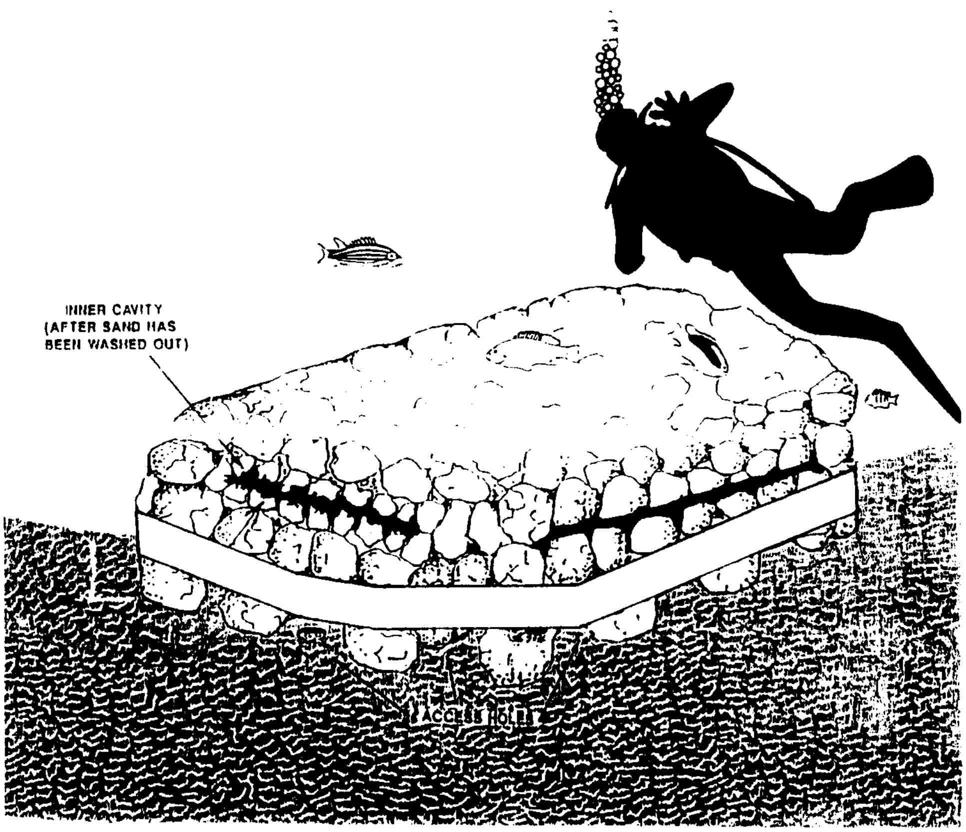
G. M. SELBY & ASSOCIATES, INC.

SUNNY ISLES ARTIFICIAL REEF MONITORING PROGRAM EIGHTH QUARTERLY REPORT

PREPARED FOR
DADE COUNTY DEPARTMENT OF ENVIRONMENTAL RESOURCE MANAGEMENT

BY
G. M. SELBY & ASSOCIATES, INC.
GEORGE DALRYMPLE, Ph.D.
WALTER M. GOLDBERG, Ph.D.
CHRISTOPHER KOENIG, Ph.D,
GERALD ZADIKOFF, P.E.



JUNE 1994

9500 S. Dadeland Blvd., Suite 705, Miami, FL 33156
Tel. (305) 670-2216 • Fax: (305) 670-3024

478 Ballard Dr., Suite 2, Melbourne, FL 32935
Tel: (407) 253-0665 • Fax: (407) 254-3118

6200 Gisholt Dr., Suite 207, Madison, WI 53713
Tel: (608) 223-9640 • Fax: (608) 223-9641

TABLE OF CONTENTS

REPORT SECTIONS	PAGE
SUMMARY	1
INTRODUCTION	5
Module descriptions	7
FIELD METHODS	
a. Invertebrates	8
b. Photographic and Visual Surveys	9
c. Fishes	9
STATISTICAL METHODS	9
SYNOPSIS OF MODULE COLONIZATION BY FISH AND MOTILE INVERTERATES	12
STATISTICAL ANALYSIS	14
SYNOPSIS OF MODULE COLONIZATION OF INVERTEBRATES AND PLANTS	19
STATISTICAL ANALYSIS	22
Analysis of Controls	25
CONCLUSIONS AND RECOMMENDATIONS	28
LITERATURE CITED	31
TABLES FOR FISHES AND LOWER INVERTEBRATES	34
FIGURES FOR FISHES AND LOWER INVERTEBRATES	48
TABLES FOR PLANTS AND SESSILE INVERTBRATES	58
FIGURES FOR PLANTS AND SESSILE INVERTEBRATES	75

APPENDICES

Appendix 1:	Photographs of Module Stations	1
Appendix 2:	History of Invertebrate and Plant Colonization of the Modules	26
Appendix 3:	Effects of Hurricane Andrew on the Modules	44

SUMMARY

Three types of artificial reef modules were placed directly on a natural reef in 60 feet of water off Sunny Isles as part of an effort to restore the habitat and mitigate dredge damage. The three artificial reef types included a small dome-shaped module (D module), a low-relief rectangular module composed of cemented coquina rock (R module) and a high relief, rectangular structure with large internal volume (M module). A total of 31 modules (11 domes, 11 R's and 9 M's), plus 31 control stations for fishes, and 10 disturbed control stations for invertebrates and plants, as well as an undisturbed reef control transect, were studied over eight successive calender quarters. The modules and control sites were examined for the purpose of monitoring the colonization and community development of invertebrates, plants and fish fauna relative to the natural substrate, as well as evaluating the effectiveness of the module designs in restoring the reef habitat. These structures differed in their ability to attract numbers of individuals and numbers of species of both fishes and invertebrates.

FISH

Numbers of Individuals: All modules showed a steady increase in the number of fish during the first year. The M's continued to show increases in the second year in contrast to D's and R's. By the end of the second year, 8485 individuals (greater than 5 fold more than the end of the first year) were associated with the modules. The M modules attracted the highest number of individuals, while the domes had the smallest number. All module types attracted significantly more fish compared to the control sites.

Numbers of Species: Of the 5784 individuals found on the M modules at the end of the study, 81% were grunts. A total of 98 species were recorded on all modules, compared to 77 at the end of the first year. However, few new species were recorded during the last 3 quarters of the study, suggesting that the modules have become saturated with respect to number of species, unlike individuals. The largest number of species was found on the M modules, while the D and R types were associated with a smaller, number of species. On the

basis of absolute number of species and individuals the M modules appeared to be superior.

Types of Species: Multivariate analyses of fish species showed that each module type had its own closely associated species as well as those associated with all three module types. While the most common module-associated fish species were grunts (81%), the most common species on the natural reef were Bicolor damselfish (36% of individuals) followed by Bluehead wrasses (13% of individuals) and redband parrotfish (8% of individuals). Grunts constituted a total of <15% of fishes on the natural reef. Thus, while there were good reasons for this (see Conclusions section), the most commonly occurring species of natural reef fish had little in common with those occurring most frequently on the modules.

Correction for Module Size: When density and diversity are adjusted for size (numbers of individuals divided by surface area) the M modules still had a significantly higher number of individuals, while the D and R modules attracted a smaller number that was not significantly different from each other. The M modules attracted a greater *average number* of species per unit area. However, D modules appeared to attract a greater *cumulative number* of species per unit area. This was true for all species, including those on lists adjusted to exclude schooling pelagic species and others with a low fidelity to the reef habitat.

INVERTEBRATES & PLANTS

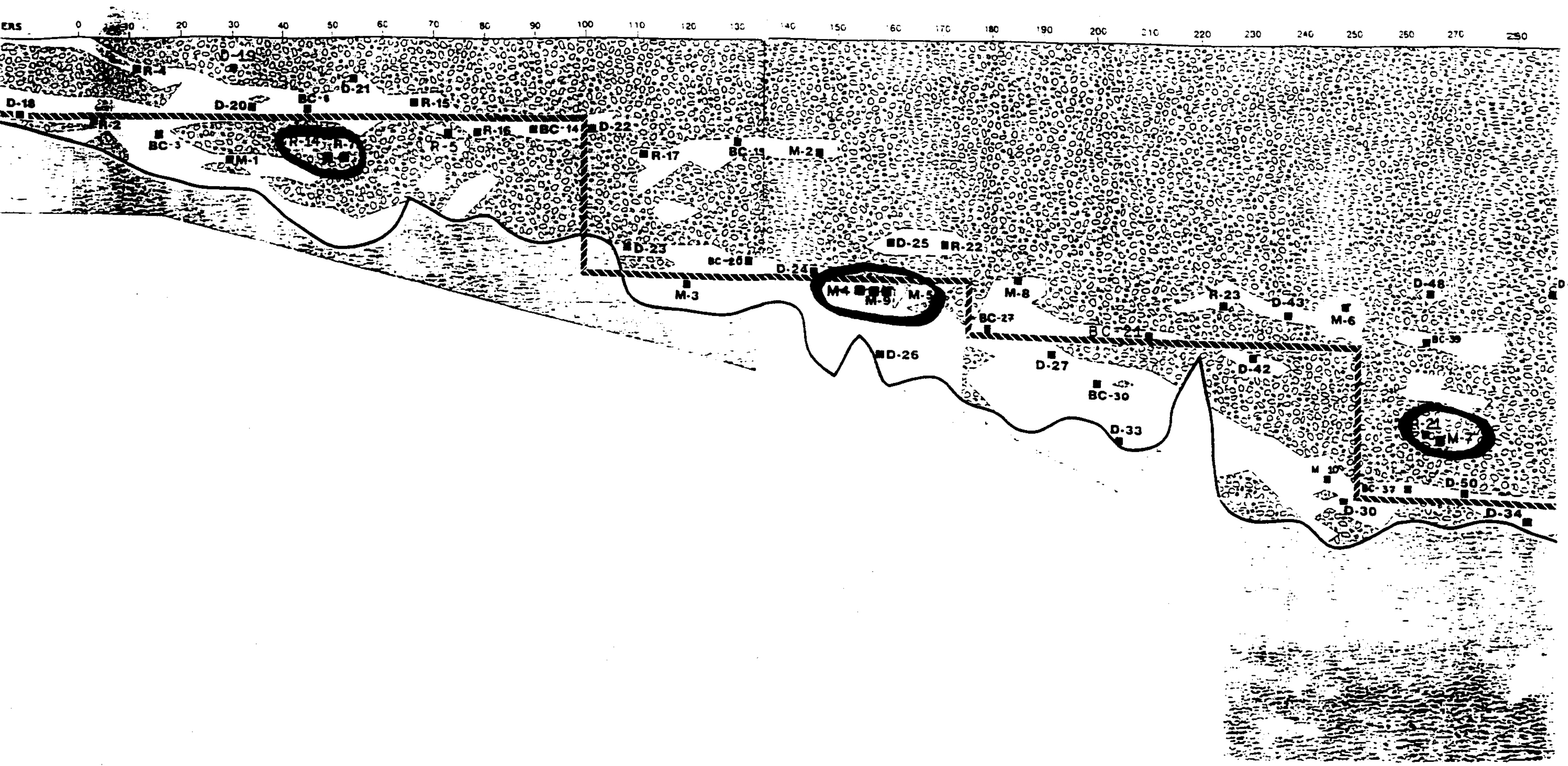
At the end of the second year 1512 individuals and 51 species of invertebrates and plants were recorded on the modules. This represented over a 4 fold increase in individuals and a 3 fold increase in the number of species since the end of the first year. Sponges were clearly the dominant colonists, followed by compound ascidians.

Numbers of Individuals: In contrast to the results concerning fishes, no significant differences were found among the number of plants and invertebrates from the D, M or R structures. All three types of modules were associated with a significantly greater number of individuals compared to control sites. The average number of individuals was not recordable for the first two quarters, as no macroscopic organisms were seen during theis period. The averages showed constant increase during the 3rd and 4th quarters but increased strongly in the 5th quarter, the first sampling period after Hurricane Andrew. Another increase noted in the last (8th) quarter, suggested that numbers of invertebrates and plants have yet to reach their maximum on the modules.

Numbers of Species: Consistent with the number of individuals, the largest average number of invertebrate and plant species was found on the R modules. There was no significant difference between the D, M and disturbed control stations. Likewise, while there have been both increases and decreases in numbers of species at D and M sites, the R modules have shown continuing increases in species since the 5th quarter. Although the number of species on the disturbed control reef sites has remained fairly constant at low levels, a higher cumulative number of species occurred there compared to the modules. These results suggest that species are undergoing considerable turnover and stability has yet to be achieved at the disturbed reef sites.

Types of Species: Multivariate analyses suggest that species inhabiting the modules were generally dissimilar from the those on the natural, undisturbed reef. The most common natural reef invertebrates were two sponge species of the genera *Aplysina* and *Niphates* (11% of the individuals), followed by two gorgonians belonging to the genera *Eunicea* and *Briareum* (10%). The largest share (46%) of the individuals recorded on the natural reef belonged to the calcareous green alga *Halimeda goreaui* . In contrast, the modules were dominated by two different sponges of the genera *Holopsamma* and *Dysidea*, which together constituted 56% of the module individuals. A compound ascidian (*Stolonica sabulosa*) added another 13% of the module individuals. Macroalgae were seasonal and generally uncommon on the modules. The most common invertebrates on the disturbed control sites were the same as the sponge (*Holopsamma*) and ascidian (*Stolonica*) noted on the modules. Nonetheless, there was a greater degree of similarity (though relatively small) between species occurring on the natural, undisturbed reef, and the disturbed reef control sites. The smallest degree of similarity was noted on comparing the invertebrate fauna of the modules as a group, and the natural reef control sites. Despite this, a small but noticeable similarity was seen on comparison of the invertebrate communities on the D modules and the disturbed control sites. Thus, while the modules are currently dissimilar to the control sites in their invertebrate composition, the they appear to be in a better position than the other module types at present, in fulfilling the function of reef enhancement and restoration.

Correction for Size: On an individuals per square foot basis, the D modules outperformed the other types. The undisturbed natural reef contained the second highest number of individuals per ft^2, followed by the R modules and the M's. The disturbed controls had the lowest number of individuals on this basis. The largest number of species per ft^2 was found on the natural reef, with nearly twice as many species as the D modules. The M modules were least diverse of the artificial reefs per unit area, but the disturbed controls had the fewest number of species of all sites.



SUNNY ISLES REEF RESTORATION
SITE 3
FOR MONITORING

LEGEND

= BASELINE
= REEF
= SAND
= DAMAGE AREA
= REEF BOUNDARY

MODULE TYPE

D = DOME
R = REEF REPLACMENT
M = MODULE DESIGN 2
BC = BARREN CONTROL

G. M. SELBY & ASSOC, INC.
9500 S. DADELAND BLVD., SUITE 705
MIAMI, FLORIDA 33156

DADE COUNTY DEPARTMENT OF ENVIRONMENTAL RESOURCES MANAGEMENT RESTORATION MAP & DETAILS	DATE: JANUARY 09, 1992 DRAWN BY: R-C-F SCALE: 1" = 10 METERS UPDATE: OCT. 8TH 93 FRIEDRI

Rev. June 27th 1994 FRIEDRICH

INTRODUCTION

The use of artifical reefs has been extensively documented in the scientific literature as a successful technique for marine fisheries enhancement (*cf.*, Bohnsack and Sutherland, 1985), but only recently have they been employed for purposes of mitigation. Mitigation for habitat loss or degradation is often required by resource agencies in attempting to obtain the objective of no net loss of in-kind habitat (USFW, 1981). However, mitigation does not necessarily mean restoration. Thus, artificial reefs of various descriptions have been employed to mitigate kelp-reef habitat resulting from power plant operations (Carter *et al.*, 1985), concrete block reefs have been employed to mitigate marina construction (Davis, 1985) and quarried rock has been installed to mitigate shoreline development (Hueckel *et al.*, 1989) and beach construction (Coastal Planning and Engineering, Inc., 1990). Where specified as restorative mitigation, actions are meant to replace damaged habitat with a structural and functional equivalent. Mitigation of coral reef damage is no small feat considering the complex and diverse nature of this community, and the limited amount of information that artificial reef literature reveals in this type of endeavor. Edwards and Clark (1992) attempted to restore reefs mined for building material in the Maldive Islands using concrete structures differing in 3-dimensional relief and different stabilizing effects on the bottom. Coral transplants were also employed on some structures. Their goals included restoring the ability of the altered habitat to support exploitable fish populations, stabilizing unconsolidated bottom remaining from mining operations, and promoting the growth of corals. Although they were successful in attracting fish, none of the structures were totally effective in stabilizing the sand and rubble. As a result, only structures with sufficient elevation above the unconsolidated substrate were observed with coral recruits. Artificial reefs designed with mitigation (as well as enhancement) in mind were conducted by Hudson *et al.*, (1989) who examined 23 dome-shaped, concrete reefs. The reefs were successful from the perpsective of coral recruitment and diversity after a decade in the water. However, because the domes were seeded with 10 species of stony corals and 11 species of soft corals, details of colonization and succession were not available. In addition, since only the dome design was employed, no comparisons of design changes could be made. Finally, since the experiments were meant to assess *feasibility* of the artificial reef module in restoration, their actual use on hard bottom was not tested. Thus much remains to be learned about artificial reefs as tool in restorative mitigation.

Reefs off Sunny Isles in Dade County, Florida are constituted by a low-relief, hard bottom community dominated by gorgonians, sponges, and to a much lesser extent, scleractinian corals (Blair and Flynn, 1989). During a beach restoration project in this area in 1988, improper control of a hopper dredge drag head caused gouging of large areas of the surrounding reef. In all, 9 areas of mechanical damage were noted, including 2.2 acres of severe damage, within which 1.5 acres of the reef community was obliterated (Blair and Flynn, 1988). During August, 1991 a total of 80 artificial reef modules of four different designs were placed within the zone of severe damage, directly on the natural reef at a depth of 60 feet off Sunny Isles (site map: **Fig. 1**). The purpose of this study is to document the process of colonization of fish, plants and invertebrates on three of the four module types in comparison with denuded natural substrate, to compare the effect of design on diversity, and to compare the species composition and diversity of the modules to the surrounding natural reef habitat. Conclusions will be drawn within the confines of the data available, as to which, if any of the three module types most closely fulfills the function of hardground restoration, and which attracts the most numerous and diverse suites of invertebrates and fish. This report is a summary and final report of the eight biological surveys conducted during our 2-year study. Supplemental monitoring will continue for at least another year.

Module Descriptions:

The three module types were designated as Module Design 2 (M-module), the Reef Replacement Module (R-module) and the Dome Module (D-module). The M-module design (**Fig. 2**) is essentially a rectangular solid with a sloped roof, entirely constructed of concrete and calcium carbonate aggregate. With a base of 8.5 x 5 ft and the roof sloping from 3.5 ft elevation on one end to 4.5 ft on the other, this module was the largest of the three, with the highest relief and void space (71.6 ft^3). The Reef Replacement Module design (**Fig. 3**) was formed from natural coquina rock cemented into an 8x4 ft rectangular structure. The R-modules had less relief (3-3.5ft) than the M modules, but had the most complex surface due to clefts and irregularities formed by cemented natural rock. Its surface area, conservatively estimated at 160 ft^2, was the greatest of all the modules.The Dome Modules (**Fig. 4**) were hemispheres composed of Portland cement with an aggregate of silica sand and chatahootchee gravel. Two types of domes were constructed, one with a smooth surface of concrete only, and the other with calcium carbonate rock grouted into the concrete surface producing a rough dome. Only rough domes were monitored in this study. The hemispheres were placed on square concrete platforms 4 ft on a side, giving the entire structure a relief of about 3 ft. These modules were designed to mimic the shape of a massive coral head, and were therefore the smallest of the artificial reef structures employed in this study, containing 28 ft^2 of exposed surface. Holes were constructed between the platform and the dome to allow access to the 7.1 ft^3 of void space.

FIELD METHODS

a. Invertebrates

Beginning in November, 1991 10-11 examples of each of the three module types were selected by their proximity to two connected transect lines extending 280 meters from the southern to the northern end of the study area. The 11 Dome modules selected were those encountered along the transect line that were of the rough surface construction only. These were designated D-18, 19, 20, 21, 22, 25, 30, 34, 43, 49 and 50 (see site map for position). The 10 M2 modules we examined were M-1, 2, 3, 4, 5, 6, 7, 8, 9 and 10. The 11 R-modules examined were numbered R-2, 4, 5, 7, 14, 15, 16, 17 21, 22, and 23. The location of these structures are shown in Fig. 1. Thus a total of 32 modules were studied initially. However, as a result of Hurricane Andrew module M6 was destroyed and this was deleted from the survey list. The remaining 31 modules were surveyed throughout the two-year period. In addition, ten squares 4.9 ft per side (=23.76 ft^2 or 2.25 m^2) constituted control quadrats (=Barren Controls or BC stations) that were prepared in the vicinity of the modules. These plots were cleared of all benthic invertebrates by and plants with wire brushes for the purpose of comparing colonization of barren, natural substrate with the modules. In addition, in October, 1991 a survey of the undamaged natural reef (UR site) was initiated in the vicinity of the modules by establishing a 65 ft (20m) long control transect line photographed and ground-truthed as described below. Invertebrates and macroalgae surveyed on both sides of the transect line constituted an area of 195 ft^2. It was intended to return to this area for re-assessment annually but the transect was obliterated during Hurricane Andrew and could not be relocated. Thus comparison of the natural reef similarity with BC control sites and module sites is limited to the 1991 survey data.

b. Photographic and Visual Surveys

The surveys of invertebrates/ algae employed a photographic arrangement consisting of A Nikonos camera and a 28mm lens placed on a fixed-distance PVC quadrupod that photographed a 18x28 inch quadrat (=0.33m^2). A photographic transect was made over each module by successive quadrat photographs, always beginning with the identity plate and continuing along the longest axis of the module. Dome modules required 4 photographs to complete each transect, R modules required 6-7 photographs, and the larger M modules required 7-8. Each transect was also carefully surveyed by eye, with counts individual taxa recorded *in situ*. The total transect area surveyed was necessarily different depending on the module type. Each M-module transect constituted 12.75 ft^2, each R-module transect was 12.0 ft^2 and each Dome module transect was 6.0 ft^2. The total of all transect areas (10 M-modules, and 11 D and R-modules) was thus 325.5 ft^2, compared to 195 ft^2 of control transect and 240 ft^2 of barren control area. These surface area differences were normalized to a ft2 basis for the purpose of reporting invertebrate data.

c. Fishes

Total counts of fishes and motile invertebrates were made simultaneously by two biologists. Both approached the modules to within 3 meters. One remained stationary and recorded on underwater census forms while the second diver videotaped the site while swimming around it, maintaining the 3 meter distance (*cf.*, Bortone *et al.*, 1986). After one complete revolution, both biologists moved in to search the void spaces of the module for cryptic species. Graduated meter sticks carried by both biologists were used to estimate fish sizes in cm standard lengths. Standard length is a basic ichthyological measurement which is defined as the distance from the tip of the snout to the end of the last vertebra, excluding the caudal or tail fin. Control sites were also sampled in the same manner as the modules. Video and written records were later compared and combined to provide the final data set for each site. The data sheets included the reference site along with the corresponding data for each module.

STATISTICAL METHODS

Standard Parametric Analyses of Study Sites

One way analysis of variance (ANOVA) on fish populations was performed on the four site types (D, M, R, and C, with samples sizes of 11, 10, 10, and 31, respectively) using both number of individuals per site and number of species per site as the data. For invertebrates and plants the four site types were the D, R, and M modules and the Barren Controls (BC's), with samples of 11, 11, 9, and 10, respectively. The tests (independent samples) were performed on each combination of site types to determine which site types were significantly different in mean numbers of fishes or invertebrates and plants and mean number of species per site type with means based upon sample sizes as listed above. In order to determine whether the control sites could be treated as a single group, they were first analysed for differences in the mean number of individuals and mean number of species within the group using an ANOVA.

Diversity Indices

Shannon-Weiner Diversity indices (H, using logarithm to the base ten) were calculated for each site type based on both the number of species and the number of individuals per species. The lowest possible value of H is zero. This would occur when all individuals in a population belong to one species. As the number of species increaes, so does the value of H. The number of individuals also affects the diversity index. If a small number of species account for most of the individuals, the value of H will be lower than if all species are represented by equal numbers of individuals.

Comparisons Between August (7th qtr) and January (8th qtr)

One-way ANOVA's were used to test for differences in the mean number of individuals and the mean number of species at a site types D, M, R, or C and D, M, R and BC between the August, 1993 and January, 1994 surveys.

Jaccard's Coeffecient of Similarity:

A simple, crude measure of the similarity of each pair of sites was calculated based upon presence/absence data only. All fish and invertebrate species were included (but analyzed separately) in the analysis. The similarity index is calculated by dividing the number of species found at both sites by the cumulative total number of species at the sites. The minimum possible similarity index is 0 and would indicate that the two sites do not have any similar species. The maximum possible value is 1.0. This would indicate that the species list for the two sites are identical. A more sophisticated measure of similarity, Pearson's product-moment correlation (r), takes into account the relative abundance of each species, and is calculated as a step in Cluster Analysis. The Pearson correlation coefficient can be read from the top axis of the cluster diagrams. See Multivariate Analyses of Sites for further details.

Multivariate Analyses of Sites

Cluster analysis and Principal Component Analyses (PCA) (Gauch, 1982; Pielou, 1988) were the multivariate techniques used in this report. Cluster analysis were performed on the correlation matrices using the Unweighted Pair Group Method, Arithmetic average (UPGMA) method. Separate PCAs were performed on the correlation matrices of data for a) the 21 most common species of fishes in terms of sites and taxa, as done previously, and b) the invertebrates and plants at the module stations and the BC stations. The PCAs were performed using the matrices to generate eigenvalues and eigenvectors (scaled as square roots, SQRT LAMBDA, Pielou, 1984; Rohlf, 1988). PCA's were performed for both the rows and columns, i.e. the sites and the species, as the OTU's (outstanding taxonomic characteristics).

In all analyses performed on the motile invertebrates and fishes at the controls (C) and modules (D,R,M), or the invertebrates and plants at D, R, M and BC stations, the following conventions were followed:

1. All analyses were done on controls and modules together. One way ANOVA's determined that the mean number of fishes and the mean number of species demonstrate no significant differences among the controls regardless of the associated module type. Simultaneous comparison of controls with treatments permits a better assessment of the ecological characteristics that may draw particular species to a site type.
2. In all cases, only fish species that actually occurred in the data sets were analyzed (i.e. species never found at any locations were excluded).
3. All analyses used Pearson product-moment correlation coefficients (r) for the similarity matrices.
4. Only standardized data (as percent of total fishes, invertebrates or plants by site types) were analyzed.
5. PCA for fishes was restricted to the 21 most common fish species ($N \geq 15$), and was performed on these fish as taxa.

SYNOPSIS OF MODULE COLONIZATION BY FISH

At the end of the first year (August, 1992) 77 species of fish and 1673 individuals were found on the modules. The R modules had the highest total number of individuals (720) among the module types, while the control sites had about the same number (722). The M modules were associated with 673 individuals and the Domes had the fewest (280). In terms of number of species, the M modules were most diverse with 46, followed by the R modules (40) and the Domes (35). The control stations were associated with 29 species and was the least diverse, with strong representation by Bluestriped grunts (*Haemulon sciurus*) and Bicolor damselfish (*Pomacentrus partitus*). These two species accounted for about 46% of the individuals found on the 31 control sites. Of the fish associated with the modules after the first year, the white grunt *Haemulon plumieri* and the bluehead wrasse *Thalassoma bifasciatum* were the most common species, but accounted for only about 31% of the artificial reef fishes.

By the 5th quarter, December, 1992, the first post-hurricane survey, the fish population had increased by about 50%, primarily due to the influx of various species of grunts, while the control stations remained essentially unchanged. Of the 3385 individuals, about 66% were accounted for by 3 species, French grunts, White grunts and Bluestriped grunts. The total number of fish and the dominance by grunt species continued to increase in 6th quarter, to 4670 individuals, about the same proportion of which were haemulonids. In the 7th quarter those numbers had increased to 5860 individuals and about 80% haemulonids.

In the eighth quarter the total number of fish on the modules increased again to 8485 individuals, while maintaining 81% of these as haemulonids. During the second year, while the modules increased their fish populations about 2.5 fold, the control stations have decreased from a total of 668 to 440 individuals. The control stations continue to be dominated (36% of the individuals) by the Bicolor damselfish *Pomacentrus partitus*, occurring with 28 other species represented by many fewer individuals. The only new species recorded during the final (8th) quarter was a single individual of the inshore lizard fish, *Synodus foetens*, found on one of the control stations. The Dome modules had about the same number of species as the controls (30), but had a greater number of individuals (690). The M modules continue to have the greatest number of individuals (5784) primarily due to the grunt populations which prefer that module type, along with grey snapper populations (*Lutjanus griseus*). The R modules, also with considerable grunt populations, had 2011 total individuals and 35 species, slightly more than the M modules with 33. These data, summarized in Tables F-3 and F-4, and described in detail below, suggest that the modules have achieved some stability with respect to accumulation of species. Further study will determine whether the modules are saturated with respect to individuals.

STATISTICAL ANALYSIS: FISHES AND MOTILE INVERTEBRATES

Raw Data and Parametric Comparisons by Anova and T-Tests:

The raw data for the controls and the three module types are presented in Tables F1 and F2, with data summarized by study site type in Table F3. Summary statistics for the four site types are given in Table F4.

Among the three module types (D, M, R), the number of individuals varied from 21 to 827 and the number of species varied from 8 to 19 (Table F4). The highest average number of individuals, and the highest average number of species were found on the M modules. The lowest average number of individuals and the lowest average number of species were found on the D modules. The control sites had a lower average number of individuals and average number of species than any of the three module types.

There were significant differences among the four study site types (D, M, and R modules plus the control sites), in both average number of fishes and average number of species (Table F5). The control sites had a lower average number of individuals and average number of species than the D, M and R modules (Table F6). The D modules had a lower average number of fishes and average number of species compared to both the M and R modules. The average numbers of fishes and species on the R modules were lower than on the M modules.

Shannon-Weiner Diversity Index:

The Shannon-Weiner Diversity Indices (H) were 0.95, 0.70, and 0.84 for the D, M, and R modules types respectively. The lower diversity index on the M modules is due to the combined overwhelming abundance of the grunts (*Haemulon* spp.) and the gray snapper (*Lutjanus griseus*), which account for 93.7% of all individuals on the M modules (see Statistical Methods: Diversity Index for further explanation of the factors affecting the value of H). The C control sites had a diversity index of 1.01 for comparison (Table F4). The higher diversity index of the control sites despite their lower average number of fishes and species results from a lack of dominance by any one species.

Jaccard's Coefficient of Similarity:

Since a measure of error cannot be calculated, it is not possible to test for significant differences among the similarity indices. The D, M and R modules were all relatively similar (Table F8). The C sites were clearly unlike any of the module types.

Multivariate Analyses of Modules and Fishes:

In a cluster analysis of the standardized occurrence of the 21 most common fishes ($N \geq 15$; Table F9) at the D, M, R, and C sites, the modules were all quite similar, while the C sites were clearly distinctive (Figure 1). (The scale at the top of each cluster is the Pearson product-moment correlation coefficient, a similarity index calculated using both the number of species and the number of individuals of species.) A clustering of the taxa (Figure F2) demonstrates that the C sites are distinct for their abundance of the bicolor damsel fish (*Pomacentrus partitus*), the bluehead wrasse (*Thalassoma bifasciatum*), the cocoa damselfish (*Pomacentrus variablis*), the redband parrotfish (*Sparisoma aurofrenatum*), the

Ocean surgeonfish (*Acanthurus bahianus*) and the striped parrotfish (*Scarus croicensus*). The similarity represented by the Jaccard coefficient, is also reflected in the clustering of a group associated with both D and C sites.

In a plot of the first three principal components by taxa, the 6 species named above as most abundant on the control sites remain tightly associated. An additional species, *Pomacentrus variabilis* (POMv) is hidden behind, i.e., identical with P. partitus (POMp). Three species with the highest abundance on the D modules and the C sites (spotted goatfish, *Pseudupeneus maculatus*, rock beauty, *Holacanthus tricolor*, and reef butterflyfish, *Chaetodon sedentarius*) are also closely associated. However, these three species are relatively rare on both the D modules, and the control sites where they account for 4.7% and 3.8% of the total number of individuals, respectively (Table F9). These low levels of species overlap do not reflect strong similarities. Overall, the D modules are much more similar to the M and R modules than to the C sites.The remaining species form loose groupings that do not correspond to any specific module type. This suggests that the differences between the three module types are becoming more subtle, or are to be found in the less common species. Unlike past samplings, the grunts do not swamp the remaining species in a plot of the first three principal components. The grunts, however, still dominate by numbers (71.5% on D modules, 85.6% on M modules, 82.3% on R modules, and 14.5% on C sites).

Simultaneous Consideration of Fish and Benthic Invertebrate Fauna:

Clustering of the 21 most abundant fish taxa and the 22 most abundant invertebrate taxa demonstrates the sharp difference between the Control sites and the module types (Figure F8). Differences among the three module types are not as clear. PCA of the taxa reiterates the clear separation of the control sites (Figure F9).

Comparison of August (1993) and January (1994) Samples:

The average number of individuals (fishes) and the average number of species at each site type during the January sampling period were compared to the August sampling period by ANOVA (Table F7). At the D and R modules, the average number of fishes were not different but the average number of species declined in the recent sampling. At the M modules, the average number of fishes increased while the average number of species did not. The control sites showed no significant change in average numbers of individuals or species.

Comparison of All Quarters: Number of Fishes:

The average number of fishes at the control sites has been relatively stable with the exception of a decreased average number of fishes in the fifth quarter (April 93, Figure F4). The average number of fishes at the M and R modules has been consistently higher than the D modules and C sites. During the second year the D modules have seen an increase in average numbers of fishes, separating them from the C sites. All three module types showed a steady increase in average numbers during the first four quarters. The M modules continued to show increased average number of fishes during the sixth, seventh, and eighth quarters. The D and R modules did not.

The dominance of grunts on the D, M and R modules was not evident until the Fifth quarter (August 92, first sampling after Hurricane Andrew; Table F10). Grunts had always occurred at low levels prior to the 5th quarter, and were most abundant on the R modules during the First thru Fifth Quarters. The hurricane shifted three of the M modules (M4, M5, M9) within 6 meters of each other and it has been suggested that groupings of modules may attract higher numbers of schooling fishes, such as grunts. If the grunts were preferentially selecting these three modules due to their close proximity, significantly more than 30% of the total number of grunts on the M modules should be found on these three modules. The number of grunts on these three M modules accounted for 15% of total grunts on the M modules during the Fifth quarter, 13% in the Sixth quarter, 52% in the Seventh quarter, and 39% during the Eighth quarter (Table F10). These results do not clearly support the hypothesis that the proximity of these three modules attracts more schooling species such as grunts.

Comparison of All Quarters: Number of Species

The average number of species on the C sites has been consistently lower than the three module types (Figure F5). Among the modules, the M modules have the highest average number of species and have shown little change during the last four quarters. The D and R modules showed increased averages in the seventh quarters but a decline in the eighth quarter.

The total number of species found throughout the eight quarters was highest on the M modules (71 species, Table F11). The D and R modules had similar cumulative numbers of species (62 and 64, respectively) while the C sites had the lowest (56). Many of species were present at each of the four site types, while some species were restricted to the modules (*Mycteroperca phenax*, *Equetus* spp, *Abudefduf saxatalis*). A plot of cumulative number of species by quarter (rarefaction curve) demonstrates that few new species have been found at the D, M, R and C sites during the last three quarters (Figure F6), even though the number of individuals at the three module types continue to increase.

Comparison of All Quarters: Diversity Index

Shannon-Weiner Diversity index for each quarter is plotted in Figure F7. The diversity on the M modules shows a sharp decline, primarily due to the combined increasing dominance of grunts and gray snapper, as discussed earlier. While the grunts show a similar high abundance on the D and R modules as on the M modules, the D and R modules do not have a second species, such as the gray snapper, accounting for more than 5% of total number of fishes. The increase in abundance of the grunts on the D and R modules in more recent quarters has decreased the diversity at these sites, but not to the extent shown on the M modules.

Differences In Module Size:

The three module types are of different sizes and shapes. The D modules have the smallest surface area (Table F12). The M modules have approximately 4 times the surface area of the D modules while the R modules have approximately 5 times the surface area of the D modules. The M modules have the highest absolute amount of internal void space. However, relative to surface area, the D modules have the highest amount of internal void space (reflected in low surface:volume ratio) while the R modules have the lowest.

Recalling that the M modules had the highest average number of individuals per module and the D modules had the lowest average (Table F4), a somewhat different picture emerges if corrected for the difference in module size. When the average number of individuals is divided by surface area and expressed as individuals per ft^2 the M modules still have a higher average than either the D or R modules (Table F13; Figure F10). However, the average numbers of individuals per ft^2 for the D and R modules were not significantly different. This contrasts with the conclusion derived for D and R modules uncorrected for size, where the mean number of species was significantly lower in the D's compared to R's.

While the D modules as a group are able to attract a similar cumulative number of species as the larger M and R modules (Table F11), the M modules had the highest average number of species and the D modules had the lowest (Table F4). When corrected for the differences in module size, however, the D modules replaced the M's in having the highest average number of species per unit area. The R modules had the lowest average number of species per unit area, and the M modules were intermediate (Table F13; Figure F11). Even though the R modules had the largest surface area, their relative lack of internal space (high Surface Area:Volume ratio) makes them less attractive to large numbers of fishes, particularily those species which maintain territories. The density of fishes defined as "tightly associated" with a module (species that would not leave when approached by divers; Table F14) was $0.120/ft^2$ on the D modules, $0.106/ft^2$ on the M modules, and $0.053/ft^2$ on the R modules.

SYNOPSIS OF MODULE COLONIZATION BY SESSILE INVERTEBRATES AND PLANTS

During November, 1991, less than three months after deployment, the modules had been colonized primarily by an unidentified filamentous green chlorophyte and tufts of red cyanobacteria. These organisms were found both on the exposed surfaces of the modules as well as the shaded portions. In addition, 2mm long filaments of the red alga *Galaxaura obtusata* were found on the outer module surfaces, along with 1-2 mm diameter plates of an unidentified calcareous red alga. The invertebrates observed included some recently settled sponge material, plus small, unbranched hydroids, occasional balanid barnacles, serpulid worms, and an occasional isopod. For the first 3 quarters, the diversity of macroinvertebrates and macroalgae remained so low that no quantitative data could be obtained (see Appendix 1, photo R-21, bottom). During the third quarter survey, only 3 Dome modules exhibited any colonization by macroinvertebrates.

One year after deployment, the modules were still dominated by filamentous cyanobacteria, but encrusting algae, especially melobesioid and lithothamnioid species, along with encrusting sponges were becoming increasingly common. The net visual effect of these organisms gave the modules a speckled pink and red appearance (see paired photos taken on 12/92 and 1/94: D25, D34, D43; M1, M7, M9 and R21). The most common invertebrates were barnacles of the genera *Balanus* sp. and *Tetraclita* sp. on the upper surfaces of the modules. The lateral surfaces of the modules, particularly the M and R types exhibited most of the invertebrate macrofauna. Calcareous bryozoan colonies, including *Parasmittina* sp., and *Watersipora* sp. (see photo M9), and juvenile file shells (*Lima lima*), also were and continue to be quite common on these modules (*cf.*, photos R4, R15). The R-modules consistently exhibited file shells, American oysters (*Spondylus americanus*) and rock urchins (*Echinometra lucunter*), although these were usually too small and cryptic to be seen in photos. The blue sponge *Callyspongia fallax* (*e.g.*, photo R22) was becoming increasingly common. The M modules continued to display clusters of orange tunicates, *Stolonica sabulosa* (*e.g.*, photo pair D25), as well as larger, individual, black sea squirts (*Ascidia nigra*), especially on the shaded surfaces. Colonies of the octocoral *Telesto riisei* were also prominent deep inside the large recesses of most of the M-modules.

After year one, a total of 340 individuals and 17 species of algae and invertebrates colonized the modules. The Domes were populated least, containing 47 individuals and 12 species of invertebrates and algae. The M modules contained 196 individuals and 14 species, the R modules contained 97 individuals and 16 species. At the end of the second year, 1512 individuals and 35 species were found. Colonization of the Domes increased by nearly an order of magnitude to 451 individuals, and the number of species increased to 19. The M modules, initially the most diverse, added only 3 additional species during the last year, while nearly doubling the number of individuals to 392. The R modules increased their number of individuals to 548, more than either of the other two types. While adding only 12 additional species during the last year, the R modules are also currently the most diverse with 28 species of macroinvertebrates. No macroalgae were noted during the eighth quarterly survey.

