RESURVEY OF COCOS LAGOON, GUAM, TERRITORY OF GUAM

Edited by

Richard H. Randall and Timothy S. Sherwood

Participating Authors

Steven S. Amesbury, Charles E. Birkeland,
Gerald W. Davis, Gretchen R. Grimm,
James A. Marsh, Jr., and Gyongyi Plucer-Rosario

UNIVERSITY OF GUAM MARINE LABORATORY

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INTRODUCTION

By
Richard H. Randall

Cocos Lagoon along with its associated patch reefs, barrier reef, and deep channels; Cocos Island; and the coastal village of Merizo are rapidly becoming major tourist use areas on Guam. At the present level of development over 100,000 tourists visit Cocos Island annually (Dept. of Commerce). Most of these tourists are transported by small boats from docks in Merizo to Cocos Island where they spend part of a day and then return to the main island, as no large-scale overnight accommodations are presently developed there. Such a use pattern of Cocos Island will most likely change in the very near future as the Cocos Lagoon Development Corporation (a subsidary of DHL International) is currently constructing a hotel and a tourist activity center (a $15 million dollar investment) on Cocos Island that will provide overnight accommodations for 300 tourists, which is in addition to the present number of daytime visitors.

Expected impact from the expansion of tourist activities in Merizo and the Cocos Lagoon-Reef-Island system includes increased boating activity, increased demand for private and public dock facilities; increased demand for water, power, and waste facilities; and an increase in a variety of tourist-related support infrastructure facilities. In addition it is expected that Merizo will also grow in importance as a commercial and sport fishing port. With the increased importance of Merizo and the Cocos Lagoon-Reef-Island system as a tourist development site, the Government of Guam recognized that a "Lagoon Use Study" should be conducted to insure that proper development and maintenance of the lagoon as a commercial and natural resource be carried out that is in harmony with various traditional aspects of usage.

On May 29, 1981, Governor Calvo requested assistance from the U.S. Army Corps of Engineers, Hawaii, to help the Government of Guam conduct a comprehensive tourism development plan for Merizo and Cocos Lagoon. On March 25, 1982 a Cocos Lagoon Workshop was conducted by the Army Corps of Engineers in Merizo that was attended by both the public and government agencies. As a result of the workshop the Government of Guam established a Cocos Lagoon Task Force, with the Department of Commerce named as the lead agency, to address planning for Merizo and Cocos Lagoon, and the Army Corps of Engineers agreed to assist the Government of Guam in producing a draft report to be circulated for public review during September 1982.

An area of interest voiced by the Cocos Lagoon Task Force and Army Corps of Engineers was to determine if the present level of tourism development in Cocos Lagoon had caused significant changes in the marine communities since the time a previous study, funded by the Army Corps of Engineers, was carried out by the University of Guam Marine Laboratory in 1975 (Randall, et al., 1975). Using the above 1975 study as a data base reference the Army Corps of Engineers asked the University of Guam to conduct a resurvey of the Cocos Lagoon area. A scope of work was agreed upon and a "notice to proceed" with the resurvey was received by the University of Guam Marine Laboratory on June 16, 1982 (Purchase Order DACW84-82-M-0290).

General Scope of Work

The purpose of this resurvey is to: 1) ascertain if any changes have occurred since the Marine Laboratory survey published in 1975, 2) provide a better reef resource and habitat map for the area, 3) attempt to determine if increased tourist traffic and housing development has affected the marine communities in the lagoon area, and 4) measure currents in the lagoon during the period of the resurvey. Specific work tasks include: 1) a resurvey of the hard and soft coral, fish, algae, seagrass, and other macroinvertebrate stations in Cocos Lagoon, barrier reefs, and deep channel areas as presented in the "Marine Biological Survey of Cocos Barrier Reef and Enclosed Lagoon", University of Guam Marine Laboratory, Technical Report No. 17 (160 pages), dated August, 1975; 2) mesurement of currents in the lagoon at the eastern end of Cocos Island, central portion of the lagoon, and at the eastern end of the lagoon opposite the head of Mamaon Channel with a minimum of three stations; and 3) preparation of large scale maps (1:4800 scale) showing the locations of marine resources and habitats discussed in the report (a large fold-out map of the entire lagoon and another in the form of sector overlays as presented in the "Atlas of Reefs and Beaches of Guam" by Randall and Eldredge, 1976). For the resurvey of the biological stations one-half of the 1975 transects from each biotope should be selected, and replicates performed so that statistical comparisons can be made between replicates and time periods.

Because of the short time frame that this resurvey is to be completed in, each of the various work tasks were assigned for the most part to single investigators as follows:

A. Faculty (Marine Laboratory)

1. RICHARD H. RANDALL, Principal Investigator and Currents
2. JAMES A. MARSH, JR., Currents
3. CHARLES E. BIRKELAND, Soft Corals
4. STEVEN S. AMESBURY, Fishes

B. Graduate Student Assistants

1. GERALD W. DAVIS, Algae and Seagrasses
2. GRETCHEN R. GRIMM, Macroinvertebrates
3. GYONGYI PLUCER-ROSARIO, Hard Corals
4. TIMOTHY S. SHERWOOD, Maps & Figures.

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ALGAE AND SEAGRASS SURVEY OF COCOS LAGOON

By

Gerry Davis

This section provides a replicate study based on the previous work of Dr. Roy T. Tsuda in 1975

METHODOLOGY

Sampling was carried out on 12 of the original 24 transect sites recognized in the previous study. The 12 transects selected encompass the maximum number of biotopes possible. The biotopes recognized are those described in the previous study (see Fig. 1 for location of transect sites).

Biotopes Recognized

IA. Barrier Reef (Transects 1, 2, 3, and 17).
B. Shallow lagoon floor (Transects 10 and 15).
C. Lagoon floor (Transects 19, 21, 22, and 23).
D. Patch reefs (Transects 11, 12, 13, 14, and 18).
E. Nearshore shelf (Transects 5, 6, 8, and 9).

IIA. Channel margins and shelves (Transects 4 and 7).
B-D. Channel slopes, walls, and caverns (Transects 16 and 24).
E. Channel floor (Transect 20).

The transecting methods applied were those described by Tsuda (1975). Upon collection of data statistical comparisons were made between the surveys of 1975 and 1982 for species list and percent algal cover (Sokal and Rohlf, 1969).

Analysis of Data

Comparison of species list between the 1975 and 1982 surveys. Hypergeometric probability test (Sokal and Rohlf, pp. 95-97).

$$P = \frac{\binom{r}{x}\binom{N-r}{n-x}}{\binom{N}{n}}$$

N = Total species list
n = Largest species list between years
r = Smallest species list between years
x = Number of species in common

If P is less than .05 then sample represents a collection from a different species pool.

Table 3.

Biotope	IA	IB	IC	ID	IE	IIA	IIB-D	IIE
N	74	58	26	78	63	66	54	31
n	61	46	24	62	53	50	40	29
r	58	39	18	62	52	47	35	13
x	48	23	17	46	42	32	22	6
P	.279	.022	.110	.016	.124	.017	.068	.012

Comparison of Relative Percent Algal Cover
Binomial Probability (Sokal and Rohlf, pp. 78-79)

$$P = \binom{n}{r} p^{r} q^{n-r}$$

n = Number of compared groups
r = Smallest number of positive or negative sums representd
Ho = p = .5
q = 1-p = .5

	1982	1975	Sum	r = 3
IA	36	33	+	
IB	14	15	-	
IC	<1	<1	0	
ID	32	35	-	
IE	22	22	0	
IIA	26	27	-	
IIB-D	56	55	+	
IIE	97	87	+	

P = .219

RESULTS AND DISCUSSION

The Marine plants found in each biotope are tabulated in Table 1. The highest species diversity was once again found in the barrier reef (Biotope IA) and patch reef (Biotope ID) which had 58 and 62 species respectively. The least number of species were found again on the lagoon floor (Biotope IC) and the channel bottom (Biotope IIE) with 23 and 24 species, respectively. Table 2 displays the relative abundance and frequency for 80 percent (± 5 percent) of the marine plants surveyed in each area. Table 1 displays the wide range of different species of algae found in a given biotope while Table 2 emphasizes the fact that a small number of species represent the greater portion of the relative abundance.

The statistical test ran on the data found on Table 3, a hypergeometric probability, indicates that half the biotopes samples in 1982 represent a collection of species from the same species pool presented in the 1975 study (IA, IC, IE, and IIB-D). The other biotpes samples in 1982 (IB, ID, IIA, and IIE) represented a collection of species from a different species pool than that presented in the 1975 study. Although one could speculate that these differences between the 1975 and 1982 study resulted from the effects of seasonality, tropical storms, desiccation or some other physical parameters; there is also reason to believe that exact transect sites were not replicated. In some cases short distances within a given transect areas revealed notable differences in habitat on an observational basis.

In general the areas sampled showed no appreciable changes from 1975 to 1982. The Cocos Lagoon area displays a wide range of marine plants (97 species). The only marked change noticed was the expansion of the seagrass beds (Halodule uninervis) in sandy areas adjacent to Cocos Island. The algal communities in Cocos Lagoon are quite rich if suitable substrate is available. If artificial reefs were supplied in the inner sandy lagoon areas increased algal communities would appear.

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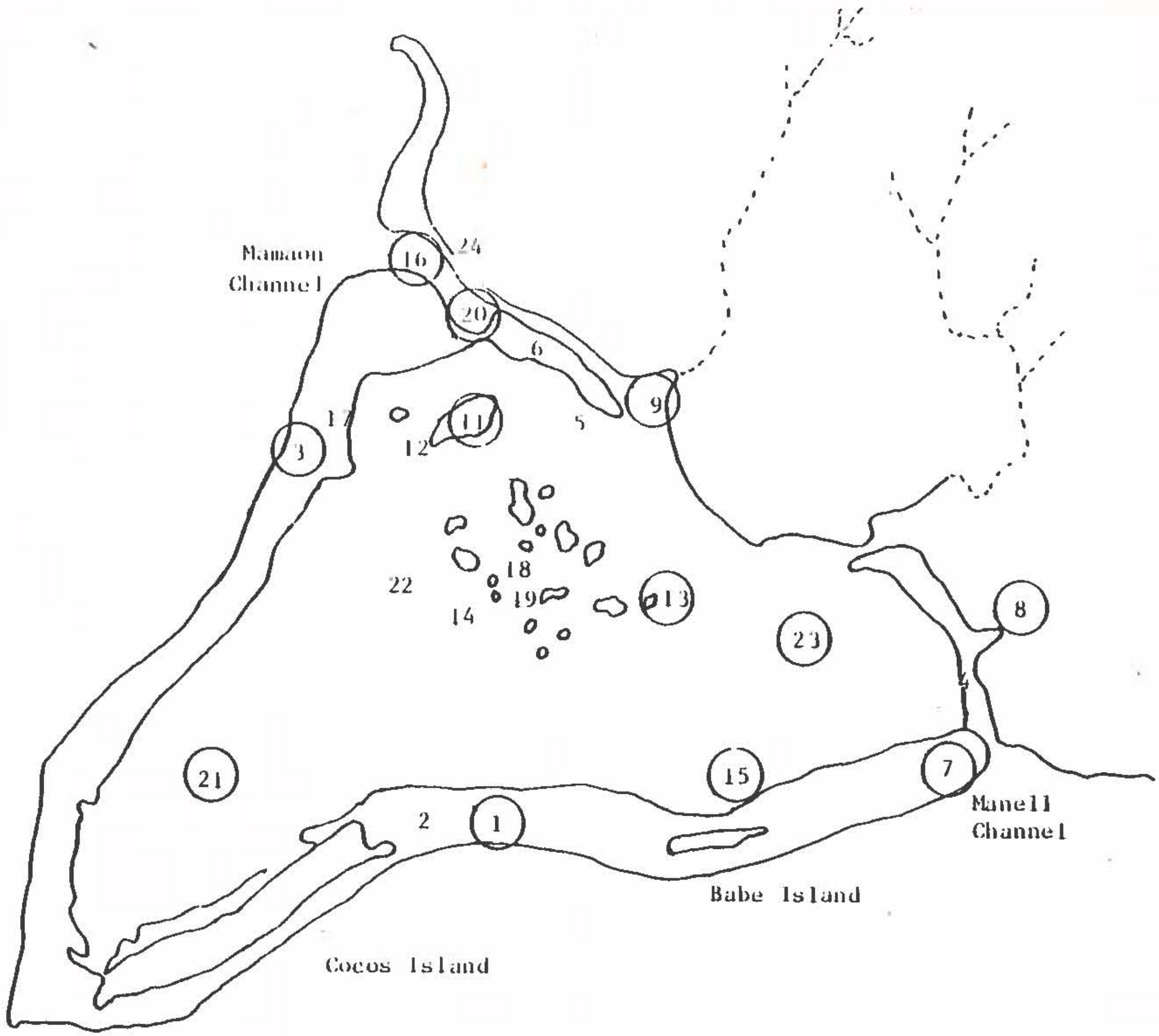

Figure 1. The original 24 station locations for 1975 are numbered 1-24. Those stations with circles represent the 12 station sample in 1982.

