

**SPATIAL PATTERNS OF REEF COMMUNITY STRUCTURE AND
ENVIRONMENTAL CORRELATES IN BISCAYNE
NATIONAL PARK, FLORIDA.**

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ABSTRACT

The coral reefs of Biscayne National Park, Florida, lie at the northern fringe of the Florida Reef Tract and of coral reef distribution in the western Atlantic. Environmental forcing of community structure is expected to be strong. Nine reef areas were quantitatively characterized within the Biscayne National Park and environmental factors such as temperature, sedimentation, and nutrient content in the sediment and water column were monitored to examine possible correlations with community structure patterns. Live cover, densities and diversity of scleractinian corals, octocorals, sponges, zoanthids and hydrocorals as well as cover of algae and other substrate types were quantified in 75-104, 1 m² quadrats along 4-5 transects for each of nine shallow bank and patch reefs and hard bottom communities selected along four east-west transects distributed from north to south within the Park. Benthic cover was dominated in all sites by algal turf, crustose and macro algae. Sponges were the most diverse group of macro invertebrates (66 spp. in 41 genera) followed by scleractinian corals (52 spp. in 23 genera) and octocorals (43 spp. in 11 genera). Octocorals were the most abundant group on eight of the nine localities sampled. Despite closer proximity to hypothetically detrimental terrestrial and bay influences, near-shore patch reefs had higher live cover, densities and species richness of cnidarians and sponges, a greater abundance of large scleractinian corals and of octocorals, and reduced prevalence of bare substrate and algal turf compared to latitudinally-similar offshore localities. Inshore patch reefs were more spatially variable in mean percent cover of the different bio-groups, with increases for sponges, hydrocorals and crustose algae towards the south and decreases in cover of turf algae, scleractinians and octocorals. Octocoral densities were significantly higher in all but one reef compared to other cnidarians and sponges with significantly higher densities in the patch reefs compared to the offshore sites. Decrease cover of turf algae towards the south, away from Miami, was correlated with an increase in live cover, densities and diversity of cnidarians and sponges, cover of macro-algae and bare substrate in offshore sites. Juvenile coral densities were higher in southern patch reefs and were significantly

correlated with adult densities for six common scleractinian species. Temperature regimes were more variable in the patch reefs, a pattern opposite to what would be expected to correspond to the greater coral cover in these localities. Sediment deposition rates, water column and sediment nutrient concentrations were temporally variable and provided no clear correlation with the observed spatial patterns of benthic community structure. This suggest that other factors such as historical effects of severe cold snaps, storms, disease outbreaks, coral recruitment and juvenile survival may be the dominant structuring forces limiting the abundances of large, reef-forming species in offshore sites in Biscayne National Park.

Key Words: Community structure, coral reef, environmental correlates, Florida, coral recruits.

INTRODUCTION

The global distribution of coral reefs is generally restricted to lower latitude environments with less variable temperature regimes and clear, well circulated waters with relatively low standing stocks of nutrients. Such correlational observations have formed the basis of consensus that these environmental factors are the primary delimiters of coral reef development and distribution. Despite its latitudinally marginal position just south of 26°N, the Florida reef tract is the second longest barrier reef system in the western Atlantic and is the most extensive reef development in the continental United States. Biscayne National Park (BNP) lies at the northern extreme of the Florida Reef Tract (Fig.1).

Temperature is probably the oldest-acknowledged limiting factor for reef building zooxanthellate corals and for reef development (Darwin, 1842; Dana, 1843; Mayor, 1914; Hudson et al., 1976a,b; Hudson, 1981). In Florida, there is a fairly long temperature record dating back to the late 19th century and documenting temperatures below 16°C on BNP reefs as far back as 1898 (Vaughan, 1918). More recent records have documented three episodes below 14°C and four additional episodes at or below 16°C between 1977 and 1981 in BNP and Florida Bay waters (Roberts et al., 1983; Tilmant, cited in Burns 1985). Coral mortality attributed to winter cold has been reported repeatedly from many reefs in the Florida Reef Tract and the Dry Tortugas (Porter et al. 1982, Davis 1981, Walker et al. 1982). Long lasting, high water temperatures can be equally detrimental to corals. Widespread coral bleaching events in Florida in the late 1980's due to higher than normal summer water temperatures also indicate stressful conditions for corals in this area. Even though temporary recovery was usually observed, bleached and "recovered" corals may show elevated rates of mortality in subsequent years (Porter & Meier 1992). Disease outbreaks such as the white band disease that significantly reduced population levels of acroporids in the Caribbean and the white plague infestation of 1995 which killed large numbers of several zooxanthellate corals in the Florida keys (Gladfelter, 1982, Richardson

et.al., 1998, Richardson, 1999) may play an important role in shifting coral reef community structure.

Sedimentation effects on coral reef communities are multi-faceted since reduced light levels (disrupting nutritional dynamics), abrasion, and smothering can all result in limiting coral reef development (Hubbard, 1986; Rogers, 1990; Wittenberg & Hunte, 1992). Coral reefs under sedimentation stress generally exhibit slower coral growth rates, lower coral diversity, and lesser rates of accretion (Roy & Smith, 1971; Loya, 1976; Rogers et al., 1984; Hubbard & Scatturo, 1985; Cortés & Risk, 1985). More recently, severe sedimentation has become a matter of increasing concern especially in developing areas undergoing rapid alterations in coastal land-use patterns (Hatcher et al., 1989; Rogers, 1990; Hodgson, 1993; Richmond, 1993). While periodic hurricanes are a normal feature of the environment in South Florida, there is concern that recent declines in water quality and changes in sedimentation regimens due to the urban and agricultural development may interact with storm disturbances (Ogden, 1992) and affect the recovery process for reefs affected by big storms like Andrew and Gordon which passed through Biscayne National Park in 1992 and 1994 respectively.

Though substantial reef development occurs at some sites within BNP, many areas are depauperate in coral cover and have very low relief. It is particularly interesting that the offshore, relic limestone areas with presumably better environmental conditions for reef development most of the year (warm, clear waters from the Florida current and stable substrate) show little development of physical structure (except for the Ball Buoy area in the extreme south of the Park), low diversity, and low abundances of corals compared to the inshore patch reefs. One regional factor potentially contributing to temperature and sedimentation stress on Florida reefs is the outflow of low quality water from Florida Bay. Ginsburg and Shinn (1993) discuss the inimical effect of bay water on reef distribution inferred from the distribution of Florida reefs adjacent to islands and lack of reefs where large passes between islands allow greater outflow of Florida Bay water. Stress due to

winter cold temperature has been documented as impacting the Florida reef tract via plumes emanating from Florida Bay (Walker et al., 1982). It is possible that similar limitation of reef development by outflow of Biscayne Bay water occurs in the Biscayne National Park area as suggested by Burns (1985). Offshore reefs on the other hand, may be affected by the occasional cold water counter current plume coming down from Fort Lauderdale and extending as far south as Triumph or Pacific reef sites (Ginsburg, 1956). Other factors potentially affecting BNP reefs include sediment abrasion and deposition from storms, anthropogenic effects from fishing and heavy tourism, and the extensive agricultural and urban development in South Florida (Hudson, 1981; Roberts et al., 1983; Jaap, 1984; Dustan & Halas, 1987; Glynn et al., 1989).

The goals of this study were: (1) to describe and compare the benthic community structure (including diversity, density and live cover of the major biological groups) between offshore reef sites and near-shore sites spanning the north/south extent of BNP, and (2) to characterize environmental factors such as temperature, sediment deposition, sediment composition, water column and sediment nutrient levels to examine possible correlations between the spatial patterns in benthic community structure and these environmental factors known to affect coral reef communities.

METHODS

Study Sites

Nine sites within Biscayne National Park were selected to include pairs of inshore reefs localities and offshore sites in four east-to-west transects in the northern, central, and southern regions of the Park respectively (Figure 1, Table 1). Fowey Rocks and Soldier Key in the northern region of the Park are characterized by low relief, relic Pleistocene hard-bottom substrate with scattered coral, octocoral and sponge colonies. In the north-central area, East Bache Shoals is part of the northernmost well developed,

inshore patch reef system with large scleractinian colonies and high densities of octocorals and sponges. Triumph Reef is a low relief, relic-hard-bottom, offshore site with scattered coral, octocoral and sponge colonies and high cover of turf and crustose algae. In the south-central region, three reefs were selected; Alina's Reef is a near-shore, well developed patch reef with substantial coral development on its shoreward side and high abundances of octocorals. Pacific Reef is an offshore hard-bottom site similar to Triumph, and Elkhorn Reef is an exposed, well developed patch reef positioned further offshore compared to the other patch reefs that used to have a dense population of *Acropora palmata*. At the southern edge of the Park we selected Ball Buoy Reef, a well developed, high relief, mid-shelf bank-barrier reef with abundant populations of elkhorn coral and hydrocorals and high densities of octocorals and sponges. Isa's Reef is a low relief patch reef with a highly diverse community of octocorals, sponges and scleractinians (see Table 1). The Soldier Key site is the only one located to the west of Hawk's channel (Fig. 1).

Benthic community structure

Reef benthic community structure was carefully quantified using 1 m² quadrats along four or five parallel transect lines at each site. The transects ran parallel to the substrate contour of offshore reefal areas usually in a northeast-southwest direction. In the offshore sites, the first transect was haphazardly placed at the deep side (fore-reef area) towards the east, four more, evenly spaced (20 or 25 m) transects were placed up the slope towards the west to cover most of the different habitats within each site (front reef, slope, crest, back reef, etc). In the inshore patch reefs transects ran parallel to the longer axis placed as follows: one on the eastern, wave-exposed zone, one in the back reef zone and two on the top of the reef. A 1 m² quadrat divided into 100 areas of 100 cm² each was moved at 2-4 m intervals along the transect line depending on the length of the reef. In each quadrat, detailed measurements were done of the live cover (to the closest cm²) and the density (number of colonies) of each species of scleractinian coral, octocoral and sponge. Cover of fleshy, crustose and turf algae, miscellaneous organisms, and other

substrates such as sand, bare substrate, and rubble was also measured. For scleractinian corals, juvenile and adult colonies were distinguished and counted. The criteria used was that all colonies measuring less than 1-5 cm in diameter (depending on the species) with no evidence of being reattached, asexual fragments or ramets of older colonies were considered juveniles. Data for each group was tested for normality (Bartlett's test) and homogeneity of variance. Mean percent cover and densities (col/m²) were then estimated for each reef site and significant differences between pairs of offshore and inshore sites tested with Student t-test and/or Mann-Whitney Rank Sum Test when the data failed to comply with normality and equality of variances. Percent cover data was transformed with the arcsin ($\sqrt{\text{cover}}$) function for univariate statistic analyses. ONEWAY ANOVAS were used to compare coverage and abundances of the major groups across the different reef within each of the offshore and inshore series. Recurrent communities (groupings) were explored with stepwise canonical discriminant function analysis using average data for all coverage and abundance variables each major group in each transect per locality.

Physico-chemical parameters

Temperature

Temperature was monitored more or less continually at several reef sites using Hobo-Temp temperature loggers (Onset Instruments, Pocasset, MA) anchored to the reef substrate in Ikelite clear plastic housings. The loggers were set to record approximately every 20 minutes, and were downloaded approximately monthly. It was determined that the housings provided some artifactual warming due to a "greenhouse effect" during daylight hours, so data reported are based on daily means of readings taken before 6 am and after 8 pm to avoid solar heating. Gaps in the data are due to dislodgement and loss of instruments, or instrument malfunction.

Sedimentation

We used two methods to assess sedimentation stress on BNP reefs. (1) Sediment accumulation plates (Baynes 1993) were used in short-term deployments (3 days). These devices (11 cm diameter astroturf surfaces with a rigid pvc backing) are intended to mimic benthic surfaces and provide an assessment of the sediment accumulation experienced by reef substrates. We performed five quarterly three-day deployments at each of six reefs (three inshore/offshore pairs). The plates (n=9-12 per reef) were attached even with the substrate to washers glued at fixed sites on the reef. At collection, lids with o-ring seals were carefully placed over the plates and brought back to the lab in an upside-down position. Accumulated sediments were rinsed out of the lids and astroturf and then washed through a series of sieves (1mm - .063 mm) to determine their size fractionation. Effluent from the smallest sieve was poured into 60 ml centrifuge tubes and centrifuged to concentrate the very fine sediments. Supernatant water was siphoned from these tubes and the concentrated fine sediments rinsed into pre-weighed drying dishes. All size fractions were dried to constant weight and weighed. Data presented are both total accumulation and percent of total accumulation in each size fraction for each deployment. The exception is that the size fractionation for the first deployment is not shown, since a different set of sieves (of uncomparable sizes) was used. One-way ANOVA was used to detect significant variation in total accumulation across sites. Size fraction data for each deployment was subjected to a Chi-squared test to determine if the distribution of sediments into size fractions varied by site. Individual fractions were tested to determine if there was variation over sites (n=5 deployments) by one-way ANOVA. Lastly, for each fraction, data for inshore and for offshore sites were pooled and T-tests (or Mann-Whitney rank sum tests, n=15) were used to detect significant differences in the percent of that fraction present at inshore versus offshore reef samples. (2) Sediment tube traps were used at nine sites in approximately monthly two week deployments. Sediment traps were constructed from 3 inch (~7.5 cm) diameter pvc pipe with a Nitex mesh bottom (so that water would drain out upon collection) and were of two heights: tall traps (~20cm) of the

recommended 3:1 height-diameter ratio were deployed at about .75 m above the reef; additional shorter traps (~12cm tall) were deployed as close to reef level as possible. Though these traps of different heights are not directly comparable, and even though the shorter traps may have been subject to greater loss of deposited sediments due to resuspension, they should provide a conservative measure of sediment deposition. Upon collection, traps were capped underwater and then drained through the Nitex bottom, brought back to the lab, and frozen until processing within one week. Thawed sediments were rinsed from the traps into a pre-weighed dish with de-ionized water, dried, and weighed. These dried sediments were then stored for later nutrient analysis (see below). One tall and one short trap were deployed at each of three stations in each of six pairs of offshore/inshore reef sites. There were 13 deployments of approximately two weeks duration. However, weather and other problems caused slight variation in the length of each deployment. Thus, data are expressed as deposition per day for the mean of 6 traps (3 short and 3 tall) for each deployment for each site.

Wind data (speed, maximum gust, and direction) was extracted from the record of the CMAN station at Fowey Rocks to help explain temporal variation in sedimentation rates.

Sediment nutrients

Samples collected from the sediment traps were analyzed in duplicate for total carbon and total nitrogen content on a Carlo-Erba 1108 elemental analyzer. For the initial deployment, all tall and short trap samples were analyzed and nitrogen content was generally higher in the tall trap samples. For subsequent samplings, only the samples from tall traps were analyzed, thus data presented represent means of ≤ 3 duplicated samples per date. Total phosphorus content of the sediments was determined by ashing the dried sediments in duplicate samples for at least 5 hours at 485°C, dissolving in .5N HCl, filtering out the residue, and determining the concentration of dissolved phosphate in the

resulting solution using an autoanalyzer.

Water column inorganic nutrients

Water samples were taken haphazardly, but approximately bi-weekly over the reefs in all 9 sites. Dedicated water sample bottles were rinsed 3 times with surface water before samples were taken. Samples before May, 1995 were taken from surface water and after this, the rinsed bottle was taken down on the dive and filled at the reef level. One sample was collected per site per date, transported back to the lab in a dark cooler, and frozen until analysis. Samples were then thawed and duplicates of each sample were analyzed for ammonia, nitrate+nitrite, and phosphate on a Technicon AutoAnalyzer II.

RESULTS

Benthic community structure

Algae (fleshy, turf, and crustose groups) make up a substantial biological component of all reefs sites (Table 1, Fig. 2A). Turf algae shows the highest mean percent cover of all substrate groups in all the localities studied except for Soldier. Mean percent cover was significantly higher (Mann-Whitney, $P < 0.001$) in offshore versus adjacent nearshore sites except for Ball Buoy and Isa's at the southern edge of the Park (Table 2). There was a general decrease in mean percent cover of turf algae from north to south for offshore reef sites and no clear spatial pattern for inshore localities (Fig. 2A). Fleshy macro algae was most abundant in Soldier where it covered 70 % of the substrate. Coverage showed no clear spatial pattern between offshore/inshore pairs and had a general trend to increase towards the south in the offshore localities. Cover of Crustose algae was higher in the southernmost sites (Ball Buoy and Isa's) but showed no clear spatial pattern (Fig. 2A) and no significant differences between offshore/inshore pairs in

this area (Table 2). Soldier was qualitatively and quantitatively very different from the other reef sites in species composition, mean percent cover and abundances of algae, cnidarians and sponges. It had significantly (Kruskal-Wallis, Dunn's post-hoc tests, $P < 0.001$) higher mean percent cover of fleshy algae and lower mean percent cover and mean densities (col/m²) of all cnidarian groups compared to the other reef sites towards the south.

