WORKING PAPER SERIES

FISHERIES STOCK ASSESSMENT

TITLE XII
Collaborative Research Support Program

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The University of Maryland, College Park, Maryland 20742

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The University of Rhode Island—International Center for Marine Resource Development
The University of Washington—Center for Quantitative Sciences
The University of Costa Rica—Centro de Investigación en Ciencias del Mar y Limnología
The University of the Philippines—Marine Science Institute (Diliman)—College of Fisheries (Visayas)

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WORKING PAPER SERIES

Working Paper No. 59

SPATIO-TEMPORAL VARIATIONS IN COMMUNITY STRUCTURE ON A HEAVILY FISHED SLOPE IN BOLINAO, PHILIPPINES

by

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ABSTRACT

An analysis of variations in community structure along a heavily fished forereef slope in the Philippines indicates that depth and heterogeneity at the 1 and 10 cm scales were dominant structuring factors. Bottom temperature also appeared to be influential but its effect was difficult to isolate from other factors related to depth. Comparisons of individual time slices of data taken 8 times on alternate months indicate that conclusions based on single sampling periods may be misleading. Groupings of the eighteen sites differed substantially between sample periods, such that no two sites grouped together consistently throughout the study.

INTRODUCTION

A substantial number of studies have been conducted on the community structure of tropical marine fishes (Longhurst and Pauly 1987). However, very few have involved repetitive samplings. Analyses of research trawl data covering 16 months in the Samar Sea have indicated that a consistent difference exists in demersal fish assemblages that are captured above and below a bathymetric region of 30-40m (McManus 1986). Other boundaries identified by divisive site clustering tended to vary erratically over time, and could easily have been misleadingly over-interpreted if analyzed from only a single set of data.

It is difficult to predict what the situation is in coral reef fish communities. Coral reefs tend to be highly stratified, with specific groups of fish being strongly identified with certain features of geomorphometry or bottom cover (Goldman and Talbot 1976). On the other hand, larval settlement and recruitment are known to vary substantially, both annually and seasonally (Munro and Williams 1985). It is important to investigate the variability at a number of scales to determine the degree to which coral reef fish communities are predictable, and ultimately to investigate the degree to which catch composition can be managed. The present study represents a preliminary step in this direction. The data represents 8 samplings on alternate months along a heavily fished forereef slope, and is directed at the questions 1) Is the analysis of site groupings based on a single survey predictive on a scale of several months?, and 2) What environmental factors most strongly influenced the average pattern of distributions and abundances during this time frame?

MATERIALS AND METHODS

The study was conducted on the forereef slope of Santiago Island, Bolinao, Pangasinan, Philippines. Of the eighteen sites monitored, four sites were located on the upper forereef slope (sites C1, C2, C3 and C4; 2-8 m) and the rest were on the lower forereef slope (8-27 m). The sites were monitored on alternate months from August 1987 to September 1988 by underwater visual census. Two 100 m transect lines were laid in opposite directions parallel to the shore in order to reduce depth variation. However, the transects did not follow depth contours. Each of four divers counted and identified fish to the species level which fell within a width (and height) of 5 meters from a transect line. Thus, a total bottom area of 2,000 m^2 was surveyed per site. During the first month, only 13 sites were monitored. Sites C3, C4, S4, S10A and S10B were added in the succeeding months.

Environmental factors monitored during each survey include depth, bottom temperature and salinity. The heterogeneity of each site was characterized nonrepetitively by measuring a horizontal distance at one scale, and measuring the same distance using a "stick" of smaller length as a series of tangents to the bottom. Objects less than 0.05 of the smaller "stick" in height were compensated to horizontal, to avoid the occasional bias which occurred when a stick was forced to a near vertical by a small fulcrum like a coral colony. The heterogeneity indices were then expressed as the ratio of the distance measured at one scale to the distance measured at the scale 10 times longer. This yielded indices at the 1 cm (1 cm in 10 cm), 10 cm (10 cm in 1 m), and 1 m (1 m in 10 m) scales. The 10 m distance involved a tape measure and marking stakes. The 1 cm measurements involved a flat brass chain with links of 1 cm accurate across at least 2 m distance. The other measurements were made with rulers to simulate measurements with a chain of appropriate link size. All measurements were accurate to 0.1 of the smaller "stick". A total of ten measurements at each scale were made at each site, and these were averaged to provide a mean value at each scale for each site. The method is similar to that described in Goldman and Talbot (1976), except that it allows for discrimination of the effects at different scales. It differs from the method used by Bradbury and Reichelt (1983) to measure the fractal index of a reef in that we have measured tangents to the bottom instead of chords through it (using calipers), because of ease of measurement.

