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SHORT-TERM VARIABILITY OF SARDINELLA AURITA AGGREGATION AND CONSEQUENCIES ON ACOUSTIC SURVEY RESULTS

by

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ABSTRACT

A single fish assemblage of Sardinella aurita was tracked over 24 hours by a research vessel equipped with acoustic devices in order to study the short-term variability of its distribution pattern in the Gulf of Cariaco (Venezuela).

Obviously the studied assemblage did not follow the usually observed aggregation pattern, considered to depend mainly on the light intensity. Nor did the mean depth of the biomass correspond exactly to the usual diurnal cycle pattern. Dense schools were observed during the first night in absence of moonlight; they dove from 15 to 35 m depth in the morning, but came back close to the surface (19 m) early in the afternoon and remained dense during the following night.

Furthermore the fish assemblage apparently presented a contagious structure most of the time, with an increasing density from the periphery (dispersed fish and/or small schools) to the center (large schools or aggregation).

Practical conclusions are drawn from these observations, specifically on the survey design (oversampling strategy on densest areas) and on the data analysis (inaccuracy of the night/day data split in some cases).

I. INTRODUCTION

The distribution pattern of coastal pelagic species, and especially of clupeoids, is usually documented as: deep schools regrouped in concentrations during the day, and surface layers during the night (Woodhead, 1966). Such a pattern, combined with the different avoidance behaviours observed between day and night periods, is generally one of the main reasons alleged to explain night-day differences in biomass estimates. Nevertheless, during acoustic survey this usual distribution is not always observed, and the relationship between the different distribution modes (school, layer, concentration) is not always clear, nor are the factors governing the changes observed in the structures.

Interpretation of the usual acoustic survey data when dealing with this topic is not easy because it is difficult to distinguish temporal effects from the spatial ones. In order to overcome this difficulty, we tried to follow the same fish assemblage during 24 hours, as did Buerkle (1986) on the Nova Scotia herring stock. The objectives of the study were:

- try to find any objective acoustic criterium allowing classification of the echos into different categories (schools, concentrations, layers, dispersed fish),

- following the nycthemeral evolution of the distribution pattern, in terms of aggregation mode and depth,

- in conclusion, infer from these observations some practical conclusions about the survey design.

II. MATERIALS AND METHODS

In order to facilitate the localisation and the tracking of the aggregation, a rich, confined and well-known area was selected for the study (Gines and Gerlotto, 1988): the Gulf of Cariaco (Venezuela), a 30x8 n.m. area, open to the sea by a relatively narrow mouth and having steep edges and a 50 m mean depth (fig. 1). On 26th and 27th November 1988, a preliminary 24 hour survey of the whole Gulf located the richest zone. Then a 1.5x3.5 n.m. rectangular track, located in the middle of this zone was performed 13 times from the 27th at 10:00 pm to the 28th at 11:00 pm. According to the apparent horizontal migration of fish (corresponding to similar previous observations) this rectangle was shifted four times to the south-west and once to the east during the study, as shown in figure 2.

The R/V La Salle (120 feet) was used for the survey, at a speed of 6.5 knots. A Simrad EY-M 70 kHz echo-sounder was connected to AGENOR, a digital echo-integrator. The integrator data were sent to a computer for automatic storage. A digital audio tape recorder was used for recording the sounder signal (DAT Sony). The transducer was fixed lateraly to the hull. A 3 mn time interval and 10 vertical layers (2-5 m; 5-10 m; 10-15 m; 15-20 m; 20-30 m; 30-40 m; 40-50 m; 50-60 m; 60-70 m; 70-80 m) were used for integration and a 50 mv threshold was retained. AGENOR provided the number of samples above the threshold per layer inside each ESDU, which allowed computation of the density by sample above the threshold (DSAT) as described by Marchal (1988).

No fishing operations were conducted during the survey, but according to the commercial landings and to the echogram characteristics, the bulk of the biomass consisted of small *Sardinella aurita* (fork length: 12 cm), while the scattered bottom targets were recognized as catfish (*Bagre marinus*; 15 to 20 cm f.l.).

The detection was classified in six groups according to the echogram analysis: dispersed pelagic fishes, dispersed catfishes, pelagic layers, small schools with clear limits, large concentrations with uncertain limits, plankton. Most of the time, only one dominant group was observed by stratum (i.e. a 3 mn interval in one layer). Only on four occasions were two important groups of detection observed in the same stratum and the corresponding density was arbitrarily split in two equal parts.

III. RESULTS AND DISCUSSION

Echograms classification

In order to check the statistical significance of the echogram classification, the mean DSATs of dispersed fish, schools and concentrations were compared. These means are significantly different ($p = .05$), before and after logarithmic transformation (table 1).

However, the three distributions show important overlaps, especially schools and concentrations, suggesting that these two structures have the same internal density most of the time and differ mostly in size and shape. Nevertheless a more detailed analysis must be carried on from recorded signal, because DSAT is dependant on the threshold retained, on the depth (Marchal, 1988) and on the ESDU length. Other objective criteria characterizing the dimensions an density of the detection could also be used (Azzali, 1982; Rose et Legget, 1988; Souid, 1988). Nevertheless a more detailed analysis must be carried on from recorded signal, because DSAT is dependent on the threshold retained, on the depth (Marchal, 1988) and on the ESDU length. Other objective criteria characterizing the dimension and density of the detection could also be used (Azzali, 1982; Rose and Legget, 1988; Souid, 1988).

Log DSAT for:	Dispersed	Concentration	School
Sample size	743	194	141
Average	-0.835	1.28	1.57
Standard deviation	1.198	0.84	1.12
Minimum	-2.878	0.008	0.01
Maximum	4.280	3.719	4.08
Skewness	0.980	0.480	0.57
Kurtosis	0.823	-0.523	-0.71

DSAT for:	Dispersed	Concentration	School
Sample size	743	194	141
Average	1.202	5.26	9.52
Minimum	0.056	1.00	1.00
Maximum	72.2667	41.21	59.08

Table 1: Summary statistics of the Densities per Sample Above the Threshold (DSAT) for dispersed fish, concentrations and schools (crude and log-transformed data).

Biomass distribution

The bulk of the biomass (89%) was detected above 50 meters depth, and was represented mostly by concentrations and schools, and secondarily by dispersed sardines, except at the beginning and at the end of the survey where typical deep anchovy layers were observed. The biomass detected in the deepest layers (over 50 m) was clearly separated from that in the upper ones and represented 99% of the total after removing that of the anchovies and catfishes. Moreover no significant exchanges between the deepest layers and the upper ones seemed to occur. Therefore, only the first 7 layers are considered in this paper.