The dominant colonist at the end of the second year was the sponge *Holopsamma helwigi* with 558 individuals. This species was more or less evenly distributed by module type (see photos: Appendix 1), but currently occurs with many more individuals per unit surface area on the Domes. At the end of the first year, this species, although present on several modules (*e.g.*, 12/92 photos of D34, D43, M1, M7, M9), was equally common on the control stations. However, by the end of the second year this sponge accounted for >40% of the invertebrate individuals on the modules, while the control populations increased by only 2 colonies. This degree of dominance is also unlike the natural reef. Thus the population increase of this species appears to be strictly an artificial reef phenomonon. The blue patch sponge *Dysidea* sp. with 208 individuals, was also strongly represented, 50% of which were found on the R modules (see photos R 16 and R 22). The orange colonial ascidian *Stolonica sabulosa* with 183 colonies, was also notable, especially on the Domes where 77% of them were found (see photos D34 and D43). Since the upper surfaces of the other module types also displayed many of these, its commonness on the domes may simply reflect the relatively small amount of shaded surface on this type of module. It is worth noting however, that the increased population of this species on the Domes occurred during the last quarter, suggesting that an equilibrated proportion has yet to emerge. The fire coral *Millepora alcicornis* was also strongly represented with 134 individuals, about 70% of which were found on the R modules (but more easily seen on Domes (*e.g.*, D18, 25 and 34). A total of 73 colonies of this species were new this quarter. Other species, while not dominant, have shown a strong increase this quarter attesting to the dynamic nature of the present invertebrate populations. The sponge *Iotrochota birotulata* increased to 51 individuals from 2 last quarter. Another sponge *Callyspongia vaginalis* also more than doubled last quarter (see photos D19 and M 7), while a related species *C. fallax* declined by nearly half. A new species of calcareous bryozoan, *Trematooecia aviculifera* was also recorded for the first time this quarter, primarily on the R modules. Other calcareous bryozoan species either declined (*i.e.*, *Parasmittina* sp.) or remained stable *Watersipora* sp. (*e.g.*, paired photo M9 and R17). The octocoral *Telesto riisei* continues to be characteristic of the M modules but during the last year colonies of this species began occupying the external surfaces, in addition to their initial preference for the internal, cryptic positions within these modules (*e.g.*, photos M2, M5). The scleractinians *Siderastrea* sp. (probably *S. siderea*) and *Meandrinea meandrites* made their appearance on the Domes during the last quarter, accompanying the gorgonian *Eunicea* sp. (probably *E. fusca*, see photo R5). Other changes are summarized by in Table I-2. Details of the history of colonization by invertebrates and plants by each site is given in Appendix 2.

Barren control (BC) Sites

The last quarter survey revealed that stations BC 8 and 19 had the highest diversity. At BC 8 there were 8 sponges among 4 taxa, plus 2 scleractinians and the calcareous chlorophyte *Halimeda goreaui.* At BC 19 there were 2 algal species, 10 sponges among 5 taxa and 3 colonies of the gorgonian *Eunicea fusca.* BC 3 clearly increased its diversity from 2 sponge taxa and one scleractinian last quarter, to 1 algal taxa, 2 sponge species, 1 gorgonian and 2 scleractinian. Other BC sites had not changed much from the previous quarter. Most of the of the taxa colonizing the BC stations were not the same as those found on the modules. At BC 30 and 37 little colonization occurred during the first year because the sites were inundated by sand. On other BC quadrats, a number of animals and plants not found on the modules made their appearance.

By the end of the first year 19 species and 111 individuals were found on BC sites, making these stations approximately as diverse as the R modules. However 4 of the 5 most common species were seasonal algal colonists. At the end of the second year 29 species and 141 individuals were found. Only one clump of macroalgae (*Dictyota* sp.) was noted, the rest were invertebrates. The most common invertebrates on these sites were the ascidian *Stolonica sabulosa* with 48 colonies, and two sponges, *Holopsamma helwigi* with 17 individuals and *Niphates digitalis* with 13 individuals. Sixteen of the other 26 species were represented by 1-2 individuals (Table I-2).

STATISTICAL ANALYSIS: PLANTS AND SESSILE INVERTEBRATES

Raw Data and Parametric Comparisons by ANOVA and t-tests

The raw data for benthic sessile invertebrates and plants at the modules and barren control sites are given in Table I1 and summarized for each site type in Table I2. Summary statistics are found in Table I3. The number of individuals ranged from 27 to 76 among the three modules types (D, M, and R) and from 3 to 25 among the barren control sites (Table I3). The number of species ranged from 3 to 15 on the modules and from 3 to 11 on the barren control (BC) sites. The highest average number of individuals was found on the R modules while the lowest was found on the barren control sites. The highest average number of species was found on the R modules and the lowest average on the D modules.

When the average number of individuals and average number of species at each of the four types of sites (D,M, R and BC) were tested for significant statistical differences, the barren control sites were significantly lower than the modules (Tables I4, I5). The modules did not differ significantly from each other in this regard. In the case of average number of species, the R modules were higher than the D, M or BC sites (Table I5). There were no differences among the D, M or BC sites in average numbers of species.

Shannon-Weiner Diversity: Plants & Sessile Invertebrates.

The Shannon-Weiner diversity indices (H) for the D, M, and R modules were 0.64, 0.80 and 0.97 respectively (Table I3; refer to Statistical Methods: Diversity Indices for further discussion of factors affecting H). The barren control sites had a diversity index of 1.12. The low diversity on the D modules results from the abundance of *Holopsamma helwigi* (48% of individuals) and *Stolonica sabulosa* (31% of individuals). The increase in diversity on the BC sites (0.80 during 7th quarter) is similar to the increase diversity seen in the previous winter quarter and is the result of seasonal fluctuations in abundance (such as seen in *Udotea*).

Jaccard's Coefficient of Similarity: Plants & Sessile Invertebrates

Since a measure of error cannot be calculated, it is not possible to test for significant differences among the similarity indices. Among the three module types, the M and R modules were the most similar (Table I6). The BC sites were clearly unlike any of the module types. However, of the three module types, the domes were the least dissimilar to the BC sites. This is not the same as saying that the D modules are the most similar of the module types to the BC sites since the Jaccard coefficients of each of the module categories and the BC sites are extremely low (<0.50). Neither the modules nor the most common species on the undamaged reef (compare Table I3 to I11). The Undamaged Reef sites were more similar to the Barren Control sites than to any of the three modules types, however, the degree of similarity between the Undamaged Reef and Barren Control was still fairly low (Table I6).

b. Differences In Size of Modules, Barren Controls And Undamaged Reef Quadrats:

The three module types are of different sizes and shapes. The D modules have the smallest surface area (Table I12). The M modules have approximately 4 times the surface area of the D modules while the R modules have approximately 5 times the surface area of the D modules. The M modules have the highest absolute amount of internal void space. However, relative to surface area (surface area to volume ratio), the D modules have the highest amount of internal void space while the R modules have the lowest. In contrast, the natural reef, including the Undamaged Reef transect sites and the Barren Control sites were flat limestone outcrops with little or no void space or relief.

The undamaged reef quadrats (UR) had a lower average number of individuals than each of the three module types; there was no significant difference between module types. However, when considered per unit area, the D modules had the highest average per ft^2 (Table I13; Figure I8). The R modules has a higher number of individuals per ft^2 than the M modules, but a lower average per ft^2 compared to the UR quadrats. There was no significant difference between the R modules and the UR quadrats.

The undamaged reef areas have nearly twice the total number of species (57) versus any of the modules (Table I11). When average number of species per sampling unit (either a module or a quadrat) was corrected for the surface area differences, the Undamaged Reef had a higher average number of species per ft^2 than the three module types and the Barren Controls (Table I13; Figure I9). The Barren control sites had the lowest average per ft^2. Among the module types, the D modules had a higher average number of species per ft^2 than the M modules but not the R modules. The was no significant difference between the M and R modules.

While the D modules have the smallest surface area, the shape of the module (either in terms of outer contour or the amount of internal void space) appears to be more favorable to colonization by benthic invertebrates than either the M or R modules (as reflected in average number of individuals per ft^2 and average number of species per ft^2). However, after the first two years of survey, the benthic invertebrate faunal community of the D modules is still not similar to the Undamaged Reef community sampled in November, 1991.

CONCLUSIONS AND RECOMMENDATIONS

The different module types have different configurations and it should not be surprising that each has its own attributes. The M modules are superior to the other types in terms of attracting large numbers of individuals and species of fish per module. In addition, the M modules attract a greater average number of fish per unit surface area. The greater cumulative number of species noted in the D modules may be a reflection of turnover rather than high diversity. The large internal volume of the M modules afforded habitat to Florida lobster and certain octocoral species as well. While the similarity of fish species inhabiting the modules (M, D & R) was low compared to the natural reef, it should be emphasized that all species recorded are reef-associates (e.g., Randall, 1963, 1968). The presence of grunts, snappers and others are typical of reefs on which there is a modicum of relief. Since the natural reef is virtually flat, the modules might be expected to have a different fish fauna.

The R modules as a unit performed best for invertebrate colonization in terms of both average numbers of species and individuals. In addition to the species common to all modules (sponges and ascidians), cryptic and photophobic species such as file clams and spiny oysters were able to occupy and maintain their position within the clefts created between the coquina rock sides, as have gorgonian corals (*Eunicea* sp.). This type of habitat may not have been unique to the R modules but it was not physically possible to adequately survey the equivalent, shaded (internal) regions of the other module types. Thus the less common species contributed to the overall diversity and abundance of invertebrates found on the R modules. However, when viewed from a per unit area perspective, the D modules had the highest average and cumulative numbers of both species and individuals, thereby out-performing the R modules on a per unit area basis. Since cost is often reduced to a square foot basis, the Dome modules may be the most cost-effective in terms of producing a diverse invertebrate community. However there is nothing obvious in the design of this module type that might explain this unit area effect, except perhaps that it was the smallest of the three.

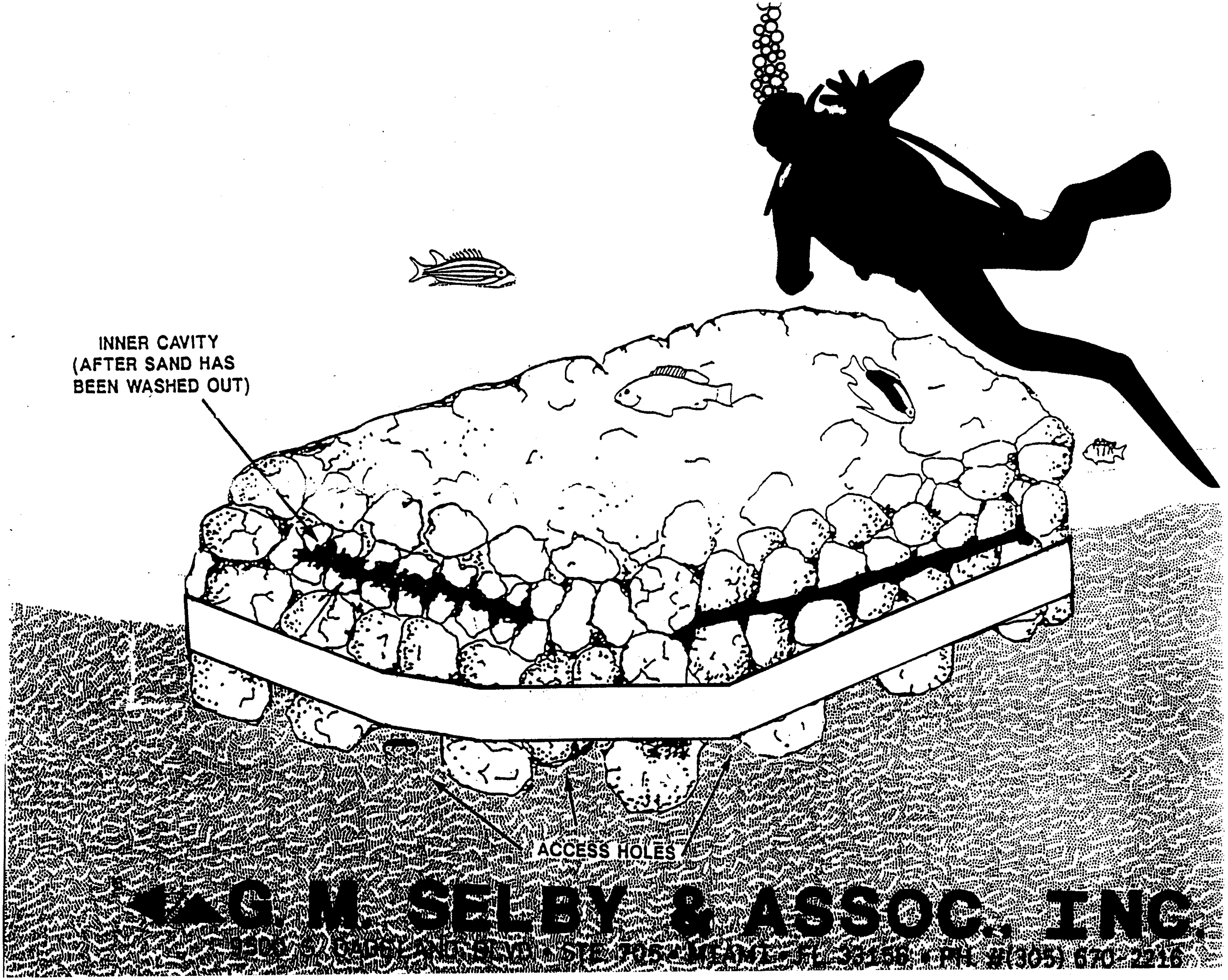
Despite the relative merits of the modules with respect to invertebrates, none of them resembled the natural reef in terms of species composition. However, scleractinian corals including the genera *Siderastrea, Meandrina, Eusmilia* and *Porites* have made their appearance on the modules over the most recent quarters, as has fire coral and other reef associated sponge species (e.g., *Callyspongia vaginalis* and *Iotrochota birotulata*) even though these were rare or absent in the UR transect. Since the data suggest that the invertebrate fauna of the modules is still in a dynamic state, it is reasonable to suspect that these communities will become more stable and reef-like with time. Some authors have found that concrete artificial reefs are capable of attracting some of the more common coral species within six months of emplacement (Edwards and Clark, 1992). Others have found that coral recruits to such structures suffer from high mortality during the first year (Fitzhardinge and Bailey-Brock, 1989), requiring a number of years for colonies several cm in diameter. While the sequence of recruitment and mortality events is unknown, Raymond (1975) found that concrete ero jacks off Broward County Florida, developed 15 species of stony corals after 8 years in depths similar to the Sunny Isles site. Thus, concrete structures have the potential to develop considerable diversity, perhaps rivaling that of natural reef substrate.

If enhancement of maximum diversity and abundance were most desirable, rather than restoration, the three module types were differentially successful. The M modules were clearly superior in attracting diversity and abundance of fish. One suspects that size considerations were important in this case. Size can be a function of total volume, height, surface area and bottom coverage (Bohnsack *et al.*, 1991). Since these factors were not controlled in our study it is not possible to pinpoint which aspect of these may have been most important. However, vertical relief of up to a meter is known to be important in attracting fish, after which their populations become asymptotic (Patton *et al.*, 1985; Bohnsack, 1991). Since the other modules were below this height, perhaps future designs should strive to keep the meter height as a standard.

Invertebrate diversity and abundance was ambiguously split between R and D modules, depending on whether the entire module, or per unit area was being considered. Two possible avenues for resolving these different considerations are suggested:

1. It has not been possible to evaluate the effect on diversity of shaded and cryptic habitat in the R modules because of differences in overall size and surface area on comparison with domes. The use of smaller R modules may solve the square foot differences between R and D modules for invertebrates.

2. Height and volume may be important factors in the success of the M modules for fishes. However, the use of smooth concrete slabs on the sides appeared to slow colonization colonization of invertebrates. One possible solution may be found in the construction of hybrid artificial reefs that present shaded and cryptic habitat (i.e., rock construction with angular sides as in the R modules) with greater relief from the bottom and greater internal volume (as in the M modules). The hybrid design may also take height/volume considerations into account from the perspective of lessening the likelihood of damage by storm events.


INNER CAVITY
(AFTER SAND HAS
BEEN WASHED OUT)
ACCESS HOLES
G. M. SELBY & ASSOC., INC.
9500 S. DADELAND BLVD. • STE 705 • MIAMI, FL 33156 • PH. #(305) 670-2216

LITERATURE CITED

Blair, S. and B. Flynn. 1988. Sunny Isles beach restoration project: mechanical damage to the reefs adjacent to the borrow area. Metro-Dade Tech. Rept. 88-14, 18 pp. and 13 figs.

Blair, S. and B. Flynn. 1989. Biological monitoring of hard bottom reef communities off Dade County, Florida: Community description. Diving for Science '89: 9-24.

Bohnsack, J.A. 1991. Habitat structure and the design of artificial reefs. In: S.S. Bell, E.D. McCoy and H.R. Mushinsky (eds.) Habitat Structure the Physical Arrangement of Objects in Space. Chapman and Hall, New York, Pp. 412-426.

Bohnsack, J.A. and D.L. Sutherland. 1985. Artificial reef research, a review with recommendations for future priorities. Bull. Mar. Sci. 37: 11-39.

Bohnsack, J.A., D.L. Johnson and R.F. Ambrose. 1991. Ecology of artificial reef habitats and fishes. In: Artificial Habitats for Marine and Freshwater Fisheries. Academic Press, New York, Pp. 61-105.

Bortone, S.A., J.J. Kimmel and C.M. Burdick. 1989. A comparison of three methods for visually assessing reef fish communities: Time and area compensated. Northeast Gulf Sci. 10: 85-96.

Carter, J.W., W.N. Jessee, M.S. Foster and A.L. Carpenter. 1985. Management of artificial reefs designed to support natural communities. Bull. Mar. Sci. 37: 114-128.

Davis, G. 1985. Artificial structures to mitigate marina construction impacts on spiny lobster. Bull. Mar. Sci. 37: 151-156.

Ebling, A. W. and M.A. Hixon. 1991. Tropical and Temperate Reef Fishes: Comparison of Comminity Structures. In: P.F. Sale (ed.) The Ecology of Fishes on Coral Reefs. Academic Press, New York, pp. 509-563.

Edwards, A.J. and S. Clark. 1992. Rehabilitation of coral reef flats using precast concrete. Concrete 26: 16-19.

Fitzhardinge, R.C. and Bailey-Brock. 1989. Colonization of artificial reef materials by corals and other sessile organisms. Bull. Mar. Sci. 44: 567-579.

Hudson, J. H., D.M. Robbin, J. T. Tilmant and J.L. Wheaton. 1989. Building a coral reef in southeast Florida: Combining technology and aesthetics. Bull. Mar. Sci. 44: 1067-1068.

Huckel, G., R.M. Buckley and B.L. Bensen. 1989. Mitigating rocky habitat loss using artificial reefs. Bull. Mar. Sci. 44: 913-922.

Gauch, H.G., Jr. 1982. Mutivariate Analysis in Community Ecology. Cambridge University Press. New York, 298 pp.

Krebs, C. J. 1989. Ecological Methodology. Harper and Row, Publishers. New York, 654 pp.

Patton, M.L., R.S. Grove and R.F. Harman. 1985. What do natural reefs tell us about designing artificial reefs in southern California? Bull. Mar. Sci. 37: 279-298.

Pielou, E. C. 1984. The Interpretation of Ecological Data. Wiley Publ. Co., New York, 263 pp.

Randall, J.A. 1963. An analysis of fish populations of artificial and natural reefs in the Virgin Islands. Carib. J. Sci. 3: 31-46.

Randall, J.A. 1968. Caribbean Reef Fishes. T.F.H. Publ., New York, New York, 318 pp.

Raymond, W.F. 1975. Sand and coral monitoring at two artificial reefs in Florida. Shore and Beach 43: 3-10.

Rohlf, F. J. 1988. NTSYS-pc. Numerical Taxonomy and Multivariate System. Applied Biostatistics Inc., New York, 148 pp.

U.S. Fish and Wildl. Serv. 1981. Mitigation Policy. Federal Register 46(15): 7644-7663.

List of Tables for Fishes and Motile Invertebrates

Table F1. Fish and motile invertebrate data for the control sites.

Table F2. Fish and motile invertebrate data for the three module types

Table F3. Summary data for fishes at the modules and controls.

Table F4. Summary statistics of fish data for the four study site types (D, M, R, and C).

Table F5. One-way Analyses of Variance (ANOVA) for the four study site types (D, M, R, and C).

Table F6. Results of t-tests (independent samples, separate variance) comparing the average number of fishes and the average number of species in the four study site types (D, M, R, and C).

Table F7. Results of t-tests (independent samples, separate variance) comparing average number of fishes and average number of species in the four study sites (D, M, R, and C) in April and August.

Table F8. Jaccard's Similarity Coefficient based upon presence/absence data for all fish species.

Table F9. Standardized occurrence of 21 most common species ($N \geq 15$).

Table F10. Number of grunts (*Haemulon* species) and % occurrence at each of the four study sites by quarter.

Table F11. Quarter in which fish taxa were first recorded.

Table F12. Surface area of modules (D, M, R) in ft^2.

Table F13. Average numbers of individuals and species per unit area (ft^2).

Table F14. Number of fishes at each module type for species "tightly associated" with module.

Table F1. Raw data for fishes at the control sites. Sites coded by nearest module type.

SPECIES	COMMON NAME	D18	D19	D20	D21	D22	D25	D30	D34	D43	D49	D50
Aulostomus maculatus	Trumpetfish	0	0	0	0	0	0	0	0	0	0	0
Holocentrus rufus	Longspine squirrelfish	0	0	0	0	0	0	0	0	0	0	1
Epinephelus cruenatus	Graysby	0	0	0	0	0	0	0	0	0	0	0
Serranus tigrinus	Harlequin bass	0	0	0	0	1	0	0	1	0	0	0
Serranus tabacarius	Tobaccofish	0	0	0	0	·0	0	0	0	0	1	1
Hypolplectrus unicolor	Hamlets	0	0	0	0	0	0	0	0	0	0	0
Pseudupeneus maculatus	Spotted goatfish	0	0	0	0	0	2	0	0	0	0	0
Ocyurus chrysurus	Yellowtail snapper	0	0	0	0	0	0	0	0	0	0	0
Lutjanus griseus	Gray snapper	0	0	0	0	0	0	5	0	0	0	0
Anisotremus surinamensis	Black margate	0	0	0	0	0	0	0	0	0	0	0
Anisotremus virginicus	Porkfish	0	0	1	0	0	0	0	0	0	0	0
Haemulon aurolineatum	Tomtate	0	0	0	0	0	0	0	0	0	0	0
Haemulon flavolineatum	French grunt	0	0	0	0	0	0	0	0	0	0	0
Haemulon plumieri	White grunt	0	5	3	4	0	0	5	0	0	2	0
Haemulon sciurus	Bluestriped grunt	0	0	0	0	0	0	0	0	15	0	0
Equetus lanceolatus	Jacknife fish	0	0	0	0	0	0	0	0	0	0	0
Equetus acuminatus	High-hat	0	0	0	0	0	0	0	0	0	0	0
Chaetodon capistratus	Four-eye butterflyfish	0	0	0	0	0	0	0	0	0	0	0
Chaetodon sedentarius	reef butteflyfish	0	0	0	0	0	0	0	0	0	0	0
Acanthurus bahianus	Ocean surgeon	0	2	1	0	0	0	1	0	0	0	0
Acanthurus coeruleus	Blue tang	0	0	0	0	0	0	0	0	0	0	0
Pomacanthus arcuatus	Gray angelfish	0	0	0	0	0	0	0	0	0	0	0
Pomacanthus paru	French angelfish	0	0	0	0	0	0	0	0	0	0	0
Holacanthus bermudensis	Blue angelfish	0	0	0	0	0	0	0	0	0	0	0
Holacanthus tricolor	Rock beauty	0	0	0	0	0	0	0	0	0	0	0
Abudefduf saxatilis	Sergeant major	0	0	0	0	0	0	0	0	0	0	0
Chromis cynaneus	Blue chromis	0	0	0	0	0	0	0	0	0	0	0
Chromis multilineatus	Brown chromis	0	0	0	0	0	0	0	0	0	0	0
Chromis insolatus	Sunshine fish	0	0	0	0	0	0	0	1	0	0	0
Chromis scotti	Purple reeffish	0	0	0	0	0	0	0	0	1	0	0
Pomacentrus leucostictus	Beaugregory	0	0	0	0	0	0	0	0	0	0	0
Pomacentrus partitus	Bicolor damselfish	7	0	6	6	0	4	8	4	5	3	5
Pomacentrus variabilis	Cocoa damselfish	0	4	0	0	7	0	0	0	0	0	0
Bodianus pulchellus	Spotfin hogfish	0	0	0	0	0	0	0	0	0	0	0
Bodianus rufus	Spanish hogfish	0	0	0	0	0	0	0	0	0	0	0
Halichoeres garnoti	Yellowhead wrasse	0	0	0	0	0	0	0	2	0	0	0
Lachnolaimus maximus	Hogfish	0	0	0	0	0	0	0	0	1	0	0
Thalassoma bifasciatum	Bluehead wrasse	0	5	0	3	0	0	0	5	0	0	4
Scarus croicensus	Striped parrotfish	0	0	0	0	0	0	0	4	0	0	0
Scarus coeruleus	Blue parrotfish	0	0	0	0	0	0	0	0	0	0	0
Sparisoma viride	Stoplight parrotfish	0	0	0	0	0	0	0	0	0	0	0
Sparisoma aurofrenatum	Redband parrotfish	2	0	0	0	0	0	1	0	0	1	0
Gobiosoma oceanops	Neon goby	0	0	0	0	0	0	0	0	0	0	0
Monacanthus hispidus	Planehead filefish	0	0	0	0	1	0	0	0	0	0	0
Cantherhines pullus	Orangespotted filefish	0	0	0	0	1	0	0	0	0	0	0
Canthigaster rostrata	Sharpnose puffer	0	0	0	0	0	0	0	1	0	0	0
Lactophyrys quadricornis	Scrawled cowfish	0	0	0	0	0	0	0	0	0	0	0
Synodus foetens	Inshore lizardfish	1	0	0	0	0	0	0	0	0	0	0
Panulirus argus	Spiny lobster	0	0	0	0	0	0	0	0	0	0	0
NUMBER OF INDIVIDUALS		10	16	11	13	10	6	20	18	22	7	11
NUMBER OF SPECIES		3	4	4	3	4	2	5	7	4	4	4

Table F1. Raw data for fishes at the control sites. Sites coded by nearest module type.

SPECIES	COMMON NAME	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	R2
Aulostomus maculatus	Trumpetfish	0	0	0	0	0	0	0	0	0	0	0
Holocentrus rufus	Longspine squirrelfish	0	0	0	0	0	0	0	0	0	0	0
Epinephelus cruenatus	Graysby	0	0	0	0	0	0	0	0	0	0	0
Serranus tigrinus	Harlequin bass	0	0	0	0	0	0	1	0	0	1	0
Serranus tabacarius	Tobaccofish	0	0	0	0	0	0	0	0	0	0	0
Hypolplectrus unicolor	Hamlets	0	1	0	0	0	0	0	0	0	0	0
Pseudupeneus maculatus	Spotted goatfish	0	0	0	0	0	2	0	1	1	0	0
Ocyurus chrysurus	Yellowtail snapper	0	0	0	0	0	0	0	0	0	0	0
Lutjanus griseus	Gray snapper	0	0	3	0	0	0	0	0	0	5	0
Anisotremus surinamensis	Black margate	0	0	0	0	0	0	0	0	0	0	0
Anisotremus virginicus	Porkfish	0	0	1	0	0	0	0	0	0	1	0
Haemulon aurolineatum	Tomtate	0	0	0	0	0	0	0	0	0	0	0
Haemulon flavolineatum	French grunt	0	0	0	0	0	0	0	0	0	0	0
Haemulon plumieri	White grunt	3	0	0	0	0	0	0	0	0	0	3
Haemulon sciurus	Bluestriped grunt	2	0	0	0	0	0	0	0	0	0	5
Equetus lanceolatus	Jacknife fish	0	0	0	0	0	0	0	0	0	0	0
Equetus acuminatus	High-hat	0	0	0	0	0	0	0	0	0	0	0
Chaetodon capistratus	Four-eye butterflyfish	0	0	0	0	0	0	0	0	0	0	0
Chaetodon sedentarius	reef butteflyfish	0	0	0	0	0	0	0	0	2	0	0
Acanthurus bahianus	Ocean surgeon	1	2	2	0	2	0	0	2	1	1	0
Acanthurus coeruleus	Blue tang	0	0	0	0	0	0	0	0	0	0	0
Pomacanthus arcuatus	Gray angelfish	0	0	0	0	0	0	0	0	0	0	0
Pomacanthus paru	French angelfish	0	0	0	0	0	0	0	0	0	0	0
Holacanthus bermudensis	Blue angelfish	0	0	0	1	1	0	0	0	0	0	0
Holacanthus tricolor	Rock beauty	0	0	2	0	0	1	0	0	1	0	0
Abudefduf saxatilis	Sergeant major	0	0	0	0	0	0	0	0	0	0	0
Chromis cynaneus	Blue chromis	0	0	0	0	0	0	0	0	0	0	0
Chromis multilineatus	Brown chromis	0	0	0	0	0	0	0	0	0	0	0
Chromis insolatus	Sunshine fish	0	0	0	0	0	0	0	0	0	0	0
Chromis scotti	Purple reeffish	0	0	0	0	0	0	0	0	0	0	0
Pomacentrus leucostictus	Beaugregory	0	0	0	0	0	0	0	0	0	0	0
Pomacentrus partitus	Bicolor damselfish	4	4	6	4	8	7	8	4	5	6	5
Pomacentrus variabilis	Cocoa damselfish	0	0	0	0	0	0	0	0	0	0	0
Bodianus pulchellus	Spotfin hogfish	0	0	0	0	0	0	0	0	0	0	0
Bodianus rufus	Spanish hogfish	0	0	0	0	0	0	0	0	1	0	0
Halichoeres garnoti	Yellowhead wrasse	0	0	0	0	0	0	0	0	0	0	0
Lachnolaimus maximus	Hogfish	0	0	0	0	0	0	0	1	0	0	0
Thalassoma bifasciatum	Bluehead wrasse	0	5	0	0	0	0	3	0	10	0	0
Scarus croicensus	Striped parrotfish	0	0	0	0	0	0	0	0	0	0	0
Scarus coeruleus	Blue parrotfish	0	0	0	0	0	0	0	0	0	0	0
Sparisoma viride	Stoplight parrotfish	0	0	0	0	0	0	0	0	0	0	0
Sparisoma aurofrenatum	Redband parrotfish	0	2	0	4	2	0	2	0	2	2	0
Gobiosoma oceanops	Neon goby	0	0	0	0	0	0	0	0	0	0	0
Monacanthus hispidus	Planehead filefish	0	0	1	0	0	0	0	0	0	0	0
Cantherhines pullus	Orangespotted filefish	0	0	0	0	0	1	0	0	0	0	0
Canthigaster rostrata	Sharpnose puffer	1	0	0	0	0	0	0	0	0	1	0
Lactophyrys quadricornis	Scrawled cowfish	0	0	0	0	0	1	0	0	0	0	0
Synodus foetens	Inshore lizardfish	0	0	0	0	0	0	0	0	0	0	0
Panulirus argus	Spiny lobster	0	0	0	0	0	0	0	0	0	0	0
NUMBER OF INDIVIDUALS		11	14	15	9	13	12	14	8	23	17	13
NUMBER OF SPECIES		5	5	6	3	4	5	4	4	8	7	3

Table F1. Raw data for fishes at the control sites. Sites coded by nearest module type.

SPECIES	COMMON NAME	R4	R7	R14	R15	R16	R17	R21	R22	R23
Aulostomus maculatus	Trumpetfish	0	0	0	0	0	0	0	0	0
Holocentrus rufus	Longspine squirrelfish	0	0	0	0	0	0	0	0	0
Epinephelus cruenatus	Graysby	0	0	0	0	0	0	0	0	0
Serranus tigrinus	Harlequin bass	0	1	0	1	0	0	0	0	0
Serranus tabacarius	Tobaccofish	0	0	1	0	1	0	0	0	0
Hypolplectrus unicolor	Hamlets	0	0	0	0	0	0	0	0	0
Pseudupeneus maculatus	Spotted goatfish	0	0	0	0	2	0	0	0	0
Ocyurus chrysurus	Yellowtail snapper	0	0	0	0	0	0	0	0	0
Lutjanus griseus	Gray snapper	0	0	0	0	0	0	10	0	0
Anisotremus surinamensis	Black margate	0	0	0	0	0	0	0	0	0
Anisotremus virginicus	Porkfish	0	0	0	0	0	0	0	0	1
Haemulon aurolineatum	Tomtate	0	0	0	0	0	0	0	0	0
Haemulon flavolineatum	French grunt	0	0	0	0	0	0	0	0	0
Haemulon plumieri	White grunt	0	3	0	0	0	0	0	0	5
Haemulon sciurus	Bluestriped grunt	2	2	5	0	0	0	0	0	0
Equetus lanceolatus	Jacknife fish	0	0	0	0	0	0	0	0	0
Equetus acuminatus	High-hat	0	0	0	0	0	0	0	0	0
Chaetodon capistratus	Four-eye butterflyfish	0	0	0	0	0	0	0	0	0
Chaetodon sedentarius	reef butteflyfish	0	2	0	0	0	0	0	0	0
Acanthurus bahianus	Ocean surgeon	2	2	1	0	0	2	0	5	0
Acanthurus coeruleus	Blue tang	0	0	0	0	0	0	0	0	0
Pomacanthus arcuatus	Gray angelfish	0	0	0	0	0	0	2	0	0
Pomacanthus paru	French angelfish	0	0	0	0	0	0	0	0	0
Holacanthus bermudensis	Blue angelfish	0	0	0	0	0	1	0	0	0
Holacanthus tricolor	Rock beauty	0	0	0	0	0	0	1	0	0
Abudefduf saxatilis	Sergeant major	0	0	0	0	0	0	0	0	0
Chromis cynaneus	Blue chromis	0	0	0	0	0	0	0	0	0
Chromis multilineatus	Brown chromis	0	0	0	0	0	0	0	0	0
Chromis insolatus	Sunshine fish	0	0	0	0	0	0	0	0	0
Chromis scotti	Purple reeffish	0	0	0	0	0	0	0	0	0
Pomacentrus leucostictus	Beaugregory	0	0	0	0	0	0	0	0	0
Pomacentrus partitus	Bicolor damselfish	8	5	7	5	6	9	0	5	5
Pomacentrus variabilis	Cocoa damselfish	0	0	0	0	0	0	0	0	0
Bodianus pulchellus	Spotfin hogfish	0	0	0	0	0	0	0	0	0
Bodianus rufus	Spanish hogfish	0	0	0	0	0	0	0	0	0
Halichoeres garnoti	Yellowhead wrasse	0	0	1	0	0	0	0	0	0
Lachnolaimus maximus	Hogfish	0	0	0	0	0	0	0	0	0
Thalassoma bifasciatum	Bluehead wrasse	0	4	0	0	5	0	10	5	0
Scarus croicensus	Striped parrotfish	0	0	0	0	0	0	0	0	0
Scarus coeruleus	Blue parrotfish	0	0	0	0	0	0	0	0	0
Sparisoma viride	Stoplight parrotfish	0	0	0	0	0	0	0	0	0
Sparisoma aurofrenatum	Redband parrotfish	0	0	3	2	0	2	0	9	0
Gobiosoma oceanops	Neon goby	0	0	0	0	0	0	0	0	0
Monacanthus hispidus	Planehead filefish	0	0	0	0	0	0	0	0	0
Cantherhines pullus	Orangespotted filefish	0	0	0	0	0	1	1	0	0
Canthigaster rostrata	Sharpnose puffer	1	0	0	1	0	0	0	0	0
Lactophyrys quadricornis	Scrawled cowfish	0	0	0	0	0	0	0	0	0
Synodus foetens	Inshore lizardfish	0	0	0	0	0	0	0	0	0
Panulirus argus	Spiny lobster	0	0	0	0	0	0	0	0	0
NUMBER OF INDIVIDUALS		13	19	18	9	14	15	24	24	11
NUMBER OF SPECIES		4	7	6	4	4	5	5	4	3

TABLE F2. RAW DATA FOR FISHES AT MODULES.

SPECIES	COMMON NAME	D18	D19	D20	D21	D22	D25	D30	D34	D43	D49	D50
Aulostomus maculatus	Trumpetfish	0	0	0	0	0	0	0	0	0	0	0
Holocentrus rufus	Longspine squirrelfish	0	0	0	0	0	0	1	0	0	0	0
Epinephelus cruenatus	Graysby	1	0	0	0	0	0	0	0	1	0	0
Serranus tigrinus	Harlequin bass	0	0	0	0	0	0	0	0	0	0	0
Serranus tabacarius	Tobaccofish	0	0	0	0	0	0	0	0	0	0	0
Hypolplectrus unicolor	Hamlets	0	0	1	1	1	0	0	0	0	0	0
Pseudupeneus maculatus	Spotted goatfish	4	2	2	3	0	0	0	2	2	0	0
Ocyurus chrysurus	Yellowtail snapper	0	0	0	0	0	0	0	0	0	0	0
Lutjanus griseus	Gray snapper	0	0	0	0	0	0	20	0	10	3	0
Anisotremus surinamensis	Black margate	0	0	0	0	0	0	0	0	0	0	0
Anisotremus virginicus	Porkfish	2	0	0	0	0	0	0	0	2	0	0
Haemulon aurolineatum	Tomtate	0	0	0	0	0	0	0	0	0	0	0
Haemulon flavolineatum	French grunt	20	10	20	10	3	5	0	15	40	2	6
Haemulon plumieri	White grunt	75	20	10	15	5	5	0	10	30	5	5
Haemulon sciurus	Bluestriped grunt	75	10	10	10	0	4	0	10	30	3	30
Equetus lanceolatus	Jacknife fish	5	0	3	0	0	0	0	0	0	0	0
Equetus acuminatus	High-hat	1	0	1	0	0	2	0	0	1	0	0
Chaetodon capistratus	Four-eye butterflyfish	0	0	0	0	0	0	0	0	0	0	0
Chaetodon sedentarius	reef butteflyfish	0	0	2	2	2	0	2	0	0	0	0
Acanthurus bahianus	Ocean surgeon	4	0	2	5	6	0	3	0	2	0	2
Acanthurus coeruleus	Blue tang	0	0	0	0	0	0	0	0	0	0	0
Pomacanthus arcuatus	Gray angelfish	0	0	0	0	2	0	2	1	0	0	1
Pomacanthus paru	French angelfish	0	0	0	0	0	0	0	0	0	0	0
Holacanthus bermudensis	Blue angelfish	0	0	0	0	0	0	0	0	0	0	0
Holacanthus tricolor	Rock beauty	0	2	0	0	0	1	1	0	0	3	2
Abudefduf saxatilis	Sergeant major	1	0	1	1	0	2	0	0	0	0	0
Chromis cynaneus	Blue chromis	0	1	1	0	0	1	0	0	0	0	0
Chromis multilineatus	Brown chromis	0	1	0	0	0	0	0	0	0	0	0
Chromis insolatus	Sunshine fish	0	0	0	0	0	0	0	0	0	0	0
Chromis scotti	Purple reeffish	0	0	0	0	0	0	0	0	0	0	0
Pomacentrus leucostictus	Beaugregory	0	1	0	1	0	1	0	0	1	1	0
Pomacentrus partitus	Bicolor damselfish	0	0	0	0	0	0	0	3	0	0	0
Pomacentrus variabilis	Cocoa damselfish	0	0	0	0	0	0	0	0	0	0	0
Bodianus pulchellus	Spotfin hogfish	0	0	0	0	0	0	2	0	0	0	0
Bodianus rufus	Spanish hogfish	1	0	0	0	0	0	0	0	0	0	0
Halichoeres garnoti	Yellowhead wrasse	0	0	0	0	1	0	0	0	0	0	0
Lachnolaimus maximus	Hogfish	0	0	0	0	0	0	0	0	0	0	0
Thalassoma bifasciatum	Bluehead wrasse	10	0	0	0	0	0	0	7	0	0	0
Scarus croicensus	Striped parrotfish	2	0	0	0	0	0	0	0	0	0	2
Scarus coeruleus	Blue parrotfish	0	0	0	0	2	0	0	0	0	0	0
Sparisoma viride	Stoplight parrotfish	0	0	0	0	2	0	0	0	0	0	0
Sparisoma aurofrenatum	Redband parrotfish	4	0	0	5	3	0	3	0	2	2	2
Gobiosoma oceanops	Neon goby	0	0	0	0	0	0	0	0	0	0	0
Monacanthus hispidus	Planehead filefish	0	0	0	0	0	0	0	0	0	0	0
Cantherhines pullus	Orangespotted filefish	0	2	0	0	0	0	0	0	0	0	0
Canthigaster rostrata	Sharpnose puffer	1	0	0	0	0	0	2	2	2	2	1
Lactophyrys quadricornis	Scrawled cowfish	0	0	0	0	0	0	0	0	0	0	0
Synodus foetens	Inshore lizardfish	0	0	0	0	0	0	0	0	0	0	0
Panulirus argus	Spiny lobster	0	0	0	0	0	0	0	0	0	0	0
NUMBER OF FISHES		206	49	53	53	27	21	36	50	123	21	51
NUMBER OF SPECIES		15	9	11	10	10	8	9	8	12	8	9

TABLE F2. RAW DATA FOR FISHES AT THE MODULES.

