Coral Reef Investigations at the Guam National Wildlife Refuge, Ritidian Unit

by

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INTRODUCTION

The Guam National Wildlife Refuge, Ritidian Unit (Guam NWR-RU), Guam, is located at the northern tip of the island (Ritidian Point) in a rural area with only little development. The refuge's reefs were relatively pristine but have suffered recently from a series of typhoons that damaged reef flat corals. Further, the reefs are threatened by future resort and urban development in adjacent land and coastal areas. To the west of the refuge is Andersen Air Force Base, a facility with an excellent record for environmental management to date, but nevertheless a possible threat from fuel spills and chemical contamination related to military ship, aircraft, and base operations. The U.S. Fish and Wildlife Service, as manager of ten important coral reef protected areas in the Pacific region, is obligated to assess and monitor the status of coral reefs at all of its refuges as an essential first step in maintaining the health of resident fish and wildlife and the integrity of its habitats. To that end, the University of Guam Marine Laboratory was contracted to conduct a project consisting of baseline and monitoring surveys of marine organisms and potential or actual environmental impacts at the Refuge. The goals of the project were as follows:

1. Conduct an initial assessment of coral reefs within and adjacent to the Guam National Wildlife Refuge, Ritidian Unit to evaluate the condition and health of the reefs.

2. Establish and survey permanently marked monitoring transects at the Refuge as the baseline for documenting long term changes in the reefs.

3. Install oceanographic and water quality loggers at the Refuge's reef sites to assess the potential for global warming, coral bleaching, and selected anthropogenic contaminants.

4. Prepare a draft report of findings of the surveys to improve future iterations of the surveys, to focus on future training of refuge staff to accomplish some monitoring and assessment tasks, and to improve management of the Refuge's reefs.

5. Upon receipt of Service review comments on the draft, prepare a final report that considers the review comments.

6. Prepare and submit electronic copies of data tables and digital copies of photographs collected during the survey.

The project has had two project officers since it began but, regrettably, no action was taken towards completing the project. On 7 June, 2004, a new project officer, the senior author, was designated to complete this project and, after delays in securing equipment and resources, began field work in October, 2004. The results of the initial assessment and subsequent monitoring of permanent transects, where established successfully, are given here and compared, where applicable, to those of recent studies in marine protected areas elsewhere on Guam. The methodology described herein may be used for training the Refuge's staff at a later date. Electronic copies of data and digital copies of photographs and film from this project will be submitted under separate cover.

METHODS

General Survey of Closed and Open Fore Reefs

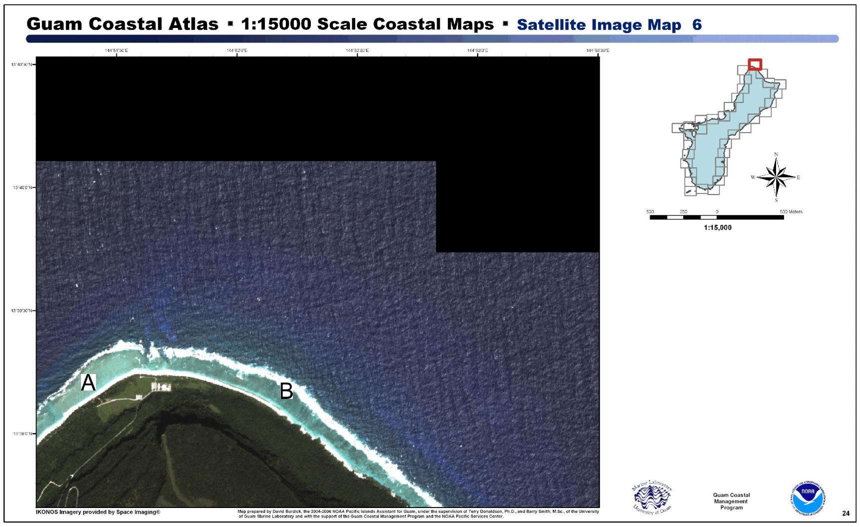
Initially, 50 m long permanent transects were to be established on the fore reef bench at depths of 12-15 and 18-20 m at both closed and open sites. Each of these transects were delineated by rebar stakes pounded into the substratum and marked with orange paint and flagging tape. Complimentary permanent transects were established adjacent to the Open Reef but outside of the Refuge's boundaries. Heavy seas and strong tidal currents (the latter especially at the open fore reef site), plus poor visibility on the shallow transects because of suspended sediments during heavy seas, prevented surveys from being conducted throughout most of the year. Only a general survey of the fore reef sites was possible and fishes, corals and benthic structure were not quantified. Thus, the results of this project are limited to comparisons of the Open and Closed Reef Flat sites within the Refuge's boundaries.

Permanent Transects on Closed and Open Reef Flats

Four permanent transects were established at random in October, 2004 on both the closed and open reef flats; each reef flat had an inner and outer transect (Figure 1).   Repeated surveys in October, November and December of 2004 indicated that these transects failed to account for relatively significant coral growth on both closed and open flats. Thus, the transects were moved at both sites in February, 2005. These transects were marked by rebar stakes pounded into the reef flat; their GPS locations are given in Table 1. Surveys began in February, 2005 on the closed sites and April, 2005 on open sites. Surveys utilized a 50 m lead core line, marked in increments of one meter, deployed between the rebar transect markers. Although the intent was to survey each site every month, heavy seas often prevented surveys from taking place on this basis. The closed transects were surveyed five times (February, March, April, June and July) while the open transects could be surveyed only four times (April, May, July and August).

Survey of Fishes

Because of visibility constraints at some transect sites, fishes were counted within a strip approximately 2.5 m on either side of the 50 m long transect line (area = 250 sq. m.). Counts were made with two passes along the transect line, i.e., on the first pass up the line, all large or mobile species were enumerated, and on the second pass down the line, all territorial and cryptic species of fishes were enumerated. Fish identifications follow Myers (1999) and Myers and Donaldson (2003).



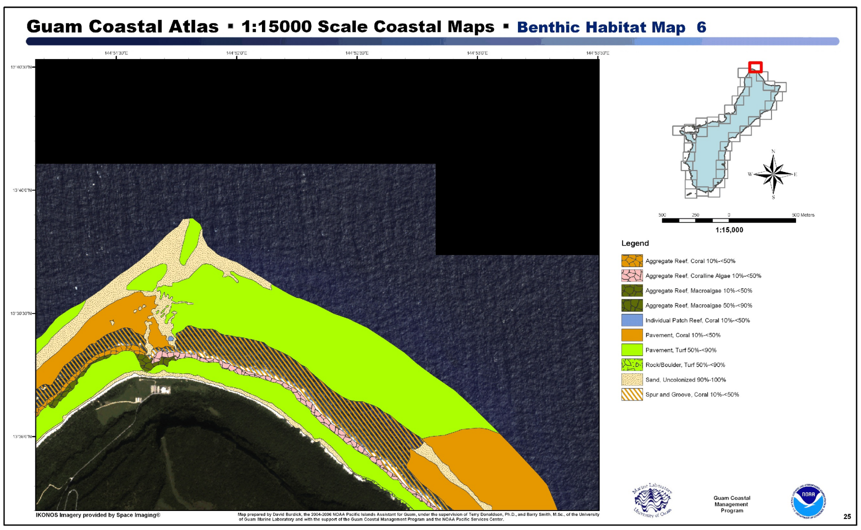


Figure 1. Aerial view of the Guam National Wildlife Refuge, Ritidian Unit, (top) and benthic habitat of reef flat and fore reef (bottom); both figures are from Burdick (2006). The Open sites are located to the left of the reef flat pass (A) and the Closed sites to the right (B).

Table 1. Global Position System (GPS) coordinates of transects on Closed Inner Reef Flat (CI), Closed Outer Reef Flat (CO), Open Inner Reef Flat (OI) and Open Outer Reef Flat (OO) sites at the Guam National Wildlife Refuge, Ritidian Unit.

Transect	**GPS Coordinates**
CI	**N 13.39.195, E 144.52.080**
CO	**N 13.39.195, E 144.52.082**
OI	**N 13.39.194, E 144.51.445**
OO	**N 13.39.216, E 144.51.442**

Survey of Benthic Structure and Corals

The percent cover of hard corals (scleractinians) along each transect line was quantified using a modified point-intercept method (Tsuda, 1972). A 50 x 50 cm quadrat frame divided into a grid of 25 squares, each 10 x 10 cm, provided 16 interior "points" where the grid line intersected. The quadrat frame was positioned within 1-meter on each side of the transect line at 5-meter intervals along the 50-meter long transect. Each species and substrata type were recorded at every "point" at which it occurred, i.e., n/16 x 100% = % cover per quadrat. Each 50-meter long belt transect provided a total of 160 points (16 points per quadrat x 10 samples). The modified point-intercept method also provided percent cover of the substrata, i.e., sand, rubble, turf algae, macroalgae, coralline algae, and live corals. Coral identifications followed Veron (2000).

Video footage of corals and benthic structure was obtained at least twice for each permanent transect in both open and closed reef flat sites. This footage has been archived in the senior author's laboratory at the University of Guam Marine Laboratory.

Water Temperature

Continuous recording water temperature loggers (ONSET HOBO WATER TEMP PRO, Onset Computer Corporation, Bourne, MA, USA) were installed on each reef flat and fore reef permanent transect site in October, 2004. On the reef flat, one logger each was installed on both inner and outer transects at both the closed and open sites; on the fore reef, loggers were installed at the head of each transect at a depth of ca. 20 m. Loggers were programmed to record temperatures once every four hours or six times per day. Loggers were to have been retrieved, downloaded, and replaced at least twice a year. Unfortunately, loggers were lost repeatedly to heavy surge activity during winter at both fore reef and reef flat transect sites, and to verifiable theft at the open reef flat transect sites. Therefore, only minimal temperature data were recorded between October, 2004 and July, 2005 and these were recovered from the Closed Reef Flat site.

Debris, Pollutants and Use

Anthropogenic debris were monitored on reef flats at both open and closed sites during survey activities. Debris on or within 5 m either side of the transect line were identified and scored.

Pollutants were not sampled because the costs of the equipment and analysis required could not be accommodated within the project's budget.

Use of the open site was scored on survey days by noting the number of people participating in any of the following activities: sunbathing, walking and swimming, snorkeling, hook and line fishing, octopus fishing, and spearfishing. Surveys were conducted concurrently with reef flat surveys and generally between 0900-1400H. Because survey dates were relatively few, this method yielded qualitative rather than qualitative. As such, the data provide only a very generalized picture of use.

Statistical Analyses

The general null hypothesis in each test (i.e., assemblage structure of reef fishes) is that the closed site does not differ significantly from the open site. The general alternate hypothesis is that the closed and open sites differ significantly from one another. During subsequent monitoring by future researchers (after this study), a second general null hypothesis should be that the open and closed sites do not differ significantly from the respective baseline open and closed sites. The second general alternate hypothesis is that the open and closed sites taken subsequently differ significantly from the initial baseline data.

Because the biological data at all sites was expected to be quite variable, and because the focus was upon potential change within communities at each site, multivariate analysis methods were used, where applicable, to determine if significant differences existed between open site and closed site transects, in fish species relative abundance, similarity and diversity, in percent cover of substrata, in coral species richness, and in relationships between substrata and patterns of fish similarity and diversity.

Fishes

For analysis of fish data, a matrix consisting of Bray-Curtis similarity values (Clarke and Gorley, 2001: PRIMER, SIMILARITY routine) was constructed. This matrix was then submitted to cluster analysis, multidimensional scaling analysis (MDS), and analysis of similarity. Values were transformed with a square-root procedure prior to construction of the matrices. Then, the matrix was submitted to a cluster analysis (Clarke and Gorley, 2001, PRIMER, CLUSTER routine: group) with an additional square root transformation (now 4th root) to determine groupings among transects at each site. If there were no differences between closed and open sites, transects would be expected to be distributed randomly within a single cluster on the cluster analysis dendrogram. This procedure was followed by submitting the square-root transformed matrix to a non-metric multidimensional scaling (MDS) analysis (Clarke and Warwick, 1994; Clarke and Gorley, 2001, PRIMER, MDS routine) with 100 iterations that constructed a plot of transects relative to their rank order of similarity; the greater the similarity. Finally, to determine significance if differences were found to exist between open and closed sites the data matrix (square-root transformed) was analyzed with a one-way analysis of similarity (Clarke and Gorley, 2001, PRIMER, ANOSIM routine). This multivariate procedure is analogous to a one-way analysis of variance (Clarke and Warwick, 1994) and utilizes 999 permutation/randomization tests of between groups (open sites or closed sites). The value generated, a global R, indicates the difference between average ranks between and within groups. If there are no differences between the groups, then between-group and within-group similarities will usually be equal or not differ by more than 15% by chance. If the value exceeds 0-0.15, then the null hypothesis is rejected at the 0.001 (0.1%) level (Clarke and Gorley, 2001).