Table 1. Cocos Lagoon algal species list (1982).

SPECIES	BIOTOPE I A	B	C	D	E	BIOTOPE II A	B-D	E
CYANOPHYTA (blue-greens) - 5 spp								
Calothri crustacea Thuret	X	X		X	X	X	X	X
Hormothamnion enteromorphoides B. & F.	X	X	X	X	X	X		
Microcoleus lyngbyaceus (Kutz.) Crouan		X	X	X	X	X	X	X
Schizothrix calcicola (Ag.) Gomont	X	X	X	X	X	X	X	X
Schizothrix mexicana Gomont	X	X		X	X			
CHLOROPHYTA (greens) - 33 spp								
Acetubularia moebii SolmsOLaubach	X			X				
Avrainvillea obscura J. Ag.		X	X		X			X
Boergesenia forbesii (Harv.) Feldmann	X			X	X	X		
Bornetella sp.	X							
Boodlea composita (Harv.) Brand	X	X		X	X			
Bryopsis pennata Lamx.	X							
Caulerpa cupressoides (West) C. Ag.	X	X	X	X	X	X	X	
Caulerpa filicoides Yamada		X						X
Caulerpa lentillifera J. Ag.				X				
Caulerpa racemosa (Forssk.) J. Ag.	X	X	X	X	X	X	X	X
Caulerpa serrulata (Forssk.) J. Ag.	X	X		X	X	X	X	
Caulerpa sertularioides (Gmel.) Howe	X		X	X	X	X	X	
Caulerpa taxifolia (Vahl) C. Ag.	X	X		X	X		X	
Caulerpa verticillata J. Ag.				X	X			
Chlorodesmis fastigiata (C. Ag.) Ducker	X			X	X			
Cladophoropsis membranacea (Ag.)	X				X			
Codium edule Silva				X		X		
Dictyosphaeria cavernosa (Forssk.) Boerg.	X	X		X	X	X	X	
Dictyosphaeria versluysii W-v. Bosse	X			X	X	X	X	
Halimeda copiosa Goreau & Graham		X		X		X	X	X
Halimeda discoidea Decaisne	X	X		X	X			
Halimeda gigas Taylor				X	X	X		
Halimeda incrassata (Ellis) Lamx.		X		X	X	X	X	X
Halimeda macroloba Decaisne	X	X	X	X	X			X
Halimeda opuntia (L.) Lamx.	X	X	X	X	X	X	X	X
Microdictyon okamorai Setch.								X
Neomeris annulata Dickie	X	X		X	X	X	X	X
Neomeris vanbosseae Howe				X		X		
Rhipilia orientalis A. & E. S. Gepp				X	X	X	X	
Tydemannia expeditionis W-v. Bosse				X	X	X	X	
Udotea argentea Zanardini					X	X	X	X
Valonia fastigiata Harv.	X	X	X	X		X		
Valonia ventricosa J. Ag.	X	X		X	X	X		
PHAEOPHYTA (browns) - 17 spp								
Chnoospora implexa (Hering) C. Ag.	X				X			
Colpomenia sinuosa (Roth) Derbes & Solier		X						

Table 1 Continued.

SPECIES	BIOTOPE I A	B	C	D	E	BIOTOPE II A	B-D	E
Dictyota bartayresii Lamx.	X	X	X	X	X	X		X
Dictyota cervicornis Kutz.			X	X				
Dictyota divaricata Lamx.			X					
Dictyota friabilis Setchell	X	X	X	X	X	X	X	X
Dictyota patens J. Ag.					X			
Ectocarpus breviarticulatus J. Ag.					X			
Feldmannia indica (Sonder) Womersley & Bailey	X				X			
Hydroclathrus clathratus (C. Ag.) Howe	X		X	X				
Lobophora variegata (Lamx.) Womersley	X	X	X	X	X	X	X	
Padina jonesii Tsuda			X				X	X
Padina tenuis Bory	X	X	X	X	X	X		
Sargassum cristaefolium C. Ag.	X							X
Sargassum polycystum C. Ag.	X				X			
Sphacelaria tribuloides Meneghini	X	X		X	X	X	X	X
Turbinaria ornata (Turner) J. Ag.	X			X	X			
RHODOPHYTA (reds) - 39 spp								
Acanthophora spicifera (Vahl) Boerg.	X	X	X	X		X	X	
Actinotrichia fragilis (Forssk.) Boerg.	X	X		X	X	X	X	
Amphiroa foliacea Lamx.						X	X	
Amphiroa fragilissima (L.) Lamx.	X	X	X	X	X	X	X	
Asparagopsis taxiformis (Delile) Collins & Harvey				X			X	
Botryocladia skottsbergii (Boerg.) Levring				X				
Centroceras clavulatum (C. Ag.) Montagne	X							X
Ceramium sp.				X				
Champia parvula (C. Ag.) Harvey	X			X			X	X
Desmia hornemanni Lyngbye	X					X	X	
Galaxaura fasciculata Kjellman	X	X	X	X	X	X	X	X
Galaxaura marginata Lamx.				X			X	
Galaxaura oblongata (E. S. C.) Lamx.	X			X		X	X	
Gelidiella acerosa (Forssk.) Feldmann & Hamel	X			X				
Gelidiopsis intricata (Ag.) Vickers		X		X	X			
Gelidium divaricatum Martens		X				X		
Gelidium pusillum (Stackh.) Le Jolis	X				X	X	X	
Gracilaria arcuata Zanardini		X		X		X		X
Gracilaria crassa Harvey					X			X
Gracilaria edulis (Gmel.) Silva								X
Gracilaria sp.								X
Griffithsia sp.				X		X		
Halymenia durvillaei Bory				X		X		
Hypnea cervicornis J. Ag.	X	X		X			X	
Hypnea pannosa J. Ag.	X	X	X	X	X	X	X	
Hypnea valentiae (Turn.) Montagne								
Jania capillacea Harvey	X	X		X	X	X	X	
Laurencia sp.	X	X		X		X		

Table 1 Continued.

SPECIES	BIOTOPE I					BIOTOPE II		
	A	B	C	D	E	A	B-D	E
Laveillea jungermannioides (Her. & Mart.) Harv.	X			X		X	X	
Lithophyllum sp.	X					X		
Mastophora sp.	X					X		
Neogoniolithon sp.	X						X	
Peyssonelia sp.	X						X	X
Polysiphonia spp.	X			X	X		X	
Porolithon onkodes Foslie	X			X	X	X	X	
Porolithon sp.						X		
Rhodymenia sp.	X	X		X	X	X		X
Spyridia filamentosa (Wulf.) Harvey						X		
Tolypiocladia glomerulata (Ag.) Schmitz & Hauptfleisch	X							
SPERMATOPHYTA (seagrass) - 3 spp								
Enhalus acoroides (L. F.) Royle		X			X			X
Halodule uninervis (Forssk.) Ascherson		X	X		X			X
Halophila minor (Zoll.) Hartog			X		X			
TOTAL	58	41	24	62	53	50	40	29

Table 2. Relative abundance and frequency (in parentheses) of marine plants representing 80 percent (± 5 percent) within each biotope and facies.

	BIOTOPE I									BIOTOPE II		
	A		B		C	D		E		A	B-D	E
Species	1	3	15	21	23	11	13	8	9	7	16	20
Percent Algal Cover.	30	36	15	1	1	36	33	21	233	27	5	87
Number of Tosses	100	97	116	40*	40*	160	160	100	100	240	120	100
Number of Species	4	5	3	3	4	6	6	4	5	5	5	
CYANOPHYTA												
Calothrix crustacea												
Hormothamnion enteromorphoides												
Microcoleus lyngbyaceus						9(5)	8(6)					
Schizothrix calcicola		16(22)		19(11)	14(7)					13(21)		
CHLOROPHYTA												
Avrainvillea obscura				34(24)	37(28)							
Boodlea composita												
Caulerpa filicoides												14(6)
Caulerpa racemosa		25(19)						10(12)	6(5)	13(6)		
Caulerpa sertularioides												
Dictyosphaeria versluysii		8(11)										
Halimeda discoidea												
Halimeda incrassata										16(7)	23(20)	
Halimeda macroloba								9(14)			19(15)	
Halimeda opuntia	21(20)	8(5)	11(6)			9(8)			11(9)	20(27)		11(7)
Udotea argentea												
PHAEOPHYTA												
Chnoospora implexa												
Dictyota bartayresii	30(17)		36(21)			40(57)	17(22)	14(17)	25(19)	16(17)		
Dictyota divaricata												
Dictyota friabilis							7(9)					
Dictyota patens												
Feldmannia indica												

Table 2 Continued.

Species	BIOTOPE I A 1	3	B 15	21	C 23	D 11	13	E 8	9	BIOTOPE II A 7	B-D 16	E 20
<u>Hydroclathrus clathratus</u>												
<u>Lobophora variegata</u>						12(9)	24(17)					
<u>Padina tenuis</u>						9(7)						
<u>Sargassum polycystum</u>						9(11)						
<u>Sphacelaria tribuloides</u>							8(17)					
<u>Turbinaria ornata</u>	13(14)											
RHODOPHYTA												
<u>Actinotrichia fragilis</u>												
<u>Amphiroa fragilissima</u>		25(3)					7(7)					8(7)
<u>Galaxaura fascicularis</u>									6(5)			
<u>Gelidiella acerosa</u>	18(12)											
<u>Gelidium divaricatam</u>											11(9)	
<u>Peyssonelia</u> sp.												35(31)
<u>Polysiphonia</u> spp.			31(19)									
<u>Porolithon onkodes</u>		8(6)									14(8)	19(11)
<u>Porolithon</u> sp.												
<u>Spyridia filamentosa</u>												
<u>Tolypiocladia glomerulata</u>											12(14)	
<u>Trichogloea</u> sp.												
SPERMATOPHYTA												
<u>Enhalus acoroides</u>					17(10)		56(34)					
<u>Halodule uninervis</u>				25(17)	8(4)			31(22)				
<u>Halophila minor</u>												

* Number of quadrats (1 quadrat = 4 pts)

HARD CORAL SURVEY

By

Gyongyi Plucer-Rosario

INTRODUCTION

This is the follow-up of a survey conducted in 1975 (Randall et al., 1975) in Cocos Lagoon. A rapid rise of recreational and other uses during the years following 1975 has caused some concern as to their possible effects on the lagoon ecosystem. Hard corals form the physiographic structure of the reef as well as many of the sediments found in the reefs and lagoon floors. Equally important is their role as a habitat and refuge for many of the fish and invertebrates found in the lagoon. The strength of the coral community therefore underlies the overall health of the lagoon flora and fauna.