SPECIES	COMMON NAME	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10
Aulostomus maculatus	Trumpetfish	0	0	0	0	0	0	0	0	0	0
Holocentrus rufus	Longspine squirrelfish	0	0	0	0	0	0	0	0	0	0
Epinephelus cruenatus	Graysby	1	0	0	0	1	0	1	2	0	1
Serranus tigrinus	Harlequin bass	0	0	0	0	0	0	0	0	0	0
Serranus tabacarius	Tobaccofish	0	0	0	0	0	0	0	0	0	0
Hypolplectrus unicolor	Hamlets	0	0	0	0	1	0	0	0	0	0
Pseudupeneus maculatus	Spotted goatfish	3	0	0	2	0	3	3	0	0	0
Ocyurus chrysurus	Yellowtail snapper	0	0	0	0	0	0	0	0	0	0
Lutjanus griseus	Gray snapper	0	2	50	50	50	80	35	50	50	100
Anisotremus surinamensis	Black margate	3	0	4	0	0	0	0	0	0	8
Anisotremus virginicus	Porkfish	12	5	0	5	10	3	0	5	5	0
Haemulon aurolineatum	Tomtate	0	0	0	0	0	50	30	0	0	60
Haemulon flavolineatum	French grunt	90	40	35	50	40	150	60	50	50	70
Haemulon plumieri	White grunt	500	80	250	200	200	100	120	150	200	70
Haemulon sciurus	Bluestriped grunt	200	80	60	400	400	400	120	250	400	0
Equetus lanceolatus	Jacknife fish	0	0	0	0	0	0	0	0	0	0
Equetus acuminatus	High-hat	2	2	0	2	0	0	0	0	1	0
Chaetodon capistratus	Four-eye butterflyfish	0	0	0	0	0	0	0	0	0	0
Chaetodon sedentarius	reef butteflyfish	0	0	0	0	0	0	0	0	0	0
Acanthurus bahianus	Ocean surgeon	0	5	3	3	0	5	4	5	3	7
Acanthurus coeruleus	Blue tang	0	0	0	0	0	1	0	0	0	0
Pomacanthus arcuatus	Gray angelfish	0	0	0	0	0	0	0	0	0	2
Pomacanthus paru	French angelfish	0	0	1	1	0	0	0	0	0	0
Holacanthus bermudensis	Blue angelfish	0	1	1	1	1	0	1	0	0	1
Holacanthus tricolor	Rock beauty	0	2	2	0	0	2	0	2	0	0
Abudefduf saxatilis	Sergeant major	2	5	3	2	1	2	2	0	3	2
Chromis cynaneus	Blue chromis	1	0	0	0	0	3	4	0	0	5
Chromis multilineatus	Brown chromis	0	1	0	0	2	1	4	0	0	2
Chromis insolatus	Sunshine fish	0	0	0	1	0	0	0	0	0	1
Chromis scotti	Purple reeffish	2	3	0	3	0	0	6	0	4	3
Pomacentrus leucostictus	Beaugregory	1	0	2	1	0	1	1	0	1	2
Pomacentrus partitus	Bicolor damselfish	0	0	0	4	0	0	0	0	2	0
Pomacentrus variabilis	Cocoa damselfish	0	0	0	0	0	0	0	0	0	0
Bodianus pulchellus	Spotfin hogfish	1	0	0	0	0	0	0	0	0	0
Bodianus rufus	Spanish hogfish	0	8	5	2	4	2	3	0	2	7
Halichoeres garnoti	Yellowhead wrasse	0	1	0	0	0	0	0	0	0	0
Lachnolaimus maximus	Hogfish	0	0	0	0	0	0	0	0	0	0
Thalassoma bifasciatum	Bluehead wrasse	5	20	7	0	0	0	0	0	0	15
Scarus croicensus	Striped parrotfish	2	3	0	1	2	2	2	1	2	2
Scarus coeruleus	Blue parrotfish	0	0	0	0	0	0	0	0	0	0
Sparisoma viride	Stoplight parrotfish	0	2	0	0	0	0	0	0	0	0
Sparisoma aurofrenatum	Redband parrotfish	0	4	0	0	5	4	5	4	0	5
Gobiosoma oceanops	Neon goby	0	0	0	0	0	0	0	1	0	0
Monacanthus hispidus	Planehead filefish	0	0	0	0	0	0	0	0	0	0
Cantherhines pullus	Orangespotted filefish	0	0	0	0	0	0	0	0	0	0
Canthigaster rostrata	Sharpnose puffer	1	0	2	1	3	2	0	2	0	0
Lactophyrys quadricornis	Scrawled cowfish	0	0	0	0	0	0	0	0	0	0
Synodus foetens	Inshore lizardfish	0	0	0	0	0	0	0	0	0	0
Panulirus argus	Spiny lobster	1	0	0	0	1	0	0	0	0	0
NUMBER OF FISHES		826	264	425	729	720	811	401	522	723	363
NUMBER OF SPECIES		16	18	14	18	14	18	17	12	13	19

TABLE F2. RAW DATA FOR FISHES AT THE MODULES.

SPECIES	COMMON NAME	R2	R4	R7	R14	R15	R16	R17	R21	R22	R23
Aulostomus maculatus	Trumpetfish	1	0	0	0	0	0	0	0	0	0
Holocentrus rufus	Longspine squirrelfish	1	0	0	0	0	0	0	0	0	0
Epinephelus cruenatus	Graysby	1	0	0	0	0	0	1	0	0	0
Serranus tigrinus	Harlequin bass	0	0	0	0	0	0	0	0	0	0
Serranus tabacarius	Tobaccofish	0	0	0	0	0	0	0	0	0	0
Hypolplectrus unicolor	Hamlets	0	0	0	1	0	0	0	0	0	0
Pseudupeneus maculatus	Spotted goatfish	4	2	2	2	2	0	4	3	0	2
Ocyurus chrysurus	Yellowtail snapper	2	0	0	0	0	0	0	0	0	0
Lutjanus griseus	Gray snapper	0	0	0	0	0	0	0	0	0	30
Anisotremus surinamensis	Black margate	0	0	0	0	0	0	0	0	0	0
Anisotremus virginicus	Porkfish	6	0	0	2	0	11	5	0	0	3
Haemulon aurolineatum	Tomtate	0	0	0	0	10	0	0	10	0	10
Haemulon flavolineatum	French grunt	60	50	50	40	20	20	40	60	30	70
Haemulon plumieri	White grunt	200	50	80	50	40	60	100	30	30	30
Haemulon sciurus	Bluestriped grunt	200	40	30	40	15	40	60	30	30	30
Equetus lanceolatus	Jacknife fish	6	0	0	0	0	0	0	0	0	0
Equetus acuminatus	High-hat	2	0	0	1	0	0	0	0	0	0
Chaetodon capistratus	Four-eye butterflyfish	0	0	0	0	2	0	0	0	0	0
Chaetodon sedentarius	reef butteflyfish	2	0	0	0	0	0	2	0	0	0
Acanthurus bahianus	Ocean surgeon	4	8	2	5	3	2	6	10	7	3
Acanthurus coeruleus	Blue tang	0	0	0	0	0	1	0	0	0	0
Pomacanthus arcuatus	Gray angelfish	0	0	0	0	0	0	0	0	0	0
Pomacanthus paru	French angelfish	0	0	0	0	0	0	0	0	0	0
Holacanthus bermudensis	Blue angelfish	0	0	0	0	0	0	0	0	0	0
Holacanthus tricolor	Rock beauty	1	0	0	0	0	2	1	0	2	0
Abudefduf saxatilis	Sergeant major	1	0	1	2	1	2	0	2	0	0
Chromis cynaneus	Blue chromis	0	1	0	0	0	0	0	7	0	0
Chromis multilineatus	Brown chromis	0	0	0	0	1	2	0	0	2	0
Chromis insolatus	Sunshine fish	0	0	0	0	0	0	0	0	0	0
Chromis scotti	Purple reeffish	4	1	0	0	0	0	5	3	4	2
Pomacentrus leucostictus	Beaugregory	0	0	1	0	0	0	0	1	1	0
Pomacentrus partitus	Bicolor damselfish	0	0	0	0	0	0	0	0	5	3
Pomacentrus variabilis	Cocoa damselfish	0	0	0	0	0	0	0	0	0	0
Bodianus pulchellus	Spotfin hogfish	0	0	0	0	0	0	0	0	0	0
Bodianus rufus	Spanish hogfish	0	2	1	0	0	4	3	4	8	3
Halichoeres garnoti	Yellowhead wrasse	0	1	0	0	0	1	0	0	0	0
Lachnolaimus maximus	Hogfish	0	0	0	0	0	0	0	0	1	0
Thalassoma bifasciatum	Bluehead wrasse	4	20	0	0	0	10	15	0	15	5
Scarus croicensus	Striped parrotfish	0	2	0	2	0	2	0	2	2	0
Scarus coeruleus	Blue parrotfish	0	0	0	0	0	0	0	0	0	1
Sparisoma viride	Stoplight parrotfish	0	0	0	0	1	0	1	0	0	0
Sparisoma aurofrenatum	Redband parrotfish	0	4	0	0	2	0	4	5	10	2
Gobiosoma oceanops	Neon goby	0	0	0	0	0	0	0	0	0	0
Monacanthus hispidus	Planehead filefish	0	0	0	0	0	0	0	0	0	0
Cantherhines pullus	Orangespotted filefish	0	0	1	0	0	0	0	0	0	0
Canthigaster rostrata	Sharpnose puffer	0	0	1	2	2	0	2	1	1	0
Lactophyrys quadricornis	Scrawled cowfish	0	0	0	0	0	0	0	0	0	0
Synodus foetens	Inshore lizardfish	0	0	0	0	0	0	0	0	0	0
Panulirus argus	Spiny lobster	0	0	7	0	0	0	1	0	0	1
NUMBER OF FISHES		499	181	169	147	99	157	249	168	148	194
NUMBER OF SPECIES		17	12	10	11	12	13	15	14	15	14

TABLE F3. SUMMARY DATA FOR FISHES AT MODULES AND CONTROLS.

SPECIES	COMMON NAME	CODE	D	M	R	C	TOTAL
Aulostomus maculatus	Trumpetfish	AULm	0	0	1	0	1
Holocentrus rufus	Longspine squirrelfish	HOLr	1	0	1	1	3
Epinephelus cruenatus	Graysby	EPIc	2	6	2	0	10
Serranus tigrinus	Harlequin bass	SERt	0	0	0	6	6
Serranus tabacarius	Tobaccofish	SERt	0	0	0	4	4
Hypolplectrus unicolor	Hamlets	HYPu	3	1	1	1	6
Pseudupeneus maculatus	Spotted goatfish	PSEm	15	11	21	8	55
Ocyurus chrysurus	Yellowtail snapper	OCYc	0	0	2	0	2
Lutjanus griseus	Gray snapper	LUTg	33	467	30	23	553
Anisotremus surinamensis	Black margate	ANIs	0	15	0	0	15
Anisotremus virginicus	Porkfish	ANIv	4	45	27	4	80
Haemulon aurolineatum	Tomtate	HAEa	0	140	30	0	170
Haemulon flavolineatum	French grunt	HAEf	131	635	440	0	1206
Haemulon plumieri	White grunt	HAEp	180	1870	670	33	2753
Haemulon sciurus	Bluestriped grunt	HAEs	182	2310	515	31	3038
Equetus lanceolatus	Jacknife fish	EQUl	8	0	6	0	14
Equetus acuminatus	High-hat	EQUa	5	7	3	0	15
Chaetodon capistratus	Four-eye butterflyfish	CHAc	0	0	2	0	2
Chaetodon sedentarius	reef butteflyfish	CHAs	8	0	4	4	16
Acanthurus bahianus	Ocean surgeon	ACAb	24	35	50	27	136
Acanthurus coeruleus	Blue tang	ACAc	0	1	1	0	2
Pomacanthus arcuatus	Gray angelfish	POMa	6	2	0	2	10
Pomacanthus paru	French angelfish	POMp	0	2	0	0	2
Holacanthus bermudensis	Blue angelfish	HOLb	0	6	0	3	9
Holacanthus tricolor	Rock beauty	HOLt	9	8	6	5	28
Abudefduf saxatilis	Sergeant major	ABUs	5	22	9	0	36
Chromis cynaneus	Blue chromis	CHRc	3	13	8	0	24
Chromis multilineatus	Brown chromis	CHRm	1	10	5	0	16
Chromis insolatus	Sunshine fish	CHRi	0	2	0	1	3
Chromis scotti	Purple reeffish	CHRs	0	21	19	1	41
Pomacentrus leucostictus	Beaugregory	POMl	5	9	3	0	17
Pomacentrus partitus	Bicolor damselfish	POMp	3	6	8	159	176
Pomacentrus variabilis	Cocoa damselfish	POMv	0	0	0	11	11
Bodianus pulchellus	Spotfin hogfish	BODp	2	1	0	0	3
Bodianus rufus	Spanish hogfish	BODr	1	33	25	1	60
Halichoeres garnoti	Yellowhead wrasse	HALg	1	1	2	3	7
Lachnolaimus maximus	Hogfish	LACm	0	0	1	2	3
Thalassoma bifasciatum	Bluehead wrasse	THAb	17	47	69	59	192
Scarus croicensus	Striped parrotfish	SCAc	4	17	10	4	35
Scarus coeruleus	Blue parrotfish	SCAc	2	0	1	0	3
Sparisoma viride	Stoplight parrotfish	SPAv	2	2	2	0	6
Sparisoma aurofrenatum	Redband parrotfish	SPAa	21	27	27	34	109
Gobiosoma oceanops	Neon goby	GOBo	0	1	0	0	1
Monacanthus hispidus	Planehead filefish	MONh	0	0	0	2	2
Cantherhines pullus	Orangespotted filefish	CANp	2	0	1	4	7
Canthigaster rostrata	Sharpnose puffer	CANr	10	11	9	5	35
Lactophyrys quadricornis	Scrawled cowfish	LACq	0	0	0	1	1
Synodus foetens	Inshore lizardfish	SYNf	0	0	0	1	1
Panulirus argus	Spiny lobster	PANa	0	2	9	0	11
NUMBER OF FISHES			690	5784	2011	440	8924
NUMBER OF SPECIES			30	33	35	29	10

Table F4. Summary statistics of fish data for the four study site types (D, M, R, and C)

MODULE	N	Diversity Index H	Total # fish	Range	Total # species	Range	Most common species	
D	11	0.95	690	21 to 206	30	8 to 15	*Haemulon spp*	n = 493
							Lutjanus griseus	n = 33
							Acanthurus bahianus	n = 24
							Sparisoma aurofrenatum	n = 21
M	10	0.70	5784	264 to 827	33	12 to 19	*Haemulon spp*	n = 495
							Lutjanus griseus	n = 467
							Thalassoma bifasciatum	n = 47
							Anisotremus virginicus	n = 45
R	10	0.84	2011	99 to 499	35	10 to 17	*Haemulon spp*	n = 165
							Thalassoma bifasciatum	n = 69
							Acanthurus bahianus	n = 50
							Lutjanus griseus	n = 30
C	31	1.01	440	6 to 24	29	2 to 8	*Pomacentrus partitus*	n = 159
							Thallasoma bifasciatum	n = 59
							Sparisoma aurofrenatum	n = 34
							Haemulon plumieri	n = 33

Module	N	$\bar{X}$ of fish per modul	s.e.	$\bar{X}$ species per modul	s.e.
D	11	62.73	17.42	9.91	0.67
M	10	578.60	68.79	15.9	0.82
R	10	202.00	37.00	13.30	0.70
C	31	14.19	0.89	4.52	0.25

TABLE F5. One-way Analysis of Variance for the four study site types (D, M, R, and C) for fish data.

Number of fishes:

Source	df	Sum of Squares	Mean Squares	F-value	p
Between	3	2517409	839136	92.58	<0.001
Within	58	525703	9063		

The calculated F-value indicates that there are significant differences among the means of the populations ($p<0.001$).

Number of species:

Source	df	Sum of Squares	Mean Squares	F-value	p
Between	3	1288	430	126.05	<0.001
Within	58	197	3		

The calculated F-value indicates that there are significant differences among the means of the populations ($p<0.001$).

Table F6. Results of t-tests (independent samples, separate variance) comparing mean number of fishes and mean number of species in the four study sites (D, M, R, and C).

Mean Number of Fishes:

Sites	df	t	p	
D vs M	19	-7.661	<0.001	M higher
D vs R	19	-3.580	0.002	R higher
M vs R	18	5.080	<0.001	M higher
D vs C	40	2.920	0.006	D higher
M vs C	39	8.648	<0.001	M higher
R vs C	39	5.336	<0.001	R higher

Mean Number of Species:

Sites	df	t	p	
D vs M	19	-5.937	<0.001	M higher
D vs R	19	-3.670	0.002	R higher
M vs R	18	2.531	0.020	M higher
D vs C	40	7.863	<0.001	D higher
M vs C	39	13.886	<0.001	M higher
R vs C	39	12.328	<0.001	R higher

Table F7. Results of ANOVA comparing mean number of fishes and mean number of species in the four study sites (D, M, R, and C) in August '93 and January '94.

Mean Number of Fishes:

Sites	df	F	p	
D modules	1, 19	0.032	0.836	
M modules	1, 18	5.413	0.034	(Recent sampling higher)
R modules	1, 18	2.79	0.109	
C sites	1, 59	0.162	0.691	

Mean Number of Species:

Sites	df	t	p	
D modules	1, 19	13.894	0.002	(Recent sampling lower)
M modules	1, 18	0.672	0.428	
R modules	1, 18	6.542	0.019	(Recent sampling lower)
C sites	1, 59	0.844	0.365	

Table F8. Jaccard's Coefficient of Similarity for Fishes. Formula for calculating coefficient is [a/(a+b+c)]. Site codes: D = D modules; M = M modules; R = R modules; C = control sites.

	D vs. M	D vs. R	M vs. R	D vs. C	M vs. C	R vs. C
# spp present at both sites (a)	25	28	26	19	19	20
# spp present at first site only (b)	5	2	7	11	14	15
# spp present at second site only (c)	9	7	9	10	10	9
Cumulative Number of Spp. (a+b+c)	39	37	42	40	43	44
Jaccard's Coefficient [a/(a+b+c)]	0.640	0.760	0.620	0.475	0.442	0.455

Table F9. Standardized occurrence of most common fishes (N≥15).

SPECIES	COMMON NAME	CODE	D	M	R	C
Pseudupeneus maculatus	Spotted goatfish	PSEm	2.2	0.2	1.0	1.8
Lutjanus griseus	Gray snapper	LUTg	4.8	8.1	1.5	5.2
Anisotremus surinamensis	Black margate	ANIs	0.0	0.3	0.0	0.0
Anisotremus virginicus	Porkfish	ANIv	0.6	0.8	1.3	0.9
Haemulon aurolineatum	Tomtate	HAEa	0.0	2.4	1.5	0.0
Haemulon flavolineatum	French grunt	HAEf	19.0	11.0	21.9	0.0
Haemulon plumieri	White grunt	HAEp	26.1	32.3	33.3	7.5
Haemulon sciurus	Bluestriped grunt	HAEs	26.4	39.9	25.6	7.0
Equetus acuminatus	High-hat	EQUa	0.7	0.1	0.1	0.0
Chaetodon sedentarius	reef butteflyfish	CHAs	1.2	0.0	0.2	0.9
Acanthurus bahianus	Ocean surgeon	ACAb	3.5	0.6	2.5	6.1
Holacanthus tricolor	Rock beauty	HOLt	1.3	0.1	0.3	1.1
Abudefduf saxatilis	Sergeant major	ABUs	0.7	0.4	0.4	0.0
Chromis cynaneus	Blue chromis	CHRc	0.4	0.2	0.4	0.0
Chromis multilineatus	Brown chromis	CHRm	0.1	0.2	0.2	0.0
Chromis scotti	Purple reeffish	CHRs	0.0	0.4	0.9	0.2
Pomacentrus leucostictus	Beaugregory	POMl	0.7	0.2	0.1	0.0
Pomacentrus partitus	Bicolor damselfish	POMp	0.4	0.1	0.4	36.1
Pomacentrus variabilis	Cocoa damselfish	POMv	0.0	0.0	0.0	2.5
Bodianus rufus	Spanish hogfish	BODr	0.1	0.6	1.2	0.2
Thalassoma bifasciatum	Bluehead wrasse	THAb	2.5	0.8	3.4	13.4
Scarus croicensus	Striped parrotfish	SCAc	0.6	0.3	0.5	0.9
Sparisoma aurofrenatum	Redband parrotfish	SPAa	3.0	0.5	1.3	7.7
Canthigaster rostrata	Sharpnose puffer	CANr	1.4	0.2	0.4	1.1
% OF TOTAL NUMBER OF FISHES INCLUDED			95.8	99.6	98.9	93.0
% OF TOTAL NUMBER OF SPECIES INCLUDED			66.7	66.7	62.9	59.3

Table F10. Occurrence of grunts (Haemulon species) at each of the four study site types by quarter. Occurrence is presented as total number of grunts at the site type and as % of total number of fishes at the site type.

Quarter		D	M	R	C
1	# Grunts	9	29	87	0
	% Total	6%	7.7%	19.7%	0%
2	# Grunts	12	87	114	97
	% Total	7%	20.2%	28%	19.1%
3	# Grunts	26	88	256	47
	% Total	13.1%	13.6%	38.1%	6.6%
4	# Grunts	19	123	191	173
	% Total	6.8%	18.3%	26.5%	24%
5	# Grunts	272	616	1220	65
	% Total	56%	47.9%	75.6%	9.7%
6	# Grunts	722	1504	1339	17
	% Total	77.6%	70.4%	83.5%	5.1%
7	# Grunts	345	3475	1033	32
	% Total	58%	89.9%	73.8%	7.3%
8	# Grunts	493	4955	1656	64
	% Total	71.5%	85.6%	82.3%	14.5%

Table F11. Quarter in which fish taxa were first recorded at the modules (D,M,R) and controls (C).

Genus/species	D	M	R	C
Ginglymostoma cirratum	---	4	1	---
Urolophus jamaicensis	---	---	---	1
Gymnothorax funebris	---	5	1	2
Synodus intermedius	---	---	---	2
Aulostomus maculatus	1	1	1	3
Holocentrus	2	2	5	2
Priacanthus arenatus	---	---	---	1
Rypticus maculatus	---	2	---	---
Epinephelus cruentatus	1	1	1	1
Epinephelus morio	1	1	2	---
Mycteroperca microlepis	---	1	---	---
Mycteroperca phenax	3	4	3	---
Serranus tigrinus	---	2	2	1
Serranus tabacarius	2	---	---	1
Hypoplecturus unicolor	1	1	1	2
Pseudupeneus maculatus	2	2	1	2
Seriola dumerili	7	7	4	4
Seriola zonata	---	2	---	---
Caranx bartholomaei	5	---	5	3
Caranx ruber	1	2	3	5
Ocyurus chrysurus	1	1	1	4
Lutjanus analis	1	1	5	7
Lutjanus buccanella	---	---	4	---
Lutjanus griseus	1	1	1	5
Lutjanus synagris	---	1	1	---
Diplodus holbrooki	---	1	---	5
Anistoremus surinamensis	---	1	2	---
Anisotremus virginicus	1	1	1	4
Haemulon flavolineatum	3	3	3	---
Haemulon plumieri	1	1	1	3
Haemulon sciurus	3	1	1	3
Equetus lanceolatus	1	2	1	---
Equetus punctatus	---	5	---	---
Equetus acuminatus	1	1	2	---
Chaetodon ocellatus	1	1	1	5
Chaetodon capistratus	5	4	4	7
Chaetodon sedentarius	1	1	1	1
Acanthurus bahianus	1	1	1	1
Acanthurus coeruleus	1	1	1	3
Acanthurus randalli	7	---	---	---
Chaetodipterus faber	4	1	3	---
Pomacanthus arcuatus	1	2	1	2
Pomacanthus paru	1	1	2	1
Holacanthus bermeudensis	2	2	1	1
Holacanthus ciliaris	1	1	3	3
Holacanthus tricolor	1	1	1	1
Abudefduf saxatilis	2	1	2	---
Chromis cyaneus	2	2	5	2
Chromis multilineatus	5	4	4	5
Chromis insolatus	4	2	3	8

Table F11. Quarter in which fish taxa were first recorded at the modules (D,M,R) and controls (C).

Genus/species	D	M	R	C
Chromis scotti	1	2	1	5
Pomacentrus leucostictus	5	6	6	1
Pomacentrus partitus	1	1	1	1
Pomacentrus variabilis	3	3	3	5
Bodianus pulchellus	7	4	---	---
Bodianus rufus	2	1	1	2
Halichoeres garnoti	1	2	1	2
Lachnolaimus maximus	1	1	1	3
Thalassoma bifasciatum	1	1	1	1
Scarus croicensus	3	3	4	6
Sparisoma viride	2	4	4	3
Sparisoma aurofrenatum	1	1	1	1
Echeneis neucratoides	---	---	1	---
Gobiosoma oceanops	---	5	---	---
Scorpaena plumieri	---	6	2	2
Monacanthus hispidus	3	2	6	4
Balistes capriscus	3	1	3	3
Balistes betula	4	4	1	---
Cantherhines pullus	1	1	1	1
Diodon holacanthus	---	---	---	2
Canthigaster rostrata	1	1	1	1
Lactophrys quadricornis	3	6	2	2
Lactophrys triqueter	---	5	4	2
Scyllarus spp	---	7	---	---
Synodus foetens	---	---	---	8
Gymnothorax moringa	7	---	---	3
Serranus baldwini	---	---	---	3
Spoerhoides spengleri	6	---	3	---
Clepticus parrai	5	6	6	-
Apogon spp	-	5	-	-
Haemulon aurolineatum	6	6	6	-
Scarus coeruleus	8	6	8	-
Calamus leucostis	6	-	-	-
Kyphosusspe spp	-	6	-	-
Scarus taeniopterus	-	6	-	-
Haliochoeres bivitatus	6	-	-	-
CUMULATIVE NUMBER OF SPECIES	62	71	64	56

Table F12. Surface area of each module type (D, M, R) in sq.ft.

	D	M	R
Surface Area (ft2) of module	28	130.5	160
Void Space (ft3) of module	7.1	71.6	12
Area/Volume of module	3.9	1.8	13.3
Area (ft2) sampled per module	28.0	130.5	160.0
% Area sampled per module	100%	100%	100%
Number of modules sampled	11	10	10

Table F13. Average numbers of individuals and species per unit area sampled (sq.ft.).

Site Type	$\bar{X}$ of individuals per ft2	Std. err.	$\bar{X}$ of species per ft2	Std. err.
D	2.24	0.593	0.354	0.023
M	4.43	0.500	0.122	0.006
R	1.26	0.220	0.083	0.004

Table F14. Number of fishes at each module type for those species defined as "tightly associated" with module by dive team.

Species		D	M	R	C
Epinephelus cruentatus	Graysby	2	6	2	0
Hypoplecturus unicolor	Hamlet	3	1	1	1
Anisotremus surinamensis	Black margate	0	15	0	0
Equetus lanceolatus	Jack-knife fish	8	0	6	0
Equetus acuminatus	High-hat	5	7	3	0
Holacanthus tricolor	Rock beauty	9	8	6	5
Abudefduf saxatilis	Sergeant major	5	22	9	0
Chromis cyaneus	Blue chromis	3	13	8	0
Chromis multilineatus	Brown chromis	1	10	5	0
Chromis insolatus	Sunshine fish	0	2	0	1
Chromis scottis	Purple reeffish	0	21	19	1
Bodianus rufus	Spanish hogfish	1	33	25	1
	Total	37	138	84	9
	# modules	11	10	10	31
	# Fish/module	3.36	13.80	8.40	0.29

Fish/module per sq.ft. after correcting for surface area

0.12 0.11 0.053

List of Figures for Fishes and Motile Invertebrates

Figure F1.	Cluster of the four study site types based upon standardized occurence the 21 most common fishes ($N \geq 15$, *Haemulon* species group together).
Figure F2.	Cluster of the taxa based upon the standardized occurence of the 21 most common fishes (*Haemulon* species grouped together), labelled by taxa abbreviations.
Figure F3.	Plot of the first three Principal Components for the 21 most common fish species (*Haemulon* species grouped together) found at the four study site types, labelled by taxa abbreviations.
Figure F4.	Plot of the average numbers of individuals at each of the four study site types by quarter.
Figure F5.	Plot of the average numbers of species at each of the four study site types for by quarter.
Figure F6.	Plot of the cumulative number of species recorded for each of the four study site types by quarter (rarefaction curve).
Figure F7.	Plot of the Shannon-Weiner Diversity Index (H) at each of the four study site types by quarter.
Figure F8.	Cluster of the 21 most common fish taxa and the 22 most common invertebrate taxa (codes followed by *), based upon standardized occurrence, labelled by taxa abbreviations.
Figure F9.	PCA of the 21 most common fish taxa and the 22 most common invertebrate taxa, based upon standardized occurrence, labelled by taxa abbreviations. Codes for the invertebrate taxa are followed by *.
Figure F10.	Average number of fishes per ft^2.
Figure F11.	Average number of species per ft^2.

Fig. F1. Cluster of sites based upon most common fishes

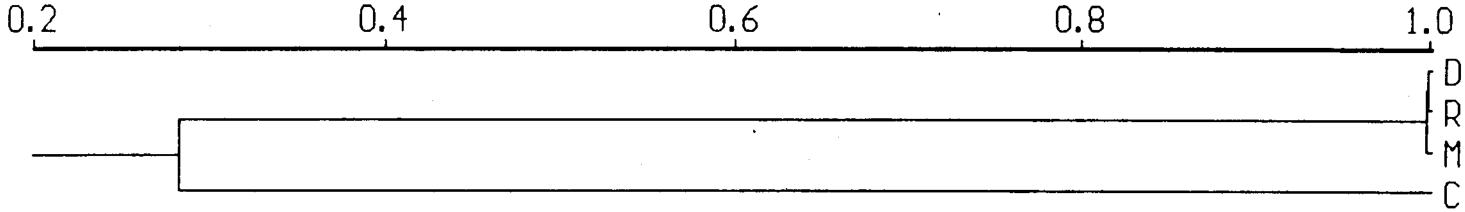


Figure F2. Cluster of 21 most common fish taxa.

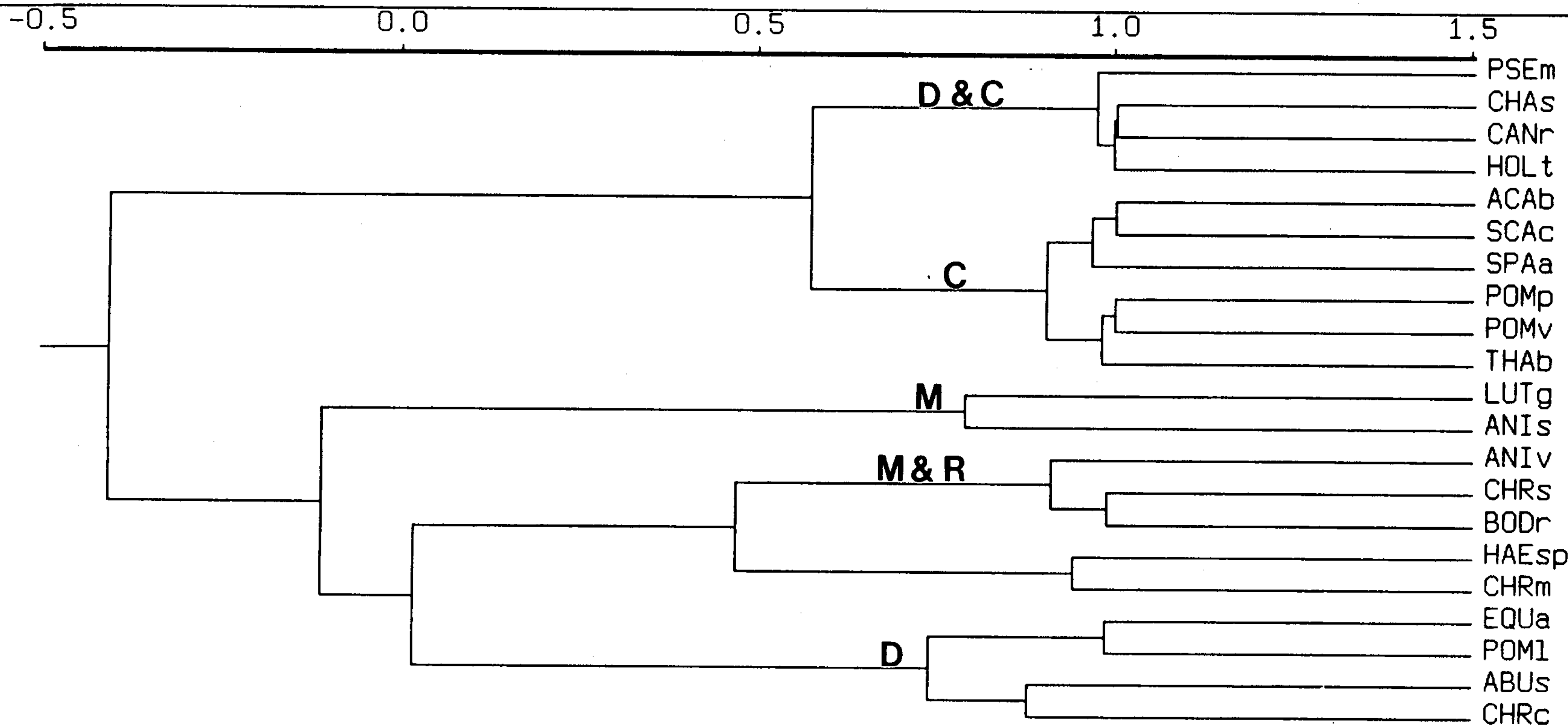


Figure F3. PCA of 21 most common fish taxa.

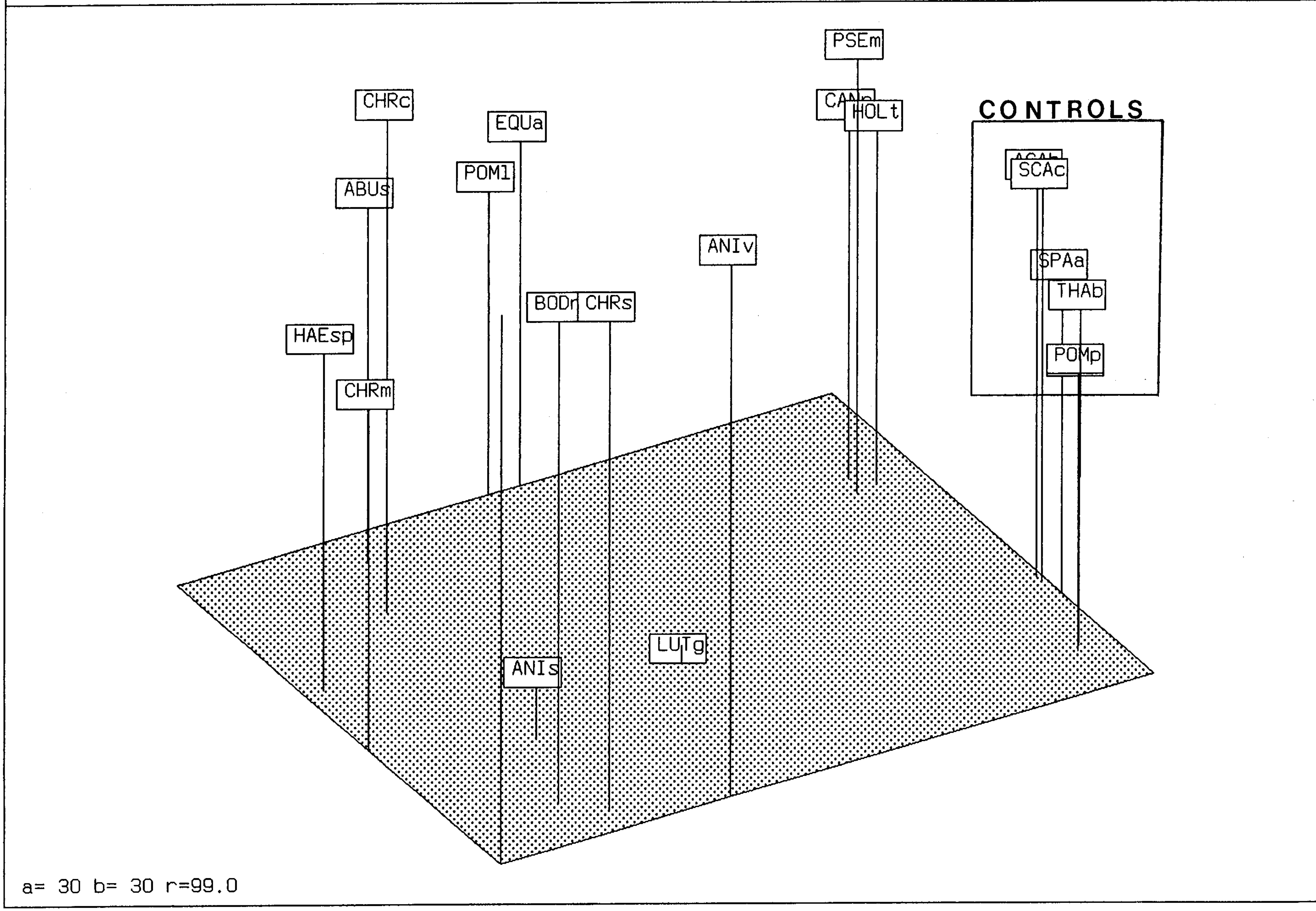


Figure F4 Average number of individuals four study sites by quarter.