Excluding Soldier Key, mean percent cover and mean densities of scleractinians were significantly higher (Mann-Whitney, $P < 0.001$) in all other inshore reef sites compared to their offshore pairs with the exception of Isa's s which showed no significant differences with Ball Buoy in coral mean percent cover (Fig. 2B). Mean percent cover of corals had opposite spatial trends between offshore and inshore sites in the north-south direction with offshore sites showing a trend to increase in percent cover of corals and inshore sites a trend to decrease (Fig. 2B). Octocoral cover was significantly higher (Mann-Whitney, $P < 0.001$) in inshore localities compared to their offshore pairs. Hydrocoral cover was similar in all localities (Table 2). Percent cover of octocorals and hydrocorals showed a trend to increase towards the south. Cover of zoanthids was generally low and showed no spatial pattern between pairs of localities and in the north to south direction. Sponges had significantly higher cover in all the inshore localities compared to their offshore pairs and showed a trend to increase in cover from north to south in both offshore and inshore localities (Fig. 2B).

Octocorals were significantly more abundant (K-W & Dunn's test, $P < 0.001$) than all other cnidarians and sponges in all reef sites except in Elkhorn, where scleractinians showed a higher density due to high numbers of juveniles of *Porites astreoides* and ramets of *P. porites* (Table 1, Fig. 3, appendix 1). With the exception of the north pair (Fowey-Soldier), all inshore reef sites had a significantly (Mann-Whitney, $P < 0.001$) higher octocoral density compared to their offshore counterparts with Isa's patch reef showing the highest (41 col/m², Table 1) abundance. Isa's also showed the highest abundances

(col/m²) of corals, zoanthids, and sponges. Scleractinians showed significantly higher densities of individual colonies in all inshore localities compared to offshore localities with the exception of Fowey and Soldier (Mann-Whitney $P < 0.01$) (Fig. 3). Hydrocoral densities were similar between all localities except Alina's and Elkhorn. All cnidarians showed a general trend to increase densities from north to south in both offshore and inshore localities (Fig. 3). Sponges also showed significant higher densities in all inshore sites from Bache to Isa's compared with their offshore counterparts (Mann-Whitney $P < 0.01$). A general trend towards an increase in density from the north to the south is also clear (Fig. 3).

The discriminant analysis readily separated 6 distinct groups with the first canonical function accounting for 52 % of the variance and the first three canonical functions explaining 93 % of the variation. CV1 weighted cover of macroalgae (ALG) most heavily and was strongly correlated with it. It separated Soldier, Ball Buoy, Elkhorn and the cluster of offshore localities (Triumph, Pacific, and Fowey). CV2 weighted octocoral cover (OCT) and crustose cover (CRU) most heavily and further separated Alina's and a cluster with Isa's and Bache Shoals (Fig. 4A). CV3 weighted cover of bare substrate (BARE) and density of octocorals (NOCT) more heavily and further separated Isa's from Bache shoals (Fig. 4B). Overall, 92.9 % of all original grouped cases were correctly classified by the analysis.

Fourteen species of scleractinians had more than 5% of the total coral cover in at least one reef site (Appendix 1). Of these, *Meandrina meandrites*, *Siderastrea siderea*, *Agaricia agaricites*, *Porites porites*, *P. astreoides* and *Montastraea cavernosa* were the most important species in the offshore reef sites. *M. meandrites* has a low density but is the dominant species in terms of cover in all offshore sites except Ball Buoy, where *Acropora palmata* and *M. faveolata* dominate. *A. agaricites*, *S. siderea*, *P. astreoides* and *P. porites* had the highest densities. *Montastraea faveolata* and *S. Siderea* were the dominant coral species in the inshore reef sites (with the exception of Soldier), with the

later also showing the highest densities.

Twelve species of octocorals had a percent cover higher than 5% of the total octocoral cover at any given reef site (Appendix 2). *Pseudoterogorgia americana*, *Erythropodium caribaeroum*, *Briareum asbestinum* (morphs 1 and 2) and *Gorgonia ventalina* showed the highest mean percent cover and densities in both offshore and inshore reef sites. *Pseudoterogorgia kallos* and *Plexaura homomalla* were very abundant in two offshore and two inshore reefs but overall, had lower mean cover than the other species mentioned above. Soldier was very different from the other reef sites in species composition and abundances with *Plexaurella dichotoma*, *P. nutans* and *Pterogorgia anceps* dominating this area. Isa's and East Bache had similar mean cover of octocorals but densities were significantly higher (Kruskal-Wallis, Dunn's post-hoc tests, $P < 0.001$) at Isa's reef.

Each of eighteen species of sponges had greater than 5% of the total sponge cover at any given reef site (Appendix 3). *Amphimedon compressa*, *Callispongia vaginalis*, *Niphates erecta*, *Ulosa ruetzleri* and *Petrosia weinbergi* were the dominant and most abundant species in offshore sites. *Iotrochota birotulata* and three of the dominant offshore species, *A. compressa*, *N. erecta*, and *P. weimbergi*, were also dominant in the inshore reefs. Soldier was again very different from the other reef sites in the composition of species and the dominant species were *Spheciospongia vesparium* and *Aplysina fistularis*.

Species Richness

With the exception of Soldier-Fowey, coral, octocoral and sponge diversity was higher in all the other inshore sites compared to their offshore pairs (Table 1). The number of species and genera (biological richness) of scleractinians (range from 12 to 43 spp.), octocorals (range from 23 to 41 spp.) and sponges (range from 21 to 48 spp.) tends to

increase from north to south in both inshore and offshore reefs with the higher diversity of all three groups found in Isa's patch reef in the southern edge of the Park (Table 1, appendices 4-6).. The sponges were the most diverse group at both the generic and species level (66 species in 41 genera) compared with the scleractinians (52 species in 23 genera) and the octocorals (44 species in 11 genera) (Table 1, appendices 4-6). *Madracis senaria*, a crustose-massive, dark brown or green scleractinian species is a new record for the Florida area. Within BMP this species was observed only in Pacific, however, survey dives showed it as a common species in reefs off Key Largo (Key Largo Dry Rocks and Conch reef) and coral communities off Ft. Lauderdale. *Montastraea faveolata* and *M. franksi* (Weil and Knowlton, 1994) have been traditionally pooled as the same species *M. annularis*.

Juvenile colonies

Juveniles colonies belonging to 31 species of scleractinian zooxanthellate corals were identified in the quadrats (Table 3). Juvenile densities (col/m²) increased from north to south. In the northern half of the Park, higher juvenile densities were found in offshore than in nearshore reefs while in the south, juvenile densities were higher on nearshore reefs, especially at Isa's patch reef (Table 3). *S. siderea* showed the highest abundances of juveniles in inshore localities followed by *P. astreoides*, *D. stockesii*, *M. cavernosa* and *P. porites*. In the offshore localities, *P. astreoides* had the highest densities of juveniles followed by *P. porites*, *M. cavernosa* and *A. agaricites*. With the exception of *S. Siderea*, neither one of the other species was a dominant coral in terms of cover and densities in any of the localities.

In general, juveniles colonies represented a significant proportion of the coral population in BNP (32 % of the total number of coral colonies of the species with juveniles and 26% considering all species of corals). Juveniles represented a proportionally higher component of the coral populations of offshore reefs (34% of population considering only

adult colonies of same species and 28% if we consider all the adult colonies) compared to inshore reef sites (31% of adult colonies of same species and 23% of all adult colonies) (Table 3). With the exception of *M. cavernosa*, juvenile and adult densities (col/m²) for the more common species were positively and significantly (Pearson) correlated accross reef sites (Fig. 5). Juveniles of mostly large, broadcasting species were more common in seven of the nine localities (3 of 4 inshore localities and 4 of 5 offshore localities) compared to brooding species. Overall, juveniles of 10 broadcasting vs. 6 brooding species were found in inshore sites compared to 9 broadcasting vs. 4 brooding species in the offshore localitiess (Table 3). More detailed results on juvenile dynamics and mortality is presented by Miller et.al., (Coral Reefs, in press).

Temperature

In general, the inshore patch reef sites showed higher variability and greater extremes of temperature, both cold in winter and warm in summer (Table 4, 5 and Fig. 6). This was most pronounced for Soldier Key which is closest to the Safety Valve, a large pass from Biscayne Bay between Key Biscayne and the the lower barrier islands. Means in temperature are not really useful in determining influence on corals, but rather the extremes. Table 3 shows the number of days that the nightly average temperature was below 20°C or above 30 °C (limits of stressful cold and warm temperatures for corals). Soldier Key is qualitatively distinct from all the other sites with an order of magnitude greater exposure to extreme temperatures (Table 4). The other three inshore patch reef sites (Bache East, Alina's and Isa's) also show approximately triple the exposure to extreme temperatures (mean = 3.1% of recorded days) as the outer shelf reef sites (mean = 1.0%).

SEDIMENTATION

Sediment accumulation plates

Results for total accumulation are given in Figure 7. Again, these data reveal Soldier Key to be qualitatively different from all the other sites in terms of total sediment accumulation. One-way ANOVA on total accumulation (six levels of the factor Site) shows significant variation among sites ($p < 0.0001$, $n = 5$ deployments), and post-hoc tests (SNK - $p < .05$) indicate that Soldier Key has significantly higher sedimentation than each of the other sites. The consistently high accumulation in the July 1994 deployment corresponded with the strongest gust winds of the five deployments and a high average wind speed (Fig. 7 and Table 6). The January 1995 deployment had highest average wind speed, but a lower gust, and showed typical levels of sediment accumulation.

The average distributions of size fractions for sediments accumulated at each site are given in Figure 8 for the last four deployments. For each deployment, Chi-square tests showed that the percentage distribution of sediment size fractions varied significantly from site to site ($p < .0001$ for each deployment). Also, ANOVA on each individual size fraction showed significant variation among sites, especially between inshore and offshore sites. That is, sediment accumulation at the offshore sites (especially Triumph) had greater incidence of the larger size fractions ($>1\text{mm}$ and $.25\text{-}1\text{mm}$) while the inshore sites had greater incidence of the smallest fractions ($.063\text{-}.25\text{ mm}$ and $<.063\text{mm}$).

Thus, while the total accumulation data shows substantial temporal variation, and similar levels of accumulation at all sites except Soldier Key, this accumulation is qualitatively different at inshore patch reefs versus offshore bank reefs. At the inshore sites, the sediment accumulated is consistently ^{composed of the} 60-85% composed of size fractions $<.25\text{mm}$ while the offshore sites have a significantly greater component of coarser

sediments.

Sediment traps

The most striking aspect of these data is, again, extreme temporal variability. The traps were deployed during Tropical Storm Gordon (November 1994) and this sample was up to an order of magnitude greater than those of any other deployment, but the extreme levels of deposition were predominantly at offshore reefs (Fig. 9). ~~Aside from the high deposition during Gordon (and perhaps the Dec. 94 deployment) which were associated with greatest magnitude of winds,~~ the other occasions when anomalously high depositions were recorded, at least at some sites (Sept 95, June 95, and Sept 94), were associated with more easterly wind directions whereas the rest of the deployments had a greater occurrence of southerly winds. ^{high deposition during} Based on C-MAN data from Fowey Rocks tower (Table 6A).

A one way ANOVA on ranks (normality test failed) indicated that there was significant variation in overall sediment deposition among sites ($p=.0153$, $n=13$), but the less powerful post-hoc tests did not yield any pairwise comparisons which were significant at $p < 0.05$ level. When the samples from four inshore sites and from 5 offshore sites were pooled, a Mann-Whitney test indicated the offshore sites as a group had significantly higher rates of deposition than the inshore sites ($p=.0145$, $n=51$, Elkhorn reef excluded), but this is probably attributable to the differentially high deposition at most offshore sites during the anomalous tropical storm sample (Nov. 1994). ^{"Gordon"}

Sediment nutrients

^{Inorganic or organic?} Nutrient analysis of the deposited sediments from the tall traps did show some clear spatial pattern. Total nitrogen content of these sediments was significantly higher at inshore (versus offshore) sites (one-way ANOVA $p<0.0001$ followed by SNK pairwise comparisons). Also, within the inshore sites there was a trend of decreasing nitrogen

content from north to south (Fig. 10A). Sediment phosphate levels were temporally variable and no spatial pattern was evident (Fig. 10B). Thus, N:P shows a similar spatial pattern to total N.

not clear - variability in Phosphorus not large enough to make a spatial pattern?

Water column inorganic nutrients

Table six (6) relates to wind characteristic not nutrients.

Overall, inorganic nutrient concentrations were quite variable in space and time with long term means around 0.1 μM for phosphate, 0.1-0.2 μM for ammonia, and 0.2-0.3 μM for nitrate+nitrite (Table 6). ^(A number of marked) Marked temporal spikes occurred in the time series, though the only one of identifiable origin is ^{has an} following Tropical Storm Gordon, in November 1994 (up to 1.7 μM nitrate+nitrite in a surface water sample). No clear spatial patterns were present, though nitrate+nitrite was consistently ^(although) marginally higher in overall mean ^{for} in the offshore component of each inshore/offshore pair (i.e. mean for Fowey marginally higher than Soldier, for Triumph marginally higher than Bache East, Pacific than Alinas, and Ball Buoy very marginally higher than Isa's; Table 6).

DISCUSSION

Coral reef community structure is influenced by processes occurring on different ranges of temporal and spatial scales (Jackson, 1991). Generally, some biological and environmental processes (i.e. predation, disease, bleaching) may happen rapidly on relatively small scales of space and time (Antonius, 1981; Glynn, 1990; Knowlton et al., 1990), whereas others such as hurricanes, epidemic diseases, mass mortalities and sea level change occur less frequently over larger spatial scales (Gladfelter, 1982; Porter et al., 1981; Woodley et al., 1981; Porter and Meier, 1992; Rogers, 1993). The purpose of this study was to characterize and quantify gradients in benthic community structure and in various physico-chemical factors that might help explain variations observed in reef benthic community structure along north/south and nearshore/offshore gradients in Biscayne National Park.

In general, patterns of community structure of reefs in BNP is characteristic of sub-tropical coral reefs influenced by cold spells, high nutrient input and high sedimentation. All reef communities studied were dominated by fleshy, turf and crustose algae with low cover of scleractinians, octocorals and sponges. The low cover of most zooxanthellate corals was comparable to that reported by Japp (1984), Dustan (1984), and Burns (1985) for the Florida reef tract and BNP. Though the current study was limited to a single survey at each site, it appears that cover of fleshy algae (including calcareous algae such as *Halimeda* spp.) changed throughout the year especially after storms that produced strong surge and currents which cleaned the algae's excess growth from the substrate and from coral colonies such as *M. annularis* (pers. obs.). Thus, storms, although detrimental in some aspects, may be important in the survival of coral colonies when they are heavily colonized by *Halimeda* spp or *Dictyota* spp. in reef communities.

Information about the reproductive biology and the associated processes of dispersion and recruitment is important for ecological studies of populations and communities (Harrison & Wallace, 1990). Reproductive studies in the Caribbean show that most of the large, cover-dominant reef building corals are broadcasters (Wyers, 1985; Szmant, 1986; Soong, 1990) and most of the small, highly abundant species are brooders (van Moorsel, 1983; Szmant, 1986; Chornesky and Peters, 1987; Soong, 1990). Brooding well developed phylopatric larvae many times a year is thought to increase recruitment and survival in coral species living in frequently disturbed habitats (Szmant, 1986), thus coral reefs in marginal areas are expected to be dominated by small, brooding species (Harriot & Banks, 1995). Recruitment patterns in Caribbean reefs have been characterized by low rates of settlement with a dominance of small brooding species and a marked lack of recruits of the large, broadcasting reef building species (Bak and Engel, 1979; Rogers et al., 1984; Smith, 1992; Porter & Meier, 1992). Results of the current study show that recruitment rates are significantly higher than previously reported for southern Caribbean reefs and that offshore and inshore reef systems had a higher number of broadcasting species with recruits and juveniles than brooding species. Similar evidence from other

studies (Smith, 1992; Chiappone & Sullivan, 1996; Miller et al., in press) does not support the hypothesis that recruitment limitation is a cause of the depauperateness of coral communities in certain Florida reefs and suggest that high mortality of juveniles and not low recruitment might be determinant in the development of the coral community structure in these marginal areas (Miller et. al., in press). This relatively high input of sexually produced recruits into the populations may be the result of one or two years of successful reproduction and recruitment, however. Our findings also contradict Porter and Meier (1992) report of no recruitment of broadcasting species over several years in two localities in BNP.