METHODS

(Except for the statistical analyses, the methods used in this study are identical to those used in the 1975 study.)

The point-quarter method (Cottam et al., 1953) was used to analyze the coral community at Stations 1 through 9, 11, 12, and 15 (Fig. 1). In this technique a series of 10 points, 10m apart were selected along a 100m long transect line laid on the substrate. The area around each transect point was divided into four equal quadrants, and the coral nearest the transect point in each quadrant was located and its specific name, diameter, and distance from the corallum center to the transect point were recorded. If in a quadrant, no coral was observed within a maximum distance of 5m from the transect point, the distance between transect point and coral was recorded as 5m, and the diameter as zero.

From the above data, basal area, percent cover (dominance), frequency and density were calculated for each species in a transect. Relative values for each of these parameters were summed to calculate an overall importance value for each of the species. This data is found in Table 1.

Stations 10, 13, 14 and 16 (Fig. 1) were extensively covered by a single colony or species. These stations were surveyed using the line intercept method as described by Smith (1974). Using this method, all coral found beneath or above the 100m transect line were recorded, along with their diameter, and the length which intercepts the line. From these data the percent cover, relative percent cover and relative frequency were calculated. These data are compiled in Table 1.

A test of variance components for 1982 was performed using a 3-way nested anova with unequal sample sizes (Sokal and Rohlf, 1969). One test was performed on each of the following data:

1. Coral diameter measurements (point quarter transects).
2. Coral diameter measurements (line intercept transects).
3. Distance (coral to point) measurements (point quarter transects).
4. Intercept length measurements (line intercept transects).

A paired comparison test was performed contrasting variance between 1975 and 1982. This test was performed once for each of the following data:

1. Density values (point quarter transects).
2. Dominance or percent cover (point quarter transects).
3. Dominance (line intercept transects).

Data from the statistical analyses are compiled in Table 3. Table 4 contains density and dominance values for transects in 1975 and 1982, arranged with the corresponding stations adjacent to each other, and lumped in biotopes.

At all stations, species seen adjacent to the transect line during a 20 minute search were included in the checklist (Table 2). Many species names have been formally changed since 1975. Names in this list are current. Where names have changed, the current name is listed first, with the name used in 1975 listed second [i.e., Acropora tenuis (Dana), 1846 = (A. kenti)].

Half of the 1975 transects were resurveyed in 1982, and each was replicated. Where an even number of transects were surveyed in an area in 1975 (i.e., Transect 6 and 7), an equal number were surveyed in 1982 (i.e., Transect 5a/b). However, sometimes 3 or 5 transects were surveyed in the same area in 1975 (i.e., Transect 8, 9, 10). In this case, only one transect was surveyed and replicated in 1982 (i.e., 6a/b). In other cases, only one transect was surveyed in a biotope in 1975 (i.e., Transect 22). In 1982 this area was surveyed once and replicated (i.e., Transect 7a/b). The number of transects surveyed in each year for each biotope is listed below:

	1975	1982
1A	8	8
B	8	6
D	6	4
E	2	2
2A	7	6
B	5	6
C	1	2
TOTAL	37	34

The stations surveyed in 1982 are mapped in Figure 1.

RESULTS AND DISCUSSION

Although almost all stations showed changes in their coral communities, there was no major reduction in density or percent coral cover for any stations or biotopes from 1975 to 1982. The only major change in these parameters was a significant increase in coral cover in the point quarter transects (Fs.05 (1,10) = 4.96+). An increase was found in 10 of the eleven stations in this group. Since variance between replicates for this group was not found to be significant (Table III part IB) this increase shows a very healthy coral community. In 1968-69, there was an extensive infestation of Acanthaster planci, a well documented predator of living corals (Tsuda, 1971). Much of Cocos Lagoon's corals were destroyed, and little or no recolonization had occurred by 1971. It is likely that recolonization had begun at least by 1975, and proceeded through 1982. This may explain the significant increase in coral cover in the point quarter transects.

In the line intercept transects, there was a highly significant (Table III part IA) degree of variance found between replicate transects. However, since only 4 stations were surveyed in this manner, it is not known if this variance is attributable to the particular stations or to the method itself. The variance between years for these stations was not found to be significant (Fs.05 (1,3) = 10.1 ns). The transects surveyed with the line intercept method are found along the Geus River channel and the Manell Channel margins (Figure 1, Transects 10,13,14,16), two areas which were not infested during the plague years. It is therefore unlikely that there would have been a significant increase in coral cover in these transects.

It should be noted that a test of variance between replicates was not performed on the 1975 data because during this year replicate samples were not taken. Also, all stations (4a,4b,4c, and 4d) in Biotope ID were not included in the testing of variance between replicates. These stations were patch reefs located in the central area of Cocos Lagoon and were too small to replicate. This biotope was also not included in the paired comparison test of variance between years. Although the 1975 stations were marked on the map, they were only approximations of position. There are many patch reefs in this biotope, many close together and therefore difficult to distinguish on a map. These patch reefs are also very different from each other, some almost completely dominated by a small number of extremely large colonies of a single species (i.e., 4a), others with numerous small scattered corals of many species (i.e., 4c). Therefore, it would have been impossible to locate the exact patch reefs used in 1975, and also it would be invalid to compare them in a paired comparison analyses. Table 4 gives the parameters for the stations surveyed during both years.

Station 4a, which shows 179.67% cover, was surveyed using the point quarter method. This station is comprised of almost complete (70-80%) cover of two species, Porites andrewsi and Porites (S.) iwayamaensis. The size of these corals were usually in the 5 or 6 digit range, and it was often difficult to distinguish where one coral ended and the next began. If only a few of the corals were of this great area, they could be removed from the analyses so that an adjusted % cover value could be obtained (as was done in station 11a). Since almost half the corals of the 40 in this transect were in this category, removing them would not give a true estimation of the coral community. Therefore, the % cover value was not adjusted, and was not included when calculating the mean, standard deviation and range (Table 4) for the biotope. Although this biotope shows a decrease in the mean % cover, it is likely that if a more accurate value for Station 4a had been obtained, the mean would have increased instead of decreased. This station should have been surveyed with the line intercept method, which would have given more appropriate parameter values. It was not resurveyed because of time constraints.

A description of each biotope can be found in the coral section of Randall et al., 1975. Using both distance and diameter values to analyze variance, it was found that there was a significant difference between biotopes (in the point quarter transects). Since biotopes are specifically chosen for their differences, this is to be expected. Only Biotopes IIa and IIb were surveyed using the line intercept method, and there was no significant difference in their percent cover values.

Many stations showed differences in species composition between years, but much of this is attributable to the extreme patchiness within coral communities. For example, Acropora hebes (a rare species which also occurs in northern Guam) occurs in only one large patch in the whole lagoon (near station 1). If a transect line were even as close as 10 yards away, it would not show up in the station species composition (Table 2). Differences were often apparent between replicate samples in the same year, as can be seen in Table 2 in Transects 1, 4, 8, and 12. In these transects, the most important coral in one replicate may be of minor importance or absent in the next.

However some differences could not be attributed to patchiness. Stations 23-24 (1975) were totally different when resurveyed in 1982 (Station 8). In 1982 much of the area was covered by extensive patches (20 m^2) of Acropora formosa. It would be impossible to stretch out a 100 m transect line without encountering some of these patches. In 1975, A. formosa, where present, was widely scattered (Randall et al., 1975). It was mentioned in the description of the stations, but did not show up in the transect data at all. This area was heavily infested with A. planci in 1969 (Tsuda, 1971) and has shown a strong recovery (Table 4).

Another noticable difference in species composition was the relative paucity of Leptastrea purpurea in 1975. In that year, it was not found in 19 of the stations surveyed, yet in 1982, it did not occur in only four stations. In the latter year, most of the encrustations were small (2 x 2 cm). Unless the previous investigator missed this species (which seems unlikely considering its present frequency) it has, since 1975, recruited in great numbers throughout all of the biotopes and most of the stations.

A number of species found in 1982 were not recorded in 1975. Acropora florida (found also in Piti Bay), Acropora striata, Acropora aculeus (found only in Cocos Lagoon) and Millepora latifolia (found also in shallow areas of Luminao Reef) are all rare species that were either not present, or missed in 1975. Alveopora japonica is found very rarely outside of Cocos Lagoon, but is common in the lagoon. Acropora echinata is a species found only in a small depression in Agat bay and in Cocos Lagoon. In 1975 only a few small heads were found in Biotope 1B near Station 17. In 1982, numerous large colonies were found scattered throughout Station 1 (Fig. 1).

In conclusion, it is apparent that although Cocos Lagoon has become a high use recreation and commercial fishing area, its coral communities have not suffered. The significant increase in most of the stations shows a strong recovery from a previous A. planci infestation. Two areas which were not preyed upon showed no significant change in the years investigated. At present or slightly increased levels of use, there is no reason to expect any detrimental effects, baring any major accidents such as large oil spills. If the level of use is greatly expanded from its present levels, with any major dredging or construction, especially if adjacent to the coral communities, it would be advisable to monitor changes as they occur.

It was occasionally noted that some large corals had been broken or otherwise physically damaged, either by an anchor, propeller, or fishing gear. Even this damage, unless of a greatly expanded nature, would not effect the community permanently, for even small pieces of living coral will grow. This phenomenon occurs naturally, often caused by storm waves, breaking off sections of large colonies. Although part of the colony may die, the newly exposed surfaces provide excellent substrate for coral recruitment, and are therefore not detrimental to the community.

