G. M. SELBY & ASSOCIATES, INC.

Sunny Isles
Artificial Reef Monitoring Project
Twelfth Quarterly Report- December, 1994

PREPARED FOR

DADE COUNTY DEPARTMENT OF
ENVIRONMENTAL RESOURCE MANAGEMENT

January 1995

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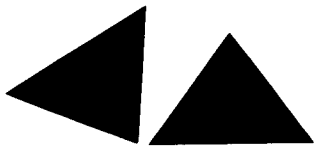

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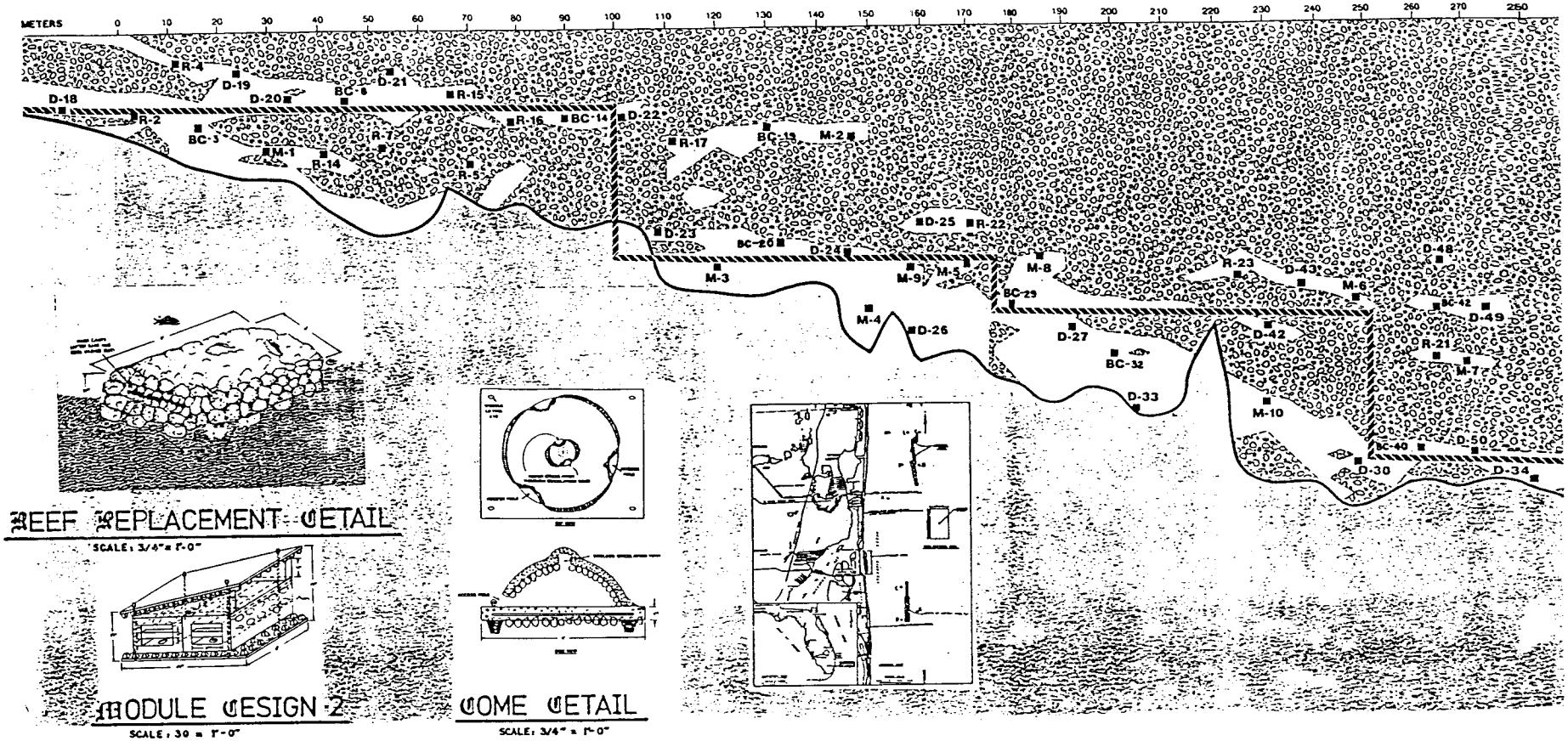

REEF REPLACEMENT DETAIL

SCALE: 3/4" = 1'-0"

MODULE DESIGN 2

SCALE: 3/4" = 1'-0"

DOME DETAIL

SCALE: 3/4" = 1'-0"

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

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DADE COUNTY DEPARTMENT OF ENVIRONMENTAL RESOURCES MANAGEMENT
RESTORATION MAP & DETAILS

DATE: JANUARY 09, 1992
DRAWN BY: R.C.F.
SCALE: 1" = 10 METERS

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I. 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 calendar quarters, and semi-annually thereafter. 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.

A. FISH & MOTILE INVERTEBRATES

1. 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. During the previous survey in June, 1994, 4943 fish and 34 crustaceans were found on the modules. This represented a increase in the motile invertebrate population, while the number of fish decreased by 42% from the end of the second year. In the current survey (December, 1994) the number of fish decreased again but only by 7% to a total of 4608. Thus the total decrease in fish numbers from the end of year 2 to the end of year 3 is nearly 50%. Unlike

the prior survey where decreases were noted at each of the module types, in this survey we found that fish populations increased on the Domes from 467 to 481 and increased on the R-modules from 1082 to 1334 individuals. Fish on the M-modules, on the other hand, declined from 3428 to 2793 individuals. In addition while fish at our reef control sites increased by 20% in June, they decreased in the current survey from 527 to 429. The reasons for the differential decline this time are as difficult to explain as the uniform decrease last time. Grunts continued to be the dominant fish group at all modules accounting for 73% of all individuals, compared to 76% in the prior survey, and 84% at the end of 1993. This dominance extended to the M-modules where 77% of the fish were grunts, and to the R- modules where 71% of the fish were grunts. However Of the 481 fish found at the domes, only 54% were grunts and only 10% of the fish found at the control reef sites were grunts. In absolute numbers, the M modules continue to have the highest average number of individuals per module, while the Domes continue to have the lowest. When corrected for size, and expressed on a fish per square foot basis, the M modules still maintained the highest average number of individuals but not significantly higher than the Domes.

2. Types and Number of Species

The number of fish species within the study site increased during the current survey from 48 to 54. This is the first increase in the number of species since the end of the second year. Unlike last June where only one of 30 species was found exclusively on the control sites out of a total of 30 species, during the December survey 5 species out of 26 were exclusively found on the natural reef. The Domes continue to have the lowest number of species of the module types with 35, followed by the R modules with 42 fish. The M modules had the highest number of fish species with 44. Thus number of species has increased by 7 on the domes, 3 on the M-modules and 9 on the R-modules from June to December, 1994. 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, the most

common species on the natural reef continue to be Bicolor damselfish, while the most common fish on the modules were the White Grunts. None of the latter was found on the natural reef during this survey, and in general, the most commonly occurring species of natural reef fish did not overlap strongly with those occurring most frequently on the modules. On the basis of absolute number of species and individuals the M modules appeared to be superior, but not significantly so compared to the R-modules.

3. Correction for Module Size

When species richness is adjusted for size (numbers of species divided by surface area) the M modules still had a higher number, but not significantly higher than the R modules. While the M modules had a greater average number of species per module, the D modules attracted a greater number of fish 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. The R modules appear to be less attractive to fishes on a per module or per square foot basis.

B. 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. During the June, 1994 survey, a total of 1317 invertebrate and plant individuals and 49 species were recorded. In December, 1994 we recorded 1167 individual and 45 species on the modules, a decrease of 11% and 8%, respectively. Of the 29 species found on the control sites, 10 were found only there, but these 9 species were only composed of 11 individuals total. On the other hand there were 16 species found commonly

on the modules but not on the controls. The remaining 19 species (42%) were held in common. In contrast of the 49 species recorded during the last survey only 14 (29%) were found on both the modules and the controls. The modules appear to becoming more reef-like after three years.

1. Types and Numbers of Individuals

The modules continue to be dominated by sponges. As in the previous survey *Holopsamma helwigi* is the most common, along with two other species. Fire coral is becoming more prominent as well. In all, 14 species of sponges, and 11 species of soft and stony corals are currently populating the modules. While the highest average number of individuals continues to be found on the Domes, no significant differences were found among the number of plants and invertebrate species from the D, M or R structures. This is in contrast to the results concerning fish populations. However, all three types of modules were associated with a significantly greater number of individuals compared to barren control (BC) sites.

2. Correction for Size

When the number of invertebrate and plant individuals or species was expressed on a unit surface area basis, the D modules clearly outperformed the other types. The M and R modules outperformed the control sites in terms of number of individuals, but in number of species, the M and control sites were only slightly different.

II. INTRODUCTION

During December, 1994, plants, invertebrates and fishes were surveyed on the artificial reef modules placed off Sunny Isles, Dade County, Florida. Thirty one modules of three different designs were examined, including 11 rough domes (#'s 18, 19, 20, 21, 22, 25, 30, 34, 42, 43 and 50); 11 Reef Replacement modules (#'s 2, 4, 5, 7, 14, 15, 16, 17, 21, 22, and 23) 9 and 10 M-types (#'s 1-10 with #6 missing due to storm damage). An odd number of Domes are surveyed due to historical accident, and an odd number of R-modules due to difficulty in finding R-5. This module is therefore not included in the data base every quarter (e.g., missing in December, 1992), but was surveyed this quarter.

III. FIELD METHODS

This report marks the second of the semi-annual, rather than quarterly surveys, and the end of the 3rd year of study. In keeping with the previous increments of quarters, we refer to this report as the 12th quarter, signifying that it represents the status of the artificial reef modules 36 months after deployment. The next report will be the 14th quarter survey.

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 quadrate (=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.

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 quadrate (=0.33m^2). A photographic transect was made over each module by successive quadrate 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 ft^2 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.

IV. STATISTICAL METHODS

A. 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 analyzed for differences in the mean number of individuals and mean number of species within the group using an ANOVA.

B. 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 increases, 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.

C. JACCARD'S COEFFICIENT 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.

D. 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.

E. COMPARISON BETWEEN JUNE (QTR 10) & DEC. (QTR 12), 1994

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 June and December, 1994 surveys.

V. STATISTICAL ANALYSIS

A. FISHES AND MOTILE INVERTEBRATES

1. 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 9 to 229 and the number of species varied from 6 to 24 (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; ANOVA results). The control sites had a lower average number of individuals and average number of species than the D, M and R modules (Table F5; t-test results). The D modules had a lower average number of fishes compared to both the M and R modules. The average numbers of fishes on the R modules were lower than on the M modules. The average numbers of species were not significantly between the D and M modules or between the M and R modules. However, the R modules had a higher average number of species than the D modules.

2. Differences In Module Size

The three module types are of different sizes and shapes. The D modules have the smallest surface area (Table F6). 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 Area:Volume ratio) while the R modules have the lowest.

In absolute numbers, the M modules had the highest average number of individuals per module and the D modules had the lowest average (Table F4). If corrected for the difference in size (by dividing average numbers by surface area), the M modules still have the highest average, but it is not significantly higher than the D modules (Table F7; Figure F1). The average number of individuals per ft^2 for the R modules was lower than the D and M modules.

In terms of the average numbers of species per module type, 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, the D modules had the highest average number of species per unit area, while the R modules had the lowest average number of species per unit area (Table F7; Figure F2). The D modules are able to attract a similar cumulative number of species as do the larger M and R modules (Figure F4). 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, particularly those species that maintain territories.

3. Shannon-Weiner Diversity Index

The Shannon-Weiner Diversity Indices (H) were 1.17, 0.81, and 1.01 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 89.0% of all individuals on the M modules (refer to Statistical Analyses: Diversity Indices for a further explanation of the factors affecting the value of H).

The C control sites had a diversity index of 0.91 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.

4. Multivariate Analyses of Modules and Fishes

In a cluster analysis of the standardized occurrence of the most common fishes (N = or > 15; Table F8) at the D, M, R, and C sites, the modules were all quite similar, while the C sites were distinctive (Figure 3; 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 4) results in five major groupings. The C sites are distinct for their abundance (standardized occurrence; not raw numbers) of the bicolor damsel fish (*Pomacentrus partitus*), reef butterflyfish (*Chaetodon sedentarius*), and the ocean surgeon (*Acanthurus bahianus*). Species most abundant on the M modules include gray snapper (*Lutjanus griseus*), greater amberjack (*Seriola dumerilii*) and two grunts (*Haemulon plumieri* and *H. sciurus*). Most abundant species on the R modules include porkfish (*Anisotremus virginicus*), rock beauty (*Holocanthus tricolor*), and the hogfish (*Lachnolaimus maximus*). The D modules do not form one distinct cluster, but are split into two clusters. One cluster represents species of similar abundance on both the D modules and the C sites, including the spotted goat fish (*Psuedupeneus maculatus*) and Redband parrotfish(*Sparisoma aurofrenatum*). There is a second cluster of species with similar abundance on the D modules and R modules.

In a plot of the first three principal components by taxa, the above groupings are not as evident (Figure F5). Abundant species (*Haemulon* species, *Lutjanus griseus*, *Thalassoma bifasciatum*, *Pomacentrus partitus*, and *Acanthurus bahianus*) separate from the less abundant species, which form a tight grouping. The grunts still dominant by numbers on each of modules(53.6% of individuals on D modules, 77.5% on M modules, 71.3% on R modules) but account for a smaller percentage of individuals on the C sites (10.0%; Table 9).

5. Comparison Between 10th and 12th Quarter Surveys

The average number of individuals (fishes) and the average number of species at each site type during the 10th quarterly sampling period were compared to the 12th quarterly sampling period by ANOVA (Table F10). The average number of individuals at each of the four site types were

not significantly different. The average number of species on the D and M modules were not different. However, at the R modules and the C sites, the average number of species was higher in the 12th quarterly sample than during the 10th quarterly sample.

6. Comparisons Between All Sampling Periods: 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 F6). The average number of fishes at the M and R modules has been consistently higher than at the D modules and C sites but both the M and R modules have lower numbers of individuals than during the eighth quarterly sampling. The D modules have maintained a relatively consistent average number of fishes since December '92.

7. Comparisons Between All Sampling Periods: Number of Species

The average number of species on the C sites has been consistently lower than the three module types (Figure F7). Among the modules, the M modules have the highest average number of species and have shown little change since May '92. The average numbers of species on the D and R modules have also remained fairly consistent since May '92, with the exception of transitory increased averages in the 7th quarter (August '93) and again in the 10th quarter (December 94).

A plot of cumulative number of species by sampling period (rarefaction curve) demonstrates that few new species have been found at the D, M, R and C sites during the last five samplings (Figure F8; Table F11). The total number of species found throughout the study was highest on the M

modules (72 species). The D and R modules had similar cumulative numbers of species (63 and 65, respectively), while the C sites had the lowest (58).

Two new species were recorded at the C sites this quarter (*Lactophrys trigonus* and *Chaetodipterus faber*). *Chaetodipterus faber* had been previously recorded at each of the three modules. One new species was recorded on the R modules (*Bodianus pulchellus*); this species had been previously recorded on the D and M modules. No new species were recorded at the D or M modules.

Many of species were present at each of the four site types. As might be expected, some species were restricted to the modules (*Mycteroperca phenax*, *Equetus* spp. *Abudefduf saxatalis*).

8. Comparisons Between All Sampling Periods: Diversity Index

Shannon-Weiner Diversity indices for each sampling period are plotted in Figure F9. The diversity on the M modules has shown a sharp decline, primarily due to the combined increasing dominance of grunts and gray snapper. 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 sampling periods has decreased the diversity at these sites, but not to the extent shown on the M modules.

List of Tables for Fishes and Motile Invertebrates

List of Figures: Fishes and Motile Invertebrates

Figure F4. Cluster of the taxa based upon the standardized occurrence of the most common fishes, labeled by taxa abbreviations (see Table F8 for abbreviations).

Figure F5. Plot of the first three Principal Components for the most common fish species found at the four study site types, labeled by taxa abbreviations (see Table F8 for abbreviations).

Figure F6. Plot of the average numbers of individuals at each of the four study site types by sampling period.

Figure F7. Plot of the average numbers of species at each of the four study site types by sampling period.

Figure F8. Plot of the cumulative number of species recorded for each of the four study site types by sampling period (rarefaction curve).

Figure F9. Plot of the Shannon-Weiner Diversity Index (H) at each of the four study site types by sampling period.

B. SESSILE INVERTEBRATES AND PLANTS

1. Raw Data and Parametric Comparisons by ANOVA and T-Tests for Sessile Invertebrates

The raw data for benthic sessile invertebrates 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 22 to 65 among the three modules types (D, M, and R) and from 8 to 16 among the barren control sites (Table I3). The highest average number of individuals was found on the D modules, while the lowest was found on the barren control sites.

The number of species ranged from 7 to 13 on the modules and from 4 to 12 on the barren control sites. The highest average number of species was found on the R modules and the lowest average on the M modules.

There were significant differences among the four site types (D, M, R, and BC) in average number of individuals and in the average number of species (Table I4, ANOVA results). The barren control sites had a lower average number of individuals than the D, M, and R modules (Table I4, t-test results). However, the modules did not differ from each other in average number of individuals. With regard to average number of species, the R modules were higher than the D modules, M modules and BC sites (Table I4). The D modules, M modules and the BC sites were not significantly different in average number of species.

2. Differences in Size of Modules and Barren Controls

The three module types are of different sizes and shapes. The D modules have the smallest surface area (Table I5). 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 a low Surface Area to Volume ratio) while the R modules have the lowest (high Surface Area to Volume ratio). The Barren Control sites were flat surfaces with an area of 2.25 m2 (23.76 ft^2) per quadrate.

Differences in area sampled on the module types were corrected by dividing average numbers of individuals and species by the square footage sampled (Table I5).

The average number of individuals per ft^2 on the Barren Control sites was significantly lower than the average number of individuals per ft^2 found on each of the module types (Table I6; Figure I1). Among the module types, the D modules had a higher average number of individuals per ft^2 than both the M and R modules. The average number of individuals per ft^2 on the M and R modules was not significantly different.

With regard to average number of species per ft^2, the D modules had a higher average than the M modules, R modules and BC sites (Table I6; Figure I2). While the average for the R modules was higher than the M modules and the BC sites, there was no significant difference in average number of species per ft^2 between the M modules and the BC sites.

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 (see 1st Quarterly Report, or 8th Quarterly Report, January 1994).

3. Shannon-Weiner Diversity Index for Sessile Invertebrates

The Shannon-Weiner diversity indices (H) for the D, M, and R modules were 0.832, 0.926 and 0.983 respectively (Table I3; refer to Statistical Analyses: Diversity Indices for further discussion of factors affecting H). The barren control sites had a diversity index of 1.323. The low diversity on the modules results from the abundance (i.e. dominance) of *Holopsamma helwigi* (42% of individuals on D modules; 31% on M modules; 37% on R modules). While *Holopsamma helwigi* is also the most abundant species on the BC sites, it accounted for only 12% of the total number of individuals. Also, the BC sites have a higher total number of species than any of the three module types.

4. Multivariate Analyses for Sessile Invertebrates

In a cluster of sites based upon the standardized occurrence of the most common invertebrate taxa ($N > 5$; Table I7), the Barren Control sites were the most distinctive, with the D and R sites being the most similar of the module types (Figure I3; the Pearson Product-Moment correlation coefficients can be read from the scale across the top of the cluster).

Analysis by taxa resulted in a cluster of species found predominantly on the BC sites (including *Aplysina cauliformis*, *Briareum asbestinum*, *Ulosa* sp., and *Spondylus americanus*; Figure I4). The remaining species cluster into four smaller groups. Three of the clusters correspond to species most abundant on the D modules (*Stolonicus sabulosa*), on the M modules (includes *Callyspongia vaginalis*, *Telesto riseii*, and *Watersipora* sp.), and on the R modules (includes *Lima lima* and *Cliona delatrix*). The remaining fourth cluster contains species with approximately equal abundance on the three modules, yet rare to absent from the BC sites (*Holopsamma helwigi* and *Millepora alcicornis*). In a PCA, *Holopsamma helwigi* separates from all other species (Figure I4). Other species with high abundances (*Dysidea* sp, *Millipora*

alcicornis, *Stolonica sabulosa*, and *Callyspongia vaginalis*) also pull out from the less abundant species, which were tightly grouped.

5. Comparison Between 10th and 12th Quarterly Surveys

One-way ANOVA comparing the four site types (D, M, R, and BC) in 10th and 12th quarters showed no significant change in either average number of individuals or average number of species at any of the four site types (Table I8).

6. Comparisons Between Sampling Periods: Number of Individuals

Data on benthic invertebrates were not collected from the modules during the first and second quarters of this study due to lag time in colonization. The average number of individuals at the BC sites has changed little through time (Figure I6). At the modules, the averages were relatively constant during the third and fourth sampling periods (May and August '92), but showed a significant increase during the fifth sampling (December '92, first sampling after Hurricane Andrew), and again during the eighth sampling (January '94). During the 10th and 12th quarters, the average number of individuals remained relatively constant on the D and M modules, yet showed a decreased on the R modules.

7. Comparisons Between Sampling Periods: Number of Species

The average number of species at the BC sites has shown an increase in the 12th quarter(Figure I7). The modules have shown both increases and decreases in average number of species. The M and R modules have remained relatively constant since the 8th quarter (January 94).

Table F3. Summary of fishes at modules (D, M, R) and controls (C).

SPECIES	COMMON NAME	CODE	D	M	R	C	Total
Scarus croicensus	Striped parrotfish	SCAc	4	4	7	3	18
Scarus taeniopterus	Princess parrotfish	SCAt	2	0	2	0	4
Sparisoma viride	Stoplight parrotfish	SPAv	4	0	1	2	7
Sparisoma aurofrenatum	Redband parrotfish	SPAa	11	6	19	7	43
Cantherhines pullus	Orangespotted filefish	CANp	1	0	1	1	3
Canthigaster rostrata	Sharpnose puffer	CANr	6	9	8	2	25
Lactophrys triqueter	Smooth trunkfish	LACtq	0	1	1	0	2
Lactophrys trigonus	Trunkfish	LACtg	0	0	0	1	1
Clepticus parrai	Creole wrasse	CLEp	0	0	10	0	10
Panulirus argus	Spiny lobster	PANa	0	5	2	0	7
Stenopus hispidus	Banded coral shrimp	STEh	2	0	0	0	2
Number of individuals of fishes			481	2793	1334	429	5037
Number of species of fishes			35	44	42	26	57

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	1.17	481	9 to 103	35	6 to 16	*Haemulon sp*	n=258
							Thalassoma bifasciatum	n=39
							Acanthurus bahianus	n=26
							Lutjanus griseus	n=24
M	10	0.81	2793	175 to 817	44	8 to 24	*Haemulon sp*	n=2166
							Lutjanus griseus	n=320
							Seriola dumerilii	n=50
							Anisotremus virginicus	n=36
R	10	1.01	1334	109 to229	42	14 to 18	*Haemulon sp*	n=951
							Thalassoma bifasciatum	n=75
							Acanthurus bahianus	n=51
							Lutjanus griseus	n=23
							Chromis scotti	n=23
C	31	0.91	429	6 to 38	26	2 to 9	*Pomacentrus partitus*	n=175
							Thalassoma bifasciatum	n=84
							Haemulon plumieri	n=37
							Acanthurus bahianus	n=35

Module	N	$\bar{X}$ of fish per module	s.e.	$\bar{X}$ species per module	s.e.
D	11	43.73	8.12	12.45	1.15
M	10	279.4	61.53	16.1	1.46
R	10	133.5	12.8	15.9	0.75
C	31	13.84	1.28	4.19	0.29

Table F5. Comparison of the average number of fishes and the average number of species at the four study site types (D, M, R, and C) for fishes.