In addition, indices of species richness (S), species diversity (Shannon H') and evenness (Pielou's J) were calculated (Clarke and Gorley, 2001, PRIMER, DIVERSE routine). Species richness simply indicates the number of species present. Species diversity (H') modifies S by considering the abundance of each species present, with higher values indicating greater diversity. Evenness (J) estimates the completeness of sampling and ranges from 0.0 (no sampling) to 1.00 (complete).

Benthic Structure and Corals

A Euclidean distance similarity matrix (Clarke and Gorley, 2001, PRIMER, SIMILARITY routine) was constructed from transformed data of both open and closed sites; the data set consisted of percent cover values of turf algae, macroalgae, coralline algae, sand, rubble, and total corals (all coral species and *Heliopora coerulea* combined). This matrix was then submitted to cluster analysis, multidimensional scaling analysis (MDS), and analysis of similarity (ANOSIM) using the procedures described above.

A Bray-Curtis similarity matrix (Clarke and Gorley, 2001, PRIMER, SIMILARITY routine) was constructed also and utilised transformed percent cover values of corals (those species scored on quadrats) of both open and closed sites. This matrix was then submitted to cluster analysis, multidimensional scaling analysis (MDS), and analysis of similarity (ANOSIM) using the procedures described above.

Relationships Between Benthic Structure, Corals and Fishes

Measures of fish species richness (S) and diversity (H') were compared graphically (SIGMALPLOT, ver. 9.0, SYSTAT, 2004) against those of percent cover, where possible, to examine the relationships between fish assemblage structure and the benthic structure of reef flat sites. The comparisons were used to determine if there were positive or negative relationships between the richness or diversity and a specific form of cover (i.e., coral, algae, sand, etc.).

RESULTS AND DISCUSSION

General Survey of Closed and Open Fore Reefs

At the Closed Fore Reef Site, fish abundance and diversity, also not quantified (see Methods), were relatively poor as well, and limited to some damselfishes (mainly *Pomachromis guamensis* and *Dascyllus reticulatus*; Pomacentridae), three hawkfishes (*Paracirrhites arcatus, Paracirrhites forsteri* and *Cirrhitichthys falco* (Cirrhitidae), the surgeonfish *Acanthurus nigrofuscus* (Acanthuridae), and the small grouper *Cephalopholis urodeta* (Serranidae).

At the Open Fore Reef Site, fish abundance and diversity, also not quantified, appeared to be greater than at the closed site. Damselfishes and hawkfishes were rather common, as were surgeonfishes (*i.e., Acanthurus nigrofuscus*, *Acanthurus nigoris*, *Ctenochaetus striatus*, *Naso literatus*, *Naso vlagmingi*; Acanthuridae), parrotfishes (*i.e., Chlorurus sordidus*, *Scarus psittacus*, and *Scarus schlegeli*; Labridae, Scarinae), wrasses (i.e., *Cheilinus trilobatus*, *Halichoeres margaritaceus*, *Labroides dimidiatus*, *Oxycheilinus unifasciatus*, *Thalassoma amblycephalum*; Labridae), butterflyfishes (*i.e., Chaetodon auriga*, *Chaetodon citrinellus*, *Chaetodon lunula*, and *Chaetodon reticulatus*; Chaetodontidae), pygmy angelfishes (*i.e., Centropyge flavissimus*;

Pomacanthidae), triggerfishes (*i.e., Balistapus undulatus*, *Odonus niger*, *Melichthys vidua*, *Sufflamen bursa*, and *Sufflamen chrysiptera*; Balistidae), the blennies *Ecsenius bicolor* and *Plagiotremus tapeinosoma* (Blenniidae), and juveniles and young adults of an emperor (*Monotaxis grandoculis*; Lethrinidae). Larger game and food fishes, such as the trevallys (*Caranx* and *Carangoides* spp.; Carangidae), snappers (*Lutjanus* spp, *Aprion viridescens*; Lutjanidae), and emperors (*Lethrinus* spp; Lethrinidae), were largely absent from both open and closed sites.

Although the substrata present at both sites were not quantified, they can be characterised as follows. The Closed Fore Reef Site consisted largely of flat pavement, resembling a car parking lot, cut by sand channels down below a depth of 20 m. Coral abundance and diversity were poor and limited mainly to single colonies of *Pocillopora eydouxi* (Pocilloporidae) scattered infrequently on the bottom. The Open Fore Reef Site consisted of sloping pavement marked by occasional rubble fields. Corals were not quantified but were mainly *Pocillopora eydouxi* or small *Acropora* spp. (Acroporidae), the former appearing to be more abundant then at the closed site.

Permanent Transects on Closed and Open Reef Flats

Fishes

A checklist of species and their relative abundance (number per 250 m^2) at each reef flat station is given in Appendix A. Measures of species richness, the number of individuals observed, species diversity (H'), and evenness are given in Table 2.

On the closed outer reef flat, species richness (S) ranged from 29 to 38 species, the number of individuals observed (N) ranged from 132 to 317, species diversity (H') ranged from 2.32 to 2.75, and evenness (J) ranged from 0.68 to 0.78 (68-78% estimated sampling completeness).

On the open outer reef flat, species richness (S) ranged from 12 to 27 species, the number of individuals observed (N) ranged from 57 to 155, species diversity (H') ranged from 1.89 to 2.38, and evenness (J) ranged from 0.72 to 0.78 (72-78% estimated sampling completeness).

On the closed inner reef flat, species richness (S) ranged from 24 to 37 species, the number of individuals observed (N) ranged from 166 to 237, species diversity (H') ranged from 2.18 to 2.68, and evenness (J) ranged from 0.65 to 0.79 (65-79% estimated sampling completeness).

On the open inner reef flat, species richness (S) ranged from 8 to 20 species, the number of individuals observed (N) ranged from 33 to 104, species diversity (H') ranged from 1.33 to 1.97, and evenness (J) ranged from 0.64 to 0.78 (64-78% estimated sampling completeness).

A list of species shared by inner and outer reef flat transects at closed and open sites is given in Appendix B. The Closed and Open Inner Reef Flat sites shared 21 species between them as did the Closed and Open Outer Reef Flat sites (Table 3).

The ten most abundant species at each of the sites is given in Table 4. Damselfishes (Pomacentridae), wrasses (Labridae), parrotfishes (Labridae: Scarinae), and surgeonfishes

(Acanthuridae) were dominant at all sites. Damselfishes (i.e., *Stegastes albifasciatus*) tended be found in territorial clusters or mosaics (Donaldson, 1984). Wrasses tended to form male-dominated territorial mating groups (i.e., *Halichoeres trimaculatus*). Parrotfishes were often observed in small aggregations of juveniles or immature females that roved across the reef flat (i.e., *Chlorurus sordidus*). Surgeonfishes were either territorial or in small aggregations (i.e., *Acanthurus triostegus*), and also associated with parrotfishes in heterospecific or mixed species aggregations or shoals (Helfman et al., 1997). Overall, the abundance of species observed appeared greater on transects of the closed reef flat compared to those of the open reef flat. The same was true of species observed adjacent to but not within the boundaries of the transect (Appendix A). These included important predators, and game and food fishes such as blacktip sharks (*Carcharhinus melapterus*, Carcharhinidae), blue trevally (*Caranx melampygus*, Carangidae), and goatfishes (Mullidae). Similar results have been reported for another marine protected area on Guam (Tsuda and Donaldson, 2004).

There were clear differences in assemblage structure between Open and Closed Reef Flat transects over time. Differences in structure between most inner and outer reef transects within sites were not so pronounced, however, and so many species likely to be found on an inner reef flight might also be found on an outer reef flat. Cluster analysis of similarity values (Bray-Curtis index) for fishes from open and closed reef flat transects generated a dendrogram (Figure 2) in which three clusters are indicated. The first cluster consisted of transect CO3 on the Closed Outer Reef Flat. The second consisted of the remaining Closed Inner and Outer Reef Flat transects, and the third consisted of all of the Open Inner and Outer Reef Flat transects. MDS analysis (Figure 3) provided a similar outcome, with open and closed transects in distinct groups but with transect CO3 as an outlier. A stress value of 0.08 indicated a good degree of reliability in this result. Analysis of similarity between open and closed reef flat transects indicated a significant difference between the two sites in the assemblage structure of fishes (Global $R = 0.018$, $p = 0.001$).

Table 2. Reef fish species richness (S), number of individuals (N), Pielou's evenness (J), and Shannon Index of Diversity (H') for inner and outer reef stations at open and closed reef flat sites at the Guam National Wildlife Refuge, Ritidian Unit.

Station	S	N	J	H'
CO1	29	244	0.68	2.32
CO2	34	170	0.78	2.78
CO3	30	132	0.77	2.63
CO4	37	317	0.75	2.74
CO5	38	258	0.75	2.75
CI1	37	178	0.71	2.58
CI2	24	166	0.79	2.51
CI3	28	208	0.65	2.18
CI4	37	237	0.73	2.64
CI5	37	220	0.74	2.68
OO1	12	57	0.78	1.95
OO2	12	83	0.76	1.89
OO3	22	85	0.74	2.30
OO4	27	155	0.72	2.38
OI1	11	37	0.78	1.88
OI2	8	33	0.64	1.33
OI3	17	84	0.64	1.82
OI4	20	104	0.65	1.97

Table 3. Number of fish species and shared species for Closed Inner Reef Flat (CI), Closed Outer Reef Flat (CO), Open Inner Reef Flat (OI) and Open Outer Reef Flat (OO) sites at the Guam National Wildlife Refuge, Ritidian Unit. Comparison is between inner reef flat sites and outer reef flat sites. See Appendix B for species lists.

	Site		
	CI	**OI**	**Both sites**
Number of species	69	29	21
	CO	**OO**	**Both sites**
Number of species	70	37	21

Table 4. Greatest species abundance on Closed Inner Reef Flat (CI), Closed Outer Reef Flat (CO), Open Inner Reef Flat (OI) and Open Outer Reef Flat (OO) sites at the Guam National Wildlife Refuge, Ritidian Unit. Abundance rank is based upon the sum of all transects for each site. Only the top ten most abundant species, including ties, are given. See Appendix A for family affiliations.

CI	OI
Stegastes albifasciatus	*Halichoeres trimaculatus*
Chlorurus sordidus	*Chlorurus sordidus*
Halichoeres trimaculatus	*Chrysiptera biocellata*
Chrysiptera brownriggi	*Stethojulis bandanensis*
Gnathodentex aurolineatus	*Chrysiptera glauca*
Halichoeres hortulanus	*Naso literatus*
Stethojulis bandanensis	*Acanthurus triostegus*
Scarus psittacus	*Chrysiptera brownriggi*
Acanthurus nigrofuscus	*Stegastes albifasciatus*
Ctenochaetus striatus	*Acanthurus nigrofuscus*
	Canthigaster solandri
CO	**OO**
Stegastes albifasciatus	*Halichoeres trimaculatus*
Chrysiptera brownriggi	*Chrysiptera brownriggi*
Chlorurus sordidus	*Chrysiptera glauca*
Stethojulis bandanensis	*Stethojulis bandanensis*
Halichoeres trimaculatus	*Stegastes albifasciatus*
Stegastes fasciatus	*Acanthurus triostegus*
Acanthurus nigrofuscus	*Naso literatus*
Acanthurus triostegus	*Anampses meleagris*
Ctenochaetus striatus	*Chaetodon citrinellus*
Pomacentrus vaiuli	*Chrysiptera biocellata*

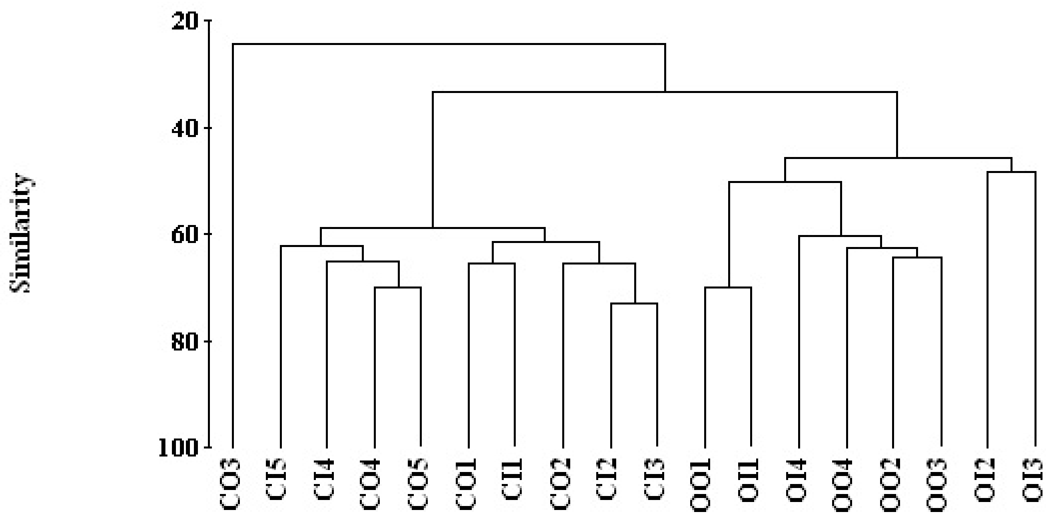


Figure 2. Cluster analysis dendrogram based upon Bray-Curtis similarity values (square root transformed) indicating reef fish assemblage structural relationships between Open Inner Reef Flat (OI), Open Outer Reef Flat (OO), Closed Inner Reef Flat (CI) and Closed Outer Reef Flat (CO) stations at the Guam National Wildlife Refuge, Ritidian Unit in 2005. The descending vertical axis indicates increasing similarity.