Analyses included only the top 150 species, comprising greater than 94% of the total individuals. Three multivariate techniques were used to analyze the data: 1) TWINSPAN (Hill 1979), 2) Canonical Correspondence Analysis (CCA) and 3) Detrended Canonical Correspondence Analysis (DCCA), the latter two being part of the CANOCO program (ter Braak 1988). All three programs were used to analyze the spatial pattern of the community averaged over the eight month period. Additionally, the divisive clustering of TWINSPAN was used to analyze time slices of data from individual sampling periods to reveal bimonthly variation of site groups on maps of the study area. CCA ordinations were made of each time slice, but are omitted here for brevity. Maps were produced from MSS satellite data using supervised clustering successively refined by aerial surveys from an ultralight aircraft.

RESULTS

A total of 746 species comprising 49 families were observed during the study period.

Figure 1 shows that grouping of sites vary from month to month. No two sites were consistently grouped together throughout the study period. Site groups were labeled arbitrarily to show as much continuity between time slices as possible. Figure 2 shows the spatial structure of the community averaged over the eight sampling periods. Clustering was halted at two levels of division, yielding four subgroups. Figure 3a shows that there is no strong correlation between depth and heterogeneity at any of the 3 scales. Greatest heterogeneity was obtained at site C2 for all of the scales used.

Figure 3b represents a CCA ordination of sites with the environmental parameters magnified 3 times. The figure shows that depth was the most important factor in separating the groups that were formed. Temperature appears to be second in importance followed by 10 cm and 1 cm scales, salinity and 1 m scale. The DCCA result was not included because it gave basically the same results as CCA (no detrending). CCA ordinations for each time slice of data revealed that the importance of each structuring factor varied somewhat over time, and the presented results are only meaningful in terms of time-averaged effects.