One-Way Analysis of Variance (ANOVA)

Number of fishes:

Source	df	Sum of Squares	Mean Squares	F-value	p
Between	3	576295	192098	30.64	<0.001
Within	58	363695	6271		

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	1814	605	74.72	<0.001
Within	58	469	8		

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

T-tests (independent samples, separate variance)

Mean number of fishes:

Sites	df	t	p	
D vs M	19	-3.800	0.002	M higher
D vs R	19	-5.926	<0.001	R higher
M vs R	18	2.323	0.030	M higher
D vs C	40	3.636	0.001	D higher
M vs C	39	4.318	<0.001	M higher
R vs C	39	9.310	<0.001	R higher

Mean number of species:

Sites	df	t	p	
D vs M	19	-1.960	0.062	
D vs R	19	-2.512	0.020	R higher
M vs R	18	0.122	0.871	
D vs C	40	6.975	<0.001	D higher
M vs C	39	7.973	<0.001	M higher
R vs C	39	14.492	<0.001	R higher

Table F6. 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

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	1.561	0.29	0.445	0.041
M	2.141	0.471	0.124	0.011
R	0.834	0.08	0.099	0.005

Table F7. Comparison of the average number of fishes per sq.ft. and the average number of species per sq.ft. at the four study site types (D, M, R, and C) for fishes.

One-Way Analysis of Variance (ANOVA)

Number of fishes per sq.ft.:

Source	df	Sum of Squares	Mean Squares	F-value	p
Between	2	8.576	4.288	4.028	0.028
Within	28	29.807	1.065		

The calculated F-value indicates that there are significant differences among the means of the populations (p=0.028).

Number of species per sq. ft.:

Source	df	Sum of Squares	Mean Squares	F-value	p
Between	2	0.791	0.395	55.992	<0.001
Within	28	0.198	0.007		

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

T-tests (independent samples, separate variance)

Mean number of fishes per sq.ft.:

Sites	df	t	p	
D vs M	19	-1.048	0.309	
D vs R	19	2.417	0.025	D modules higher
M vs R	18	2.734	0.013	M modules higher

Mean number of species per sq.ft.:

Sites	df	t	p	
D vs M	19	7.564	<0.001	D modules higher
D vs R	19	7.564	<0.001	D modules higher
M vs R	18	1.979	0.061	

Table F8. Standardized occurrence of most common fish taxa (n=> 15)

Common name	Code	D	M	R	C
Spotted goatfish	PSEm	0.83	0.25	0.75	0.70
Greater amberjack	SERd	0.00	1.79	0.00	0.00
Gray snapper	LUTg	4.99	11.46	1.72	2.56
Black margate	ANIs	0.00	0.50	0.00	0.00
Porkfish	ANIv	1.66	1.29	1.12	0.00
Tomtate	HAEa	3.74	2.90	4.95	0.00
French grunt	HAEf	14.76	13.61	27.74	0.00
White grunt	HAEp	26.40	44.04	26.24	8.62
Bluestriped grunt	HAEs	8.73	17.01	12.37	1.40
High-hat	EQUa	3.12	0.43	1.27	0.00
Reef butteflyfish	CHAs	1.04	0.14	1.05	4.20
Ocean surgeon	ACAb	5.41	0.75	3.82	8.16
Rock beauty	HOLt	1.66	0.36	0.82	0.47
Sergeant major	ABUs	1.66	0.97	0.90	0.00
Blue chromis	CHRc	2.08	0.50	0.60	0.00
Purple reeffish	CHRs	0.83	0.50	1.72	0.47
Bicolor damselfish	POMp	0.42	0.07	0.90	40.79
Cocoa damselfish	POMv	1.66	0.29	0.45	2.10
Spanish hogfish	BODr	1.25	0.61	0.90	0.00
Hogfish	LACm	1.66	0.04	0.75	0.47
Bluehead wrasse	THAb	8.11	0.47	5.62	19.58
Striped parrotfish	SCAc	0.83	0.14	0.52	0.70
Redband parrotfish	SPAa	2.29	0.21	1.42	1.63
Sharpnose puffer	CANr	1.25	0.32	0.60	0.47
Creole wrasse	CLEp	0.00	0.00	0.75	0.00
% of fishes included in analysis		94.4	98.6	97.0	92.3
% of species included in analysis		62.9	54.5	54.8	57.7

Table F9. 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%
10	# Grunts	327	2725	720	192
	% Total	70.0%	79.5%	66.5%	36.4%
12	# Grunts	258	2166	951	43
	% Total	53.6%	77.5%	71.3%	10.0%

Table F10. Results of ANOVA comparing mean number of fishes and mean number of species at the four study sites (D, M, R, and C) during 10th and 12th quarters.

Mean number of fishes

Sites	df	F	p
D modules	1, 19	0.015	0.871
M modules	1, 18	0.425	0.911
R modules	1, 18	2.874	0.104
C sites	1, 59	2.745	0.099

Mean number of species

Sites	df	F	p	
D modules	1, 19	4.198	0.051	
M modules	1, 18	0.003	0.911	
R modules	1, 18	7.215	0.014	Recent sampling higher
C sites	1, 59	7.694	0.007	Recent sampling higher

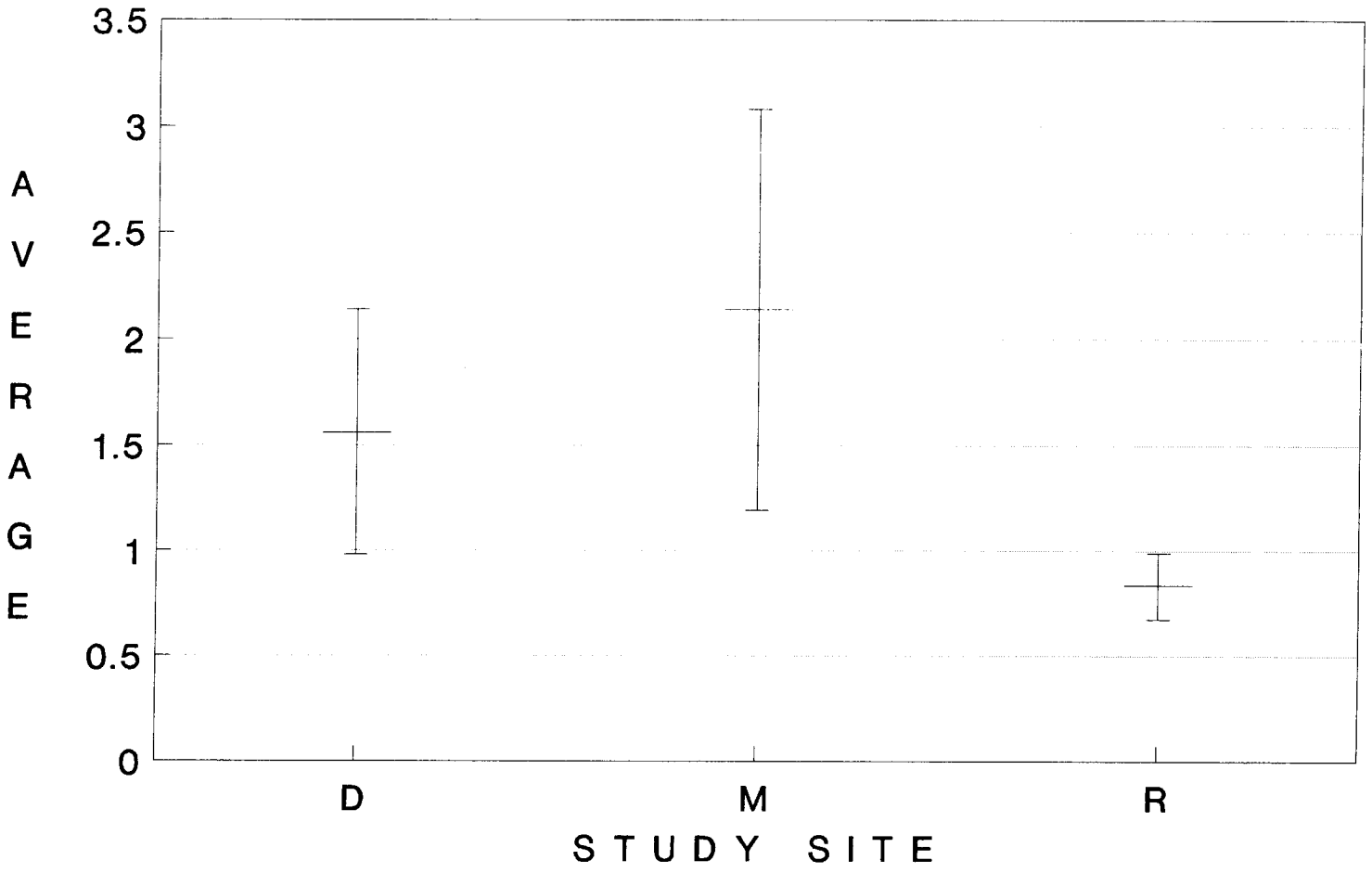
Table F11. Quarter in which fish taxa were first recorded at the modules (D,M,R) and controls (C).

Genus/species	D	M	R	C
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
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	12	---
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
Lactophrys trigonus	---	---	---	12
Scyllarus spp	---	7	---	---
Synodus foetens	---	---	---	8
Gymnothorax moringa	7	---	---	3
Serranus baldwini	---	---	---	3
Spoerhoides spengleri	6	---	3	---
Clepticus parrai	5	6	6	-
Scarus coeruleus	8	6	8	-
Calamus leucostis	6	-	-	-
Kyphosusspe spp	-	6	-	-
Scarus taeniopterus	-	6	-	-
Haliochoeres bivitatus	6	-	-	-
CUMULATIVE NUMBER OF SPECIES	63	72	65	58

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

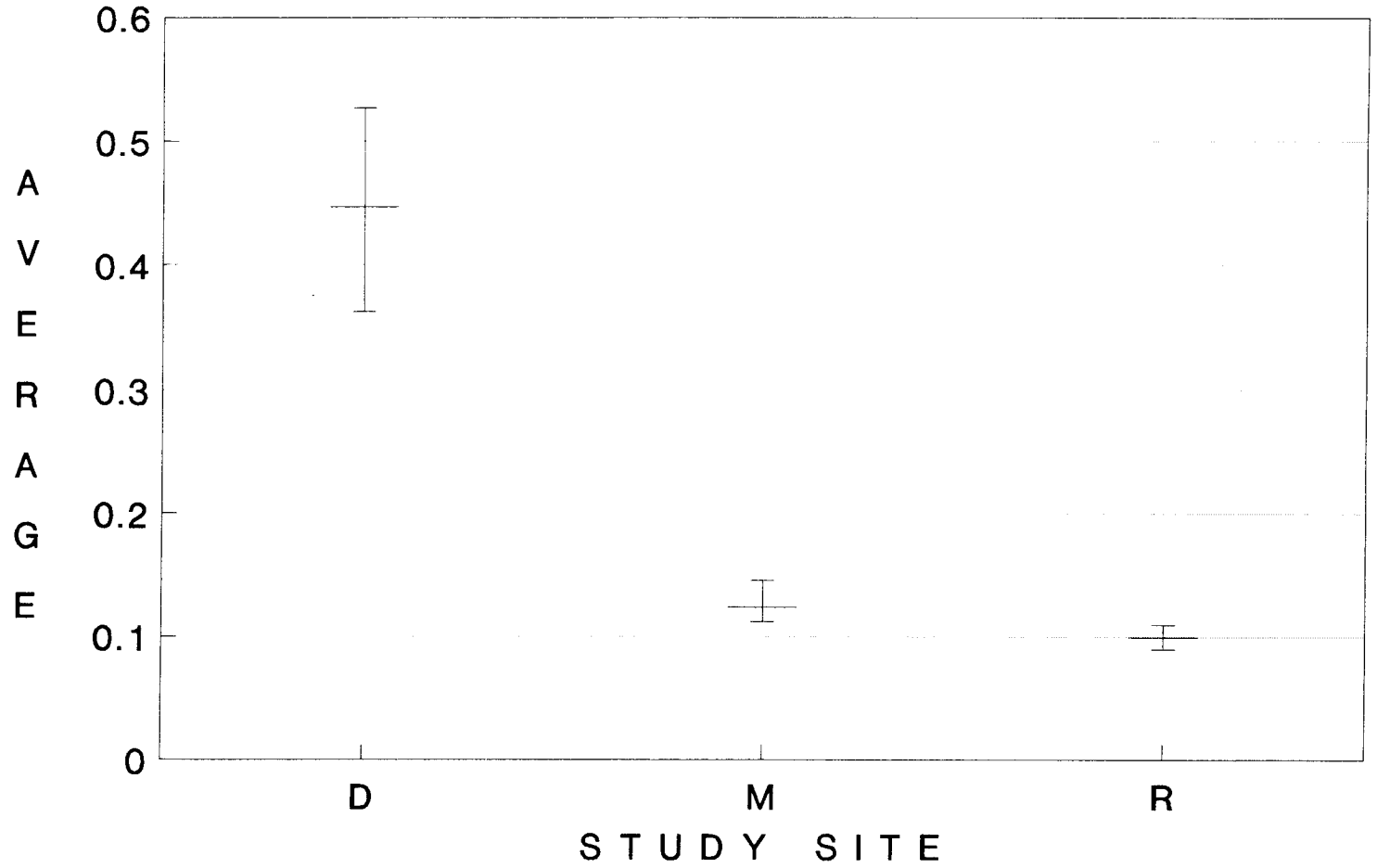
Genus/species	D	M	R	C
Ginglymostoma cirratum	---	4	1	---
Urolophus jamaicensis	---	---	---	1
Gymnothorax funebris	---	5	1	2
Synodus intermedius	---	---	---	2
Aulostomus maculatus	1	1	1	3
Holocentrus	2	2	5	2
Priacanthus arenatus	---	---	---	1
Rypticus maculatus	---	2	---	---
Epinephelus cruentatus	1	1	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
Apogon spp	-	5	-	-
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	10	10	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 aurolineatum	6	6	6	-
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	12
Pomacanthus arcuatus	1	2	1	2
Pomacanthus paru	1	1	2	1
Holacanthus bermeudensis	2	2	1	1
Holacanthus ciliaris	1	1	3	3

Figure F1 Average number of fishes per sq.ft. +/- 2 Std.err.



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

Figure F2 Average number of species per sq.ft. +/- 2 Std.err.



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

Fig F3 Cluster based upon most common fish taxa

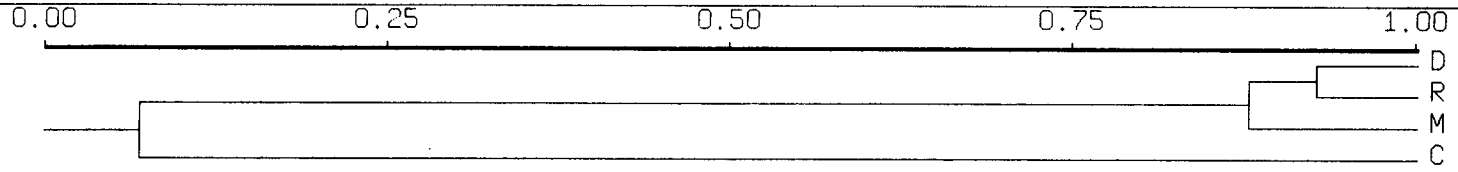


Fig F4 Cluster based upon most common fish taxa

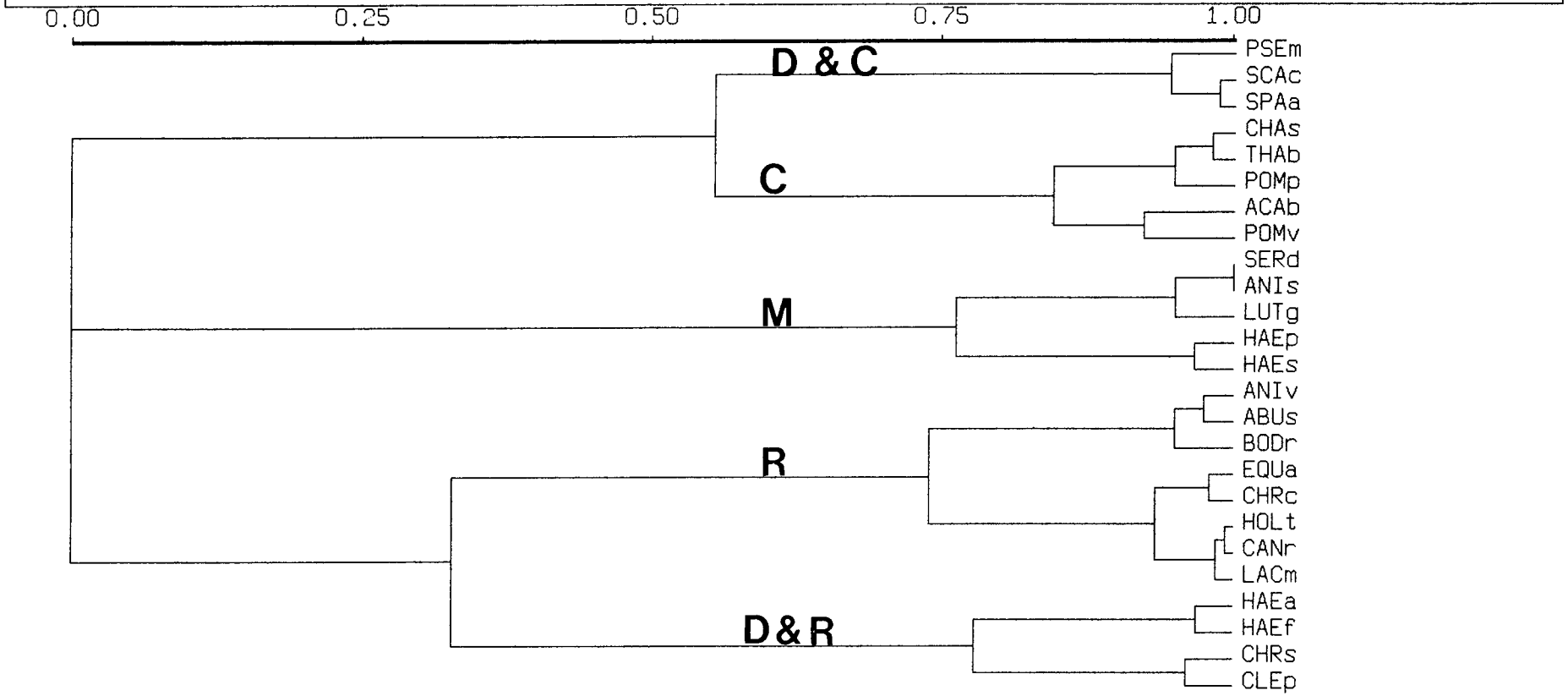
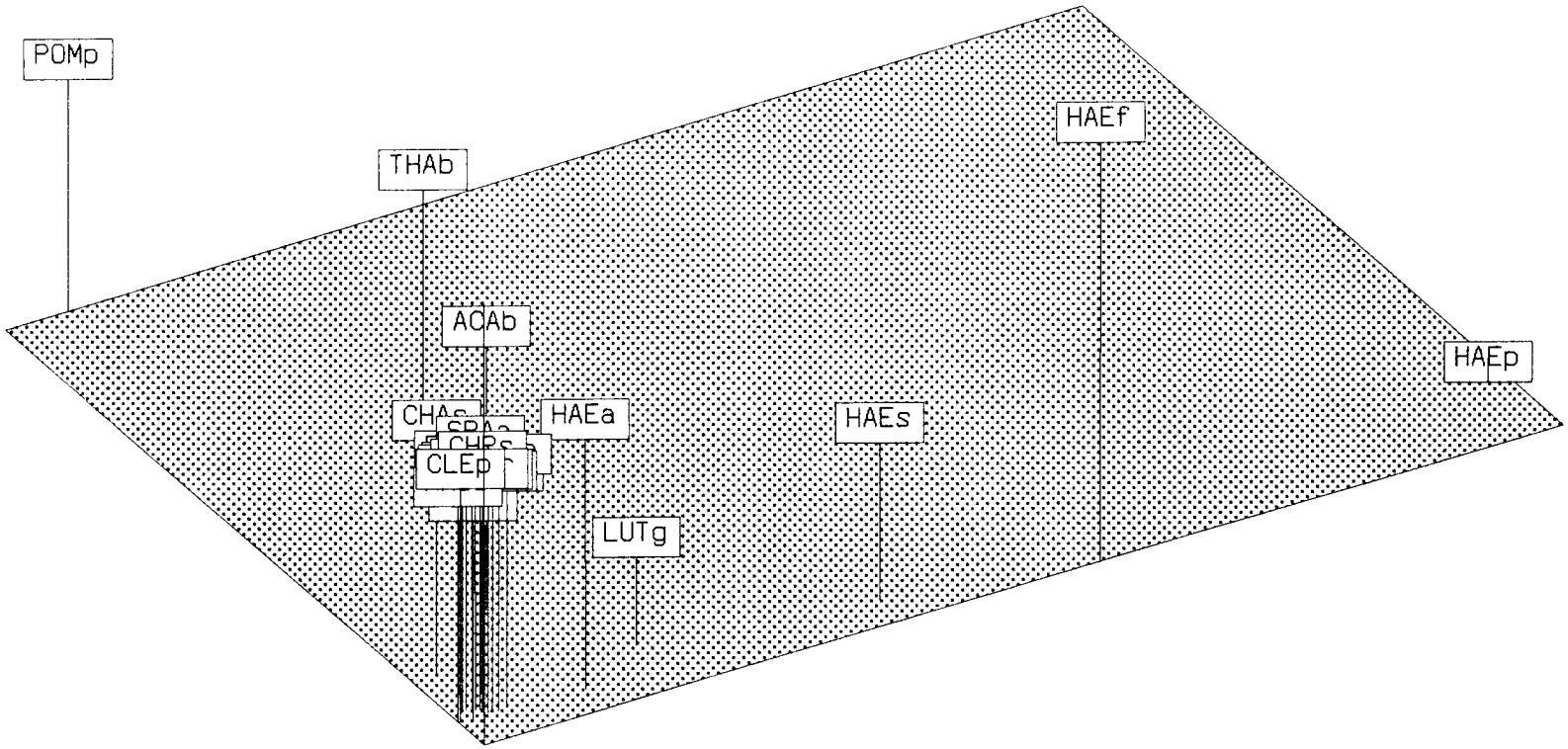


Fig F5 PCA based upon most common fishes



a= 30 b= 30 r=99.0

Figure F6 Average number of fishes at four study sites by sampling period.