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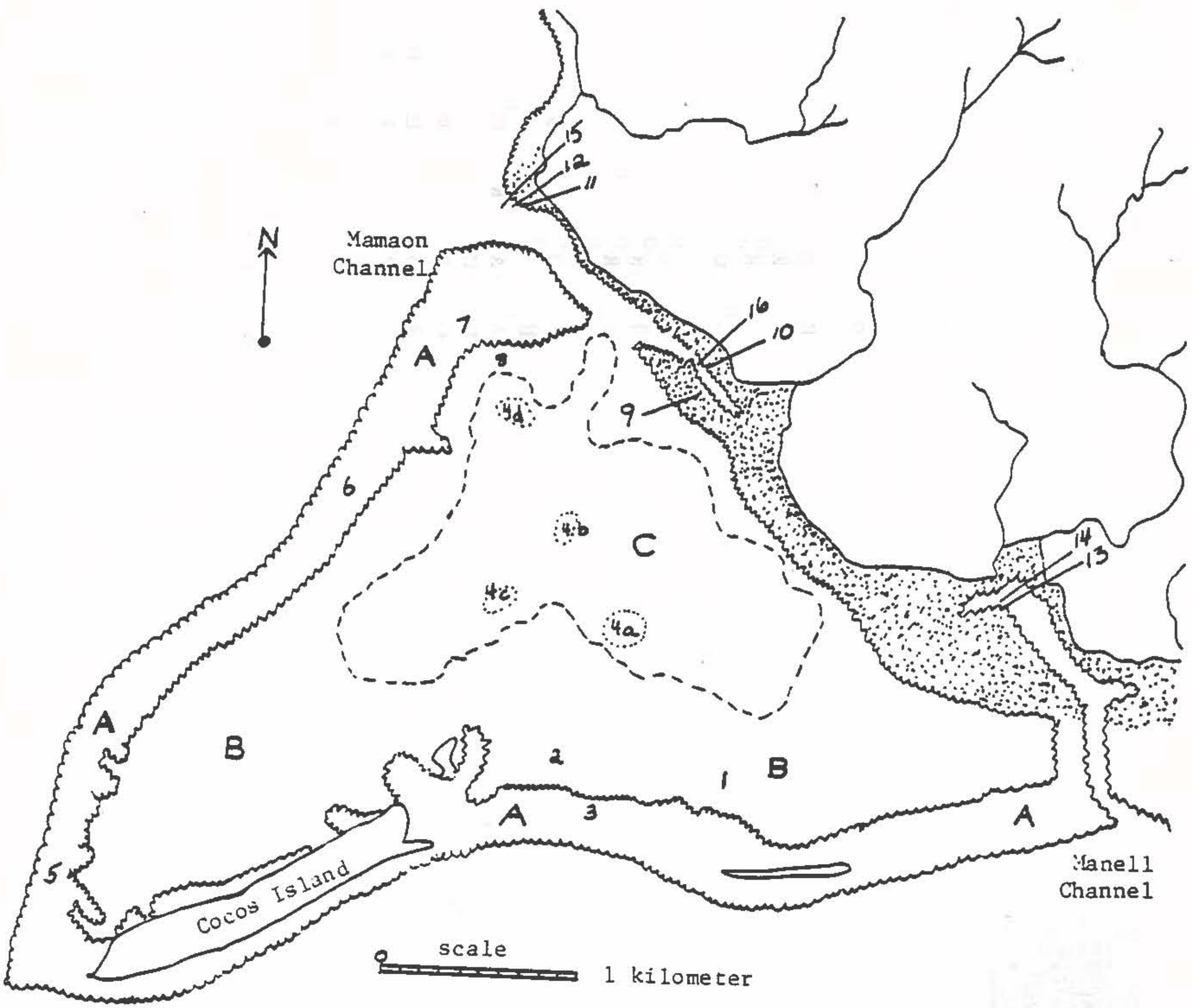

Figure 1. Map showing distribution of Biotope IA, B, C, and E. Mamaon and Manell Channels constitute Biotope II. Descriptions of Facies for each Biotope are in Randall et al., 1975. Numbers 1 to 16 designate station sites, and in each case includes a replicate. Biotope ID includes all patch reefs inside Biotope IC, including stations 4a through 4d (other patch reefs are not labelled on this map). Stipled area is Biotope IE.

Table 1. Checklist of corals and their relative frequency of occurrence at Cocos Lagoon. Symbols for relative frequency are: D = dominant, A = abundant, C = common, O = occasional, U = uncommon, and R = rare.

	IA	IB	IC	ID	IE	IIA	IIB	IIC
Stylocoeniella armata (Ehrenberg), 1834	C	U	C	C	R	C	R	R
Psammocora contigua (Esper), 1797	A	U	R	O	C	O		
Psammocora digitata Milne Edwards & Haime, 1851 = [Ps. (S.) togianensis]	R	R		O	O		O	
Psammocora haimeana Milne Edwards & Haime, 1851		R			R			
Psammocora nierstrazi van der Horst, 1921		R		U		R		
Psammocora obtusangulata (Lamarck), 1816	C	O			O	U		
Psammocora profundacella Gardiner, 1898				U		U		R
Psammocora stellata (Verrill), 1866	D	A		R	O	O		
Psammocora superficialis Gardiner, 1898 = [P. verrilli]	O	R				R		
Psammocora sp. 1	U	R						R
Stylophora mordax (Dana), 1846	C	O				O		
Seriatopora hystrix (Dana), 1846		O		U				R
Pocillopora ankeli Scheer & Pillai, 1974	U	U				C		
Pocillopora damicornis (Linnaeus), 1758	A	A	R	C	O	C	U	
Pocillopora danae Verrill, 1864	O	O				O		
Pocillopora elegans Dana, 1846	O	O		R	O	U		
Pocillopora eydouxi Milne Edwards & Haime, 1960	R	U		U	U	O		
Pocillopora ligulata Dana, 1846		R		R	R			
Pocillopora setchelli Hoffmeister, 1929	O	R				O		
Acropora aculeus (Dana), 1846				R				
Acropora acuminata Verrill, 1864	O	A	O	C	C			
Acropora abrotanoides (Lamarck), 1816						R	R	
Acropora arbuscula (Dana), 1846		O			O			
Acropora aspera (Dana), 1846	A	D		U		O		
Acropora cerealis (Dana), 1846	O	R				R		
Acropora convexa (Dana), 1846						R	R	
Acropora delicatula (Brook), 1891				R				R
Acropora echinata (Dana), 1846		C						
Acropora florida (Dana), 1846			R	R				
Acropora formosa (Dana), 1846	J	A	A	A	O	R	O	

Table 1 Continued.

	IA	IB	IC	ID	IE	IIA	IIB	IIC
Acropora granulosa (Milne Edwards & Haime), 1860							R	
Acropora hebes (Dana), 1846		O						
Acropora humilis (Dana), 1846	O	O		O	O	C		
Acropora monticulosa (Bruggemann), 1879	U					U		
Acropora nasuta (Dana), 1846	O	R		R	O	O		
Acropora palifera (Lamarck), 1816	U	O	R	O	O	O		
Acropora smithi (Brook), 1893	O	U			U	O		
Acropora squarrosa (Ehrenberg), 1834	O	O			U	U		
Acropora striata Verrill, 1866		R						
Acropora studeri (Brook), 1893		R				R		
Acropora surculosa (Dana), 1846	U	O		U	U	O		
Acropora tenuis (Dana), 1846 = [A. kenti]		U		R	U	U	R	
Acropora teres (Verrill), 1866	U	D	O	O	R	U	U	
Acropora variabilis (Klunzinger), 1879	O	R				U		
Acropora virgata (Dana), 1846		O	O	O	R	U		
Acropora wardii Verrill, 1901	O	O		O	R	C		
Astreopora gracilis Bernard, 1896		U		R	U			
Astreopora listeri Bernard, 1896		R			R			
Astreopora myriophthalma (Lamarck), 1816	O	O	U	C	U		O	
Astreopora randalli Lamberts, 1981		R						
Montipora acanthella Bernard, 1897 = [M. floweri]				U				
Montipora berryi Hoffmeister, 1925								
Montipora cf. M. caliculata (Dana), 1846	U	O	O	O		O		
Montipora ehrenbergii Verill, 1875	U	O		O	C	O	O	
Montipora elschneri Vaughan, 1918	O	U	U	O	R	U		
Montipora cf. M. floweri Wells, 1954	C		R	U	O			
Montipora foliosa (Pallas), 1766						R		
Montipora foveolata (Dana), 1846	R	O		O	O			
Montipora hoffmeisteri Wells, 1954	O	O		O	O	O		
Montipora lobulata Bernard, 1897	C	C	C	A	C	U	C	
Montipora monasteriata (Forskaal), 1775		R	U					
Montipora planiuscula (Dana), 1846		U	R		U			
Montipora socialis Bernard, 1897					R			

Table 1 Continued.

	IA	IB	IC	ID	IE	IIA	IIB	IIC
Montipora cf. *M.* *subtilis* Bernard, 1897	C	C	U	C	C			
Montipora cf. *M.* *tuberculosa* (Lamarck), 1816	U	O		O	C	U		
Montipora *verrilli* Vaughan, 1907	C	C	U	C	C	U	U	C
Montipora *venosa* (Ehrenberg), 1834	R		U			R		
Montipora *verrucosa* (Lamarck), 1816	U	O	O	C		U	R	O
Montipora (tuberculate sp. 1)	O	O	R	C	O	O	O	
Montipora (tuberculate sp. 2)	O	O		O	O	O		
Montipora (tuberculate sp. 3)		U		U		U		
Montipora (papillate sp. 4)	O			C		U	C	
Montipora (tuberculate sp. 5)						R		
Pavona *clavus* (Dana), 1846	O	O		O	U	R		
Pavona *decussata* (Dana), 1846	O	O		O	U	R		
Pavona *divaricata* (Lamarck), 1816		U		U	O	O		
Pavona *duerdeni* Vaughan, 1907	O	O				U	U	
Pavona *explanulata* (Lamarck), 1816					R		U	
Pavona *maldivensis* (Gardiner), 1905				U		R		
Pavona *minuta* Wells, 1954				R			R	
Pavona (*P.*) *obtusata* (Quelch), 1884	U	O		U		U	U	
Pavona *varians* Verrill, 1864	O	O		U	O	O	O	
Pavona (*P.*) *venosa* (Ehrenberg), 1834	C	A		C	O	O		
Pavona (encrusting) sp. 1	O	O	U	O	O			
Pavona sp. 2 = [*P.* (*P.*) *obtusata*]	U	O				O		
Gardineroseris *planulata* (Dana), 1846 = [*P.* (*P.*) *planulata*]	R	R		R		R		
Leptoseris *hawaiiensis* Vaughan, 1907				R			R	
Leptoseris *incrustans* (Quelch), 1886			R					R
Leptoseris *mycetoseroides* Wells, 1951								
Pachyseris *speciosa* (Dana), 1846			R	R			C	U
Coscinaraea *columna* (Dana), 1846					R			
Coscinaraea sp. 1 = [*Anomastrea* sp. 1]				U				R
Cycloseris *costulata* (Ortmann), 1889							R	
Fungia *fungites* Linnaeus, 1758	O	O		R	O			
Fungia *scutaria* Lamarck, 1801		U			U		U	
Fungia *paumotensis* Stutchbury, 1833					U		R	

Table 1 Continued.

	IA	IB	IC	ID	IE	IIA	IIB	IIC
Goniopora arbuscula Umbrgrove, 1939	U	O	O	C		U		
Goniopora columna Dana, 1846	R	O	O	C				R
Goniopora somaliensis Vaughan, 1907		R						R
Goniopora tenuidens (Quelch), 1886		U						R
Stylarea punctata Klunzinger, 1879	O	O	R	O				
Porites andrewsi Vaughan, 1918	C	O	O	D	A	U	D	
Porites annae Crossland, 1952	C	C	U	O		O		
Porites australiensis Vaughan, 1918		O						
Porites cocosensis Wells, 1950	O	O		D	A	C	D	
Porites lichen Dana, 1846	C	O						
Porites lobata Dana, 1846	O	O						O
Porites lutea Milne Edwards & Haime, 1851	A	C	O	C	D	D	D	D
Porites murrayensis Vaughan, 1918	O	O		R	R			
Porites (ramose) sp. 1	O				O	R		
Porites (massive) sp. 2	O	O		R				
Porites (massive) sp. 3	O	O		R		O		
Porites (massive) sp. 4	R	O						
Porites (*S.*) *convexa* Verrill, 1864	O	O	O	R	O	O	O	U
Porites (*S.*) *horizontalata* Hoffmeisteri, 1925	R	O	O	C	O	O	A	C
Porites (*S.*) *iwayamaensis* Eguchi, 1938	O	U	O	D	R	C	O	D
Porites (*S.*) *vaughani* Crossland, 1952		U		C		R	O	O
Porites (*S.*) sp. 1		R			R			
Alveopora japonica Eguchi, 1968		R	U	O				
Alveopora sp. 1					R		R	
Favia favus (Forskaal), 1775	O	O		O		U		U
Favia matthai Vaughan, 1918	O	O		O	O	R		
Favia pallida (Dana), 1846	O	O		C	R	U	R	C
Favia rotumana (Gardiner), 1889	R							
Favia stelligera (Dana), 1846	C	U	R	R		U		
Favites abdita (Ellis & Solander), 1786	R	O				U		
Favites cf. *favosa* (Ellis & Solander), 1786				R				
Favites flexuosa (Dana), 1846	U	U			R			
Favites russelli (Wells), 1954 = [*F. complanata*]	R	O		R	O	R		

Table 1 Continued.