All the high densities were first observed close to the South-west corner, then on the South-east corner as well, along a 1.5 to 3 n.m. distance. An increase of the mean surface density by rectangle was observed during the study (fig. 3).

Short-term evolution of the distribution pattern

The mean depth of the biomass increased from 17 to 35 meters during the first part of the day, decreased in the afternoon, then remained more or less stable at 19 meters (fig. 4).

The dispersed fish were only important during the first part of the first night, while the schools and the concentration represented the bulk of the biomass (fig. 5). Surprisingly the schools were only predominant during the morning and were responsible for the increase of the mean biomass depth. No apparent nyctemeral cycle appears in the time-plots of depth or density, and the moonlight variation does not explain this result.

The usual figure (dispersed at night and in school at day) was only applicable during the first half of the study. From rectangle #6 (9:00 am) a typical macro-structure was observed which remained more or less the same up to the end of the observation (10:00 pm): a large central concentration surrounded by schools and/or by dispersed fish (figs. 6a and 6b). This typical structure was sometimes uncomplete on one side (fig. 6c).

The increase of the total biomass detected by rectangle (fig. 3) can be explained by two factors. Firstly, an increase of the number (one then two) of macro-structure cross-sections by rectangle, and secondly, by a slight increase of the internal density of these detections, especially during the second part of the study. In order to give a more realistic figure of the changes in the aggregative structure, the data have also been split into macro-structure cross-sections in figures 7 and 8. The number of single macro-structures observed remain uncertain (one large or two small), but does not seem essential owing to the similarity of the echograms.

A progressive shift in the position of the cross-sections during the study (fig. 9) may partially explain the observed changes in the echograms and mean densities (figs. 3 and 8). The localisation of the nucleus of the macro-structure along the survey would explain the predominance of dispersed fish at the beginning of the study, then of schools and, finally, of concentration.

It remains clear that other experiments are necessary to validate the reliability of this distribution, and to determine its limits of application (fish size, species, area, season, etc). A first element of confirmation is yet available. The day following this study, we studied the internal structure of the main concentration and observed the same echogram pattern. From 5:30 pm to 11:00 pm we repeated the rectangle experiment in order to verify if schools and concentration were still present as on 27th, or absent as on 26th at the beginning of our first study. We found similar structures to those observed on 27th (fig. 10). Nevertheless the increasing tendency of the mean density by rectangle was observed one more time, suggesting that some changes in the aggregation mode occured.

CONCLUSION

Obviously the observed macro-structure did not follow the normally observed aggregation pattern. Even though our experimental survey design did not completely overcome the problem of distinguishing between spatial and temporal effects, it seems that during this particular observation, the aggregative behaviour was not completely dependent on the light intensity. Possibly it was governed by a longer time period of evolution. Nor did the mean depth of the biomass correspond completely to the usual nycthemeral pattern (see Woodhead (1966) for similar examples). These observations suggest that the usual split of acoustic survey data in day-time and night-time series before processing could be done using criteria other than day and night periods.

The well-documented contagious structure of fish distribution was again confirmed, and the increasing density of the macro-structure, from the periphery to the center, is an additional argument in favor of over-sampling the areas of highest density located during a routine survey (Gerlotto, this meeting). Such an oversampling methodology must be carefully designed in order to avoid overestimation if the area assigned to the nucleus is overestimated, or under estimations if the dense nucleus is not found. Owing to the usual inversed binomial distribution of the density, it must be noted that the magnitude of an overestimation of the biomass would be much more important than the magnitude of an underestimation.

Even though the preliminary survey covered the entire Gulf twice, by day and by night, using a 5 n.m. inter-transect distance, the highest densities per ESDU were much lower than those observed during the rectangle experiment. The data are not completely evaluated but it is obvious that the total biomass estimated through this preliminary survey for the whole Gulf is lower than the biomass estimated inside one of the last rectangles. This confirms the necessity of over-sampling around the highest detection after a preliminary survey in this area.

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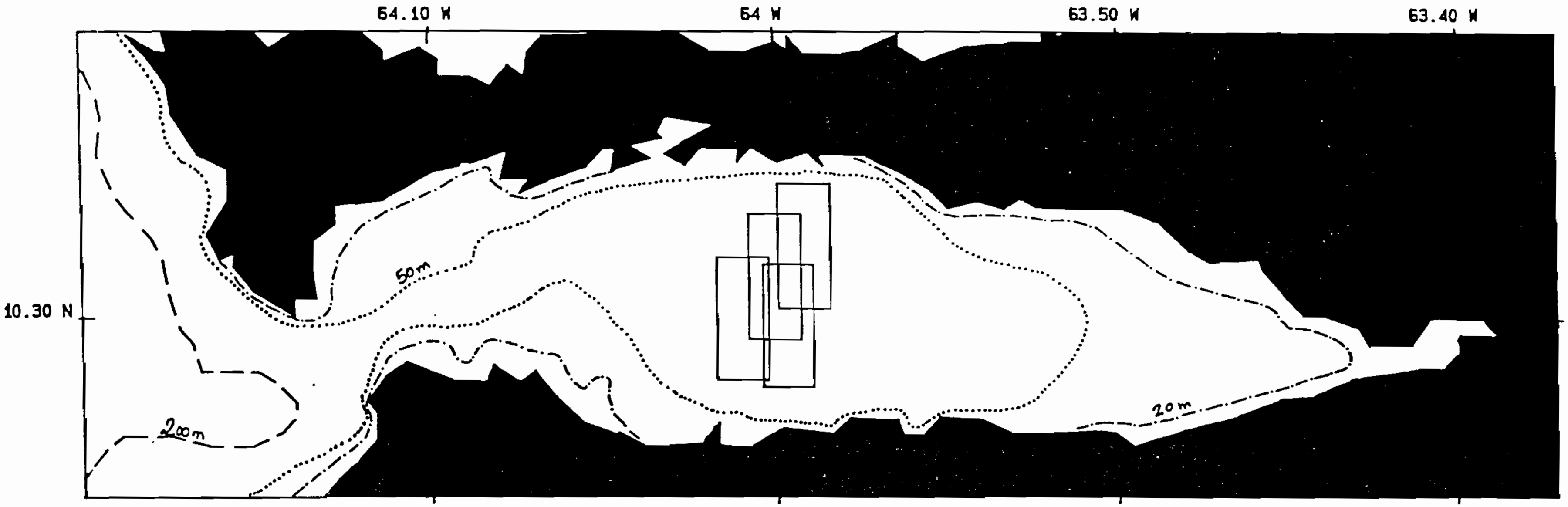