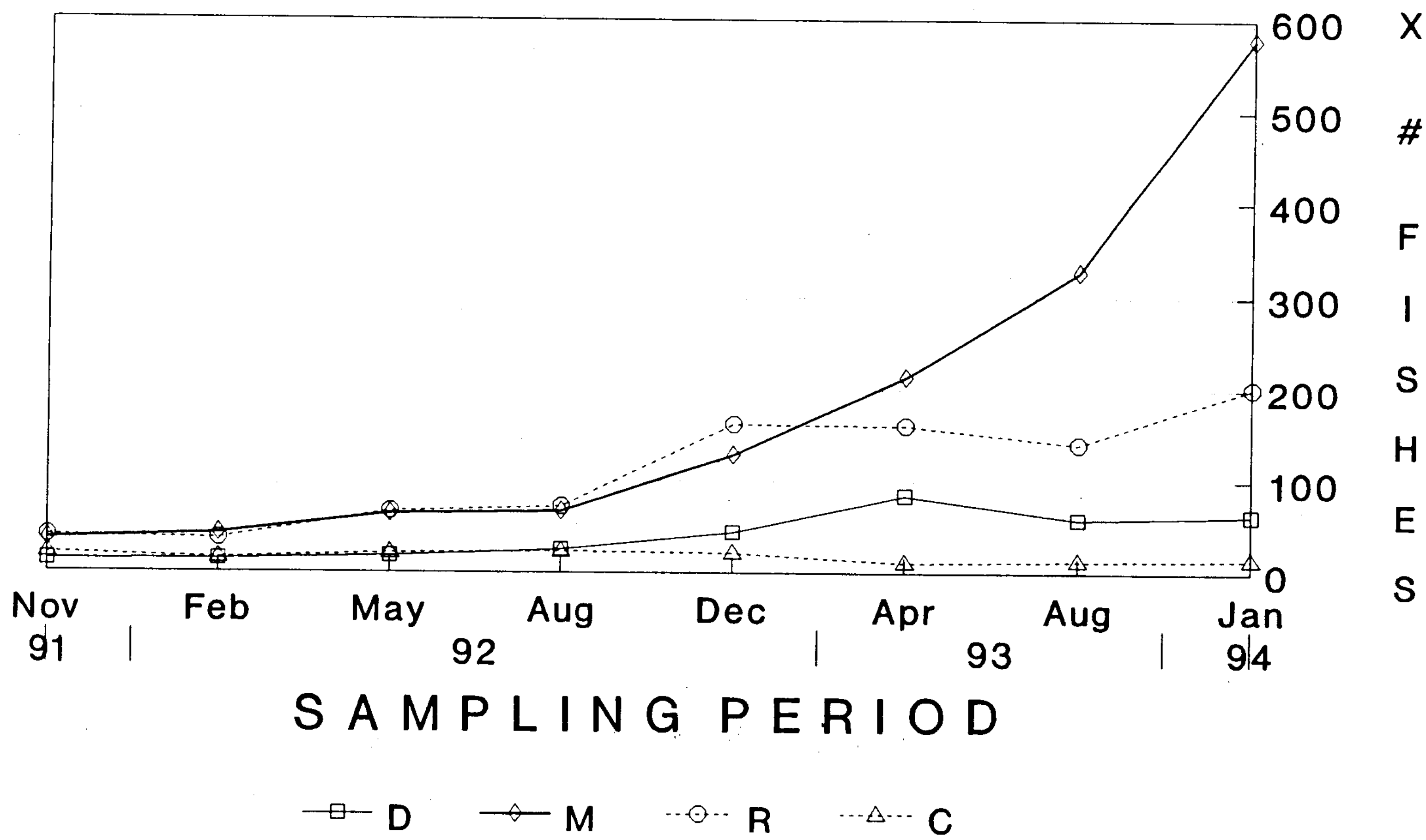


Figure F5 Average number of species four study sites by quarter.

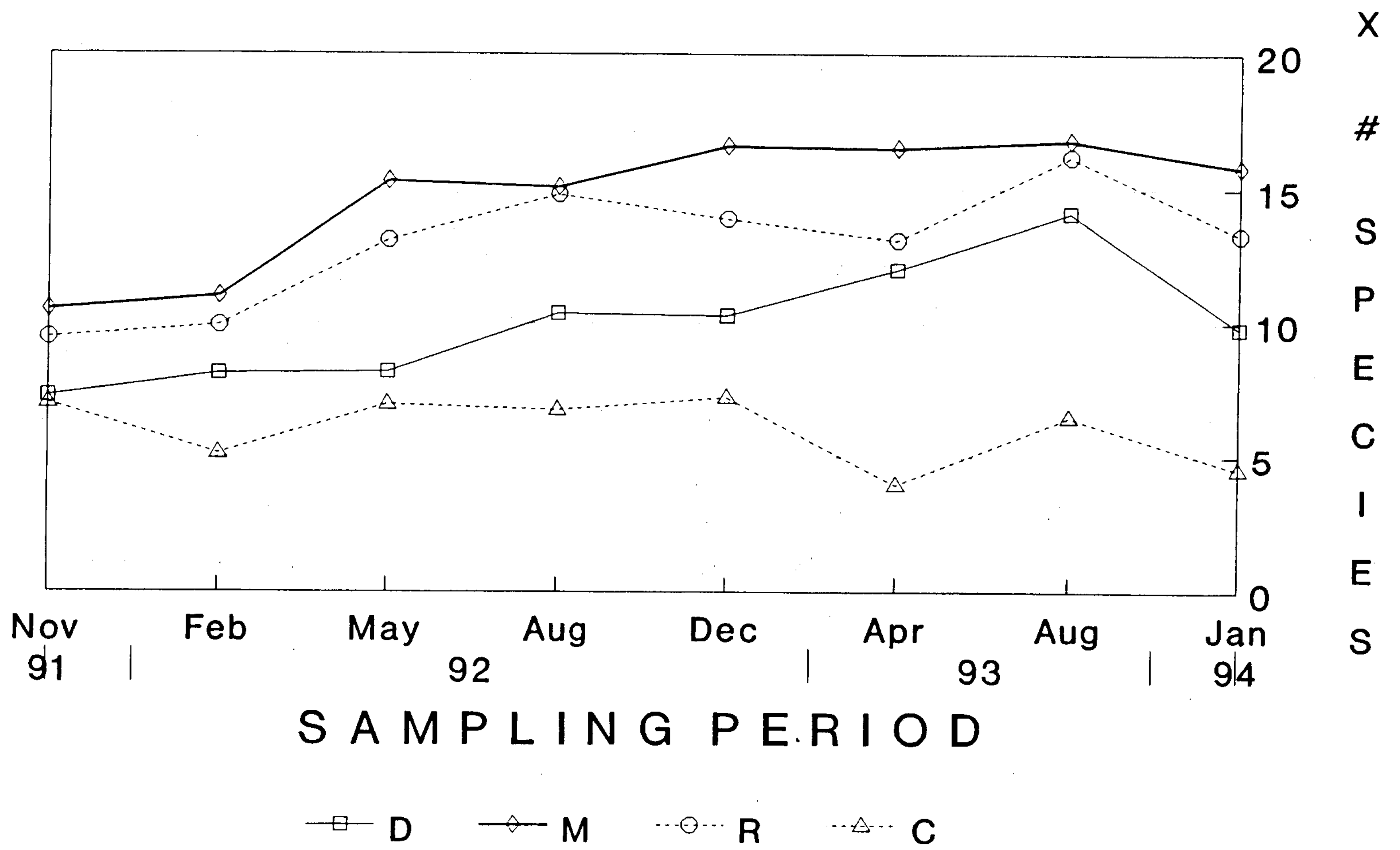


Figure F6. Rarefaction curve for the cumulative number of fish taxa.

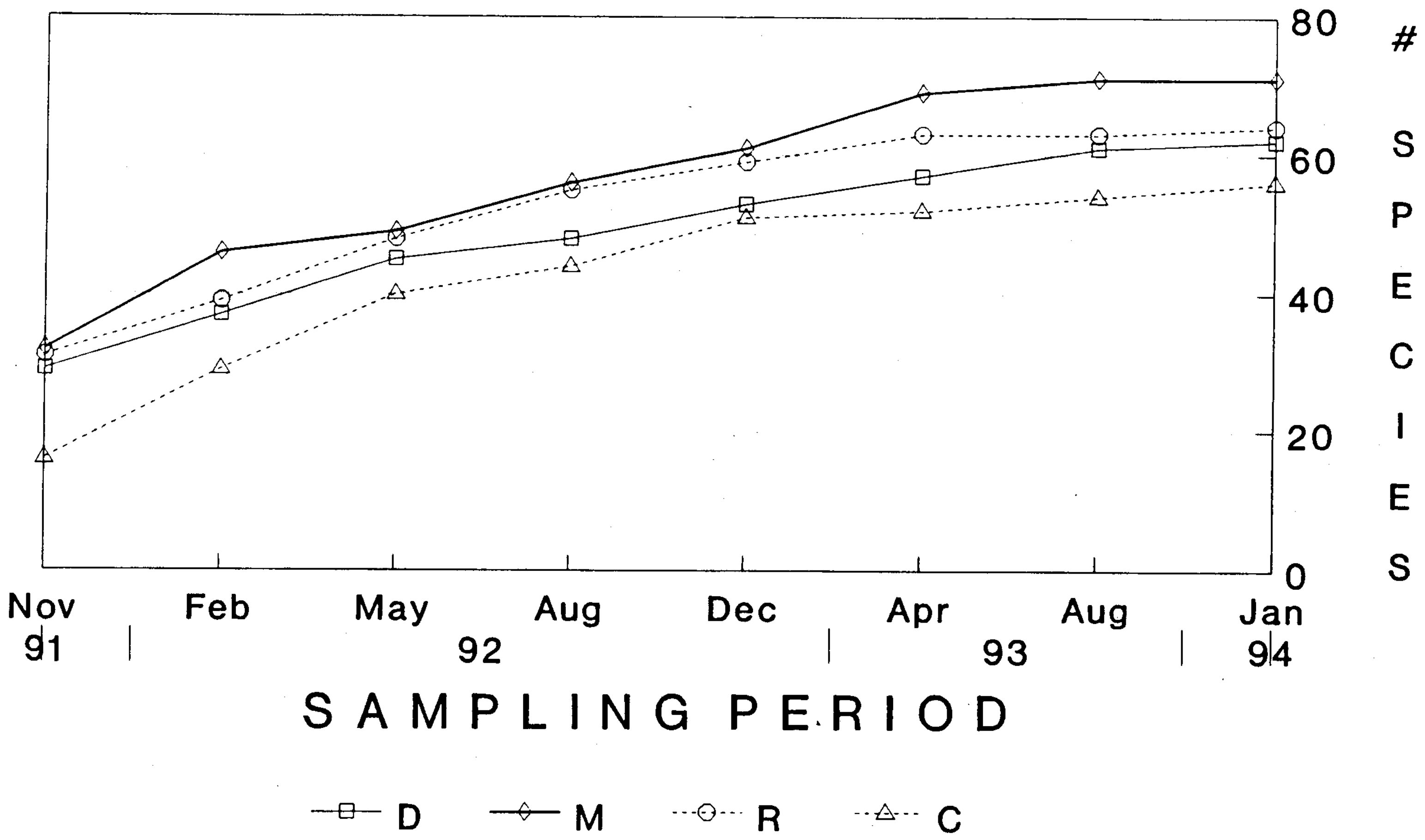


Figure F7 Shannon-Weiner diversity index (H) for fishes by quarter

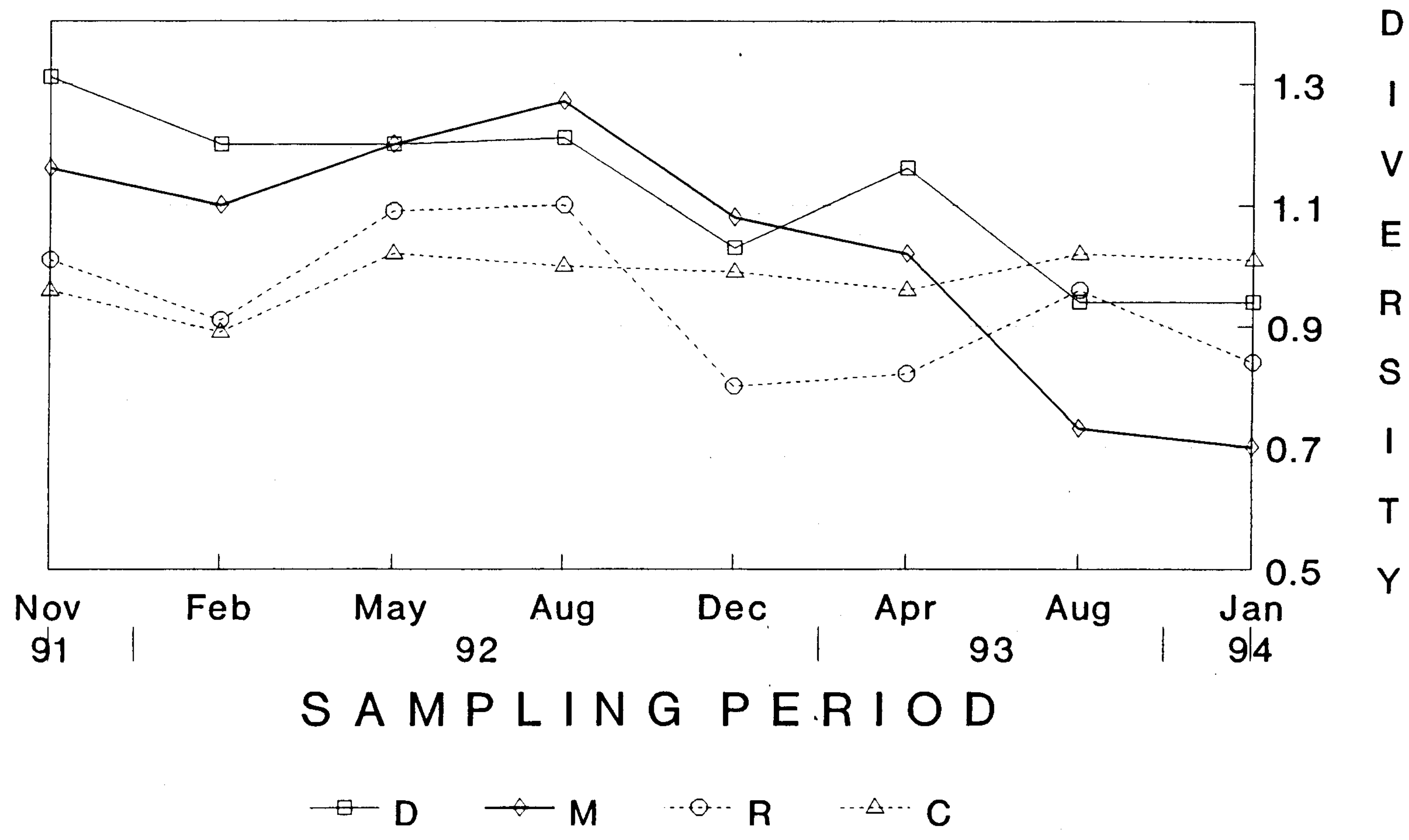


Figure F8. Cluster of 44 fish and invertebrate taxa.

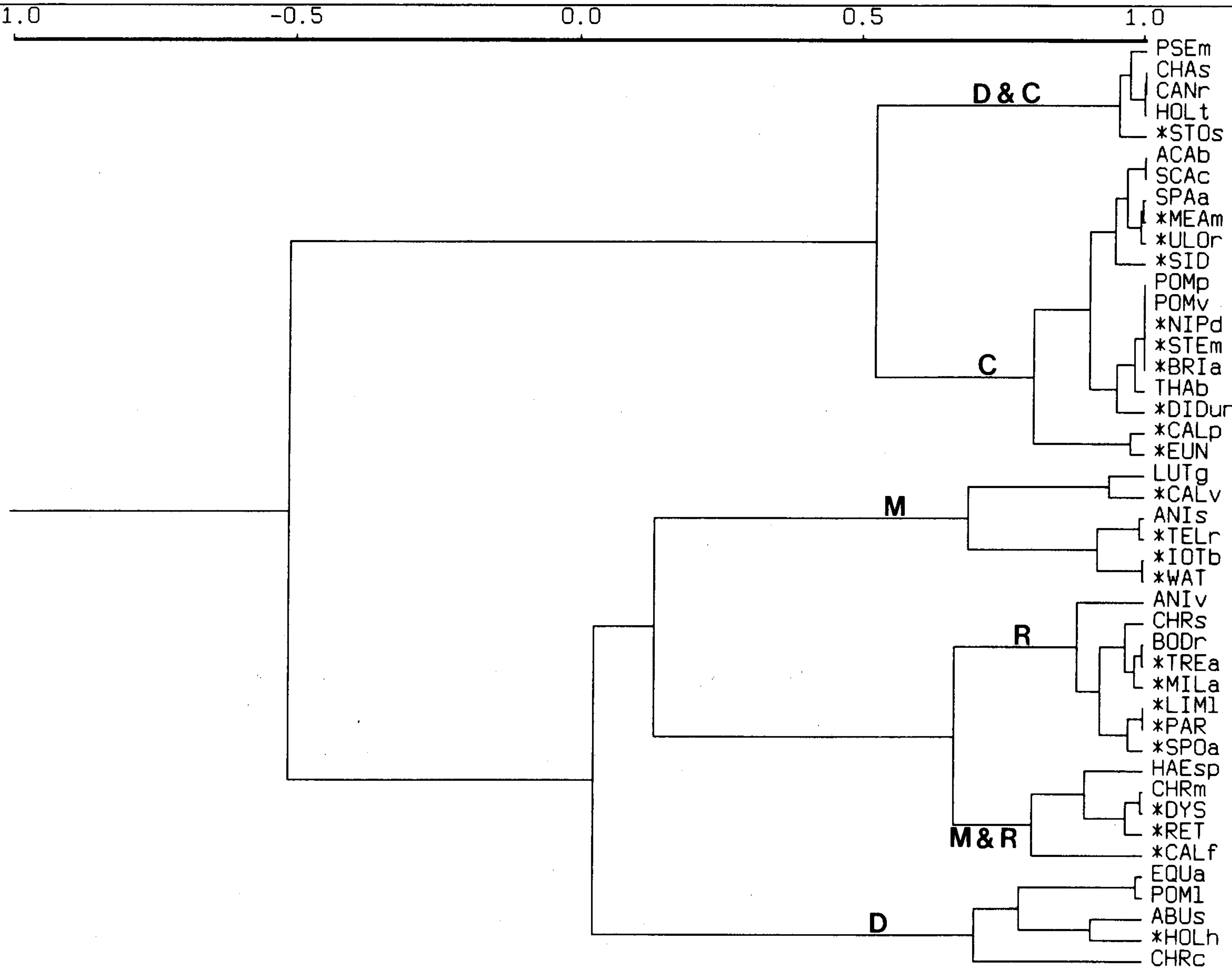


Fig. F9. PCA of 44 fish and invertebrate taxa.

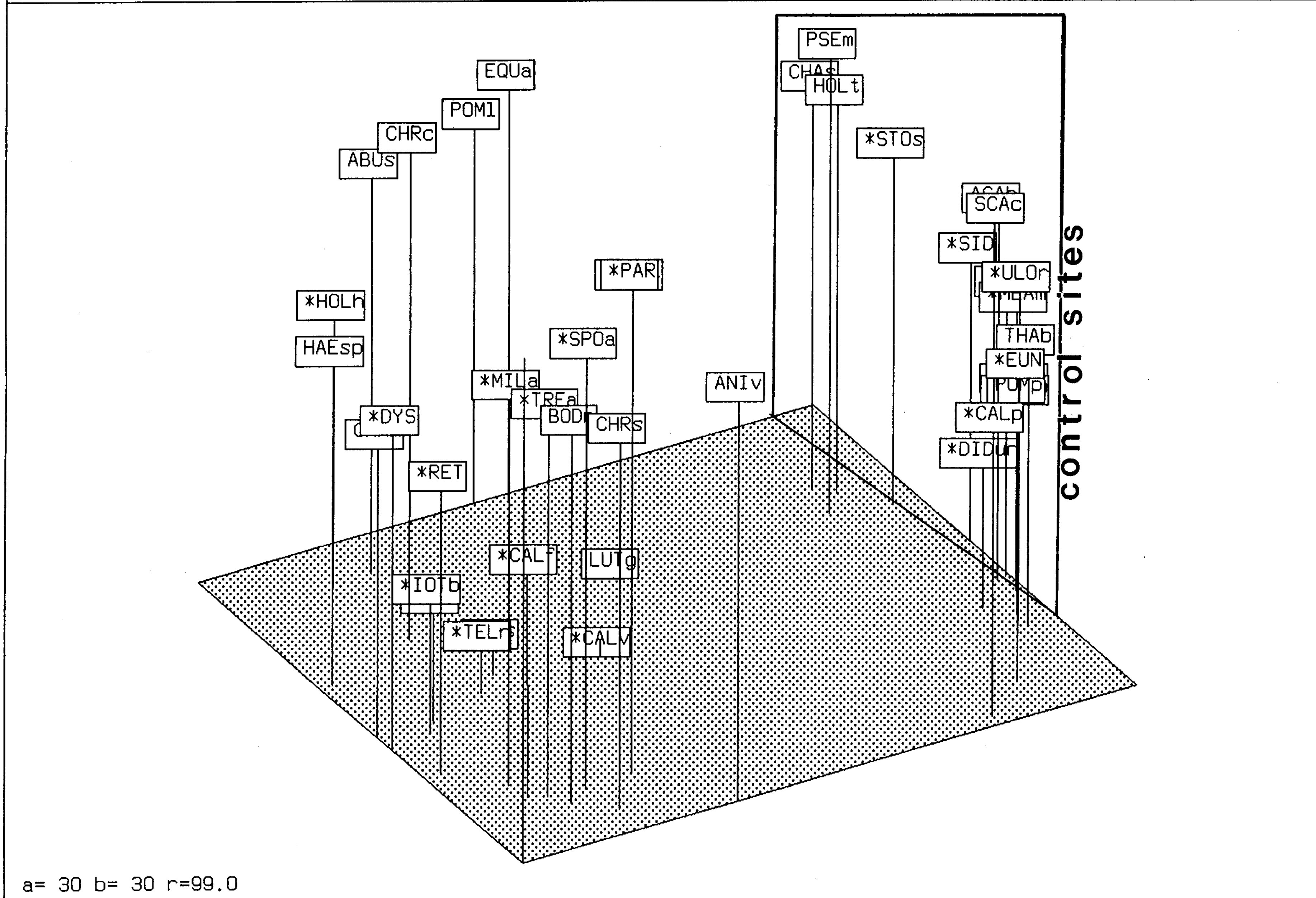
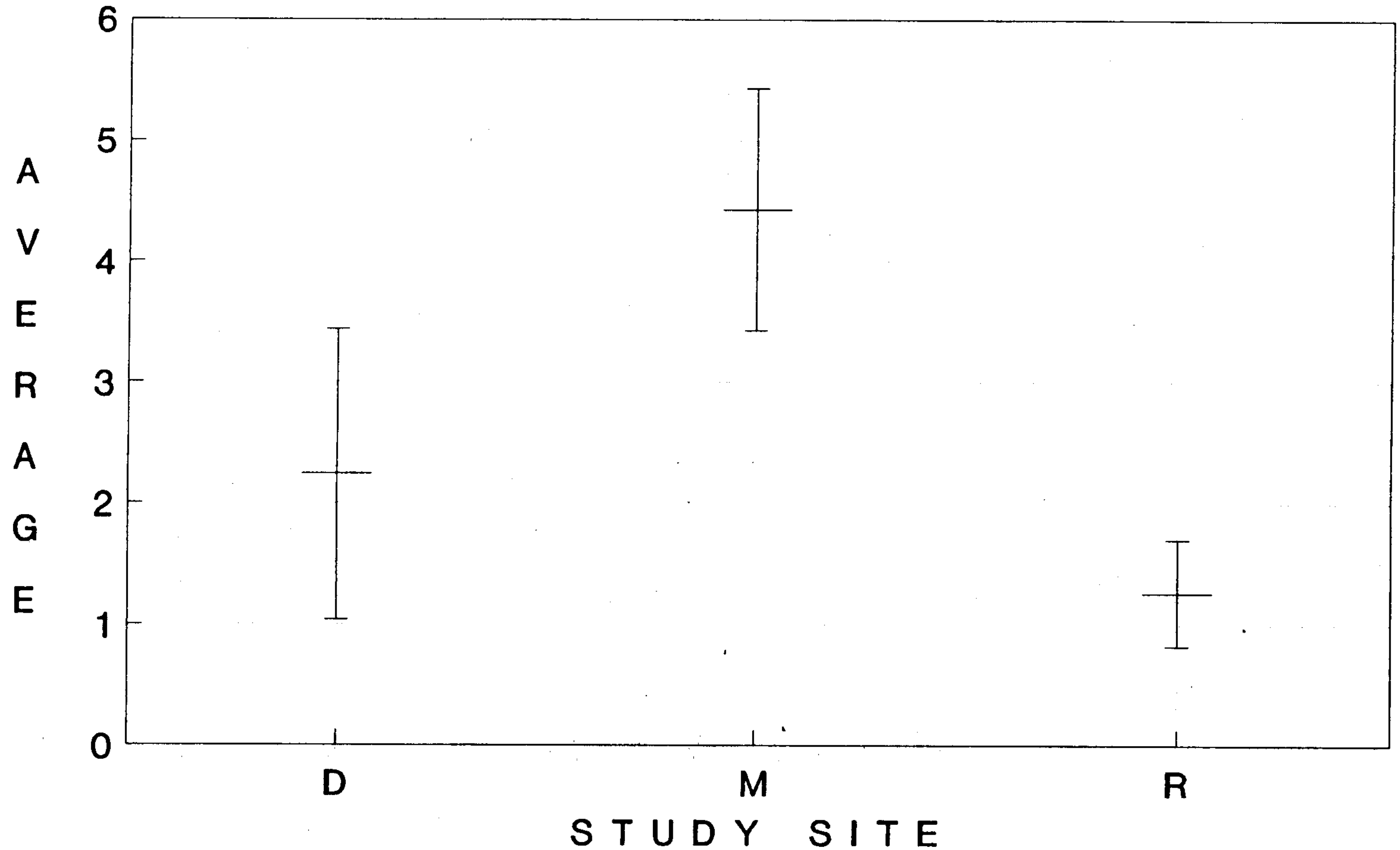
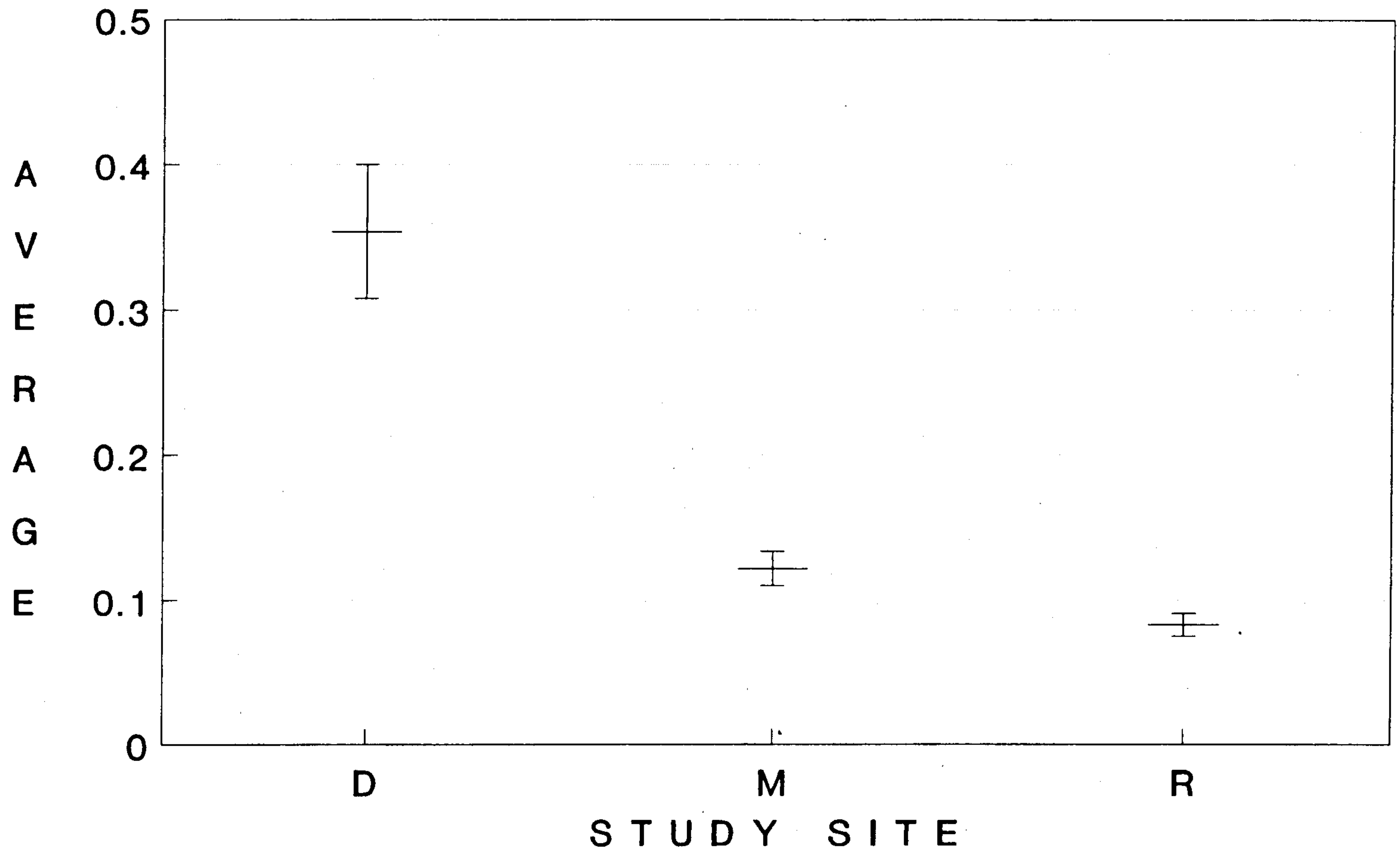


Figure F10. Average number of fishes per sq.ft +/- 2 Std.err.



If error bars do not overlap, means are significantly different.

Figure F11. Average number of species per sq.ft +/- 2 Std.err.



If error bars do not overlap, means are significantly different.

List of Tables for Plants and Sessile Invertebrates

Table I1. Raw data for benthic invertebrates at modules and barren controls.

Table I2. Summary of benthic invertebrate data for the four study site types.

Table I3. Summary statistics of benthic invertebrate data for the four study sites (D, M, R, & BC).

Table I4. One-way Analysis of Variance for the four study site types (D, M, R, and BC).

Table I5. Results of t-tests (independent samples, separate variance) comparing average number of individuals in the four study sites (D, M, R, & BC).

Table I6. Jaccard's Similarity Coefficient based upon presence/absence data for all invertebrate species.

Table I7. Results of ANOVA's comparing average number of individuals and average number of species in the four study sites (D, M, R, and BC) in August and January.

Table I8. Standardized invertebrate data for modules and barren control sites.

Table I9. Quarter in which benthic invertebrate taxa were first recorded.

Table I10. Raw data from 1st quarter sampling (November 1991) of undamaged reef areas. Each quadrat 0.38 m^2.

Table I11. Summary statistics of benthic invertebrate data from undamaged part of reef (collected November 1991). 52 quadrats were sampled along a 20 m transect. Each quadrat was 0.38 m^2, for a total area sampled of 19.8 m^2.

Table I12. Surface area of each module type (D, M, R), Barren Control quadrats (BC) and the Undamaged Reef quadrats (UR; sampled in November, 1991) in ft^2.

Table I13. Average numbers of individuals and species per unit area (ft^2).

TABLE I1. RAW DATA FOR BENTHIC INVERTEBRATES AT MODULES AND BARREN CONTROLS.

SPECIES	CODE	D18	D19	D20	D21	D22	D25	D30	D34	D43	D49	D50	M1	M2	M3	M4
Agaricia sp	AGAsp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aplysina cauliformis	APLc	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ascidia nigra	ASCn	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0
Briareum asbestinum	BRIa	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Callyspongia fallax	CALf	0	0	1	0	0	0	0	0	1	1	0	9	1	0	3
Callyspongia plicifera	CALp	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Callyspongia vaginalis	CALv	0	1	3	0	1	3	0	3	1	1	0	0	4	2	2
Dasychalina cyathina	DASc	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dichocoenia stokesii	DICs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dictyota sp.	DICsp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Didemnid unid.	DIDunid	1	0	1	0	0	0	0	0	1	0	0	0	0	1	1
Dysidea etheria	DYSe	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Dysidea sp.	DYSsp	4	2	1	2	4	3	3	0	5	4	11	13	15	9	3
Echinometra lucunter	ECHI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eucidaris sp.	EUCsp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eunicea sp.	EUNsp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eusmilia fastigiata	EUSf	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Haliclona rubens	HALr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Holopsamma helwigi	HOLh	20	20	20	20	20	20	18	19	20	20	20	20	20	17	20
Iotrochota birotulata	IOTb	0	0	0	2	0	0	1	1	0	1	0	6	5	3	4
Leucosolenia sp.	LEUsp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lima lima	LIMI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Meandrina meandrites	MEAm	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Melanostigma nigromaculata	MELn	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Millepora alcicornis	MILa	1	1	3	2	1	1	2	1	1	0	0	20	5	0	1
Montastrea annularis	MONa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Montastrea cavernosa	MONc	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mycale sp.	MYCsp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Niphates digitalis	NIPd	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Niphates erecta	NIPe	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Niphates sp.	NIPsp	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
Panulirus argus	PANa	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Parasmittina sp.	PARsp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Porites sp.	PORsp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Reteporellina sp.	RETsp	0	0	0	0	1	0	0	0	0	0	0	3	0	0	0
Siderastrea sidera	SIDs	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
Siderastrea sp.	SIDsp	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spirastrella coccinea	SPIc	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spondylus americanus	SPOa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sponge unid.	SPONG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stenopus hispidus	STEh	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0
Stenorhynchus seticornis	STEs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stephanocoenia michelini	STEm	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stolonica sabulosa	STOs	4	8	20	20	5	3	20	20	20	0	20	0	2	0	3
Telesto riisei	TELr	0	0	0	0	0	0	0	0	0	0	0	2	5	0	0
Trematooecia aviculifera	TREa	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Udotea sp.	UDOsp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ulosa reutzleri	ULOr	0	0	1	1	2	0	0	0	1	0	0	0	1	0	0
Verongia longissima	VERI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Watersipora sp.	WATsp	0	0	0	0	1	0	0	0	0	0	0	0	0	1	1
Xestospongia muta	XESm	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NUMBER INDIVIDUALS		32	33	50	47	39	32	44	45	51	27	51	76	59	34	39
NUMBER SPECIES		7	6	8	6	11	7	5	6	9	5	3	9	10	7	10

TABLE I1. RAW DATA FOR BENTHIC INVERTEBRATES AT MODULES AND BARREN CONTROLS.

SPECIES	CODE	M5	M7	M8	M9	M10	R2	R4	R5	R7	R14	R15	R16	R17	R21	R22
Agaricia sp	AGAsp	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Aplysina cauliformis	APLc	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ascidia nigra	ASCn	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Briareum asbestinum	BRIa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Callyspongia fallax	CALf	1	0	0	1	1	8	4	1	3	1	0	0	0	2	1
Callyspongia plicifera	CALp	0	1	0	0	0	0	0	1	0	0	0	1	0	0	0
Callyspongia vaginalis	CALv	5	2	3	0	1	0	0	1	0	1	2	1	1	3	2
Dasychalina cyathina	DASc	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dichocoenia stokesii	DICs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dictyota sp.	DICsp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Didemnid unid.	DIDunid	2	0	0	0	0	0	0	0	1	0	0	0	1	0	0
Dysidea etheria	DYSe	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dysidea sp.	DYSsp	1	15	0	5	3	20	20	1	3	9	2	12	17	10	7
Echinometra lucunter	ECHl	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Eucidaris sp.	EUCsp	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0
Eunicea sp.	EUNsp	0	0	0	0	0	0	0	2	0	1	0	2	0	0	0
Eusmilia fastigiata	EUSf	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Haliclona rubens	HALr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Holopsamma helwigi	HOLh	20	15	20	19	20	9	0	20	20	11	20	20	20	10	20
Iotrochota birotulata	IOTb	6	4	2	0	1	0	0	4	0	5	4	1	8	0	1
Leucosolenia sp.	LEUsp	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Lima lima	LIMl	0	0	0	0	0	4	3	3	1	6	4	1	3	3	2
Meandrina meandrites	MEAm	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Melanostigma nigromaculata	MELn	0	0	0	0	0	0	0	1	0	0	0	0	0	2	0
Millepora alcicornis	MILa	0	1	1	2	1	4	20	20	0	0	20	1	1	1	20
Montastrea annularis	MONa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Montastrea cavernosa	MONc	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mycale sp.	MYCsp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Niphates digitalis	NIPd	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Niphates erecta	NIPe	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Niphates sp.	NIPsp	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Panulirus argus	PANa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Parasmittina sp.	PARsp	0	0	0	0	0	6	3	3	0	0	0	0	0	0	0
Porites sp.	PORsp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Reteporellina sp.	RETsp	0	0	0	0	0	0	0	1	0	0	0	0	3	0	0
Siderastrea sidera	SIDs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Siderastrea sp.	SIDsp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spirastrella coccinea	SPIc	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spondylus americanus	SPOa	0	0	0	0	1	1	1	0	1	2	2	0	0	0	0
Sponge unid.	SPONG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stenopus hispidus	STEh	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stenorhynchus seticornis	STEs	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Stephanocoenia michelini	STEm	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stolonica sabulosa	STOs	0	0	1	0	0	10	6	1	0	3	0	7	0	0	0
Telesto riisei	TELr	3	0	0	0	2	0	0	0	0	0	1	0	1	0	0
Trematooecia aviculifera	TREa	0	0	0	0	0	0	0	2	0	0	2	0	0	0	0
Udotea sp.	UDOsp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ulosa reutzleri	ULOr	0	0	0	0	0	0	1	1	0	2	0	0	0	0	0
Verongia longissima	VERl	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Watersipora sp.	WATsp	0	0	0	2	2	0	0	0	2	0	1	0	1	0	0
Xestospongia muta	XESm	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
NUMBER INDIVIDUALS		38	38	27	29	32	63	59	62	32	42	59	48	57	33	54
NUMBER SPECIES		7	6	5	5	9	9	9	15	8	11	11	11	11	9	8

TABLE I1. RAW DATA FOR BENTHIC INVERTEBRATES AT MODULES AND BARREN CONTROLS.

SPECIES	CODE	R23	BC3	BC8	BC14	BC19	BC20	BC21	BC27	BC30	BC37	BC39
Agaricia sp	AGAsp	0	0	0	0	0	0	0	0	0	0	0
Aplysina cauliformis	APLc	0	0	0	0	0	0	0	0	0	2	0
Ascidia nigra	ASCn	1	0	0	0	0	0	0	0	0	0	0
Briareum asbestinum	BRIa	0	1	0	0	2	0	0	0	3	0	0
Callyspongia fallax	CALf	4	0	0	0	1	0	0	0	0	0	1
Callyspongia plicifera	CALp	1	0	0	0	0	0	0	0	1	0	0
Callyspongia vaginalis	CALv	2	1	1	2	0	0	0	0	0	1	0
Dasychalina cyathina	DASc	0	1	1	2	0	0	0	0	0	0	0
Dichocoenia stokesii	DICs	0	1	1	2	0	0	0	0	0	0	0
Dictyota sp.	DICsp	0	0	0	0	1	0	0	0	0	0	0
Didemnid unid.	DIDunid	0	4	0	0	0	0	0	0	0	0	0
Dysidea etheria	DYSe	0	0	0	0	0	0	0	0	0	0	0
Dysidea sp.	DYSsp	4	0	0	0	0	0	0	0	0	0	0
Echinometra lucunter	ECHI	0	0	0	0	0	0	0	0	0	0	0
Eucidaris sp.	EUCsp	1	0	0	0	0	0	0	0	0	0	0
Eunicea sp.	EUNsp	0	0	0	0	2	0	0	0	0	1	0
Eusmilia fastigiata	EUSf	0	0	0	2	0	0	0	0	0	0	0
Haliclona rubens	HALr	0	1	0	0	0	0	0	0	1	0	0
Holopsamma helwigi	HOLh	20	0	1	1	1	2	4	5	1	0	2
Iotrochota birotulata	IOTb	0	0	0	0	0	0	0	0	0	0	0
Leucosolenia sp.	LEUsp	0	0	0	0	0	0	0	0	0	0	0
Lima lima	LIMI	2	0	0	0	0	0	0	0	0	0	0
Meandrina meandrites	MEAm	0	0	0	1	0	0	0	0	1	0	0
Melanostigma nigromaculata	MELn	0	0	0	0	0	0	0	0	0	0	0
Millepora alcicornis	MILa	2	0	0	0	0	0	0	0	0	1	0
Montastrea annularis	MONa	0	0	1	0	0	0	0	0	0	0	0
Montastrea cavernosa	MONc	0	0	1	0	0	0	0	0	0	0	0
Mycale sp.	MYCsp	0	0	0	0	1	0	0	0	0	0	0
Niphates digitalis	NIPd	0	2	2	1	1	1	1	3	0	2	0
Niphates erecta	NIPe	0	0	0	1	0	0	0	0	0	0	0
Niphates sp.	NIPsp	0	0	0	0	0	0	0	0	0	0	0
Panulirus argus	PANa	0	0	0	0	0	0	0	0	0	0	0
Parasmittina sp.	PARsp	0	0	0	0	0	0	0	0	0	0	0
Porites sp.	PORsp	0	0	0	0	0	0	0	0	0	0	0
Reteporellina sp.	RETsp	1	0	0	0	0	0	0	0	0	0	0
Siderastrea sidera	SIDs	0	1	0	0	0	0	0	0	0	0	0
Siderastrea sp.	SIDsp	0	0	1	0	0	0	0	0	0	0	0
Spirastrella coccinea	SPIc	0	0	0	1	0	0	0	0	0	0	0
Spondylus americanus	SPOa	0	0	0	0	0	0	0	0	0	0	0
Sponge unid.	SPONG	0	3	0	0	0	0	0	0	0	0	0
Stenopus hispidus	STEh	0	0	0	0	0	0	0	0	0	0	0
Stenorhynchus seticornis	STEs	0	0	0	0	0	0	0	0	0	0	0
Stephanocoenia michelini	STEm	0	0	4	0	0	0	0	0	0	1	0
Stolonica sabulosa	STOs	0	0	1	10	1	1	10	1	3	1	20
Telesto riisei	TELr	0	0	0	0	0	0	0	0	0	0	0
Trematooecia aviculifera	TREa	0	0	0	0	0	0	0	0	0	0	0
Udotea sp.	UDOsp	0	0	0	0	0	0	0	1	0	0	1
Ulosa reutzleri	ULOr	1	2	0	0	0	0	0	0	1	0	1
Verongia longissima	VERI	0	0	2	0	0	1	0	0	0	0	0
Watersipora sp.	WATsp	0	0	0	0	0	0	0	0	0	0	0
Xestospongia muta	XESm	0	0	0	0	0	0	0	0	0	0	0
NUMBER INDIVIDUALS		39	17	16	23	10	5	15	10	11	9	25
NUMBER SPECIES		11	10	11	10	8	4	3	4	7	7	5

TABLE I2. SUMMARY DATA FOR BENTHIC INVERTEBRATES AT MODULES AND BARREN CONTROLS.