	IA	IB	IC	ID	IE	IIA	IIB	IIC
Oulophyllia crispa (Lamarck), 1816			R					
Montastrea curta (Dana), 1846 = [*Plesiastrea versipora*]	O	O		O	R	R		
Plesiastrea versipora (Lamarck), 1816				R				
Goniastrea edwardsi Chevalier, 1971 = [*G. parvistella*]	O	C	C	C	U	C	O	U
Goniastrea pectinata (Ehrenberg), 1834			O	U				R
Goniastrea retiformis (Lamarck), 1816	C	C		O	C	U	O	
Platygyra daedalea (Ellis & Solander), 1786 = [*P. lamellina*]	O	U		O		U	O	O
Platygyra pini Chevalier, 1975 = [*P. rustica*]	R	O	C	O	O	O	O	R
Leptoria phrygia (Ellis & Solander), 1786	O	O		O		C		
Hydnophora microconos (Lamarck), 1816	U	O		O	U	O		
Hydnophora tenella Quelch, 1886						R		
Leptastrea bottae (Milne Edwards & Haime), 1849	R	O						
Leptastrea purpurea (Dana), 1846	A	A	D	C	U	U	O	C
Leptastrea transversa (Klunzinger), 1879		O				U		
Cyphastrea chalcidicum (Forskal), 1775				R				
Cyphastrea microphthalma (Lamarck), 1816	O			O		R		
Cyphastrea serailia (Forskaal), 1775	O		R	U	R	R		U
Echinopora lamellosa (Esper), 1787	U	R	R		R			U
Diploastrea heliopora (Lamarck), 1816	O	O	R	R	O			U
Galaxea fascicularis (Linnaeus), 1758	C	O		O	C	A	O	O
Acrhelia horrescens (Dana), 1846		O	R	C	O		C	
Merulina ampliata (Ellis & Solander), 1786					O	U		
Lobophyllia corymbosa (Forskaal), 1775		O				U		R
Lobophyllia costata (Dana), 1846		R		R	R			
Lobophyllia hemprichii (Ehrenberg), 1834	O	O	U	O	O	O		
Acanthastrea echinata (Dana), 1846	R		T			U		R
Echinophyllia aspera (Ellis & Solander), 1786		R						R
Mycedium elephantotus (Pallas), 1776			R					R
Plerogyra sinuosa (Dana), 1846		R	R	R		O	R	R
Euphyllia glabrescens (Chamisso & Eysenhardt), 1821	O	O	U	O	O	U	C	O
Heliopora coerulea (Pallas), 1766	C	C	O	O	O	O	O	O
Millepora dichotoma Forskaal, 1775	A	C	R	O	C	C	O	U
Millepora latifolia Boschma, 1948	A	A						

Table 1 Continued.

	IA	IB	IC	ID	IE	IIA	IIB	IIC
Millepora platyphylla Hemprich & Ehrenberg, 1834	A	C		O	C	U	O	R
Millepora tuberosa Boschma, 1966 = [*M. exaesa*]	C	O		O	A	A		U
Distichopora gracilis Dana, 1846 = [*D. violacea*]		R				O		

Table 2. Living coral density, percent substratum coverage (Dominance), and frequency of occurrence. Importance value is the sum of the relative values of the above parameters. Corals arranged in order of their importance value.

PART A. Point Quarter Transects		Density	Relative Density	Dominance (Percent)	Relative Dominance	Frequency	Relative Frequency	Importance Value
1a	*Acropora teres*	.43	47.5	1.53	34.0	.70	36.84	118.34
	Pocillopora damicornis	.32	35.00	.46	10.22	.70	36.84	82.06
	Porites andrewsi	.07	7.50	2.24	49.78	.20	10.52	67.80
	Montipora lobulata	.04	5.00	.22	4.89	.10	5.3	10.52
	Acropora echinata	.023	2.50	0.99	2.2	.10	5.3	10.0
	Leptastrea purpurea	.023	2.50	.005	.11	.10	5.3	7.91
		Total Density - .91			Total Species - 6			
		Total Dominance - 4.5%			Total Genera - 5			
1b	*Acropora aspera*	.76	40	3.35	62.04	.50	29.40	131.44
	Pocillopora damicornis	.52	27.50	.93	17.22	.50	29.40	74.12
	Porites cocosensis	.47	25.00	.57	10.55	.40	23.50	59.05
	Porites lutea	.09	5.0	.21	3.89	.20	11.70	20.59
	Acropora formosa	.05	2.50	.37	6.85	.10	5.80	8.67
		Total Density - 1.90			Total species - 5			
		Total Dominance - 5.40%			Total Genera - 3			
2a	*Acropora aspera*	1.70	35.00	4.34	39.97	.70	20.59	92.56
	Pocillopora damicornis	1.47	30.00	1.76	14.99	.70	20.59	65.58
	Porites andrewsi	.12	2.50	2.80	23.85	.10	2.94	29.29
	Porites (S.) iwayamaensis	.24	5.00	2.06	17.55	.10	2.94	25.49
	Porites cocosensis	.37	7.50	.06	.51	.30	8.82	16.83
	Pavona decussata	.24	5.00	.14	1.19	.20	2.94	10.52
	Leptastrea purpurea	.37	7.50	.01	.08	.10	2.94	10.52
	Porites lutea	.12	2.50	.32	2.73	.10	2.94	8.17

Table 2 Continued.

		Density	Relative Density	Dominance (Percent)	Relative Dominance	Frequency	Relative Frequency	Importance Value
	Porites annae	.12	2.50	.25	2.13	.10	2.94	7.57
	Porites murrayensis	.12	2.50	.004	.03	.10	2.94	5.47
		Total Density	- 4.87		Total Species	- 10		
		Total Dominance	- 11.74%		Total Genera	- 5		
2b	Acropora aspera	.29	52.5	10.14	64.55	.90	36.00	153.05
	Porites cocosensis	.56	10.00	11.49	42.52	.20	8.00	60.52
	Pocillopora damicornis	1.12	20.00	1.39	5.14	.60	24.00	49.14
	Pavona venosa	.42	7.50	2.17	8.03	.30	12.00	27.53
	Porites lutea	.14	2.50	1.54	5.70	.10	4.00	12.20
	Porites annae	.14	2.50	.16	.59	.10	4.00	7.09
	Pavona decussata	.14	2.50	.12	.44	.10	4.00	6.94
	Leptastrea purpurea	.14	2.50	.01	.04	.10	4.00	6.54
		Total Density	- 5.6		Total Species	- 8		
		Total Dominance	- 27.02%		Total Genera	- 5		
3a	Pocillopora damicornis	1.73	52.50	2.03	47.54	.10	7.69	107.73
	Acropora aspera	.58	17.50	1.26	29.51	.30	23.08	70.09
	Porites lutea	.41	12.50	.77	18.03	.30	23.08	53.61
	Leptastrea purpurea	.33	10.00	.03	.70	.40	30.77	41.47
	Goniastrea retiformis	.25	7.50	.18	4.21	.20	15.38	27.09
		Total Density	- 3.3		Total Species	- 5		
		Total Dominance	- 4.27%		Total Genera	- 5		
3b	Porites lutea	1.40	22.50	9.41	79.95	.50	19.23	121.68
	Leptastrea purpurea	1.89	30.00	.17	1.44	.70	26.92	58.36

Table 2 Continued.

		Density	Relative Density	Dominance (Percent)	Relative Dominance	Frequency	Relative Frequency	Importance Value
	<u>Pocillopora damicornis</u>	1.73	27.50	.83	7.05	.60	23.08	57.63
	<u>Goniastrea retiformis</u>	.79	12.50	1.05	8.92	.50	19.23	40.09
	<u>Porites annae</u>	.16	2.50	.24	2.04	.10	3.85	8.39
	<u>Porites cocosensis</u>	.16	2.50	.07	.59	.10	3.85	6.94
	<u>Heliopora coerulea</u>	.16	2.50	.005	.04	.10	3.85	6.39
		Total Density - 6.29			Total Species - 7			
		Total Dominance - 11.77%			Total Genera - 5			
4a	<u>Porites (S.) iwayamaensis</u>	.10	17.50	148.02	82.38	.30	14.29	114.26
	<u>Porites andrewsi</u>	.14	25.00	28.32	15.76	.30	14.29	55.05
	<u>Porites cocosensis</u>	.10	17.50	2.86	1.59	.30	14.29	33.38
	<u>Stylocoeniella armata</u>	.04	7.50	.001	.0006	.30	14.29	21.79
	<u>Montipora</u> (pap.) sp. 4	.04	7.50	.07	.04	.20	9.52	17.06
	<u>Pocillopora damicornis</u>	.04	7.50	.03	.02	.20	9.52	17.04
	<u>Goniopora columna</u>	.04	7.50	.26	.14	.10	4.76	12.40
	<u>Montipora subtilis</u>	.01	2.50	.03	.02	.10	4.76	7.28
	<u>Porites lutea</u>	.01	2.50	.04	.02	.10	4.76	7.28
	<u>Montipora lobulata</u>	.01	2.50	.009	.005	.10	4.76	7.26
	<u>Goniastrea edwardsi</u>	.01	2.50	.003	.002	.10	4.76	7.26
		Total Density - .54			Total Species - 11			
		Total Dominance - 179.67%			Total Genera - 6			
4b	<u>Acropora formosa</u>	.26	40.00	3.16	93.49	.50	15.15	148.64
	<u>Leptastrea purpurea</u>	.08	12.50	.02	.59	.50	15.15	28.24
	<u>Pocillopora damicornis</u>	.05	7.50	.08	2.37	.30	9.09	18.96
	<u>Acrhelia horrescens</u>	.05	7.50	.05	1.48	.20	6.06	15.04
	<u>Montipora lobulata</u>	.05	7.50	.05	1.48	.20	6.06	11.12

Table 2 Continued.

		Density	Relative Density	Dominance (Percent)	Relative Dominance	Frequency	Relative Frequency	Importance Value
	<u>Stylocoeniella</u> <u>armata</u>	.03	5.00	.002	.06	.20	6.06	11.12
	<u>Porites</u> <u>lutea</u>	.02	2.50	.02	.59	.10	3.03	6.12
	<u>Montipora</u> <u>subtilis</u>	.02	2.50	.01	.30	.10	3.03	5.83
	<u>Alveopora</u> <u>japonica</u>	.02	2.50	.005	.15	.10	3.03	5.68
	<u>Goniastrea</u> <u>pectinata</u>	.02	2.50	.005	.15	.10	3.03	5.68
	<u>Montipora</u> <u>conicula</u>	.02	2.50	.004	.12	.10	3.03	5.65
	<u>Pavona</u> <u>varians</u>	.02	2.50	.004	.12	.10	3.03	5.65
	<u>Astreopora</u> <u>myriophthalma</u>	.02	2.50	.003	.09	.10	3.03	5.62
	<u>Favites</u> <u>russelli</u>	.02	2.50	.001	.03	.10	3.03	5.56
		Total Density - .68			Total Species - 14			
		Total Dominance - 3.38%			Total Genera - 12			
4c	<u>Montipora</u> <u>lobulata</u>	.15	15.00	.22	45.83	.40	13.33	74.16
	<u>Leptastrea</u> <u>purpurea</u>	.27	27.50	.02	4.17	.60	20.00	51.67
	<u>Montipora</u> <u>verrilli</u>	.10	10.00	.06	12.50	.40	13.33	35.83
	<u>Porites</u> <u>(S.)</u> <u>vaughani</u>	.12	12.50	.04	8.33	.30	10.00	30.83
	<u>Stylocoeniella</u> <u>armata</u>	.12	12.50	.005	1.04	.40	13.33	26.87
	<u>Coscinaraea</u> sp.	.05	5.00	.03	6.25	.20	6.66	17.91
	<u>Montipora</u> <u>subtilis</u>	.05	5.00	.02	4.17	.20	6.66	15.83
	<u>Montipora</u> <u>verrucosa</u>	.02	2.50	.03	6.25	.10	3.33	12.08
	<u>Goniastrea</u> <u>edwardsi</u>	.02	2.50	.02	4.17	.10	3.33	10.00
	<u>Favia</u> <u>pallida</u>	.02	2.50	.02	4.17	.10	3.33	10.00
	<u>Pavona</u> sp. 1	.02	2.50	.007	1.46	.10	3.33	7.29
	<u>Astreopora</u> <u>myriophthalma</u>	.02	2.50	.007	1.46	.10	3.33	7.29
		Total Density - .96			Total Species - 12			
		Total Dominance - .48%			Total Genera - 9			

Table 2 Continued.