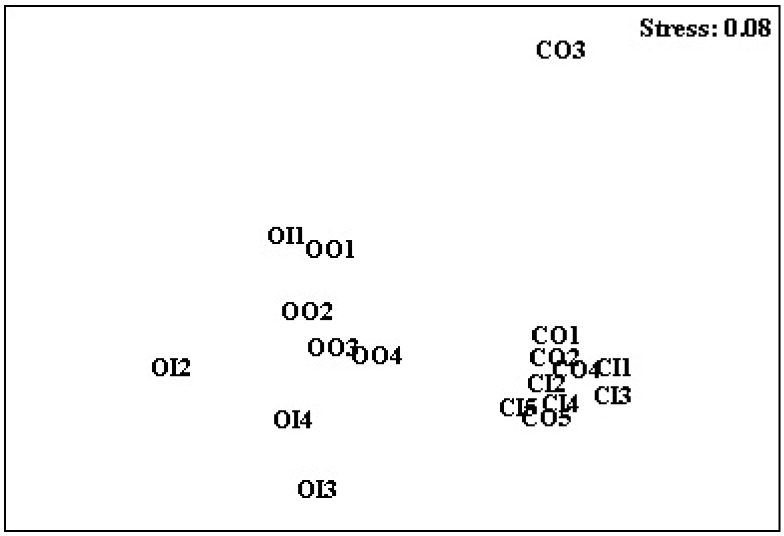


Figure 3. Multidimensional scaling (MDS) analysis of reef fish assemblage structure between Open Inner Reef Flat (OI), Open Outer Reef Flat (OO), Closed Inner Reef Flat (CI) and Closed Outer Reef Flat (CO) stations at the Guam National Wildlife Refuge, Ritidian Unit in 2005.

Benthic Structure and Corals

Percent cover of benthic structure is given in Table 5. Turf algae was dominant at all transect sites, followed by sand and coral cover. Coral cover was greatest at both of the closed sites and nearly equivalent between inner and outer transects. At the Open Reef Flat sites, coral cover was just 4 % on the outer transect quadrats and virtually absent from the inner transect quadrats. A good number of coral boulders, mainly *Porites lutea*, plus *Porites lichen*, and *Porites vaughani*, were observed adjacent to the inner transect at this site, however.

Cluster analysis of similarity values (Euclidiean distance) of benthic structure from open and closed reef flat transects generated a dendrogram (Figure 4) in which two major clusters, closed and open reef flats, are indicated. Both showed some similarities between inner and outer transects and, as such, were not clearly defined. The first cluster was partitioned into four smaller clusters, two of which stood alone (CO3 and CI1), and two which combined both outer and inner transects (CO1, CI2-CO2 and CO4, CI3-CI4). The second cluster was partitioned into seven smaller clusters, six of which were single transects (OI4, OI1, OO1, OO4, OO2, and OO3), and the last consisting of transects OI2-OI3. MDS analysis (Figure 7) provided a similar outcome, but with the inner and outer transects showing more differentiation. A stress value of 0.06 indicated a good degree of reliability in this result. Analysis of similarity between open and closed reef flat transects indicated a significant difference in benthic structure (Global $R = 0.816$, $p = 0.001$).

Species richness of corals was $S = 14$ at the Closed Inner Reef Flat site , $S = 7$ at the Closed Outer Reef Flat site, $S = 9$ at the Open Inner Reef Flat site, and $S = 11$ at the Open Outer Reef Flat site. The distribution of species, including those observed at each site but not recorded on quadrats, is given in Table 6.

Cluster analysis of similarity values (Bray-Curtis index) for corals from closed and open reef flat transects generated a dendrogram (Figure 6) in which three clusters are indicated. The first cluster consisted of the Closed Outer Reef Flat transects, the second cluster consisted of the Outer Reef Flat transects, and the third consisted of the Closed Inner and Open Inner Reef Flat transects. Thus, the Open and Closed outer reef flats are different from one another in both benthic structure and corals but the inner reef flats at both sites are more similar to one another. This similarity likely reflects structural conditions on the inner reef flats, mainly the moat and inner algal flat, that are similar at both sites. MDS analysis (Figure 7) provided a similar outcome, but with the Closed Outer and Open Outer Reef Flat transects differing considerably from one another in species composition. A stress value of 0.00 indicated a very good degree of reliability in this result. Analysis of similarity between open and closed reef flat transects was discounted because the coral similarity matrix allowed for too few comparisons of coral assemblage structure for the test to be made.

Relationships Between Fishes, Benthic Structure and Corals

Although data were limited, some trends in fish species richness and diversity with respect to percent cover of macroalgae, sand, and corals were evident. The relationship between the percent cover of macroalgae and fish species richness was slightly negative on transects at both closed sites, negative on the Open Inner Reef Flat transect, and positive on the Open Outer Reef Flat transect (Figure 8). Fish species diversity was approximately equivalent on transects at both closed sites, but negative on the inner and positive on the outer transects of the open site (Figure 8). The relationship between percent cover of sand and fish species richness was slight positive on all transects (Figure 9). For fish species diversity, however, the relationship was essentially equivocal on the closed inner and open outer transects but slightly positive for the closed outer and open inner transects (Figure 9). Fish species richness and diversity showed a positive relationship with increased coral cover on both transects at the Closed Reef Flat site but not at the Open Reef Flat site (Figure 10).

Water Temperature

Limited data from the Closed Inner and Outer Reef Flats indicated a mean water temperature of 28.28 degrees C (SE = 0.0171) and a range of 5.85 degrees C. The minimum water temperature was 25.28 degrees C (28 January, 2005: 0400H) and the maximum was 31.13 degrees C (10 October, 2004: 1200H). Higher water temperatures likely resulted from low tides during summer (warmest) months. Long-term monitoring of water temperature on both Closed and Open reef flats is required to establish a meaningful pattern, however.

Debris, Pollutants and Use

No anthropogenic debris were observed on or in the vicinity of the transects at both open and closed reef flat sites. Both sites are swept by strong currents, generated either by surf, tidal flows, or both. Debris likely carried over the reef may be swept down-current to the Ritidian Pass during a falling tide. Refuge personnel reported that they regularly remove debris from the area of the Pass, however (M. Brown, U.S. Fish and Wildlife Service, personal communication, 2006).

No pollutants were sampled during the course of this study (see Methods).

The Open Reef Flat site was utilized occasionally. Observations indicated the proportional use (n = 26 users) of the reef flat and beach over the survey period was as follows: swimmers, sunbathers and walkers (76.9%), hook and line fishers (11.5%), octopus fishers (7.6%), and spearfishers (4%). Because of logistical constraints the sampling methodology failed to sample use of this reef flat and beach on weekends, when the abundance of various user groups is likely greatest (G. Deutscher, U.S. Fish and Wildlife Service, personal communication, 2004). With respect to resource extraction, this site is apparently one of the most heavily fished and productive reef flats for octopus on Guam (J. Guitterez, Guam Division of Aquatic and Wildlife Resources, personnel communication, 2005).

Table 5. Benthic structure of Closed Inner Reef Flat (CI), Closed Outer Reef Flat (CO), Open Inner Reef Flat (OI) and Open Outer Reef Flat (OO) sites at the Guam National Wildlife Refuge, Ritidian Unit. Values are mean percent coverage (+/- SE, with n = 4 for each site).

	Site			
Benthos	**CI**	**OI**	**CO**	**OO**
Turf algae	66.16 (3.66)	64.38 (5.39)	69.06 (3.77)	75 (2.27)
Macroalgae	5.63 (2.02)	1.56 (0.65)	5.79 (2.27)	1.09 (0.39)
Coralline algae	0 0	0 0	0.47 (0.3)	0 0
Sponges	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Sand	9.53 (2.05)	31.41 (5.28)	5.48 (1.64)	18.28 (2.52)
Rubble	0 (0.0)	1.09 (1.09)	0 (0.0)	0.47 (0.47)
Total corals	19.53 (1.99)	0.94 (0.4)	19.2 (1.37)	4.53 (1.83)
Corals:				
Heliopora coerulea	0.47 (0.29)	0 (0.0)	0.31 (0.31)	0 (0.0)
Acropora palifera	13.28 (2.19)	0 (0.0)	14.84 (1.43)	0 (0.0)

Table 5, continued.

Benthos	Site CI	OI	CO	OO
Corals				
Astreapora randalli	0 (0.0)	0 (0.0)	0.16 (0.16)	0 (0.0)
Leptastrea purpurea	0.16 (0.16)	0 (0.0)	0.16 (0.16)	0 (0.0)
Pocillopora damicornis	5.63 (4.4)	0.47 (0.3)	1.41 (0.59)	0.46 (0.16)
Pocillopora setchelli	0.16 (0.16)	0 (0.0)	0 (0.0)	0 (0.0)
Porites lichen	3.91 (1.47)	0 (0.0)	1.84 (0.67)	0 (0.0)
Porites lutea	0 (0.0)	0.47 (0.3)	0.16 (0.16)	4.06 (1.7)
Porites vaughani	0 (0.0)	0 (0.0)	0.16 (0.16)	0 (0.0)
Stylophora mordax	0 (0.0)	0 (0.0)	0.31 (0.18)	0 (0.0)

Table 6. Coral species present (X) on Closed Inner Reef Flat (CI), Closed Outer Reef Flat (CO), Open Inner Reef Flat (OI) and Open Outer Reef Flat (OO) sites at the Guam National Wildlife Refuge, Ritidian Unit. This list includes species not observed directly on the transect line or quadrat.