Fig. 1. Gulf of Cariaco (Eastern Venezuela): position of some rectangular tracks performed by the R/V LA SALLE

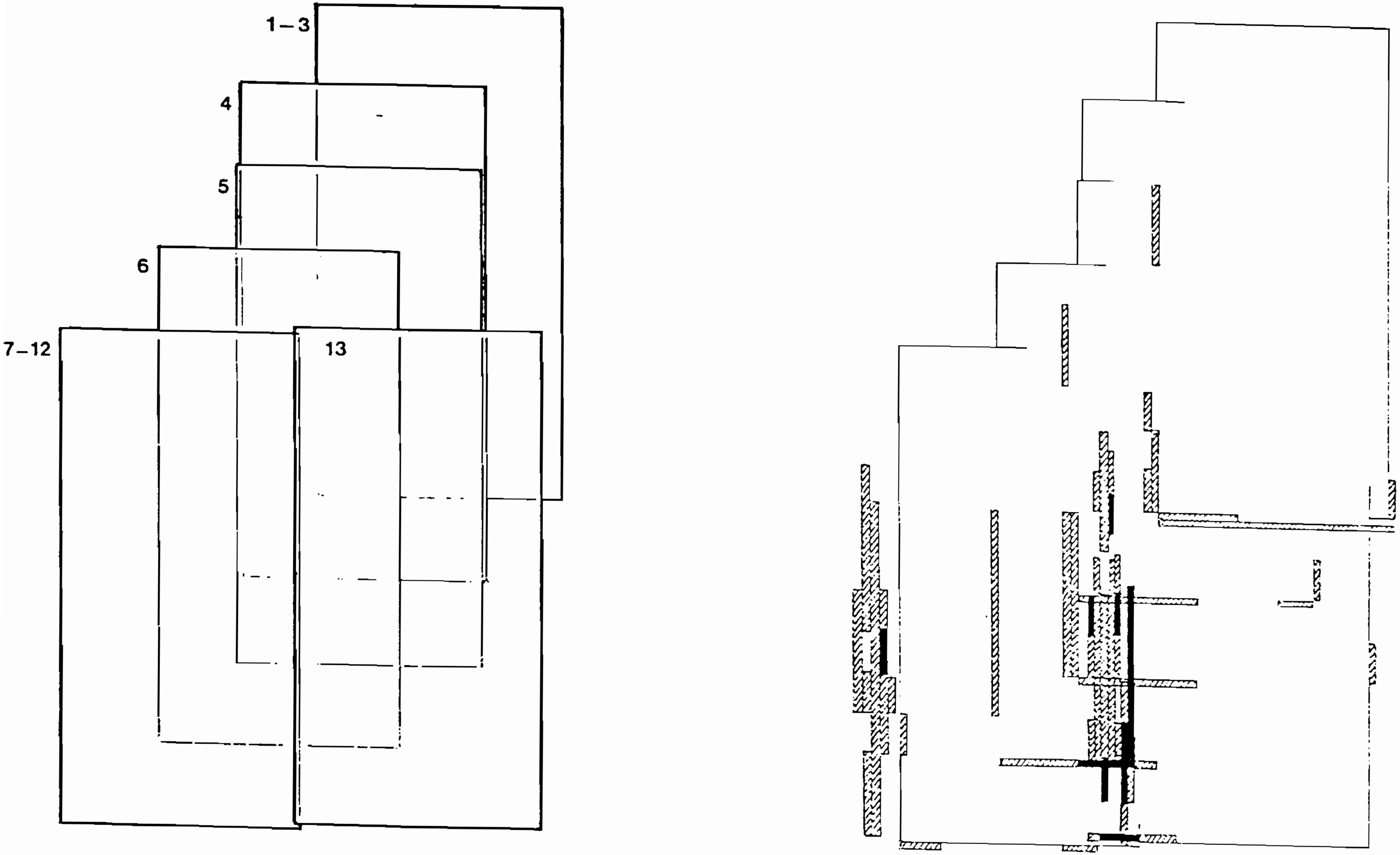


Fig. 2a. Successive positions of the rectangular tracks performed by the vessel (from 1 to 13).
2b. Location of the highest surface densities (SD):
▬ SD ≥ 10^5 ▨ SD < 10^5