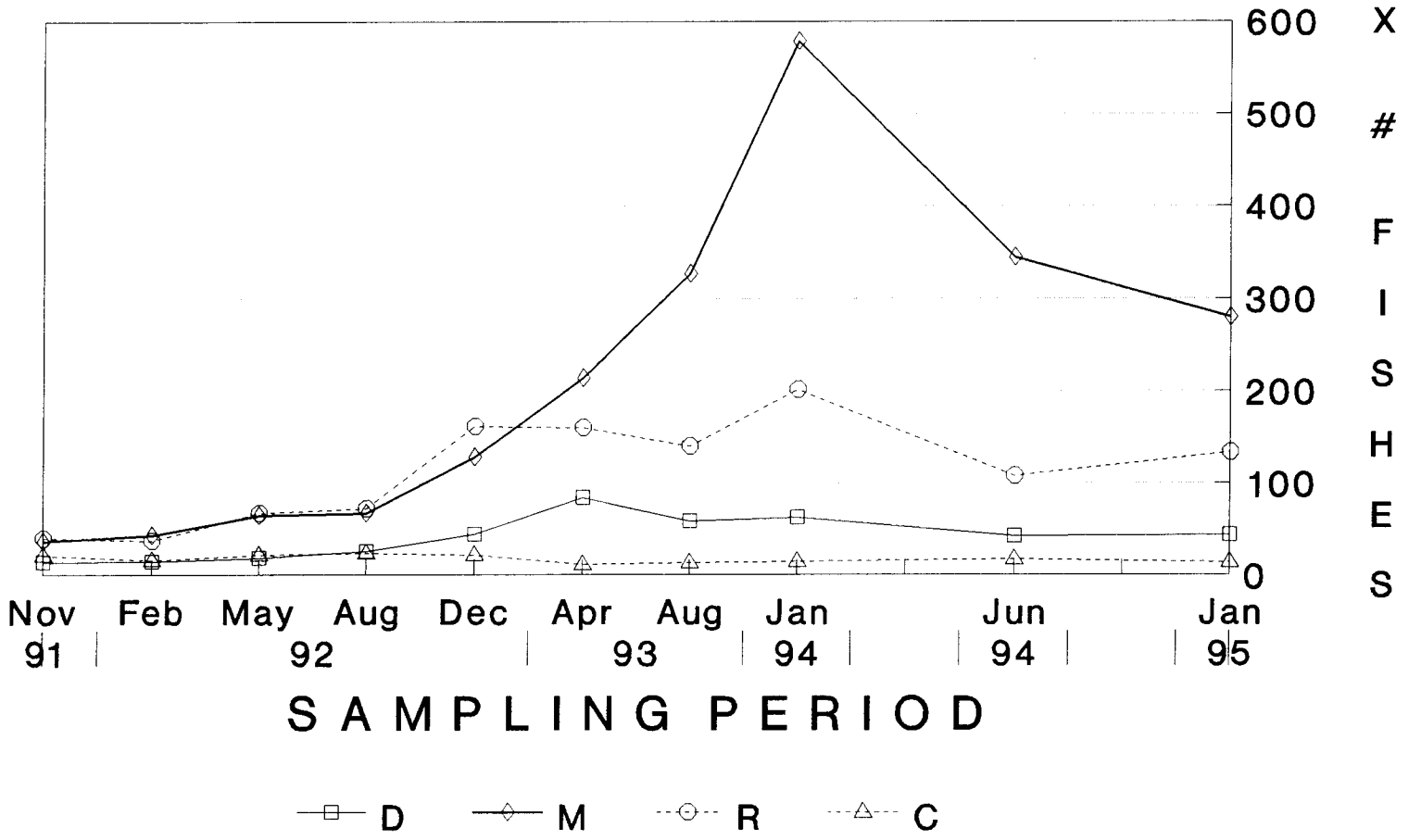


Figure F7 Average number of species at four study sites by sampling period.

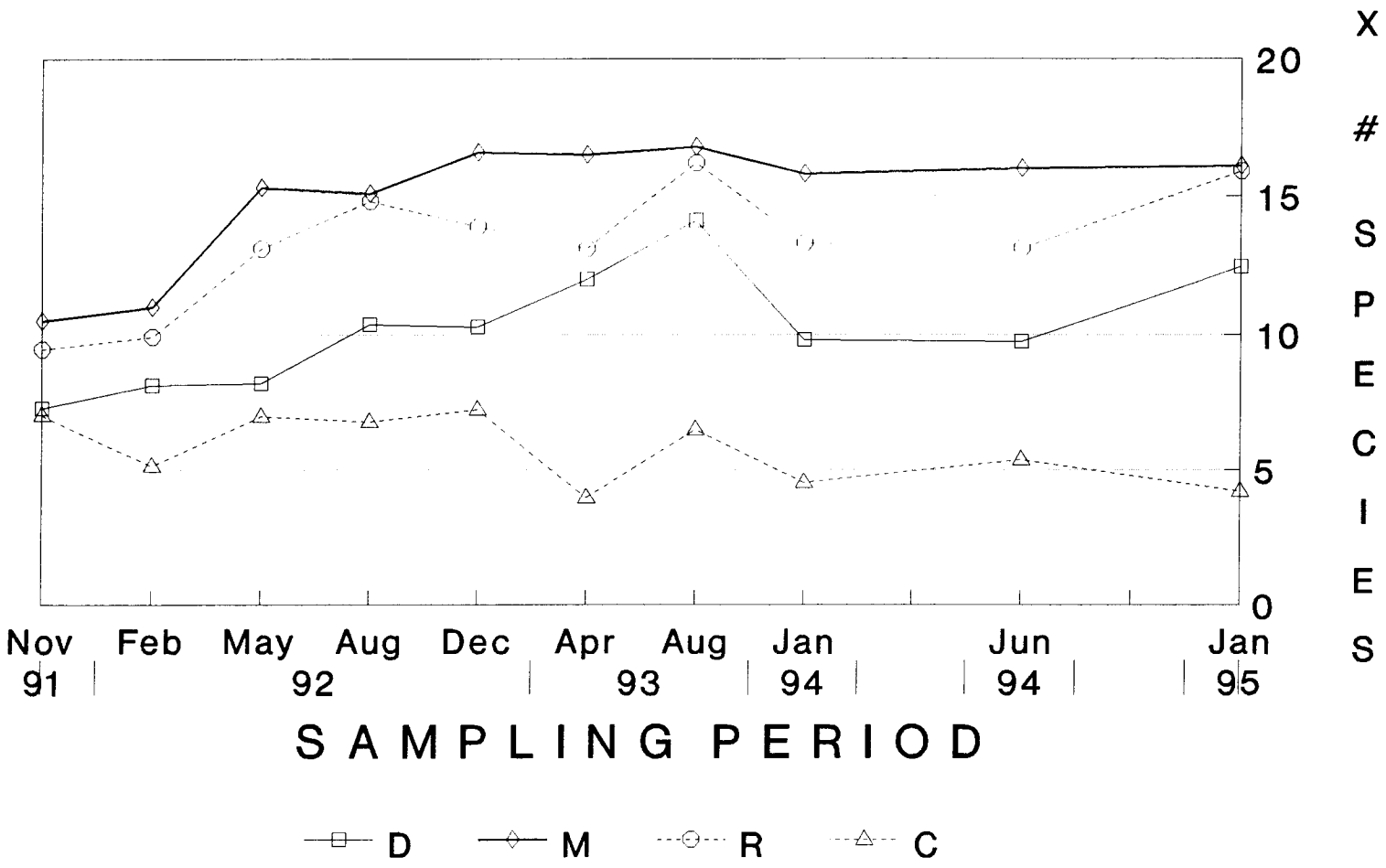


Figure F8. Rarefaction curve for the cumulative number of fish taxa.

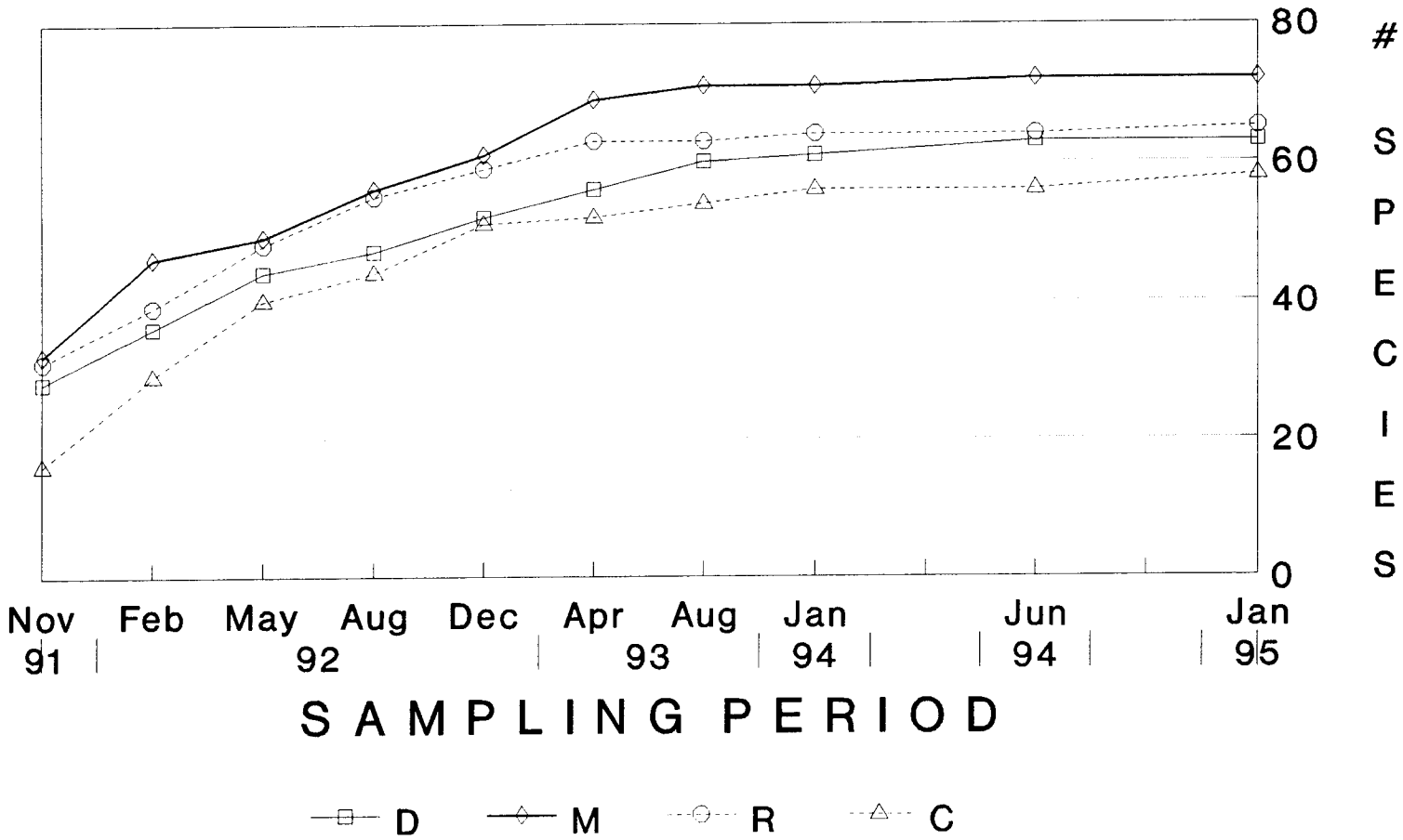


Figure F9 Shannon-Weiner diversity index (H) for fishes by sampling period.

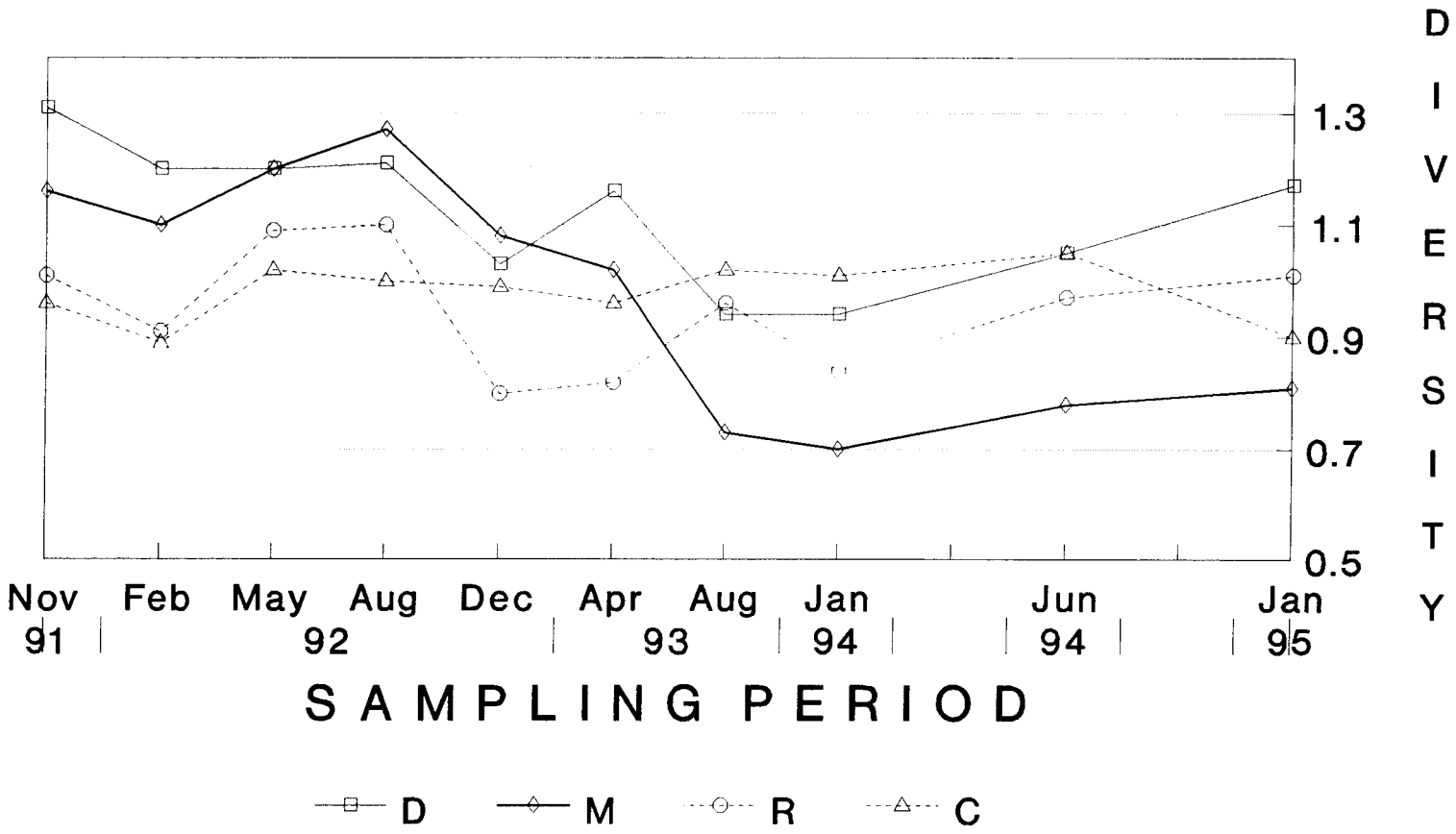


Table I1 Raw data for 12th qtr sampling of benthic invertebrates at modules (D, M, R) and barren controls (BC).

SPECIES	CODE	D18	D19	D20	D21	D22	D25	D30	D34	D43	D50
Aplysina cauliformis	APLc	1	0	0	0	0	0	0	0	0	0
Briareum asbestinum	BRIa	0	0	1	0	0	1	0	0	0	0
Callyspongia fallax	CALf	0	0	0	0	0	0	0	0	0	0
Callyspongia plicifera	CALp	0	0	0	0	0	0	0	0	0	0
Callyspongia vaginalis	CALv	0	3	4	4	1	5	1	7	2	5
Cinachyra sp	CINsp	0	0	0	0	0	0	0	0	0	0
Cliona delatrix	CLId	1	0	0	0	1	0	0	0	0	0
Dasychalina cyathina	DASc	0	0	0	0	0	0	0	0	0	0
Dichocoenia stokesii	DICs	0	0	1	0	0	1	0	0	0	0
Dictyota sp.	DICsp	0	0	0	0	0	0	1	0	0	0
Didemnid unid.	DIDunid	1	1	0	0	0	0	0	1	0	0
Diploria sp	DIPsp	0	0	0	0	0	0	0	0	0	0
Dysidea sp.	DYSsp	2	20	0	2	2	5	7	2	4	2
Eucidaris sp.	EUCsp	0	0	0	0	0	0	0	0	0	0
Eunicea sp.	EUNsp	0	0	0	0	0	0	0	0	0	0
Eusmilia fastigiata	EUSf	0	0	0	0	0	0	0	0	0	0
Haliclona rubens	HALr	0	0	0	0	0	0	0	0	0	0
Holopsamma helwigi	HOLh	20	20	20	20	20	12	20	20	12	20
Iotrochota birotulata	IOTb	0	0	4	3	3	0	1	0	1	0
Ircinia sp	IRCsp	0	0	0	1	0	0	0	0	0	0
Lima lima	LIMl	1	0	0	0	0	0	0	0	0	0
Meandrina meandrites	MEAm	1	1	0	0	0	0	0	0	0	1
Melanostigma nigromac	MELn	0	0	0	0	0	0	0	0	0	0
Millepora alcicornis	MILa	3	1	4	6	5	6	1	4	1	3
Mussa sp	MUSsp	0	0	0	0	0	0	0	0	0	0
Niphates digitalis	NIPd	0	0	0	0	0	0	0	0	0	0
Niphates sp.	NIPsp	1	0	0	0	0	0	0	1	0	1
Plexaura flexuosa	PLEf	0	0	0	0	0	0	0	0	0	0
Psuedoplexaura sp	PSEsp	0	0	0	0	0	0	0	0	0	0
Reteporellina sp.	RETsp	0	0	0	0	0	0	0	0	0	0
Siderastrea sidera	SIDs	0	0	0	0	1	3	0	0	1	3
Siderastrea sp.	SIDsp	2	2	1	1	0	0	0	0	0	0
Spirastrella coccinea	SPIc	0	0	0	0	0	0	0	0	0	0
Spondylus americanus	SPOa	0	0	0	0	0	0	0	0	0	0
Sponge unid.	SPONGE	0	1	0	0	0	0	0	0	0	0
Stephanocoenia michel	STEm	0	0	0	0	0	1	0	0	1	0
Stolonica sabulosa	STOs	5	6	20	0	4	5	1	8	20	9
Styella plicata	STYp	0	0	0	0	0	0	0	0	0	0
Telesto riisei	TELr	0	0	0	0	0	0	0	0	0	0
Teichaxinella sp	TEIsp	0	0	0	0	0	0	0	0	0	0
Thalysias sp	THAsp	0	0	0	0	0	0	0	0	0	0
Udotea sp.	UDOsp	0	0	0	0	0	0	0	0	0	0
Ulosa reutzleri	ULOr	0	6	1	0	0	1	3	1	2	1
Watersipora sp.	WATsp	0	0	0	0	0	0	0	0	0	0
Xestospongia muta	XESm	0	0	0	0	0	0	0	0	0	0
NUMBER INDIVIDUALS		38	61	56	37	37	40	35	44	44	45
NUMBER OF SPECIES		11	10	9	7	8	10	8	8	9	9
Individuals per unit area		6.33	10.17	9.33	6.17	6.17	6.67	5.83	7.33	7.33	7.50
Species per unit area		1.83	1.67	1.50	1.17	1.33	1.67	1.33	1.33	1.50	1.50

Table I1 Raw data for 12th qtr sampling of benthic invertebrates at modules (D, M, R) and barren controls (BC).

SPECIES	CODE	M1	M2	M3	M4	M5	M7	M8	M9	M10
Aplysina cauliformis	APLc	0	0	0	0	0	0	0	0	0
Briareum asbestinum	BRIa	0	0	1	0	0	0	0	0	0
Callyspongia fallax	CALf	0	0	1	1	0	0	0	0	1
Callyspongia plicifera	CALp	0	1	0	0	0	0	0	0	0
Callyspongia vaginalis	CALv	7	3	3	0	8	9	3	5	1
Cinachyra sp	CINsp	0	0	0	0	0	0	0	0	0
Cliona delatrix	CLId	0	0	0	0	0	0	1	0	0
Dasychalina cyathina	DASc	0	0	0	0	0	0	0	0	0
Dichocoenia stokesii	DICs	0	0	0	0	0	0	0	0	0
Dictyota sp.	DICsp	0	0	0	0	0	0	0	0	0
Didemnid unid.	DIDunid	0	3	0	0	0	0	0	0	0
Diploria sp	DIPsp	0	0	0	0	0	0	0	0	0
Dysidea sp.	DYSsp	0	4	1	1	0	7	4	3	5
Eucidaris sp.	EUCsp	0	0	0	0	0	0	0	0	0
Eunicea sp.	EUNsp	0	0	0	0	0	0	0	0	0
Eusmilia fastigiata	EUSf	0	0	0	0	0	0	0	0	0
Haliclona rubens	HALr	0	0	0	0	0	0	0	0	0
Holopsamma helwigi	HOLh	8	10	12	12	13	20	7	12	15
Iotrochota birotulata	IOTb	6	2	3	3	4	1	2	12	8
Ircinia sp	IRCsp	0	0	0	0	0	0	0	0	0
Lima lima	LIMl	0	0	0	0	0	0	0	0	0
Meandrina meandrites	MEAm	0	0	0	0	0	0	0	0	0
Melanostigma nigromac	MELn	0	0	0	0	0	0	0	0	0
Millepora alcicornis	MILa	5	1	1	1	4	1	6	20	1
Mussa sp	MUSsp	0	0	0	0	0	0	0	0	0
Niphates digitalis	NIPd	0	0	0	0	0	0	0	0	0
Niphates sp.	NIPsp	1	3	0	0	0	0	0	1	0
Plexaura flexuosa	PLEf	0	0	0	0	0	0	0	0	0
Psuedoplexaura sp	PSEsp	0	0	0	0	0	0	0	0	0
Reteporellina sp.	RETsp	0	0	0	0	0	0	0	0	0
Siderastrea sidera	SIDs	0	0	0	0	0	0	0	0	0
Siderastrea sp.	SIDsp	0	0	0	0	0	0	0	0	0
Spirastrella coccinea	SPIc	0	0	0	0	0	0	0	0	0
Spondylus americanus	SPOa	0	0	0	2	0	1	0	1	0
Sponge unid.	SPONGE	0	0	0	0	0	0	0	0	0
Stephanocoenia michel	STEm	0	0	0	0	0	0	0	0	0
Stolonica sabulosa	STOs	0	0	0	0	7	0	20	6	3
Styella plicata	STYp	0	0	0	0	0	0	0	0	0
Telesto riisei	TELr	6	8	0	8	2	0	0	0	2
Teichaxinella sp	TEIsp	0	0	0	0	0	0	0	0	0
Thalysias sp	THAsp	0	0	0	0	0	0	0	0	0
Udotea sp.	UDOsp	0	0	0	0	0	0	0	0	0
Ulosa reutzleri	ULOr	0	1	0	0	1	1	0	1	1
Watersipora sp.	WATsp	4	0	0	0	0	0	1	4	1
Xestospongia muta	XESm	0	0	0	0	0	0	0	0	0
NUMBER INDIVIDUALS		37	36	22	28	39	40	44	65	38
NUMBER OF SPECIES		7	10	7	7	7	7	8	10	10
Individuals per unit area		2.90	2.82	1.73	2.20	3.06	3.14	3.45	5.10	2.98
Species per unit area		0.55	0.78	0.55	0.55	0.55	0.55	0.63	0.78	0.78

Table I1 Raw data for 12th qtr sampling of benthic invertebrates at modules (D, M, R) and barren controls (BC).