	Site				
	CI	**OI**	**CO**	**OO**	**Total sites**
Heliopora coerulea	X		X		2
Acropora abrotanoides			X		1
Acropora digitifera			X		1
Acropora pallifera		X	X		2
Astreapora randalli			X		1
Cyphastrea chalcidicum	X				1
Favia mathaii	X	X		X	3
Favia pallida	X			X	2
Goniastrea edwardsi	X				1
Goniastrea retiformis				X	1
Leptastrea purpurea	X	X		X	3
Pavona varians				X	1
Pocillopora damicornis	X	X	X	X	4
Pocillopora setchelli	X				1
Platigyra daedalea	X		X	X	3
Platigyra pini				X	1
Porites lichen	X		X	X	3
Porites lobata	X		X	X	3
Porites lutea	X	X	X		3
Porites vaughani	X	X			2
Psammacora stelata				X	1
Stylophora mordax	X				1

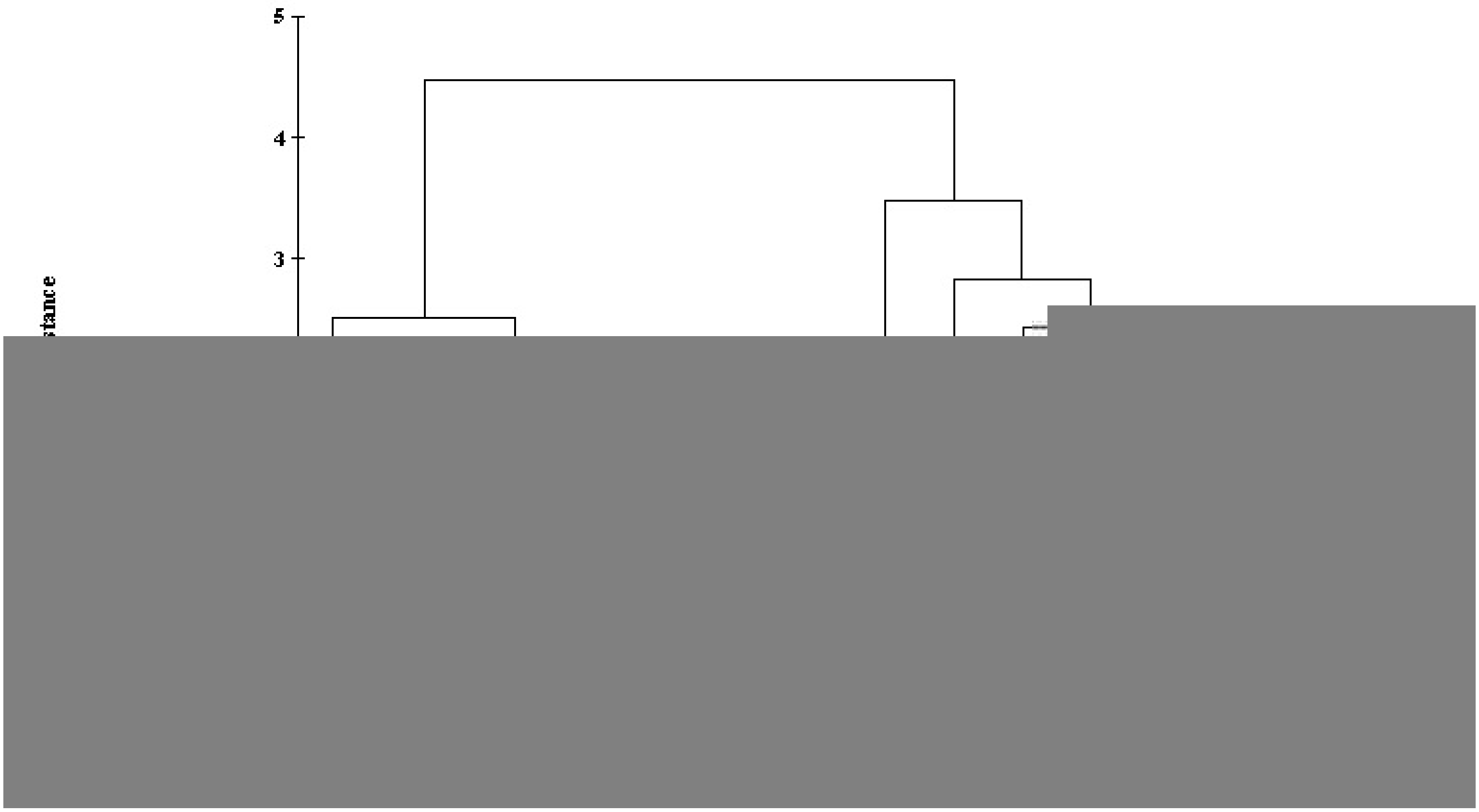


Figure 4. Relationships determined from cluster analysis of Euclidean distance similarity matrix values for benthic habitat structure of Open Inner Reef Flat (OI), Open Outer Reef Flat (OO), Closed Inner Reef Flat (CI) and Closed Outer Reef Flat (CO) stations at the Guam National Wildlife Refuge, Ritidian Unit in 2005.

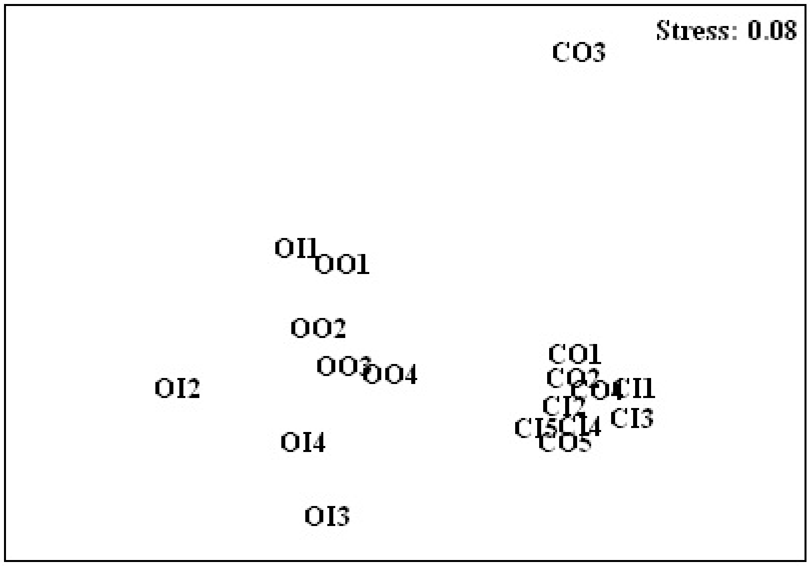


Figure 5. Relationships determined from multidimensional scaling (MDS) analysis of benthic habitat structure between Open Inner Reef Flat (OI), Open Outer Reef Flat (OO), Closed Inner Reef Flat (CI) and Closed Outer Reef Flat (CO) stations at the Guam National Wildlife Refuge, Ritidian Unit in 2005.

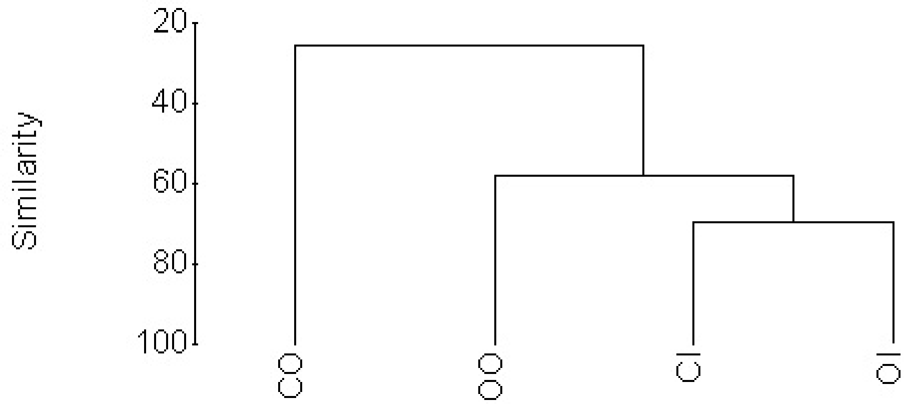


Figure 6. Relationships determined from cluster analysis of Bray-Curtis index similarity matrix values for coral species observed on quadrats on Open Inner Reef Flat (OI), Open Outer Reef Flat (OO), Closed Inner Reef Flat (CI) and Closed Outer Reef Flat (CO) stations at the Guam National Wildlife Refuge, Ritidian Unit in 2005.

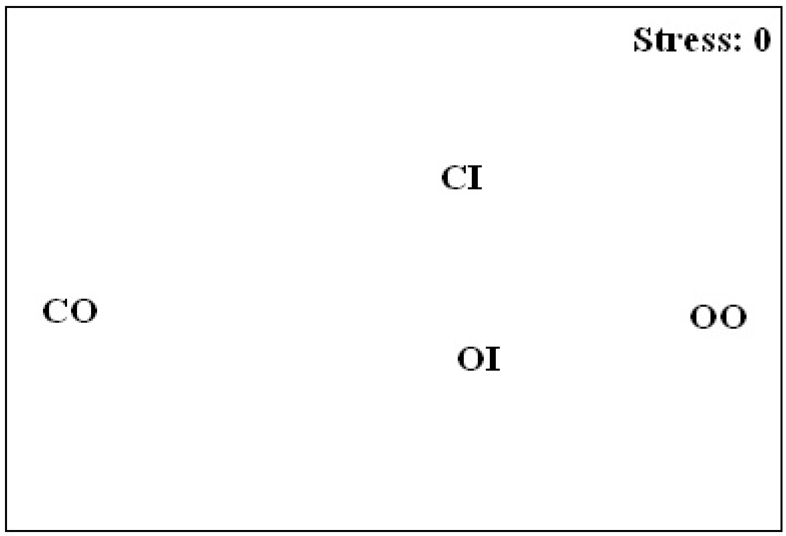
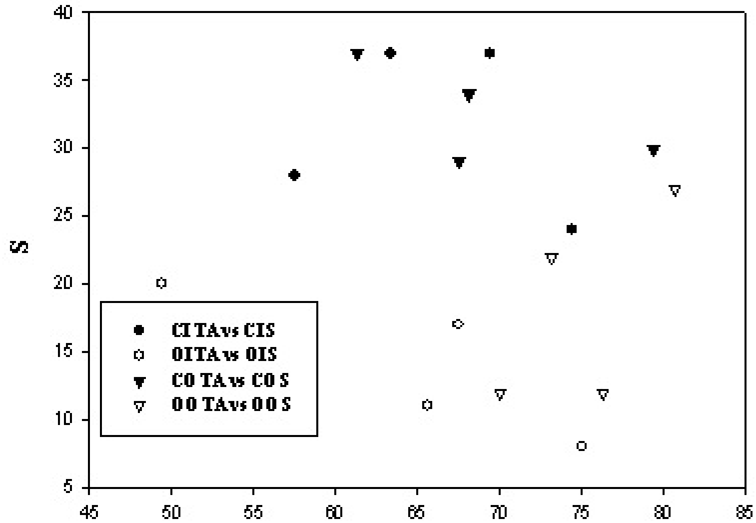


Figure 7. Relationships determined from multidimensional scaling analysis (MDS) of Bray-Curtis index similarity matrix values for coral species observed on quadrats on Open Inner Reef Flat (OI), Open Outer Reef Flat (OO), Closed Inner Reef Flat (CI) and Closed Outer Reef Flat (CO) stations at the Guam National Wildlife Refuge, Ritidian Unit in 2005.



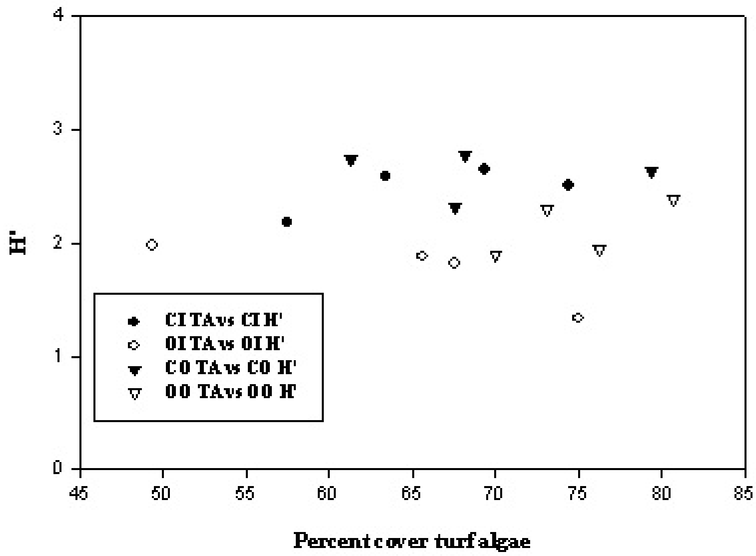


Figure 8. Relationship between fish species richness (S) and diversity (H') and percent turf algae (TA) cover at Open Inner Reef Flat (OI), Open Outer Reef Flat (OO), Closed Inner Reef Flat (CI) and Closed Outer Reef Flat (CO) stations at the Guam National Wildlife Refuge, Ritidian Unit in 2005.