SPECIES	CODE	D	M	R	BC	TOTAL
Agaricia sp	AGAsp	0	0	1	0	1
Aplysina cauliformis	APLc	0	0	0	2	2
Ascidia nigra	ASCn	1	1	2	0	4
Briareum asbestinum	BRIa	1	0	0	6	7
Callyspongia fallax	CALf	3	16	24	2	45
Callyspongia plicifera	CALp	1	1	3	1	6
Callyspongia vaginalis	CALv	13	19	13	5	50
Dasychalina cyathina	DASc	0	0	0	4	4
Dichocoenia stokesii	DICs	0	0	0	4	4
Dictyota sp.	DICsp	0	0	0	1	1
Didemnid unid.	DIDunid	3	4	2	4	13
Dysidea etheria	DYSe	1	0	0	0	1
Dysidea sp.	DYSsp	39	64	105	0	208
Echinometra lucunter	ECHI	0	0	1	0	1
Eucidaris sp.	EUCsp	0	0	4	0	4
Eunicea sp.	EUNsp	0	0	5	3	8
Eusmilia fastigiata	EUSf	0	0	0	2	2
Haliclona rubens	HALr	0	0	0	2	2
Holopsamma helwigi	HOLh	217	171	170	17	575
Iotrochota birotulata	IOTb	5	31	23	0	59
Leucosolenia sp.	LEUsp	0	0	1	0	1
Lima lima	LIMI	0	0	32	0	32
Meandrina meandrites	MEAm	2	0	1	2	5
Melanostigma nigromaculata	MELn	0	0	3	0	3
Millepora alcicornis	MILa	13	31	89	1	134
Montastrea annularis	MONa	0	0	0	1	1
Montastrea cavernosa	MONc	0	0	0	1	1
Mycale sp.	MYCsp	0	0	0	1	1
Niphates digitalis	NIPd	0	0	0	13	13
Niphates erecta	NIPe	0	0	0	1	1
Niphates sp.	NIPsp	0	2	1	0	3
Panulirus argus	PANa	0	1	0	0	1
Parasmittina sp.	PARsp	0	0	12	0	12
Porites sp.	PORsp	0	1	0	0	1
Reteporellina sp.	RETsp	1	3	5	0	9
Siderastrea sidera	SIDs	2	0	0	1	3
Siderastrea sp.	SIDsp	1	0	0	1	2
Spirastrella coccinea	SPIc	0	0	0	1	1
Spondylus americanus	SPOa	0	1	7	0	8
Sponge unid.	SPONG	0	0	0	3	3
Stenopus hispidus	STEh	2	0	0	0	2
Stenorhynchus seticornis	STEs	0	0	1	0	1
Stephanocoenia michelini	STEm	0	0	0	5	5
Stolonica sabulosa	STOs	140	6	27	48	221
Telesto riisei	TELr	0	12	2	0	14
Trematooecia aviculifera	TREa	0	1	4	0	5
Udotea sp.	UDOsp	0	0	0	2	2
Ulosa reutzleri	ULOr	5	1	5	4	15
Verongia longissima	VERI	0	0	0	3	3
Watersipora sp.	WATsp	1	6	4	0	11
Xestospongia muta	XESm	0	0	1	0	1
NUMBER INDIVIDUALS		451	372	548	141	1512
NUMBER SPECIES		19	19	28	29	51

TABLE I3. Summary statistics of benthic invertebrate data for the four study site types (D, M, R, BC).

MODULE	N	Diversity Index H	Total # indiv.	Range	Total # species	Range	Most common species	
D	11	0.64	451	27 to 51	19	3 to 11	*Holopsamma helwigi*	n=217
							Stolonica sabulosa	n=140
							Dysidea sp	n=39
							Callyspongia vaginalis	n=13
							Millepora alcicornis	n=13
M	9	0.80	372	27 to 76	19	5 to 10	*Holopsamma helwigi*	n=171
							Dysidea spp	n=64
							Iotrochota birotulata	n=31
							Millepora alcicornis	n=31
R	11	0.97	548	32 to 63	28	8 to 15	*Holopsamma helwigi*	n=170
							Dysidea spp	n=105
							Millepora alcicornis	n=89
							Lima lima	n=32
BC	10	1.12	141	3 to 25	29	3 to 11	*Stolinoca sabulosa*	n=48
							Holopsamma helwigi	n=17
							Niphates digitalis	n=13
							Briareum asbestinum	n=6

Module	N	$\bar{X}$ of indiv. per modul	s.e.	$\bar{X}$ species per modul	s.e.
D	11	41.00	2.73	6.64	0.68
M	9	41.33	5.65	7.56	0.71
R	11	49.82	3.67	10.23	0.63
BC	10	14.10	2.12	6.90	0.95

TABLE 14. One-way Analysis of Variance for the four study site types (D, M, R, and BC) for benthic invertebrate data.

Number of individuals:

Source	df	Sum of Squares	Mean Squares	F-value	p
Between	3	7395	2465	20.21	<0.001
Within	37	4512	122		

The calculated F-value indicates that there are significant differences among the means of the populations ($p<0.001$).

Number of species:

Source	df	Sum of Squares	Mean Squares	F-value	p
Between	3	91	30	5.821	0.003
Within	37	191	5		

The calculated F-value indicates that there are significant differences among the means of the populations ($p<0.0003$).

Table I5. Results of t-tests (independent samples, separate variance) comparing mean number of individuals in the four study sites (D, M, R, and BC).

Mean Number of Individuals:

Sites	df	t	p	
D vs M	18	-0.056	0.910	
D vs R	20	-2.014	0.055	
M vs R	18	-1.333	0.197	
D vs BC	19	8.105	<0.001	(Module higher)
M vs BC	17	4.787	<0.001	(Module higher)
R vs BC	19	8.866	<0.001	(Module higher)

Mean Number of Species:

Sites	df	t	p	
D vs M	18	-0.985	0.340	
D vs R	20	-4.095	0.001	(R modules higher)
M vs R	18	-3.014	0.007	(R modules higher)
D vs BC	19	-0.237	0.800	
M vs BC	17	0.585	0.573	
R vs BC	19	3.111	0.006	(Module higher)

TABLE I6. Jaccard's Coefficient of Similarity for Benthic Invertebrates. Formula for calculating coefficient is [a/(a+b+c)]. Site codes: D = D modules; M = M modules; R = R modules; BC = Barren Controls; UR = Undamaged Reef sampled November, 1991.

	D vs. M	D vs. R	M vs. R	D vs. BC	M vs. BC	R vs. BC
# spp present at both sites (a)	13	14	17	12	8	10
# spp present at first site only (b)	6	5	2	7	11	18
# spp present at second site only (c)	6	14	11	17	21	19
Cumulative Number of Spp. (a+b+c)	25	33	30	36	40	47
Jaccard's Coefficient [a/(a+b+c)]	0.520	0.424	0.567	0.333	0.200	0.213

	D vs. UR	M vs. UR	R vs. UR	BC vs. UR
# spp present at both sites (a)	10	7	10	21
# spp present at first site only (b)	9	12	18	7
# spp present at second site only (c)	47	50	47	36
Cumulative Number of Spp. (a+b+c)	66	69	75	64
Jaccard's Coefficient [a/(a+b+c)]	0.150	0.100	0.130	0.330

Table 17. Results of ANOVA comparing mean number of individuals and mean number of species at the four study sites (D, M, R, and BC) during August '93 and January '94.

Mean Number of Individuals:

Sites	df	F	p	
D module	1, 20	18.694	0.001	(Recent sampling higher)
M module	1, 16	14.391	0.002	(Recent sampling higher)
R module	1, 19	14.391	0.002	(Recent sampling higher)
BC sites	1, 18	0.000	0.967	

Mean Number of Species:

Sites	df	F	p	
D module	1, 20	6.827	0.016	(Recent sampling higher)
M module	1, 16	16.022	0.001	(Recent sampling higher)
R module	1, 19	13.499	0.002	(Recent sampling higher)
BC sites	1, 18	1.147	0.299	

Table I8. Standardized invertebrate data for modules and barren control sites.

SPECIES	CODE	D	M	R	BC
Briareum asbestinum	BRIa	0.2	0.0	0.0	4.3
Callyspongia fallax	CALf	0.7	4.3	4.4	1.4
Callyspongia plicifera	CALp	0.2	0.3	0.5	0.7
Callyspongia vaginalis	CALv	2.9	5.1	2.4	3.5
Didemnid unid.	DIDunid	0.7	1.1	0.4	2.8
Dysidea sp.	DYSsp	8.6	17.2	19.2	0.0
Eunicea sp.	EUNsp	0.0	0.0	0.9	2.1
Holopsamma helwigi	HOLh	48.1	46.0	31.0	12.1
Iotrochota birotulata	IOTb	1.1	8.3	4.2	0.0
Lima lima	LIMl	0.0	0.0	5.8	0.0
Meandrina meandrites	MEAm	0.4	0.0	0.2	1.4
Millepora alcicornis	MILa	2.9	8.3	16.2	0.7
Niphates digitalis	NIPd	0.0	0.0	0.0	9.2
Parasmittina sp.	PARsp	0.0	0.0	2.2	0.0
Reteporellina sp.	RETsp	0.2	0.8	0.9	0.0
Siderastrea sidera	SIDsp	0.7	0.0	0.0	1.4
Spondylus americanus	SPOa	0.0	0.3	1.3	0.0
Stephanocoenia michelini	STEm	0.0	0.0	0.0	3.5
Stolonica sabulosa	STOs	31.0	1.6	4.9	34.0
Telesto riisei	TELr	0.0	3.2	0.4	0.0
Trematooecia aviculifera	TREa	0.0	0.3	0.7	0.0
Ulosa reutzleri	ULOr	1.1	0.3	0.9	2.8
Watersipora sp.	WATsp	0.2	1.6	0.7	0.0
% OF TOTAL NUMBER OF INDIVIDUALS		99.113	98.656	97.263	80.142
% OF TOTAL NUMBER OF TAXA INCLUDE		78.947	78.947	67.857	48.276

TABLE I9. QUARTER (3RD THRU 8TH) IN WHICH
WERE FIRST RECORDED ON MODULES (D,M,R)
SAMPLING OF MODULES AND FINAL BARREN C
DID NOT BEGIN UNTIL THE THIRD QUARTER.

	D	M	R	BC
Agaricia sp.	---	---	8	---
Aplysina	---	---	---	4
Ascidia nigra	4	---	3	---
Briareum asbestinum	8	3	---	3
Callyspongia fallax	3	---	3	5
Callyspongia plicifera	8	8	8	5
Callyspongia vaginalis	5	5	6	3
Cyanobacterial mats	---	---	---	6
Dasychalina cyathina	---	---	---	8
Dichocoenia stokesi	---	---	---	3
Dictyota bartayresii	3	---	---	3
Didemnid unid.	4	3	4	7
Dysidea sp.	6	6	6	6
Echinometra lucunter	3	3	3	---
Eucidaris sp.	5	4	4	---
Eunicea sp.	---	---	6	3
Eusmilia fastigata	---	---	---	3
Haliclona rubens	---	---	---	3
Halimeda goreaui	---	---	---	3
Holopsamma helwigi	3	5	5	3
Hydroids	---	6	---	---
Iotrochota birotulata	7	7	8	7
Ircinia sp.	---	---	---	6
Leucosolenia sp.	---	---	6	---
Lima lima	4	4	3	3
Meandrina meandrites	8	---	7	3
Melanostigma nigromaculat	---	4	4	---
Millepora alcicornis	6	7	4	7
Mithrax sp.	---	6	---	---
Montastrea annularis	---	---	---	5
Montastrea cavernosa	---	---	---	5
Mycale sp.	---	---	---	8
Mycetophyllia sp.	---	---	---	5
Niphates digitalis	---	---	---	3
Niphates erecta	---	---	---	3
Niphates sp.	---	8	8	---
Octopus sp.	---	---	6	---
Panuluris argus	---	5	4	---
Parasmittina sp.	3	3	4	---
Porites sp.	---	8	---	---
Reteporellina sp.	5	5	5	5
Sabella sp.	---	3	3	3
Serpula sp.	---	3	3	---
Siderastrea sidera	8	---	---	3
Siderastrea sp.	---	---	---	7
Spirastrella coccinea	---	---	---	3
Spondylus americanus	4	3	3	---
Sponge unid	5	5	5	6
Stenopus hispidus	3	3	3	---

TABLE I9. QUARTER (3RD THRU 8TH) IN WHICH
WERE FIRST RECORDED ON MODULES (D,M,R)
SAMPLING OF MODULES AND FINAL BARREN C
DID NOT BEGIN UNTIL THE THIRD QUARTER.

	D	M	R	BC
Stenorhynchus seticomis	4	3	3	---
Stephanocoenia michelini	---	---	---	4
Stolonica sabulosa	3	3	3	3
Styella plicata	---	4	4	---
Teichaxinella morchella	---	---	---	5
Telesto riisei	---	3	5	---
Trematooecia aviculifera	---	8	8	---
Udotea sp.	---	3	3	3
Ulosa reutzleri	7	8	6	3
Verongia longissima	---	---	---	4
Watersipora sp.	4	3	4	6
Wrangelia argus	5	---	---	4
Xestospongia muta	---	---	6	5
CUMULATIVE NUMBER OF SPECIES	26	33	36	42

Table I10. Raw data from 1st quarter sampling of undamaged reef areas. Each quadrat 3.75 sq.ft (0.38 sq.m.).

SPECIES	QUADRAT 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Agaricia lamarcki	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Agelas conifera	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Alloclada sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
Anthosigmella varians	0	0	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aplysina cauliformis	3	0	0	4	2	6	7	0	2	1	0	0	0	1	1	1	2	0	0	0	0	2	0
Aplysina fistularis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0	0	0
Aplysina lacunosa	0	1	0	0	0	0	2	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Aplysina sp. B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aplysina sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1
Briareum asbestinum	0	2	1	0	1	0	1	0	0	1	0	1	1	1	1	1	1	1	0	1	0	0	1
Callyspongia fallax	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Callyspongia plicifera	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Callyspongia vaginalis	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0
Cliona sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Colpophyllia natans	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dichocoenia stokesii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dictyota bartayresii	0	0	0	10	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Dysidea etheria	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0	1	0	0	0	0
Eunicea calyculata	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0
Eunicea fusca	0	1	0	3	1	3	2	0	0	0	0	0	2	1	0	0	0	1	1	1	0	0	0
Eunicea knighti	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eusmilia fastigiata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gorgonia ventalina	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Haliclona rubens	1	1	1	0	0	3	0	0	0	0	0	0	0	1	0	0	0	1	0	1	0	0	0
Haliclona sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Haliclona viridis	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Halimeda goreaui	10	10	10	10	10	10	10	10	0	10	10	10	10	10	10	10	10	10	10	0	10	0	10
Iotrochota birotulata	0	0	1	1	0	0	0	0	0	0	1	0	1	1	0	1	1	0	0	0	0	1	0
Ircinia campana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ircinia felix	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Ircinia sp.	1	0	0	0	0	0	0	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0
Ircinia strobilina	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Meandrina meandrites	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Millepora alcicornis	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	0	0	0	0	0	0
Monanchora uvifera	0	0	0	0	0	0	0	0	1	0	0	0	2	0	0	2	0	0	0	0	0	1	0
Montastrea annularis	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Montastrea cavernosa	1	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
Mussa angulosa	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Table I10. Raw data from 1st quarter sampling of undamaged reef areas. Each quadrat 3.75 sq.ft (0.38 sq.m.).

SPECIES	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46
Mycetophyllia sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Niphates digitalis	0	0	4	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Niphates erecta	0	0	0	1	0	1	0	3	2	1	1	1	1	1	1	1	1	0	0	0	1	N	1
Plexaura flexuosa	0	1	0	0	0	0	1	0	0	0	0	1	0	2	0	0	0	0	0	0	1	0	0
Porites astreoides	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pseudaxinella rosacea	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pseudopterogorgia ameri	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sabella sp.	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Siderastrea siderea	0	0	0	0	0	0	0	0	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0
Solenastrea hyades	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Spirastrella coccinea	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	1	0	1	1	1	0	0
Stephanocoenia michelini	0	0	0	0	0	0	1	2	0	0	0	1	1	0	1	0	0	0	0	1	1	1	0
Teichaxinella lunaecharta	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	1	0
Thalysias juniperina	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Ulosa reutzleri	0	0	0	2	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Unidentified sponge A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unidentified sponge B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Unidentified sponge C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Xestospongia muta	1	0	0	1	0	1	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
#Individuals	19	21	22	23	7	21	19	24	25	21	16	18	4	18	15	17	8	0	21	16	22	15	15
#Species	8	10	10	10	7	10	10	7	11	12	7	9	4	7	5	8	7	0	9	11	13	8	5

Table I10. Raw data from 1st quarter sampling of undamaged reef areas. Each quadrat 3.75 sq.ft (0.38 sq.m.).

SPECIES	47	48	49	50	51	52	Totals
Mycetophyllia sp.	0	0	0	0	0	0	1
Niphates digitalis	1	0	1	0	0	0	22
Niphates erecta	1	N	1	1	0	1	46
Plexaura flexuosa	0	0	0	0	0	1	25
Porites astreoides	0	0	0	0	0	0	2
Pseudaxinella rosacea	0	0	0	0	0	0	1
Pseudopterogorgia ameri	0	0	0	0	0	0	3
Sabella sp.	0	0	0	0	0	0	1
Siderastrea siderea	0	0	0	0	0	0	4
Solenastrea hyades	0	0	0	0	0	0	1
Spirastrella coccinea	2	0	1	0	0	1	11
Stephanocoenia michelini	0	0	0	0	0	0	16
Teichaxinella lunaecharta	0	0	0	0	0	0	5
Thalysias juniperina	0	0	0	0	0	0	4
Ulosa reutzleri	0	0	0	0	0	0	10
Unidentified sponge A	0	0	0	0	0	0	1
Unidentified sponge B	0	0	0	0	0	0	1
Unidentified sponge C	0	0	0	0	0	0	1
Xestospongia muta	1	0	0	0	1	0	10
#Individuals	17	13	15	17	9	6	901
#Species	7	5	6	8	9	6	57

Table I10. Raw data from 1st quarter sampling of undamaged reef areas. Each quadrat 3.75 sq.ft (0.38 sq.m.).

	QUADRAT																						
SPECIES	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Mycetophyllia sp.	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Niphates digitalis	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	3	6	0	0	0	0	0	1
Niphates erecta	1	1	2	1	1	0	0	4	0	3	0	1	2	1	1	0	4	0	0	0	0	2	1
Plexaura flexuosa	0	0	1	1	0	0	0	0	0	0	2	0	1	1	1	2	0	7	2	0	0	0	0
Porites astreoides	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pseudaxinella rosacea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pseudopterogorgia ameri	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	2	0	0	0	0	0	0
Sabella sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Siderastrea siderea	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solenastrea hyades	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spirastrella coccinea	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stephanocoenia michelini	0	0	0	0	0	3	0	0	0	0	1	0	0	0	0	0	1	1	0	0	0	1	0
Teichaxinella lunaecharta	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Thalysias juniperina	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0
Ulosa reutzleri	0	0	0	1	1	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
Unidentified sponge A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Unidentified sponge B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unidentified sponge C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Xestospongia muta	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
#Individuals	18	17	19	32	19	26	37	18	6	17	16	16	23	22	15	23	30	23	17	4	10	11	18
#Species	7	7	8	9	9	6	11	6	4	5	6	7	11	13	6	10	11	8	6	4	1	9	9

Table I10. Raw data from 1st quarter sampling of undamaged reef areas. Each quadrat 3.75 sq.ft (0.38 sq.m.).

SPECIES	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46
Agaricia lamarcki	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Agelas conifera	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Alloclada sp.	0	1	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Anthosigmella varians	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aplysina cauliformis	1	0	0	0	1	1	0	0	1	1	10	0	1	1	0	0	0	0	3	1	1	0	0
Aplysina fistularis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aplysina lacunosa	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aplysina sp. B	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Aplysina sp.	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Briareum asbestinum	1	0	1	3	1	3	0	1	0	1	1	1	0	2	2	N	1	0	1	3	1	N	1
Callyspongia fallax	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Callyspongia plicifera	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Callyspongia vaginalis	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cliona sp.	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Colpophyllia natans	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Dichocoenia stokesii	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dictyota bartayresii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dysidea etheria	0	1	0	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0
Eunicea calyculata	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
Eunicea fusca	3	2	1	0	0	1	0	5	5	0	0	1	1	0	0	2	2	0	2	0	1	0	2
Eunicea knighti	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eusmilia fastigiata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gorgonia ventalina	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Haliclona rubens	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	1	2	1	1	1
Haliclona sp.	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Haliclona viridis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Halimeda goreaui	10	10	10	10	0	10	10	10	10	10	0	10	0	10	10	10	0	0	10	0	10	10	10
Iotrochota birotulata	0	2	0	1	1	0	1	0	0	1	0	0	0	0	0	1	0	0	1	1	0	2	0
Ircinia campana	0	0	0	1	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0
Ircinia felix	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
Ircinia sp.	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	1	0	0	2	0	0	0
Ircinia strobilina	0	0	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Meandrina meandrites	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Millepora alcicornis	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Monanchora uvifera	0	0	0	2	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0
Montastrea annularis	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Montastrea cavernosa	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0
Mussa angulosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table I10. Raw data from 1st quarter sampling of undamaged reef areas. Each quadrat 3.75 sq.ft (0.38 sq.m.).

SPECIES	47	48	49	50	51	52	Totals
Agaricia lamarcki	0	1	0	0	0	0	1
Agelas conifera	0	0	0	0	1	0	3
Alloclada sp.	0	0	0	0	1	0	6
Anthosigmella varians	0	0	0	0	0	0	3
Aplysina cauliformis	0	1	0	0	1	1	57
Aplysina fistularis	0	0	0	0	0	0	3
Aplysina lacunosa	0	0	0	0	0	0	7
Aplysina sp. B	0	0	0	0	0	0	1
Aplysina sp.	0	0	0	1	0	0	7
Briareum asbestinum	1	1	1	1	1	1	45
Callyspongia fallax	0	0	0	0	0	0	1
Callyspongia plicifera	0	0	0	0	0	0	2
Callyspongia vaginalis	0	0	0	1	1	0	7
Cliona sp.	0	0	0	1	0	0	2
Colpophyllia natans	0	0	0	0	0	0	1
Dichocoenia stokesii	0	0	0	0	0	0	2
Dictyota bartayresii	0	0	0	0	0	0	20
Dysidea etheria	0	0	0	0	0	0	10
Eunicea calyculata	0	0	0	0	0	0	7
Eunicea fusca	1	0	0	0	1	1	47
Eunicea knighti	0	0	0	0	0	0	1
Eusmilia fastigiata	0	0	1	0	0	0	1
Gorgonia ventalina	0	0	0	0	0	0	1
Haliclona rubens	0	0	0	1	1	0	18
Haliclona sp.	0	0	0	0	0	0	1
Haliclona viridis	0	0	0	0	0	0	1
Halimeda goreaui	10	10	10	10	0	0	410
Iotrochota birotulata	0	0	0	0	1	0	20
Ircinia campana	0	0	0	0	0	0	4
Ircinia felix	0	0	0	0	0	0	5
Ircinia sp.	0	0	0	0	0	0	10
Ircinia strobilina	0	0	0	0	0	0	4
Meandrina meandrites	0	0	0	0	0	0	1
Millepora alcicornis	0	0	0	0	0	0	4
Monanchora uvifera	0	0	0	1	0	0	11
Montastrea annularis	0	0	0	0	0	0	3
Montastrea cavernosa	0	0	0	0	0	0	7
Mussa angulosa	0	0	0	0	0	0	2

TABLE I11. Summary statistics of benthic invertebrate data from undamaged part of reef (collected Nov., 1991). 52 quadrats were sampled along a 20 m transect. Each quadrat was 3.75 ft2, for a total area sampled of 197 ft2.

N	Diversity Index H	Total # indiv.	Range	Total # species	Range	Most common species	
52	1.08	901	0 to 37	57	0 to 13	*Halimeda goreaui*	n = 410
						Aplysina cauliformis	n = 57
						Eunicea fusca	n = 47
						Niphates erecta	n = 46
						Briareum asbestinum	n = 45

	Mean	Std. Err.
Individual	17.34	0.98
Species	7.73	0.37

TABLE I12. Surface area of each module (D, M, R), Barren Control (BC) quadrats, and the Undamaged Reef quadrats (UR; sampled November 1991) in ft2.

	D	M	R	BC	UR
Surface Area (ft2) of module	28	130.5	160		
Void Space (ft3) of module	7.1	71.6	12		
Area/Volume of module	3.9	1.8	13.3		
Area (ft2) sampled per module	6.0	12.75	12.0	23.76	3.75
% Area sampled per module	21%	10%	8%		
Number of modules sampled	11	10	10	10	52

Table I13. Average numbers of individuals and species per unit area sampled (ft2).

Site Type	$\bar{X}$ of individuals per ft2	Std. err.	$\bar{X}$ of species per ft2	Std. err.
D	6.83	0.440	1.11	0.108
M	3.24	0.417	0.59	0.052
R	4.15	0.291	0.86	0.050
BC	0.59	0.085	0.29	0.038
UR	4.62	0.260	2.06	0.099

List of Figures for Sessile Invertebrates

Figure I1. Cluster analysis of the four study site types based upon the standardized occurrence of the sessile invertebrate taxa.

Figure I2. Cluster analysis of the standardized occurrence of sessile invertebrate taxa at the four study site types (D, M, & R modules and BC sites).

Figure I3. Projection of the first three principal components for the four study site types based on the upon the standardized occurrence of the sessile invertebrate taxa.

Figure I4. Plot of the average number of individuals at each of the four study site types by quarter.

Figure I5. Plot of the average number of species at each of the four study site types by quarter.

Figure I6. Plot of the cumulative number of species recorded for each of the four study site types by quarter (rarefaction curve).

Figure I7. Plot of the Shannon-Weiner Diversity Index (H) for each of the four study site types by quarter.

Figure I8. Average number of individuals per ft^2.

Figure I9. Average number of species per ft^2.

Fig. I1. Cluster of sites based upon 23 most common taxa.

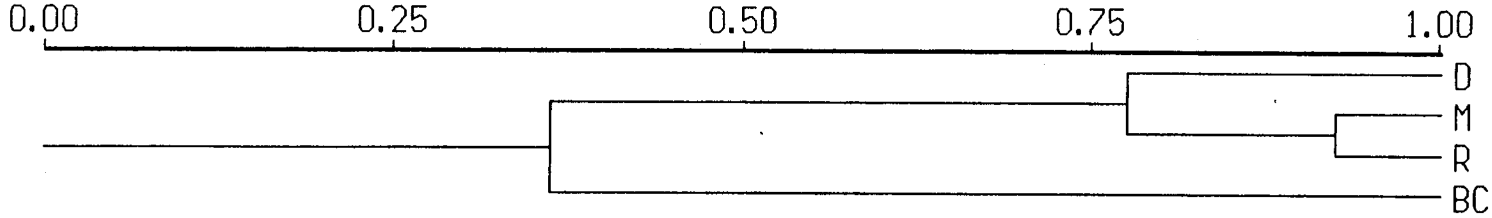


Figure I2. Cluster of 23 most common invertebrate taxa.

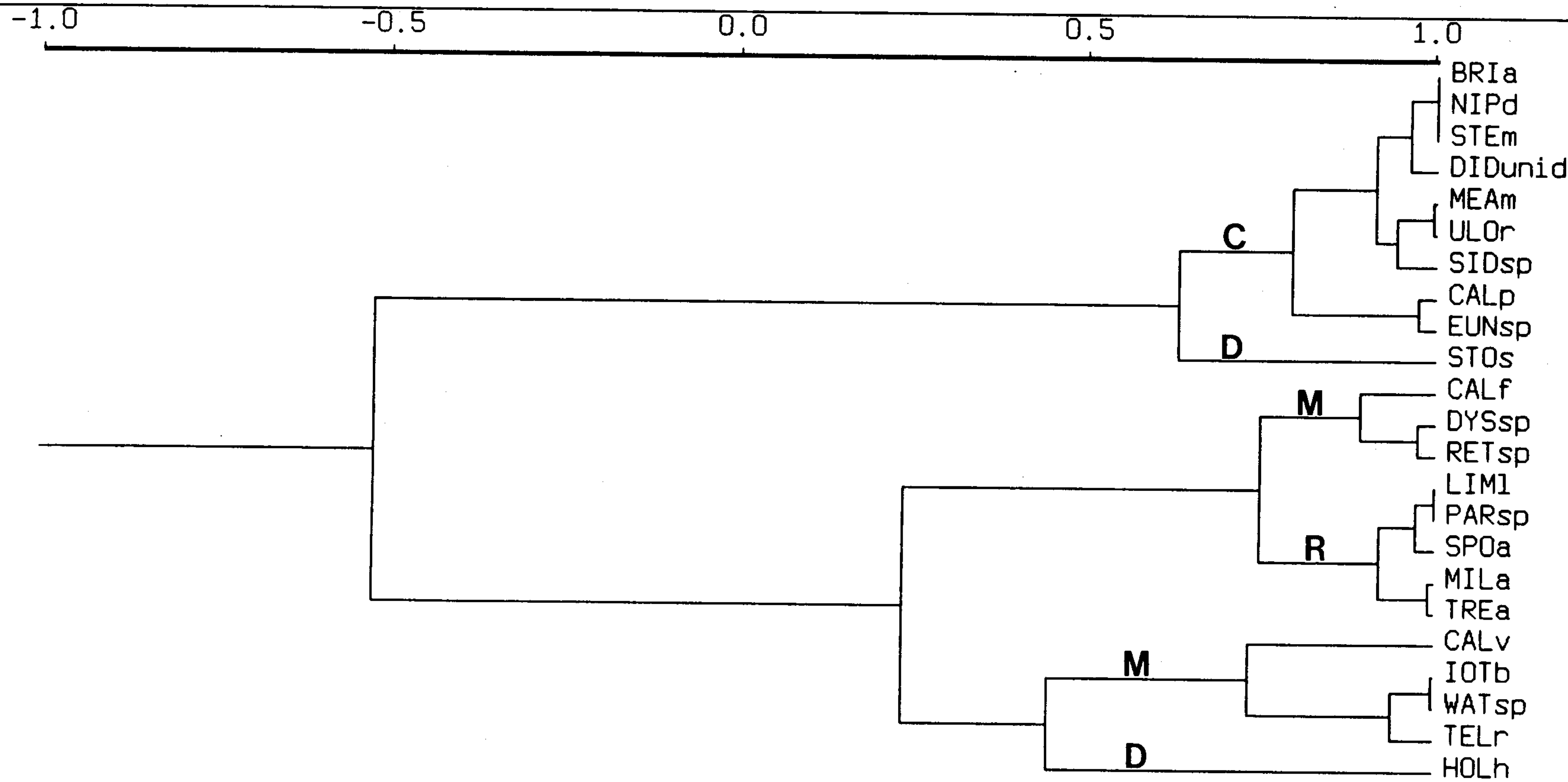


Figure I3. PCA of 23 most common invertebrate taxa.

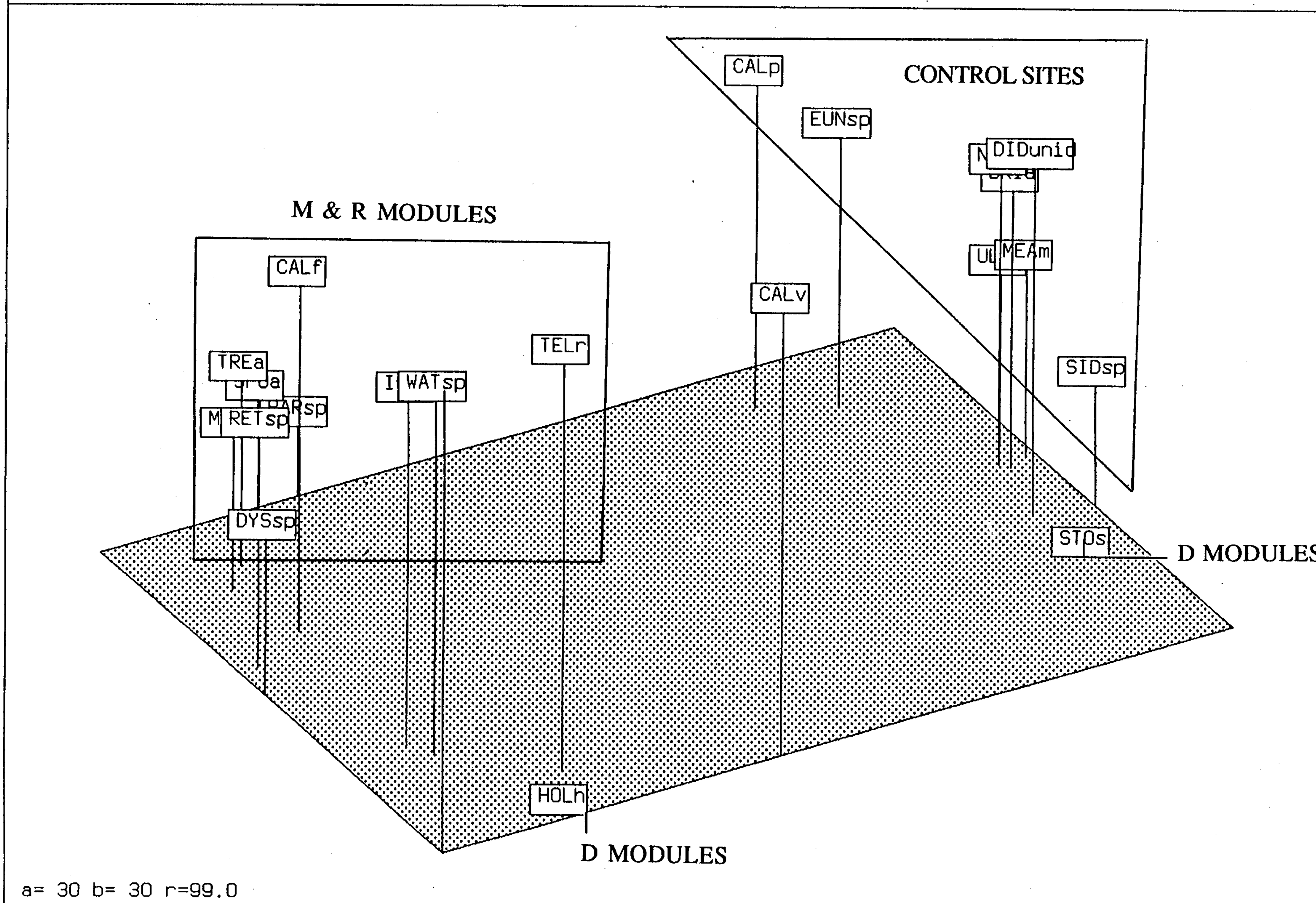


Figure I4 Average number of benthic invertebrate individuals at four study sites by quarter.

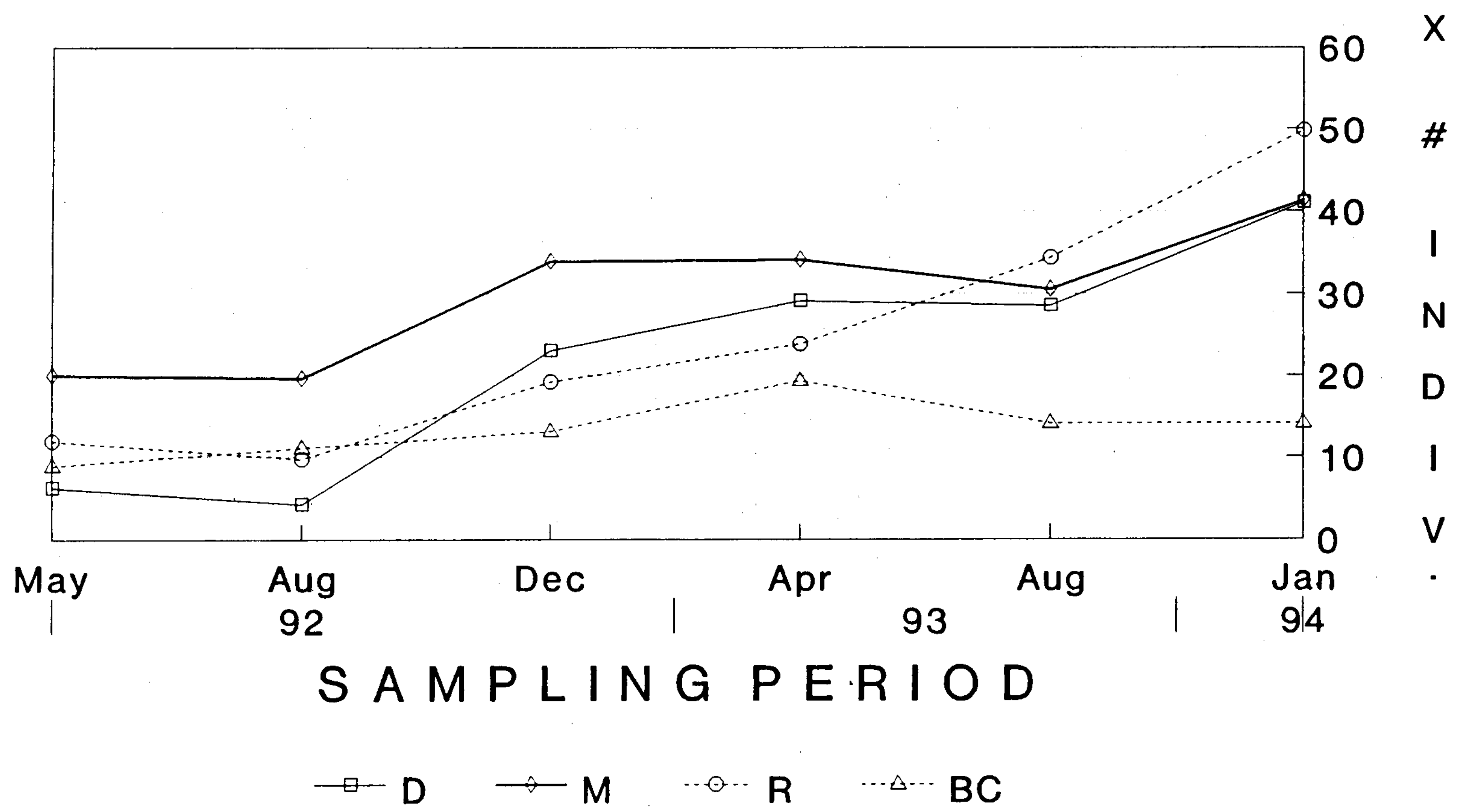


Figure I5 Average number of benthic invertebrate species at four study sites by quarter.