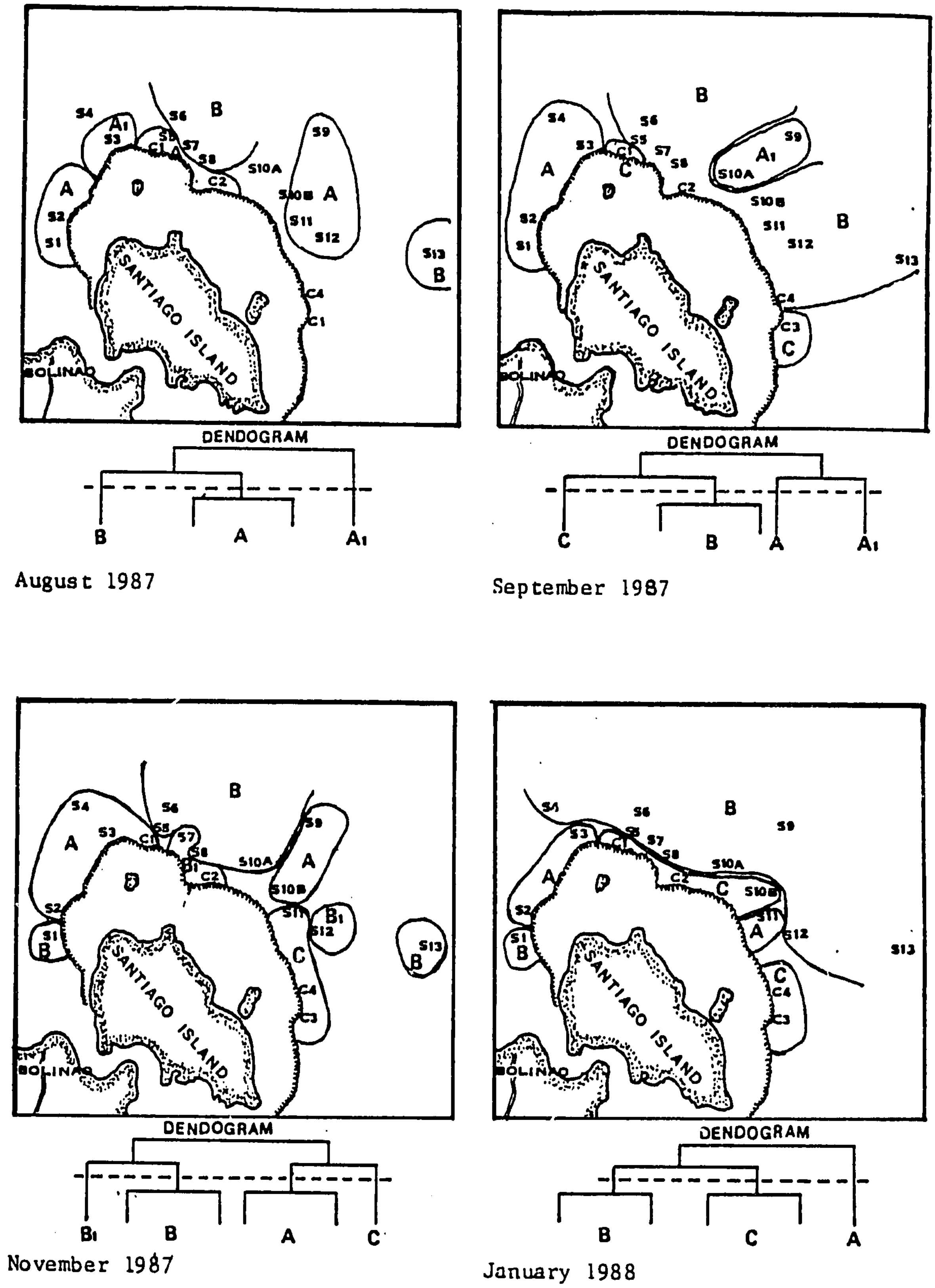
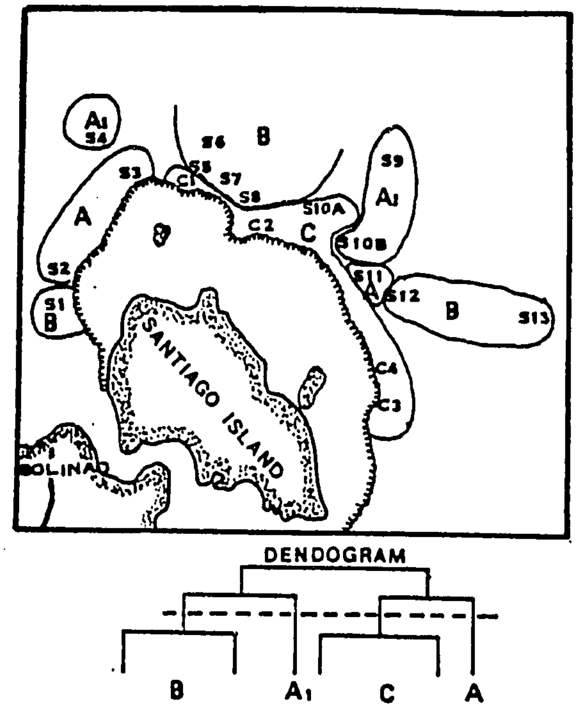


Figure 1. TWINSPAN results of the time slices from August 1987 to September 1988 showing the dendogram and grouping of sites on the forereef slope. Groups were labeled arbitrarily to show as much continuity between the time slices as possible. No data was gathered for the sites C3, C4, S4, and S10B during the month of August 1987.



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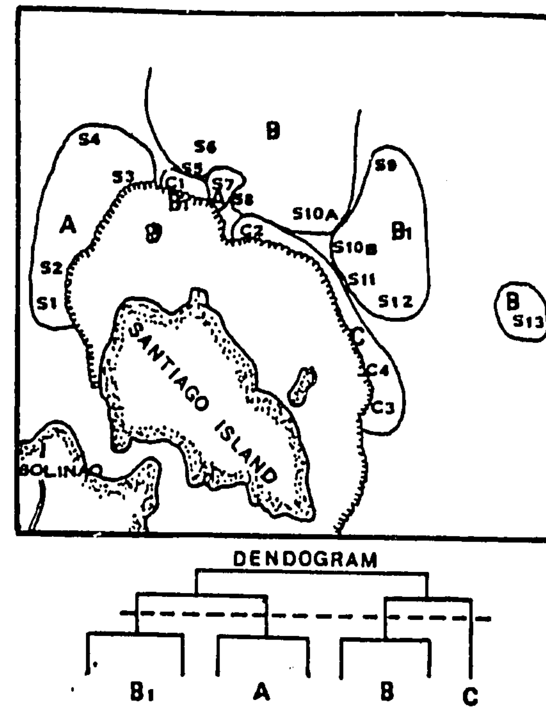