SPECIES	CODE	R2	R4	R7	R14	R15	R16	R17	R21	R22	R23
Aplysina cauliformis	APLc	0	0	0	0	0	0	0	0	0	0
Briareum asbestinum	BRIa	0	0	0	0	0	1	1	0	0	1
Callyspongia fallax	CALf	0	0	0	0	0	2	0	4	1	0
Callyspongia plicifera	CALp	0	0	1	0	0	2	1	0	0	1
Callyspongia vaginalis	CALv	3	9	4	3	6	1	2	2	3	0
Cinachyra sp	CINsp	0	0	0	0	0	0	0	0	0	0
Cliona delatrix	CLId	0	0	1	0	2	1	0	0	1	0
Dasychalina cyathina	DASc	0	0	0	0	0	0	0	0	0	0
Dichocoenia stokesii	DICs	0	0	0	0	0	0	0	0	0	0
Dictyota sp.	DICsp	0	0	0	0	0	0	0	0	0	0
Didemnid unid.	DIDunid	1	1	0	0	0	0	0	0	0	0
Diploria sp	DIPsp	0	0	0	0	0	0	0	0	0	1
Dysidea sp.	DYSsp	3	9	3	2	1	2	6	11	2	1
Eucidaris sp.	EUCsp	1	0	0	0	1	0	0	0	0	1
Eunicea sp.	EUNsp	0	0	1	2	0	0	0	0	0	0
Eusmilia fastigiata	EUSf	0	0	0	0	0	0	0	0	0	0
Haliclona rubens	HALr	0	0	0	0	0	0	0	0	0	0
Holopsamma helwigi	HOLh	7	12	11	8	13	20	20	9	20	20
Iotrochota birotulata	IOTb	1	0	2	2	3	2	6	3	2	3
Ircinia sp	IRCsp	0	0	0	0	0	0	0	0	0	0
Lima lima	LIMl	3	0	0	2	2	0	2	0	4	4
Meandrina meandrites	MEAm	0	0	2	0	0	0	0	0	0	0
Melanostigma nigromac	MELn	0	0	0	0	1	0	0	0	0	0
Millepora alcicornis	MILa	6	5	1	5	6	2	5	7	3	8
Mussa sp	MUSsp	0	0	0	0	0	0	0	0	0	0
Niphates digitalis	NIPd	0	0	0	0	0	0	0	0	0	0
Niphates sp.	NIPsp	0	0	0	1	0	0	1	0	0	1
Plexaura flexuosa	PLEf	0	0	0	0	0	0	0	0	0	0
Psuedoplexaura sp	PSEsp	0	0	0	0	0	3	0	0	0	0
Reteporellina sp.	RETsp	0	1	0	0	0	0	0	0	0	0
Siderastrea sidera	SIDs	0	0	0	0	0	0	0	0	0	0
Siderastrea sp.	SIDsp	0	0	0	0	0	0	0	0	0	0
Spirastrella coccinea	SPIc	0	0	0	0	0	0	0	0	0	0
Spondylus americanus	SPOa	0	2	0	3	1	0	0	0	0	0
Sponge unid.	SPONGE	0	0	0	0	0	0	0	0	0	0
Stephanocoenia michel	STEm	0	0	0	0	0	0	0	0	0	0
Stolonica sabulosa	STOs	1	1	1	1	0	0	2	0	4	5
Styella plicata	STYp	0	0	0	0	0	0	0	2	0	0
Telesto riisei	TELr	0	0	0	0	0	0	0	0	0	0
Teichaxinella sp	TEIsp	0	0	0	0	0	0	0	0	0	0
Thalysias sp	THAsp	0	0	0	0	0	1	0	0	0	0
Udotea sp.	UDOsp	0	0	0	0	0	0	0	0	0	0
Ulosa reutzleri	ULOr	1	5	0	0	2	1	0	1	1	2
Watersipora sp.	WATsp	2	0	0	0	0	0	0	0	0	0
Xestospongia muta	XESm	0	0	0	0	0	1	0	0	0	0
NUMBER INDIVIDUALS		29	45	28	30	38	39	46	39	41	48
NUMBER OF SPECIES		11	9	11	11	11	13	10	8	10	12
Individuals per unit area		2.42	3.75	2.33	2.50	3.17	3.25	3.83	3.25	3.42	4.00
Species per unit area		0.92	0.75	0.92	0.92	0.92	1.08	0.83	0.67	0.83	1.00

Table I1 Raw data for 12th qtr sampling of benthic invertebrates at modules (D, M, R) and barren controls (BC).

SPECIES	CODE	BC3	BC8	BC14	BC19	BC20	BC21	BC27	BC30	BC37	BC39
Aplysina cauliformis	APLc	0	1	1	1	3	1	0	0	2	0
Briareum asbestinum	BRIa	1	1	0	4	0	0	0	3	1	1
Callyspongia fallax	CALf	0	0	0	0	0	0	0	0	0	0
Callyspongia plicifera	CALp	0	1	0	0	0	0	0	1	0	0
Callyspongia vaginalis	CALv	1	1	1	1	0	0	1	0	0	0
Cinachyra sp	CINsp	0	0	0	0	0	1	0	0	0	0
Cliona delatrix	CLId	0	0	0	0	0	0	0	0	0	0
Dasychalina cyathina	DASc	0	1	1	0	1	0	1	0	0	0
Dichocoenia stokesii	DICs	1	0	0	0	0	0	1	0	0	0
Dictyota sp.	DICsp	0	0	0	1	0	0	0	0	0	0
Didemnid unid.	DIDunid	0	0	0	0	0	0	0	0	0	0
Diploria sp	DIPsp	0	0	0	0	0	0	0	0	0	0
Dysidea sp.	DYSsp	0	0	0	0	0	0	0	0	0	0
Eucidaris sp.	EUCsp	0	0	0	0	0	0	0	0	0	0
Eunicea sp.	EUNsp	0	0	0	2	0	0	0	0	1	0
Eusmilia fastigiata	EUSf	0	0	1	0	0	0	0	0	0	0
Haliclona rubens	HALr	1	0	0	0	1	0	1	0	0	0
Holopsamma helwigi	HOLh	0	0	2	1	4	1	0	1	1	3
Iotrochota birotulata	IOTb	0	1	0	0	0	0	0	0	0	0
Ircinia sp	IRCsp	0	1	0	0	0	0	1	0	0	0
Lima lima	LIMl	0	0	0	0	0	0	0	0	0	0
Meandrina meandrites	MEAm	0	0	1	1	0	0	0	1	1	0
Melanostigma nigromac	MELn	0	0	0	0	0	0	0	0	0	0
Millepora alcicornis	MILa	0	0	0	0	0	0	0	0	0	0
Mussa sp	MUSsp	0	0	0	1	0	0	0	0	0	0
Niphates digitalis	NIPd	2	1	1	2	0	0	1	0	1	0
Niphates sp.	NIPsp	0	0	0	0	0	0	0	1	0	3
Plexaura flexuosa	PLEf	0	0	0	0	0	0	0	0	0	1
Psuedoplexaura sp	PSEsp	0	0	0	0	0	0	0	0	0	0
Reteporellina sp.	RETsp	0	1	0	0	0	0	0	0	0	0
Siderastrea sidera	SIDs	0	0	0	0	0	1	1	0	0	1
Siderastrea sp.	SIDsp	1	0	0	0	0	0	0	0	2	0
Spirastrella coccinea	SPIc	0	0	0	0	0	1	1	1	0	0
Spondylus americanus	SPOa	2	0	0	0	0	0	0	0	0	0
Sponge unid.	SPONGE	0	0	0	0	0	0	0	0	0	0
Stephanocoenia micheli	STEm	1	5	0	1	0	0	1	1	0	0
Stolonica sabulosa	STOs	1	1	1	0	0	1	1	0	0	3
Styella plicata	STYp	0	0	0	0	0	0	0	0	0	0
Telesto riisei	TELr	0	0	0	0	0	0	0	0	0	0
Teichaxinella sp	TEIsp	0	0	0	0	0	0	0	1	0	0
Thalysias sp	THAsp	0	0	0	0	0	0	0	0	0	0
Udotea sp.	UDOsp	0	0	0	0	0	0	0	1	0	0
Ulosa reutzleri	ULOr	1	1	0	0	0	2	0	1	0	1
Watersipora sp.	WATsp	0	0	0	0	0	0	0	0	0	0
Xestospongia muta	XESm	0	0	0	0	0	0	0	0	0	0
NUMBER INDIVIDUALS		12	16	9	15	9	8	10	12	9	13
NUMBER OF SPECIES		10	12	8	10	4	7	10	10	7	7
Individuals per unit area		0.51	0.67	0.38	0.63	0.38	0.34	0.42	0.51	0.38	0.55
Species per unit area		0.83	1.00	0.67	0.83	0.33	0.58	0.83	0.83	0.58	0.58

Table I2. Summary of raw data for benthic invertebrates at modules (D, M, R) and barren controls (BC).

SPECIES	CODE	D	M	R	BC	TOTAL
Aplysina cauliformis	APLc	1	0	0	9	10
Briareum asbestinum	BRIa	2	1	3	11	17
Callyspongia fallax	CALf	0	3	7	0	10
Callyspongia plicifera	CALp	0	1	5	2	8
Callyspongia vaginalis	CALv	32	39	33	5	109
Cinachyra sp	CINsp	0	0	0	1	1
Cliona delatrix	CLId	2	1	5	0	8
Dasychalina cyathina	DASc	0	0	0	4	4
Dichocoenia stokesii	DICs	2	0	0	2	4
Dictyota sp.	DICsp	1	0	0	1	2
Didemnid unid.	DIDunid	3	3	2	0	8
Diploria sp	DIPsp	0	0	1	0	1
Dysidea sp.	DYSsp	46	25	40	0	111
Eucidaris sp.	EUCsp	0	0	3	0	3
Eunicea sp.	EUNsp	0	0	3	3	6
Eusmilia fastigiata	EUSf	0	0	0	1	1
Haliclona rubens	HALr	0	0	0	3	3
Holopsamma helwigi	HOLh	184	109	140	13	446
Iotrochota birotulata	IOTb	12	41	24	1	78
Ircinia sp	IRCsp	1	0	0	2	3
Lima lima	LIMl	1	0	17	0	18
Meandrina meandrites	MEAm	3	0	2	4	9
Melanostigma nigromaculata	MELn	0	0	1	0	1
Millepora alcicornis	MILa	34	40	48	0	122
Mussa sp	MUSsp	0	0	0	1	1
Niphates digitalis	NIPd	0	0	0	8	8
Niphates sp.	NIPsp	3	5	3	4	15
Plexaura flexuosa	PLEf	0	0	0	1	1
Psuedoplexaura sp	PSEsp	0	0	3	0	3
Reteporellina sp.	RETsp	0	0	1	1	2
Siderastrea sidera	SIDs	8	0	0	3	11
Siderastrea sp.	SIDsp	6	0	0	3	9
Spirastrella coccinea	SPIc	0	0	0	3	3
Spondylus americanus	SPOa	0	4	6	2	12
Sponge unid.	SPONGE	1	0	0	0	1
Stephanocoenia michelini	STEm	2	0	0	9	11
Stolonica sabulosa	STOs	78	36	15	8	137
Styella plicata	STYp	0	0	2	0	2
Telesto riisei	TELr	0	26	0	0	26
Teichaxinella sp	TEIsp	0	0	0	1	1
Thalysias sp	THAsp	0	0	1	0	1
Udotea sp.	UDOsp	0	0	0	1	1
Ulosa reutzleri	ULOr	15	5	13	6	39
Watersipora sp.	WATsp	0	10	2	0	12
Xestospongia muta	XESm	0	0	1	0	1
NUMBER OF INDIVIDUALS		437	349	381	113	1280
NUMBER OF SPECIES		21	16	26	29	45

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	0.832	437	35 to 61	21	7 to 11	*Holopsamma helwigi*	n=184
							Stolonica sabulosa	n=78
							Dysidea sp.	n=46
							Millepora alcicornis	n=34
M	9	0.926	349	22 to 65	16	7 to 10	*Holopsamma helwigi*	n=109
							Iotrochota birotulata	n=41
							Millepora alcicornis	n=40
							Callyspongia vaginalis	n=39
R	11	0.983	381	28 to 48	26	8 to 13	*Holopsamma helwigi*	n=140
							Millepora alcicornis	n=48
							Dysidea sp.	n=40
							Callyspongia vaginalis	n=33
BC	10	1.323	113	8 to 16	29	4 to 12	*Holopsamma helwigi*	n=13
							Briareum asbestinum	n=11
							Aplysina cauliformis	n=9
							Stephanocoenia michelini	n=9

Module	N	$\bar{X}$ of indiv. per module	s.e.	$\bar{X}$ species per module	s.e.
D	11	43.70	2.12	8.90	0.38
M	9	38.78	3.95	8.11	0.48
R	11	38.30	2.28	10.60	0.45
BC	10	11.30	0.87	8.50	0.73

A plot of the cumulative number of species by sampling period (rarefaction curve) demonstrates that the new species are recorded each sampling period (Figure I8; Table I9). The cumulative number of species found throughout the study is highest on the BC sites (47 species). This is misleading, since many of these species occurred at low densities during a single sampling period and then disappeared. Clearly, the benthic invertebrate fauna has not yet stabilized and will continue to change.

8. Comparisons Between All Sampling Periods: Diversity Index

A plot of the Shannon-Weiner Diversity Indices (H) for each study site by sampling period reflects the high rate of turnover in benthic invertebrate fauna (Figure I9). The diversity on the M modules has remained fairly consistent throughout the study. The D modules, R modules, and BC sites all demonstrate wide fluctuations.

List of Tables for Sessile Invertebrates

List of Figures for Sessile Invertebrates

Figure I5. Plot of the first three Principal Components for the most common invertebrate taxa found at the four study site types, labeled by taxa abbreviations (see Table I8 for abbreviations).

Figure I6. Plot of the average numbers of individuals at each of the four study site types by sampling period.

Figure I7. Plot of the average numbers of species at each of the four study site types for by sampling period.

Figure I8. Plot of the cumulative number of species recorded for each of the four study site types by sampling period (rarefaction curve).

Figure I9. Plot of the Shannon-Weiner Diversity Index (H) at each of the four study site types by sampling period.

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APPENDIX A

TABLES AND FIGURES

Table F1. Raw data for fishes at controls, coded by nearest module type (D, M, R).

SPECIES	COMMON NAME	CODE	D18	D19	D20	D21	D22	D25	D30	D34	D43	D49	D50	M1	M2
Urolophus jamaicensis	Yellow stingray	UROj	0	0	0	0	0	0	0	0	0	0	0	0	0
Serranus tigrinus	Harlequin bass	SERt	0	0	0	0	0	0	0	2	1	0	1	0	0
Serranus tabacarius	Tobaccofish	SERt	2	1	0	0	0	0	0	0	2	0	0	0	1
Hypolplectrus unicolor	Hamlets	HYPu	0	0	0	0	0	0	1	1	0	0	0	0	0
Pseudupeneus maculatus	Spotted goatfish	PSEm	0	0	0	1	0	0	0	0	0	0	0	0	0
Lutjanus griseus	Gray snapper	LUTg	0	0	0	0	0	0	0	0	0	2	0	0	0
Haemulon plumieri	White grunt	HAEp	0	2	0	0	0	3	0	0	0	0	0	0	5
Haemulon sciurus	Bluestriped grunt	HAEs	0	0	0	0	0	0	0	0	0	0	0	0	2
Chaetodon sedentarius	Reef butteflyfish	CHAs	0	0	0	0	2	0	2	0	0	0	0	2	0
Acanthurus bahianus	Ocean surgeon	ACAb	0	1	1	0	3	0	2	0	0	2	0	2	2
Chaetodiptierus faber	Spadefish	CHAf	0	0	0	0	0	0	0	0	0	0	0	0	0
Pomacanthus arcuatus	Gray angelfish	POMa	0	0	0	0	0	0	0	0	0	0	0	1	0
Pomacanthus paru	French angelfish	POMp	0	0	0	0	0	0	0	0	0	0	0	0	0
Holacanthus tricolor	Rock beauty	HOLt	0	0	0	0	0	0	0	0	0	0	1	0	0
Chromis insolatus	Sunshinefish	CHRi	0	0	0	0	0	0	0	1	0	0	1	0	0
Chromis scotti	Purple reeffish	CHRs	0	0	0	0	0	0	0	0	0	0	2	0	0
Pomacentrus partitus	Bicolor damselfish	POMp	6	5	5	6	4	7	4	6	8	2	6	10	6
Pomacentrus variabilis	Cocoa damselfish	POMv	0	0	0	0	0	1	0	0	2	0	1	0	0
Lachnolaimus maximus	Hogfish	LACm	0	0	0	1	0	0	0	0	0	0	0	0	0
Thalassoma bifasciatum	Bluehead wrasse	THAb	0	0	0	0	0	0	0	5	25	0	2	1	0
Scarus croicensus	Striped parrotfish	SCAc	1	2	0	0	0	0	0	0	0	0	0	0	0
Sparisoma viride	Stoplight parrotfish	SPAv	0	0	0	0	0	0	2	0	0	0	0	0	0
Sparisoma aurofrenatum	Redband parrotfish	SPAa	0	0	0	0	2	0	1	0	0	0	0	0	0
Cantherhines pullus	Orangespotted filefish	CANp	0	0	0	0	0	0	0	0	0	0	0	0	0
Canthigaster rostrata	Sharpnose puffer	CANr	1	0	0	0	0	0	0	0	0	0	0	0	0
Lactophrys trigonus	Trunkfish	LACtg	0	0	0	0	0	0	0	0	0	0	0	0	0
NUMBER OF FISHES			10	11	6	8	11	11	12	15	38	6	14	16	16
NUMBER OF SPECIES			4	5	2	3	4	3	6	5	5	3	7	5	5
FISHES PER SQ.FT.			0.36	0.39	0.21	0.29	0.39	0.39	0.43	0.54	1.36	0.21	0.50	0.12	0.12
SPECIES PER SQ.FT.			0.14	0.18	0.07	0.11	0.14	0.11	0.21	0.18	0.18	0.11	0.25	0.04	0.04

Table F1. Raw data for fishes at controls, coded by nearest module type (D, M, R).

SPECIES	M3	M4	M5	M6	M7	M8	M9	M10	R2	R4	R7	R14	R15	R16	R17	R21	R22	R23
Urolophus jamaicensis	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Serranus tigrinus	0	0	0	0	0	0	1	1	0	0	0	0	1	0	0	0	0	0
Serranus tabacarius	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hypolplectrus unicolor	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Pseudupeneus maculatus	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0
Lutjanus griseus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	3
Haemulon plumieri	0	5	0	0	0	0	0	0	0	0	7	10	0	0	0	0	5	0
Haemulon sciurus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
Chaetodon sedentarius	2	0	2	0	0	0	2	1	0	0	0	1	0	0	1	1	0	2
Acanthurus bahianus	0	1	0	0	1	3	0	1	4	2	0	3	2	0	0	2	0	3
Chaetodiptierus faber	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pomacanthus arcuatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pomacanthus paru	2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Holacanthus tricolor	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Chromis insolatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chromis scotti	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pomacentrus partitus	9	5	4	7	5	7	5	8	4	5	3	7	3	7	8	3	5	5
Pomacentrus variabilis	0	0	0	0	0	1	0	0	0	1	0	1	0	0	0	0	0	2
Lachnolaimus maximus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Thalassoma bifasciatum	0	3	4	0	8	0	0	3	0	0	0	0	5	10	0	0	3	15
Scarus croicensus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sparisoma viride	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sparisoma aurofrenatum	0	0	0	0	0	2	0	0	0	0	0	0	1	0	0	0	0	1
Cantherhines pullus	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Canthigaster rostrata	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Lactophrys trigonus	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
NUMBER OF FISHES	13	14	11	12	15	14	9	15	8	9	10	23	13	18	10	12	13	36
NUMBER OF SPECIES	3	4	4	2	4	5	4	6	2	4	2	6	6	3	2	4	3	9
FISHES PER SQ.FT.	0.10	0.11	0.08	0.09	0.11	0.11	0.07	0.11	0.05	0.06	0.06	0.14	0.08	0.11	0.06	0.08	0.08	0.23
SPECIES PER SQ.FT.	0.02	0.03	0.03	0.02	0.03	0.04	0.03	0.05	0.01	0.03	0.01	0.04	0.04	0.02	0.01	0.03	0.02	0.06

Table F2. Raw data for fishes at modules (D, M, R).

SPECIES	COMMON NAME	CODE	D18	D19	D20	D21	D22	D25	D30	D34	D43	D49	D50	M1	M2
Ginglymostoma cirratum	Nurse shark	GINc	0	0	0	0	0	0	0	0	0	0	0	0	0
Gymnothorax funebris	Green moray	GYMf	0	0	0	0	0	0	0	0	0	0	0	0	0
Holocentrus rufus	Longspine squirrelfish	HOLr	0	0	0	0	0	0	0	0	0	0	1	0	0
Epinephelus cruenatus	Graysby	EPIc	0	0	0	1	0	0	0	0	0	1	0	1	1
Epinephelus morio	Red grouper	EPIm	0	0	0	0	0	0	0	1	0	0	0	0	0
Mycteroperca phenax	Scamp	MYCp	0	0	0	0	0	0	0	0	1	0	0	0	0
Hypolplectrus unicolor	Hamlets	HYPu	0	0	0	1	1	0	0	0	1	1	1	0	0
Pseudupeneus maculatus	Spotted goatfish	PSEm	1	0	0	2	0	0	1	0	0	0	0	2	0
Apogon sp.	Cardinalfish	APOsp	0	0	0	0	0	0	0	0	0	0	0	0	0
Seriola dumerili	Greater amberjack	SERd	0	0	0	0	0	0	0	0	0	0	0	0	0
Caranx ruber	Bar jack	CARr	0	0	0	0	0	0	0	0	0	0	0	0	0
Ocyurus chrysurus	Yellowtail snapper	OCYc	0	0	0	0	0	0	0	0	0	0	0	0	1
Lutjanus griseus	Gray snapper	LUTg	0	0	0	0	0	3	0	0	20	1	0	0	25
Anisotremus surinamensis	Black margate	ANIs	0	0	0	0	0	0	0	0	0	0	0	0	0
Anisotremus virginicus	Porkfish	ANIv	0	3	4	1	0	0	0	0	0	0	0	10	5
Haemulon aurolineatum	Tomtate	HAEa	0	0	0	5	0	0	0	0	3	0	10	1	0
Haemulon flavolineatum	French grunt	HAEf	3	5	10	25	5	3	0	5	5	0	10	50	35
Haemulon plumieri	White grunt	HAEp	25	20	15	40	4	6	0	2	15	0	0	100	600
Haemulon sciurus	Bluestriped grunt	HAEs	3	10	8	5	0	3	0	0	10	0	3	35	100
Equetus lanceolatus	Jacknife fish	EQUl	2	0	1	0	0	0	0	0	0	0	0	0	2
Equetus puctatus	Spotted drum	EQUp	0	0	0	0	0	0	0	0	0	0	0	0	1
Equetus acuminatus	High-hat	EQUa	0	0	2	1	2	1	2	0	5	1	1	0	2
Chaetodon ocellatus	Spotfin butterflyfish	CHAo	0	0	0	2	0	2	0	0	0	0	0	0	1
Chaetodon capistratus	Four-eye butterflyfish	CHAc	0	0	0	0	0	0	0	0	0	0	0	0	0
Chaetodon sedentarius	Reef butteflyfish	CHAs	1	0	0	0	2	0	0	2	0	0	0	0	2
Acanthurus bahianus	Ocean surgeon	ACAb	4	3	2	6	4	1	3	0	0	1	2	2	10
Acanthurus coeruleus	Blue tang	ACAc	0	0	0	0	0	0	0	0	0	0	0	0	0
Pomacanthus arcuatus	Gray angelfish	POMa	0	0	0	0	0	0	0	0	0	0	0	0	0
Pomacanthus paru	French angelfish	POMp	0	0	0	0	0	0	0	0	0	0	0	0	0
Holacanthus bermudensis	Blue angelfish	HOLb	0	0	0	0	1	0	0	0	0	0	0	0	0
Holacanthus ciliaris	Queen angelfish	HOLc	0	0	0	1	0	0	0	0	0	0	0	0	0
Holacanthus tricolor	Rock beauty	HOLt	0	0	0	2	0	0	1	1	1	2	1	1	3
Abudefduf saxatilis	Sergeant major	ABUs	0	0	1	0	0	4	0	0	3	0	0	0	10
Chromis cynaneus	Blue chromis	CHRc	2	2	2	0	0	1	1	1	0	0	1	3	3

Table F2. Raw data for fishes at modules (D, M, R).