Fig 3. Evolution of the surface density from rectangle 1 to 13

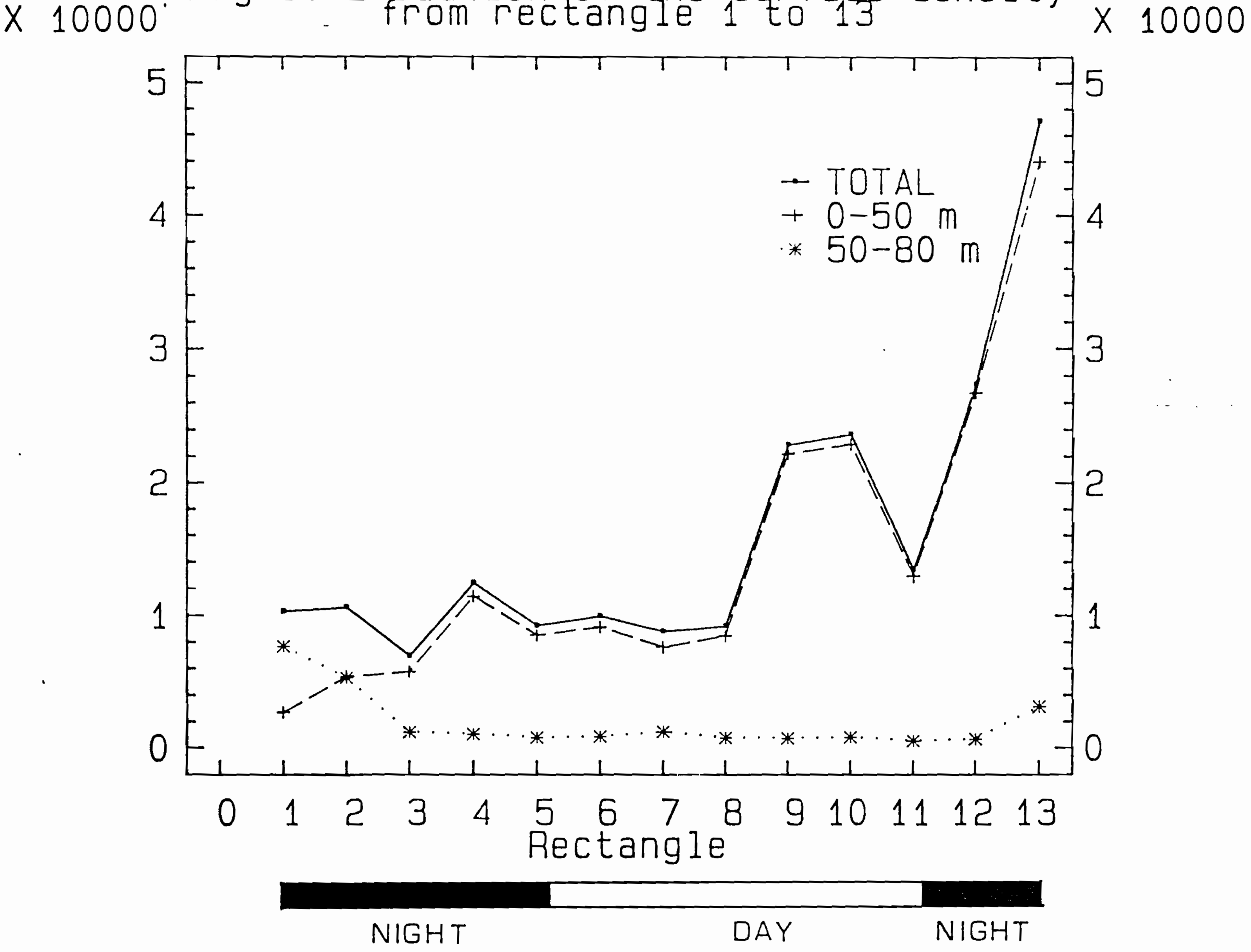