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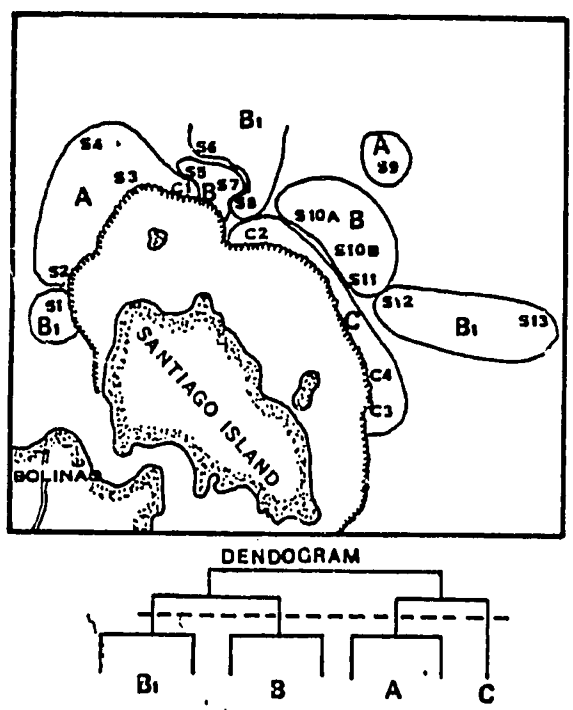

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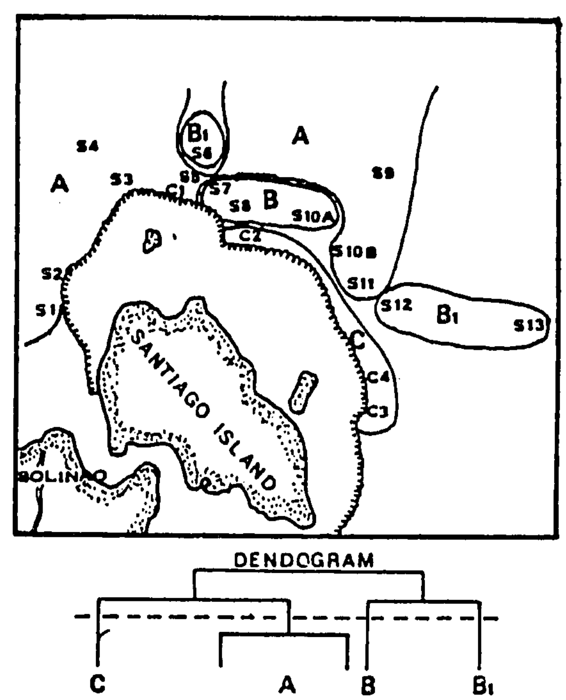

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(Fig.1. cont.)