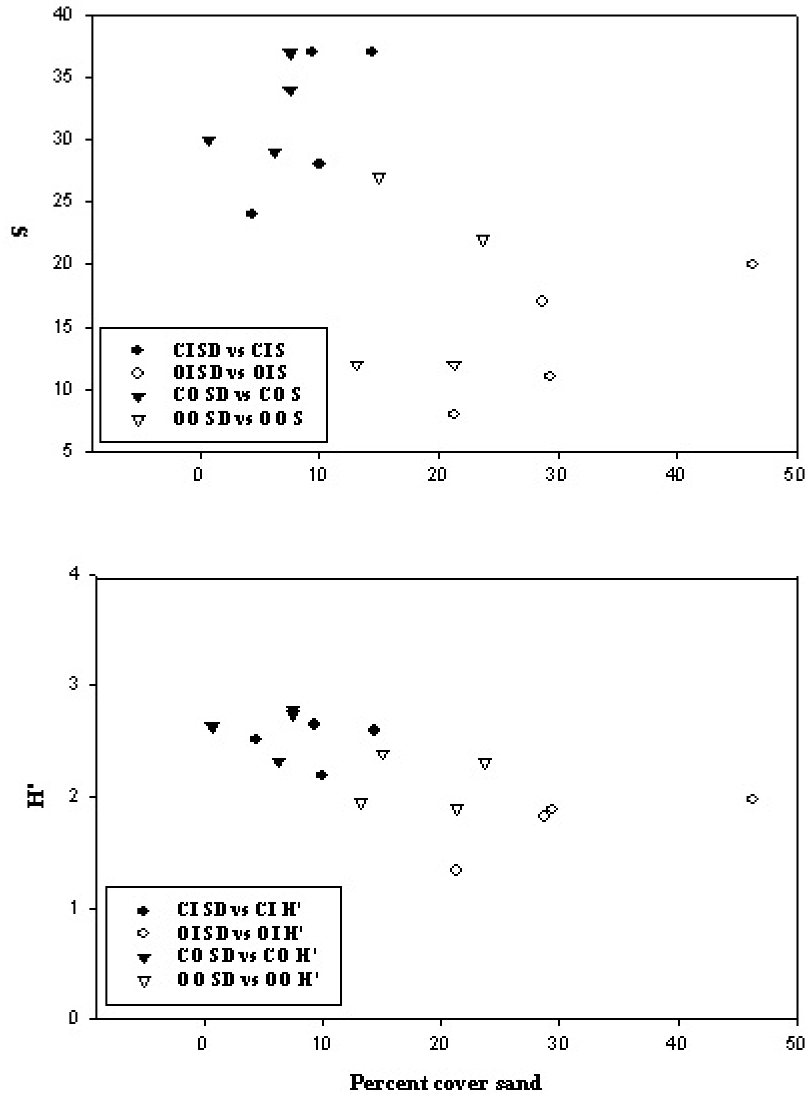


Figure 9. Relationship between fish species richness (S) and diversity (H') and percent cover of sand (SD) at Open Inner Reef Flat (OI), Open Outer Reef Flat (OO), Closed Inner Reef Flat (CI) and Closed Outer Reef Flat (CO) stations at the Guam National Wildlife Refuge, Ritidian Unit in 2005.

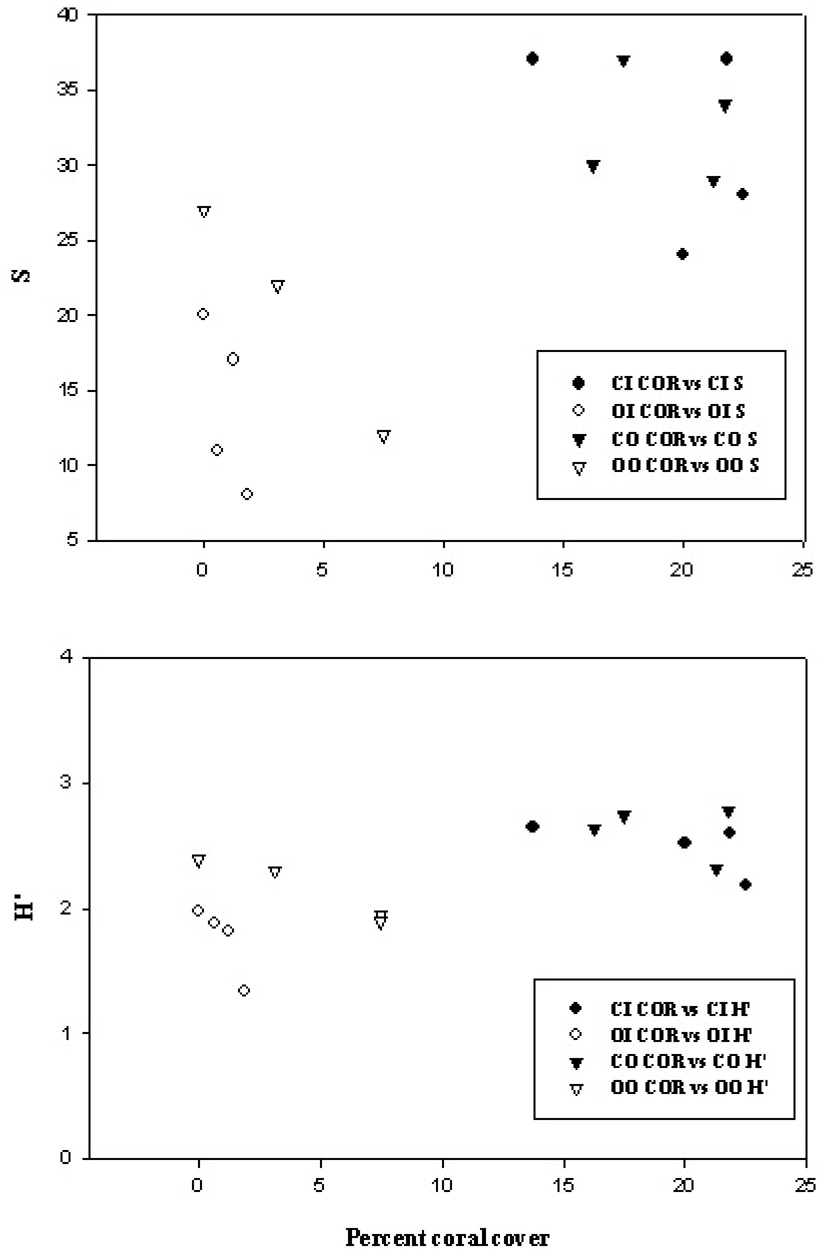


Figure 10. Relationship between fish species richness (S) and diversity (H') and percent coral (COR) cover at Open Inner Reef Flat (OI), Open Outer Reef Flat (OO), Closed Inner Reef Flat (CI) and Closed Outer Reef Flat (CO) stations at the Guam National Wildlife Refuge, Ritidian. Unit in 2005.

CONCLUSIONS

The data presented here constitute a baseline a monitoring series of reef fishes, benthic structure, corals, debris and use on closed and open sites within the Guam National Wildlife Refuge, Ritidian Unit. A limited water temperature profile for the closed site is provided as well.

Some clear differences existed between closed and open sites in reef fish species richness, diversity, and assemblage structure. The Closed Reef Flat site had greater overall values of species richness and diversity and the assemblage structure of this site differed significantly from that of the Open Reef Flat site. Further, abundance and density of reef fishes on the closed site appeared to differ from those of the open site. Individuals of predatory, food and game fish species observed outside the transect boundaries at the closed site appeared to be more common than those observed outside transect boundaries at the open site. Data obtained from future monitoring and subjected to time series analysis are required to determine if these differences will be consistent over time.

Benthic structure of the Closed Reef Flat site differed significantly from that of the Open Reef Flat site, as well. Total corals and macroalgae were both greater on the closed site compared to the open site. Differences in coral species richness and diversity was less pronounced. Outer reef transects at both sites differed significantly from one another but also from the inner reef transects of both sites. This may be because coral assemblages were more developed on outer transects of both sites compared to inner transects, with the latter having considerable sand and macroalgal development instead of corals.

Greater fish species richness and diversity tended to be associated with greater coral cover on outer reef flat transects at both sites but relationships between these two parameters and percent cover of macroalgae or sand were negative or essentially equivocal. This suggests that coral cover at both sites promotes fish assemblage structure and that increases in coral cover may have a positive effect upon fish species richness and diversity over time.

Water temperatures measured for the Closed Reef Flat site ranged just over 5.8 degrees C between October, 2004 and July, 2005, with colder temperatures recorded, as might be expected, during winter months when heavy seas forced cooler water up on to the reef flat. Warmer temperatures occurred during summer months and usually during low tides when much of the reef flat was exposed or nearly so to direct solar heating. Long term monitoring on both closed and open sites, with loggers protected from theft or loss from heavy seas, is needed to discern any pattern that might be attributed to coral bleaching or other negative impacts.

Qualitative observations of anthropogenic debris on and in the area around the permanent transects at both sites indicated that debris deposition is virtually nonexistent, and that debris that may come up onto the reef from offshore would likely be swept downcurrent and into the Ritidian Pass. Long term monitoring, coupled with observations conducted in the Pass with scuba (during periods when surf conditions are slight and currents are slack) should provide data sufficient enough to test this hypothesis.

Qualitative observations of reef and beach use indicated that swimming and sunbathing are principal activities on at the open site, but that hook and line fishing and octopus fishing are also important activities. A more intensive monitoring program, fashioned along the lines of a standard creel survey, conducted both during the week and on weekends during time periods when the Refuge is open, is needed to assess adequately fishing activities at the open site.

RECOMMENDATIONS

1. Long-term monitoring of reef fish species richness, diversity, abundance and density is needed to determine if significant differences between open and closed sites are consistent over time. If differences are consistent, and the closed site maintains values that are greater than those of the open site, then the effectiveness of retaining the closed site in its current state as a “no-take reserve” can be demonstrated.

2. Long-term monitoring of benthic structure and coral species richness, diversity, and abundance of both open and closed sites is needed to assess accurately both stability and changes over time. Coral assemblages on both sites, although differing to some extent in species composition, are in a period of recovery after suffering the destructive effects of previous typhoons. As corals recruit, grow, and mature, the percentage cover of corals will increase with direct effect upon the benthic structure of both sites. In turn, changes in this structure may have a considerable effect upon reef fish assemblage structure at both sites.

3. Long-term water temperature monitoring is needed in order to determine annual patterns and to define and predict periods where negative impacts, such as coral bleaching, may occur. Multiple (to allow for redundancy) temperature loggers should be installed on inner and outer transects at each site and be protected from theft.

4. Long-term monitoring of debris deposition rates is needed to determine seasonal and annual patterns.

5. Long-term monitoring of open site use and a formal creel survey are needed to determine seasonal and annual patterns of use but also to determine patterns and the relative effectiveness of different methods of extraction for reef fishes, octopuses and other marine organisms.

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PLATES

Plate 1. Eroded *Porites lutea* corals and sand on the inner transect of the Open Reef Flat, Guam National Wildlife Refuge, Ritidian Unit. (T.J. Donaldson photograph.)

Plate 2. Typical benthic structure of the Open Reef Flat, Guam National Wildlife Refuge, Ritidian Unit. The bottom is dominated by sand, rubble, some corals, and various macroalgae species. (T.J. Donaldson photograph.)

Plate 3. *Acropora palifera* coral stands on the outer transect of the Closed Reef Flat at the Guam National Wildlife Refuge, Ritidian Unit. This species provided considerable cover to various reef fish species. High surf conditions at this site often resulted in the suspension of sediments in the water column. (T.J. Donaldson photograph.)

Plate 4. *Acropora palifera* ,various eroded corals, macroalgae and sand on the inner transect of the Closed Reef Flat at the Guam National Wildlife Refuge, Ritidian Unit. (T.J. Donaldson photograph.)

Appendix A. Density (number per 250 square meters) of reef fishes at transect stations on open and closed reef flat sites of the Guam National Wildlife Refuge, Ritidian Unit. CI = closed inner reef flat; CO = closed outer reef flat; OI = open inner reef flat; OO = open outer reef flat. Note that many of the species reported here were observed on adjacent transects only, and have values of 0 density.