SPECIES	COMMON NAME	CODE	D18	D19	D20	D21	D22	D25	D30	D34	D43	D49	D50	M1	M2
Chromis multilineatus	Brown chromis	CHRm	0	0	0	0	0	0	0	0	0	0	0	0	0
Chromis insolatus	Sunshinefish	CHRi	0	0	0	0	0	0	0	0	0	0	0	0	0
Chromis scotti	Purple reeffish	CHRs	2	0	0	0	0	1	0	0	0	0	1	0	4
Pomacentrus partitus	Bicolor damselfish	POMp	2	0	0	0	0	0	0	0	0	0	0	0	0
Pomacentrus variabilis	Cocoa damselfish	POMv	0	1	0	3	0	1	0	1	1	1	0	1	1
Bodianus pulchellus	Spotfin hogfish	BODp	0	0	0	0	0	0	0	0	0	0	0	0	0
Bodianus rufus	Spanish hogfish	BODr	0	0	1	2	1	1	0	0	1	0	0	2	2
Halichoeres garnoti	Yellowhead wrasse	HALg	0	0	0	1	0	0	0	0	0	0	0	1	0
Lachnolaimus maximus	Hogfish	LACm	1	0	0	0	1	3	0	2	1	0	0	0	0
Thalassoma bifasciatum	Bluehead wrasse	THAb	5	2	2	0	10	15	0	3	0	0	2	0	5
Scarus croicensus	Striped parrotfish	SCAc	0	0	0	0	1	0	0	1	0	1	1	1	2
Scarus taeniopterus	Princess parrotfish	SCAt	0	0	0	0	0	2	0	0	0	0	0	0	0
Sparisoma viride	Stoplight parrotfish	SPAv	0	0	0	1	1	0	0	1	0	0	1	0	0
Sparisoma aurofrenatum	Redband parrotfish	SPAa	1	1	0	1	0	0	3	0	2	0	3	1	0
Cantherhines pullus	Orangespotted filefish	CANp	0	0	0	1	0	0	0	0	0	0	0	0	0
Canthigaster rostrata	Sharpnose puffer	CANr	0	1	1	2	1	1	0	0	0	0	0	1	2
Lactophrys triqueter	Smooth trunkfish	LACtq	0	0	0	0	0	0	0	0	0	0	0	0	0
Clepticus parrai	Creole wrasse	CLEp	0	0	0	0	0	0	0	0	0	0	0	0	0
Panulirus argus	Spiny lobster	PANa	0	0	0	0	0	0	0	0	0	0	0	2	1
Stenopus hispidus	Banded coral shrimp	STEh	0	0	0	0	2	0	0	0	0	0	0	0	0
NUMBER OF FISHES			52	48	49	103	34	48	11	20	69	9	38	212	817
NUMBER OF SPECIES			13	10	12	20	13	16	6	11	14	8	14	16	22
FISHES PER SQ.FT.			1.86	1.71	1.75	3.68	1.21	1.71	0.39	0.71	2.46	0.32	1.36	1.62	6.26
SPECIES PER SQ.FT.			0.46	0.36	0.43	0.71	0.46	0.57	0.21	0.39	0.50	0.29	0.50	0.12	0.17

Table F2. Raw data for fishes at modules (D, M, R).

SPECIES	M3	M4	M5	M6	M7	M8	M9	M10	R2	R4	R7	R14	R15	R16	R17	R21	R22	R23
Ginglymostoma cirratum	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Gymnothorax funebris	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Holocentrus rufus	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Epinephelus cruenatus	1	0	0	1	1	2	1	1	0	1	0	0	0	1	0	0	0	1
Epinephelus morio	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
Mycteroperca phenax	0	0	1	2	1	1	0	0	0	1	0	0	0	0	0	0	0	0
Hypolplectrus unicolor	0	0	1	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0
Pseudupeneus maculatus	2	2	0	0	0	0	0	1	6	0	0	2	0	2	0	0	0	0
Apogon sp.	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Seriola dumerili	0	0	0	0	0	50	0	0	0	0	0	0	0	0	0	0	0	0
Caranx ruber	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Ocyurus chrysurus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lutjanus griseus	0	50	30	40	50	40	50	35	0	0	0	0	0	0	0	3	0	20
Anisotremus surinamensis	7	2	1	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0
Anisotremus virginicus	0	5	10	3	2	0	0	1	4	8	3	0	0	0	0	0	0	0
Haemulon aurolineatum	0	0	0	50	5	0	0	25	0	0	0	1	5	0	0	30	0	30
Haemulon flavolineatum	35	25	15	75	60	25	25	35	10	25	25	45	50	25	25	60	45	60
Haemulon plumieri	125	100	50	70	25	40	100	20	50	40	50	45	50	30	5	0	20	60
Haemulon sciurus	25	50	50	70	15	50	50	30	15	40	10	20	10	5	5	10	15	35
Equetus lanceolatus	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0
Equetus puctatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Equetus acuminatus	0	2	4	2	0	0	2	0	2	10	1	0	0	0	2	0	0	2
Chaetodon ocellatus	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	2	0
Chaetodon capistratus	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	2	0
Chaetodon sedentarius	0	0	2	0	0	0	0	0	0	4	0	2	2	2	0	0	4	0
Acanthurus bahianus	0	0	1	3	1	2	0	2	5	6	5	3	5	5	7	1	4	10
Acanthurus coeruleus	1	0	0	0	0	0	0	1	1	0	0	0	1	0	0	0	0	1
Pomacanthus arcuatus	0	0	0	0	0	1	0	0	2	0	0	0	0	0	0	2	0	0
Pomacanthus paru	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
Holacanthus bermudensis	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0
Holacanthus ciliaris	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Holacanthus tricolor	0	0	2	0	2	0	0	2	2	2	0	0	2	0	1	1	2	1
Abudefduf saxatilis	1	2	0	10	0	2	0	2	0	2	1	0	2	2	1	2	2	0
Chromis cynaneus	0	0	4	0	4	0	0	0	0	2	0	5	0	0	0	1	0	0

Table F2. Raw data for fishes at modules (D, M, R).

SPECIES	M3	M4	M5	M6	M7	M8	M9	M10	R2	R4	R7	R14	R15	R16	R17	R21	R22	R23
Chromis multilineatus	0	0	1	0	1	0	0	1	0	1	0	0	2	0	0	0	0	0
Chromis insolatus	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Chromis scotti	0	0	0	0	5	0	0	5	4	0	0	4	0	5	3	5	2	0
Pomacentrus partitus	0	0	0	0	0	0	0	2	2	0	0	2	0	0	3	3	0	2
Pomacentrus variabilis	1	0	0	1	2	1	0	1	0	0	2	2	0	0	0	1	0	1
Bodianus pulchellus	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Bodianus rufus	3	2	2	2	0	1	0	3	3	2	4	0	0	1	0	0	2	0
Halichoeres garnoti	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lachnolaimus maximus	0	0	0	0	0	0	0	1	2	2	2	0	0	0	0	1	1	2
Thalassoma bifasciatum	3	0	0	0	0	5	0	0	8	0	0	2	3	30	15	10	7	0
Scarus croicensus	0	0	0	0	0	0	0	1	1	1	0	0	2	1	0	0	0	2
Scarus taeniopterus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
Sparisoma viride	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Sparisoma aurofrenatum	0	0	0	0	1	1	2	1	2	1	2	0	3	4	2	1	2	2
Cantherhines pullus	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Canthigaster rostrata	0	1	3	0	1	0	0	1	3	0	1	2	0	0	1	0	1	0
Lactophrys triqueter	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0
Clepticus parrai	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0
Panulirus argus	0	1	0	0	1	0	0	0	0	0	2	0	0	0	0	0	0	0
Stenopus hispidus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NUMBER OF FISHES	206	242	177	332	178	223	232	175	130	148	109	136	139	116	71	144	113	229
NUMBER OF SPECIES	13	12	16	16	18	16	8	24	21	17	14	14	15	15	13	18	17	15
FISHES PER SQ.FT.	1.58	1.85	1.36	2.54	1.36	1.71	1.78	1.34	0.81	0.93	0.68	0.85	0.87	0.73	0.44	0.90	0.71	1.43
SPECIES PER SQ.FT.	0.10	0.09	0.12	0.12	0.14	0.12	0.06	0.18	0.13	0.11	0.09	0.09	0.09	0.09	0.08	0.11	0.11	0.09

Table F3. Summary of fishes at modules (D, M, R) and controls (C).

SPECIES	COMMON NAME	CODE	D	M	R	C	Total
Ginglymostoma cirratum	Nurse shark	GINc	0	1	1	0	2
Urolophus jamaicensis	Yellow stingray	UROj	0	0	0	1	1
Gymnothorax funebris	Green moray	GYMf	0	1	0	0	1
Holocentrus rufus	Longspine squirrelfish	HOLr	1	0	1	0	2
Epinephelus cruenatus	Graysby	EPIc	2	9	3	0	14
Epinephelus morio	Red grouper	EPIm	1	2	2	0	5
Mycteroperca phenax	Scamp	MYCp	1	5	1	0	7
Serranus tigrinus	Harlequin bass	SERt	0	0	0	7	7
Serranus tabacarius	Tobaccofish	SERt	0	0	0	7	7
Hypolplectrus unicolor	Hamlets	HYPu	5	3	1	3	12
Pseudupeneus maculatus	Spotted goatfish	PSEm	4	7	10	3	24
Apogon sp.	Cardinalfish	APOsp	0	1	0	0	1
Seriola dumerili	Greater amberjack	SERd	0	50	0	0	50
Caranx ruber	Bar jack	CARr	0	1	0	0	1
Ocyurus chrysurus	Yellowtail snapper	OCYc	0	1	0	0	1
Lutjanus griseus	Gray snapper	LUTg	24	320	23	11	378
Anisotremus surinamensis	Black margate	ANIs	0	14	0	0	14
Anisotremus virginicus	Porkfish	ANIv	8	36	15	0	59
Haemulon aurolineatum	Tomtate	HAEa	18	81	66	0	165
Haemulon flavolineatum	French grunt	HAEf	71	380	370	0	821
Haemulon plumieri	White grunt	HAEp	127	1230	350	37	1744
Haemulon sciurus	Bluestriped grunt	HAEs	42	475	165	6	688
Equetus lanceolatus	Jacknife fish	EQUl	3	2	6	0	11
Equetus puctatus	Spotted drum	EQUp	0	1	0	0	1
Equetus acuminatus	High-hat	EQUa	15	12	17	0	44
Chaetodon ocellatus	Spotfin butterflyfish	CHAo	4	1	4	0	9
Chaetodon capistratus	Four-eye butterflyfish	CHAc	0	1	3	0	4
Chaetodon sedentarius	Reef butteflyfish	CHAs	5	4	14	18	41
Acanthurus bahianus	Ocean surgeon	ACAb	26	21	51	35	133
Acanthurus coeruleus	Blue tang	ACAc	0	2	3	0	5
Chaetodiptierus faber	Spadefish	CHAf	0	0	0	5	5
Pomacanthus arcuatus	Gray angelfish	POMa	0	1	4	1	6
Pomacanthus paru	French angelfish	POMp	0	0	2	3	5
Holacanthus bermudensis	Blue angelfish	HOLb	1	1	1	0	3
Holacanthus ciliaris	Queen angelfish	HOLc	1	0	0	0	1
Holacanthus tricolor	Rock beauty	HOLt	8	10	11	2	31
Abudefduf saxatilis	Sergeant major	ABUs	8	27	12	0	47
Chromis cynaneus	Blue chromis	CHRc	10	14	8	0	32
Chromis multilineatus	Brown chromis	CHRm	0	3	3	0	6
Chromis insolatus	Sunshinefish	CHRi	0	1	0	2	3
Chromis scotti	Purple reeffish	CHRs	4	14	23	2	43
Pomacentrus partitus	Bicolor damselfish	POMp	2	2	12	175	191
Pomacentrus variabilis	Cocoa damselfish	POMv	8	8	6	9	31
Bodianus pulchellus	Spotfin hogfish	BODp	0	0	1	0	1
Bodianus rufus	Spanish hogfish	BODr	6	17	12	0	35
Halichoeres garnoti	Yellowhead wrasse	HALg	1	1	0	0	2
Lachnolaimus maximus	Hogfish	LACm	8	1	10	2	21
Thalassoma bifasciatum	Bluehead wrasse	THAb	39	13	75	84	211

TABLE I4. Comparison of the average number of individuals and the average number of species at the four study site types (D, M, R, and BC) for benthic invertebrate data.

One-Way Analysis of Variance (ANOVA)
Number of individuals:

Source	df	Sum of Squares	Mean Squares	F-value	p
Between	3	6434	2144		
				32.276	<0.001
Within	37	2325	66		

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	35	12		
				4.248	0.012
Within	37	97	3		

The calculated F-value indicates that there are significant differences among the means of the populations (p=0.012).

T-tests (Independent samples, separate variance)
Mean Number of Individuals:

Sites	df	t	p	
D vs M	18	1.026	0.320	
D vs R	20	1.522	0.142	
M vs R	18	0.105	0.881	
D vs BC	19	11.359	<0.001	(Module higher)
M vs BC	17	6.787	<0.001	(Module higher)
R vs BC	19	11.062	<0.001	(Module higher)

Mean Number of Species:

Sites	df	t	p	
D vs M	18	1.283	0.215	
D vs R	20	-2.883	0.010	(R modules higher)
M vs R	18	-3.756	0.002	(R modules higher)
D vs BC	19	0.484	0.639	
M vs BC	17	-0.442	0.667	
R vs BC	19	2.436	0.024	(Module higher)

Table I5. Surface area of each module (D, M, R) and barren control (BC) quadrats, and correction of average number of individuals and species for differences in surface area.

	D	M	R	BC
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
% Area sampled per module	21%	10%	8%	
Number of modules sampled	11	10	10	10

	X of individuals		X of species	
Site Type	per ft2	Std. err.	per ft2	Std. err.
D	7.283	0.453	1.483	0.063
M	3.042	0.310	0.635	0.037
R	3.192	0.190	0.884	0.038
BC	0.477	0.036	0.706	0.061

TABLE I6. Comparison of the average number of individuals per sq. ft. and the average number of species per sq.ft. at the four study site types (D, M, R, and BC) for benthic invertebrates.

One-Way Analysis of Variance (ANOVA)
Number of individuals per sq. ft.:

Source	df	Sum of Squares	Mean Squares	F-value	p
Between	3	237	79		
				96.37	<0.001
Within	37	29	1		

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

Number of species per sq. ft.:

Source	df	Sum of Squares	Mean Squares	F-value	p
Between	3	4.36	1.45		
				55.087	<0.001
Within	37	0.92	0.03		

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

T-tests (Independent samples, separate variance)
Mean number of individuals per sq. ft.:

Sites	df	t	p	
D vs M	18	7.729	<0.001	D module higher
D vs R	20	8.832	<0.001	D module higher
M vs R	18	-0.412	0.687	
D vs BC	19	14.984	<0.001	Module higher
M vs BC	17	8.221	<0.001	Module higher
R vs BC	19	14.037	<0.001	Module higher

Mean number of species per sq. ft.:

Sites	df	t	p	
D vs M	18	11.563	<0.001	D modules higher
D vs R	20	8.151	<0.001	D modules higher
M vs R	18	-4.708	<0.001	R modules higher
D vs BC	19	8.825	<0.001	Module higher
M vs BC	17	0.983	0.341	
R vs BC	19	2.477	0.022	Module higher

Table I7. Standardized occurrence of most common invertebrate taxa (n =>5).

SPECIES	CODE	D	M	R	BC
Aplysina cauliformis	APLc	0.23	0.00	0.00	7.96
Briareum asbestinum	BRIa	0.46	0.29	0.79	9.73
Callyspongia fallax	CALf	0.00	0.86	1.84	0.00
Callyspongia plicifera	CALp	0.00	0.29	1.31	1.77
Callyspongia vaginalis	CALv	7.32	11.17	8.66	4.42
Cliona delatrix	CLId	0.46	0.29	1.31	0.00
Didemnid unid.	DIDunid	0.69	0.86	0.52	0.00
Dysidea sp.	DYSsp	10.53	7.16	10.50	0.00
Eunicea sp.	EUNsp	0.00	0.00	0.79	2.65
Holopsamma helwigi	HOLh	42.11	31.23	36.75	11.50
Iotrochota birotulata	IOTb	2.75	11.75	6.30	0.88
Lima lima	LIMl	0.23	0.00	4.46	0.00
Meandrina meandrites	MEAm	0.69	0.00	0.52	3.54
Millepora alcicornis	MILa	7.78	11.46	12.60	0.00
Niphates digitalis	NIPd	0.00	0.00	0.00	7.08
Niphates sp.	NIPsp	0.69	1.43	0.79	3.54
Siderastrea sidera	SIDs	1.83	0.00	0.00	2.65
Siderastrea sp.	SIDsp	1.37	0.00	0.00	2.65
Spondylus americanus	SPOa	0.00	1.15	1.57	1.77
Stephanocoenia michelini	STEm	0.46	0.00	0.00	7.96
Stolonica sabulosa	STOs	17.85	10.32	3.94	7.08
Telesto riisei	TELr	0.00	7.45	0.00	0.00
Ulosa reutzleri	ULOr	3.43	1.43	3.41	5.31
Watersipora sp.	WATsp	0.00	2.87	0.52	0.00
% of individuals included for analysis		98.9	100.0	96.6	80.5
% of species included for analysis		81.0	100.0	55.2	55.0

Table I8. Results of ANOVA comparing mean number of fishes and mean number of species at the four study sites (D, M, R, and BC) during 10th and 12th quarters.

Mean number of invertebrates

Sites	df	F	p
D modules	1, 18	0.102	0.748
M modules	1, 16	0.168	0.689
R modules	1, 18	1.350	0.260
BC sites	1, 18	1.678	0.209

Mean number of species

Sites	df	F	p
D modules	1, 18	1.117	0.305
M modules	1, 16	0.281	0.609
R modules	1, 18	1.308	0.267
BC sites	1, 18	3.655	0.069

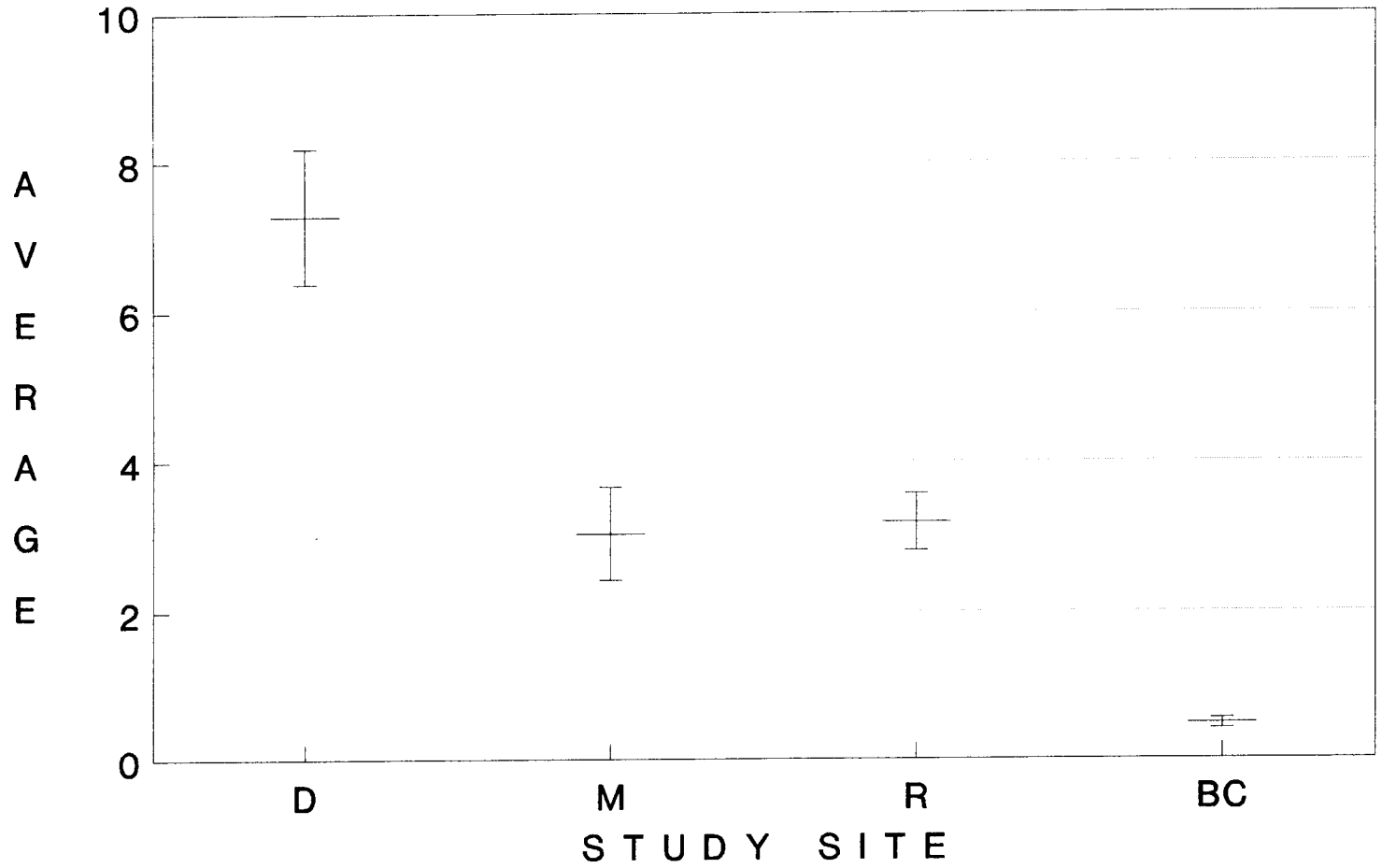
Table I9. Quarter in which invertebrate species were first recorded on the modules (D, M, R) and barren controls (BC). Sampling of modules and final barren control sites did not begin until the third quarter.

Genus/species	D	M	R	BC
Agaricia sp.	---	---	8	---
Aplysina	10	---	---	4
Ascidia nigra	4	---	3	---
Briareum asbestinum	8	3	12	3
Callyspongia fallax	3	12	3	5
Callyspongia plicifera	8	8	8	5
Callyspongia vaginalis	5	5	6	3
Cinachyra sp	---	---	---	12
Cliona delatrix	10	12	10	---
Cyanobacterial mats	---	---	---	6
Dasychalina cyathina	---	---	---	8
Diadema antillarum	---	---	10	---
Dichocoenia stokesi	12	---	---	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.	12	---	---	6
Leucosolenia sp.	---	---	6	---
Lima lima	4	4	3	3
Meandrina meandrites	8	---	7	3
Melanostigma nigromaculata	---	4	4	---
Millepora alcicornis	6	7	4	7
Mithrax sp.	---	6	---	---
Montastrea annularis	---	---	10	5
Montastrea cavernosa	---	---	---	5
Mussa sp	---	---	---	12
Mycale sp.	---	---	---	8
Mycetophyllia sp.	---	---	---	5
Niphates digitalis	---	---	---	3
Niphates erecta	10	---	---	3
Niphates sp.	10	8	8	12
Octopus sp.	---	---	6	---
Panuluris argus	---	5	4	---
Parasmittina sp.	3	3	4	---
Plexuar flexuosa	---	---	---	12
Porites sp.	10	8	---	---
Pseudoplexura	---	---	10	---
Reteporellina sp.	5	5	5	5
Sabella sp.	---	3	3	3

Table I9. Quarter in which invertebrate species were first recorded on the modules (D, M, R) and barren controls (BC). Sampling of modules and final barren control sites did not begin until the third quarter.