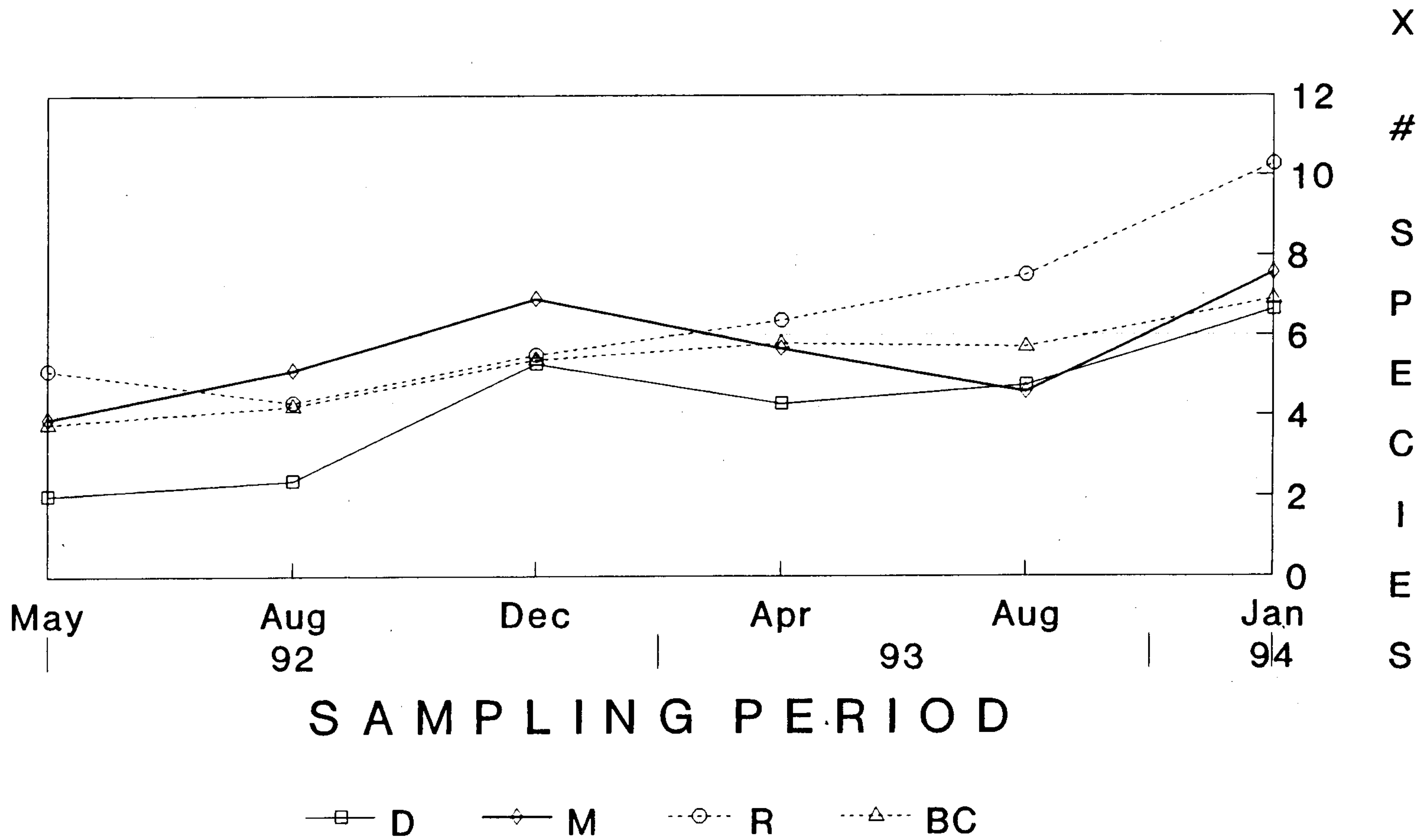


Figure I6. Rarefaction curve for the cumulative number of invertebrate taxa

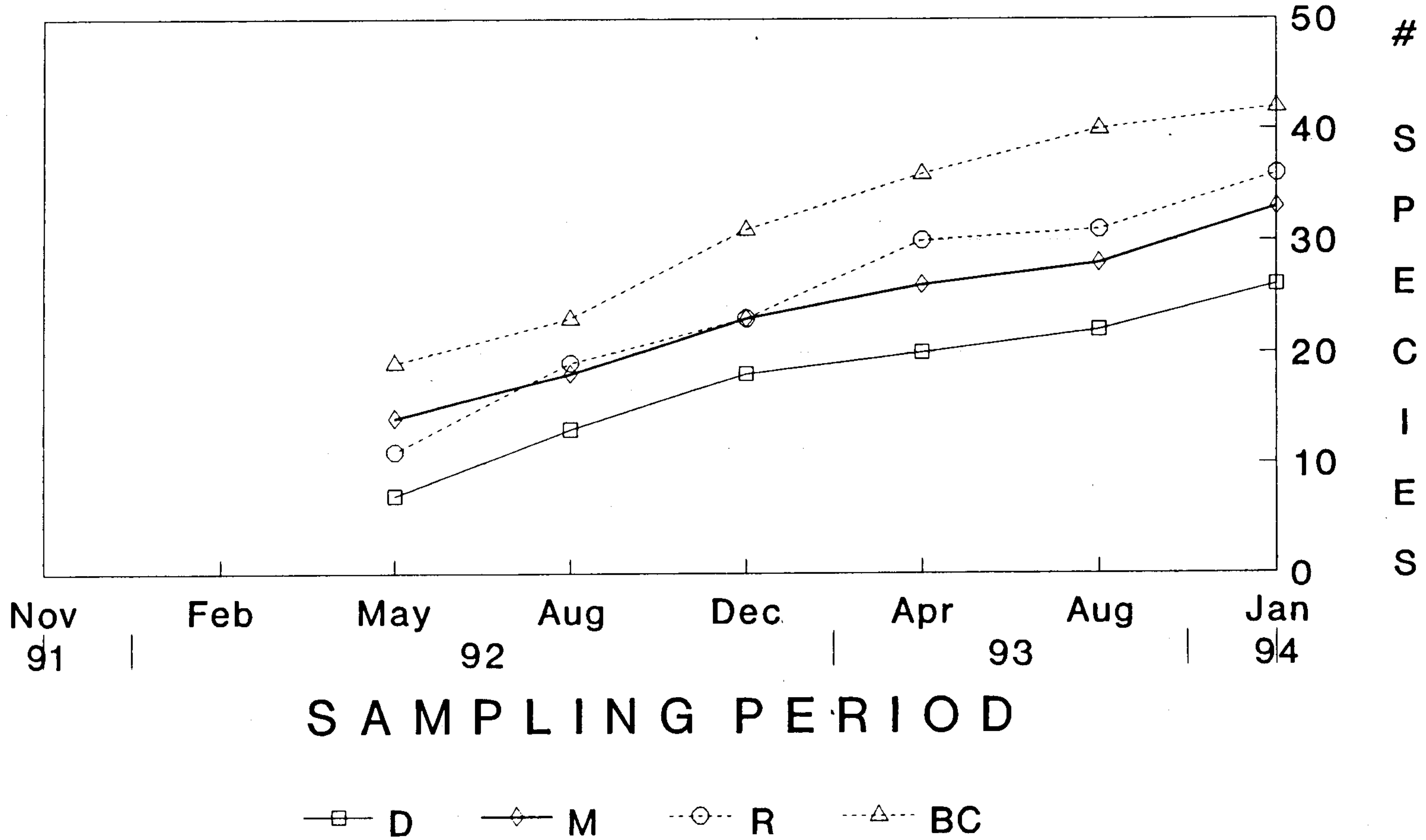


Figure I7 Shannon-Weiner diversity index (H) for benthic invertebrates by quarter.

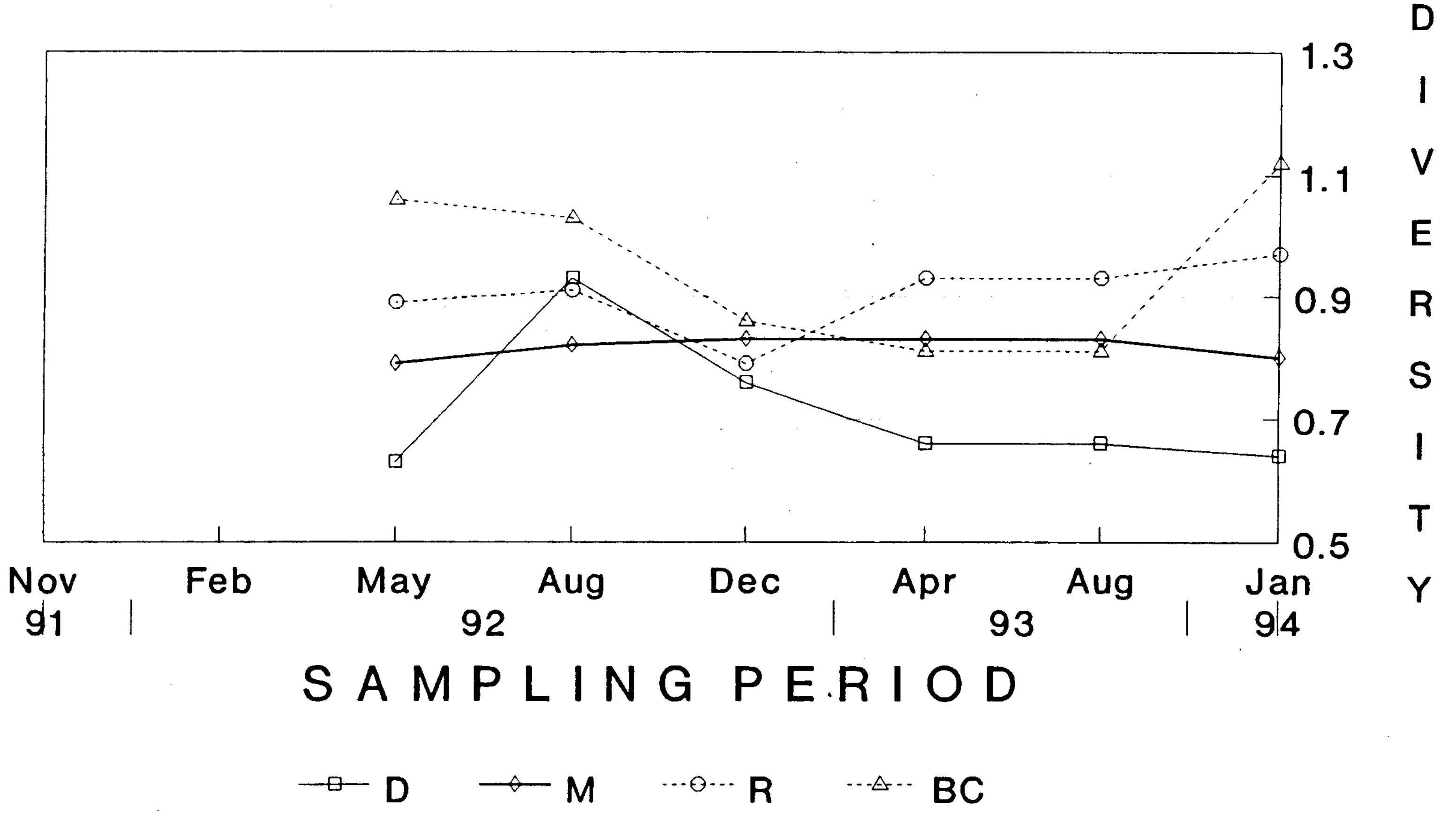
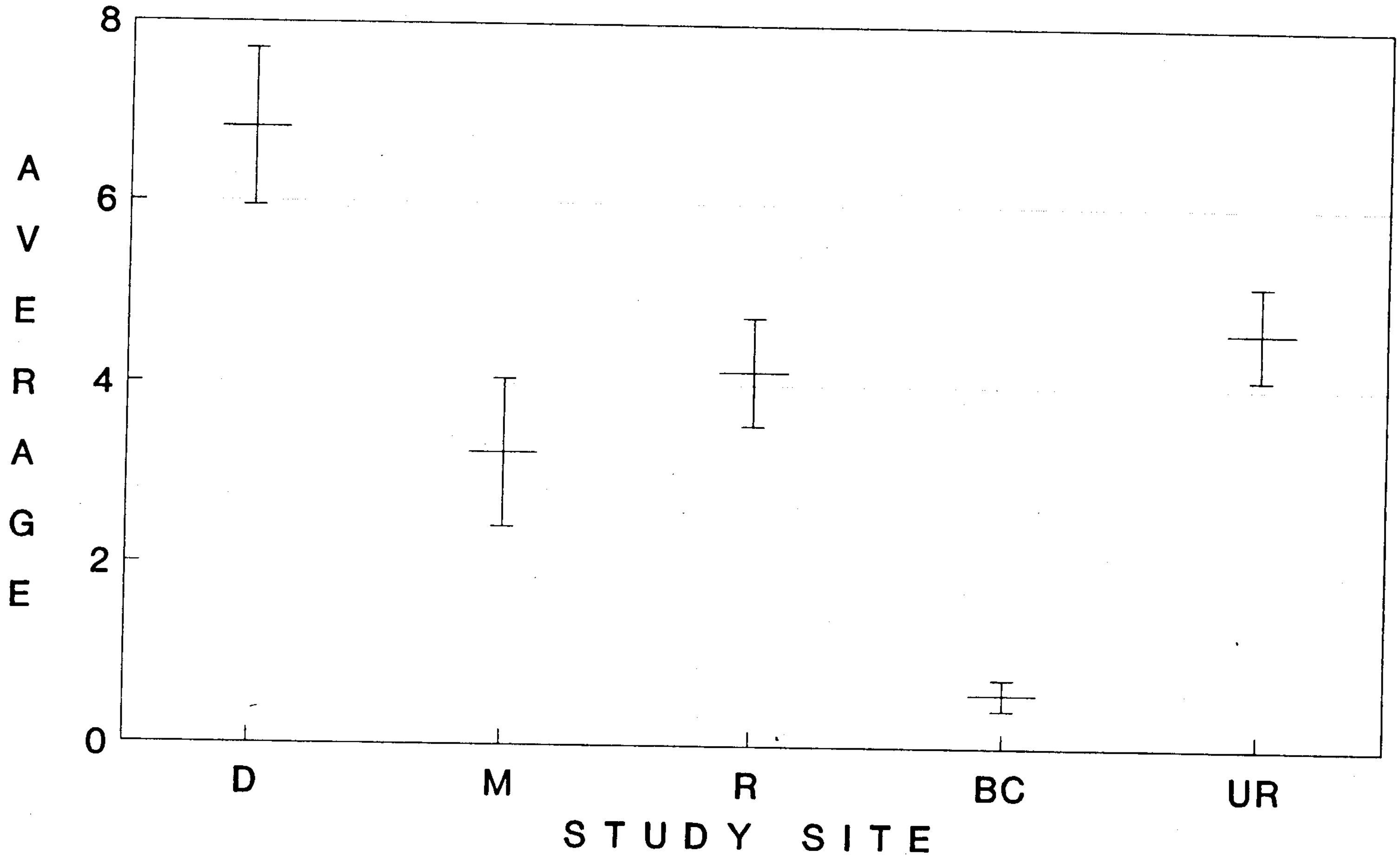
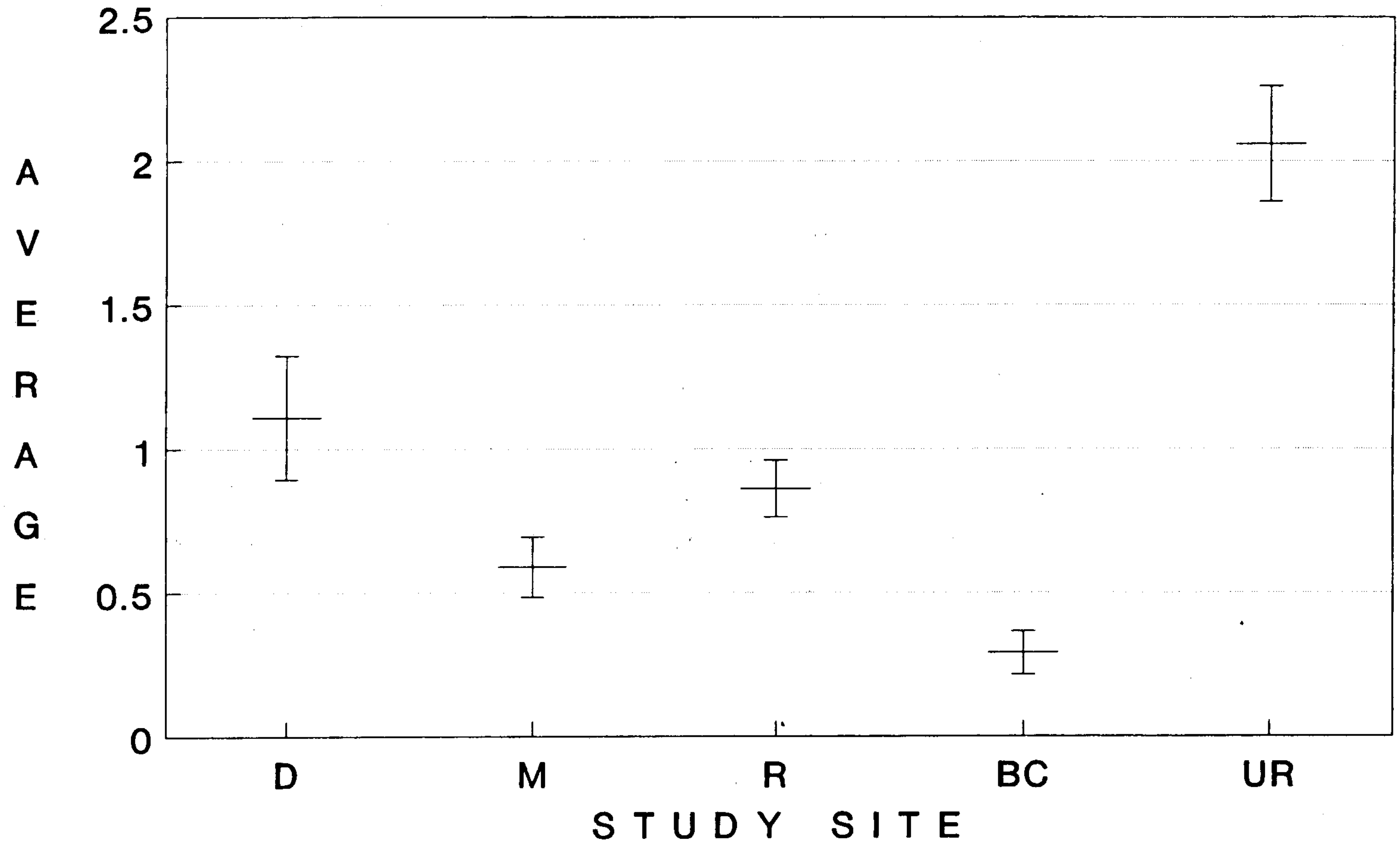


Figure 18. Average number of individuals per sq.ft +/- 2 Std.err.



If error bars do not overlap, means are significantly different.

Figure I9. Average number of species per sq.ft.



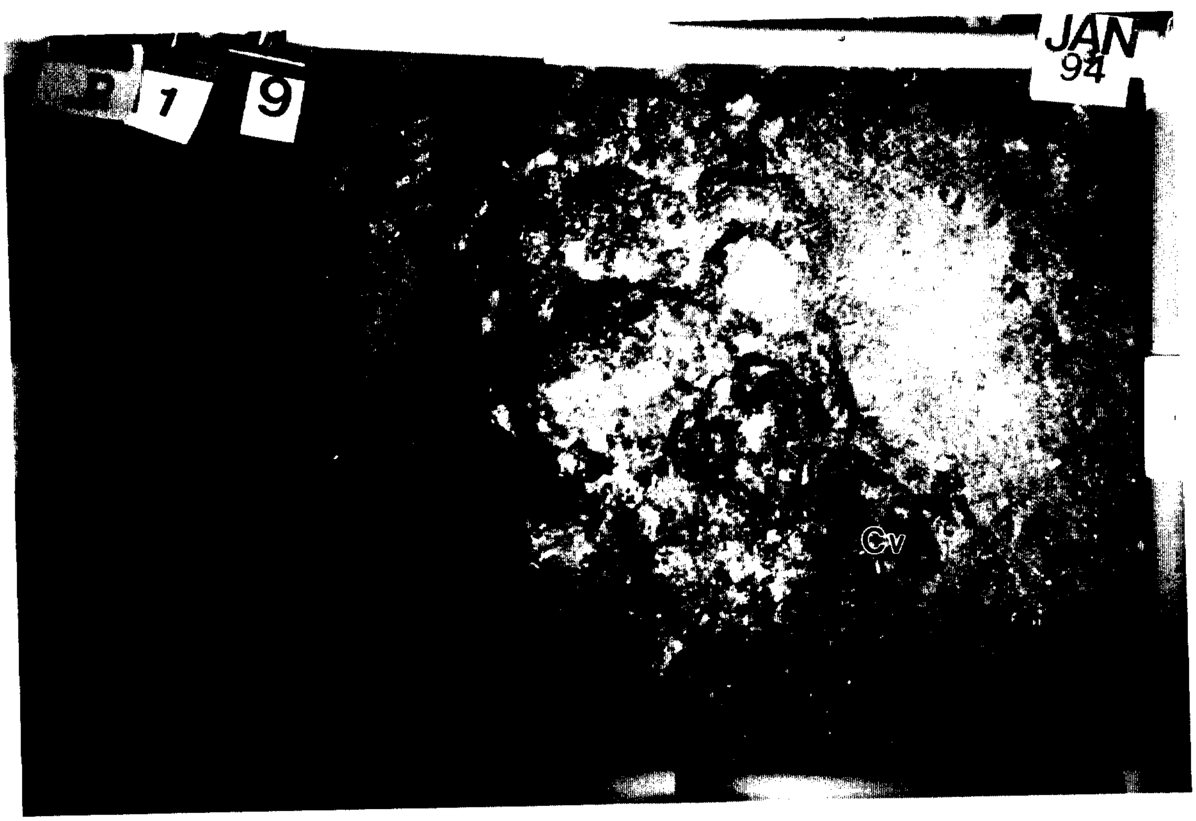
If error bars do not overlap, means are significantly different.

Appendix 1
Photographs

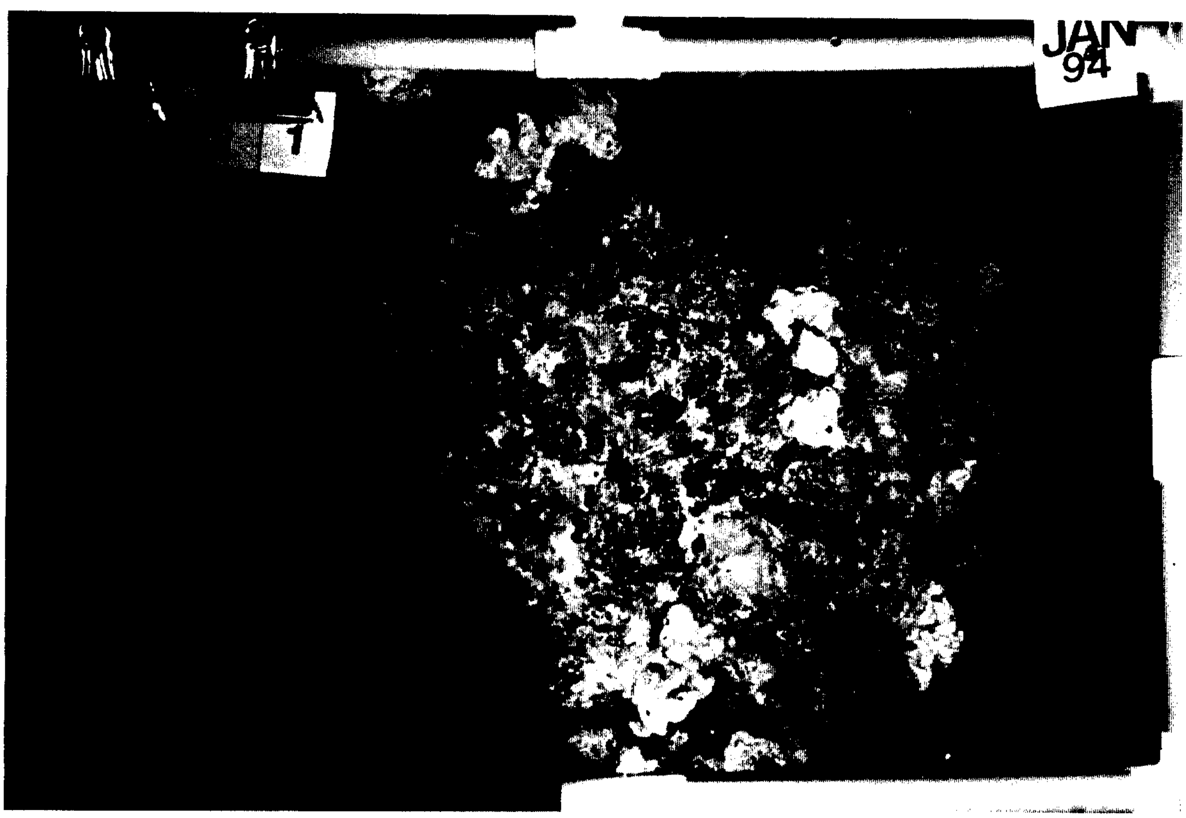
Key to abbreviations:

Cf= Callyspongia fallax (Porifera)
Cv= Callyspongia vaginalis (Porifera)
Ef= Eunicea fusca (Cnidaria: Gorgonacea)
D= Dysidea sp. (Porifera)
Hh= Holopsamma helwigi (Porifera)
L= Lima lima (Mollusca:Bivalvia)
Ma= Millipora alcicornis (Cnidaria: Hydrozoa)
Ss= Stolonica sabulosa (Chordata: Ascidiacea)
Tr= Telesto riisei (Cnidaria: Telestacea)
W= Watersipora sp. (Bryozoa)

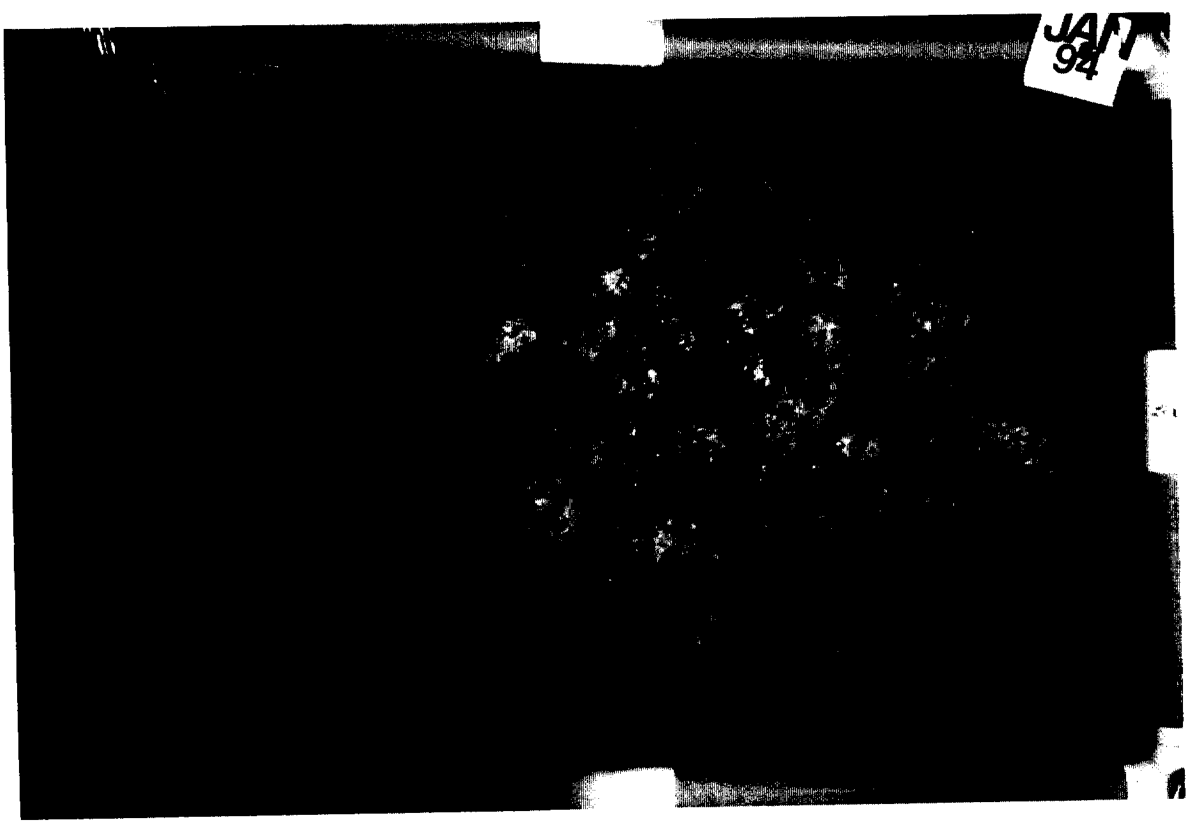

1
8
JAN
94
Ma


1
9
JAN
94
Cv

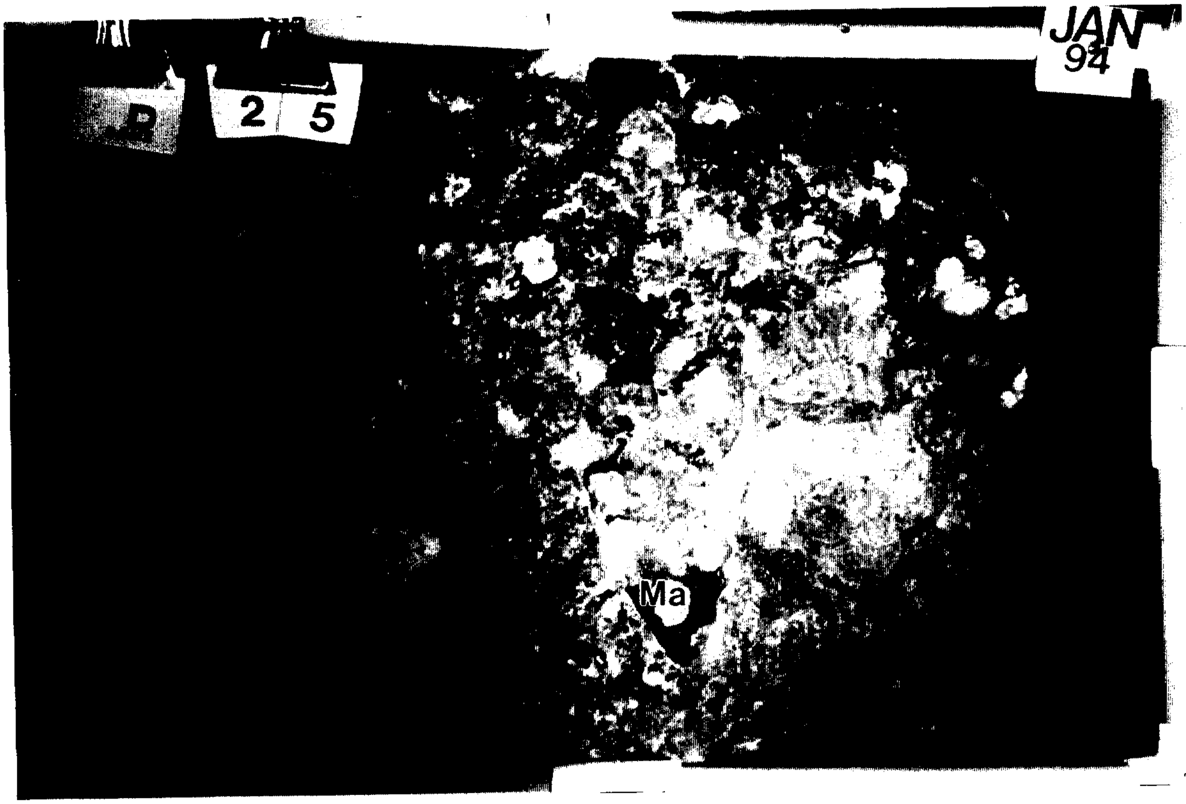

JAN
94


JAN
94
1


22
JAN
94

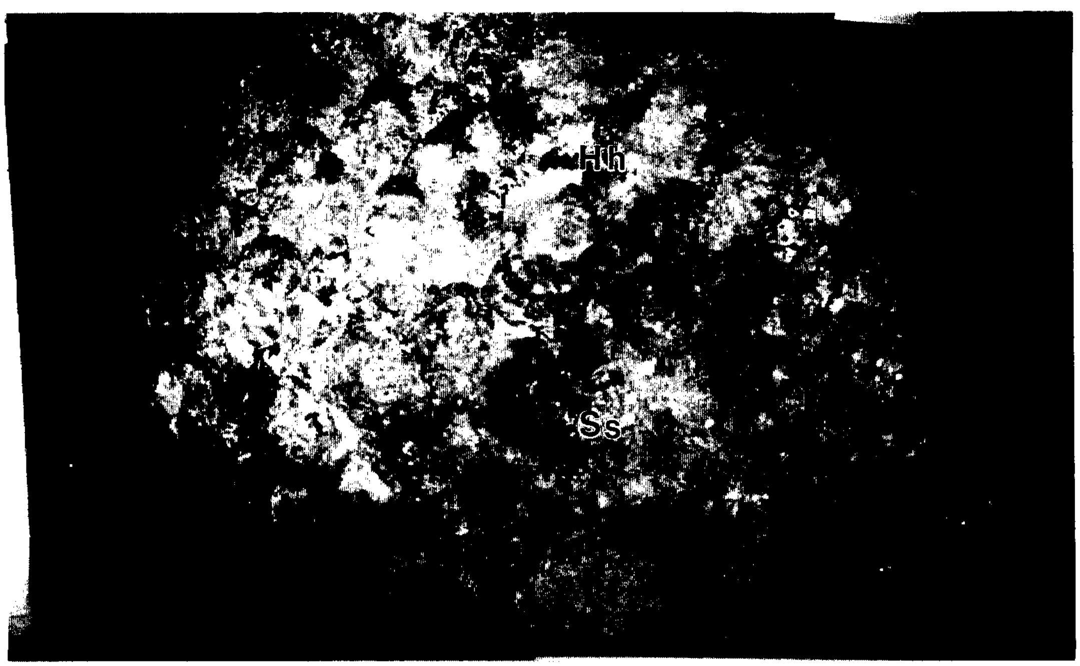

JAN
94

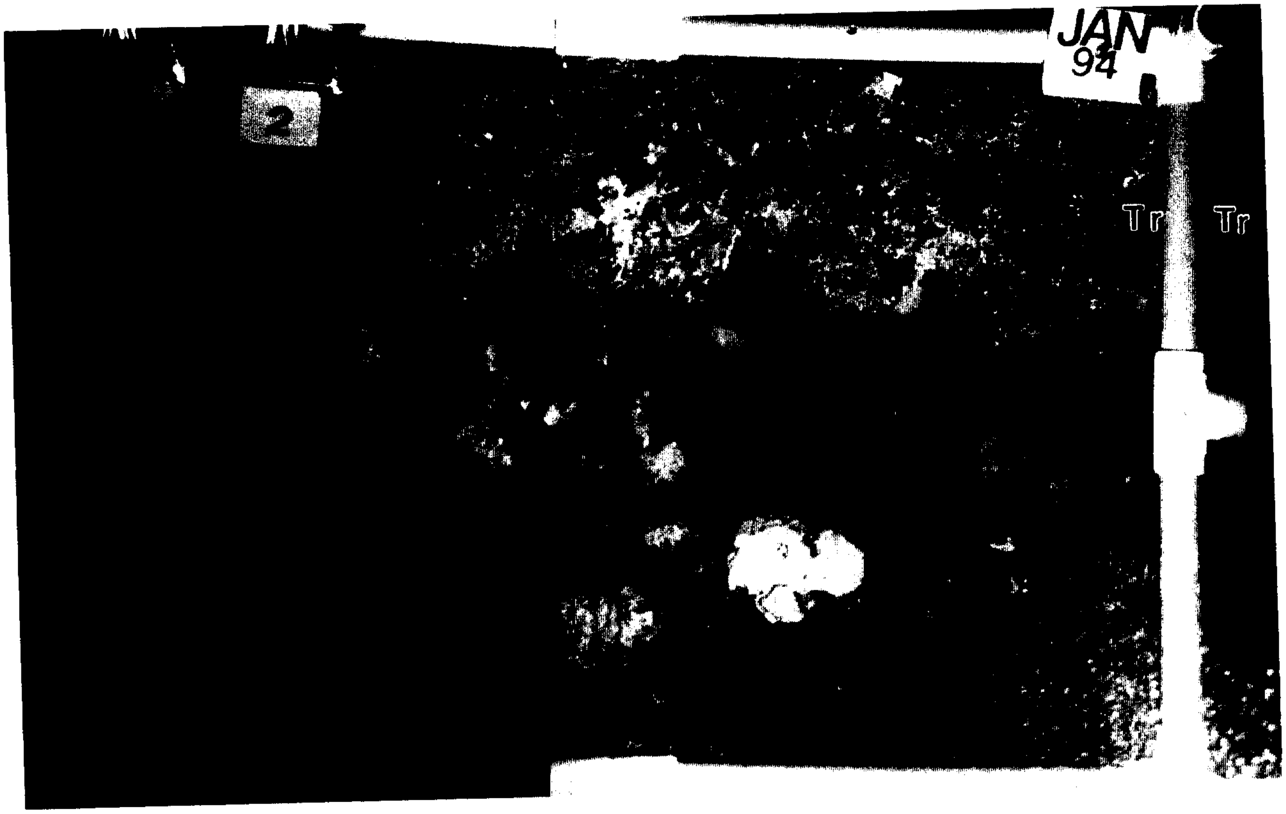
D 25 Top: January, 1994
Bottom: December, 1992

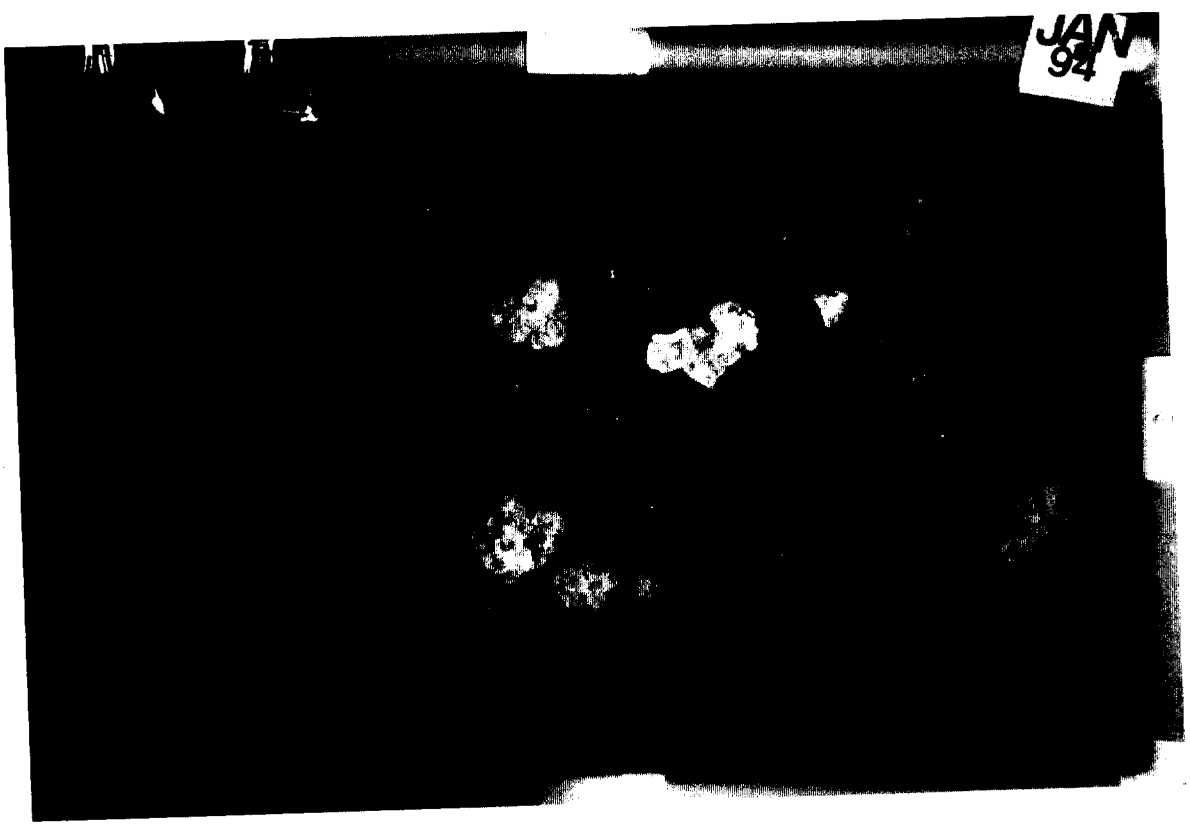


D 34 Top: January, 1994
Bottom: December, 1992

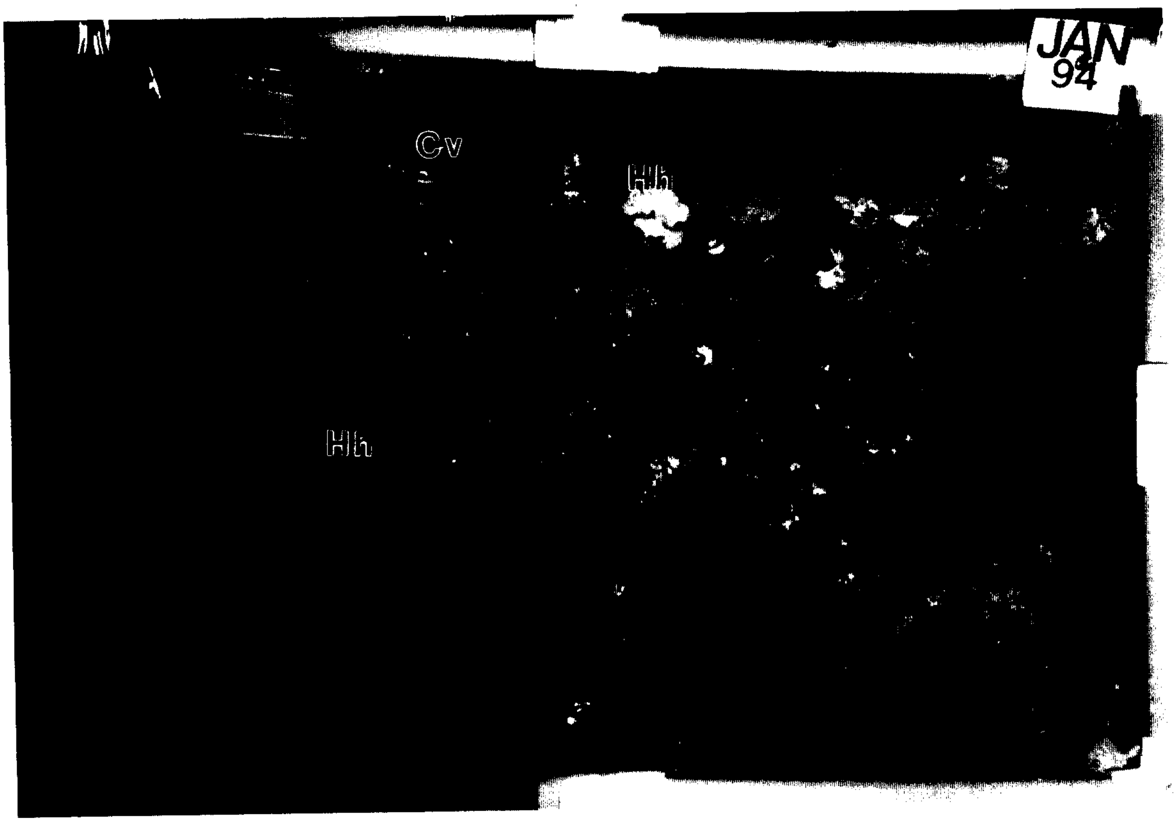
D 43 Top: January, 1994
Bottom: December, 1992