		Density	Relative Density	Dominance (Percent)	Relative Dominance	Frequency	Relative Frequency	Importance Value
4d	Acropora formosa	1.4	62.50	8.47	76.03	.90	52.94	191.47
	Pocillopora damicornis	.40	17.50	.98	8.80	.40	23.52	49.82
	Acropora aspera	.17	7.50	1.04	9.33	.10	5.88	22.71
	Montipora lobulata	.11	5.00	.51	4.58	.10	5.99	15.46
	Stylocoeniella armata	.11	5.00	.002	.02	.10	5.88	10.90
	Pavona divaricata	.06	2.50	.14	1.26	.10	5.88	9.64
		Total Density - 2.29			Total Species - 6			
		Total Dominance - 11.14%			Total Genera - 5			
5a	Psammocora stellata	5.80	45.00	.75	15.72	.80	32.00	92.72
	Porites lutea	.64	5.00	1.79	37.53	.20	8.00	50.53
	Leptastrea purpurea	2.58	20.00	.08	1.64	.50	20.00	41.64
	Psammocora obtusangulata	.64	5.00	.70	14.67	.20	8.00	27.67
	Psammocora contigua	.32	2.50	.85	17.82	.10	4.00	24.32
	Leptoria phrygia	1.00	7.50	.29	6.08	.10	4.00	17.58
	Pocillopora damicornis	.64	5.00	.04	.83	.20	8.00	13.83
	Millepora platyphylla	.32	2.50	.13	2.72	.10	4.00	9.22
	Pavona venosa	.32	2.50	.09	1.89	.10	4.00	8.39
	Goniastrea edwardsi	.32	2.50	.04	.83	.10	4.00	7.33
	Stylocoeniella armata	.02	2.50	.01	.21	.10	4.00	6.71
		Total Density - 12.60			Total Species - 11			
		Total Dominance - 4.77%			Total Genera - 9			
5b	Psammocora stellata	11.88	45.00	2.14	16.25	.70	29.17	90.42
	Leptastrea purpurea	5.28	20.00	.37	2.81	.60	25.00	47.81
	Porites lutea	1.98	7.50	2.42	18.37	.30	12.50	38.37
	Psammocora verrilli	.66	2.50	3.77	28.63	.10	4.17	35.30

Table 2 Continued.

		Density	Relative Density	Dominance (Percent)	Relative Dominance	Frequency	Relative Frequency	Importance Value
	Montipora (pap.) sp. 4	2.64	10.00	2.51	19.06	.10	4.17	33.23
	Leptoria phrygia	.66	2.50	1.32	10.02	.10	4.17	16.69
	Pocillopora damicornis	1.32	5.00	.14	1.06	.20	8.33	14.39
	Pavona varians	.66	2.50	.40	3.07	.10	4.17	9.74
	Stylocoeniella armata	.66	2.50	.06	.46	.10	4.17	7.13
	Millepora platyphylla	.66	2.50	.04	.31	.10	4.17	6.98
		Total Density - 26.40			Total Species - 10			
		Total Dominance - 13.17%			Total Genera - 9			
6a	Pocillopora damicornis	1.87	42.50	4.66	66.67	.90	36.00	145.17
	Leptastrea purpurea	1.21	27.50	.11	1.57	.60	24.00	53.07
	Porites lutea	.66	15.00	.36	5.15	.50	20.00	40.15
	Montipora (pap.) sp. 3	.22	5.00	.29	4.15	.10	4.00	13.15
	Pavona sp. 1	.22	5.00	.29	4.15	.10	4.00	13.15
	Leptoria phrygia	.11	2.50	.21	3.00	.10	4.00	9.50
	Pavona obtusata	.11	2.50	.11	1.57	.10	4.00	8.07
		Total Density - 4.42			Total Species - 7			
		Total Dominance - 6.99%			Total Genera - 6			
6b	Pocillopora damicornis	1.85	32.50	4.28	88.42	.70	30.43	147.35
	Leptastrea purpurea	2.85	50.00	.23	4.54	1.00	43.48	98.02
	Porites lutea	.71	12.50	.55	10.85	.40	17.39	40.74
	Goniopora arbuscula	.14	2.50	.01	.20	.10	4.35	7.05
	Montipora venosa	.14	2.50	.004	.08	.10	4.35	6.93
		Total Density - 5.69			Total Species - 5			
		Total Dominance - 5.07%			Total Genera - 5			

Table 2 Continued.

		Density	Relative Density	Dominance (Percent)	Relative Dominance	Frequency	Relative Frequency	Importance Value
6b	Pocillopora damicornis	1.85	32.50	4.28	88.42	.70	30.43	147.35
	Leptastrea purpurea	2.85	50.00	.23	4.54	1.00	43.48	98.02
	Porites lutea	.71	12.50	.55	10.85	.40	17.39	40.74
	Goniopora arbuscula	.14	2.50	.004	.08	.10	4.35	7.05
	Montipora (fov.) sp. 2	.14	2.50	.004	.08	.10	4.35	6.93
		Total Density	- 5.69		Total Species	- 5		
		Total Dominance	- 5.07%		Total Genera	- 5		
7a	Pocillopora damicornis	.81	47.50	1.08	36.00	.90	37.50	121.00
	Acropora aspera	.51	30.00	1.77	59.00	.60	25.00	114.00
	Porites lutea	.08	5.00	.08	2.67	.20	8.33	16.01
	Montipora lobulata	.02	2.50	.003	.10	.10	4.17	14.01
	Leptastrea purpurea	.08	5.00	.01	.33	.20	8.33	13.66
	Goniastrea edwardsi	.02	2.50	.03	1.13	.10	4.17	7.80
	Goniopora arbuscula	.02	2.50	.02	.67	.10	4.17	7.34
	Psammocora contigua	.02	2.50	.002	.07	.10	4.17	6.74
	Porites cocosensis	.02	2.50	.0002	.007	.10	4.17	6.68
		Total Density	- 15.80		Total Species	- 9		
		Total Dominance	- 3.0%		Total Genera	- 8		
7b	Pocillopora damicornis	1.90	47.50	2.00	31.01	.90	37.50	116.01
	Acropora aspera	.90	22.50	2.92	45.27	.40	16.67	84.44
	Porites lutea	.50	12.50	1.28	19.84	.40	16.67	49.01
	Psammocora contigua	.30	7.50	.06	.93	.30	12.50	20.93
	Porites annae	.10	2.50	.12	1.86	.10	4.17	8.53
	Heliopora coerulea	.10	2.50	.04	.62	.10	4.17	7.29
	Leptastrea purpurea	.10	2.50	.03	.46	.10	4.17	7.13

Table 2 Continued.

		Density	Relative Density	Dominance (Percent)	Relative Dominance	Frequency	Relative Frequency	Importance Value
	<u>Psammocora</u> <u>stellata</u>	.10	2.50	.005	.08	.10	4.17	6.75
		Total Density - 4.00			Total Species - 8			
		Total Dominance - 6.45%			Total Genera - 6			
8a	<u>Acropora</u> <u>formosa</u>	2.22	92.50	13.69	99.49	1.00	76.92	268.91
	<u>Acropora</u> <u>aspera</u>	.06	2.50	.09	.65	.10	7.69	10.84
	<u>Goniastrea</u> <u>retiformis</u>	.06	2.50	.007	.05	.10	7.69	10.24
	<u>Leptastrea</u> <u>purpurea</u>	.06	2.50	.0006	.004	.10	7.69	10.19
		Total Density - 2.40			Total Species - 4			
		Total Dominance - 13.67%			Total Genera - 3			
8b	<u>Porites</u> <u>lutea</u>	.07	7.50	15.16	69.64	.30	10.71	87.85
	<u>Acropora</u> <u>formosa</u>	.35	37.50	1.61	7.39	.50	17.85	62.74
	<u>Montipora</u> <u>ehrenbergii</u>	.14	15.00	.30	1.38	.50	17.85	34.24
	<u>Montipora</u> (tub.) sp. 1	.07	7.50	1.34	6.15	.30	10.71	24.36
	<u>Montipora</u> <u>verrilli</u>	.07	7.50	.18	.83	.30	10.71	19.04
	<u>Porites</u> <u>murrayensis</u>	.05	5.00	1.05	4.82	.20	7.14	16.96
	<u>Leptastrea</u> <u>purpurea</u>	.07	7.50	.03	.14	.20	7.14	14.78
	<u>Psammocora</u> <u>digitata</u>	.02	2.50	1.54	7.07	.10	3.57	13.14
	<u>Stylocoeniella</u> <u>armata</u>	.05	5.00	.004	.02	.20	7.14	12.16
	<u>Montipora</u> <u>lobulata</u>	.02	2.50	.51	2.34	.10	3.175	8.41
	<u>Porites</u> (<u>S.</u>) <u>iwayamaensis</u>	.02	2.50	.05	.23	.10	3.75	6.30
		Total Density - .92			Total Species - 11			
		Total Dominance - 21.77%			Total Genera - 6			

Table 2 Continued.

		Density	Relative Density	Dominance (Percent)	Relative Dominance	Frequency	Relative Frequency	Importance Value
9a	Porites lutea	.12	32.50	9.00	86.04	.80	22.59	146.13
	Montipora (tub.) sp. 1	.06	15.00	.41	3.92	.50	17.24	36.16
	Porites cocosensis	.06	15.00	.60	5.74	.40	13.79	34.53
	Montipora subtilis	.06	15.00	.12	1.15	.40	13.79	29.94
	Acropora formosa	.02	5.00	.11	1.51	.20	6.90	13.41
	Leptastrea purpurea	.02	5.00	.001	.01	.20	6.90	11.91
	Porites andrewsi	.02	5.0	.20	1.91	.10	3.45	10.36
	Montipora verrilli	.009	2.50	.02	.19	.10	3.45	6.14
	Favia pallida	.009	2.50	.0007	.007	.10	3.45	5.96
	Pocillopora damicornis	.009	2.50	.0004	.004	.10	3.45	5.95
		Total Density - .39			Total Species - 10			
		Total Dominance - 10.46%			Total Genera - 6			
9b	Porites lutea	.08	22.50	3.48	65.66	.70	25.00	113.16
	Porites andrewsi	.06	17.5	1.21	22.83	.60	21.43	61.76
	Montipora verrilli	.07	20.00	.46	8.70	.40	14.28	42.98
	Porites cocosensis	.08	22.50	.09	1.70	.50	17.86	42.06
	Pocillopora damicornis	.02	5.0	.003	.06	.20	7.14	12.70
	Leptastrea purpurea	.02	5.0	.0007	.01	.20	7.14	12.15
	Montipora venosa	.008	2.50	.05	.94	.10	3.57	7.01
	Montipora subtilis	.008	2.50	.002	.04	.10	3.57	6.11
		Total Density - .35			Total Species - 8			
		Total Dominance - 5.3%			Total Genera - 4			
11a	Porites (S.) iwayamaensis	1.59	32.50	93.32	81.62	.60	20.69	134.81
	Porites lutea	1.10	22.50	19.06	16.56	.60	20.69	59.75
	Leptastrea purpurea	.46	16.00	.02	.02	.40	13.79	14.81

Table 2 Continued.