The diversity of zooxanthellate scleractinians and sponges compares well with more tropical coral reefs systems (i.e Puerto Rico) but are still below those observed in well developed reef areas in the southern and western Caribbean [i.e. Jamaica (Wells and Lang, 1973); Curacao (Bak, 1974); Venezuela (Weil, 1985, in press); Panama (Weil and Jackson, unpubl. data); Colombia, (Von Prael & Erhardt; 1985; Zea, 1987). A new record for the Florida area was the crustose-massive species *Madracis senaria*. In our transects, it was found only at Pacific reef at 10 m depth but we found it to be common in deeper reef areas to the south (Key Largo Dry Rocks and Conch reef) and shallow reefal areas to the north (Ft. Lauderdale). This species was believed to be endemic to Jamaica (Wells, 1973), but it has been reported or observed all over the southern (Venezuela, Bonaire, Curacao) and western (Panama) Caribbean as well as in coral reefs of the Bahamas and Puerto Rico (Bak, 1984; Weil, 1985; Weil and Jackson, unpub. data; Weil, in press). *Porites* "branneri", a small crustose species reported by Burns (1985) as common on some of the offshore localities in BNP, is a misidentification. *P. branneri* is likely to be endemic to Brazil and what has been reported for the southern Caribbean as *P. "branneri"* is probably a different taxon (Weil, 1992a, b). The colonies that Burns (1985) reports as *P. "branneri"* in BNP are blue crustose morphs of *P. porites* growing in exposed reef platforms. The blue coloration might be produced by a UV-light reflection from UV-protection pigments produced by the polyp.

is this reference necessary? It does not relate to anything or more

Low cover and small colony sizes (Miller et al., in press) of most scleractinian species in BNP (especially offshore bank reef sites) may imply that partial mortality rates are high and/or colony growth rates are low. This suggests that corals are experiencing physiological stress (e.g., ^{possibly from} decreased photosynthesis of zooxanthellae), weakened defense mechanisms to diseases, reduced sediment-cleaning efficiency and feeding capacities) due to some environmental variable(s). However, the environmental parameters hypothesized to affect coral community structure in this study (temperature, sedimentation, nutrient regime) do not coincide with expectations based on community structure. For example, while the temperature data help explain a general lack of coral cover and of significant reef development at Soldier Key, they show the opposite pattern from that which would help explain greater coral cover, diversity and reef development on the nearshore patch reefs versus the offshore reefs. That is, temperature regimes are more, not less, stressful at these nearshore sites. Similarly, the lack of discernable spatial pattern in the water column nutrient data provide no insight into possible effects on benthic community structure. Long-term means are in the ranges expected for subtropical reef areas (Szmant & Forrester, 1996). ^{what is this?}

Stress due to winter cold temperature has been documented as impacting the Florida reef tract via plumes emanating from Florida Bay (Walker et al., 1982). It is possible that similar limitation of reef development by outflow of Biscayne Bay water occurs in the Biscayne National Park area as suggested by Burns (1985). Offshore reefs on the other hand, may be affected by the occasional cold water counter current plume coming down from Fort Lauderdale and extending as far south as Triumph or Pacific reef sites (Ginsburg, 1956).

Results for sediment accumulation further confirm the uniqueness of Soldier Key among the sites examined in this study, but do not provide any further distinction along spatial gradients. While the distinctive size distributions of accumulating sediments at

inshore versus offshore sites might make sense in terms of the greater energy regimes, (offshore filtering of ~~the~~ fine sediments allowing them to accumulate inshore) it is not clear whether this result can help explain the depauperateness of coral populations at the offshore sites. That is, it is not clear whether ~~or~~ why fine sediments should be more favorable to corals than coarser sediments. It may be that the abrasive effects of larger particles in the higher energy regimes of the offshore sites are detrimental or that fine sediments (especially nitrogen-rich ones) are beneficial to corals as a food source. It should be noted that the ^{mean} chronic levels of sediment accumulation we measured at the reef sites in this study of around 1.75 to 3.5 mg/cm²/day are substantially below the threshold of 10 mg/cm²/day suggested by Rogers (1990) as representing stressful levels of sedimentation for reef corals.

The data from the sediment traps show ~~that there is~~ no clear spatial pattern in chronic sedimentation levels, even to distinguish Soldier Key. These chronic levels ranged up to about 400 mg/trap/day or 8.6 mg/cm²/day which is still below the 10 mg/cm²/day threshold proposed by Rogers (1990). However, offshore sites seem to experience greater sediment deposition during extreme storm events (and perhaps ^{why? what is the potential source?} periods of more easterly winds) and these factors may represent a source of mortality for (especially juvenile) corals. We did observe partial burial and scour of coral colonies at Triumph reef after Tropical Storm Gordon. Small colonies may be more susceptible to mortality due to sediment abrasion and/or burial during storms since most of the colony surface may be affected making the probability of recovery ~~is~~ low.

Hurricane damage to reefs can vary from severe (Rogers et al., 1982, Woodley et al., 1981) to moderate (Rogers et al., 1983; Fenner, 1991) and the degree of damage might be more of a function of the time since the previous storm (Kjerfve et al., 1986) and the length of time it ^{the storm stays} spends over the area. For example, Tropical storm Gordon was a weak storm compared to hurricane Andrew, however, it produced far more damage over the 5 days it ^{interval where it was} expended close to the Florida coast and BNP reefs than Andrew ^{did during its rapid} in its fast-

move across the area. Blair et al. (1994) found significantly more damage on deeper areas of the reefs after hurricane Andrew with significant movement of sediment across all reefs surveyed. This suggests that episodic storm events can have a significant impact on coral populations at a given site via sediment disturbance and abrasion without distinctness of long-term mean sedimentation.

[not sure what you are saying here!]

The sediment nutrient levels ~~we~~ ^{ed} report here are somewhat higher than those reported for other reefs in the Florida Keys and around the Caribbean (Szmant and Forrester, 1996 and references therein). This may be due to a different source ~~of~~ ^{for} sediments. ^{in Biscayne National Park} The other studies analyzed sediment cores from areas of accumulated sediments on the reef. The sediments analyzed in this study were deposited in sediment traps approximately 1 m above the reef surface, and likely were composed of both resuspended reef sediments as well as some portion of imported sediment, possibly of terrestrial origin. Indeed, the nitrogen gradient in these sediments may be due to relatively greater contribution by terrigenous sediments at the nearshore sites. *900 m point*

In any case, the only environmental factor examined in this study that we could determine to correspond with spatial patterns of reef community distribution in Biscayne National Park was sediment quality (size and nutrient content), though other physical factors that we did not measure (such as energy regime) are no doubt important. The best explanation ^(p. 100) may have to do with a combination of high energy sediment scour as well as biotic factors such as high grazing mortality (Miller et. al., in press) ^{which} ~~that~~ prevent small corals from growing up. The factors preventing reef development at the northern offshore sites remain somewhat enigmatic.

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Table 1. Summary table of site and biotic characteristics of nine localities sampled in Biscayne National Park, Florida.
Density is in colonies/m². Percent cover is relative cover in each reef.

REEF SITE	FOWEY	SOLDIER	TRIUMPH	EBACHE	PACIFIC	ALINA'S	ELKHORN	BBUOY	ISA'S
Latitude (N)	25° 35.38	25° 35.25	25° 28.31	25° 28.98	25° 22.18	25°23.20	25° 21.78	25°18.52	25° 19.91
Longitude (W)	80° 05.69	80° 09.18	80° 06.72	80° 08.44	80° 08.36	80°09.77	80° 09.94	80° 11.99	80°11.87
Depth (m)	3-10	3.5-4.5	3-7	1-5	2-10	2-6	1-5	2-9	2-6
Reef/site/ structure	relic-bank	relic-bank	relic-bank	patch	relic-bank	patch	patch	bank-barrier	patch
Number of transects	5	5	5	4	5	4	5	5	4
Number of quadrats	100	100	100	80	100	91	100	100	75
NUMBER OF SPECIES									
Hard Corals	28	12	24	40	30	39	29	40	43
Octocorals	28	23	32	40	29	39	34	39	41
Sponges	37	21	31	31	30	34	34	36	48
NUMBER OF GENERA									
Hard Corals	15	8	13	18	15	21	14	20	22
Octocorals	11	8	11	11	11	11	11	11	11
Sponges	25	16	21	23	19	25	23	29	35
PERCENT COVER									
Hard Corals	2.54	0.48	2.01	19.38	1.93	16.12	9.89	12.69	12.89
Octocorals	1.18	0.85	1.7	9.23	1.34	4.79	1.98	3.37	10.59
Sponges	5.04	2.34	2.22	6.43	1.02	4.34	2.39	4.85	11.82
Zoanthids	0.59	0	1.96	2.27	0.64	0.85	0.38	2.1	2.66
Hydrocorals	0.19	0.82	0.33	1.76	0.74	0.84	0.94	2.52	0.92
Fleshy Algae	12	70.32	13.07	9.25	13.81	24.87	18.62	14.77	8.36
Turf Algae	55.6	5.07	59.96	36.6	48.5	34.1	46.75	26.49	20.7
Crustose Algae	10.9	0.4	8.76	10.47	15.3	5.88	7.48	15.55	11
Sand	8.79	19.72	8.76	1.59	7.59	4.73	7.31	11.86	15.76
Bare substrate	3.17	0	1.14	3.02	9.13	3.48	4.26	5.8	5.3
DENSITY (col/sqm)									
Hard Corals	3.46	0.8	3.2	7.92	4.68	10.08	10.6	10.52	11.84
Octocorals	8.14	7.93	14.66	22.27	8.46	19.52	7.82	16.41	41.11
Sponges	5.36	3.77	3.84	8.68	3.29	8.77	4.84	8.04	21.25
Zoanthids	1.82	0	2.43	2.22	1.71	2.13	1.62	2.16	2.81
Hydrocorals	1.9	1.8	3.14	2.51	2.37	2.73	2.21	3.59	3.17

Table 2. Results of Wilks-Lambda rank tests for paired means of percent cover of the major biological groups and the abundances of Cnidarians and Sponges between paired latitudinal localities in BNP.

* Significantly different; N= non significantly different.

Localities	ALG	CRU	TURF	BARE	SCLE	OCT	HYDR	SPO	ZOA
SOLDIER - FOWEY	*	*	*	*	*	*	N	*	N
BACHE - TRIUMPH	*	*	*	N	*	*	N	*	N
ALINA'S - PACIFIC	*	*	*	*	*	*	N	*	N
ALINA'S - ELKHORN	*	N	*	N	*	*	N	*	*
ISA'S - BALL BUOY	*	N	N	*	N	*	N	*	*

Localities	NOCT	NSCL	SPON	NHYD	NZOA
SOLDIER - FOWEY	N	*	*	*	N
BACHE - TRIUMPH	*	*	*	*	N
ALINA'S - PACIFIC	*	*	*	N	N
ALINA'S - ELKHORN	*	N	*	*	*
ISA'S - BALL BUOY	*	*	*	N	*

Table 3. Summary table for juvenile/adult densities (col/m²) and reproductive patterns of the spp. in each locality sampled in BNP. ° = Hermaphrodite-broadcaster, ° = hermaphroditic brooder; ° = gonochoric broadcaster; ° = gonochoric brooder; * = mixed pattern; ° = unknown reproductive pattern and developmental mode. Total inshore and offshore numbers are the sum of juveniles and adult colonies in quadrats. P. astreoides Y and B are the two common color morphs (yellow-green and brown) and are considered as the same species. Total adult colonies and densities include all species of coral sampled in quadrats.

REEF SITES	FOWEY	SOLDIER	TRIUMPH	BACHE EAST	PACIFIC	ALINA'S	ELKHORN	BALL BUOY	ISA'S	Colonies Inshore	Colonies Offshore	Total
<i>Acropora cervicornis</i> °						.02/.11	.01/.01			2/11	1/1	3/12
<i>Acropora palmata</i> °						.02/.02				2/2	0	2/2
<i>Agaricia agaricites</i> °	.08/.62		.03/.67	.01/.20	.12/.34		.02/.28	.05/.25	.05/.09	4/82	30/516	34/598
<i>Agaricia purpurea</i> *										1/16	0	1/16
<i>Agaricia tenuifolia</i> °						.01/.19				1/17	0	1/17
<i>Colpophyllia natans</i> °					.01/.01	.01/.01			.05/.01	5/2	1/1	6/3
<i>Dichocoenia stockesii</i> °	.05/.46	.01/0	.07/.17	.04/.14	.04/.04	.05/.22		.02/.27	.24/.17	27/109	18/94	45/203
<i>Dichocoenia stellaris</i> °				.03/.01						2/11	0	2/11
<i>Diploria clivosa</i> °	.02/.10					.04/.09	.04/.28		.01/0	5/8	6/38	11/46
<i>Diploria labyrinthiformis</i> °	.04/.01				.03/.02	.03/.01		.04/.09	.03/.04	5/4	11/12	16/16
<i>Diploria strigosa</i> °					.02/.03	.04/.05	.03/.06	.02/.09	.04/.15	7/16	7/18	14/34
<i>Eusmilia fastigiata</i> °									.04/.05	2/4	0	2/4
<i>Favia fragum</i> °		.09/.11				.01/.33				10/41	0	10/41
<i>Madracis decactis</i> °					.01/.10					0	1/10	1/10
<i>Meandrina meandrites</i> °	.01/.12		.01/.08		.01/.05					0	3/25	3/25
<i>Meandrina memorialis</i> °					.01/.01					0	1/1	1/1
<i>Montastraea annularis</i> °			.01/0	.01/.14	.01/.01	.05/.26			.01/.04	7/38	2/1	9/39
<i>Montastraea cavernosa</i> °	.04/.06		.11/.12	.04/.31	.11/.01	.04/.24		.11/.50	.20/.23	22/74	37/69	59/143
<i>Montastraea faveolata</i> °	.02/.02				.01/0	.01/.38		.06/.14	.07/.28	6/46	6/16	15/62
<i>Montastraea franksi</i> °	.01/0			.03/.11	.04/.02			.01/.08	.03/.09	4/16	6/10	10/26
<i>Mycetophyllia aliciae</i> °				.01/.31					.07/.05	6/29	0	6/29
<i>Mycetophyllia danaana</i> °									.12/.20	9/15	0	9/15
<i>Mycetophyllia lamarckiana</i> °								.06/.14	.01/.04	1/3	6/14	7/17
<i>Porites astreoides</i> B °	.06/.18		.09/.12	.20/.78	.02/0	.25/.55	.03/.08	.08/.11	.48/.65	161/75	28/49	189/124
<i>Porites astreoides</i> Y °	.10/.11		.09/.10	.08/.33	.12/.12	.46/.63	1.87/3.03	.52/1.16	.23/.13	65/93	271/452	336/545
<i>Porites divaricata</i> °		.01/.04								1/4	0	1/4
<i>Porites porites</i> °	.10/.27		.10/.34	.01/.38	.23/.85	.22/.3.4	.45/3.14	.19/1.36		21/339	107/596	128/935
<i>Scolymia cubensis</i> °									.01/.33	1/25	0	1/25
<i>Siderastrea siderea</i> °	.21/.26	.31/.24	.24/.33	.26/.98	.41/.18	.20/.84	.04/.39	.21/.63	1.4/1.7	173/174	111/179	284/353
<i>Solenastrea bourmonii</i> °		.01/0							.01/.07	5/2	0	2/5
<i>Solenastrea hyades</i> °		.01/0								1/0	0	1/0
<i>Stephanocoenia intersepta</i> °	.01/.03		.02/0		.05/.03				.05/.44	4/33	8/6	12/39
Number of quadrats	100	100	100	80	100	91	100	100	75	346	500	846
Juvenile colonies	75	44	77	57	125	136	249	137	235	472	663	1135
Juvenile density (col/m ²)	0.75	0.44	0.77	0.71	1.25	1.49	2.49	1.37	3.13	1.36	1.33	1.34
Adult colonies	224	39	193	305	282	668	727	682	541	1553	2108	3661
Adult density (col/m ²)	2.24	0.39	1.93	3.81	2.82	7.34	7.27	6.82	7.21	4.49	4.22	4.33
Total adult colonies	240	49	213	553	310	781	800	904	653	2036	2467	4503
Overall adult density (col/m ²)	2.4	0.49	2.13	6.91	3.1	8.58	8	9.04	12.71	5.88	4.93	5.32
Broadcasting species	6	1	3	4	7	9	4	6	8	10	9	10
Brooding species	2	2	3	1	4	3	3	2	3	6	4	6
Mixed and unknown mode	4	3	3	6	6	3	0	3	7	12	8	15

Table 4: Tally from the temperature records for each site of the number of days with stressful temperature exposure (arbitrarily set at less than 20°C or higher than 30°C). Since each site has gaps in the temperature records due to instrument loss and malfunction, the number of days of incidence of stressful temperature is standardized to the total number of days of record for each particular reef site.

SITE	Days below 20°C	Days above 30°C	Stressful days	Total days of record	% stressful days
FOWEY	0	3	3	217	1.4
SOLDIER	19	29	48	306	15.7
TRIUMPH	0	4	4	332	1.2
BACHE E.	9	0	9	290	3.1
ALINA'S	2	6	8	287	2.8
BALL BUOY	1	0	1	271	0.4
ISA'S	5	6	11	322	3.4

Table 5. Summary table of environmental parameters measured at each site. Temperature stress indicates percent of days monitored when average temperatures were above 30 or below 20 degrees C. Sedimentation (Mean of 13 two-week deployments) in mg/cm²/day. Water column nutrient concentrations are long term means (n= 18-21) given in μ M (s.d.)