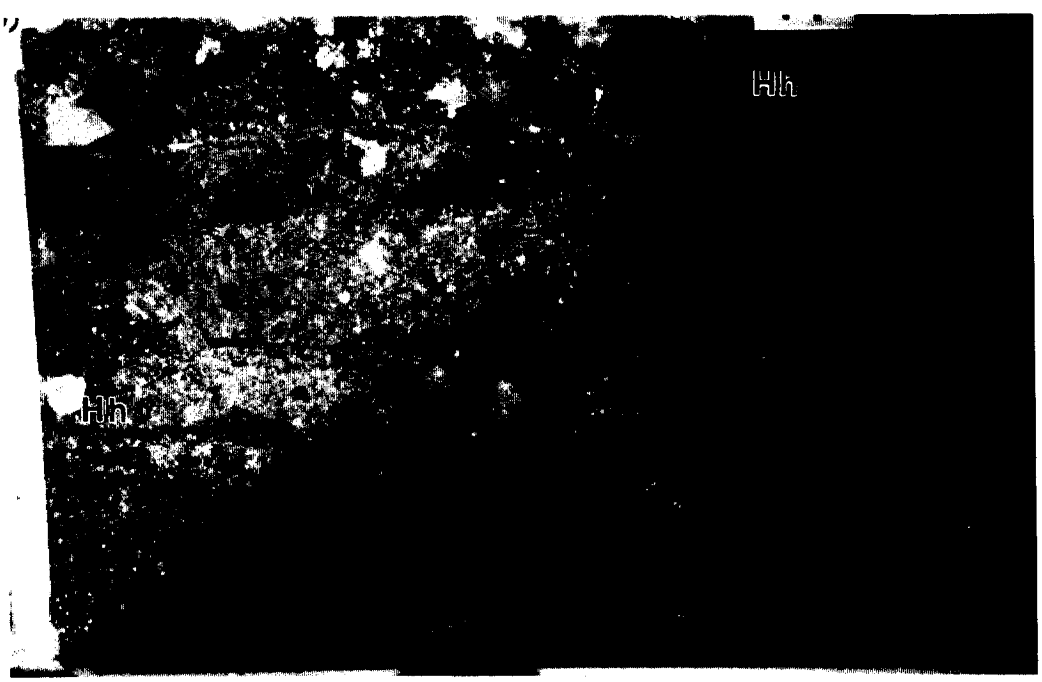



JAN
94
2
Tr
Tr

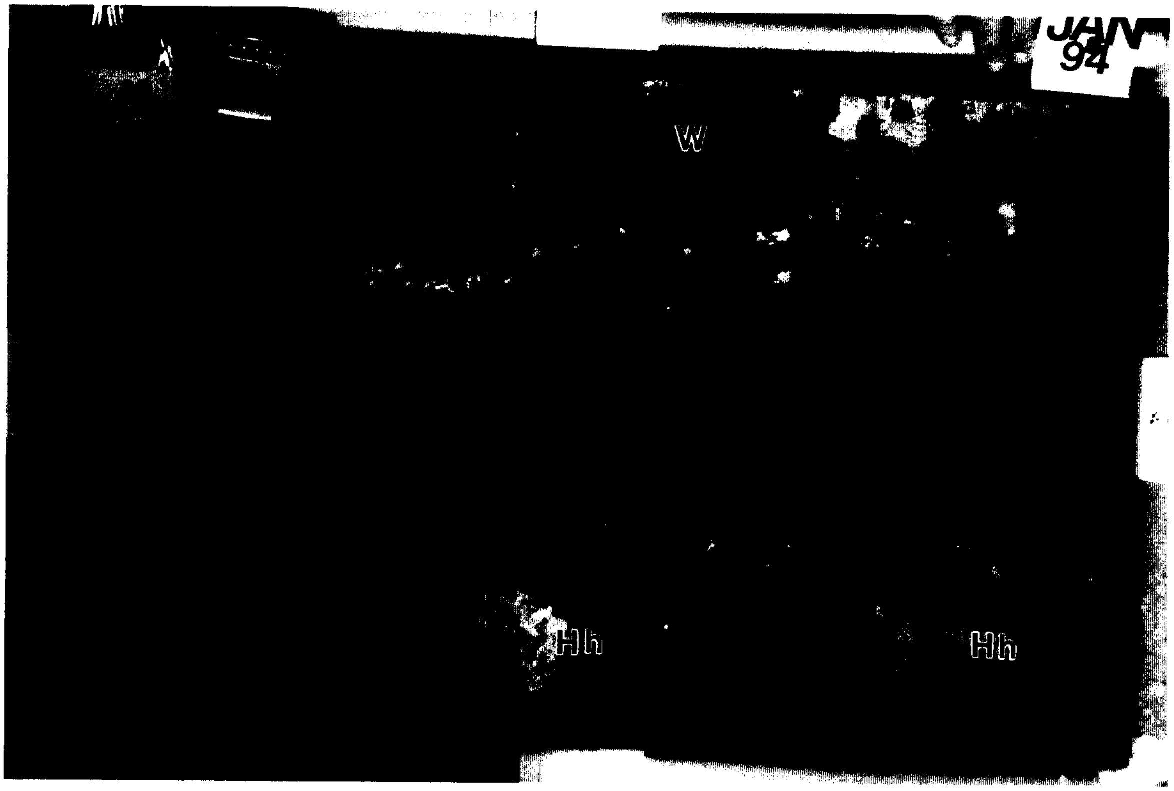

JAN
94

M 7 Top: January, 1994
Bottom: December, 1992





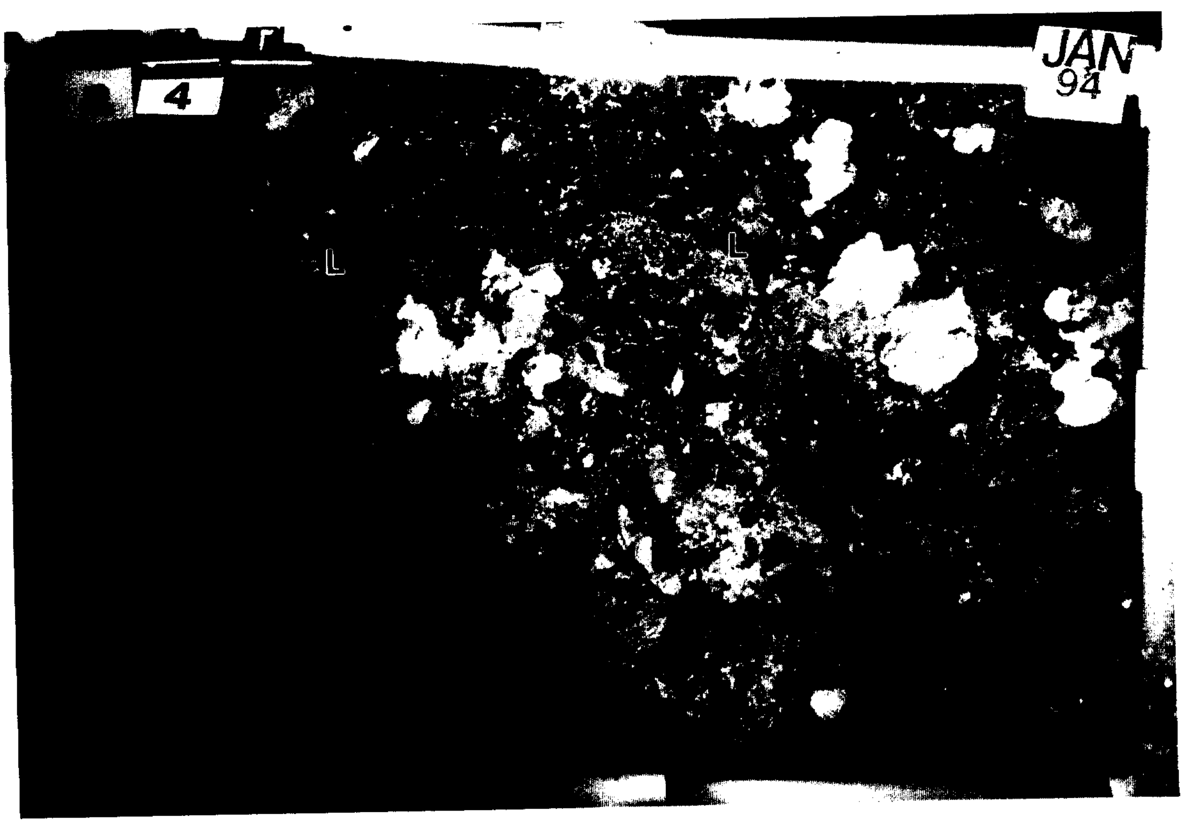
M 9 Top: January, 1994
Bottom: December, 1992

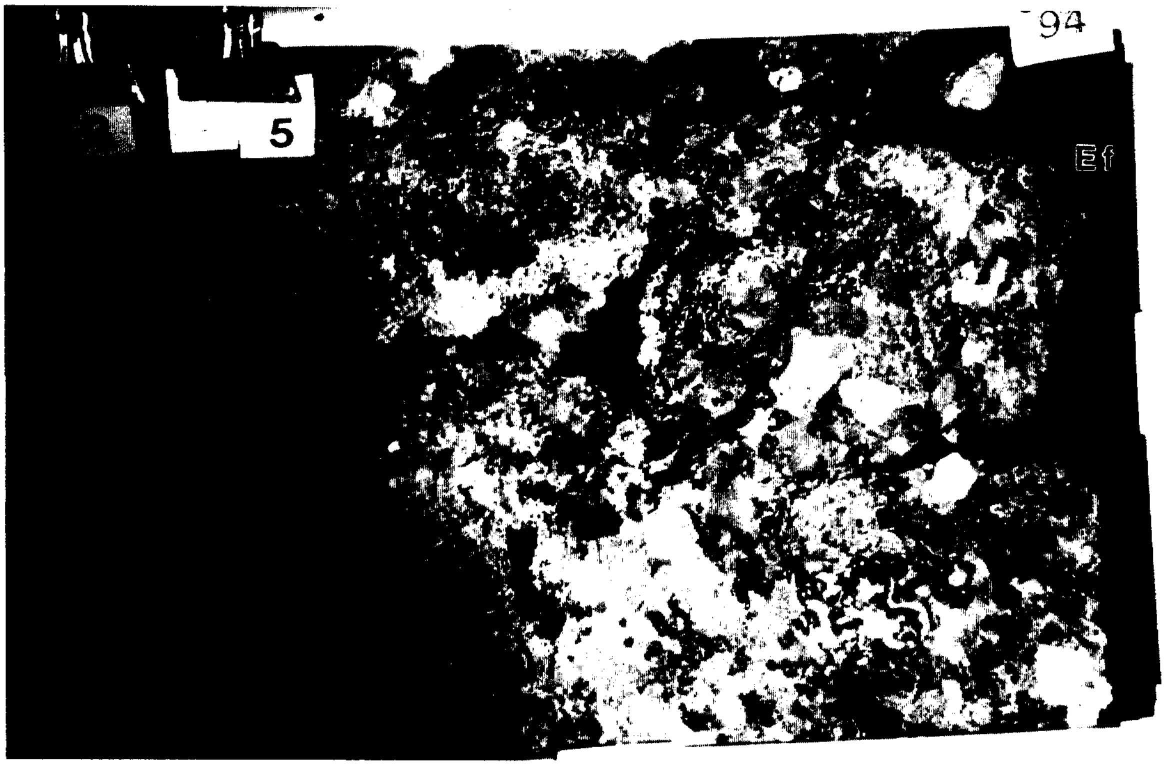



JAN
94

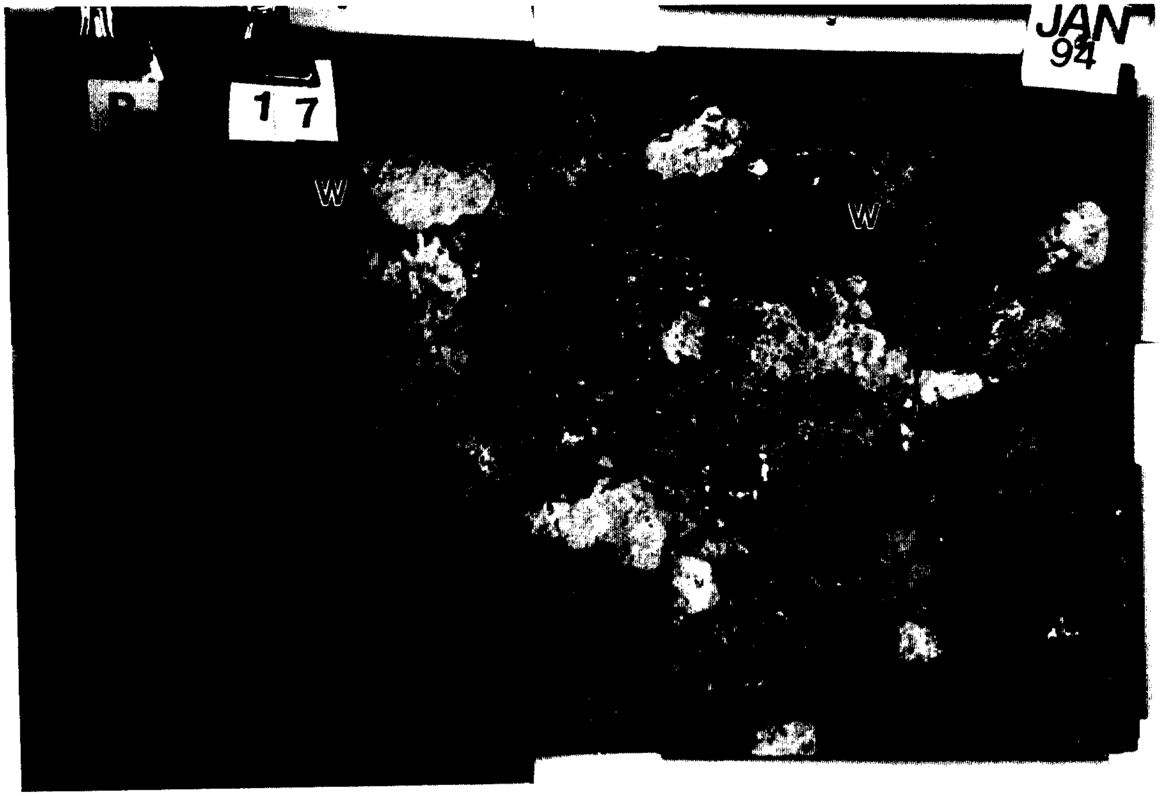

94

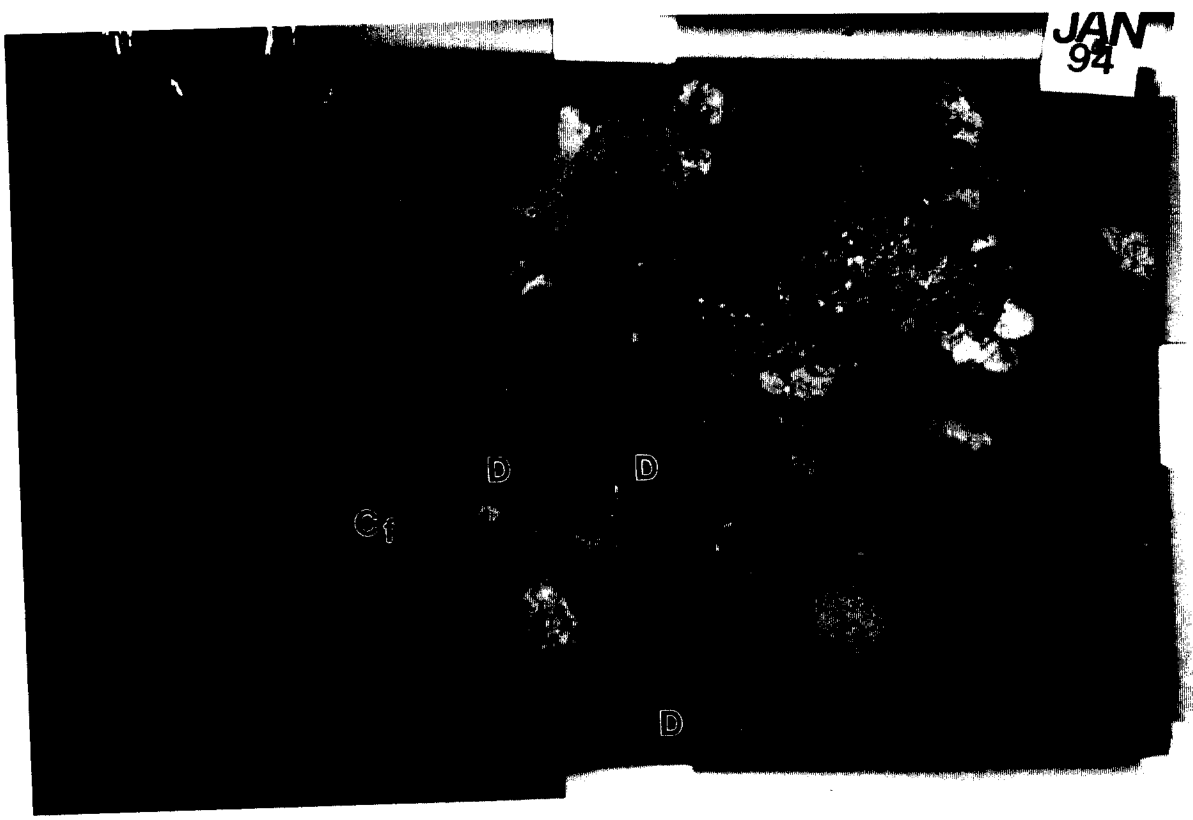

R
2
JAN
94


4
JAN
94
L
L


5
94

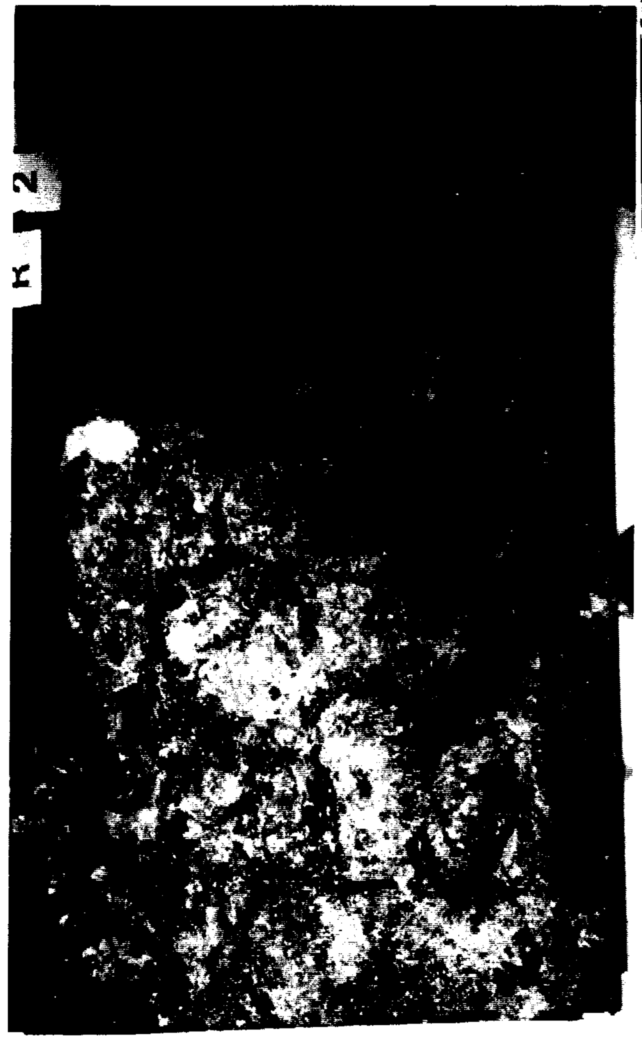

94


1 7
JAN
94
W
W


JAN
94
D
D
D

R 21
January, 1994

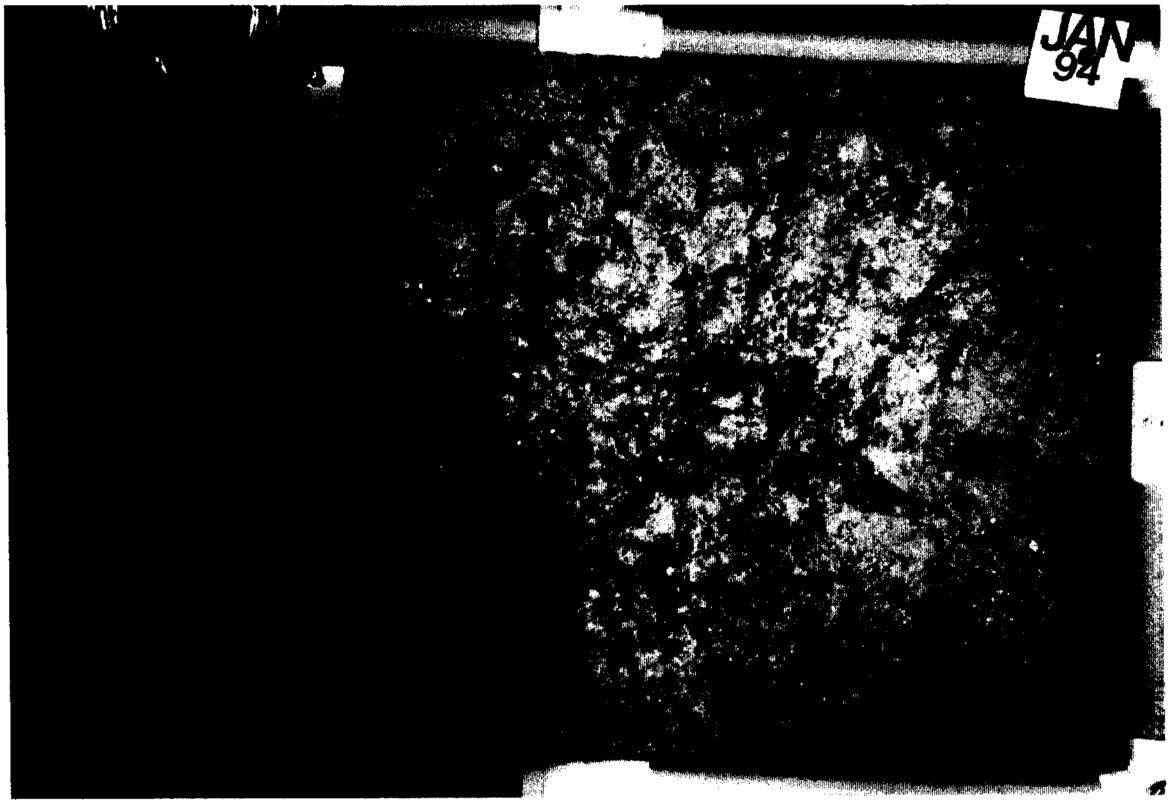
R 21
December, 1992

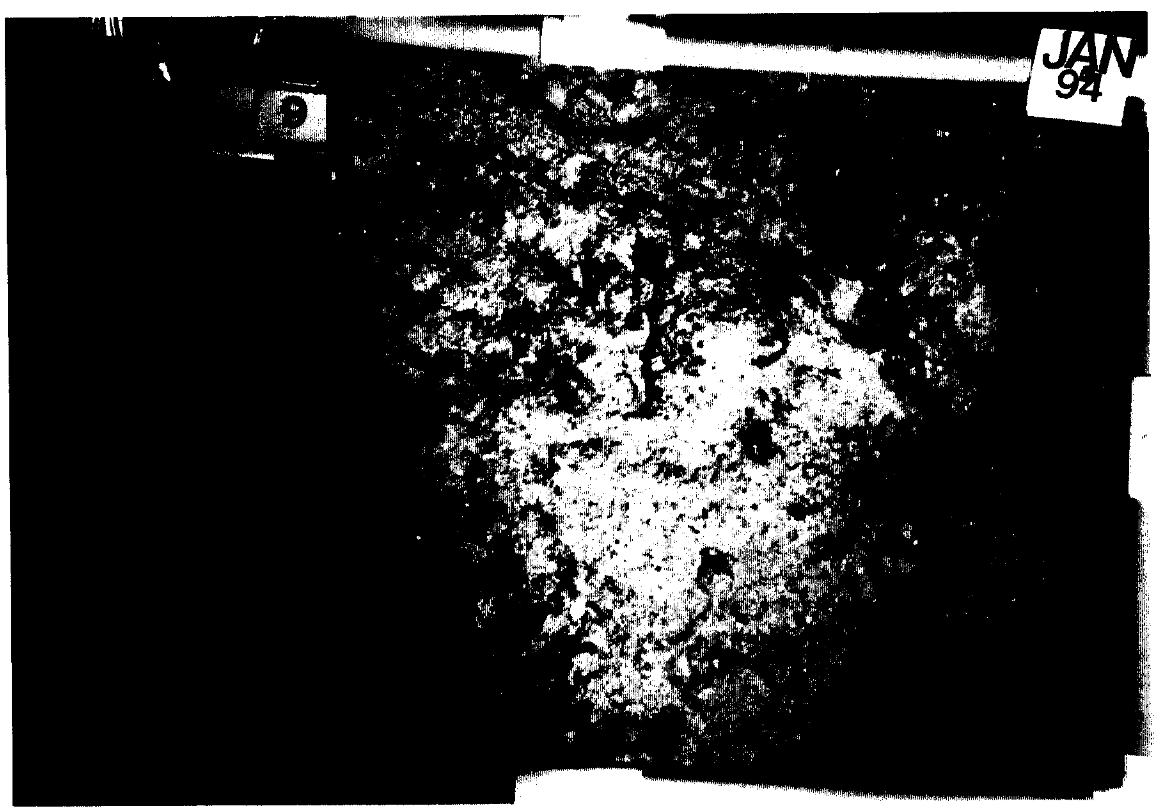


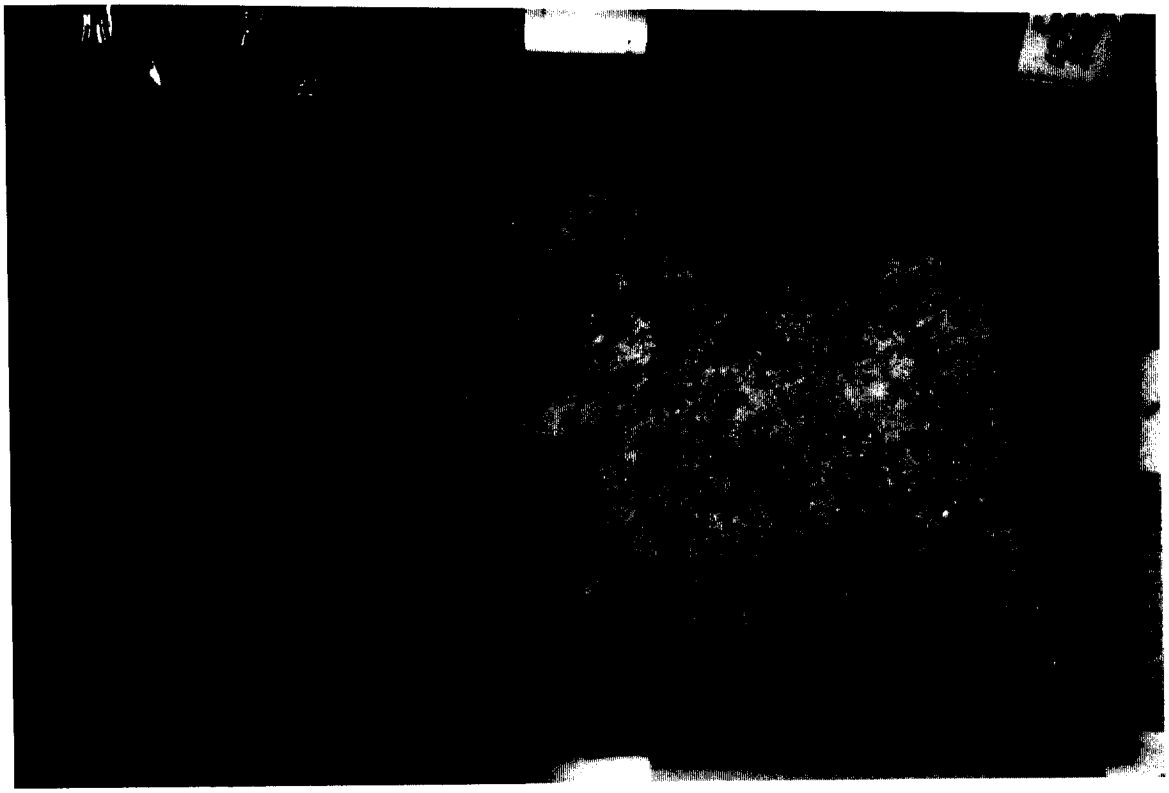
R 21
November, 1991

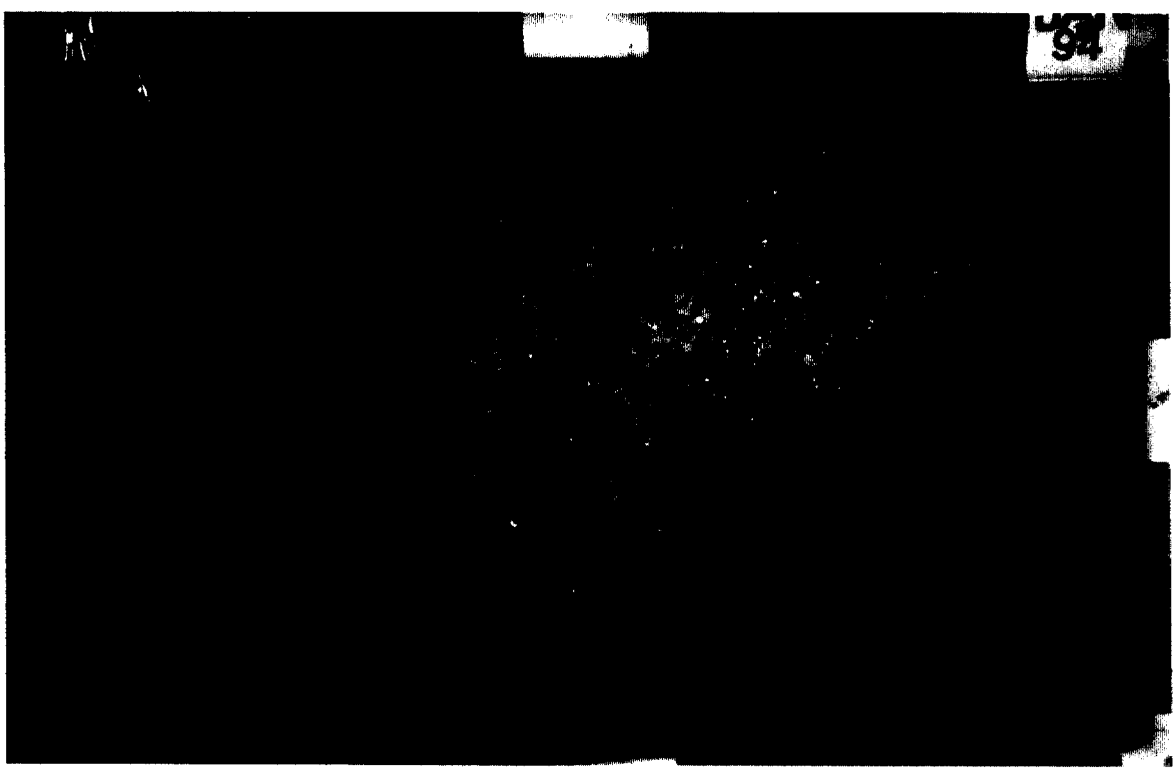

3
JAN
94


94

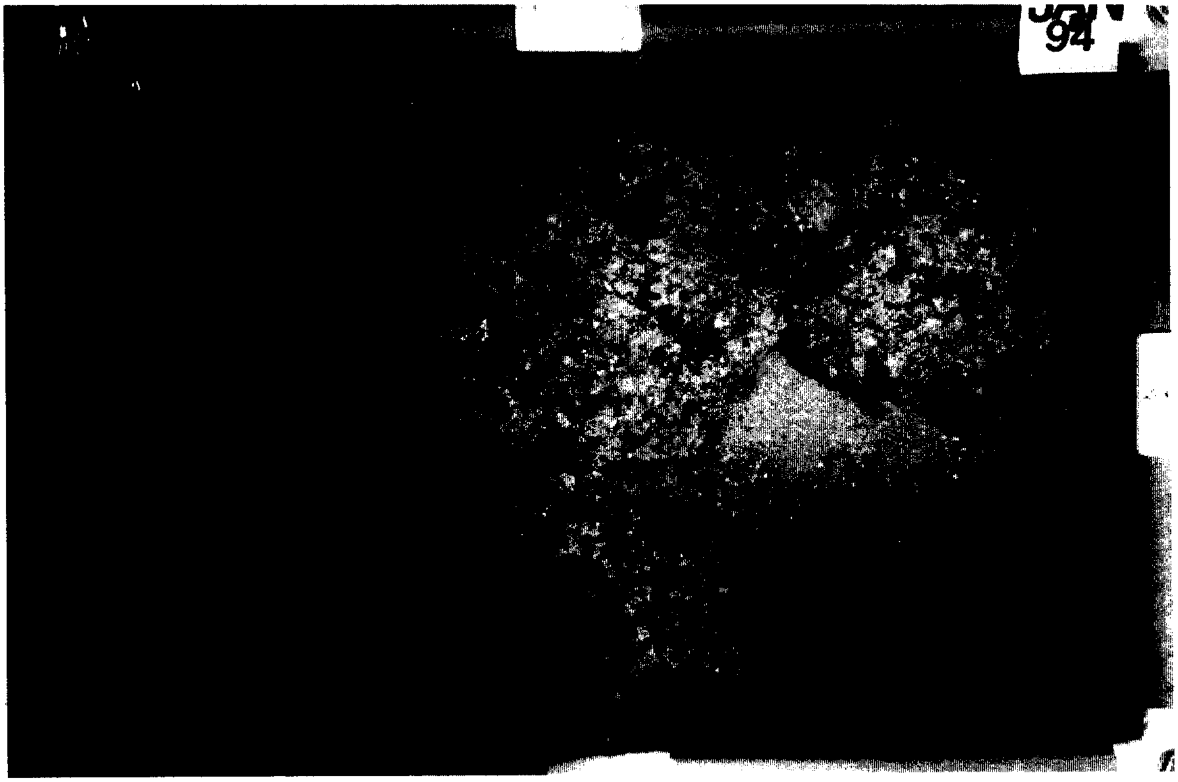

JAN
94


JAN
94

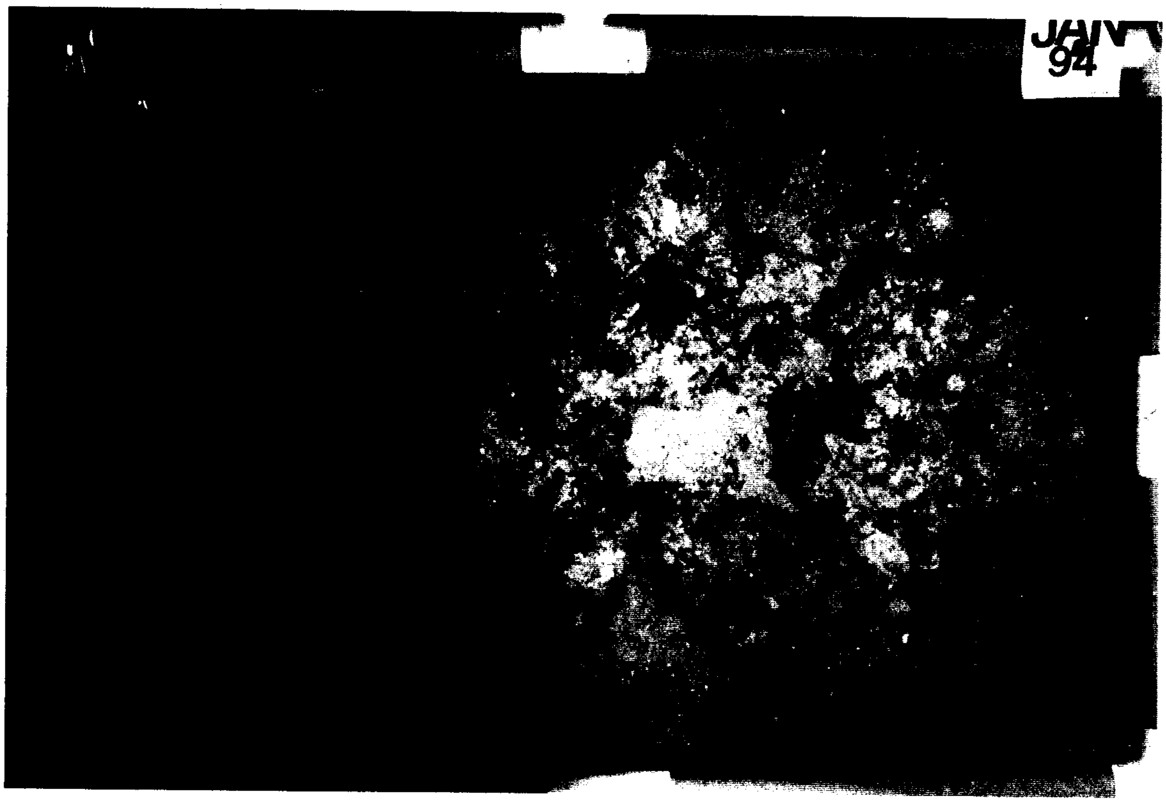


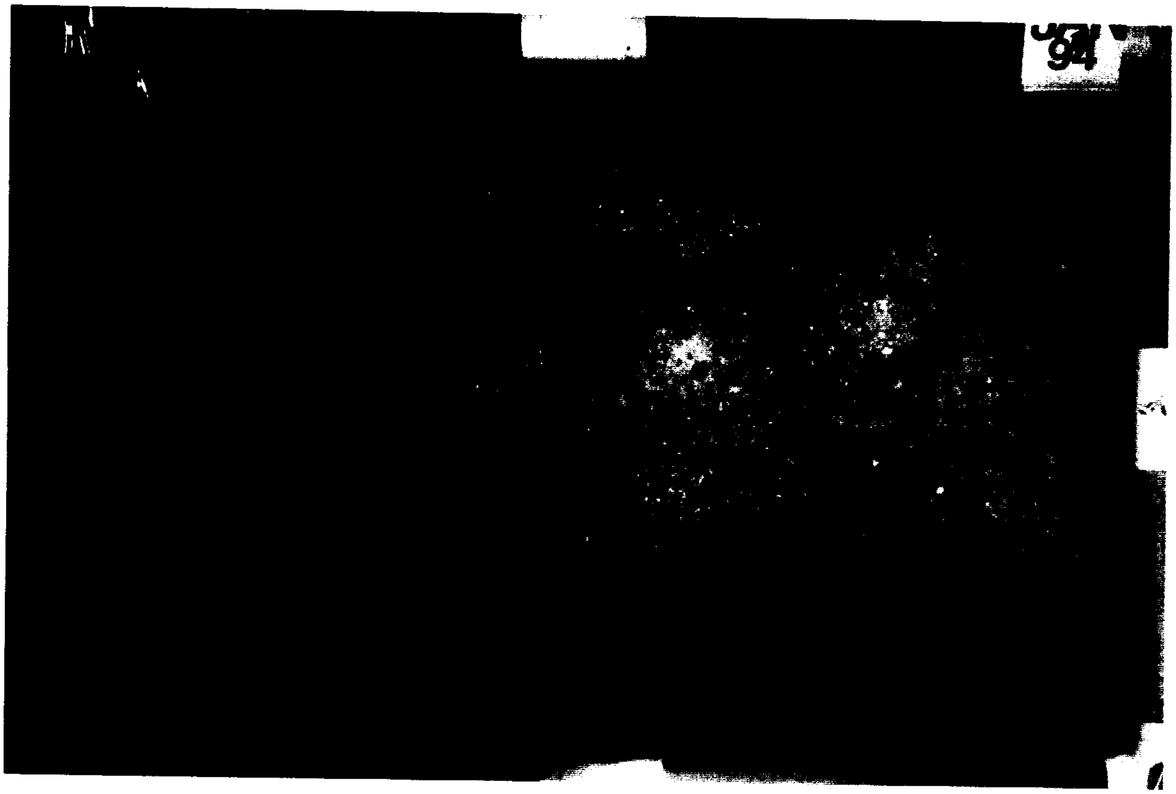

94

BC 21: Top Jan. 1994
Bottom: Dec. 1992



BC 27 Top: Jan. 1994
Bottom: Dec. 1992




94


JAN
94

APPENDIX 2: HISTORY OF INVERTEBRATE AND PLANT COLONIZATION OF MODULES AND CONTROLS

Data in left column indicates current population; population history is shown in parenthesis as follows: (The number of individuals: month/year). Species designated as new are new to that module.

