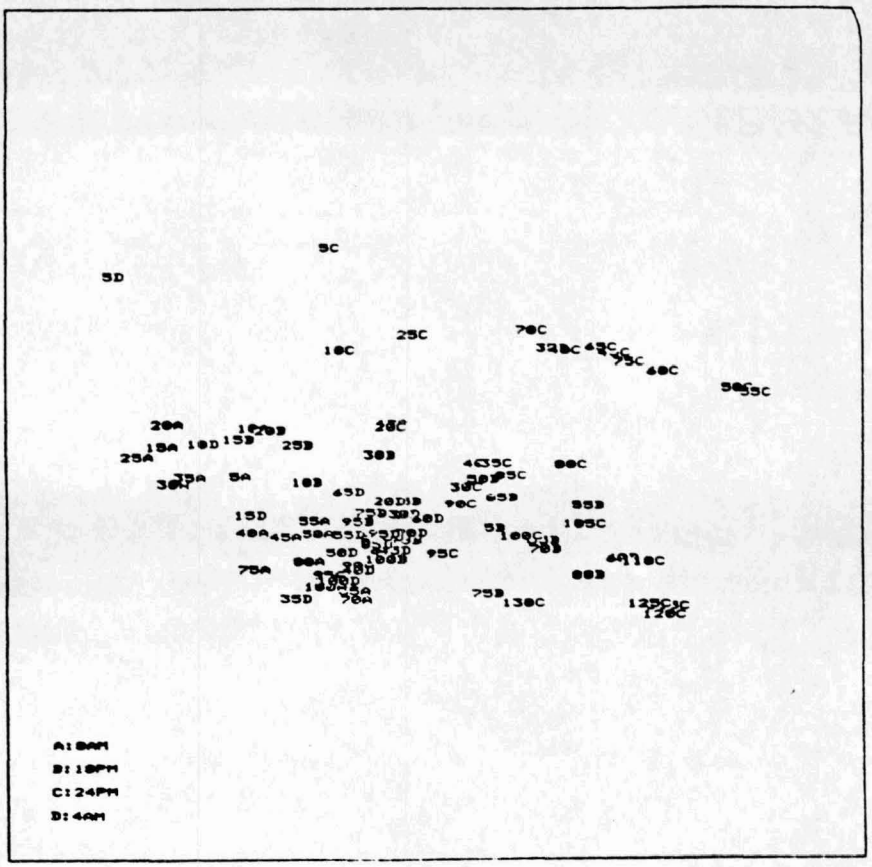


Fig. 8

DEPTH-TIME MICROZOOPLANKTON IN LA CORUÑA