Fig 4. Mean depth of the detections from rectangle 1 to 13

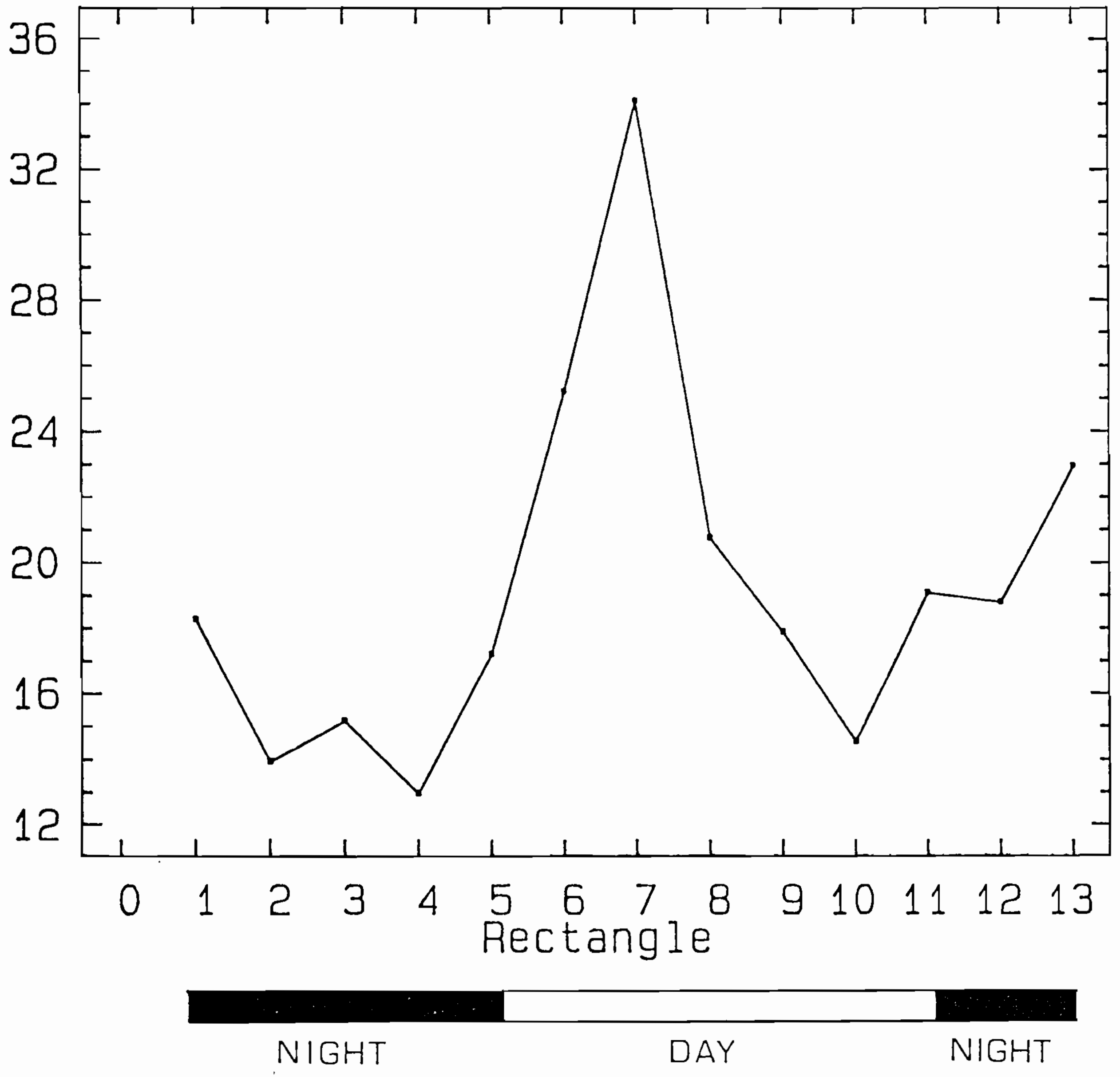
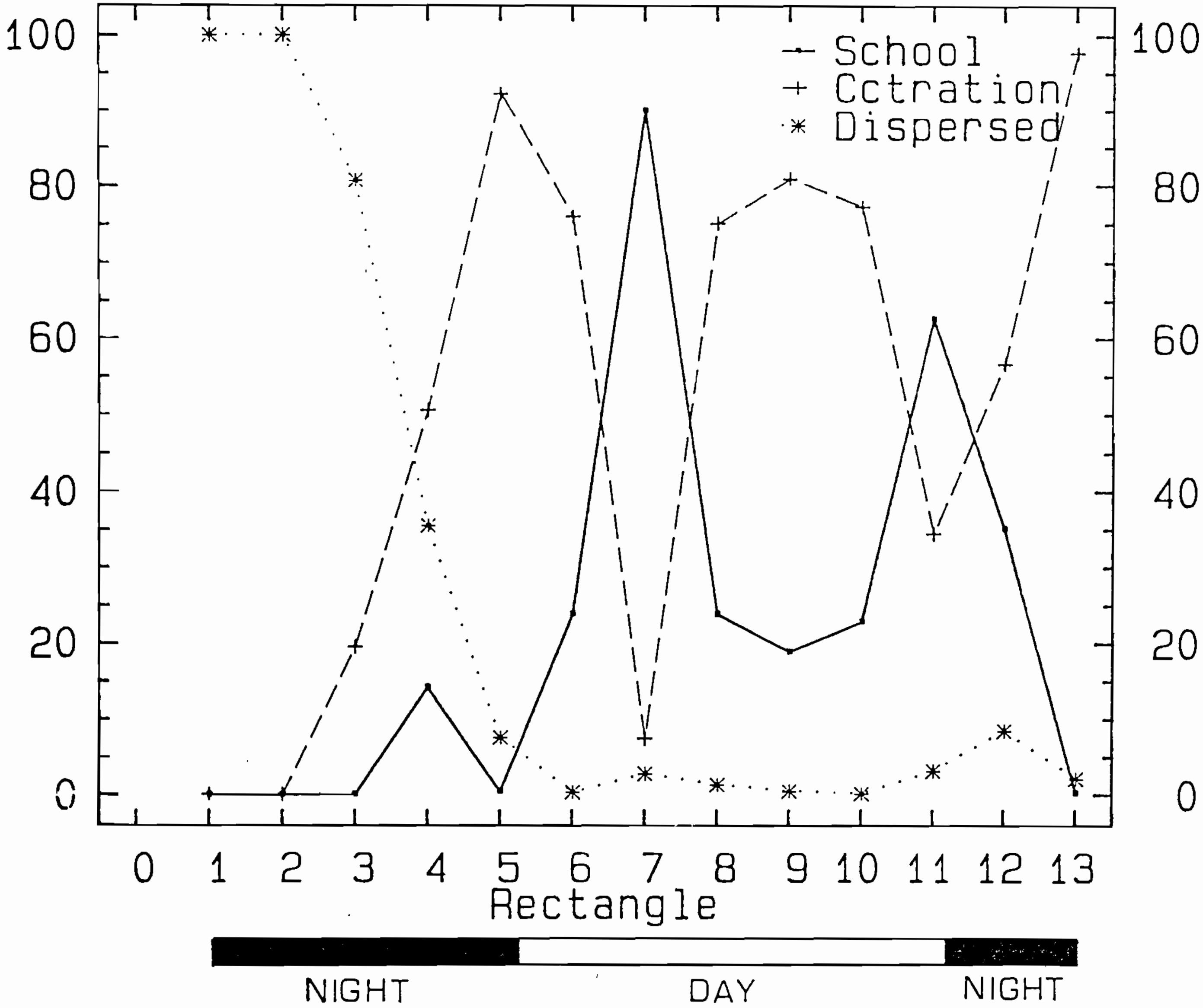