REEF SITE	FOWEY	SOLDIER	TRIUMPH	EBACHE	PACIFIC	ALINA'S	ELKHORN	BBUOY	ISA'S
Reef type	relic-bank	relic-bank	relic-bank	patch	relic-bank	patch	patch	bank-barrier	patch
Temperature stress	1.4	15.7	1.2	3.1	n.a.	2.8	n.a.	0.4	3.4
Sedimentation rate	5.4	11.2	3.7	3.3	4.7	3.7	9.3	15	1.9
WATER COLUMN									
[nitrate+nitrite]	0.25 (0.16)	0.21 (0.19)	0.31 (0.22)	0.29 (0.24)	0.43 (0.47)	0.25 (0.19)	0.35 (0.39)	0.26 (0.28)	0.26 (0.40)
[ammonium]	0.08 (0.08)	0.13 (0.16)	0.11 (0.11)	0.10 (0.14)	0.29 (0.51)	0.11 (0.07)	0.10 (0.16)	0.11 (0.13)	0.22 (0.32)
[phosphate]	0.11 (0.05)	0.08 (0.05)	0.09 (0.06)	0.10 (0.05)	0.11 (0.07)	0.09 (0.07)	0.10 (0.05)	0.10 (0.07)	0.11 (0.07)
TIN:IP	3.0	4.3	4.7	3.9	6.5	4.0	4.5	3.7	4.4

Table 6: Wind data extracted from CMAN records for Fowey Rocks Light for the duration of each sediment accumulation plate (A) and each sediment trap (B) deployment. Mean speed and gusts are given in knots, direction is given in degrees (ie. 0 to 360°).

A- Plate deployments

Date placed	Date retrieved	Mean speed	Mean max. gust	Mean direction
07/26/94	07/29/94	5.7	11.1	148
10/25/94	10/28/94	4.1	6.8	167
01/27/95	01/30/95	5.8	9.6	167
04/25/95	04/28/95	4.4	8.9	140
08/11/95	08/14/95	3.9	7	194

B- Sediment trap deployments:

Date placed	Date retrieved	Mean speed	Mean max. gust	Mean direction	Direction range
7/13/94	8/8/94	4.9	14.6	137	92-235
8/9/94	9/7/94	4.9	17.6	120	83-169
9/28-29/94	10/13-14/94	4.8	13.9	141	79-258
11/9/94	11/25/94	8.4 (Gordon)	26.0	159	43-294
14/14/94	1/3/95	6.8	23.8	202	76-316
1/20/95	2/2-8/95	6.8	20.2	250	144-311
2/16/95	3/1/95	6.8	16.5	143	86-251
3/23/95	4/5/95	6.6	13.4	166	55-245
4/28/95	5/15/95	5.1	17.7	139	84-185
5/25/95	6/9/95	6.2	15.5	136	93-200
6/27/95	7/11/95	4.1	11.5	159	59-219
8/11/95	8/28/95	5.1	19.3	183	94-236
9/20/95	10/6/95	4.9	17.4	120	81-199

Appendix 1. Scleractinian species with more than 5 % of coral cover in each reef site.
Mean cover is in cm²/m², total cover is in cm², mean density is in colonies/m².
Percent cover within the scleractinian group only.

SITE	SPECIES	Percent cover	Mean cover	Total cover	Mean density
FOWEY	<i>Meandrina meandrites</i>	19.29	3.82	4963	0.13
	<i>Dichocoenia stockesii</i>	16.79	1.2	4320	0.51
	<i>Siderastrea siderea</i>	9.98	0.76	2569	0.47
	<i>Agaricia agaricites</i>	9.86	0.67	2536	0.70
	<i>Diploria clivosa</i>	9.52	2.23	2450	0.12
	<i>Montastraea faveolata</i>	6.45	5.53	1660	0.04
	<i>Porites porites</i>	5.98	0.57	1538	0.37
	<i>Montastraea cavernosa</i>	5.44	1.56	1401	0.10
SOLDIER	<i>Diploria clivosa</i>	53.45	10.38	2075	0.02
	<i>Porites astreoides</i> Y	17.52	3.4	680	0.02
	<i>Siderastrea siderea</i>	13.99	0.18	543	0.55
	<i>Favia fragum</i>	6.88	0.27	267	0.20
TRIUMPH	<i>Meandrina meandrites</i>	30.13	6.6	5940	0.09
	<i>Siderastrea siderea</i>	16.29	0.85	3211	0.57
	<i>Agaricia agaricites</i>	14.26	0.7	2811	0.70
	<i>Dichocoenia stockesii</i>	8.78	0.75	1731	0.24
	<i>Montastraea cavernosa</i>	8.53	0.84	1682	0.23
	<i>Porites porites</i>	7.39	0.61	1456	0.44
	<i>Porites astreoides</i> Y	5.31	0.7	1047	0.19
BACHE EAST	<i>Montastraea faveolata</i>	33.58	30.66	52130	0.35
	<i>Siderastrea siderea</i>	11.41	4.03	17720	1.24
	<i>Montastraea cavernosa</i>	10.12	8.27	15710	0.35
	<i>Colpophyllia natans</i>	7.61	13.13	11820	0.13
	<i>Montastraea annularis</i>	6.88	11.87	10680	0.15
PACIFIC	<i>Meandrina meandrites</i>	19.83	6.32	3790	0.06
	<i>Agaricia agaricites</i>	18.39	0.53	3515	1.46
	<i>Porites porites</i>	15.59	0.57	2980	1.08
	<i>Siderastrea siderea</i>	12.21	0.61	2333	0.59
ALINA'S	<i>Montastraea faveolata</i>	39.25	30.07	54130	0.40
	<i>Siderastrea siderea</i>	16.07	4.52	22169	1.03
	<i>Porites porites</i>	11.94	2.26	16472	3.62
ELKHORN	<i>Porites astreoides</i> Y	28.40	3.95	27653	4.90
	<i>Porites porites</i>	24.15	2.61	23516	3.59
	<i>Siderastrea siderea</i>	14.40	4.25	14023	0.43
	<i>Acropora palmata</i>	9.86	12	9600	0.12
	<i>Diploria strigosa</i>	7.21	7.81	7025	0.09
	<i>Diploria clivosa</i>	6.69	2.33	6515	0.32
BALL BUOY	<i>Acropora palmata</i>	20.34	22.08	26490	0.41
	<i>Montastraea cavernosa</i>	10.17	3.08	13250	0.61
	<i>Siderastrea siderea</i>	10.07	2.91	13115	0.84
	<i>Porites porites</i>	9.39	2.04	12231	1.55
	<i>Porites astreoides</i> Y	8.31	2.21	10818	1.68
	<i>Agaricia agaricites</i>	7.91	1.43	10300	2.30
	<i>Colpophyllia natans</i>	5.72	24.83	7450	0.04
ISA'S	<i>Montastraea faveolata</i>	22.90	12.22	20770	0.35
	<i>Siderastrea siderea</i>	19.88	2.91	18023	3.04
	<i>Dichocoenia stockesii</i>	11.55	2.33	10472	1.41
	<i>Stephanocoenia intersepta</i>	6.84	2.3	6200	0.49

Appendix 2. Octocoral species with more than 5 % of the octocoral cover in each site studied in Biscayne National Park. Mean cover is in cm²/m², total cover is in cm², density is in colonies/m².

SITE	SPECIES	Percent cover	Mean cover	Total cover	Mean density
FOWEY	<i>Pseudoterogorgia americana</i>	35.362	0.47	4225	4.57
	<i>Erythropodium caribaeroum</i>	26.214	1.49	3132	0.75
	<i>Eunicea tourneforti</i>	10.880	0.36	1300	0.74
	<i>Briareum asbestinum 1 *</i>	10.462	0.89	1250	0.36
SOLDIER	<i>Plexaurella dichotoma</i>	35.758	0.35	2701	2.47
	<i>Pterogorgia anceps</i>	17.343	0.23	1310	1.44
	<i>Plexaurella nutans</i>	12.312	0.29	930	0.50
	<i>Pseudoterogorgia acerosa</i>	6.659	0.14	503	0.61
	<i>Eunicea palmieri</i>	6.302	0.14	476	0.85
	<i>Pseudoterogorgia americana</i>	6.262	0.21	473	0.46
TRIUMPH	<i>Pseudoterogorgia americana</i>	22.785	0.44	3868	4.69
	<i>Gorgonia ventalina</i>	20.405	0.63	3464	1.40
	<i>Erythropodium caribaeroum</i>	16.258	2.76	2760	0.32
	<i>Pseudoterogorgia acerosa</i>	15.051	0.32	2555	3.93
	<i>Pseudoterogorgia kallos</i>	6.515	0.24	1106	2.15
	<i>Briareum asbestinum 1</i>	5.067	0.72	860.1	0.15
BACHE EAST	<i>Erythropodium caribaeroum</i>	33.301	5.02	24620	1.41
	<i>Briareum asbestinum 1</i>	32.516	3.76	24040	5.35
	<i>Plexaura homomalla</i>	5.674	0.63	4195	2.93
	<i>Pseudoplexaura porosa</i>	5.394	0.74	3988	1.80
PACIFIC	<i>Gorgonia ventalina</i>	37.595	2	5001	0.82
	<i>Erythropodium caribaeroum</i>	26.913	2.24	3580	0.31
	<i>Pseudoterogorgia americana</i>	21.418	0.32	2849	5.26
ALINA'S	<i>Erythropodium caribaeroum</i>	29.277	2.47	12580	1.49
	<i>Briareum asbestinum 1</i>	12.197	0.92	5241	1.99
	<i>Pseudoterogorgia americana</i>	8.986	0.56	3861	3.73
	<i>Gorgonia ventalina</i>	8.429	0.66	3622	1.53
	<i>Briareum asbestinum 2</i>	8.308	1.98	3570	0.38
	<i>Plexaura homomalla</i>	5.848	0.42	2513	2.38
ELKHORN	<i>Gorgonia ventalina</i>	22.642	0.97	4458	1.31
	<i>Erythropodium caribaeroum</i>	16.811	3.68	3310	0.25
	<i>Pseudoterogorgia americana</i>	12.814	0.4	2523	2.06
	<i>Briareum asbestinum 1</i>	12.647	2.26	2490	0.35
	<i>Plexaura homomalla</i>	9.244	0.42	1820	0.93
BALL BUOY	<i>Erythropodium caribaeroum</i>	30.120	3.48	10425	0.65
	<i>Gorgonia ventalina</i>	17.341	0.88	6002	2.10
	<i>Pseudoterogorgia americana</i>	12.995	0.62	4498	4.23
	<i>Briareum asbestinum 1</i>	11.600	1.54	4015	0.76
	<i>Pseudoterogorgia kallos</i>	6.584	0.38	2279	3.91
ISA'S	<i>Erythropodium caribaeroum</i>	36.429	4.73	28375	2.83
	<i>Briareum asbestinum 1</i>	9.520	1.45	7415	3.01
	<i>Pseudoterogorgia americana</i>	8.100	0.9	6309	7.04
	<i>Plexaura homomalla</i>	6.061	0.7	4721	4.43
	<i>Briareum asbestinum 2</i>	5.639	1.76	4392	0.56
	<i>Pseudoplexaura porosa</i>	5.171	0.62	4028	2.80

* The erect form of the species complex.

Appendix 3. Sponge species with more than 5% of the total cover of sponges in each site studied in Biscayne National Park. Mean cover is in cm²/m², total cover is in cm², density is in colonies/m².

REEF	SPECIES	Percent cover	Mean cover	Total cover	Mean density
FOWEY	<i>Callyspongia vaginalis</i>	23.69	6.73	121.16	0.24
	<i>Niphates digitalis</i>	19.52	5.55	99.85	0.20
	<i>Amphimedon compressa</i>	12.48	2.37	63.86	0.80
	<i>Aplysina fistularis</i>	8.57	1.02	43.82	1.33
	<i>Niphates erecta</i>	7.65	1.19	39.15	0.60
	<i>Cliona spp.</i>	6.46	1.94	33.02	0.27
	<i>Xetosporgia muta</i>	5.10	8.7	26.1	0.06
SOLDIER	<i>Spheciospongia vesparium</i>	57.41	3.38	128.35	0.78
	<i>Aplysina fistularis</i>	14.37	0.76	32.12	0.91
	<i>Aplysina fulva</i>	8.27	0.84	18.49	0.60
	<i>Ircina felix</i>	7.96	1.11	17.8	0.30
TRIUMPH	<i>Callyspongia vaginalis</i>	22.66	1.95	50.6	0.33
	<i>Agelas wiedenmyeri</i>	15.96	1.98	35.64	0.37
	<i>Ulosa ruetzleri</i>	10.18	0.45	22.74	0.93
	<i>Amphimedon compressa</i>	10.12	1.61	22.6	0.35
	<i>Ircina strobilina</i>	6.81	1.52	15.2	0.18
	<i>Niphates erecta</i>	6.72	1	15	0.19
	<i>Petrosia weinbergi</i>	0.76	0.57	1.7	0.03
BACHE EAST	<i>Petrosia weinbergi</i>	30.71	2.31	133.7	2.23
	<i>Amphimedon compressa</i>	18.31	1.99	79.7	1.74
	<i>Iotrochota birotulata</i>	10.98	2.39	47.8	0.71
	<i>Ulosa ruetzleri</i>	6.91	1.11	30.1	0.93
	<i>Niphates erecta</i>	6.34	1.2	27.6	0.83
PACIFIC	<i>Ulosa ruetzleri</i>	17.06	0.34	17.24	0.91
	<i>Niphates erecta</i>	15.74	0.76	15.9	0.38
	<i>Amphimedon compressa</i>	12.57	1.59	12.7	0.11
	<i>Cliona aprica</i>	12.27	1.38	12.4	0.09
	<i>Niphates digitalis</i>	6.63	0.39	6.7	0.21
	<i>Callyspongia vaginalis</i>	5.74	1.45	5.8	0.04
ALINA'S	<i>Amphimedon compressa</i>	31.36	1.91	124.1	3.21
	<i>Petrosia weinbergi</i>	21.49	1.52	85.05	1.44
	<i>Niphates erecta</i>	7.50	0.99	29.7	0.71
	<i>Ircina felix</i>	7.48	1.97	29.6	0.25
	<i>Iotrochota birotulata</i>	5.69	0.9	22.5	0.37
ELKHORN	<i>Amphimedon compressa</i>	36.16	1.65	82.75	1.44
	<i>Ircina felix</i>	11.97	1.52	27.4	0.20
	<i>Petrosia weinbergi</i>	8.00	1.08	18.3	0.23
BALL BUOY	<i>Niphates erecta</i>	12.49	1.48	62.35	1.58
	<i>Amphimedon compressa</i>	11.96	1.87	59.7	1.07
	<i>Ircina felix</i>	10.67	1.33	53.3	0.54
	<i>Iotrochota birotulata</i>	8.19	1.57	40.9	0.53
	<i>Ircina strobilina</i>	5.77	1.69	28.8	0.19
	<i>Callyspongia vaginalis</i>	5.72	1.1	28.55	0.33
	<i>Ectyoplasia ferox</i>	5.37	2.23	26.8	0.26
	<i>Verongula rigida</i>	0.10	0.5	0.5	0.01
ISA'S	<i>Amphimedon compressa</i>	16.17	2.28	143.5	3.91
	<i>Niphates erecta</i>	13.64	1.86	121.1	4.60
	<i>Iotrochota birotulata</i>	11.90	1.92	105.6	2.68
	<i>Ircina strobilina</i>	8.39	2.26	74.5	0.59
	<i>Petrosia weinbergi</i>	6.58	1.95	58.4	0.61
	<i>Callyspongia vaginalis</i>	5.97	1.77	53	0.47
	<i>Aplysina caulliformis</i>	5.08	0.94	45.11	2.71

Appendix 4: List of scleractinian and hydrocoral species observed in 9 sites of Biscayne National Park, Florida. ¹ = Offshore sites, ² = Inshore sites. Sites ordered in a north-south direction from left to right.