SARDINE ABUNDANCE

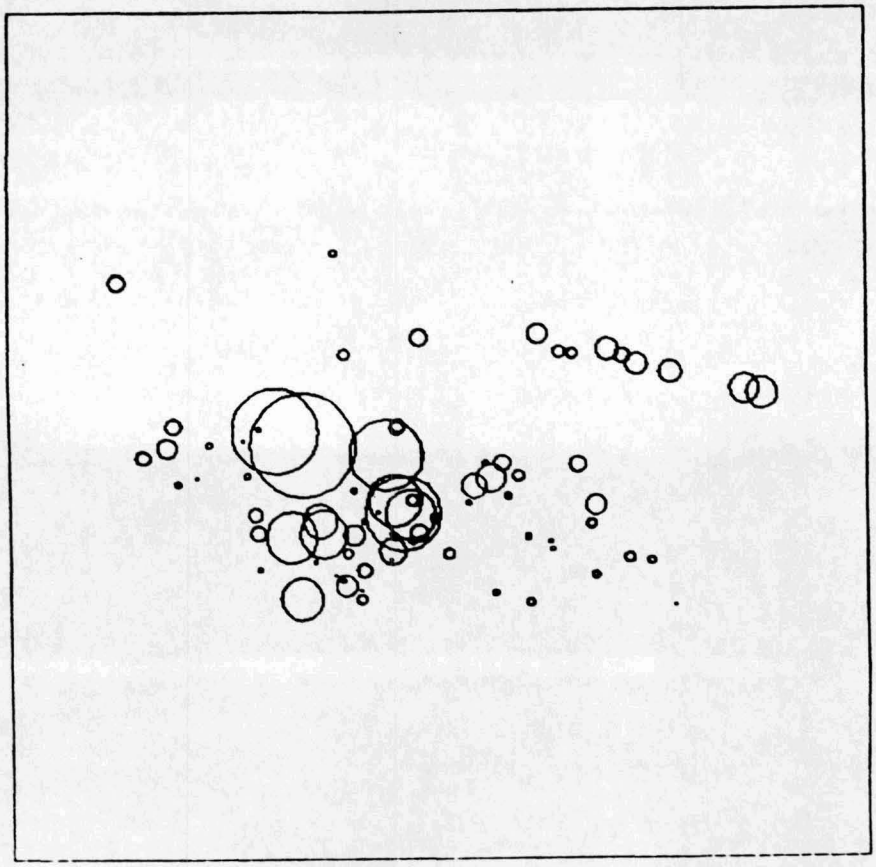
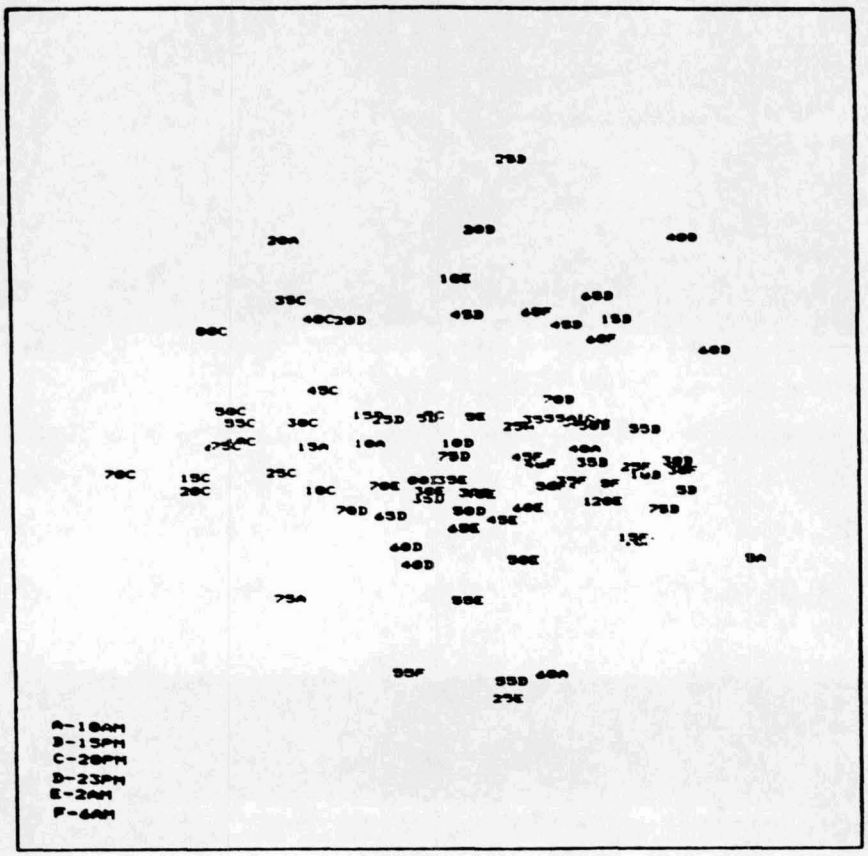