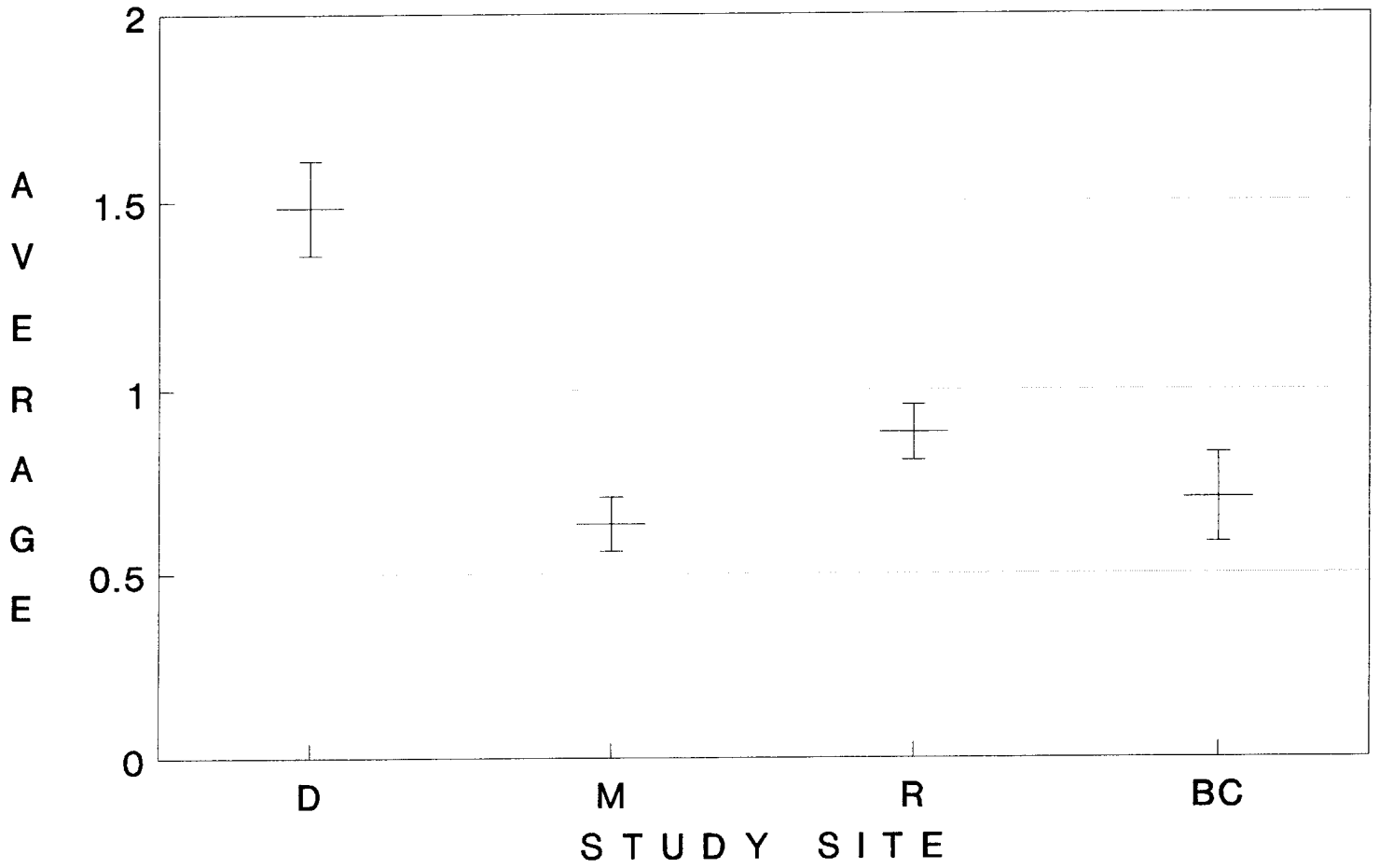
Genus/species	D	M	R	BC
Serpula sp.	---	3	3	---
Siderastrea sidera	8	---	---	3
Siderastrea sp.	12	---	---	7
Spirastrella coccinea	---	---	---	3
Spondylus americanus	4	3	3	12
Sponge unid	5	5	5	6
Stenopus hispidus	3	3	3	---
Stenorhynchus seticornis	4	3	3	---
Stephanocoenia michelini	12	---	---	4
Stolonica sabulosa	3	3	3	3
Styella plicata	---	4	4	---
Teichaxinella morchella	---	---	---	5
Telesto riisei	---	3	5	---
Thalysias sp	---	10	12	---
Trematooecia aviculifera	10	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	10	---	4
Xestospongia muta	---	---	6	5
CUMULATIVE NUMBER OF SPECIES	36	36	42	47

Figure I1. Average number of individuals per sq.ft. +/- 2 Std.err.



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

Figure I2 Average number of species per sq.ft. +/- 2 Std.err.



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

Fig I3 Cluster based upon most common invertebrates

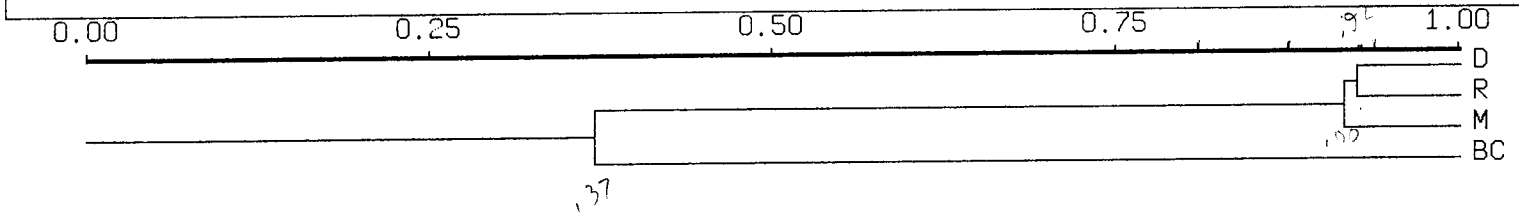


Fig I4 Cluster based upon most common invertebrates

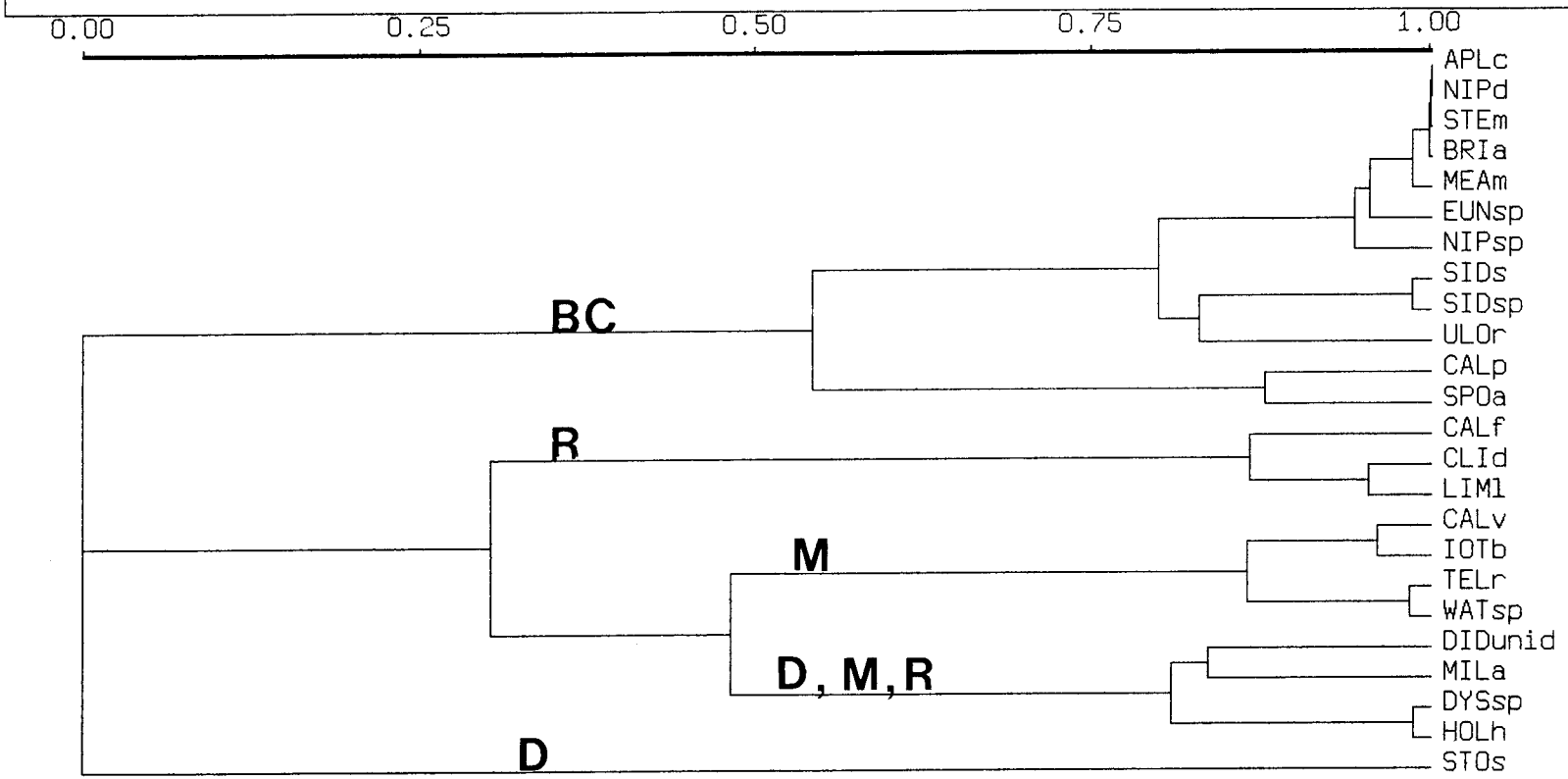
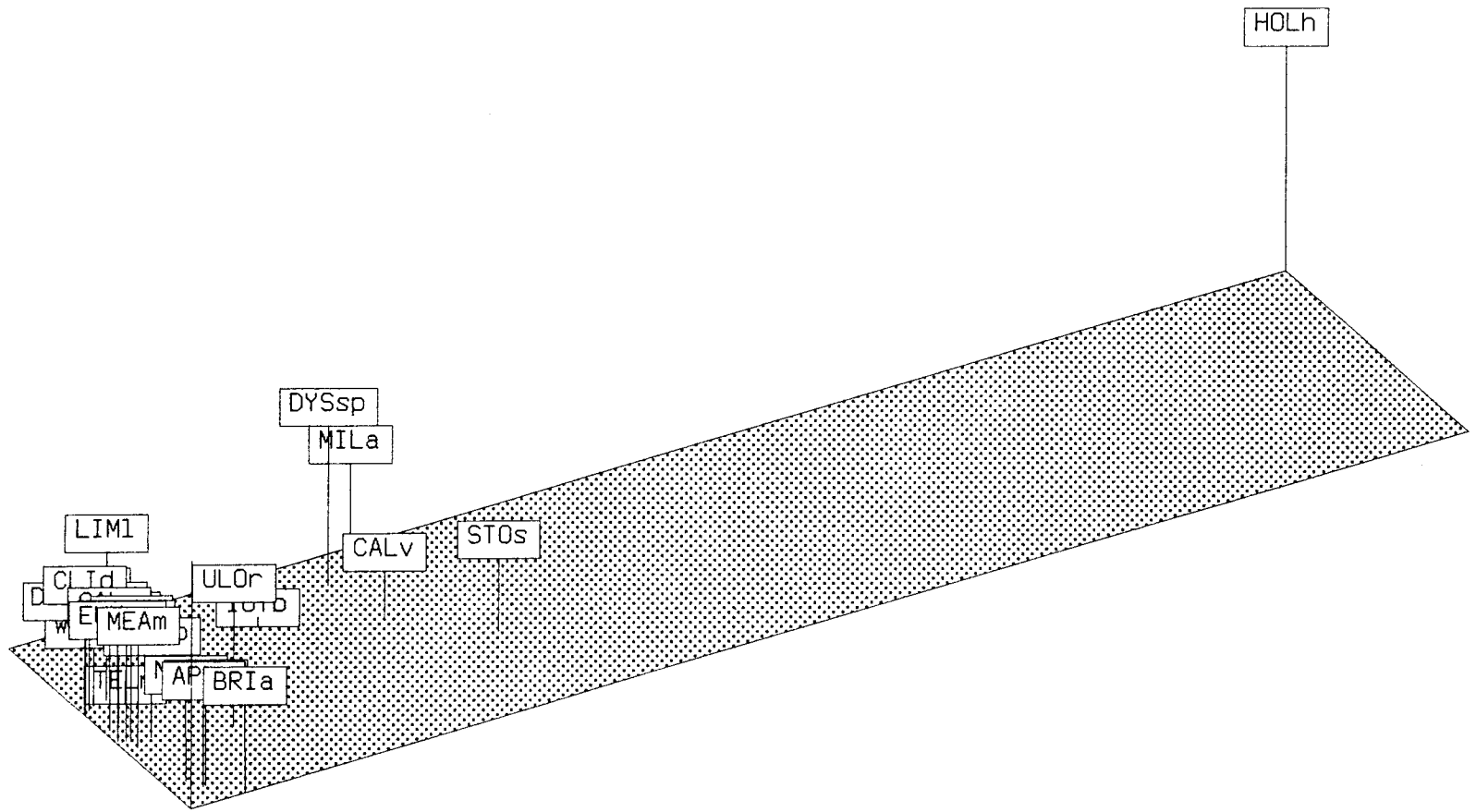


Fig I5 PCA based upon most common invertebrates



a= 30 b= 30 r=99.0

Figure I6 Average number of benthic invertebrates at four study sites by sampling period.

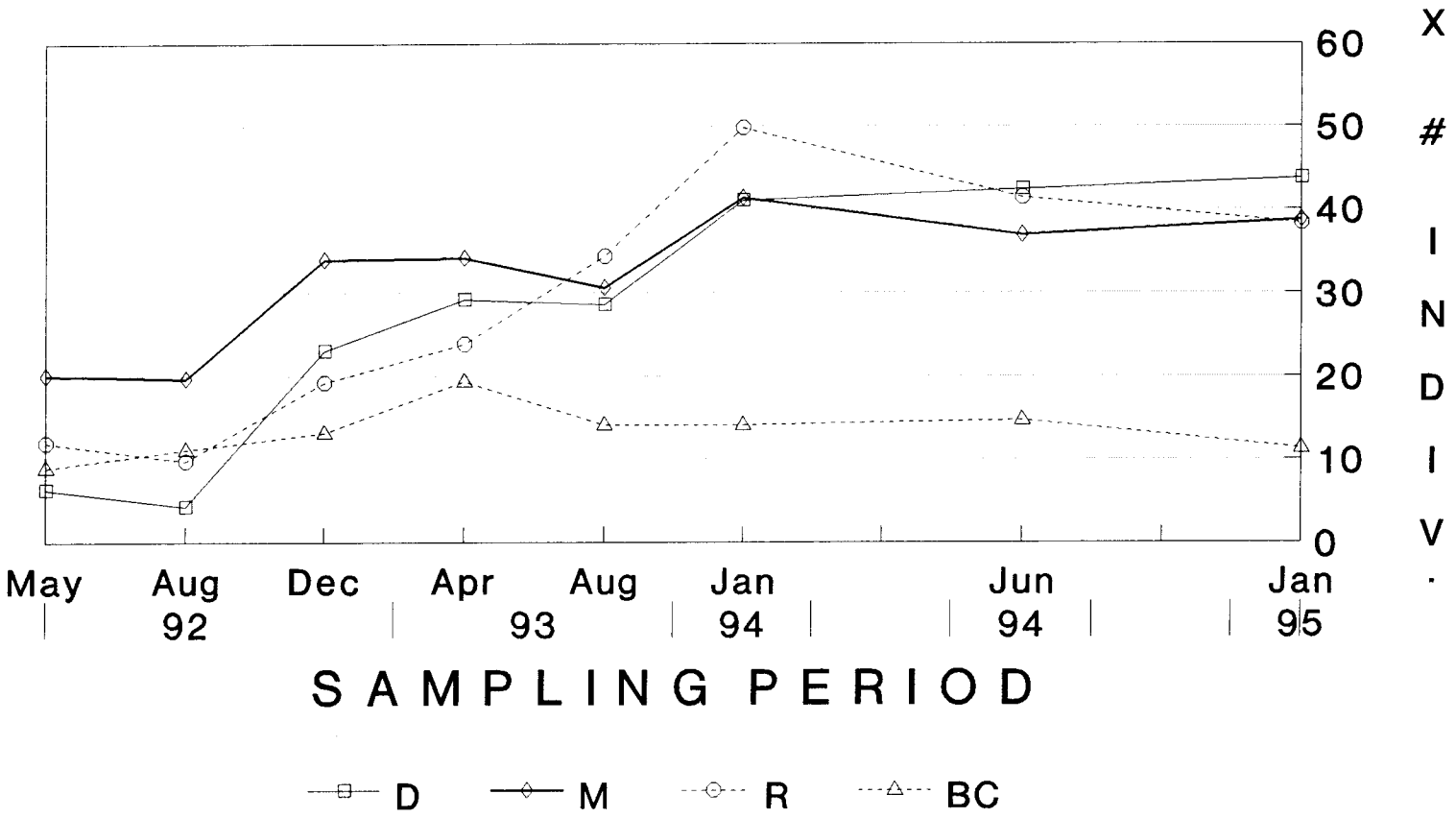


Figure 17 Average number of benthic invertebrate species at four study sites by sampling period.

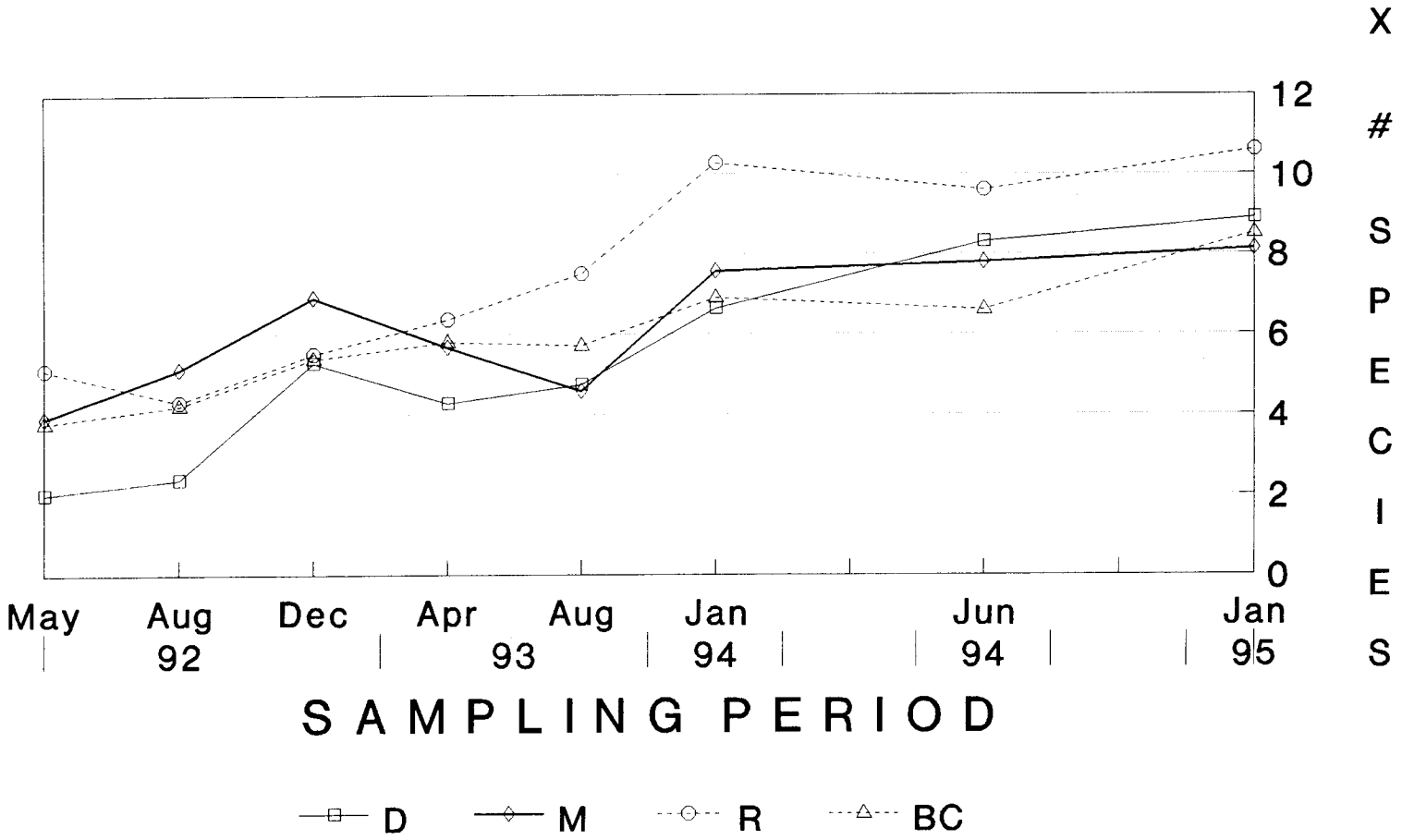


Figure 18. Rarefaction curve for the cumulative number of invertebrates.