Domes

D-18

>20 Holopsamma helwigi (Porifera) (1: 12/92; 7: 4/93; >20: 8/94)
4 Dysidea sp. (Porifera) (1: 12/92 ; 4/93; 4: 8/93)
1 Millepora alcicornis (fire coral) (2: 8/93)
0 Parasmittina sp. (Bryozoa) (2: 12/92; 0 :4/93; 0: 8/93)
0 Lima lima (file shells-in Keyway) (2 Dec. 92; 0 April, 93; 1: 8/94)
4 Stolonica sabulosa (Ascidia) (1 Dec. 92; 7 April 93; 0: 8/93)
1 unidentified didemnid (Ascidia) (1: 12/92; 1: 4/93; 1: 8/93)
1 Meandrina meandrites (Scleractinia- **new**)
1 Siderastrea sp. (Scleractinia- **new**)

D-19

0 Wrangelia argus (Rhodophyta) (0: 12/92; >20: 4/93; 0: 8/93)
>20 Holopsamma helwigi (Porifera) (3: 12/92; 10: 4/93; >20: 8/93)
1 Callyspongia vaginalis (Porifera) (1: 12/92; 1: 4/93; 1: 8/93)
0 Callyspongia fallax (Porifera) (1: 8/93)
2 Dysidea sp. (Porifera) (3: 8/93)
1 Stenopus hispidus (cleaning shrimp in keyway) (1: 8/93)
8 Stolonica sabulosa (Ascidia) (4: 12/92; >20: 4/93; 0: 8/93)
0 unid. didemnid (Ascidia) (1: 12/92; 1: 4/93; 0: 8/93)
0 Lima lima (bivalve in keyway) (1: 12/92; 0: 4/93; 0: 8/93)
0 Reteporellina sp. (Bryozoa)(1: 12/92; 0: 4/93; 0: 8/93)
1 Millepora alcicornis (fire coral- **new**)

D-20 (knocked off base; toppled into valley)

0 Wrangelia argus (Rhodophyta) (>20: 12/92; >20: 4/93; 0: 8/93)
>20 Holopsamma helwigii (Porifera) (0: 12/92; 11: 4/93; >20: 8/93)
3 Callyspongia vaginalis (Porifera- **new**)
1 Callyspongia fallax (Porifera)(0: 12/92; 1: 4/93; 0: 8/93)
1 Dysidea sp. (Porifera) (1: 8/93)
1 Ulosa reutzleri (Porifera- **new**)
3 Millepora alcicornis (fire coral) (2: 8/93)
0 Spondylus americanus (spiny oyster) (1: 12/92 1: 4/93; 1: 8/93)
0 Reteporellina sp. (Bryozoa) (1: 12/92; 0: 4/93; 0: 8/93)
>20 Stolonica sabulosa (Ascidia) (>20: 12/92; >20: 4/93; 0?: 8/93)
1 unidentified didemnid ascidian (**new**)

D-21

>20 Holopsamma helwigi (Porifera) (4: 12/92; >20: /93; >20: 8/93)
2 Dysidea sp. (Porifera) (2: 12/92; 1: 4/93; 2: 8/93)
0 Callyspongia vaginalis (Porifera) (1: 12/92; 0: 4/93; 0: 8/93)
0 Callyspongia fallax (Porifera) (1: 12/92; 0: 4/93; 0: 8/93)
2 Iotrochota birotulata (Porifera- **new**)
1 Ulosa reutzleri (Porifera- **new**)
>20 Stolonica sabulosa (Ascidia) (9: 12/92; >20: 4/93; 1: 8/93)
0 Spondylus americanus (spiny oyster) (0: 12/92; 2: 4/93; 0: 8/93)
0 Lima lima in keyway (file shell) (0: 12/92; 2: 4/93; 0: 8/93)
0 Parasmittina sp. (Bryozoa) (0: 12/92; 1: 4/93; 0: 8/93)
2 Millepora alcicornis (fire coral) (0: 12/92; 1: 4/93; 3: 8/93)

D-22

0 Wrangelia argus (Rhodophyta) (0: 12/92; >20: 4/93; 0: 8/93)
>20 Holopsamma helwigi (Porifera) (3: 12/92; >20: 4/93; 20: 8/93)
4 Dysidea sp. (Porifera) (0: 12/92; 2: 4/93; 4 :8/93)
2 Ulosa reutzleri (Porifera) (2: 8/93)
1 Callyspongia vaginalis (Porifera- **new**)
1 Millepora alcicornis (fire coral) (1: 8/93)
0 Parasmittina sp. (Bryozoa) (1: 12/92; 0: 4/93; 0: 8/93)
1 Watersipora sp. (Bryozoa) (1: 12/92; 1: 4/93 0?: 8/93)

0 Dysidea sp. (Porifera) (0: 12/92; 2: 4/93; 3: 8/93)
0 Callyspongia fallax (Porifera) (1: 12/92; 0: 4/93 ?; 2: 8/93)
0 unid. brown Porifera (1 Aug. 92; 0 thereafter)
3 Callyspongia vaginalis (Porifera- **new**)
1 Iotrochota birotulata (Porifera- **new**)
1 Millepora alcicornis (fire coral) (1: 8/93)
0 Siderastrea radians (Scleractinia) (0: 12/92; 1: 4/93; 0: 8/93)
1 Meandrina meandrites (Scleractinia- **new**)
0 Stenopus hispidus in keyway (2: 12/92; 0: 4/93; 0: 8/93)
0 Watersipora sp. (1 Aug. 92; 0 thereafter)
>20 Stolonica sabulosa (>20: 12/92; >20: 4/93; 0??: 8/93)

D-43
0 Wrangelia argus (Rhodophyta) (>20: 12/92; >20: 4/93; 0: 8/93)
>20 Holopsamma helwigi (Porifera)(5: 12/92; >20: 4/93; >20: 8/93)
1 Callyspongia fallax (Porifera) (2: 12/92; 1: 4/93; 3: 8/93)
1 Callyspongia vaginalis (Porifera- **new**)
1 Callyspongia plicifera (Porifera- **new**)
1 Ulosa reutzleri (Porifera- **new**)
5 Dysidea sp. (Porifera) (0: 12/92; 1: 4/93; 3: 8/93)
1 Millepora alcicornis (fire coral) (0: 12/92; 1: 4/93; 2: 8/93)
1 unidentified didemnid ascidian (1: 8/93)
>20 Stolonica sabulosa (Ascidia) (4: 12/92; >20: 4/93; 0??: 8/93)
0 Eucidaris sp. in keyway (1 Dec. 92; 0 thereafter)

D-49 (module slid into valley 8/92)
0 Wrangelia argus (Rhodophyta) (0: 12/92; >20: 4/93; 0: 8/93)
>20 Holopsamma helwigi (Porifera) (9: 12/92; 13: 4/93; >20: 8/93)
1 Callyspongia fallax (Porifera) (1: 12/92; 3: 4/93; 2: 8/93
4 Dysidea sp. (Porifera) (0: 12/92; 1: 4/93; 2: 8/93)
1 Callyspongia vaginalis (Porifera) (1: 12/92; 0: 4/93; 0: 8/93)
1 Iotrochota birotulata (Porifera- **new**)
0 Stolonica sabulosa (Ascidia) (>20: 12/92; >20:4/93; 0: 8/93)
0 Reteporellina sp. (Bryozoa) (1: 12/92; 0: 4/93; 0: 8/93)
0 Lima lima in keyway (1 Aug. 92; 0 thereafter)
0 Stenopus hispidus (1: 8/93)

D-50

0 Wrangelia argus (Algae) (>20: 12/92; >20: 4/93; 0: 8/93)
2 Unid. fluorescent red calcareous alga at module top (1: 8/93)
>20 Holopsamma helwigi (Porifera) (1: 12/92; 18: 4/93; >20: 8/93)
11Dysidea sp. (Porifera) (0: 12/92; 2: 4/93; 7: 8/93)
0 Callyspongia fallax (Porifera) (0: 12/92; 3: 4/93; 5: 8/93)
0 unid. brown Porifera (1 Aug '92.; 0 thereafter)
0 Iotrochota birotulata (Porifera) (1: 8/93)
0 Parasmittina sp. (Bryozoa) (1: 12/92, 0: 4/93; 0: 8/93)
0 Watersipora sp. (Bryozoa) (1 Dec. 92; 0 thereafter)
>20 Stolonica sabulosa (>20: 12/92; >20: 4/93; 1??: 8/93)
0 Lima lima (2 Aug. 92; 0 thereafter)
0 Stenopus hispidus in keyway (1 Aug. 92; 0 thereafter)
0 Diadema antillarum in key (1: 12/92; 0: 4/93; 0: 8/93)

Reef Replacement Modules (when no location within the module is noted, the organisms are on the sides only)

R-2

9 Holopsamma helwigi (10: 8/93)
8 Callyspongia fallax (2: 12/92; 5: 4/93; 8: 8/93)
0 Ulosa reutzleri (0: 12/92; 1: 4/93; 1: 8/93)
>20 Dysidea sp. (0: 12/92; 2:4/93; 12: 8/93)
1 Niphates sp. (Porifera- **new**)
4 Millepora alcicornis (2: 8/93)
4 Lima lima (6: 12/92; 3: 4/93; 6: 8/93)
1 Spondylus americanus (Bivalvia- **new**)
6 Parasmittina sp. (1: 12/92; 0: 4/93; 6: 8/93)
10 Stolonica sabulosa (1: 12/92; 0: 4/93; 1: 8/93)
0 Echinometra lucunter (0: 12/92; 2: 4/93; 0: 8/93)
0 Melanostigma nigromaculatus (0: 12/92; 4: 4/93; 0: 8/93)
0 unid. didemnid ascidians (2: 12/92; 2: 4/93; 0: 8/93)

R-4
>20 Dysidea sp. (9: 8/93)
4 Callyspongia fallax (7: 8/93)
1 Ulosa reutzleri (2: 8/93)
>20 Millepora alcicornis (5: 8/93)
3 Parasmittina sp. (3: 8/93)
1 Spondylus americanus (0: 12/92; 1: 4/93; 1: 8/93)
3 Lima lima (6: 12/92; 1: 4/93; 4: 8/93)
0 unid. didemnid ascidians (6: 12/92; 2: 4/93; 0: 8/93)
1 Agaricia sp. (fragilis ?) (Scleractinia- **new**)
6 Stolonica sabulosa (Ascidia- **new**)

R-5 (Not surveyed Dec. 92)
>20 Holopsamma helwigi (5: 4/93; 8: 8/93)
1 Dysidea sp. (3: 4/93; 2: 8/93)
1 Callyspongia fallax (1: 4/93; 0: 8/93)
1 Callyspongia plicifera (Porifera- **new**)
1 Callyspongia vaginalis (Porifera- **new**)
4 Iotrochota birotulata (Porifera- **new**)
1 Ulosa reutzleri (Porifera- **new**)
>20 Millepora alcicornis (0: 4/93; 1: 8/93)
3 Lima lima (0: 4/93; 3: 8/93)
3 Parasmittina sp. (4: 4/93; 3: 8/93)
2 Trematooecia aviculifera (Bryozoa- **new**)
1 Reteporellina sp. (Bryozoa- **new**)
1 Stolonica sabulosa (1: 4/93; 0: 8/93)
2 Eunicea sp. (1: 4/93; 2: 8/93)
1 Melanostigma nigrmaculatus (Sabellidae- **new**)

R-7
>20 Holopsamma helwigi (1: 12/92; 13: 4/93; >20: 8/93)
3 Dysidea sp. (0: 12/92; 1: 4/93; 3: 8/93)
0 unid. red sponge (0: 12/92; 3: 4/93; 0: 8/93)
3 Callyspongia fallax (2: 12/92; 2: 4/93; 3: 8/93)
1 Meandrina meandrites juvenile (1: 8/93)
1 Lima lima (0: 12/92; 1: 4/93; 1: 8/93)

1 Spondylus americanus (1: 12/92; 1: 4/93; 1: 8/93)
0 Parasmittina (1: 12/92; 0: 4/93; 0: 8/93)
2 Watersipora sp. (2: 8/93)
0 Reteporellina sp. (Bryozoa) (1: 12/92; 0: 4/93; 0: 8/93)
0 Ascidia nigra (0: 12/92; 2: 4/93; 0: 8/93)
1 didemnid ascidian (2: 12/92; 0: 4/93; 1: 8/93)

R-14

11 Holopsamma helwigi (0: 12/92; 3: 4/93; >20: 8/93)
9 Dysidea sp. (0: 12/92; 3: 4/93; 6: 8/93)
1 Callyspongia fallax (1: 12/92; 1: 4/93; 1: 8/93)
1 Callyspongia vaginalis (1: 8/93)
5 Iotrochota birotulata (Porifera- **new**)
2 Ulosa reutzleri (Porifera- **new**)
1 Eunicea fusca (0: 12/92; 1: 4/93; 1: 8/93)
1 unidentified scleractinian (Scolymia sp. ?- **new**)
0 unid. serpulid polychaetes (3: 12/92; 0: 4/93; 0: 8/93)
6 Lima lima (5: 12/92; 1: 4/93; 3: 8/93)
2 Spondylus americanus (1: 12/92; 3: 4/93; 1: 8/93)
0 Reteporellina sp. (1: 8/93)
0 Ascidia nigra (1: 12/92; 0: 4/93; 0: 8/93)
3 Stolonica sabulosa (Ascidia- **new**)
1 Echinometra lucunter (1: 8/93)
1 Eucidaris sp. (Echinodermata- **new**)

R-15

>20 Holopsamma helwigi (0: 12/92; 9: 4/93; 16: 8/93)
0 Callyspongia fallax (2: 12/92; 5: 4/93; 3: 8/93)
2 Callyspongia vaginalis (1: 8/93)
2 Dysidea sp. (0: 12/92; 3: 4/93; 0: 8/93)
4 Iotrochota birotulata (porifera- **new**)
1 Telesto riisei (1: 8/93)
>20 Millepora alcicornis (fire coral- **new**)
0 Melanostigma nigromaculata (1: 8/93)
0 Reteporellina sp. (Bryozoa) (2: 12/92; 0: 4/93; 0: 8/93)
1 Watersipora sp. (5: 8/93)

2 Trematooecia aviculifera (Bryozoa- **new**)
4 Lima lima (3: 8/93)
2 Spondylus americanus (1: 8/93)
0 Stolonica sabulosa (2: 12/92; 0: 4/93; 0: 8/93)
1 Eucidaris sp. (1: 12/92; 1: 4/93; 2: 8/93)

R-16
0 Callyspongia fallax (7: 12/92; 7: 4/93; 3: 8/93)
>20 Holopsamma helwigi (0: 12/92; 13: 4/93; 15; 8/93)
12 Dysidea sp. (0: 12/92; 5: 4/93; 4: 8/93)
1 Callyspongia vaginalis (Porifera- **new**)
1 Callyspongia plicifera (Porifera- **new**)
1 Iotrochota birotulata (Porifera- **new**)
1 Xestospongia muta (0: 12/92; 1: 4/93; 1: 8/93)
1 Leucosolenia sp. (0: 12/92; 1: 4/93; 0: 8/93)
2 Eunicea sp. (E. knighti ?) (Gorgonacea- **new**)
1 Millepora alcicornis (fire coral- **new**)
0 Ascidia nigra (1: 12/2; 0: 4/93; 0: 8/93
1 Lima lima (7: 12/92; 0: 4/93; 1: 8/93)
0 Spondylus americanus (0: 12/92; 1: 4/93; 0: 8/93)
0 Parasmittina sp. (1: 12/92; 0: 4/93; 0: 8/93)
7 Stolonica sabulosa (Ascidia- **new**)

R-17
>20 Holopsamma helwigi (0: 12/92; 10: 4/93; >20 8/93)
17 Dysidea sp. (0: 12/92; 7: 4/93; 10: 8/93)
0 Callyspongia fallax (0: 12/92; 1: 4/93; 1: 8/93)
1 Callyspongia vaginalis (Porifera- **new**)
8 Iotrochota birotulata (Porifera- **new**)
1 Millepora alcicornis (1: 8/93)
3 Lima lima (3 : 12/92; 1: 4/93; 4: 8/93)
0 Parasmittina sp. (2: 12/92; 5: 4/93; 0: 8/93)
3 Reteporellina sp. (Bryozoa- **new**)
1 Trematooecia aviculifera (Bryozoa- **new**)
1 Watersipora sp. (1: 8/93)
0 Stenopus hispidus (1: 12/92; 0: 4/93; 0: 8/93)

1 unidentified didemnid ascidian (**new**)

R-21

10 Holopsamma helwigi (0: 12/92; 5: 4/93; 10: 8/93)
10 Dysidea sp. (2: 12/92; 8: 4/93; 4: 8/93)
2 Callyspongia fallax (2: 12/92 6: 4/93; 7: 8/93)
3 Callyspongia vaginalis (1: 8/93)
0 Ulosa reutzleri (0: 12/92; 1: 4/93; 0: 8/93)
1 Callyspongia vaginalis (0: 12/92; 0: 4/93; 1: 8/93)
1 Millepora alcicornis (0: 12/92; 1: 4/93; 3: 8/93)
2 Melanostigma nigromaculatus (2: 12/92; 1: 4/93; 1: 8/93)
3 Lima lima (5: 12/92; 2: 4/93; 5: 8/93)
0 Stenopus hispidus (2: 12/92; 0: 4/93; 0: 8/93)
1 Stenorhynchus seticornis (1: 8/93)
0 Echinometra lucunter (urchin) (1: 12/92; 0: 4/93; 0: 8/93)
1 Eucidaris sp. (urchin)(1: 12/92; 0: 4/93; 0: 8/93)
0 Ascidia nigra (2: 12/92; 0: 4/93; 0: 8/93)

R-22

>20 Holopsamma helwigi (0: 12/92; >20: 4/93; >20 8/93)
7 Dysidea sp. (0: 12/92; 3: 4/93; 7: 8/93)
1 Callyspongia fallax (2: 12/92; 3: 4/93; 3: 8/93)
2 Callyspongia vaginalis (Porifera- **new**)
1 Iotrochota birotulata (Porifera- **new**)
>20 Millepora alcicornis (fire coral- **new**)
0 Melanostigma nigromaculata (1: 12/2; 1: 4/93; 0: 8/93)
2 Lima lima (2: 12/92; 0: 4/93; 6; 8/93)
0 Watersipora sp. (3: 8/93)
1 Ascidia nigra (0: 12/92; 1: 4/93; 1: 8/93)

R-23

>20 Holopsamma helwigi (0: 12/92; 20: 4/93; >20: 8/93)
4 Callyspongia fallax (0: 12/92; 6: 4/93; 3: 8/93)
2 Callyspongia vaginalis (1: 8/93)
1 Callyspongia plicifera (Porifera- **new**)
4 Dysidea sp. (3: 12/92; 9: 4/93; 3: 8/93)

1 Ulosa reutzleri (Porifera- **new**)
2 Millepora alcicornis (2: 8/93)
1 Reteporellina sp. (Bryozoa- **new**)
2 Lima lima (0: 12/92; 1: 4/93; 1: 8/93)
0 Spondylus americanus (0: 12/92; 1: 4/93; 0: 8/93)
0 Echinometra lucunter (2: 12/92; 1: 4/93; 0: 8/93)
1 Eucidaris sp. (1: 8/93)
0 Stolonica sabulosa (1: 12/92; 0: 4/93; 0: 8/93)
1 Ascidia nigra (1: 8/93)

M-Modules

M-1
>20 Holopsamma helwigi (1: 12/92; >20: 4/93; >20: 8/93)
13 Dysidea sp. (4: 12/92; 2: 4/93; 4: 8/93)
9 Callyspongia fallax (0: 12/92; 7: 4/93; 9: 8/93)
6 Iotrochota birotulata (Porifera- **new**)
2 Niphates sp. (Porifera- **new**)
>20 Millepora alcicornis (fire coral- **new**)
2 Telesto riisei (0: 12/92; 2: 4/93; 2: 8/93)
3 Reteporellina sp. (5: 12/92; 0: 4/93; 0: 8/93)
0 Parasmittina sp. (0: 12/92; 2: 4/93; 0: 8/93)
0 Ascidia nigra (2 Aug. 92; 0 thereafter)
0 Unid. brown didemnid ascidian (0: 12/92; 1: 4/93; 0: 8/93)
1 Panulirus argus (1: 12/92; 0: 4/93; 0: 8/93)

M-2 (module moved 8/92 but undamaged)
>20 Holopsamma helwigi (0: 12/92; >20: 4/93; >20: 8/93)
1 Callyspongia fallax (1: 12/92; 0: 4/93; 2: 8/93)
4 Callyspongia vaginalis (Porifera- **new**)
5 Iotrochota birotulata (Porifera- **new**)
1 Ulosa reutzleri (Porifera- **new**)
15 Dysidea sp. (8: 12/92; 8: 4/93; 6: 8/93)
5 Millepora alcicornis (fire coral- **new**)
5 Telesto riisei (0: 12/92; 3: 4/93; >20: 8/93)

0 Parasmittina sp. (4: 12/92; 4: 4/93; 0: 8/93)
0 Watersipora sp. (1: 8/93)
1 Trematooecia aviculifera (Bryozoa- **new**)
0 Melanostigma nigromaculata (1 Aug. 92; 0 thereafter)
0 Ascidia nigra (1 Aug. 92; 0 thereafter)
0 Unid. didemnid ascidian (0: 12/92; 1: 4/93; 0: 8/93)
2 Stolonica sabulosa (Ascidia- **new**)

M-3 (module moved into valley 8/92)
17 Holopsamma helwigi (0: 12/92; 13: 4/93; >20: 8/93)
9 Dysidea sp. (2: 12/92; 6: 4/93; 0 ??: 8/93)
0 Callyspongia fallax (3: 8/92; 2: 12/92; 1: 4/93; 5: 8/93)
2 Callyspongia vaginalis (2: 8/93)
3 Iotrochota birotulata (Porifera- **new**)
0 Telesto riisei inside (3 Aug. 92; 0 thereafter)
0 Melanostigma nigromaculata (0: 12/92; 1: 4/93; 0: 8/93)
0 Parasmittina sp. (15: 12/92; 1: 4/93; 0: 8/93)
1 Watersipora sp. (1: 12/92; 2: 4/93; 0? 8/93)
1 unidentified didemnid ascidian
0 Mithrax sp. (1: 8/93)
1 Unid. bivalve (1: 8/93)
1 Ascidia nigra (1: 8/93)
0 Stolonica sabulosa (1: 8/93)

M-4 (moved into valley 8/92; could not photograph long side or ID plate. New transect: short side adjacent to ID plate
>20 Holopsamma helwigi (4: 12/92; 13: 4/93; >20: 8/93)
3 Dysidea sp. (Porifera- **new**)
3 Callyspongia fallax (2: 12/92; 3: 4/93; 3: 8/93)
2 Callyspongia vaginalis (Porifera- **new**)
4 Iotrochota birotulata (Porifera- **new**)
0 Telesto riisei inside (3 Aug. 92; 0 thereafter)
0 T. riisei outside in phototransect (0: 12/92; 3: 4/93; 3: 8/93)
1 Millepora alcicornis (fire coral- **new**)
1 Porites sp. (Scleractinia- **new**)
0 Parasmittina sp. (4: 12/92; 1: 4/93; 0: 8/93)

1 Watersipora sp. (1: 12/92; 1:4/93; 1: 8/93)
0 Spondylus americanus (1: 12/92; 0: 4/93; 0: 8/93)
3 Stolonica sabulosa (2: 12/92; 0: 4/93; 0: 8/93)
1 unidentified didemnid ascidian (**new**)
0 Mithrax sp. (M. spinosissimus ?) (0: 12/92; 1: 4/93; 0: 8/93)

M-5
>20 Holopsamma helwigi (11: 12/92; 18: 4/93; >20 8/93)
1 Dysidea sp. (1: 12/92; 2: 4/93; 3: 8/93)
6 Iotrochota birotulata (1: 8/93)
5 Callyspongia vaginalis (1: 8/93)
1 Callyspongia fallax (Porifera- **new**)
3 Telesto riisei (0: 12/92; 3: 4/93; 0 ??: 8/93)
0 Parasmittina sp. (10: 12/92; 6: 4/93; 0: 8/93)
0 Watersipora sp. (2: 12/92; 0: 4/93; 1: 8/93)
0 Ascida nigra (2 Aug. 92; 0 thereafter)
2 Didemnid ascidian (1: 8/93)
0 Spondylus americanus (1 Aug. 92; 0 thereafter)
0 Stenopus hispidus (2 Aug. 92; 0 thereafter)
top of module dominated by Stolonicus sabulosa (ascidia)

M-6: module destroyed by hurricane- no survey

M-7
15 Holopsamma helwigi (9: 12/92; 10: 4/93; 15: 8/93)
15 Dysidea sp. (2: 8/92; 4: 12/92; 10: 4/93; 12: 8/93)
0 Callyspongia fallax (0: 12/92; 4/93; 3: 8/93)
2 Callyspongia vaginalis (0: 12/92; 1: 4/93; 3: 8/93)
1 Callyspongia plicifera (Porifera- **new**)
4 Iotrochota birotulata (Porifera- **new**)
1 Millepora alcicornis (fire coral- **new**)
0 Parasmittina sp. (8 : 8/92; 11: 12/92; 11: 4/93; 5: 8/93)
0 Watersipora sp. (Bryozoa) (7: 12/92; 0: 4/93; 5: 8/93)
0 Spondylus americanus (3: 8/92; 0: 12/92; 0: 4/93; 0: 8/93)
0 Ascidia nigra (2: 8/92; 0: 12/92; 0: 4/93; 0: 8/93)
0 Reteporellina sp. (2: 12/92; 0: 4/93; 0: 8/93)

1 Iotrochota birotulata (Porifera- **new**)
2 Telesto riisiei (Octocorallia- **new**)
1 Millepora alcicornis (fire coral- **new**)
0 Parasmittina sp. (10: 8/92; 8: 12/92; 3: 4/93; 0: 8/93)
2 Watersipora sp. (1: 12/92; 2: 4/93; 1: 8/93)
1 Spondylus americanus (Bivalvia- **new**)
0 Stenorhynchus seticornis (2 Aug. 92; 0 thereafter)
0 Ascidia nigra (6: 8/92; 5: 12/92; 0: 4/93; 0: 8/93)
0 Diadema antillarum (1 Aug. 92; 0 thereafter)
0 Melanostigma nigromaculatus (1: 12/92; 0: 4/93; 0: 8/93)
0 Reteporellina sp. (Bryozoa) (3: 12/92; 0: 4/93; 0: 8/93)

BARREN CONTROLS

BC-3
0 Wrangelia argus (Rhodophyta) (>20 Aug. 92; 0 thereafter)
0 Dictyota sp. (Phaeophyta) (1: 8/93)
0 Holopsamma helwigi (2: 12/92; 2: 4/93; 1: 8/93)
1 Haliclona rubens (1: 8/92; 0: 12/92; 0: 4/93; 1: 8/93)
2 Niphates digitalis (2: 8/92; 1: 12/92; 0: 4/92; 1: 8/93)
1 Dasychalina cyathina (Porifera- **new**)
3 unidentified porifera (**new**)
1 Callyspongia vaginalis (1: 8/93)
2 Ulosa reutzleri (Porifera- **new**)
0 Aplysina cauliformis (0: 12/92; 2: 4/93; 0: 8/93)
0 Teichaxinella morchella (1 Dec. 92; 0 thereafter)
1 Briareum asbestinum (Octocorallia) (1: 12/92; 1: 4/93; 1: 8/93)
1 Dichoecoenia stokesi (Scleractinia) (1: 12/92; 1: 4/93; 1: 8/93)
1 Siderastrea sp. juvenile " (1 Aug. 92; 0 thereafter)
0 Stolonica sabulosa (5: 12/92; 2: 4/93; 0: 8/93)
4 unidentified ascidian (**new**)
0 Opisthognathus aurifrons (jawfish- 2: 12/92; 0: 4/93; 0: 8/93)

BC-19: All stakes missing: 1/94

0 Halimeda goreauii (1 Aug 92; 0 thereafter)
1 Dictyota sp. (>20: 8/92; 0: 12/92; 0: 4/93; 1 8/93)
0 Wrangelia argus (0: 12/92; >20; 4/93; 0: 8/93)
1 Niphates digitalis (2: 8/92; 0: 12/92; 2: 4/93; 1: 8/93)
1 Holopsamma helwigi (5: 9/92; 3: 12/92; 3: 4/93; 1: 8/93)
1 Callyspongia fallax (1: 8/93)
0 Haliclona rubens (1 Aug. 92; 0 thereafter)
0 Xestospongia muta (1 Dec. 92; 0 thereafter)
1 Mycale sp. (Porifera- **new ?**)
0 Spirastrella coccinea (1 Dec. 92; 0 thereafter)
2 Eunicea fusca (Octocorallia) 3: 8/92; 4: 12/92; 4: 4/93; 8/93)
2 Briareum asbestinum (1: 12/92; 2: 4/93; 1: 8/93)
0 Dichocoenia stokesii (1: 12/92; 0: 4/93; 1: 8/93)
0 Montastrea cavernosa (1: 8/93)
0 Siderastrea radians (1: 8/93)
1 Stolonica sabulosa (0: 12/92; 3: 4/93; 1: 8/93)

BC-20

0 Halimeda goreauii (1: 12/92; 0: 4/93; 1: 8/93)
0 Wrangelia argus (>20: 12/92; >20: 4/93; 0: 8/93)
0 Dictyota sp. (1: 8/93)
2 Holopsamma helwigi (0: 12/92; 2: 4/93; 5: 8/93)
0 Callyspongia fallax (1 Dec. 92; 0 thereafter)
1 Niphates digitalis (1: 8/93)
1 Verongia longissima (Porifera- **new**)
0 Meandrina meandrites (in sand) (1: 12/92; 1: 4/93; 0: 8/93)
1 Stolonica sabulosa (2: 12/92; 1: 4/93; 0: 8/93)

BC-21

0 Udotea sp. (Chlorophyta) 8: 8/92; 0: 12/92; 1: 4/93; 7: 8/93)
0 Dictyota sp. (5: 8/93)
0 Halimeda goreauii (1: 8/93)
0 Wrangelia argus (>20: 12/92; >20: 4/93; 0: 8/93)
4 Holopsamma helwigi (0: 12/92; 2: 4/93; 0: 8/93)
0 Ulosa reutzleri (0: 12/92; 1: 4/93; 1: 8/93)

0 Spirastrella coccinea (1: 8/92; 0: 12/92; 1: 4/93; 0: 8/93)
1 Niphates digitalis (1: 8/92; 0: 12/92; 1: 4/93; 0: 8/93)
0 Stephanocoenia michelini (1 Aug. 92; 0 thereafter)
0 Montastrea cavernosa juv. (1 Dec. 92; 0 threreafter)
10 Stolonica sabulosa (1: 12/92; 1: 4/93; 0: 8/93)

BC-27

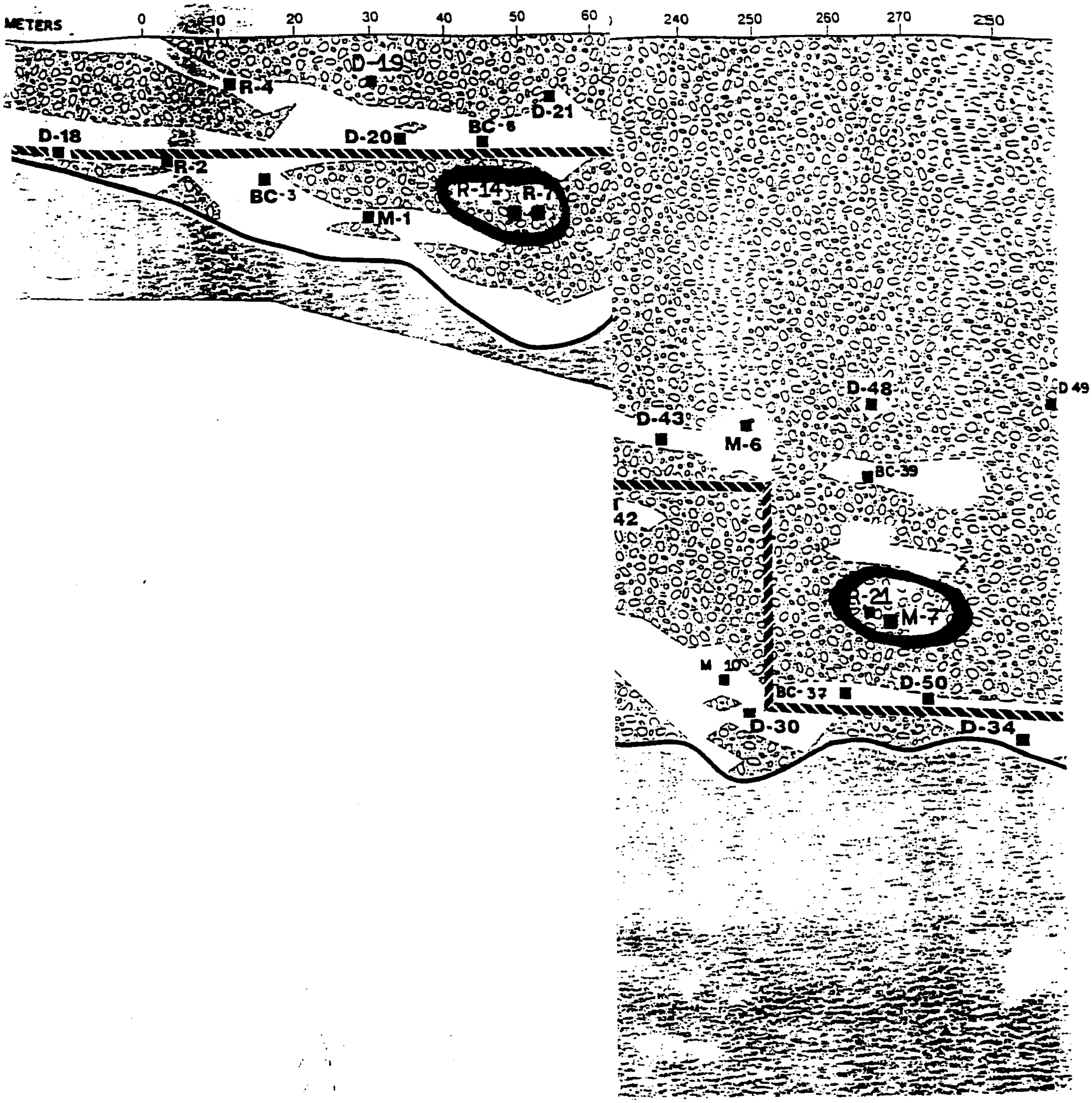
1 Udotea sp. (3: 12/92; 0: 12/92; 0: 4/93; 7: 8/93)
0 Halimeda goreauii (2 in Aug. 0 thereafter)
0 Wrangelia argus (>20: 12/92; >20: 4/93; 0: 8/93)
0 Aplysina sp. (0: 12/92; 1: 4/93; 0: 8/93)
5 Holopsamma helwigi (2 : 8/92; 1: 12/92; 4: 4/93; 6: 8/93)
3 Niphates digitalis (0: 12/92; 1: 4/93; 1: 8/93)
0 Eunicea fusca (1 Aug. 92; 0 thereafter)
1 Stolonica sabulosa (3: 12/92; 1: 4/93; 0: 8/93)
0 Unid. didemnid ascidian (1: 8/93)

BC-30

0 Wrangelia argus (0: 12/92; >20: 4/93; 0: 8/93)
0 Halimeda goreaui (1 Dec. 93; 0 thereafter)
0 Udotea sp. (7: 8/93)
1 Holopsamma helwigi (0: 12/92; 1: 4/93; 3: 8/93)
0 Dysidea sp. (0: 12/92; 1: 4/93; 0: 8/93)
1 Callyspongia plicifera (ptly. hidden) (1: 12/92; 1: 4/93; 0: 8/93)
1 Haliclona rubens (1: 8/93)
1 Ulosa reutzleri (Porifera- **new**)
3 Briareum asbestinum (1: 12/92; 0: 4/93; 0: 8/93)
0 Siderastrea siderea (hidden) (1: 12/92; 1: 4/93; 0: 8/93)
1 Meandrina meandrites (1: 12/92; 1: 4/93; 1: 8/93)
3 Stolonica sabulosa (1: 12/92; 1: 4/3; 0: 8/93)

BC-37

0 Udotea sp. (4: 8/92; 0: 12/92; 1: 4/93; 11: 8/93)
0 Wrangelia argus (0: 12/92; >20: 4/93; 0: 8/93)
0 Holposamma helwigi (0: 12/92; 2: 4/93; 1: 8/93)
2 Aplysina cauliformis (1: 8/92; 0: 12/92; 1: 4/93; 0: 8/93)



MODULE TYPE

D = DOME
R = REEF REPLACMENT
M = MODULE DESIGN 2
BC = BARREN CONTROL

SUNNY ISLES SITE FOR MONIT

G. M. SELBY & ASSOC., INC.
9500 S. DADELAND BLVD., SUITE 705
MIAMI, FLORIDA 33156

DEPARTMENT	DATE: JANUARY 09, 1992
NTAL	DRAWN BY: R.C.F.
NAGEMENT	SCALE: 1" = 10 METERS
MAP & DETAILS	UPDATE: OCT. 8TH 93 FRIEDRI