Fig. 9

DEPTH-TIME MICROZOOPLANKTON IN SANTANDER



SARDINE ABUNDANCE IN SANTANDER

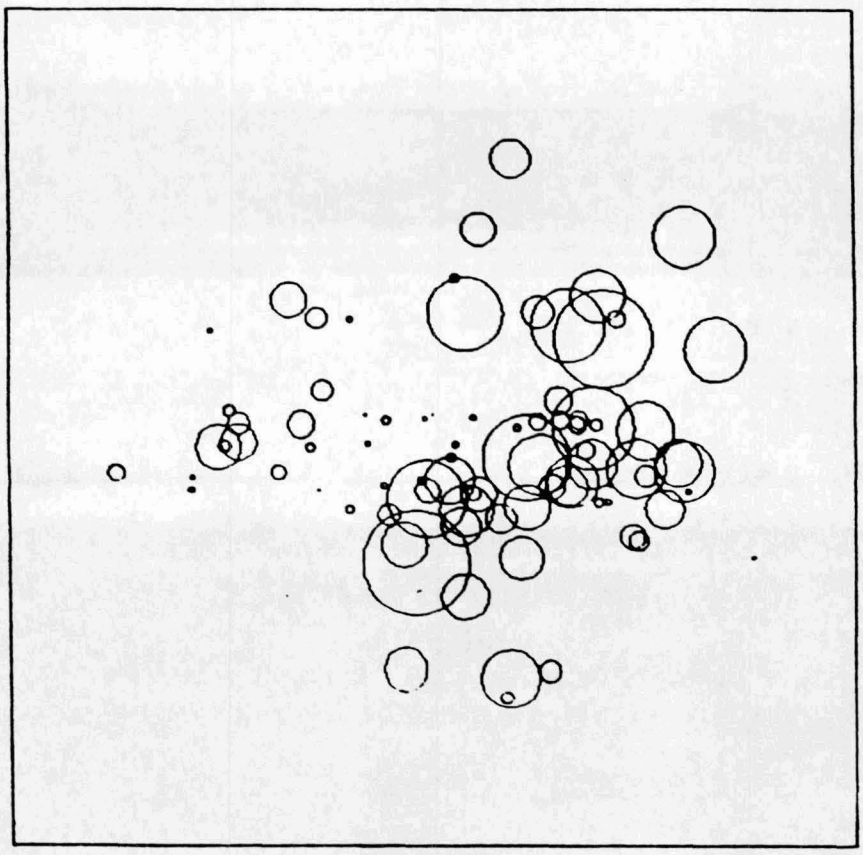
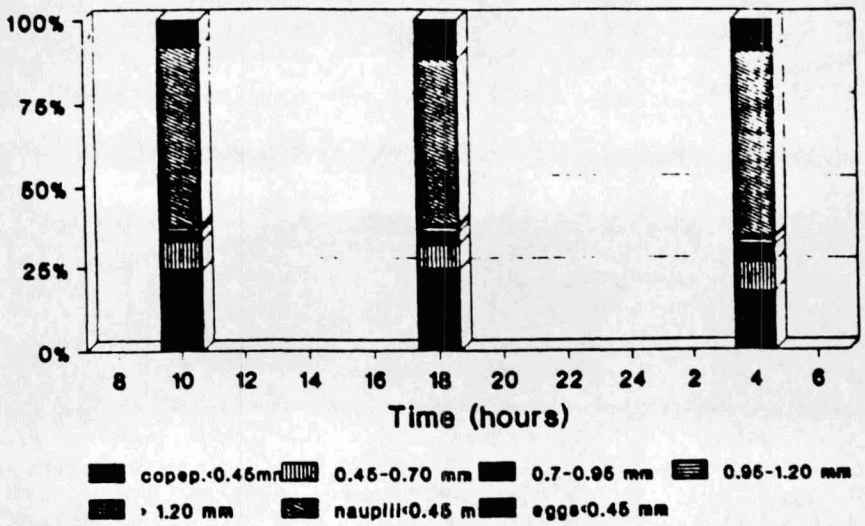
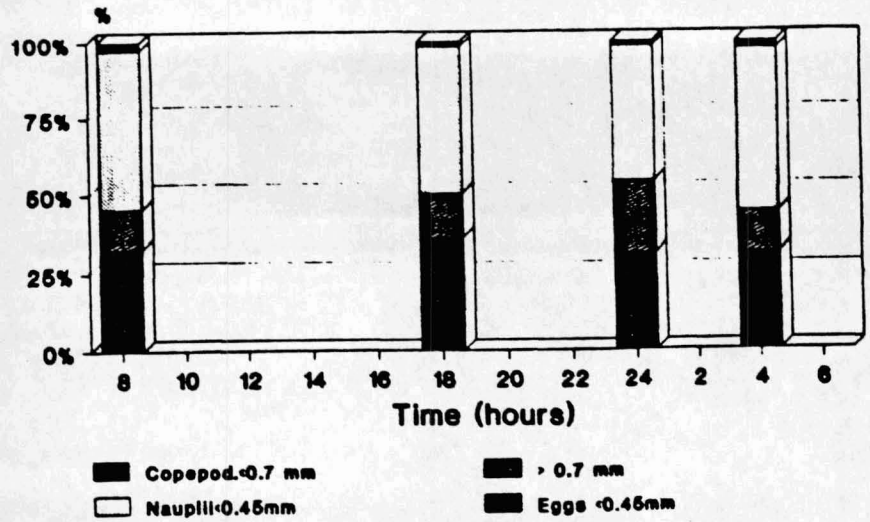


Fig. 10

Diel variation of Copepods abundance
Gijon (St.1)



Diel variation of Copepods abundance
La Coruña (St. 2)



Santander (St. 3)

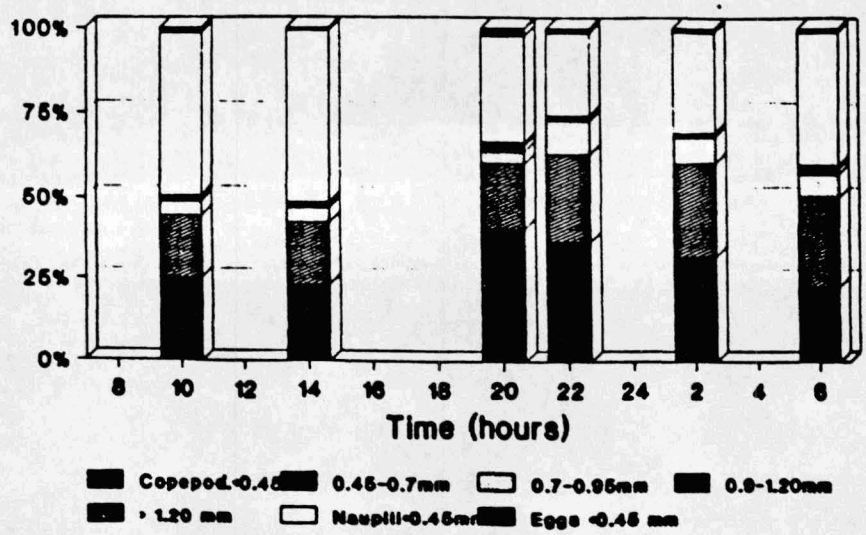


Fig. 11