		Station							
		CI	OI	CO	OO	CI	OI	CO	OO
Species	**Family**	1	1	1	1	2	2	2	2
Carcharhinus melapterus	Carcharhinidae	0	0	0	0	0	0	0	0
Synodus dermatogenys	Synodontidae	0	0	0	0	0	0	0	0
Myrpristis amaena	Holocentridae	0	0	0	0	0	0	0	0
Myrpristis berndti	Holocentridae	0	0	0	0	0	0	0	0
Myrpristis murdjan	Holocentridae	0.004	0	0	0	0	0	0	0
Neoniphon sammara	Holocentridae	0.012	0	0.004	0	0	0	0	0
Sargocentron diadema	Holocentridae	0	0.004	0	0	0	0	0	0
Sargocentron spiniferum	Holocentridae	0	0	0	0	0	0	0	0
Fistularis commersoni	Fistularidae	0	0	0	0	0	0	0	0
Cephalopholis argus	Serranidae	0.004	0	0	0	0	0	0.004	0
Epinephelus merra	Serranidae	0.008	0.004	0.02	0.004	0	0	0	0
Epinephelus tauvina	Serranidae	0	0	0	0	0	0	0.004	0
Cirrhitus pinnulatus	Cirrhitidae	0	0	0	0	0	0	0	0
Paracirrhites forsteri	Cirrhitidae	0	0	0	0	0	0	0.004	0
Apogon novemfasciatus	Apogonidae	0	0	0	0	0	0	0	0
					Station				

Species	Family	CI 1	OI 1	CO 1	OO 1	CI 2	OI 2	CO 2	OO 2
Caranx melampygus	Carangidae	0	0	0	0	0	0	0	0
Gnathodentex aurolineatus	Lethrinidae	0.028	0	0.016	0	0.048	0	0.024	0
Monotaxis grandoculis	Lethrinidae	0.004	0	0	0	0	0	0	0
Scolopis bilineata	Nemipteridae	0.008	0	0.008	0	0	0	0.004	0
Mulloidichthys flavolineatus	Mullidae	0	0	0	0	0	0	0	0
Mulloidichthys vanicolensis	Mullidae	0	0	0	0	0	0	0	0
Parupeneus crassilabris	Mullidae	0	0	0	0	0	0	0	0
Parupenus cyclostoma	Mullidae	0	0	0	0	0	0	0	0
Parupenus multifasciata	Mullidae	0	0	0	0	0	0	0	0
Pempheris oualensis	Pempheridae	0	0	0	0	0	0	0	0
Chaetodon auriga	Chaetodontidae	0.016	0.004	0	0.008	0.016	0	0.016	0.004
Chaetodon bennetti	Chaetodontidae	0	0	0	0	0	0	0	0
Chaetodon citrinellus	Chaetodontidae	0	0	0.008	0.004	0.016	0.0	0.004	0.004
Chaetodon ephippium	Chaetodontidae	0.004	0	0	0	0	0	0	0
Chaetodon lunula	Chaetodontidae	0	0	0	0	0	0.0	0	0
Chaetodon melanotus	Chaetodontidae	0	0	0	0	0	0	0	0
Chaetodon ornatissimus	Chaetodontidae	0	0	0	0	0	0	0.004	0
Chaetodon reticulatus	Chaetodontidae	0.008	0	0	0	0.004	0	0.008	0
Chaetodon trifascialis	Chaetodontidae	0	0	0.004	0	0	0	0	0
Chaetodon ulietensis	Chaetodontidae	0	0	0	0	0	0	0	0

Station

Species	Family	CI 1	OI 1	CO 1	OO 1	CI 2	OI 2	CO 2	OO 2
Forcipinger flavissimus	Chaetodontidae	0	0	0	0	0	0	0	0
Heniochus chrysostomus	Chaetodontidae	0	0	0	0	0	0	0	0
Pomacanthus imperator	Pomacanthidae	0	0	0	0	0	0	0	0
Pygoplites diacanthus	Pomacanthidae	0	0	0	0	0	0	0	0
Abudefduf sexfasciatus	Pomacentridae	0	0	0	0	0	0	0	0
Abudefduf sordidus	Pomacentridae	0	0	0	0	0	0	0	0
Abudefduf septemfasciatus	Pomacentridae	0	0	0	0	0	0	0	0
Abudefduf vaigiensis	Pomacentridae	0	0	0	0	0	0	0	0
Chrysiptera biocellata	Pomacentridae	0	0	0	0.004	0	0.0	0	0
Chrysiptera brownriggi	Pomacentridae	0.008	0.012	0.092	0.076	0.04	0	0.04	0.028
Chrysiptera glauca	Pomacentridae	0	0.032	0	0.036	0	0.0	0.004	0.052
Chrysiptera traceyi	Pomacentridae	0	0	0.012	0	0	0	0	0
Plectroglyphididon dickii	Pomacentridae	0.024	0	0	0	0.004	0	0.016	0
Plectroglyphididon johnstonianus	Pomacentridae	0	0	0	0	0	0	0.004	0
Plectroglyphididon lacrymatus	Pomacentridae	0	0	0	0	0	0	0	0
Plectroglyphididon leucozona	Pomacentridae	0	0	0	0	0	0	0	0
Plectroglyphididon phoenixensis	Pomacentridae	0	0	0	0	0	0	0	0
Pomacentrus vaiuli	Pomacentridae	0.024	0	0.02	0	0.012	0	0.02	0
Stegastes albifasciatus	Pomacentridae	0.296	0.008	0.428	0.016	0.224	0	0.176	0.016
Stegastes fasciatus	Pomacentridae	0	0	0	0	0	0	0	0
Stegastes lividus	Pomacentridae	0	0	0	0	0	0	0	0

Station

Species	Family	CI 1	OI 1	CO 1	OO 1	CI 2	OI 2	CO 2	OO 2
Stegastes nigricans	Pomacentridae	0.020	0	0.004	0	0	0	0	0
Anampses caeruleopunctatus	Labridae	0.004	0	0.004	0	0	0	0	0
Anampses meleagris	Labridae	0.012	0	0.028	0	0.048	0	0.036	0.004
Cheilinus trilobatus	Labridae	0	0	0	0.004	0.004	0	0	0
Cheilinus undulatus	Labridae	0.008	0	0.004	0	0	0	0.012	0
Coris aygula	Labridae	0.004	0	0	0	0	0	0	0
Coris gaimard	Labridae	0	0	0	0	0	0	0	0
Epibulus insidiator	Labridae	0.004	0	0	0	0	0	0	0
Gomphosus varius	Labridae	0	0	0	0	0.004	0	0	0
Halichoeres hortulanus	Labridae	0.028	0	0.04	0	0.044	0	0.012	0
Halichoeres margaritaceus	Labridae	0.004	0	0.02	0	0	0	0.008	0
Halichoeres ornatissimus	Labridae	0	0	0	0	0	0	0	0
Halichoeres richmondi	Labridae	0	0	0	0	0	0	0	0
Halichoeres trimaculatus	Labridae	0.024	0.056	0.044	0.048	0.024	0.0	0.016	0.12
Hemigymnus fasciatus	Labridae	0.004	0	0.04	0.004	0	0	0.004	0
Hemigymnus melapterus	Labridae	0	0	0.004	0	0	0	0	0
Labroides dimidiatus	Labridae	0.020	0	0.012	0	0.004	0	0	0
Novaculichthys taeniorous	Labridae	0	0	0	0	0	0	0	0.004
Oxycheilinus unifasciatus	Labridae	0	0	0	0	0	0	0	0
Stethojulis bandanensis	Labridae	0.004	0.016	0.052	0.012	0.016	0.0	0.008	0.056
Stethojulis strigiventer	Labridae	0.004	0.004	0.008	0	0	0	0.016	0

Station

Species	Family	CI 1.000	OI 1	CO 1	OO 1	CI 2	OI 2	CO 2	OO 2
Thalassoma amblycephalum	Labridae	0.008	0	0.004	0	0	0	0	0
Thalassoma hardwicke	Labridae	0	0	0.004	0	0.008	0	0	0
Thalassoma lutescens	Labridae	0	0	0	0	0.012	0	0.008	0
Thalassoma purpureum	Labridae	0	0	0	0	0	0	0	0
Thalassoma quinquevittatum	Labridae	0	0	0	0	0	0	0	0
Calatomus carolinus	Scaridae	0	0	0	0	0.016	0	0.004	0
Chlorurus microrhinos	Scaridae	0	0	0	0	0	0	0	0
Chlorurus sordidus	Scaridae	0.040	0	0.036	0	0.044	0	0.112	0
Scarus niger	Scaridae	0	0	0	0	0	0	0	0
Scarus psittacus	Scaridae	0	0	0	0	0	0	0	0
Parapercis clathrata	Pinguipedidae	0	0	0	0	0	0	0	0
Parapercis millipunctata	Pinguipedidae	0	0	0	0	0	0	0	0
Cirripectes variolusus	Blenniidae	0	0	0	0	0	0	0	0
Ecsenius bicolor	Blenniidae	0	0	0	0	0	0	0	0
Exalias brevis	Blenniidae	0	0	0	0	0	0	0	0
Plagiotremus tapeinosoma	Blenniidae	0	0	0	0	0	0	0	0.004
Salarias fasciatus	Blenniidae	0.004	0	0	0	0	0	0	0
Valenciennea strigata	Gobiidae	0	0	0	0	0	0	0	0
Zanclus cornutus	Zanclidae	0	0	0	0	0	0	0.004	0
Siganus spinus	Siganidae	0	0	0	0	0	0	0	0
		CI	OI	CO	OO	CI	OI	CO	OO

Species	Family	1	1	1	1	2	2	2	2
Acanthurus guttatus	Acanthuridae	0	0	0	0	0	0	0	0
Acanthurus lineatus	Acanthuridae	0	0	0	0	0	0	0	0
Acanthurus nigoris	Acanthuridae	0.004	0	0	0	0.024	0	0	0
Acanthurus nigricans	Acanthuridae	0.008	0	0	0	0.004	0	0.008	0
Acanthurus nigrofuscus	Acanthuridae	0.036	0.004	0.032	0.012	0.028	0	0.012	0
Acanthurus triostegus	Acanthuridae	0.004	0.004	0.012	0	0.016	0.0	0.036	0.032
Ctenochaetus binotatus	Acanthuridae	0	0	0	0	0	0	0	0
Ctenochaetus striatus	Acanthuridae	0.004	0	0	0	0	0	0.032	0
Naso annulatus	Acanthuridae	0	0	0	0	0	0	0.004	0
Naso literatus	Acanthuridae	0.008	0	0.012	0	0.004	0.0	0.012	0.008
Zebrasoma flavescens	Acanthuridae	0.008	0	0	0	0	0	0.004	0
Zebrasoma scopas	Acanthuridae	0	0	0	0	0	0	0	0
Balistapus undulatus	Balistidae	0	0	0.004	0	0	0	0	0
Pseudobalistes flavimarginatus	Balistidae	0	0	0	0	0	0	0	0
Rhinecanthus aculeatus	Balistidae	0	0	0	0	0	0	0	0
Rhinecanthus rectangularis	Balistidae	0	0	0	0	0	0	0	0
Sufflamen chrysoptera	Balistidae	0	0	0	0	0	0	0	0
Amanses scopas	Monacanthidae	0	0	0	0	0	0	0	0
Oxymonacanthus longirostris	Monacanthidae	0	0	0	0	0	0	0	0
Ostracion cubicus	Ostracionidae	0	0	0	0	0	0	0	0
Canthigaster janthinaoptera	Tetraodontidae	0	0	0	0	0	0	0	0
Canthigaster solandri	Tetraodontidae	0	0	0	0	0	0	0	0

		Station									
		CI	OI	CO	OO	CI	OI	CO	OO	CI	CO
Species	Family	3	3	3	3	4	4	4	4	5	5
Carcharhinus melapterus	Carcharhinidae	0	0	0	0	0	0	0	0	0.004	0
Synodus dermatogenys	Synodontidae	0	0	0	0.004	0	0	0	0	0	0
Myrpristis amaena	Holocentridae	0	0	0	0	0	0	0	0	0	0
Myrpristis berndti	Holocentridae	0	0	0	0	0.004	0	0	0	0	0
Myrpristis murdjan	Holocentridae	0	0	0	0	0	0	0	0	0	0
Neoniphon sammara	Holocentridae	0	0	0	0	0.004	0	0.004	0	0	0
Sargocentron diadema	Holocentridae	0	0	0.004	0	0	0	0	0	0.004	0
Sargocentron spiniferum	Holocentridae	0	0	0	0	0	0	0	0	0	0
Fistularis commersoni	Fistularidae	0	0	0	0	0	0.0	0	0	0	0
Cephalopholis argus	Serranidae	0	0	0.004	0	0.004	0	0.004	0	0	0
Epinephelus merra	Serranidae	0	0	0.004	0	0.004	0	0.008	0	0.004	0.004
Epinephelus tauvina	Serranidae	0	0	0	0	0	0	0	0	0	0
Cirrhitus pinnulatus	Cirrhitidae	0	0	0	0	0	0	0	0	0	0
Paracirrhites forsteri	Cirrhitidae	0	0	0	0	0.004	0	0.004	0	0.004	0
Apogon novemfasciatus	Apogonidae	0	0	0	0.004	0	0.0	0	0	0	0
Caranx melampygus	Carangidae	0	0	0.004	0	0	0	0	0	0	0
Gnathodentex aurolineatus	Lethrinidae	0.016	0	0.004	0	0.028	0	0.048	0	0.016	0.02
Monotaxis grandoculis	Lethrinidae	0	0	0	0	0	0	0	0	0	0