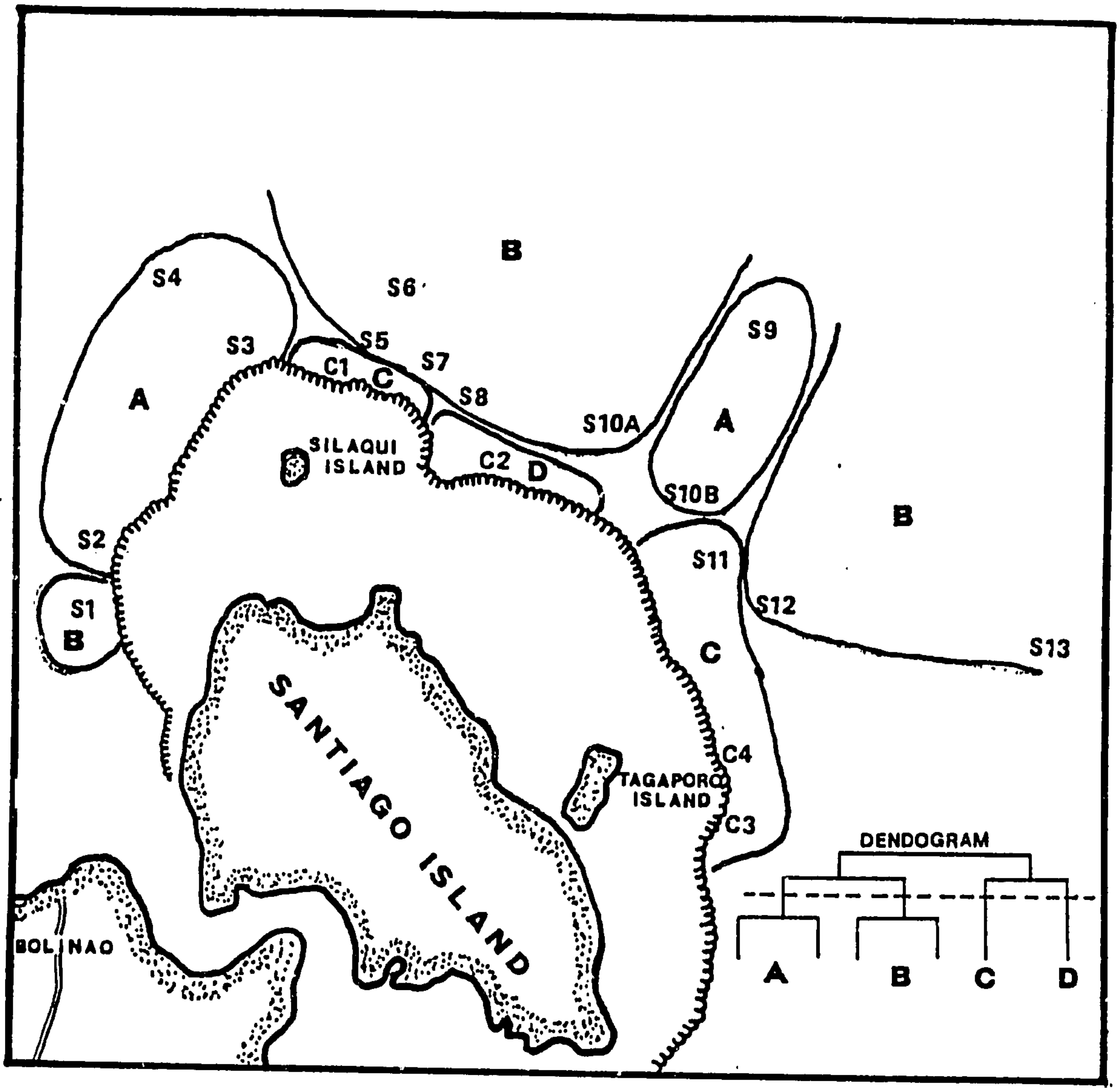

Figure 2. TWINSPAN result for the averaged 8 month period showing the dendogram and the grouping of sites on the forereef slope.

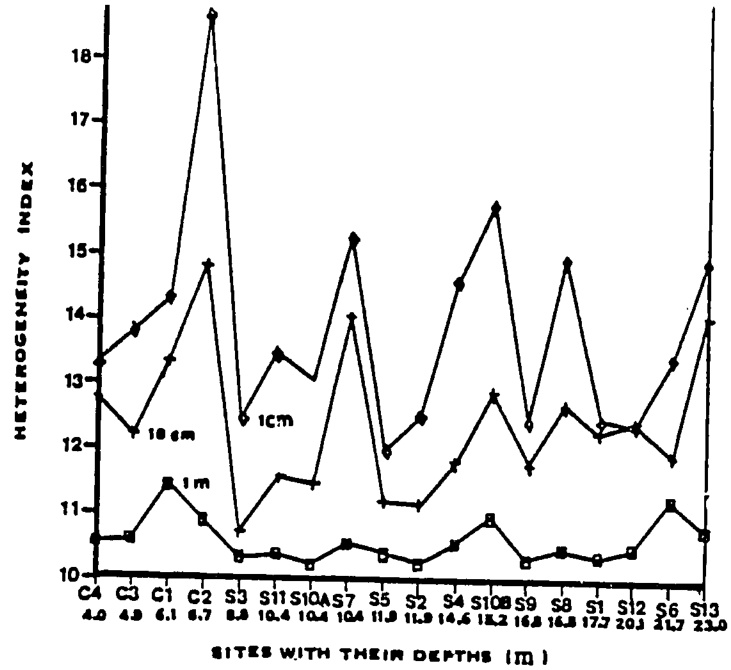

Figure 3a. Index of heterogeneity. Sites are arranged according to increasing average depth in meters. The 3 scales are based on distances obtained with measuring units of various sizes, such that 1 cm = ratio of 1 cm to 10 cm, 10 cm = ratio of 10 cm to 1 m and 1 m = ratio of 1 m to 10 m.