Fig 5. Proportions of dipersed fish, schools and concentrations. Rect 1-13



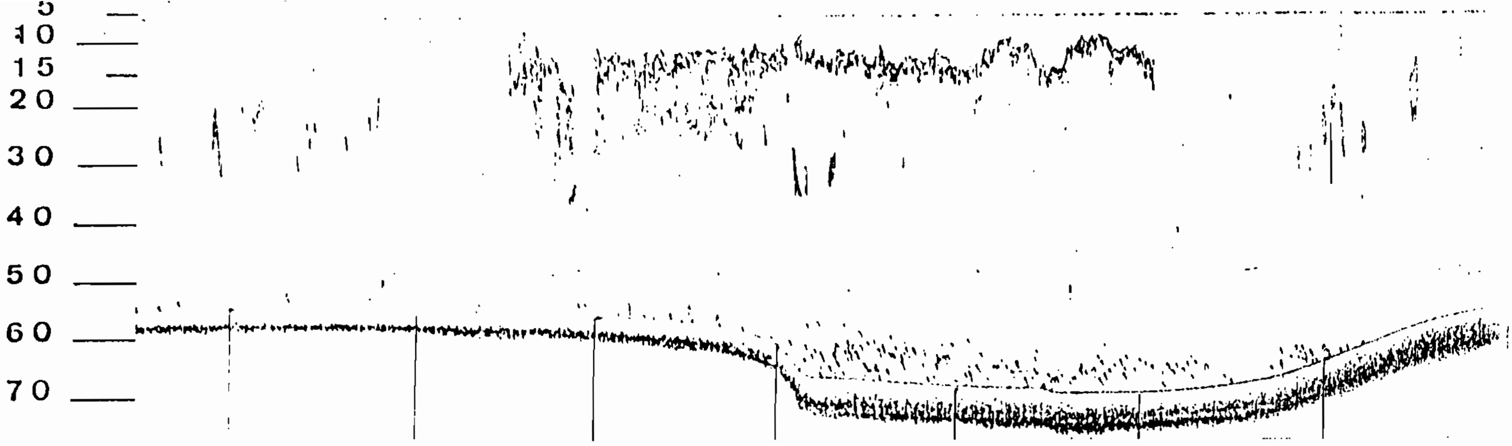


Fig 6a: Concentration surrounded by schools.

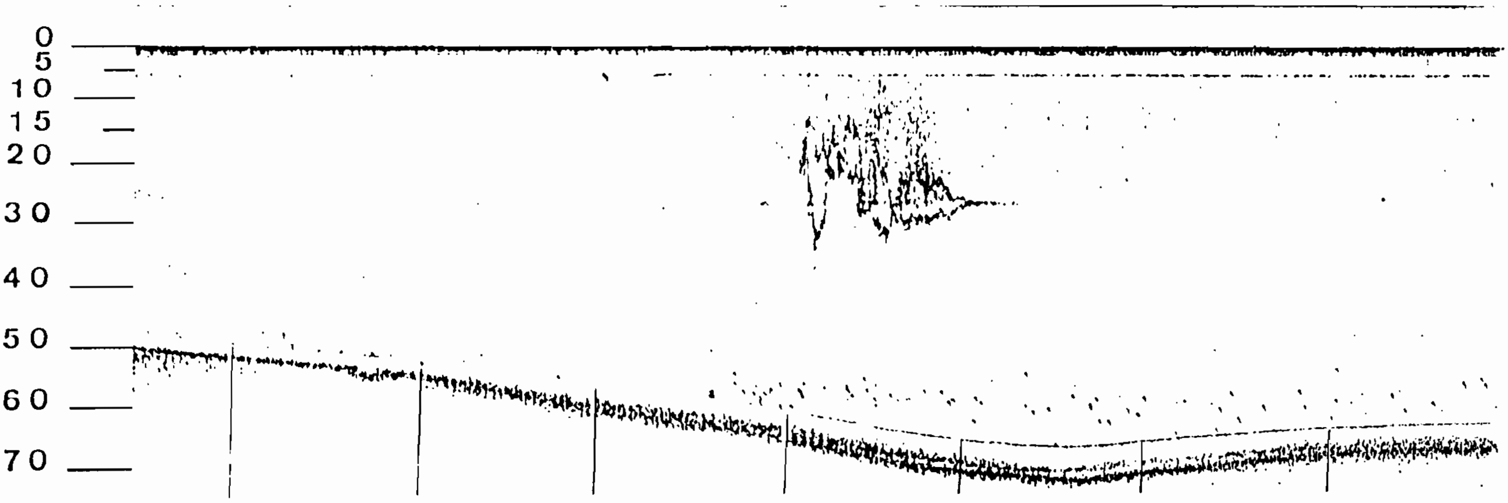


Fig 6b: Concentration surrounded by dispersed fish.