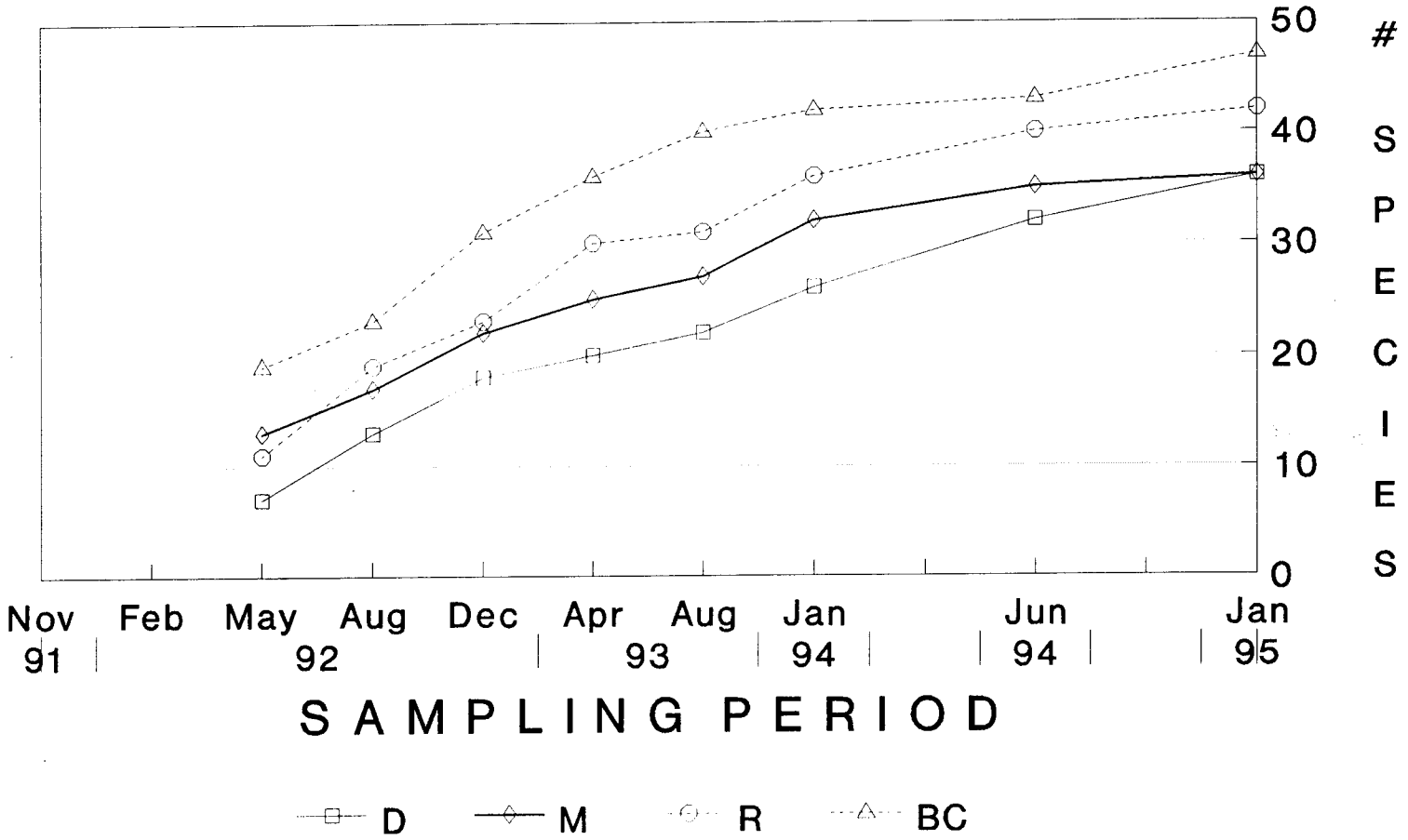
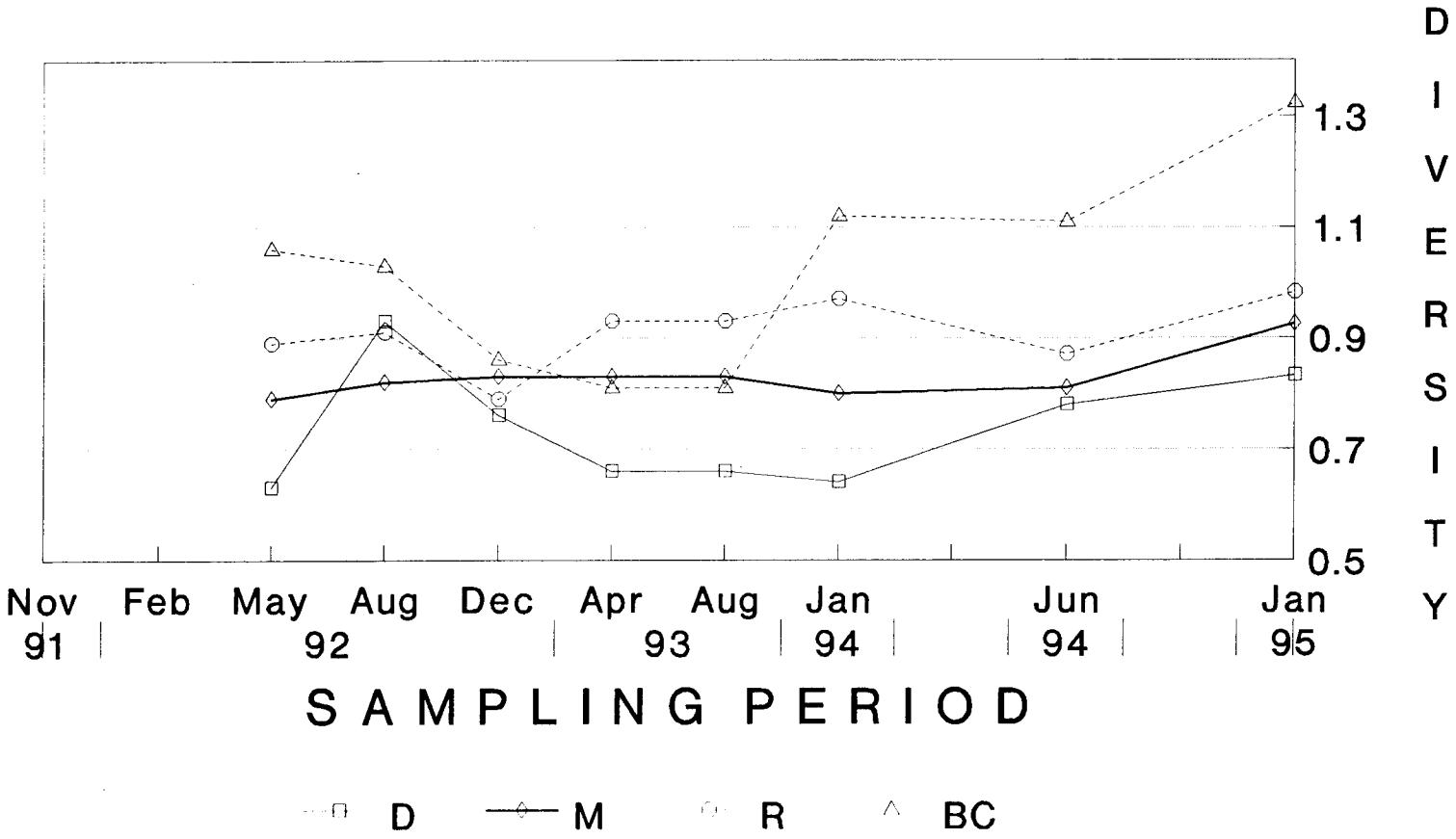


Figure 19Shannon-Weiner diversity index (H) for benthic invertebrates by sampling period.

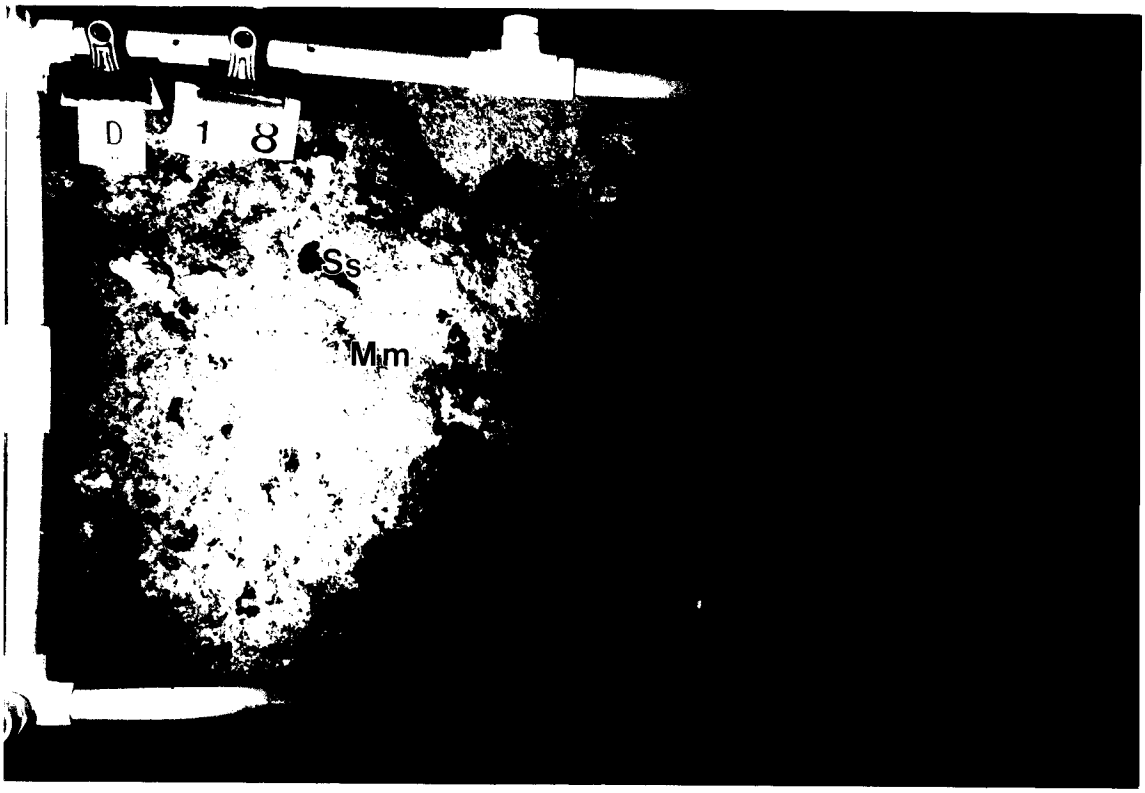


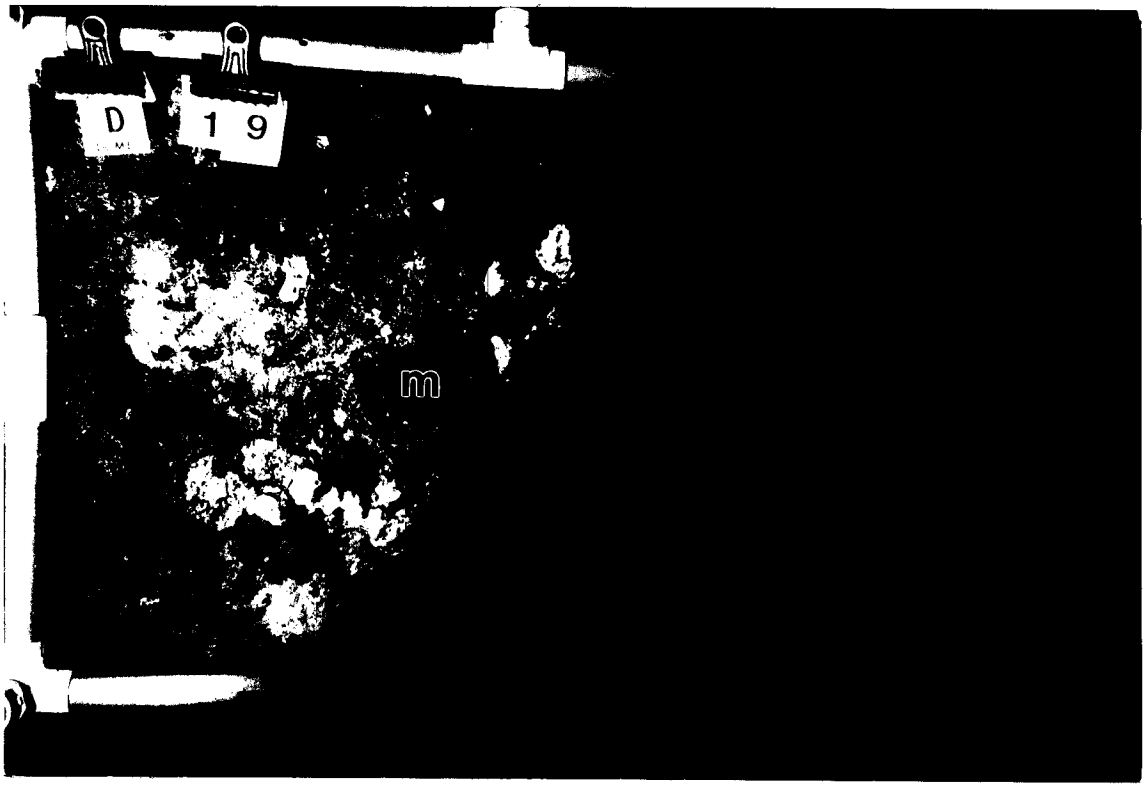
APPENDIX B

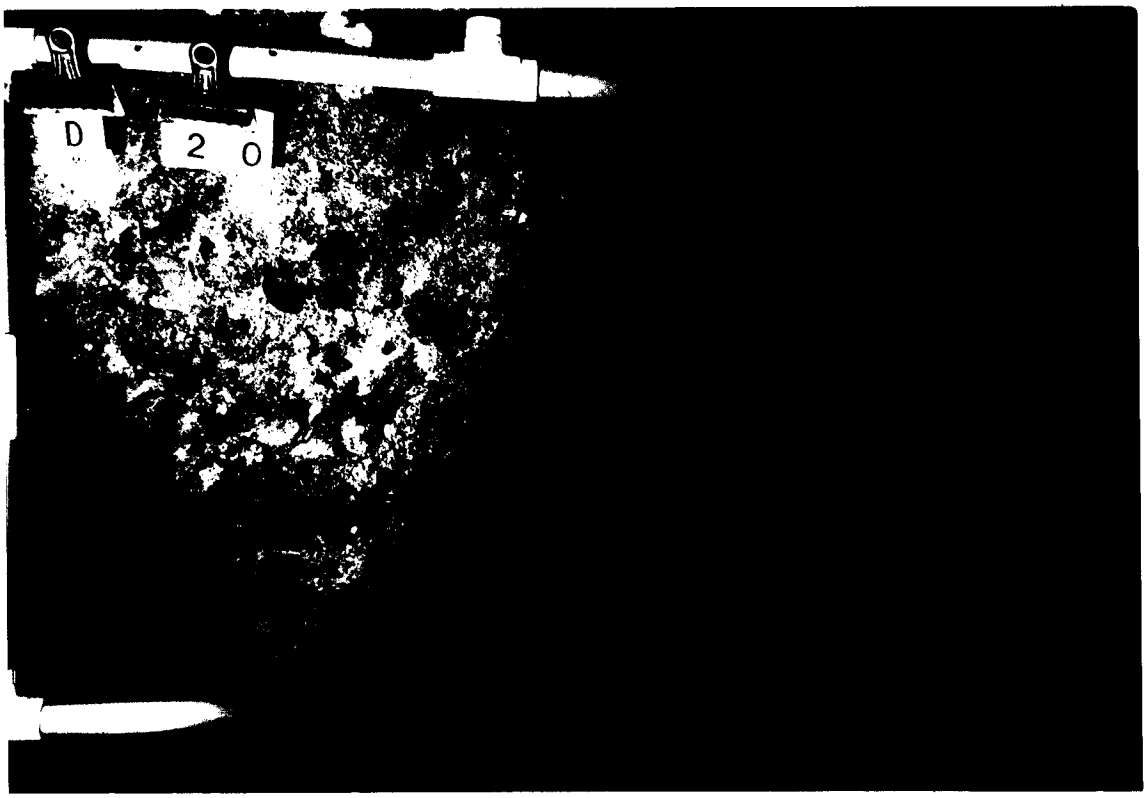
PHOTOGRAPHIC LOG

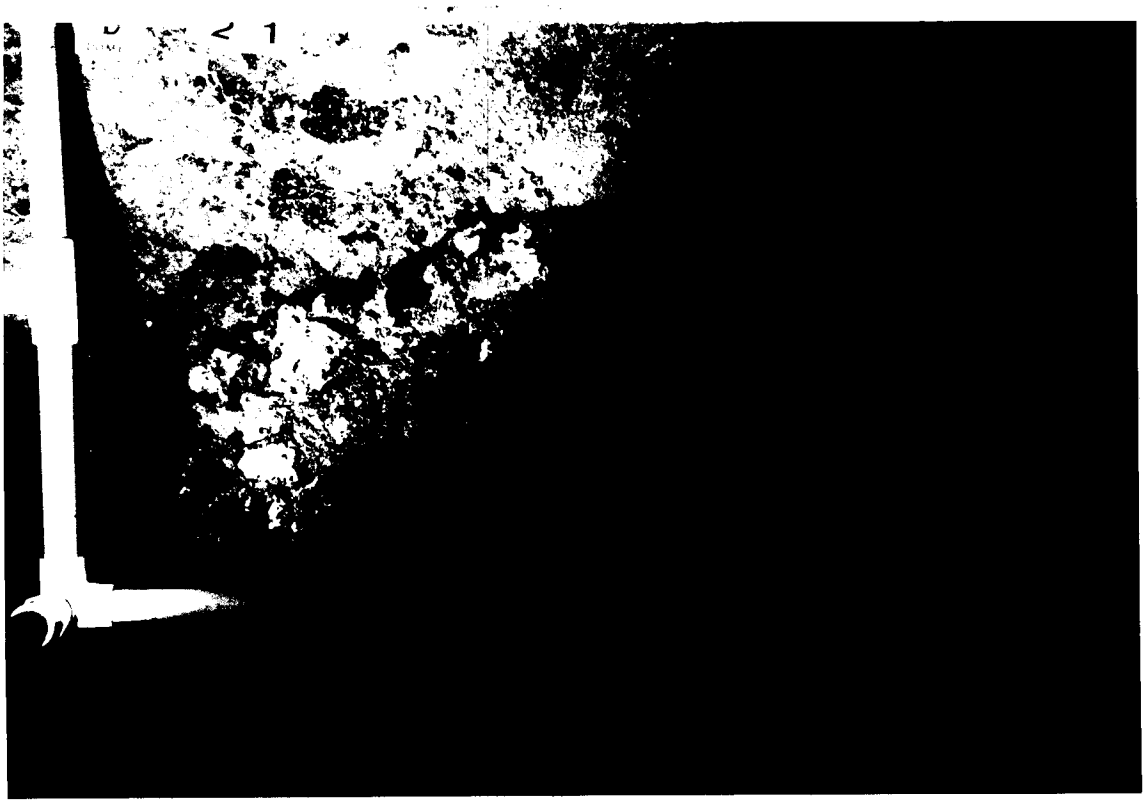
APPENDIX B: PHOTOGRAPHIC LOG ABBREVIATION KEY

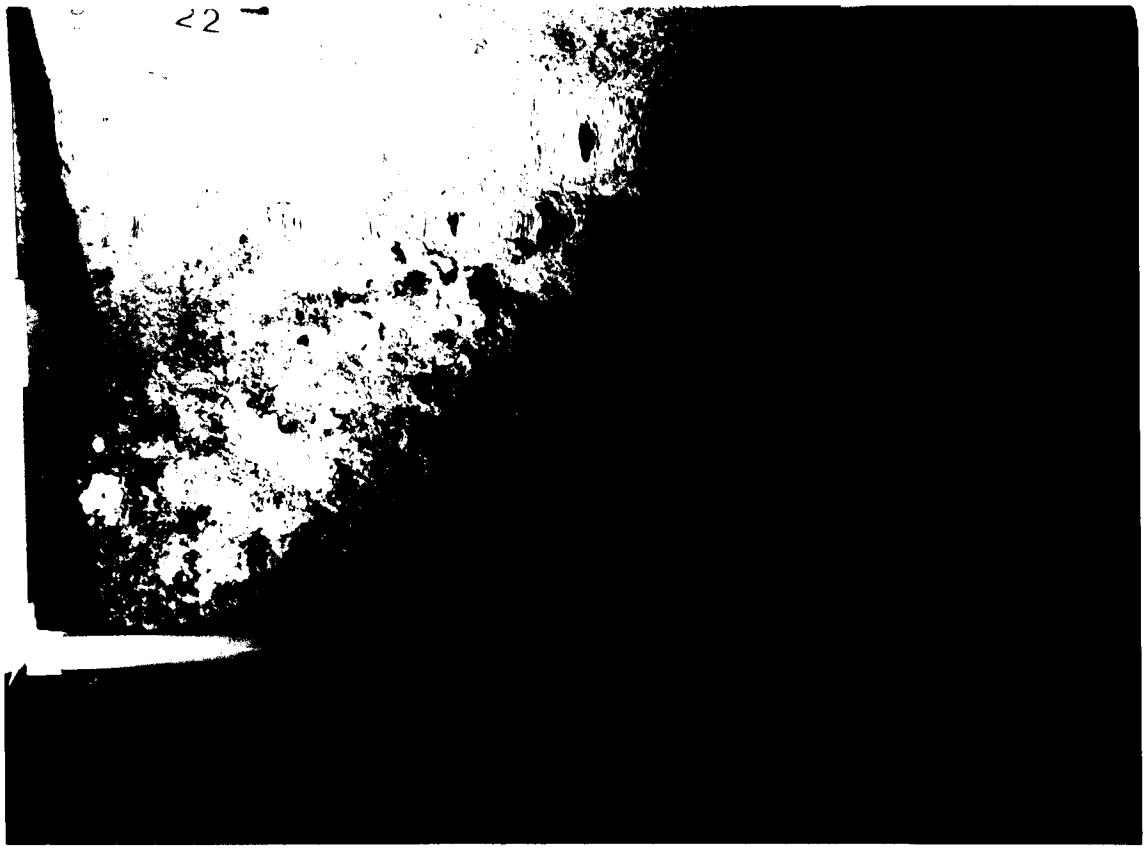
Symbol	Abbreviation
B	Briarium asbestinum (gorgonian coral)
CV	Callyspongia vaginalis (sponge)
d	Diploria sp. (scleractinian coral)
L	Lima lima (bivalve)
m	Millepora alcicornis (fire coral)
Mm	Meandrina meandrites (scleractinian coral)
p	Pseudoplexaura sp. (gorgonian coral)
Ss	Siderastrea siderea (scleractinian coral)
t	Telesto riseii (octocoral)