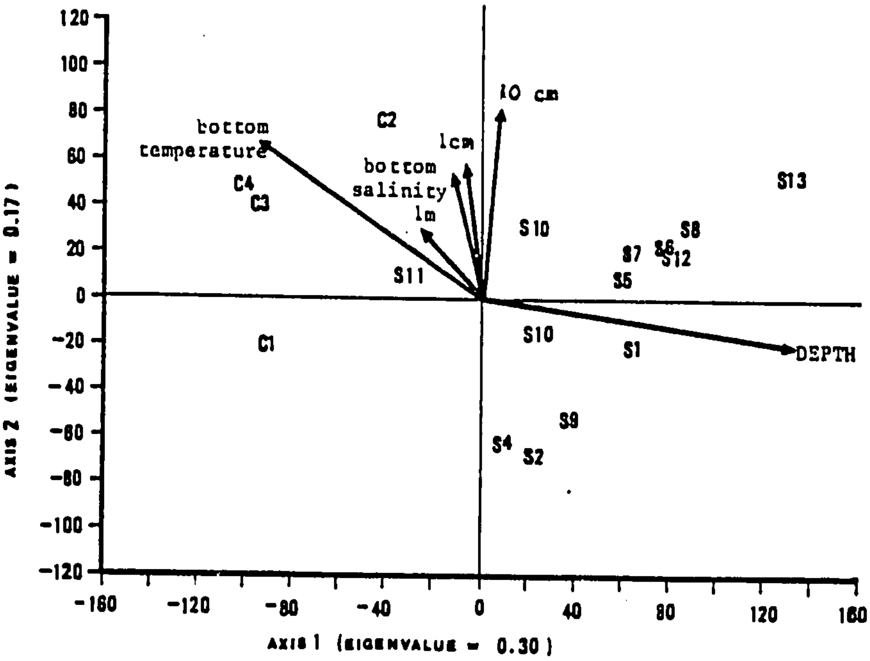

Figure 3b. Canonical Correspondence Analysis (CCA) ordination diagram. Environmental factors (arrows) shown are magnified 3 times. These are the depth, bottom temperature and salinity, and heterogeneity index in the scales of 1 cm, 10 cm and 1 m. The directions of environmental factor vectors indicate their relationship with the ordination of sites, and their lengths indicate the strengths of these relationships.

DISCUSSION

1) Is the analysis of site groupings based on a single survey predictive on a scale of several months?

Without further information on the variability, an analysis based on any one of the sampling periods would have been misleading. Unlike the case of the Samar Sea analysis (McManus 1986), there does not appear to be a strong difference in aggregations found in shallow and deep sites.

2) What environmental factors most strongly influenced the average pattern of distributions and abundances during this time frame?

Of variables investigated, depth was consistently the dominant structuring force. This is apparent in the patterns of site groupings, as well as in the canonical correspondence analysis (CCA) ordination, in which the primary species axis was correlated with depth (r = 0.89, all reported values are significant to P > 0.95). Average bottom temperature appeared to be important, but this variable was negatively correlated with depth (r = [illegible] 73) and not necessarily the controlling factor. Another important variable was heterogeneity, particularly at scales of somewhat less than one meter. This is evidenced by the fact that the second axis in the CCA was strongly correlated with heterogeneity at the 10 cm scale (r = 0.66), and that the third axis was similarly correlated with heterogeneity at the 1 cm scale (r = 0.67). These two sets of measurements were highly intercorrelated (r = 0.82), but weakly correlated with heterogeneity at the one meter scale (r = 0.59 and 0.52, respectively). Heterogeneity at the 1 m scale was not a dominant effect until the fourth axis (r = 0.55), and bottom salinity was not significant in effect on the first four axes. The pattern was similar when detrending was included in the analysis, and is neither an artifact of correlations between axes (the arch effect) nor of the detrending process. The effects of the variables tended to vary between sampling periods, and the results should be interpreted as a time averaged effect.

The importance of fine-scale heterogeneity confirms earlier studies (Goldman and Talbot 1976, Carpenter et al. 1981) emphasizing that heterogeneity is important in determining fish abundances and distributions on coral reefs, and indicates that the effect may be strongest at the 10 cm scale.

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