GENUS	SPP / REEF	Fowey ¹	Soldier ²	Triumph ¹	EBache ²	Pacific ¹	Alina's ²	Elkhorn ¹	Ball Buoy ¹	Isa's ²
<i>Stephanocoenia</i>	<i>S.intersepta</i>	1	1	1	1	1	1	1	1	1
<i>Madracis</i>	<i>M.decaetis</i>	1		1	1	1	1	1	1	1
	<i>M.senaria</i> [*]					1				
	<i>M.pharensis</i> L ^{**}	1			1	1	1		1	
<i>Acropora</i>	<i>A.palmata</i>	1					1	1	1	
	<i>A.cervicornis</i>				1		1	1	1	1
<i>Agaricia</i>	<i>A.agaricites</i>	1		1	1	1	1	1	1	1
	<i>A.humilis</i>	1		1	1			1	1	1
	<i>A.purpurea</i>	1		1	1	1	1	1	1	1
	<i>A.danae</i>						1	1	1	1
	<i>A.carinata</i>				1				1	
	<i>A.tenuifolia</i>				1		1	1	1	1
	<i>A.fragilis</i>			1	1	1				
<i>Leptoseris</i>	<i>L.cucullata</i>	1		1	1	1	1		1	1
<i>Siderastrea</i>	<i>S.siderea</i>	1	1	1	1	1	1	1	1	1
	<i>S.radians</i>	1	1	1	1	1	1	1	1	1
<i>Porites</i>	<i>P.porites</i>	1	1	1	1	1	1	1	1	1
	<i>P.furcata</i>					1		1		1
	<i>P.divaricata</i>		1							
	<i>P.astreoides</i>	1	1	1	1	1	1	1	1	1
<i>Favia</i>	<i>F.fragum</i>	1	1	1	1	1	1	1	1	1
<i>Diploria</i>	<i>D.strigosa</i>	1		1	1	1	1	1	1	1
	<i>D.clivosa</i>	1	1	1	1	1	1	1	1	1
	<i>D.labyrinthiformis</i>	1		1	1	1	1	1	1	1
	<i>D.clivosa</i> sp.	1				1	1			
<i>Colpophyllia</i>	<i>C.natans</i>				1	1	1	1	1	1
<i>Manicina</i>	<i>M.aerolata</i>				1					1
	<i>M.mayori</i>						1		1	1
<i>Montastraea</i>	<i>M.annularis</i>			1	1	1	1	1	1	1
	<i>M.faveolata</i>	1		1	1	1	1	1	1	1
	<i>M.franksi</i>	1		1	1	1	1		1	1
	<i>M.cavernosa</i> 1	1		1	1	1	1	1	1	1
	<i>M.cavernosa</i> 2 ^{***}	1			1	1	1	1	1	1
<i>Solenastrea</i>	<i>S.bournoni</i>	1	1	1	1	1	1		1	1
	<i>S.hyades</i>	1	1							1
<i>Meandrina</i>	<i>M.meandrites</i>	1		1	1	1	1	1	1	1
	<i>M.memoralis</i> ^{****}	1		1	1	1			1	1
<i>Dichocoenia</i>	<i>D.stokesii</i>	1	1	1	1	1	1	1	1	1
	<i>D.stellaris</i>				1	1	1	1	1	1
<i>Eusmilia</i>	<i>E.fastigiata</i>	1		1	1	1	1		1	1
<i>Mycetophyllia</i>	<i>M.aliciae</i>				1	1	1	1	1	1
	<i>M.lamarckiana</i>				1		1		1	1
	<i>M.danaana</i>				1		1	1	1	1
	<i>M.ferox</i>				1		1		1	1
	<i>M.reesi</i>				1					
<i>Mussa</i>	<i>M.angulosa</i>						1			1
<i>Scolymia</i>	<i>S.cubensis</i>				1		1		1	1
<i>Isophyllastrea</i>	<i>I.rigida</i>							1	1	
<i>Isophyllia</i>	<i>I.sinuosa</i>	1			1	1				1
<i>Oculina</i>	<i>O.diffusa</i>				1		1		1	1
	<i>O.varicosa</i>									1
<i>Cladocora</i>	<i>C.arbuscula</i>		1				1			1
<i>Millepora</i>	<i>M.alcicornis</i>	1	1	1	1	1	1	1	1	1
	<i>M.complanata</i>	1		1	1	1	1	1	1	1
Number of species	52	28	12	24	40	30	39	29	40	43
Number of genera	23	15	8	13	18	15	21	14	20	22
Hydrozoans	2	2	1	2	2	2	2	2	2	2

* = New report for the Florida area; ** = forma luciphogous; *** = form with large, less integrated calices;

**** = form with wide colines and thick septa.

Appendix 5: List of octocoral species observed in 9 reefal sites of Biscayne National Park, Florida. ¹ = Offshore sites; ² = inshore sites. Sites oriented in a north-south gradient from left to right.

GENUS	SITE SPECIES	Fowey ¹	Soldier ²	Triumph ¹	EBache ²	Pacific ¹	Alina's ²	Elkhorn ¹	Ball Buoy ¹	Isa's ²
<i>Briaerum</i>	<i>B.asbestinum</i> 1 *	1	1	1	1	1	1	1	1	1
	<i>B.asbestinum</i> 2 **	1		1	1	1	1	1	1	1
<i>Erythropodium</i>	<i>E.caribaeorum</i>	1		1	1	1	1	1	1	1
<i>Eunicea</i>	<i>E.laxispica</i>	1				1	1		1	1
	<i>E.succinea</i> S	1	1	1	1	1	1	1	1	1
	<i>E.succinea</i> P ***	1	1	1	1	1	1	1	1	1
	<i>E.lascinata</i>			1	1	1	1	1	1	1
	<i>E.asperula</i>				1		1	1	1	1
	<i>E.fusca</i>	1	1	1	1	1	1	1	1	1
	<i>E.mammosa</i>	1		1	1		1	1	1	1
	<i>E.laxa</i>									1
	<i>E.clavigera</i>		1		1		1	1	1	1
	<i>E.tourneforti</i> 1	1	1	1	1	1	1	1	1	1
	<i>E.tourneforti</i> 2 ****	1		1						1
	<i>E.calyculata</i>	1		1	1	1	1	1		1
	<i>E.palmieri</i>	1	1	1	1	1	1	1	1	1
	<i>E.knighty</i>				1	1	1		1	1
	<i>E. sp</i>		1		1	1	1	1	1	1
<i>Gorgonia</i>	<i>G.ventalina</i>	1		1	1	1	1	1	1	1
	<i>G.flabellum</i>	1		1	1		1	1	1	
	<i>G.mariae</i>	1		1	1	1	1	1	1	1
<i>Iciligorgia</i>	<i>I.schrammi</i>	1		1	1		1	1	1	1
<i>Muricea</i>	<i>M.muricata</i>	1	1	1	1	1	1	1	1	1
	<i>M.laxa</i>			1	1	1	1		1	1
	<i>M.elongata</i>				1		1	1	1	1
	<i>M.flavida</i>	1	1	1	1	1	1	1	1	1
	<i>P.homomalla</i>	1	1	1	1	1	1	1	1	1
<i>Plexaura</i>	<i>P.flexuosa</i>	1	1	1	1	1	1	1	1	1
	<i>P.kuna</i>		1	1	1	1	1	1	1	1
	<i>P.dichotoma</i>	1	1	1	1	1	1	1	1	1
<i>Plexaurella</i>	<i>P.grisea</i>				1		1		1	1
	<i>P.nutans</i>		1	1	1		1	1	1	1
	<i>P.flagellosa</i>	1	1		1	1	1	1	1	1
<i>Pseudoplexaura</i>	<i>P.porosa</i>	1	1	1	1	1	1	1	1	1
	<i>P.crucis</i>				1		1	1	1	1
	<i>P.wagenaari</i>		1	1	1		1	1	1	1
	<i>P.americana</i>	1	1	1	1	1	1	1	1	1
	<i>P.kallos</i>	1		1	1	1	1	1	1	1
<i>Pseudotergorgia</i>	<i>P.acerosa</i>	1	1	1	1	1	1	1	1	1
	<i>P.bipinnata</i>			1	1	1				
	<i>P. sp</i>				1			1	1	1
	<i>P.citrina</i>	1	1	1		1	1	1	1	1
	<i>P.anceps</i>	1	1		1					1
<i>Pterogorgia</i>	<i>P.guadalupensis</i>		1	1	1	1	1		1	
Number of species		44	28	23	32	40	29	39	34	39
Number of genera		11	11	8	11	11	11	11	11	11

*= *B. asbestinum*1 = is the crustose form; ** = *B. asbestinum*2 = is the erect form; *** = *E. succinea*P = forma plantaginea; **** = *E. tourneforti*2 = is forma atra.

Appendix 6 : List of species of Porifera observed in 9 reefs of Biscayne National Park, Florida. ¹ = Offshore sites; ² = Inshore sites. Sites oriented in a north-south gradient from left to right.

GENUS	SPP / REEF	Fowey ¹	Soldier ²	Triumph ¹	EBache ²	Pacific ¹	Alina's ²	Elkhorn ¹	Ball Buoy ¹	Isa's ²
<i>Amphimedon</i>	<i>A.compressa</i>	1		1	1	1	1	1	1	1
	<i>A.erina</i>			1						
<i>Anthosigmella</i>	<i>A.varians</i>	1		1		1			1	1
<i>Aplysina</i>	<i>A.fulva</i>	1	1		1		1	1		1
	<i>A.fistularis</i>	1	1		1		1	1	1	1
	<i>A.cauliformis</i>	1	1	1	1	1	1	1	1	1
	<i>A.archeri</i>	1								
<i>Agelas</i>	<i>A.conifera</i>		1	1		1		1		
	<i>A.wiedenmyeri</i>			1	1	1	1	1		
	<i>A.clathrodes</i>			1		1				
	<i>A.dispar</i>			1				1		
<i>Calix</i>	<i>C.podatypa</i>		1	1			1		1	1
<i>Callyspongia</i>	<i>C.vaginalis</i>	1	1	1		1	1	1	1	1
	<i>C.vaginalis2*</i>	1	1			1	1	1	1	1
	<i>C.plicifera</i>	1				1		1	1	1
	<i>C.armigera</i>	1								1
<i>Clathria</i>	<i>C. sp</i>			1	1				1	
<i>Cliona</i>	<i>C. sp</i>	1		1	1	1	1	1	1	1
	<i>C.aprica</i>			1		1	1	1		1
	<i>C.delitrix</i>	1			1					
	<i>C.lampa</i>	1		1	1	1	1			
	<i>C.langae</i>	1								
	<i>C.vasculum</i>								1	1
<i>Cribochalina</i>	<i>C. sp</i>				1					1
<i>Cynachira</i>	<i>D.anchorata</i>	1						1	1	1
<i>Desmapsamma</i>	<i>D.megastellata</i>				1	1	1		1	
<i>Diplastrella</i>	<i>Diplastrella sp.</i>	1		1	1			1	1	1
<i>Dysidea</i>	<i>D.janiae</i>									1
	<i>D.etheria</i>	1	1	1					1	
<i>Ectyoplasia</i>	<i>E.ferox</i>	1	1	1	1	1	1	1	1	1
<i>Geodia</i>	<i>G.neptuni</i>									1
<i>Halisarca</i>	<i>H. sp</i>									1
<i>Holpsamma</i>	<i>H.intestinalis</i>							1		1
	<i>H.helwigi</i>	1	1		1	1	1	1	1	1
<i>Hyrtios</i>	<i>H.proteous</i>					1		1	1	1
<i>Iotrochota</i>	<i>I.biotulata</i>	1	1	1	1	1	1	1	1	1
<i>Ircina</i>	<i>I.felix</i>	1	1	1	1	1	1	1	1	1
	<i>I.strobilina</i>	1	1	1	1	1	1	1	1	1
	<i>I.campana</i>			1		1				
<i>Monachora</i>	<i>M.unguifera</i>	1		1	1	1	1	1	1	1
	<i>M.barbadensis</i>			1	1	1	1	1	1	1
<i>Mycale</i>	<i>M.laevis</i>				1	1	1		1	1
<i>Neofibularia</i>	<i>N.nolitangere</i>	1					1	1	1	1
<i>Niphates</i>	<i>N.alba</i>						1			1
	<i>N.erecta</i>	1	1	1	1	1	1	1	1	1
	<i>N.digitalis</i>	1	1	1	1	1	1		1	1
<i>Oceanapia</i>	<i>O.bartsi</i>						1			
<i>Pellina</i>	<i>P.carbonaria</i>		1						1	1
<i>Petrosia</i>	<i>P.weinbergi</i>	1		1	1	1	1	1	1	1
<i>Phorbas</i>	<i>P.amaranthus</i>	1	1	1	1	1	1	1	1	1
<i>Plesiastrea</i>	<i>P. sp</i>									1
<i>Pseudaxinella</i>	<i>P.luneacarta</i>	1			1		1	1	1	1
<i>Pseudoceratina</i>	<i>P.crassa</i>	1					1	1	1	1

Appendix 6 con List of species of Porifera observed in 9 reefs of Biscayne National Park, Florida. ¹ = Offshore sites; ² = Inshore sites. Sites oriented in a north-south gradient from left to right.

GENUS	SPP / REEF	Fowey ¹	Soldier ²	Triumph ¹	EBache ²	Pacific ¹	Alina's ²	Elkhorn ¹	Ball Buoy ¹	Isa's ²
<i>Siphonodictyon</i>	<i>S.coralliphagum</i>							1		
<i>Spheciospongia</i>	<i>S.vesparium</i>	1	1		1					1
<i>Spirastella</i>	<i>S.coccinea</i>									1
<i>Spongia</i>	<i>S.obtusa</i>	1	1	1	1	1	1	1	1	1
	<i>S.pertusa</i>						1	1		1
<i>Strongylacidon</i>	<i>S. sp</i>				1			1	1	1
<i>Tedania</i>	<i>T.ignis</i>		1		1		1			1
<i>Tethya</i>	<i>T.crypta</i>	1								
<i>Ulosa</i>	<i>U.ruetzleri</i>	1	1	1	1	1	1	1	1	1
<i>Verongula</i>	<i>V.gigantea</i>									1
	<i>V.rigida</i>	1		1	1	1	1	1	1	1
<i>Xetospongia</i>	<i>X.muta</i>	1		1						
	<i>X.proxima</i>	1								
# of species	66	37	21	31	31	30	34	34	36	48
# of genera	41	25	16	21	23	19	25	23	29	35

*= dark gray, rope sponge with spine-like protrusions

LIST OF FIGURES

Figure 1. Map of Biscayne National Park showing study localities.

Figure 2. Spatial variability for mean percent cover (%) of the (A) different algal groups and bare substrate and (B) cnidarians groups and sponges. Bare substrate includes sand, substrate with no live cover and rubble. Localities are distributed in offshore-inshore pairs in a north-south direction. Different letters on error lines indicate significant differences (Mann-Whitney Rank Test) in percent cover of the particular group between offshore-inshore locality pairs.

Figure 3. Spatial variation in colony densities for cnidarian groups and sponges. Different letters indicate significant differences (Mann-Whitney Rank Test) in density (col/m^2) of the different groups between offshore-inshore locality pairs.

Figure 4. Classification of the different localities (communities) based on the first two discriminant functions (A) and the first and third discriminant functions (B) using transect averages for coverage of main groups and densities of cnidarians and sponges. CV1 was most heavily weighted by macroalgal cover, CV2 was most heavily weighted by octocoral coverage and CV3 was most heavily weighted by bare substrate and octocoral densities. Filled symbols are inshore localities. Hexagons with sign are the centroid for the cluster of each locality.

Figure 5. Relationship between juvenile and adult densities (col/m^2) of the most common scleractinian species with juveniles colonies in the localities sampled. *P. astreoides* includes both the brown morph (squares) and the yellow morph (triangles). There was no significant correlation between juveniles and adults in *M. cavernosa*.

Figure 6. Temperature records obtained using Hobo-Temp loggers for six sites in BNP. Values represent means of all measurements recorded (every 24 minutes) between 8pm and 6am of each day. Panels depict records for inshore/offshore reef pairs in the A) northern, B) central, and C) southern region of the Park. Periods of missing data were due to loss of malfunction of instruments.

Figure 7. Mean ($\pm 1\text{SD}$) sediment accumulation observed during each three day sediment accumulation plate deployment at three offshore (A) and inshore (B) pairs of reef sites from north to south within BNP. Sites with the same hatching in the two panels have similar latitudinal position. n = number of plates per deployment per site.

Figure 8. Grain size distribution of sediments collected with the sediment accumulation plates during the last four deployments (which utilized comparable sieve sizes). The various size fractions are shown as percent of total sediment dry mass. n = 9-12 samples per deployment per site.

Figure 9. Sediment deposition collected in sediment tube traps at nine sites. Each

value is the mean (± 1 SD) of three short and three tall traps (see text). Results of eleven deployments are depicted in the upper panel, and those of two deployments during winter 1994 (following Tropical Storm Gordon) are plotted in the lower panel on a larger scale.

Figure 10. Box plots summarizing water column nutrient data for each site. Upper panel, ortho-phosphate; middle panel, nitrate+ nitrite; lower panel, ammonium. The darker horizontal bar within each box is the mean and the lighter bar the median. Upper and lower limits of each box indicate the 25th to 75th percentiles, and the error bars indicate the 5th and 95th percentiles. Circles represent maximum and minimum values for each site.