D 1 8
Ss
Mm


D 1 9
m


D 2 0


D 2 1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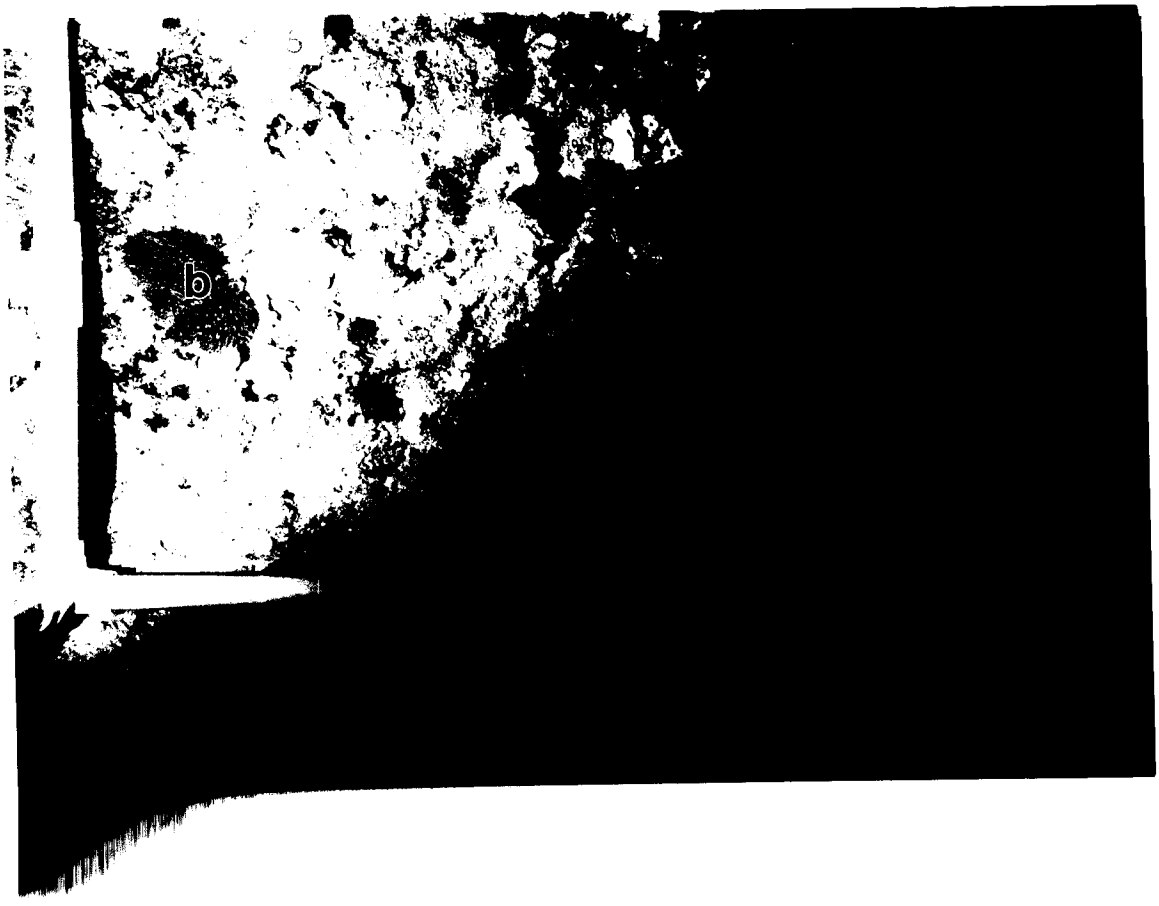
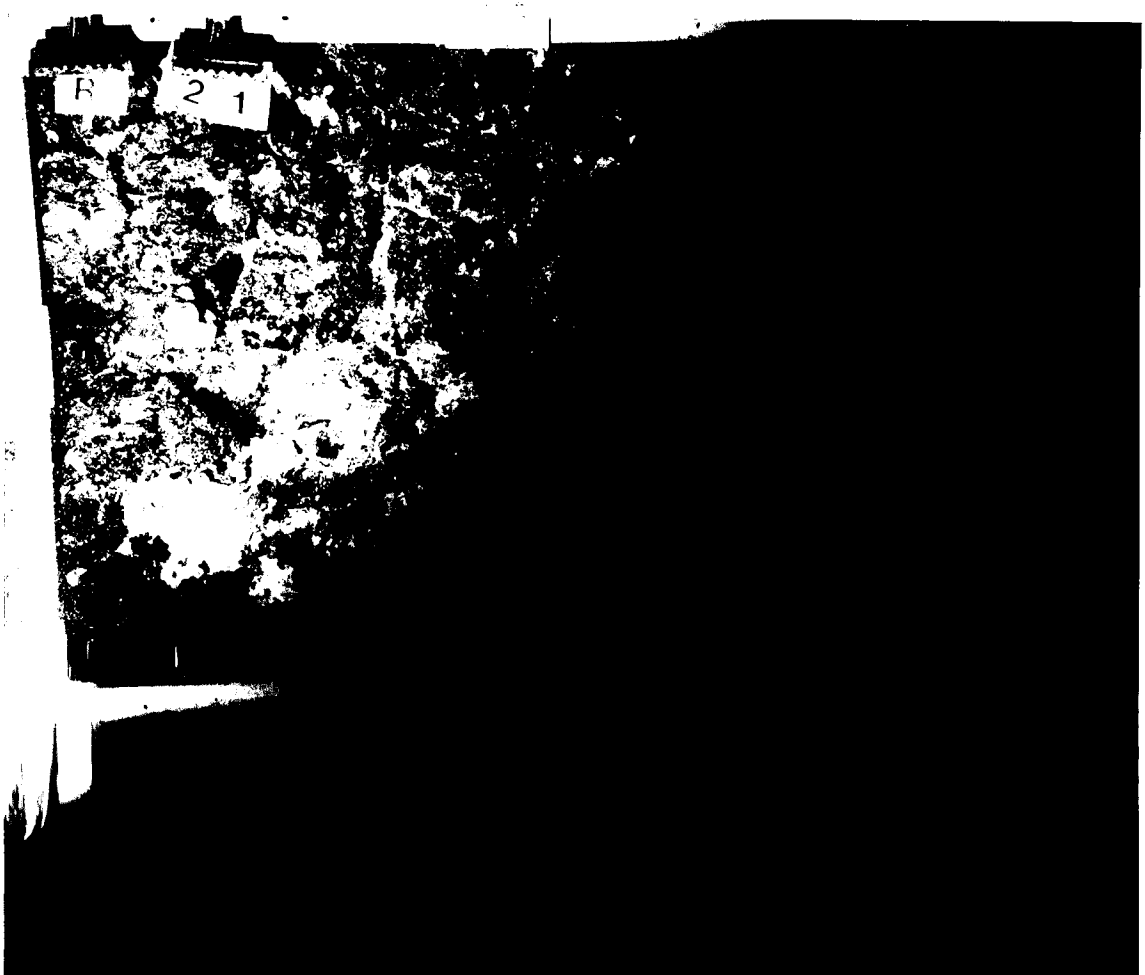
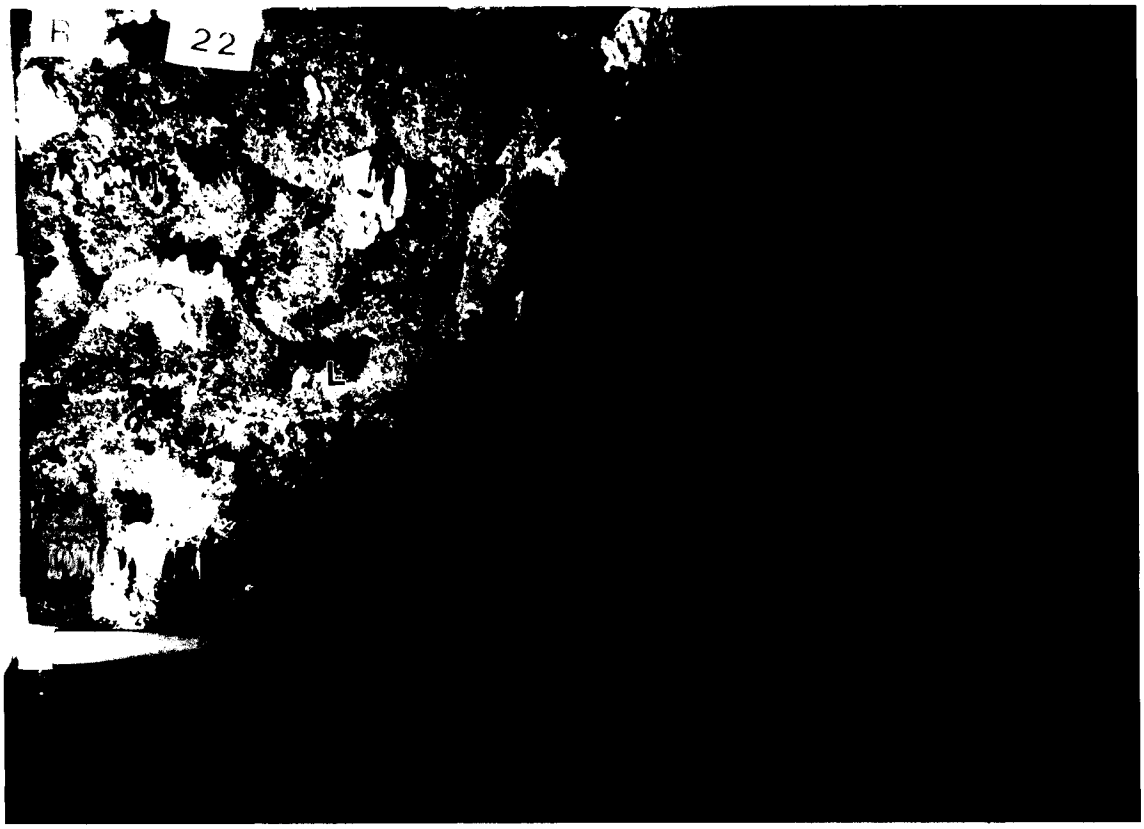

b


3 4
D


D
DOME

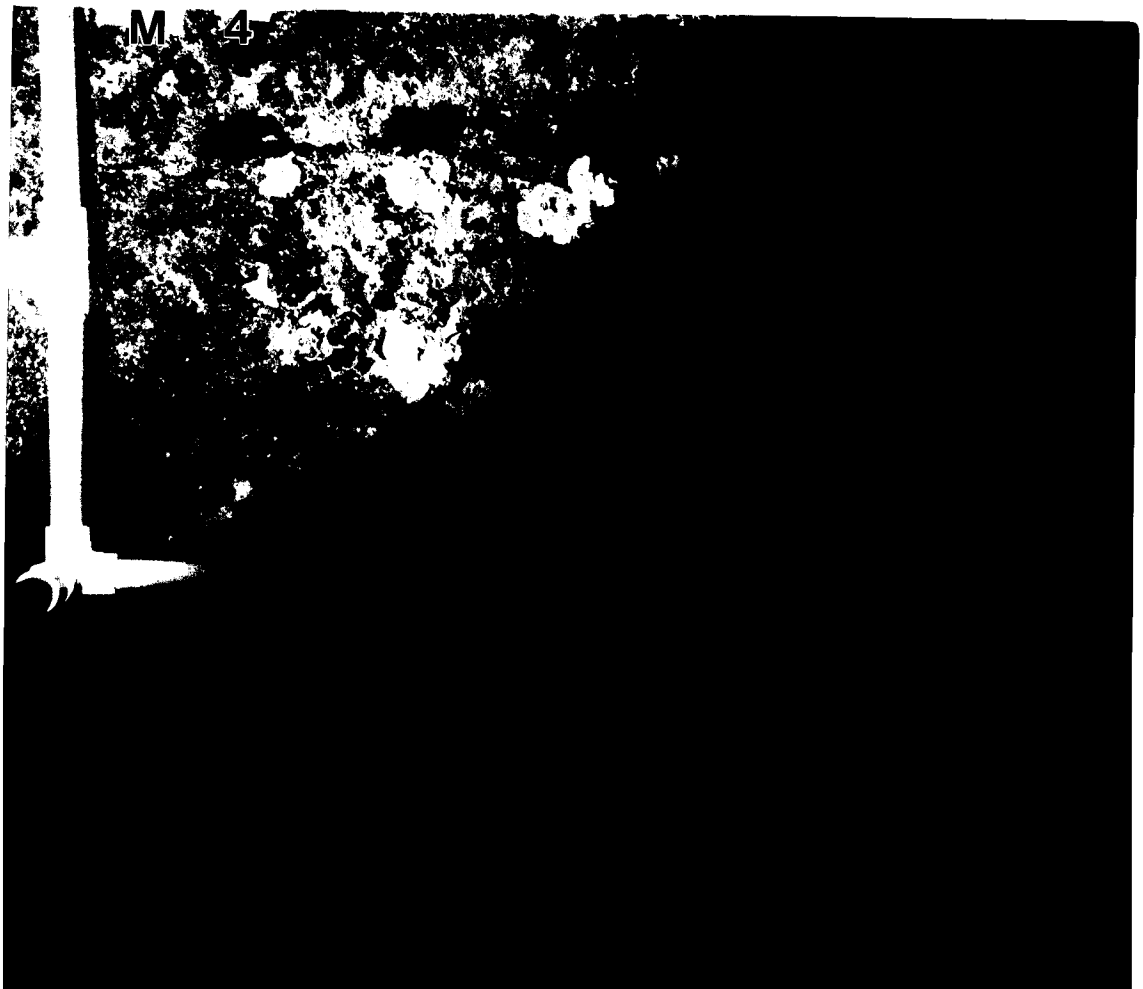

R


R 2 1

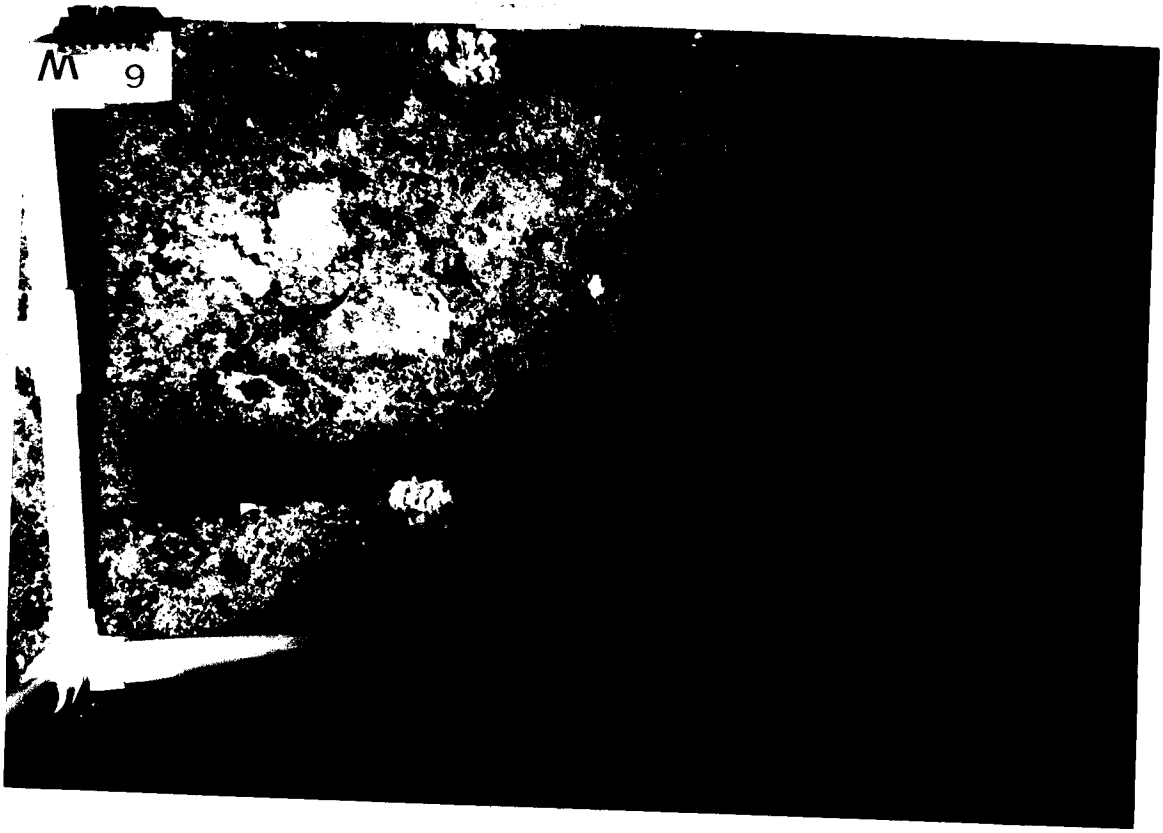

R
22
L


R
23
m


M 3

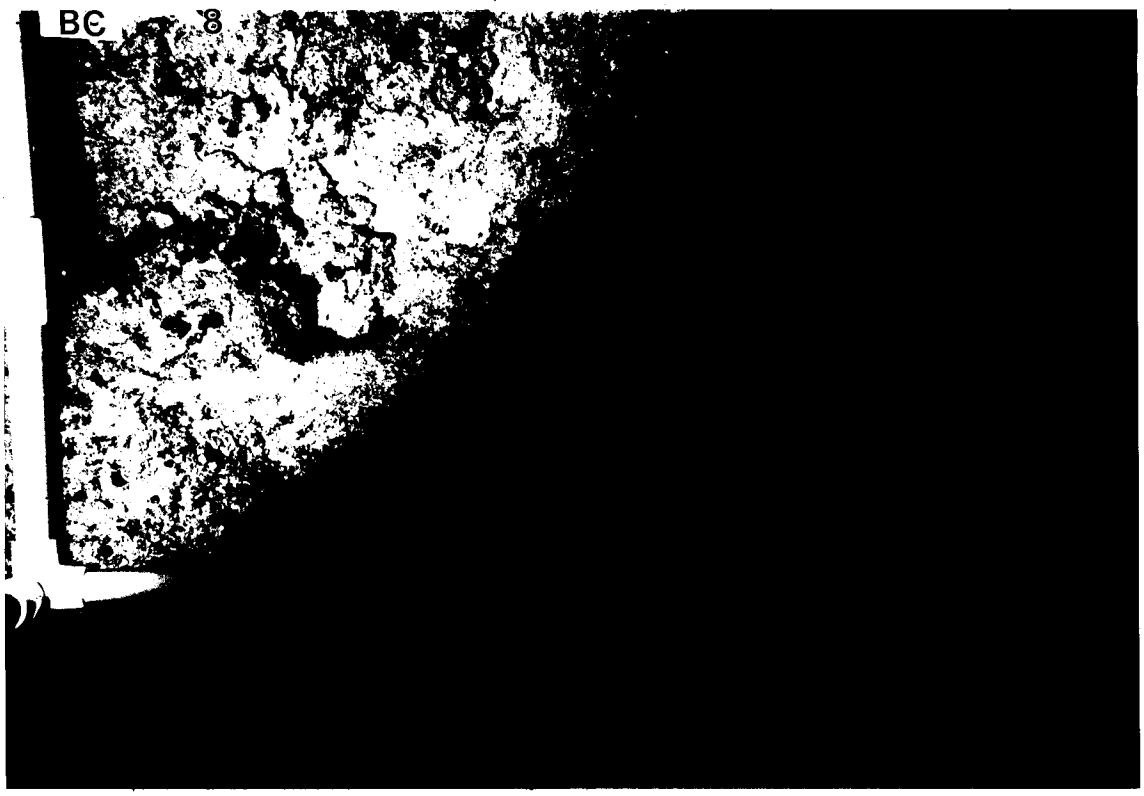

M 4


M8

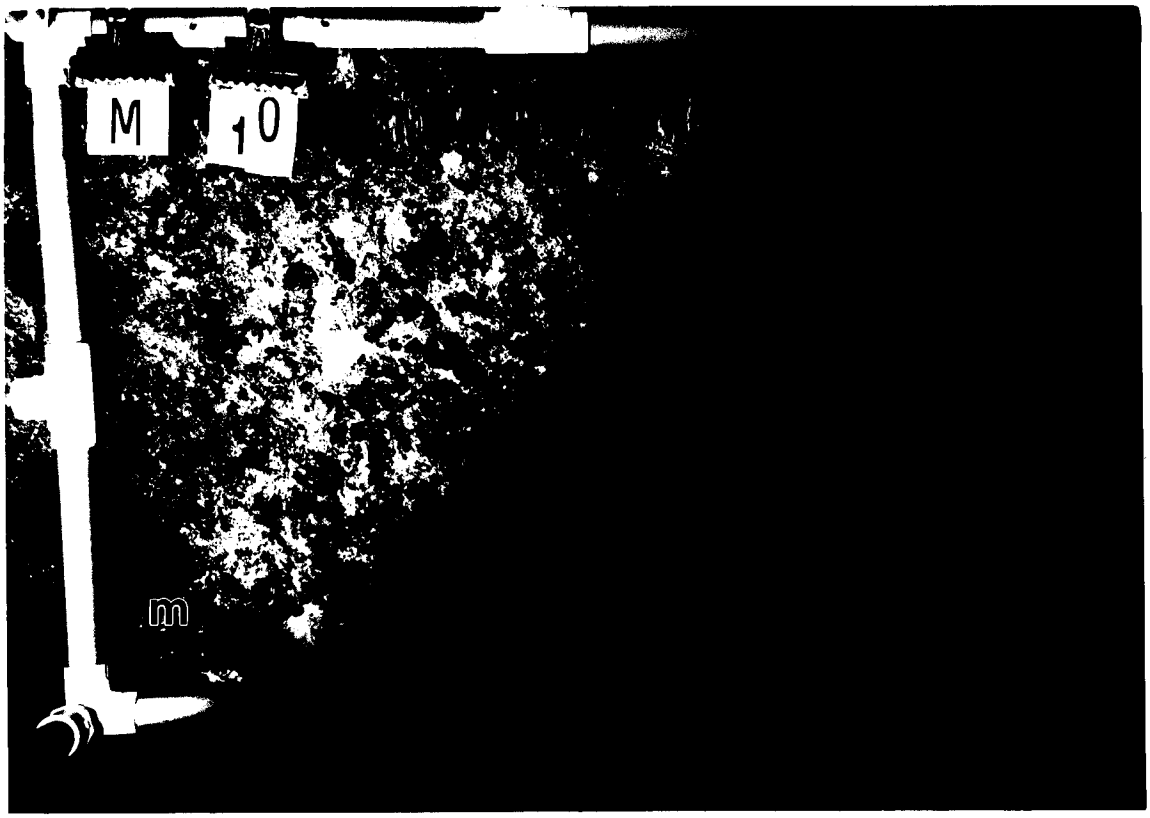

M 9

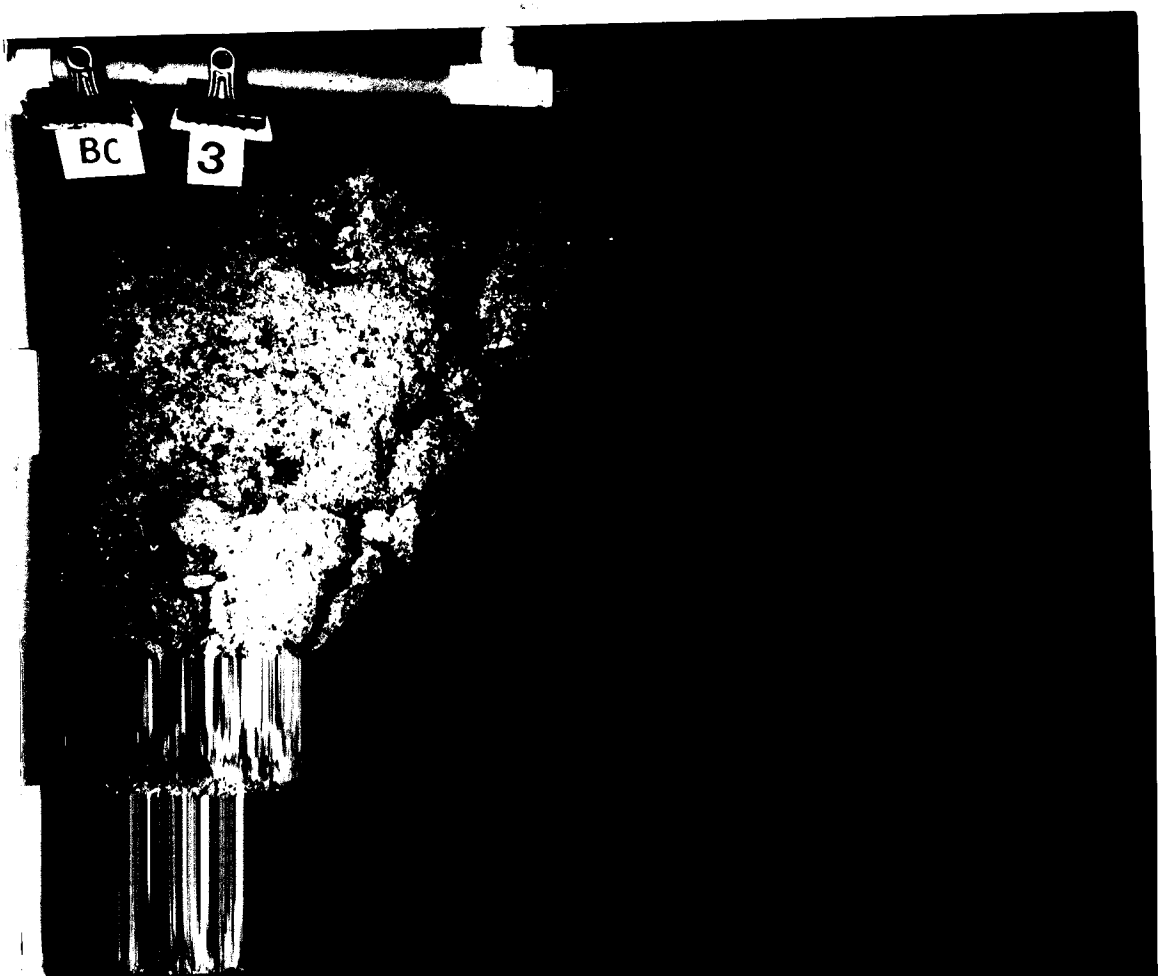

M
5
d
m


M
7
cv


BC 8


BC 14


M
10
m


BC
3


C 2 7


BC
3 0