Station

Species	Family	CI 3	OI 3	CO 3	OO 3	CI 4	OI 4	CO 4	OO 4	CI 5	CO 5
Scolopis bilineata	Nemipteridae	0.004	0	0.004	0	0	0	0.008	0	0	0
Mulloidichthys flavolineatus	Mullidae	0	0	0	0	0	0	0	0	0	0
Mulloidichthys vanicolensis	Mullidae	0	0	0	0	0	0	0	0	0	0.004
Parupeneus crassilabris	Mullidae	0	0	0	0.004	0	0	0	0	0	0
Parupenus cyclostoma	Mullidae	0.008	0	0	0	0	0	0	0	0	0
Parupenus multifasciata	Mullidae	0	0	0	0	0	0	0.012	0	0	0
Pempheris oualensis	Pempheridae	0	0	0	0	0	0	0	0	0	0
Chaetodon auriga	Chaetodontidae	0.004	0	0.008	0.004	0.004	0	0.004	0.012	0.008	0.004
Chaetodon bennetti	Chaetodontidae	0	0	0	0	0	0	0	0	0	0
Chaetodon citrinellus	Chaetodontidae	0.004	0	0.004	0.004	0.012	0.0	0	0.008	0.004	0
Chaetodon ephippium	Chaetodontidae	0.004	0	0	0	0	0	0.004	0	0	0.004
Chaetodon lunula	Chaetodontidae	0	0	0	0	0	0	0	0	0	0
Chaetodon melanotus	Chaetodontidae	0	0	0	0	0.004	0	0.008	0	0	0
Chaetodon ornatissimus	Chaetodontidae	0	0	0	0	0	0	0	0	0	0
Chaetodon reticulatus	Chaetodontidae	0.004	0	0	0	0.004	0	0.008	0	0.004	0.008
Chaetodon trifascialis	Chaetodontidae	0	0	0.012	0	0	0	0	0	0	0
Chaetodon ulietensis	Chaetodontidae	0	0	0	0	0	0	0	0	0.004	0
Forcipinger flavissimus	Chaetodontidae	0	0	0	0	0	0	0	0	0	0
Heniochus chrysostomus	Chaetodontidae	0	0	0	0	0	0	0	0	0	0
Pomacanthus imperator	Pomacanthidae	0	0	0	0	0	0	0	0.008	0	0
Pygoplites diacanthus	Pomacanthidae	0	0	0	0	0	0	0	0	0	0

Station

Species	Family	CI 3	OI 3	CO 3	OO 3	CI 4	OI 4	CO 4	OO 4	CI 5	CO 5
Abudefduf sexfasciatus	**Pomacentridae**	**0**	**0**	**0**	**0**	**0**	**0**	**0.004**	**0**	**0.004**	**0**
Abudefduf sordidus	**Pomacentridae**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Abudefduf septemfasciatus	**Pomacentridae**	**0**	**0.008**	**0**	**0.004**	**0**	**0**	**0**	**0**	**0**	**0**
Abudefduf vaigiensis	**Pomacentridae**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0.072**	**0.008**
Chrysiptera biocellata	**Pomacentridae**	**0**	**0.016**	**0**	**0.012**	**0**	**0.0**	**0**	**0.004**	**0**	**0**
Chrysiptera brownriggi	**Pomacentridae**	**0.016**	**0.004**	**0**	**0.016**	**0.036**	**0.0**	**0.152**	**0.132**	**0.06**	**0.104**
Chrysiptera glauca	**Pomacentridae**	**0**	**0.004**	**0.032**	**0.04**	**0.008**	**0.0**	**0.036**	**0.068**	**0.008**	**0.02**
Chrysiptera traceyi	**Pomacentridae**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Plectroglyphididon dickii	**Pomacentridae**	**0.028**	**0**	**0**	**0**	**0.024**	**0**	**0.012**	**0.008**	**0.02**	**0.06**
Plectroglyphididon johnstonianus	**Pomacentridae**	**0**	**0**	**0.008**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Plectroglyphididon lacrymatus	**Pomacentridae**	**0**	**0**	**0.004**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Plectroglyphididon leucozona	**Pomacentridae**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Plectroglyphididon phoenixensis	**Pomacentridae**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Pomacentrus vaiuli	**Pomacentridae**	**0.012**	**0.004**	**0**	**0.008**	**0.028**	**0.0**	**0.052**	**0.004**	**0.008**	**0.028**
Stegastes albifasciatus	**Pomacentridae**	**0.396**	**0**	**0.016**	**0.032**	**0.292**	**0.0**	**0.344**	**0.044**	**0.252**	**0.284**
Stegastes fasciatus	**Pomacentridae**	**0**	**0**	**0.176**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Stegastes lividus	**Pomacentridae**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0.004**
Stegastes nigricans	**Pomacentridae**	**0**	**0**	**0**	**0**	**0.008**	**0**	**0**	**0**	**0.008**	**0**
Anampses caeruleopunctatus	**Labridae**	**0**	**0**	**0**	**0**	**0.012**	**0**	**0.008**	**0**	**0**	**0**
Anampses meleagris	**Labridae**	**0.036**	**0.004**	**0**	**0**	**0.004**	**0.0**	**0.032**	**0.02**	**0**	**0.02**

Station

Species	Family	CI 3	OI 3	CO 3	OO 3	CI 4	OI 4	CO 4	OO 4	CI 5	CO 5
Cheilinus trilobatus	Labridae	0.008	0	0.008	0	0.012	0	0.004	0	0	0
Cheilinus undulatus	Labridae	0.004	0	0.004	0	0	0	0	0	0.004	0.004
Coris aygula	Labridae	0	0	0	0.004	0.004	0	0	0.004	0	0
Coris gaimard	Labridae	0	0	0	0	0	0	0	0.004	0	0
Epibulus insidiator	Labridae	0	0	0	0	0	0	0	0	0	0
Gomphosus varius	Labridae	0.004	0	0	0	0	0	0.008	0	0.016	0.016
Halichoeres hortulanus	Labridae	0.036	0	0	0.004	0.012	0	0.016	0.004	0.012	0.02
Halichoeres margaritaceus	Labridae	0	0	0.036	0.004	0.02	0	0.004	0.004	0.012	0
Halichoeres ornatissimus	Labridae	0	0.004	0	0	0	0	0.012	0	0	0.024
Halichoeres richmondi	Labridae	0	0	0.008	0	0	0	0	0	0	0
Halichoeres trimaculatus	Labridae	0.008	0.072	0	0.124	0.104	0.2	0.076	0.176	0.088	0.076
Hemigymnus fasciatus	Labridae	0	0.004	0.004	0	0	0	0	0	0	0
Hemigymnus melapterus	Labridae	0	0	0	0	0	0	0	0	0.004	0.004
Labroides dimidiatus	Labridae	0.008	0	0	0	0.008	0	0.012	0	0	0.012
Novaculichthys taeniorous	Labridae	0	0	0	0	0	0	0	0.004	0.004	0
Oxycheilinus unifasciatus	Labridae	0	0	0	0	0	0	0	0	0	0
Stethojulis bandanensis	Labridae	0.012	0.012	0	0.036	0.008	0.0	0.084	0.028	0.084	0.096
Stethojulis strigiventer	Labridae	0	0	0.028	0	0	0	0	0	0	0
Thalassoma amblycephalum	Labridae	0	0	0	0	0	0	0	0	0	0
Thalassoma hardwicke	Labridae	0	0.004	0	0.004	0.028	0.0	0.032	0.004	0.004	0.012

Station

Species	Family	CI 3	OI 3	CO 3	OO 3	CI 4	OI 4	CO 4	OO 4	CI 5	CO 5
Thalassoma lutescens	Labridae	0	0	0	0	0.016	0	0.012	0	0	0
Thalassoma purpureum	Labridae	0	0	0	0	0	0	0	0	0	0
Thalassoma quinquevittatum	Labridae	0	0	0	0	0	0	0.008	0.008	0	0.004
Calatomus carolinus	Scaridae	0	0	0	0	0	0	0	0.012	0	0
Chlorurus microrhinos	Scaridae	0	0	0	0	0	0	0	0	0.004	0
Chlorurus sordidus	Scaridae	0.072	0.16	0	0	0.032	0.0	0.04	0	0.064	0.06
Scarus niger	Scaridae	0	0	0.052	0	0	0	0	0	0	0
Scarus psittacus	Scaridae	0	0	0	0	0.104	0	0.004	0	0.012	0
Parapercis clathrata	Pinguipedidae	0	0	0	0	0	0	0	0.004	0	0
Parapercis millipunctata	Pinguipedidae	0	0	0	0.004	0	0	0	0	0	0
Cirripectes variolusus	Blenniidae	0	0	0.008	0	0	0	0	0	0	0
Ecsenius bicolor	Blenniidae	0	0	0	0	0	0	0	0	0	0
Exalias brevis	Blenniidae	0	0	0	0	0	0	0	0	0.004	0
Plagiotremus tapeinosoma	Blenniidae	0	0	0	0	0	0	0	0	0	0
Salarias fasciatus	Blenniidae	0.004	0	0	0	0	0.0	0	0	0	0.008
Valenciennea strigata	Gobiidae	0	0	0	0	0	0.0	0	0.004	0	0
Zanclus cornutus	Zanclidae	0.004	0	0	0	0.004	0	0	0.004	0.004	0.016
Siganus spinus	Siganidae	0	0	0	0	0	0	0	0	0	0
Acanthurus guttatus	Acanthuridae	0	0	0	0	0	0	0	0	0	0
Acanthurus lineatus	Acanthuridae	0	0	0	0	0	0	0	0	0	0

Station

Species	Family	CI 3	OI 3	CO 3	OO 3	CI 4	OI 4	CO 4	OO 4	CI 5	CO 5
Acanthurus nigoris	Acanthuridae	0.052	0	0.004	0	0.004	0	0.004	0	0	0.004
Acanthurus nigricans	Acanthuridae	0.004	0.004	0	0	0.004	0.0	0	0	0.008	0.004
Acanthurus nigrofuscus	Acanthuridae	0.036	0.008	0.008	0.004	0.004	0	0.104	0	0.012	0.012
Acanthurus triostegus	Acanthuridae	0.02	0.004	0.016	0.004	0.008	0.0	0.072	0.036	0.004	0.004
Ctenochaetus binotatus	Acanthuridae	0	0	0	0	0.004	0	0	0	0.04	0
Ctenochaetus striatus	Acanthuridae	0.024	0	0.012	0	0.084	0	0.02	0	0.004	0.06
Naso annulatus	Acanthuridae	0	0	0.032	0.004	0	0.0	0	0.004	0	0.004
Naso literatus	Acanthuridae	0	0.02	0	0.016	0	0.0	0	0.004	0.012	0.004
Zebrasoma flavescens	Acanthuridae	0	0	0.008	0	0	0	0.004	0	0	0.004
Zebrasoma scopas	Acanthuridae	0	0	0	0	0	0	0	0	0	0.004
Balistapus undulatus	Balistidae	0	0	0.012	0	0	0	0	0	0	0
Pseudobalistes flavimarginatus	Balistidae	0	0	0	0	0	0	0	0	0	0
Rhinecanthus aculeatus	Balistidae	0	0	0	0	0	0	0	0	0	0
Rhinecanthus rectangularis	Balistidae	0	0	0	0	0	0	0	0	0	0
Sufflamen chrysoptera	Balistidae	0	0	0	0	0	0	0	0	0	0
Amanses scopas	Monacanthidae	0.004	0	0	0	0	0	0	0	0	0
Oxymonacanthus longirostris	Monacanthidae	0	0	0	0	0	0	0	0	0	0.004
Ostracion cubicus	Ostracionidae	0	0	0.004	0	0	0	0	0	0	0
Canthigaster janthinaoptera	Tetraodontidae	0	0	0	0	0	0	0	0	0	0
Canthigaster solandri	Tetraodontidae	0	0.004	0	0	0.004	0.0	0	0.008	0	0.004

Appendix B. **Benthic structure of Closed Inner Reef Flat (CI), Closed Outer Reef Flat (CO), Open Inner Reef Flat (OI), and Open Outer Reef Flat (OO) sites at the Guam National Wildlife Refuge, Ritidian Unit. Values are percent cover.**