Fig 1

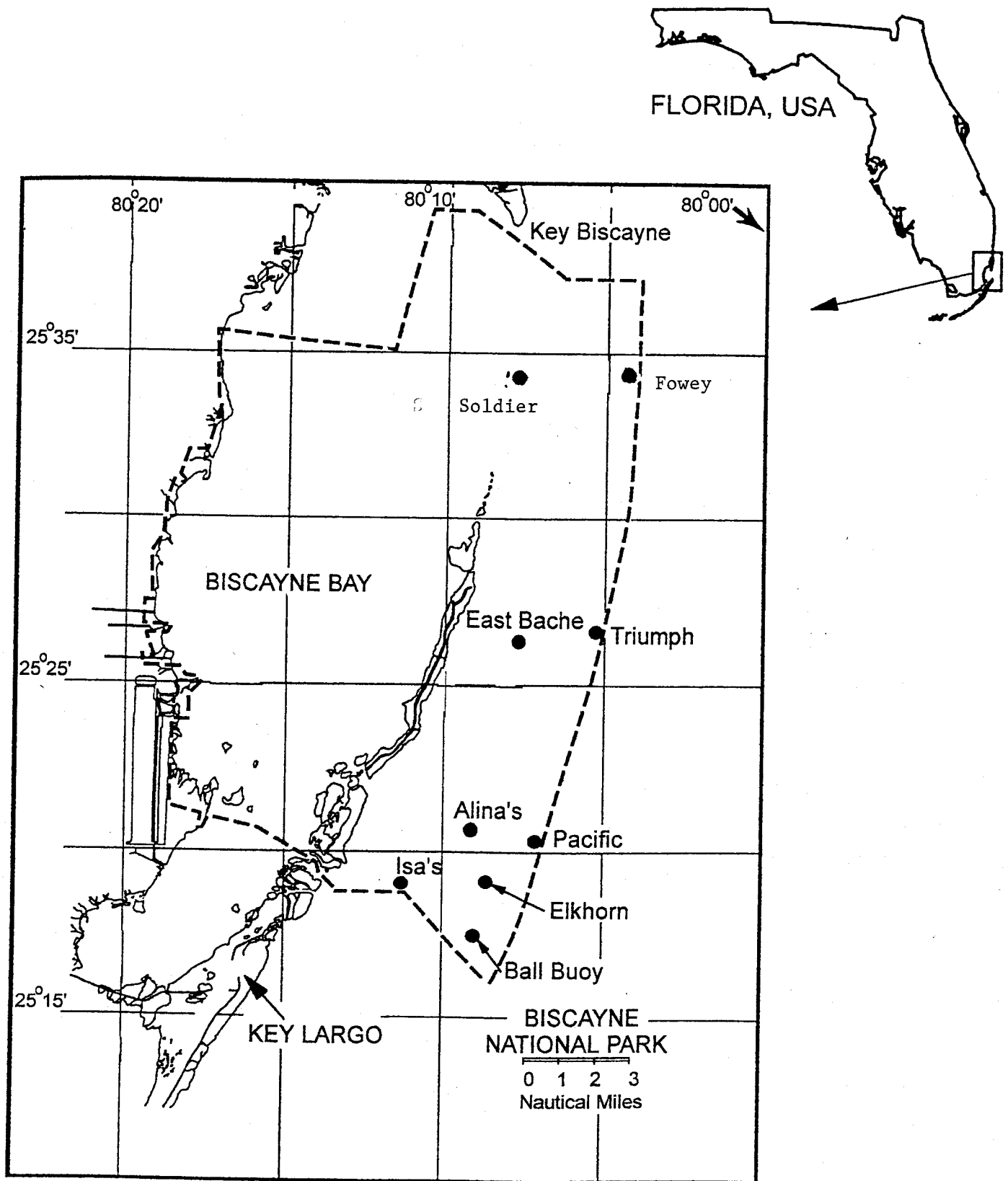


Fig. 2

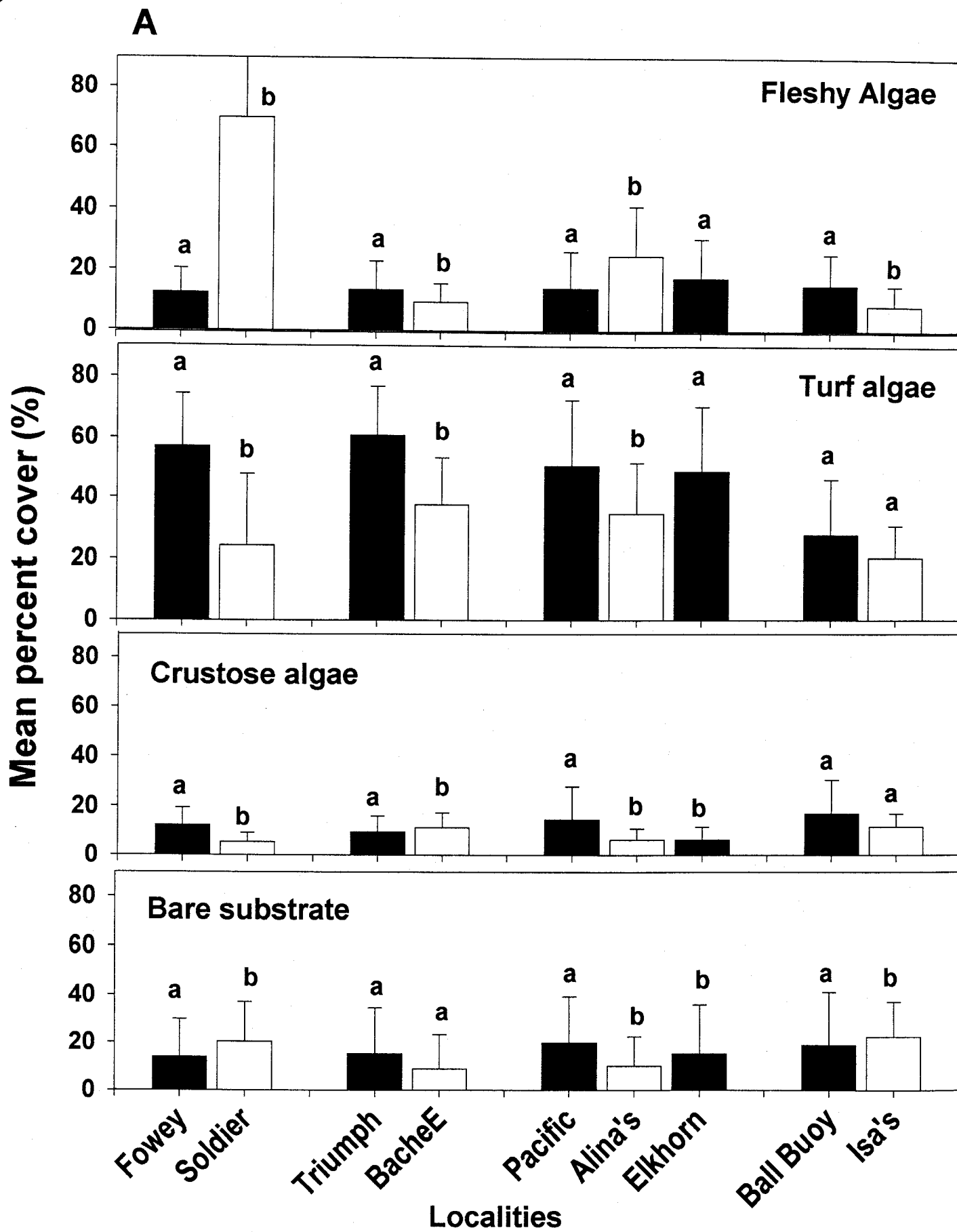
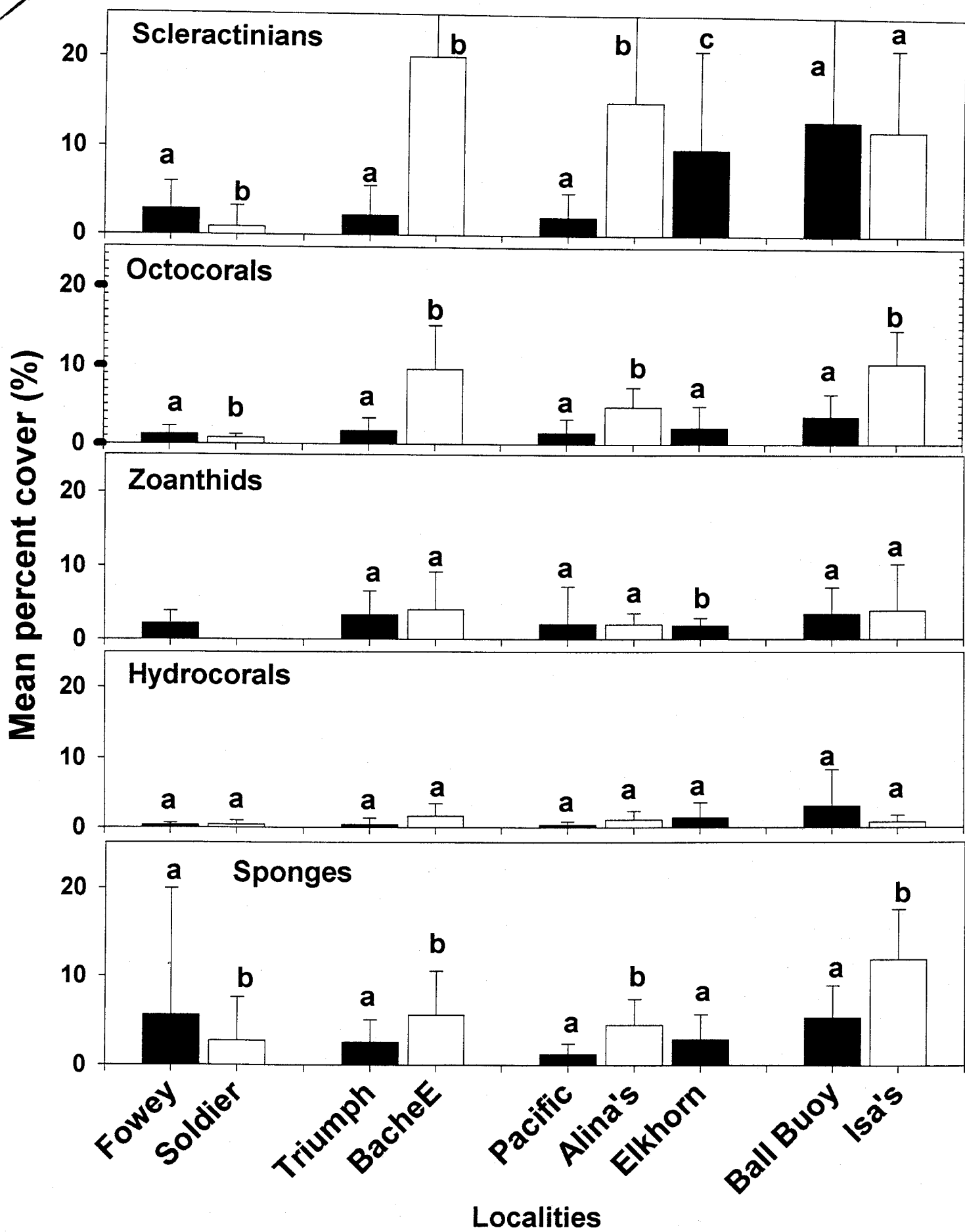


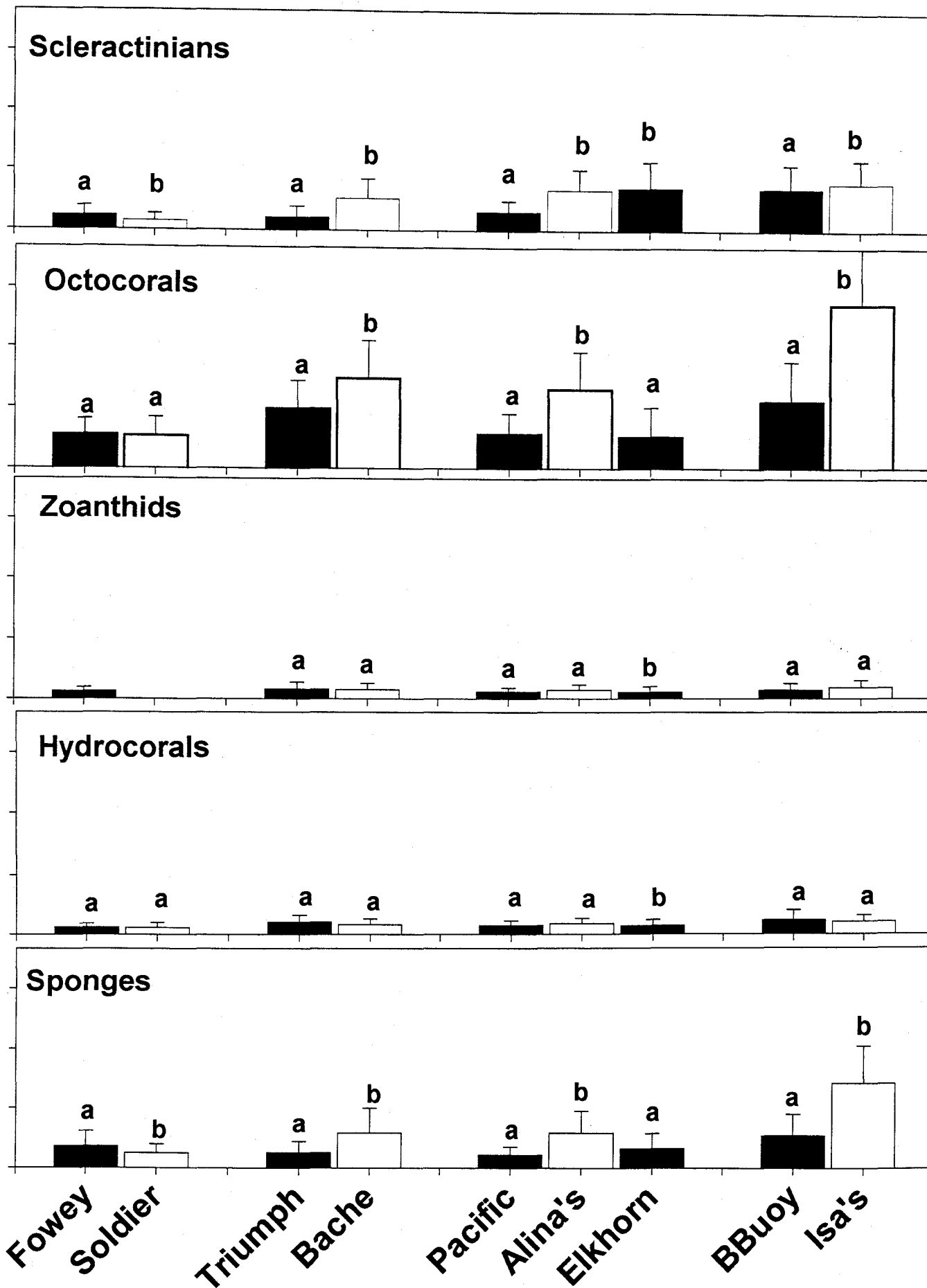
Fig. 2

B



F163

Mean density (col/m²)