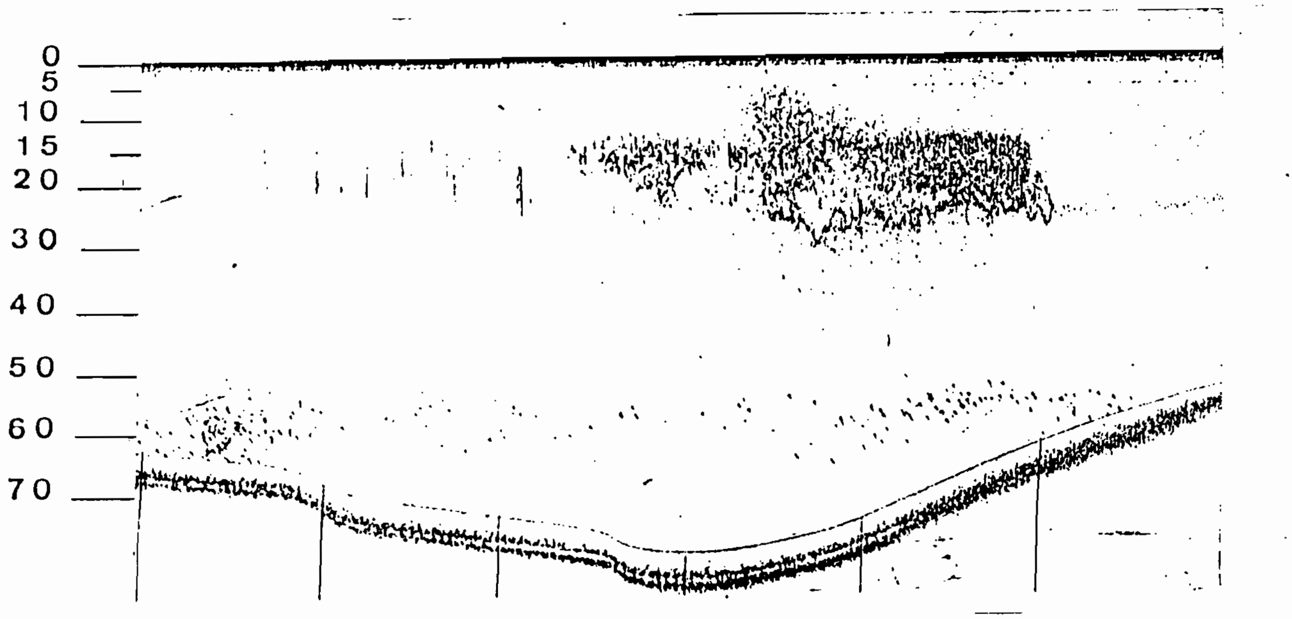


Fig 6c: Concentration with dispersed fish and schools on one side

Fig 7: Biomass from Macro-structure 1 to 21

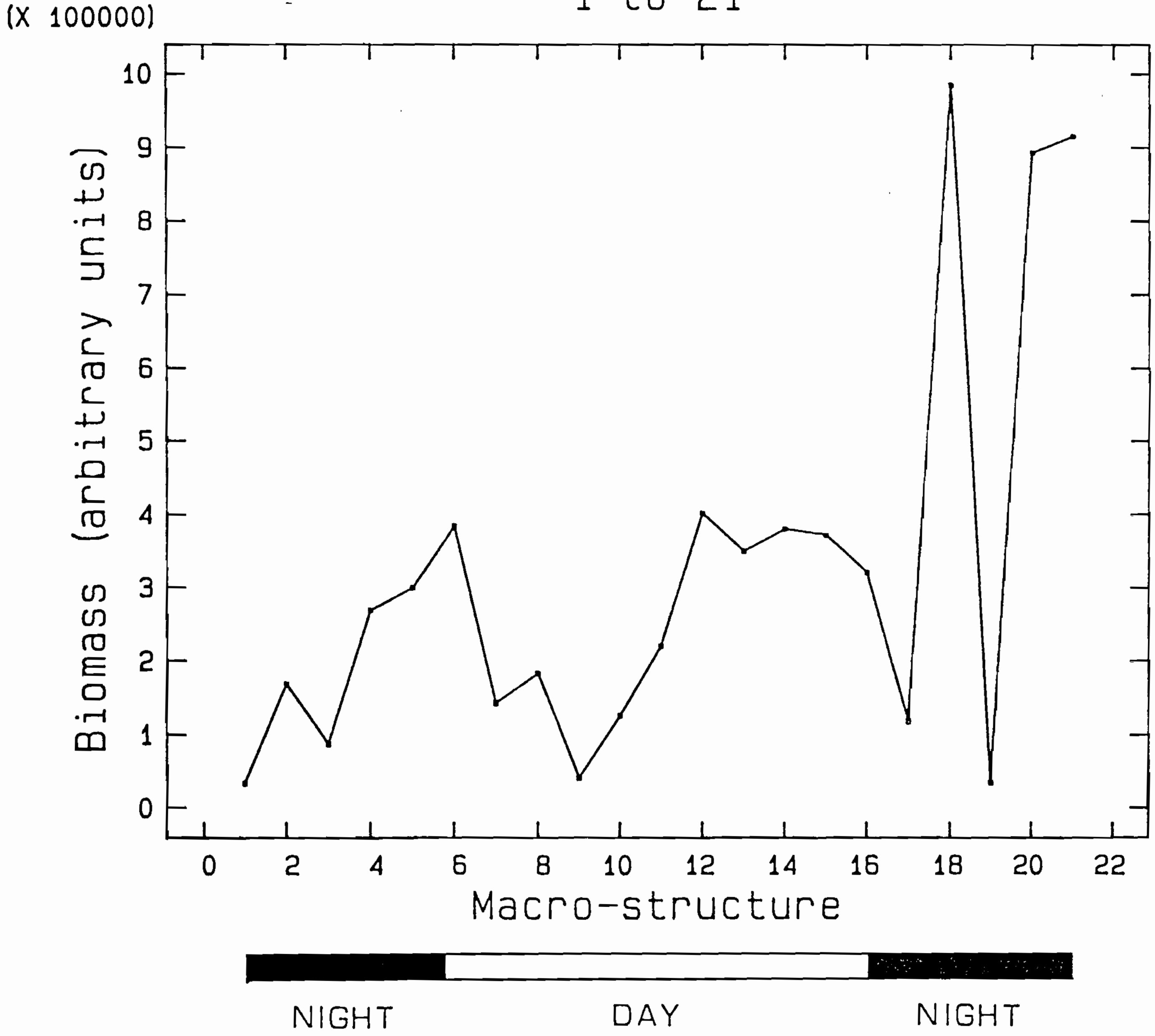
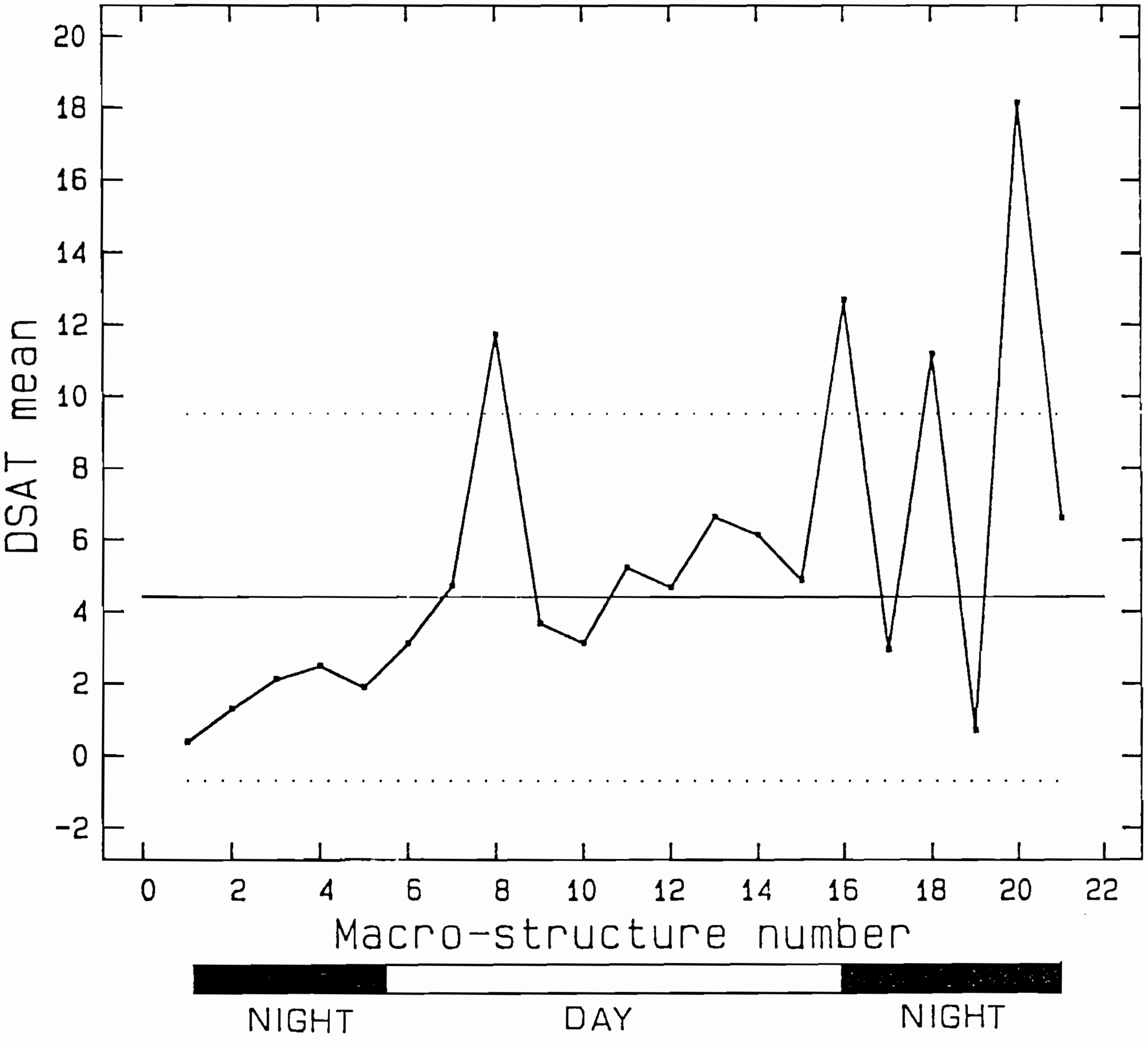