Species	Family	CI	OI	Both	CO	OO	Both
Carcharhinus melapterus	Carcharhinidae	1					
Synodus dermatogenys	Synodontidae					1	
Myrpristis amaena	Holocentridae						
Myrpristis berndti	Holocentridae	1					
Myrpristis murdjan	Holocentridae	1					
Neoniphon sammara	Holocentridae	1			1		
Sargocentron diadema	Holocentridae	1	1	1	1		
Sargocentron spiniferum	Holocentridae						
Fistularis commersoni	Fistularidae		1				
Cephalopholis argus	Serranidae	1			1		
Epinephelus merra	Serranidae	1	1	1	1	1	1
Epinephelus tauvina	Serranidae				1		
Cirrhitus pinnulatus	Cirrhitidae						
Paracirrhites forsteri	Cirrhitidae	1			1		
Apogon novemfasciatus	Apogonidae		1			1	
Caranx melampygus	Carangidae				1		
Gnathodentex aurolineatus	Lethrinidae	1			1		
Monotaxis grandoculis	Lethrinidae	1					
Scolopsis lineata	Nemipteridae	1			1		

Species	Family	CI	OI	Both	CO	OO	Both
Mulloidichthys flavolineatus	Mullidae						
Mulloidichthys vanicolensis	Mullidae				1		
Parupeneus crassilabris	Mullidae					1	
Parupenus cyclostoma	Mullidae	1					
Parupenus multifasciata	Mullidae				1		
Pempheris oualensis	Pempheridae						
Chaetodon auriga	Chaetodontidae	1	1	1	1	1	1
Chaetodon bennetti	Chaetodontidae						
Chaetodon citrinellus	Chaetodontidae	1	1	1	1	1	
Chaetodon ephippium	Chaetodontidae	1			1		
Chaetodon lunula	Chaetodontidae		1				
Chaetodon melanotus	Chaetodontidae	1			1		
Chaetodon ornatissimus	Chaetodontidae				1		
Chaetodon reticulatus	Chaetodontidae	1			1		
Chaetodon trifascialis	Chaetodontidae				1		
Chaetodon ulietensis	Chaetodontidae	1					
Forcipinger flavissimus	Chaetodontidae						
Heniochus chrysostomus	Chaetodontidae						
Pomacanthus imperator	Pomacanthidae					1	
Pygoplites diacanthus	Pomacanthidae						
Abudefduf sexfasciatus	Pomacentridae	1			1		
Abudefduf sordidus	Pomacentridae						

Species	Family	CI	OI	Both	CO	OO	Both
Abudefduf septemfasciatus	**Pomacentridae**		**1**			**1**	
Abudefduf vaigiensis	**Pomacentridae**	**1**			**1**		
Chrysiptera biocellata	**Pomacentridae**		**1**			**1**	
Chrysiptera brownriggi	**Pomacentridae**	**1**	**1**	**1**	**1**	**1**	**1**
Chrysiptera glauca	**Pomacentridae**	**1**	**1**	**1**	**1**	**1**	**1**
Chrysiptera traceyi	**Pomacentridae**				**1**		
Plectroglyphididon dickii	**Pomacentridae**	**1**			**1**	**1**	**1**
Plectroglyphididon johnstonianus	**Pomacentridae**				**1**		
Plectroglyphididon lacrymatus	**Pomacentridae**				**1**		
Plectroglyphididon leucozona	**Pomacentridae**						
Plectroglyphididon phoenixensis	**Pomacentridae**						
Pomacentrus vaiuli	**Pomacentridae**	**1**	**1**	**1**	**1**	**1**	**1**
Stegastes albifasciatus	**Pomacentridae**	**1**	**1**	**1**	**1**	**1**	**1**
Stegastes fasciatus	**Pomacentridae**				**1**		
Stegastes lividus	**Pomacentridae**				**1**		
Stegastes nigricans	**Pomacentridae**				**1**		
Anampses caeruleopunctatus	**Labridae**	**1**			**1**		
Anampses meleagris	**Labridae**	**1**	**1**	**1**	**1**	**1**	**1**
Cheilinus trilobatus	**Labridae**	**1**			**1**	**1**	**1**
Cheilinus undulatus	**Labridae**	**1**			**1**		
Coris aygula	**Labridae**	**1**				**1**	
Coris gaimard	**Labridae**					**1**	

Species	Family	CI	OI	Both	CO	OO	Both
Epibulus insidiator	Labridae	1					
Gomphosus varius	Labridae	1			1		
Halichoeres hortulanus	Labridae	1			1	1	1
Halichoeres margaritaceus	Labridae	1			1	1	1
Halichoeres ornatissimus	Labridae		1		1		
Halichoeres richmondi	Labridae				1		
Halichoeres trimaculatus	Labridae	1	1	1	1	1	1
Hemigymnus fasciatus	Labridae	1	1	1	1	1	1
Hemigymnus melapterus	Labridae	1			1		
Labroides dimidiatus	Labridae	1			1		
Novaculichthys taeniorous	Labridae	1				1	
Oxycheilinus unifasciatus	Labridae						
Stethojulis bandanensis	Labridae	1	1	1	1	1	
Stethojulis strigiventer	Labridae	1	1	1	1		
Thalassoma amblycephalum	Labridae	1			1		
Thalassoma hardwicke	Labridae	1	1	1	1	1	1
Thalassoma lutescens	Labridae	1			1		
Thalassoma purpureum	Labridae						
Thalassoma quinquevittatum	Labridae				1	1	1
Calatomus carolinus	Scaridae	1			1	1	1
Chlorurus microrhinos	Scaridae	1					
Chlorurus sordidus	Scaridae	1	1	1	1		

Species	Family	CI	OI	Both	CO	OO	Both
Scarus niger	Scaridae				1		
Scarus psittacus	Scaridae	1			1		
Parapercis clathrata	Pinguipedidae					1	
Parapercis millipunctata	Pinguipedidae					1	
Cirripectes variolusus	Blenniidae				1		
Ecsenius bicolor	Blenniidae						
Exalias brevis	Blenniidae	1					
Plagiotremus tapeinosoma	Blenniidae					1	
Salarias fasciatus	Blenniidae	1	1	1	1		
Valenciennea strigata	Gobiidae		1			1	
Zanclus cornutus	Zanclidae	1			1	1	
Siganus spinus	Siganidae						
Acanthurus guttatus	Acanthuridae						
Acanthurus lineatus	Acanthuridae						
Acanthurus nigoris	Acanthuridae	1			1		
Acanthurus nigricans	Acanthuridae	1	1	1	1		
Acanthurus nigrofuscus	Acanthuridae	1	1	1	1	1	1
Acanthurus triostegus	Acanthuridae	1	1	1	1	1	1
Ctenochaetus binotatus	Acanthuridae	1					
Ctenochaetus striatus	Acanthuridae	1			1		
Naso annulatus	Acanthuridae		1		1	1	1
Naso literatus	Acanthuridae	1	1	1	1	1	1

Species	Family	CI	OI	Both	CO	OO	Both
Zebrasoma flavescens	**Acanthuridae**	1			1		
Zebrasoma scopas	**Acanthuridae**				1		
Balistapus undulatus	**Balistidae**				1		
Pseudobalistes flavimarginatus	**Balistidae**						
Rhinecanthus aculeatus	**Balistidae**						
Rhinecanthus rectangularis	**Balistidae**						
Sufflamen chrysoptera	**Balistidae**						
Amanses scopas	**Monacanthidae**	1					
Oxymonacanthus longirostris	**Monacanthidae**				1		
Ostracion cubicus	**Ostracionidae**				1		
Canthigaster janthinaoptera	**Tetraodontidae**						
Canthigaster solandri	**Tetraodontidae**	1	1	1	1	1	1
Total species		61	29	21	70	37	21

Appendix C. Benthic structure of Closed Inner Reef Flat (CI), Closed Outer Reef Flat (CO), Open Inner Reef Flat (OI), and Open Outer Reef Flat (OO) sites at the Guam National Wildlife Refuge, Ritidian Unit. Values are percent cover.

Turf algae			Site		Macroalgae			Site	
	CI	OI	CO	OO		CI	OI	CO	OO
Transect					Transect				
1	63.3	65.6	67.5	76.25	1	0.63	0	4.4	1.25
2	74.3	75	68.12	70	2	4.37	1.87	2.5	1.25
3	57.5	67.5	79.37	73.12	3	10	1.25	3.75	0
4	69.3	49.37	61.25	80.62	4	7.5	3.12	12.5	1.87
mean	66.1	64.38	69.06	75	mean	5.63	1.56	5.79	1.09
SE	3.6	5.39	3.77	2.27	SE	2.02	0.65	2.27	0.39
n	4	4	4	4	n	4	4	4	4

Coralline algae			Site		Sponge			Site	
	CI	OI	CO	OO		CI	OI	CO	OO
Transect					Transect				
1	0	0	0.62	0	1	0	0	0	0
2	0	0	0	0	2	0	0	0	0
3	0	0	0	0	3	0	0	0	0
4	0	0	1.25	0	4	0	0	0	0
mean	0	0	0.47	0	mean	0	0	0	0
SE	0	0	0.3	0	SE	0	0	0	0
n	4	4	4	4	n	4	4	4	4

Sand		Site		
	CI	OI	CO	OO
Transect				
1	14.3	29.37	6.3	13.12
2	4.37	21.25	7.5	21.25
3	10	28.75	0.62	23.75
4	9.37	46.25	7.5	15
mean	9.53	31.41	5.48	18.28
SE	2.05	5.28	1.64	2.52
n	4	4	4	4

Rubble			Site	
	CI	OI	CO	OO
Transect				
1	0	4.375	0	1.875
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0
mean	0	1.09	0	0.47
SE	0	1.09	0	0.47
n	4	4	4	4

Total corals			Site	
	CI	OI	CO	OO
Transect				
1	21.8	0.62	21.3	7.5
2	20	1.87	21.75	7.5
3	22.5	1.25	16.25	3.12
4	13.7	0	17.5	0
mean	19.5	0.94	19.2	4.53
SE	1.99	0.4	1.37	1.83
n	4	4	4	4

Heliopora coerulea			Site	
	CI	OI	CO	OO
Transect				
1	1.25	0	1.25	0
2	0.62	0	0	0
3	0	0	0	0
4	0	0	0	0
mean	0.47	0	0.31	0
SE	0.29	0	0.31	0
n	4	4	4	4

Acropora palifera			Site	
	CI	OI	CO	OO
Transect				
1	16.2	0	18.75	0
2	11.2	0	14.37	0
3	17.5	0	14.37	0
4	8.12	0	11.87	0
mean	13.2	0	14.84	0
SE	2.19	0	1.43	0
n	4	4	4	4

Asteropora randalli			Site	
	CI	OI	CO	OO
Transect				
1	0	0	0	0
2	0	0	0.62	0
3	0	0	0	0
4	0	0	0	0
mean	0	0	0.16	0
SE	0	0	0.16	0
n	4	4	4	4

Lepastrea purpurea			Site	
	CI	OI	CO	OO
Transect				
1	0.62	0	0.62	0
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0
mean	0.16	0	0.16	0
SE	0.16	0	0.16	0
n	4	4	4	4

Pocillopora damicornis			Site	
	CI	OI	CO	OO
Transect				
1	1.25	0.62	0.62	0.62
2	0	1.25	3.12	0.62
3	18.75	0	0.62	0.62
4	2.5	0	1.25	0
mean	5.63	0.47	1.41	0.46
SE	4.4	0.3	0.59	0.16
n	4	4	4	4

Pocillopora setcheli			Site	
	CI	OI	CO	OO
Transect				
1	1.25	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0
mean	0.16	0	0	0
SE	0.16	0	0	0
n	4	4	4	4

Porites lichen			Site	
	CI	OI	CO	OO
Transect				
1	1.25	0	0	0
2	8.12	0	2.5	0
3	3.12	0	1.75	0
4	3.12	0	3.12	0
mean	3.91	0	1.84	0
SE	1.47	0	0.67	0
n	4	4	4	4

Porites lutea			Site	
	CI	OI	CO	OO
Transect				
1	0	0	0	6.87
2	0	0.62	0.62	6.87
3	0	1.25	0	2.5
4	0	0	0	0
mean	0	0.47	0.16	4.06
SE	0	0.3	0.16	1.7
n	4	4	4	4

Porites vaughani			Site	
	CI	OI	CO	OO
Transect				
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0	0.62	0
mean	0	0	0.16	0
SE	0	0	0.16	0
n	4	4	4	4

Stylophora mordax			Site	
	CI	OI	CO	OO
Transect				
1	0	0	0	0
2	0	0	0.62	0
3	0	0	0	0
4	0	0	0.62	0
mean	0	0	0.31	0
SE	0	0	0.18	0
n	4	4	4	4