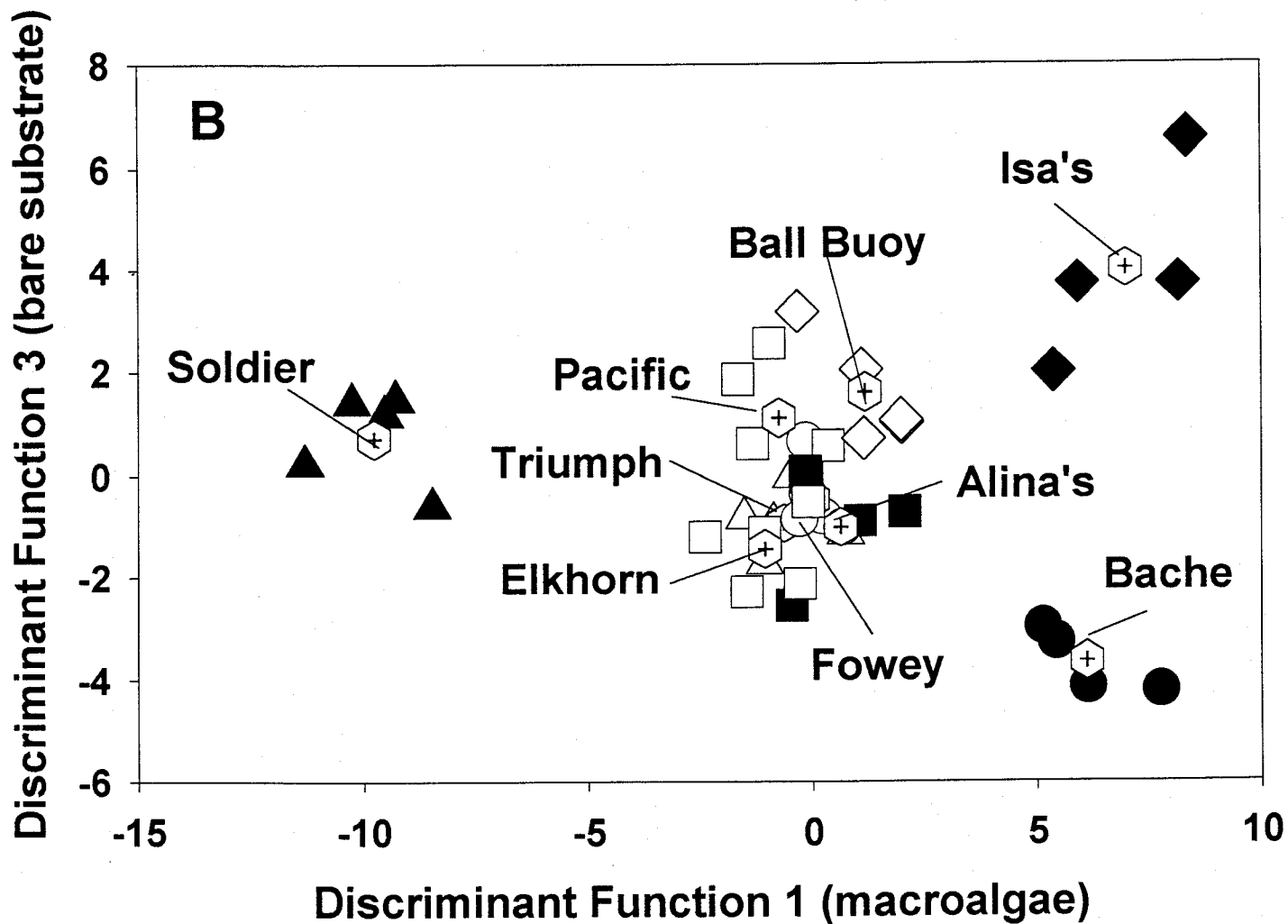
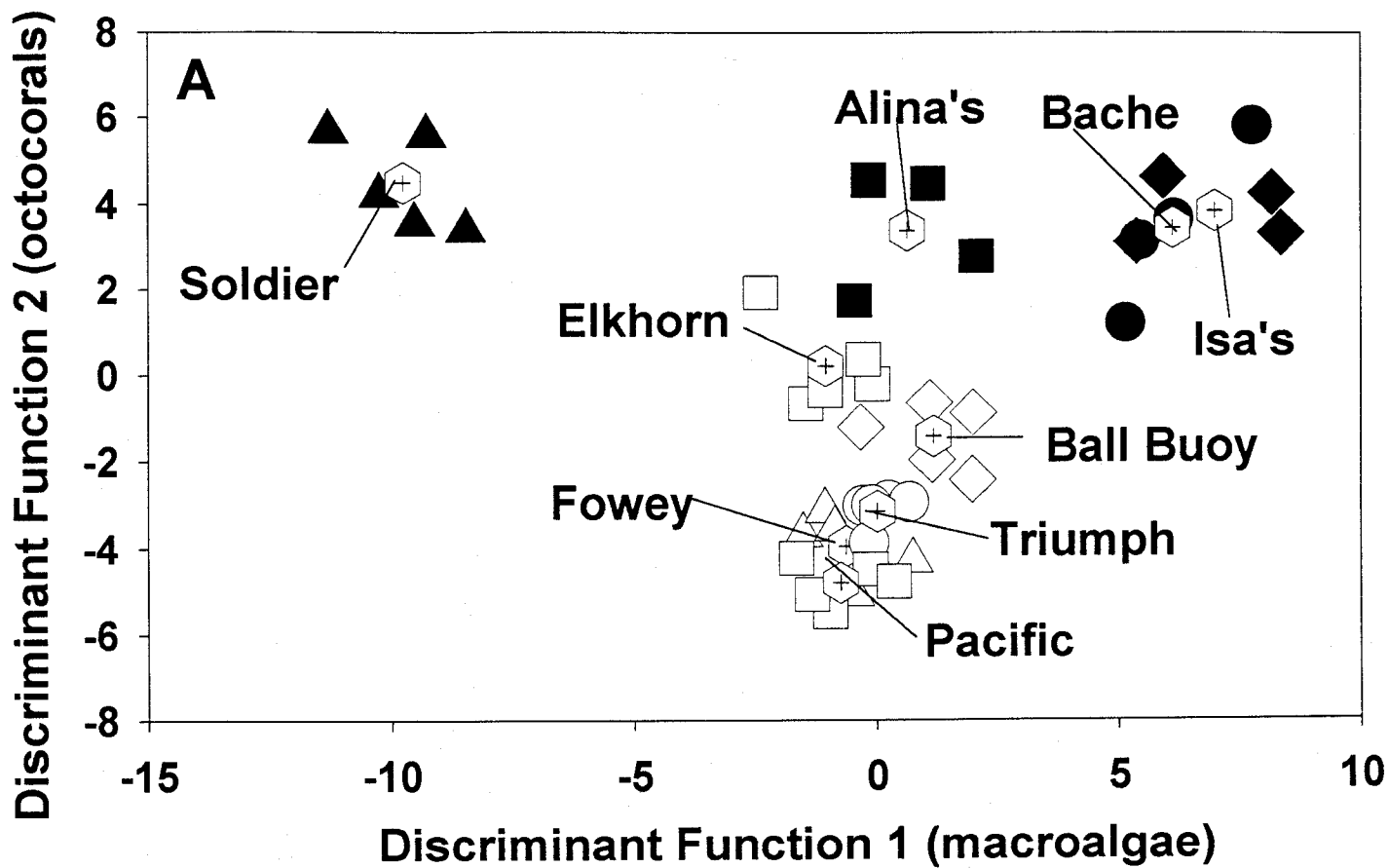
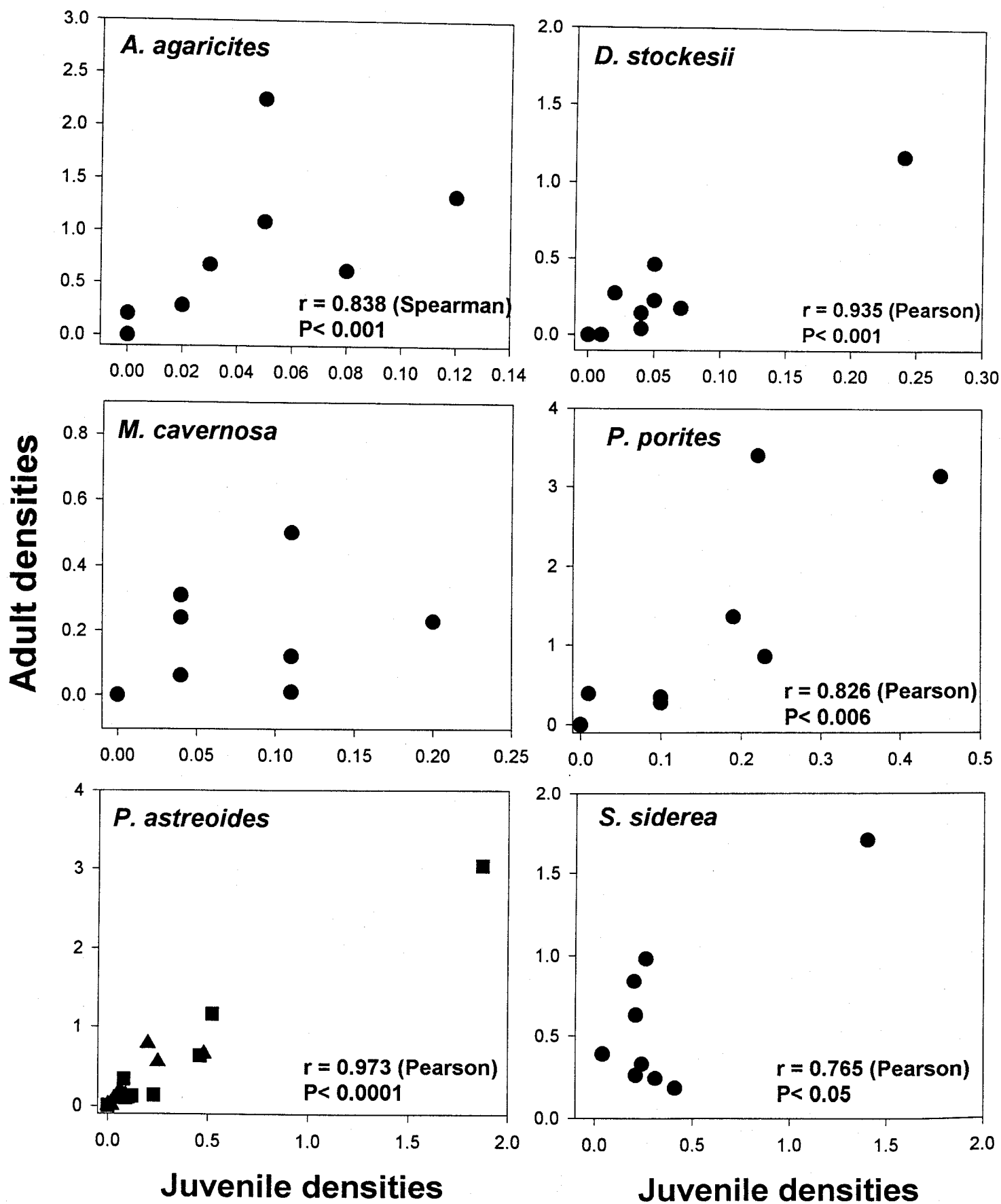


FIG. 5



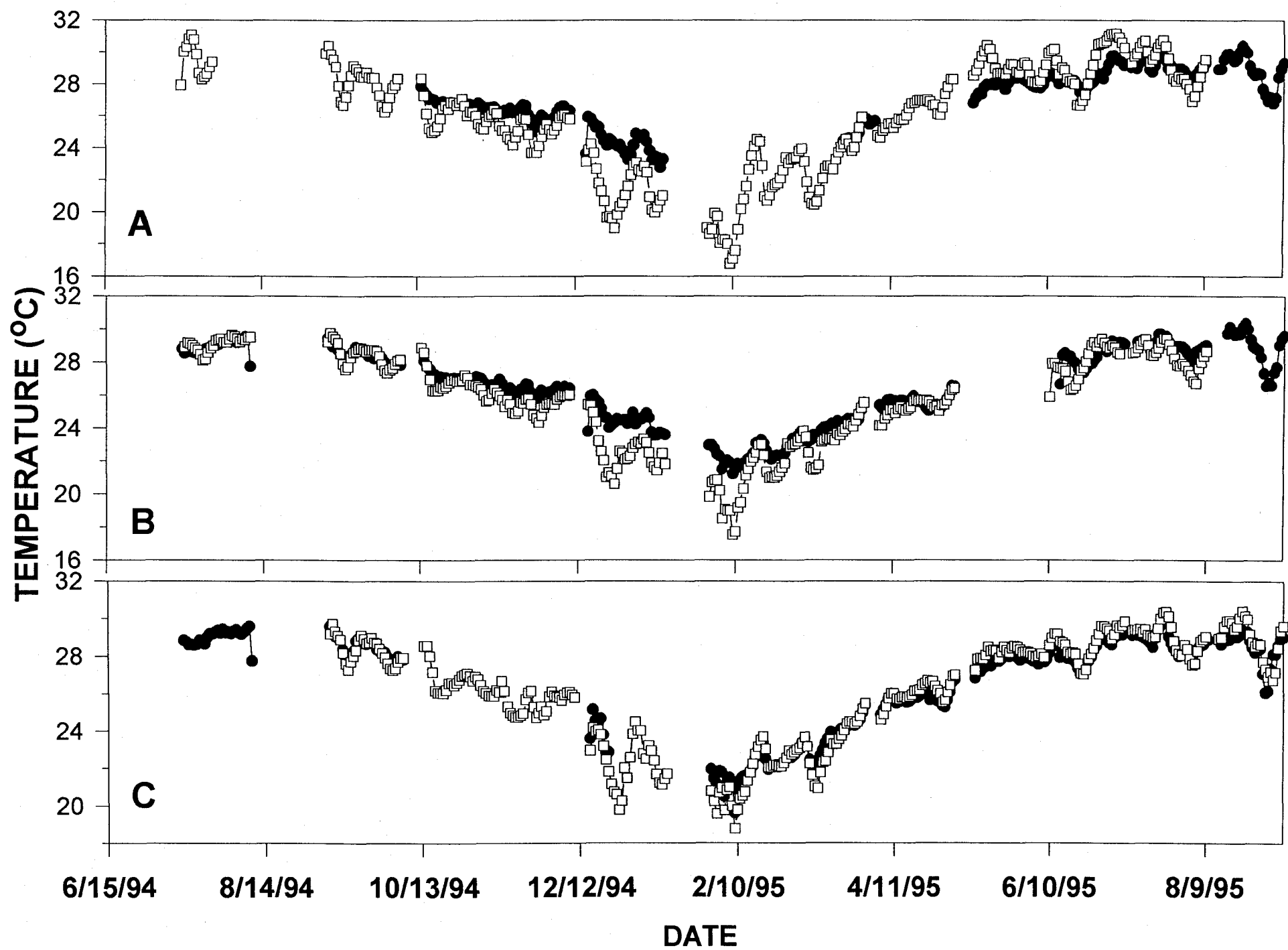
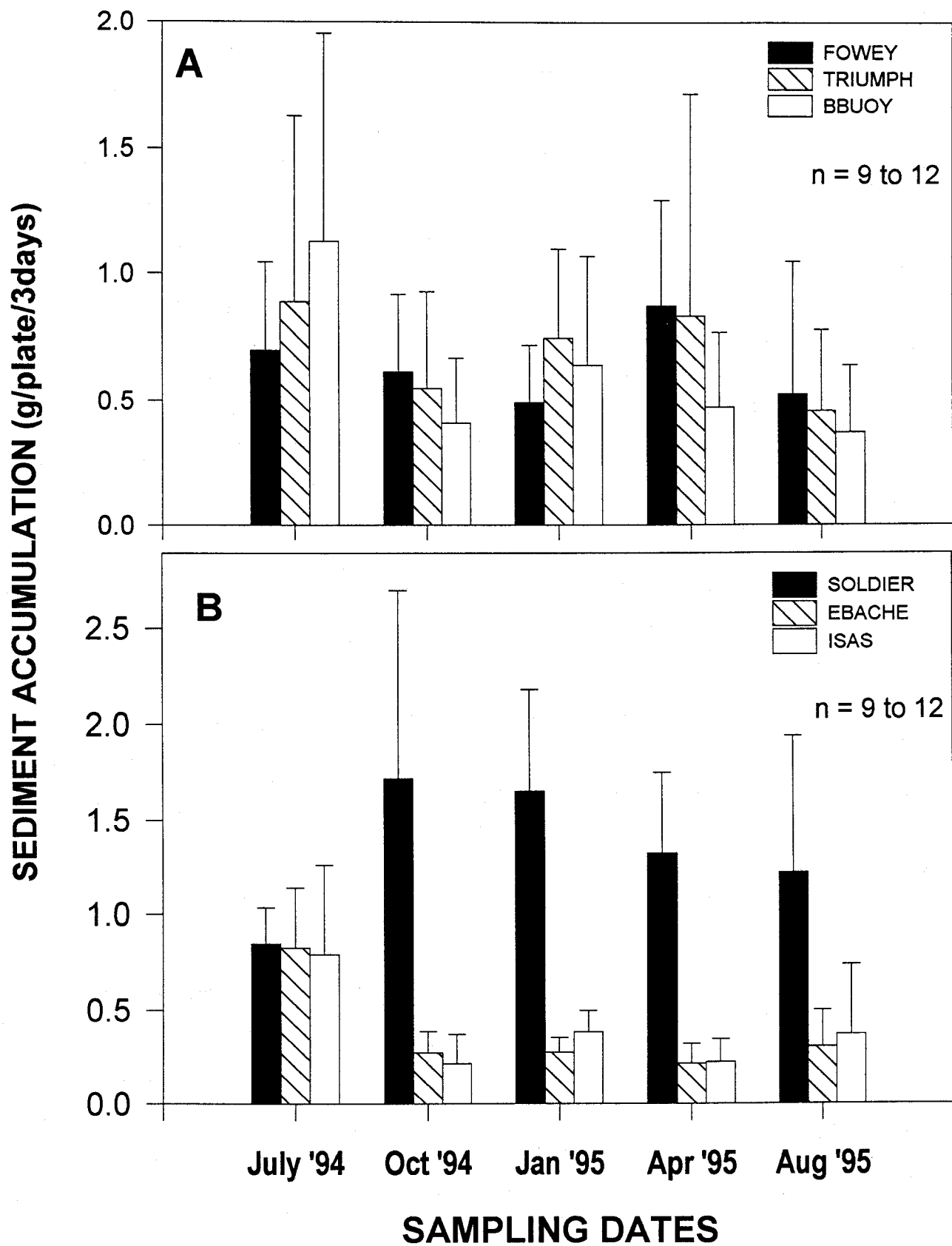
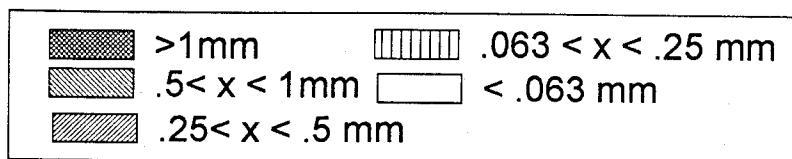
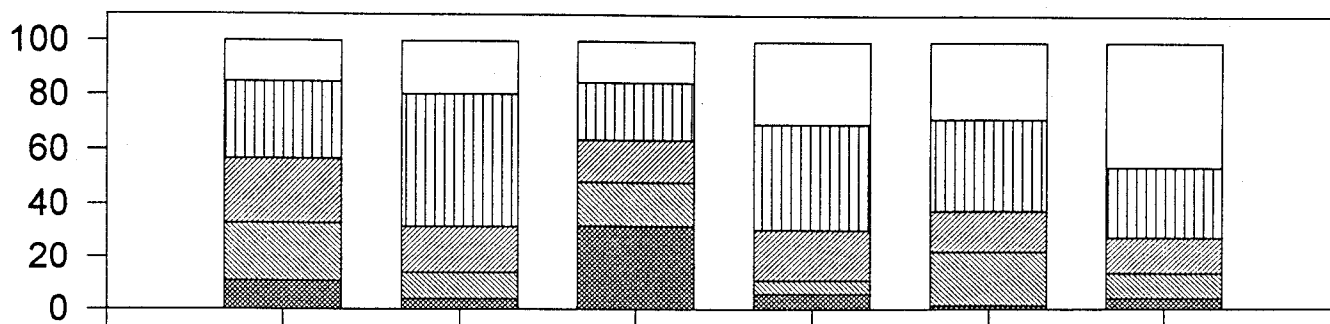