	Density	Relative Density	Dominance (Percent)	Relative Dominance	Frequency	Relative Frequency	Importance Value
Heliopora coerulea	.24	5.00	.79	.69	.20	6.90	12.59
Porites lichen	.24	5.00	.09	.08	.20	6.90	11.98
Montipora verrucosa	.24	5.00	1.05	.91	.10	3.45	9.36
Gardineroseris planulata	.12	2.50	.65	.56	.10	3.45	6.51
Cyphastrea serailia	.12	2.50	.03	.03	.10	3.45	5.98
Favites russelli	.12	2.50	.02	.02	.10	3.45	5.97
Goniastrea edwardsi	.12	2.50	.01	.01	.10	3.45	5.96
Stylophora mordax	.12	2.50	.008	.007	.10	3.45	5.96
Stylocoeniella armata	.12	2.50	.01	.01	.10	3.45	5.96
Astreopora myriophthalma	.12	2.50	.009	.007	.10	3.45	5.96
Favia pallida	.12	2.50	.004	.003	.10	3.45	5.95

Total Density	- 4.83	Total Species	- 14
Total Dominance	-115.07%*	Total Genera	- 12

11a [Corrected for large corals]*

	Density	Relative Density	Dominance (Percent)	Relative Dominance	Frequency	Relative Frequency	Importance Value
Porites (S.) iwayamaensis	1.94	27.78	8.17	34.06	.66	20.69	82.83
Porites lutea	1.55	22.22	4.70	19.59	.55	17.24	59.09
Gardineroseris planulata	.19	2.78	8.82	36.76	.11	3.45	42.99
Leptastrea purpurea	.78	11.11	.03	.12	.44	13.79	25.02
Heliopora coerulea	.39	5.56	1.25	5.21	.22	6.90	17.67
Porites lichen	.39	5.56	.53	2.21	.22	6.90	14.67
Montipora verrucosa	.39	5.56	.33	1.38	.22	6.90	13.84
Cyphastrea serailia	.39	5.56	.33	1.38	.22	6.90	13.84
Favites russelli	.19	2.78	.05	.21	.11	3.45	6.44

* This station had a few extremely large corals, causing an incorrect % cover. This has been corrected in this 2nd set of data for the same transect.

Table 2 Continued.

		Density	Relative Density	Dominance (Percent)	Relative Dominance	Frequency	Relative Frequency	Importance Value
	Goniastrea edwardsi	.19	2.78	.04	.17	.11	3.45	6.40
	Stylocoeniella armata	.19	2.78	.02	.08	.11	3.45	6.31
	Stylophora mordax	.19	2.78	.01	.04	.11	3.45	6.27
	Astreopora myriophthalma	.19	2.78	.01	.04	.11	3.45	6.27
	Favia pallida	.19	2.78	.006	.02	.11	3.45	6.25
		Total Density - 6.96			Total Species - 14			
		Total Dominance - 23.99%			Total Genera - 12			
11b	Porites (S.) iwayamaensis	3.27	27.50	3.60	27.23	.90	23.68	78.41
	Heliopora coerulea	1.10	10.00	2.63	19.89	.40	10.52	40.41
	Millepora tuberosa	.89	7.50	2.12	16.04	.30	7.89	31.43
	Porites lichen	.89	7.50	1.22	9.23	.30	7.89	24.62
	Diploastrea heliopora	.30	2.50	1.60	12.10	.10	2.63	17.23
	Astreopora myriophthalma	.60	5.00	.64	4.84	.20	5.26	15.10
	Porites lutea	.60	5.00	.27	2.04	.20	5.26	12.30
	Favia pallida	.60	5.00	.20	1.51	.20	5.26	11.47
	Leptastrea purpurea	.60	5.00	.09	.68	.20	5.26	10.94
	Goniastrea edwardsi	.60	5.00	.06	.45	.20	5.26	10.71
	Stylocoeniella armata	.60	5.00	.01	.08	.20	5.26	10.34
	Platygyra daedalea	.30	2.50	.33	2.50	.10	2.63	7.63
	Galaxea fascicularis	.30	2.50	.27	2.04	.10	2.63	7.17
	Montipora lobulata	.30	2.50	.09	.68	.10	2.63	5.81
	Millepora dichotoma	.30	2.50	.07	.53	.10	2.63	5.66
	Porites (S.) vaughani	.30	2.50	.01	.08	.10	2.63	5.21
	Stylophora mordax	.30	2.50	.009	.07	.10	2.63	5.20
		Total Density - 11.94			Total Species - 17			
		Total Dominance -13.22%			Total Genera - 12			

Table 2 Continued.

		Density	Relative Density	Dominance (Percent)	Relative Dominance	Frequency	Relative Frequency	Importance Value
12a	Porites lutea	.34	5.00	2.69	31.54	.30	11.53	48.07
	Galaxea fascicularis	.85	12.50	1.18	13.83	.30	11.53	37.86
	Pocillopora ankeli	.68	10.00	1.06	12.43	.30	11.53	33.97
	Porites (S.) iwayamaensis	1.02	15.00	.16	1.87	.40	15.39	32.25
	Psammocora profundacella	.68	10.00	.66	7.74	.30	11.53	29.27
	Goniastrea retiformis	.85	12.50	.76	8.91	.20	7.69	29.10
	Lobophyllia corymbosa	.17	2.50	.77	9.03	.10	3.85	15.38
	Millepora tuberosa	.34	5.00	.39	4.57	.10	3.85	13.42
	Stylocoeniella armata	.34	5.00	.02	.23	.20	7.69	12.92
	Platygyra daedalea	.17	2.50	.47	5.51	.10	3.85	11.86
	Leptastrea purpurea	.51	7.50	.03	.35	.10	3.85	11.70
	Leptoria phrygia	.17	2.50	.28	3.28	.10	3.85	9.63
	Goniastrea edwardsi	.17	2.50	.06	.70	.10	3.85	7.05

Total Density - 6.29 Total Species - 13
Total Dominance - 8.53% Total Genera - 11

		Density	Relative Density	Dominance (Percent)	Relative Dominance	Frequency	Relative Frequency	Importance Value
12b	Millepora tuberosa	.79	17.50	4.79	34.04	.30	10.34	61.88
	Pocillopora ankeli	.22	5.00	2.43	17.27	.20	6.90	29.17
	Leptoria phrygia	.34	7.50	1.44	10.23	.20	6.90	24.63
	Galaxea fascicularis	.11	25.00	.10	.71	.50	17.24	20.45
	Stylocoeniella armata	.34	7.50	.01	.07	.30	10.34	17.91
	Acropora palifera	.11	2.50	1.61	11.44	.10	3.45	17.39
	Acropora tenuis	.22	5.00	.76	5.40	.10	3.45	13.85
	Acropora humilis	.11	2.50	.56	3.98	.10	3.45	9.93
	Hydnophora microconos	.11	2.50	.49	3.48	.10	3.45	9.43
	Montipora (pap.) sp. 4	.11	2.50	.49	3.48	.10	3.45	9.43
	Acropora surculosa	.11	2.50	.40	2.84	.10	3.45	8.79
	Montipora (pap.) sp. 2	.11	2.50	.33	2.34	.10	3.45	8.29

Table 2 Continued.

		Density	Relative Density	Dominance (Percent)	Relative Dominance	Frequency	Relative Frequency	Importance Value
	Platygyra daedalea	.11	2.50	.16	1.14	.10	3.45	7.09
	Montipora (tub.) sp. 1	.11	2.50	.14	.99	.10	3.45	6.94
	Goniopora arbuscula	.11	2.50	.12	.85	.10	3.45	6.80
	Pocillopora damicornis	.11	2.50	.09	.63	.10	3.45	6.58
	Favia favus	.11	2.50	.06	.43	.10	3.45	6.38
	Porites lutea	.11	2.50	.06	.43	.10	3.45	6.38
	Favia pallida	.11	2.50	.03	.21	.10	3.45	6.16
		Total Density - 3.45			Total Species - 19			
		Total Dominance - 14.07%			Total Genera - 12			
15a	Porites (S.) iwayamaensis	2.52	35.00	47.20	69.52	.70	28.00	132.52
	Porites lutea	1.98	27.50	16.31	24.02	.50	20.00	71.52
	Leptastrea purpurea	1.26	17.50	.39	.57	.60	24.00	42.07
	Millepora tuberosa	.36	5.00	.22	.32	.20	8.00	13.32
	Porites lobata	.18	2.50	3.11	4.58	.10	4.00	11.08
	Heliopora coerulea	.36	5.00	.08	.12	.10	4.00	9.12
	Favia pallida	.18	2.50	.34	.51	.10	4.00	7.01
	Platygyra daedalea	.18	2.50	.13	.19	.10	4.00	6.69
	Millepora platyphylla	.18	2.50	.11	.16	.10	4.00	6.66
		Total Density - 7.20			Total Species - 9			
		Total Dominance - 67.89%			Total Genera - 6			
15b	Porites lutea	2.36	40.00	14.16	88.06	.90	29.03	157.09
	Leptastrea purpurea	.88	15.00	.36	2.24	.40	12.90	30.14
	Cyphastrea serailia	.59	10.00	.41	2.55	.40	12.90	25.45
	Millepora tuberosa	.44	7.50	.13	.81	.30	9.68	17.99
	Favia pallida	.29	5.00	.03	.19	.20	6.45	11.64

Table 2 Continued.

	Density	Relative Density	Dominance (Percent)	Relative Dominance	Frequency	Relative Frequency	Importance Value
Porites (S.) iwayamaensis	.29	5.00	.02	.12	.20	6.45	11.57
Galaxea fascicularis	.15	2.50	.41	2.55	.10	3.22	8.27
Porites lichen	.15	2.50	.24	1.49	.10	3.22	7.21
Astreopora myriophthalma	.15	2.50	.23	1.43	.10	3.22	7.15
Porites lobata	.15	2.50	.06	.37	.10	3.22	6.09
Montipora verrucosa	.15	2.50	.02	.12	.10	3.22	5.84
Stylocoeniella armata	.15	2.50	.01	.06	.10	3.22	5.78
Acanthastrea echinata	.15	2.50	.004	.02	.10	3.22	5.74

Total Density - 5.90   Total Species - 13
Total Dominance - 16.08%   Total Genera - 10

PART B. Line Intercept Transects		Dominance (Percent)	Relative Dominance	Relative Frequency	Importance Value		
10a	Porites lutea	.76	76.00	39.13	115.13	Total Cover	- 1.00%
	Pavona decussata	.01	1.00	35.87	36.87	Total Species	- 4
	Porites cocosensis	.19	19.00	17.39	36.39	Total Genera	- 2
	Porites andrewsi	.04	4.00	7.61	11.61		
10b	Porites (S.) iwayamaensis	4.90	27.68	80.09	116.77	Total Cover	- 17.70%
	Porites lutea	10.43	58.93	.41	59.34	Total Species	- 5
	Porites cocosensis	1.01	5.71	9.10	14.89	Total Genera	- 3
	Acropora formosa	.92	5.20	.27	5.47		
	Montipora verrilli	.44	2.49	1.09	3.58		

Table 2 Continued.