Fig. 8: Density by Sample Above the Threshold from macro-structure 1 to 21



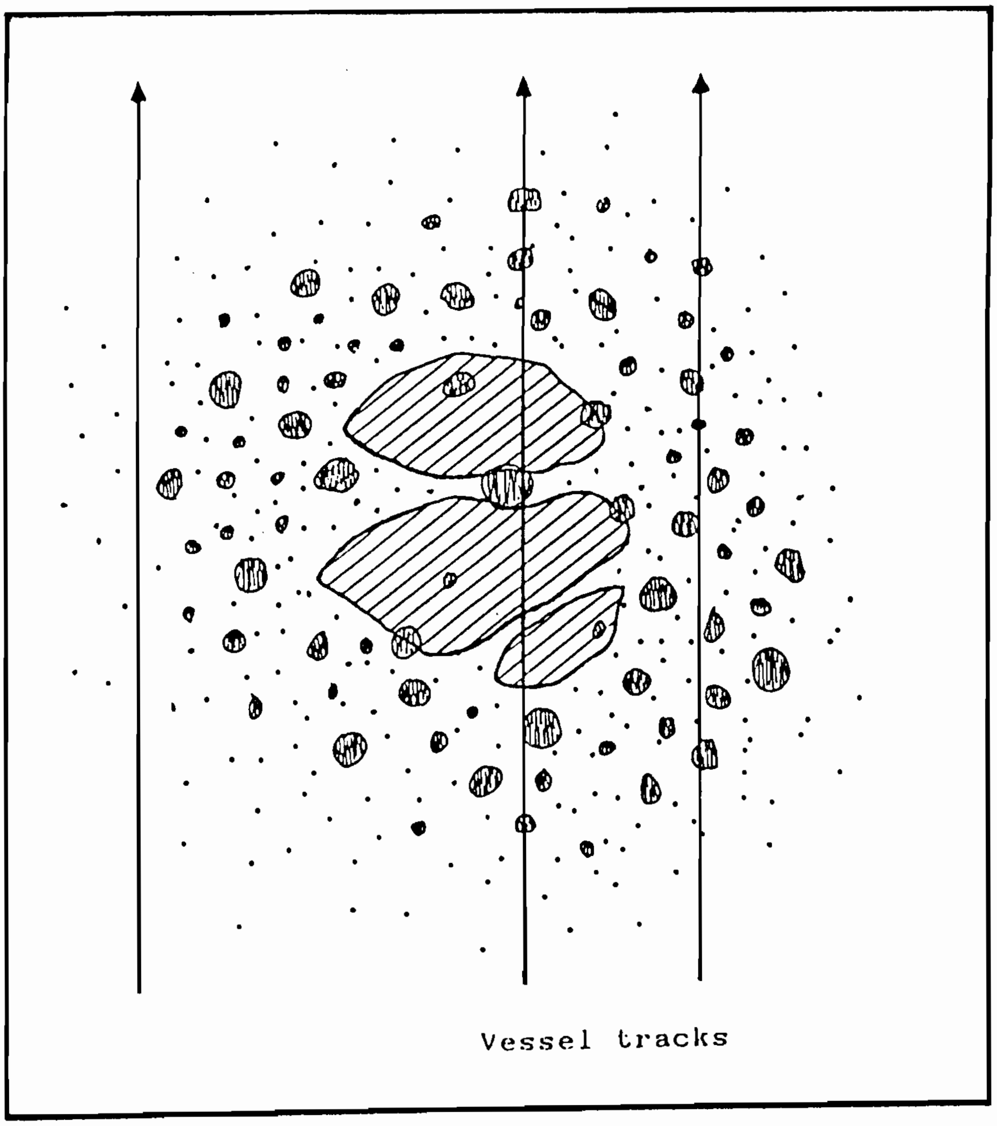


Fig. 9 Schematic representation of a macrostructure as observed through 3 different cross sections by the vessel.

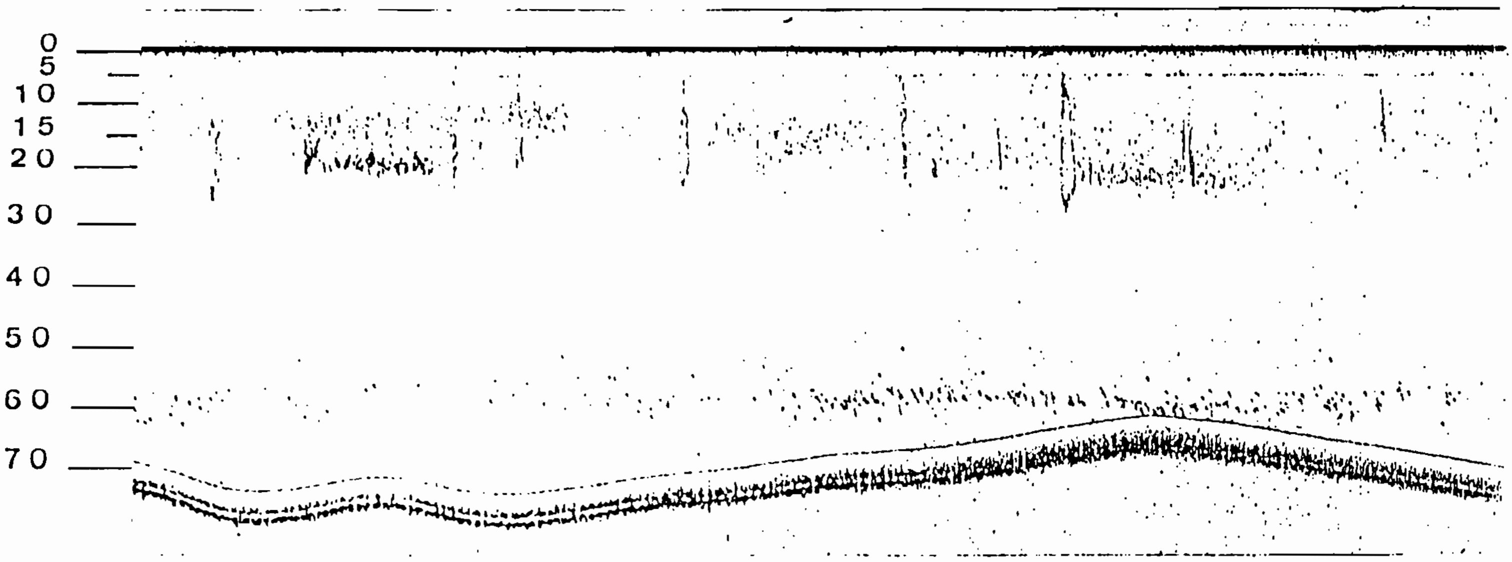


Fig 10a: 2nd Experience: NOV 29. 7H30 PM. Dense schools observed by night.

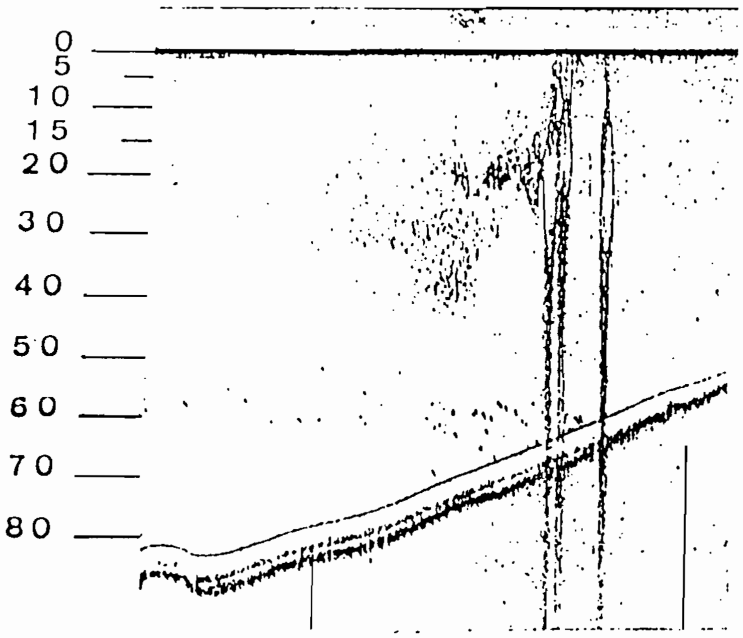


Fig 10b: 2nd Experience: NOV 29. 9H00 PM. Dense schools observed by night.