Fig. 6

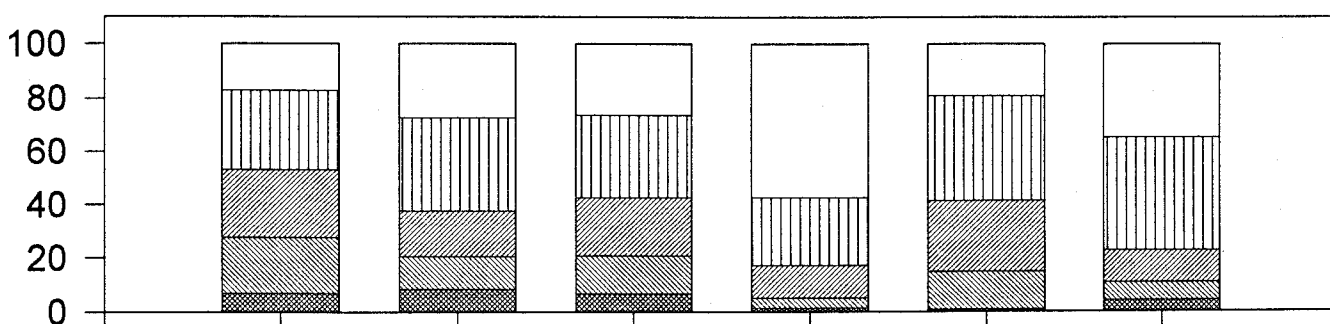




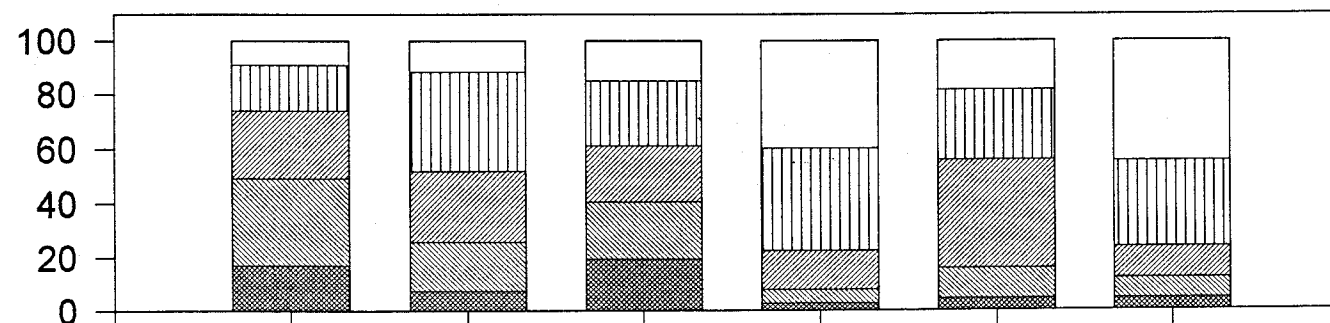
OCTOBER 1994



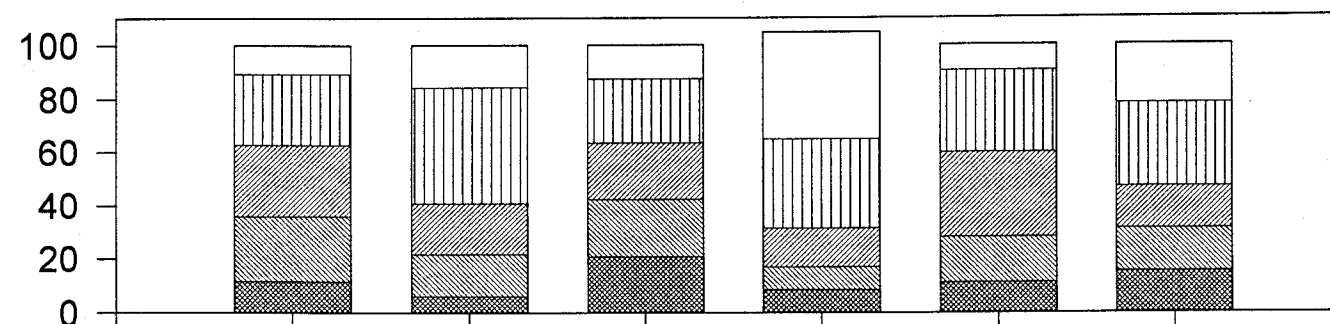
JANUARY 1995



APRIL 1995



AUGUST 1995



Fowey

Soldier

Triumph

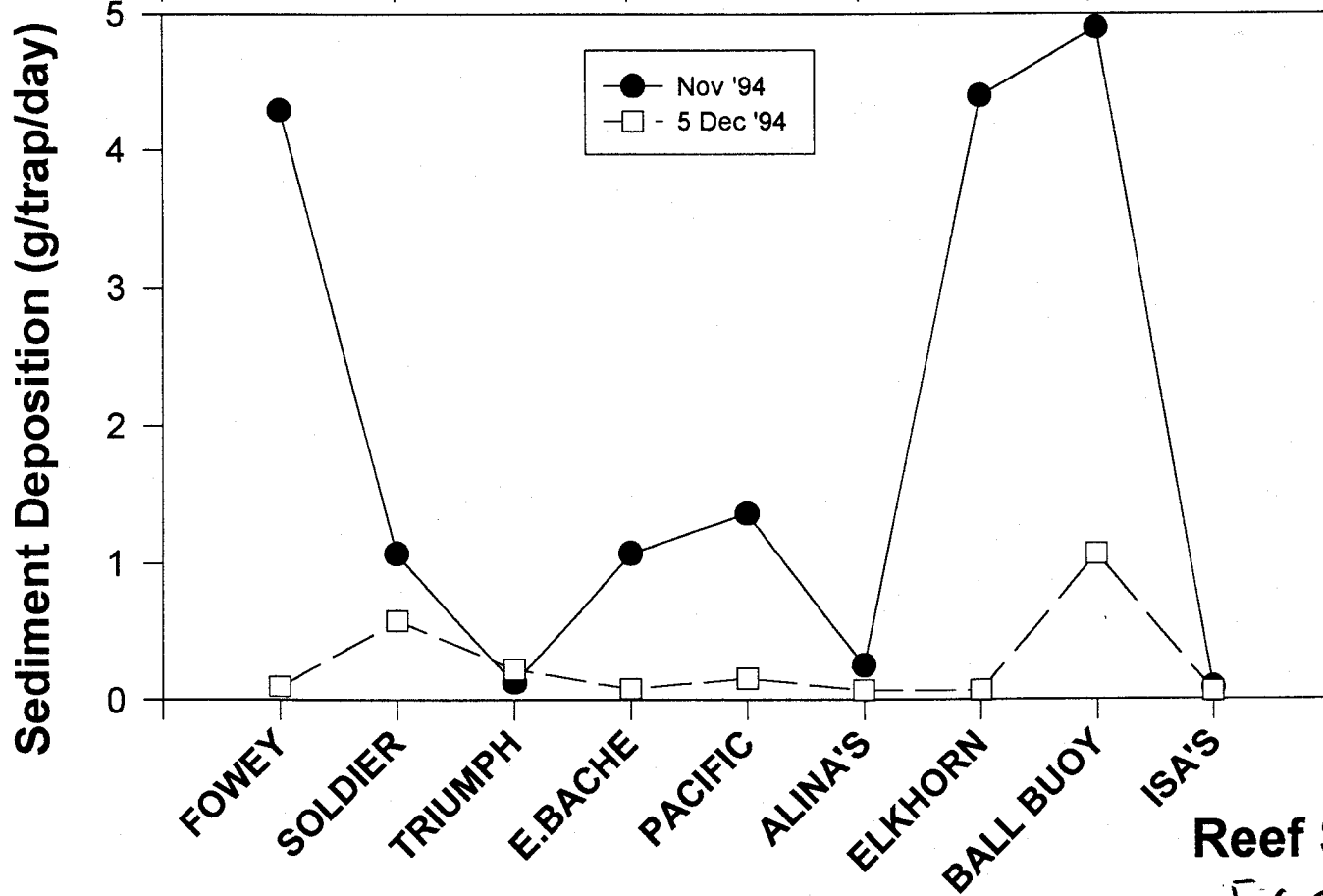
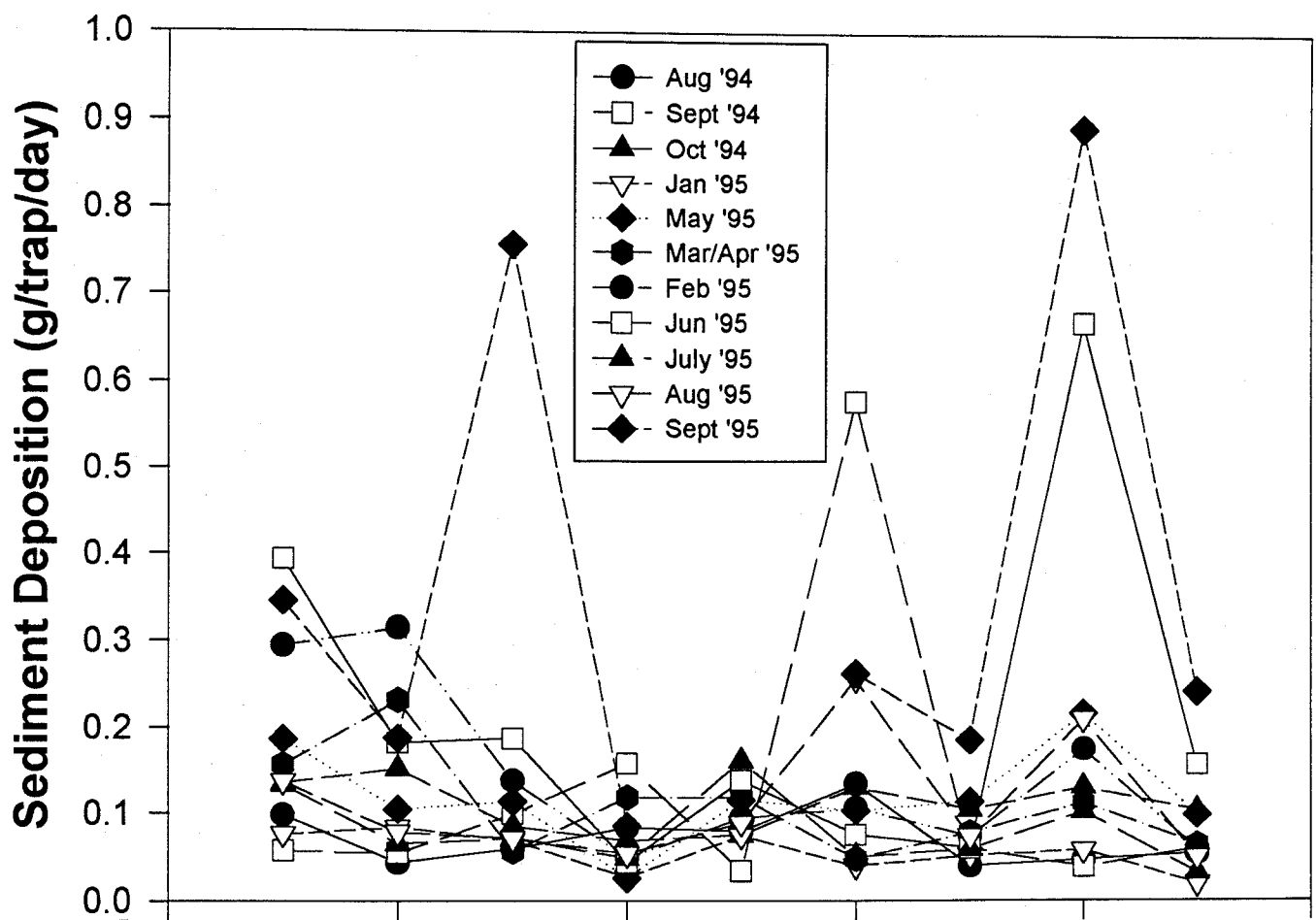
EBache

Ball Buoy

Isa,s

SITE

Fig 8



Reef Site

Fig. 9

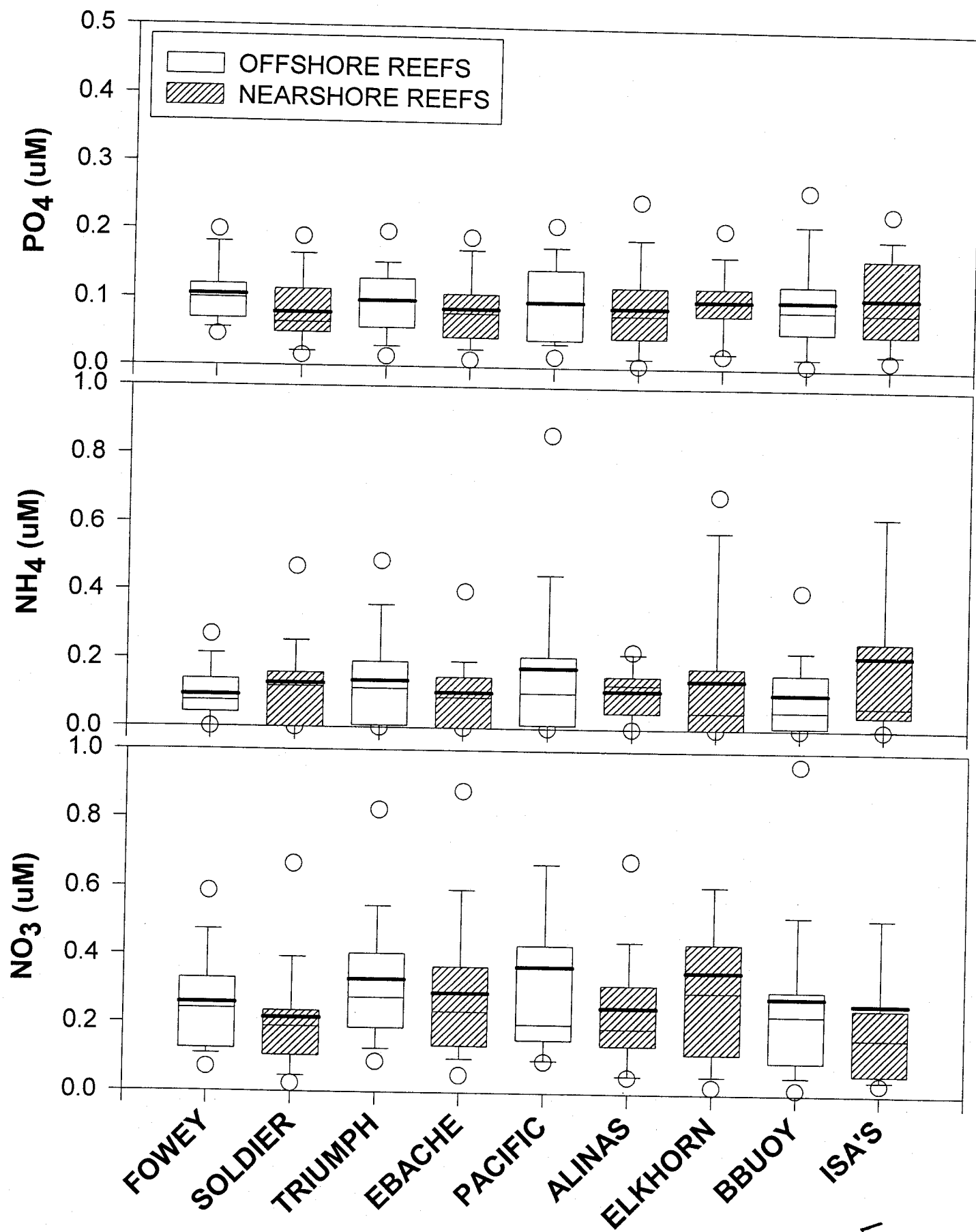


FIG. 10