		Dominance	Relative Dominance	Relative Frequency	Importance Value	
13a	Porites lutea	1.27	69.40	53.27	122.67	Total Cover - 1.83%
	Pocillopora damicornis	.51	27.87	33.64	61.51	Total Species - 3
	Leptastrea purpurea	.05	2.73	13.08	15.81	Total Genera - 3
13b	Porites lutea	1.52	74.51	40.49	115.00	Total Cover - 2.04%
	Leptastrea purpurea	.18	8.82	49.59	58.41	Total Species - 3
	Pocillopora damicornis	.34	16.67	9.92	26.59	Total Genera - 3
14a	Porites lutea	5.67	65.70	55.10	120.80	Total Cover - 8.63%
	Leptastrea purpurea	.10	1.16	28.57	29.73	Total Species - 8
	Porites andrewsi	2.00	23.17	.31	23.48	Total Genera - 6
	Plerogyra sinuosa	.07	.81	8.16	8.97	
	Montipora lobulata	.28	3.24	1.02	4.26	
	Pocillopora damicornis	.06	.69	3.06	3.75	
	Pavona obtusata	.05	.58	3.06	3.64	
	Porites cocosensis	.25	2.90	.20	3.10	
	Montipora (tub.) sp. 2	.15	1.74	1.02	2.76	
14b	Porites cocosensis	16.56	70.65	25.00	95.65	Total Cover - 23.44%
	Porites andrewsi	5.93	25.30	42.86	68.16	Total Species - 4
	Porites lutea	.80	3.41	21.43	24.84	Total Genera - 2
	Acrhelia horrescens	.15	.64	10.71	11.35	

Table 2 Continued.

		Dominance Percent	Relative Dominance	Relative Frequency	Importance Value		
16a	Porites (S.) iwayamaensis	4.60	52.57	10.26	62.83	Total Cover -	8.75%
	Montipora (pap.) sp. 4	.06	.68	43.59	44.27	Total Species -	6
	Porites (S.) horizontalata	2.36	26.97	15.38	42.35	Total Genera -	3
	Porites andrewsi	1.08	12.34	10.26	22.60		
	Porites cocosensis	.16	1.83	15.38	17.66		
	Pachyseris speciosa	.49	5.60	5.12	10.72		
16b	Porites (S.) horizontalata	1.00	31.54	48.00	79.54	Total Cover -	3.17%
	Porites lutea	.50	15.77	20.00	35.77	Total Species -	7
	Acrhelia horrescens	.80	25.24	10.00	35.24	Total Genera -	4
	Montipora (pap.) sp. 4	.25	7.89	8.00	15.89		
	Montipora verrilli	.20	6.31	6.00	12.31		
	Porites (S.) iwayamaensis	.32	10.09	2.00	12.09		
	Pachyseris speciosa	.10	3.15	6.00	9.15		

Table 3. Significance values from the statistical analyses.

I. Nested Anova (1982 only)

A. Line intercept transects

	Diameter	Intercept
Biotopes	Fs.05(1,2) = 18.5 ns	Fs.05(1,2) = 18.5 ns
Stations	Fs.05(2,4) = 6.94 ns	Fs.05(2,4) = 6.94 ns
Transects	Fs.05(4,162) = 2.37+++	Fs.05(4,162) = 237+++

B. Point Quarter transects

	Diameter	Distance
Biotopes	Fs.05(5,5) = 5.05+	Fs.05(5,5) = 5.05++
Stations	Fs.05(5,11) = 3.20 ns	Fs.05(5,11) = 3.20+
Transects	Fs.05(11,429) = 1.79 ns	Fs.05(11,492) = 1.79 ns

II. Paired Comparison (1975 vs 1982)

A. Line Intercept transects (% cover = dominance)

Years	Fs.05(1,3) = 10.1 ns
Stations	Fs.05(3,3) = 9.28++

B. Point Quarter Transects

	Density	% Cover
Years	Fs.05(1,10) = 4.96 ns	Fs.05(1,10) = 4.96+
Stations	Fs.05(10,10) = 2.98+++	Fs.05(10,10) = 2.98 ns

Table 4. Density and dominance values in 1975 and 1982. Corresponding stations are adjacent to each other (Stations 3 and 5 in 1975 correspond to Stations 3a and 3b in 1982). The mean (Y), sample number (N) standard deviation (S) and range (R) are computed for each biotope.

Biotope	Corresponding Transect 1975	Corresponding Transect 1982	Total Density m^2 1975	Total Density m^2 1982	Total Dominance % 1975	Total Dominance % 1982
IA	3	3a	1.72	3.36	3.45%	4.27
	5	3b	.62	6.29	.83	11.77
	6	5a	20.17	12.60	2.89	4.77
	7	5b	14.42	26.40	4.55	13.77
	8	6a	*	4.42	*	6.99
	9	6b	*	5.69	*	5.07
	10		.41		.15	
	22	7a	.37	1.58	.83	3.00
		7b		4.00		6.45
	Y	Y	6.28	8.03	2.12	7.04
	N	N	6	8	6	8
	S	S	8.70	8.11	1.75	3.79
	R	R	.37- 20.17	1.58- 26.40	.15- 4.55	3.00- 13.77
IB	16	1a	.29	.91	5.51	4.50
	17	1b	.46	1.90	3.52	5.40
	2	2a	17.88	4.87	51.66	11.74
	4	2b	1.75	5.60	4.50	27.02
	23	8a	1.20	2.40	3.72	13.76
	24	8b	.20	.92	.10	21.77
	Y	Y	3.64	2.76	11.50	14.03
	N	N	6	6	6	6
	S	S	6.99	2.01	19.76	8.94
	R	R	.20- 17.88	.91- 5.60	.10- 51.66	4.50- 27.02
ID	11	4a	1.34	.54	48.18	179.67+++
	12	4b	4.28	.68	8.40	3.38
	14	4c	1.44	.96	5.95	.48
	15	4d	1.16	2.29	8.72	11.14
	Y	Y	2.0-5	1.31	17.81	5.09
	N	N	4	4	4	3
	S	S	1.49	.80	20.28	5.51
	R	R	1.16- 4.28	.54- 2.29	5.95- 48.18	.48- 11.14
IE	18	9a	.33	.39	.34	10.46
	19	9b	1.16	.35	17.86	5.30
	Y	Y	.74	.37	9.10	7.88
	N	N	2	2	2	2
	S	S	.59	.03	12.39	3.65

Table 4 Continued.

Biotope	Transect 1975	Corresponding 1982	Total Density m^2 1975	Total Density m^2 1982	Total Dominance % 1975	Total Dominance % 1982
	R	R	.33- 1.16	.35- .39	.34- 17.86	5.30- 10.46
IIA	28	10a	++	++	22.00	1.00
	29	10b	++	++	8.00	17.00
	25	12a	3.62	6.29	3.57	8.53
		12b		3.45		14.07
	32	13a	++	++	1.00	1.83
		13b		++		2.04
	Y	Y		4.87	8.64	7.41
	N	N		2	4	6
	S	S		2.01	9.36	7.41
	R	R		3.45- 6.29	1.00- 22.00	1.00- 17.00
IIB	26	11a	2.29	6.96++++	9.41	23.99++++
		11b		11.94		13.22
	35	14a	++	++	1.84	8.63
	36	14b	++	++	4.20	23.44
		16a		++		8.75
	34	16b	++	++	15.00	3.17
	Y	Y		9.45	7.61	13.53
	N	N		2	4	6
	S	S		3.52	5.85	8.51
	R	R		6.96- 11.94	1.84- 9.41	3.17- 23.99
IIC	27	15a	.22	7.20	1.60	67.89
		15b		5.90		16.08
		Y		6.55		41.98
		N		2		2
		S		.92		36.63
		R		5.90- 7.20		16.08- 67.89

* No quantitative data for these stations because only a few corals found.
++ No density values computed for line intercept transects.
+++ This station had extremely large corals covering most of the surface. The large values tend to throw off dominance values. Line intercept should have been used here. Not included in Y, N, S, R values.
++++ This station also had extremely large colonies. Results for density and dominance values shown here are adjusted values obtained by removing the four large colones from the data. Nine points remained and calculations proceeded accordingly. Adjusted and unadjusted values are found in Table 1 for this transect. These are the adjusted values.

SOFT CORAL SURVEY

By

Charles Birkeland

Two replicate transects were taken in each of 12 selected areas sampled with transects in 1973-1974 (cf. pages 34-38, Tables 14 and 15, and Figure 39 in Randall et al., 1975). The same point-quarter technique was used in this study (1982) as in the previous study (1973-1974) except that a quadrant was recorded as having no coral at a maximum distance of 20 m rather than 5 m. This is probably the reason that no soft corals were recorded for 15 out of 32 transects in 1973-1974, but density and percent cover estimates are available for all transects in 1982. This is also probably the reason that the density estimates are lower in 1982 (Table 1); distances of 15 to 20 m were frequently included in the calculations rather than zero after a limit of 5 m.

To examine the sampling program, a nested anova was performed on two replicates from each of four facies. The facies were found to differ significantly ($p<.05$) and there were no significant differences among transects within facies. The within transect error variance made up 71.45% of the total variance. The variance between replicate transects made up 2.95% of the total and variance between facies made up 25.60%.

There was no indication of a significant difference in percent cover by soft corals between years (Table 1). An average of percent cover on 4 patch reefs was 2.3 ± 1.7 in 1973-1974 and 2.2 ± 1.8 in 1982. The estimates of cover were greater on transects IEc and IIAb in 1982 than in 1973-1974 and less on transects IIAa and IIAc. Although there were no soft corals recorded on the leeward barrier reef flat and on the lagoon shelf in 1973-1974, the very low density and percent cover recorded in 1982 indicates that this is probably simply a matter of searching as far as 20 m rather than 5 m from the points of sampling.

The distribution and relative abundance of soft corals and zoanthids is not notably different in 1982 than it was in 1973-1974. *Asterospicularia randalli* was numerically predominant on the windward barrier reef flat and windward reef margin. *Sinularia* spp. were the predominant alcyonaceans in Cocos Lagoon, both in terms of density and percent cover. *Zoanthus* was common only on the lagoonal patch reefs. *Alcyonium*, *Sympodium*, nephthyids, and xeniids were not observed in 1982. They are most likely still there but were not seen because they are rare and the total amount of search time was less in 1982 than in 1973-1974.

In summary, there is no substantive evidence of any differences in soft corals between 1973-1974 and 1982.

LITERATURE CITED

Randall, R. H., R. T. Tsuda, R. S. Jones, M. J. Gawel, J. A. Chase, and R. Rechebei. 1975. Marine biological survey of the Cocos barrier reefs and enclosed lagoon. Univ. Guam Mar. Lab., Tech. Rept. No. 17. 160 p.

Table 1. Density and percent cover of soft corals on 100 m transects in Cocos Lagoon. Data from 1974 were based on single transects. Data from 1982 were based on two replicates each, except for those marked "1". For locations of transects, see Figure 39 in Randall et al., 1975.

		Total Density		Percent Cover	
Facies	Transect	1973-74	1982	1973-74	1982
Windward Barrier Reef Flat	IAWc	2.54	$5x10^{-4}$	.08	$4.5x10^{-5}$
Leeward Barrier Reef Flat	IALb	0	$2.5x10^{-3}$	0	.02
	IALd	0	$1.1x10^{-3}$	0	.01
Lagoon Shelf	IBc	0	.06	0	0.1
	F_1	-	.06	-	1.3
	F_2[1]	-	.09	-	0.7
Patch Reef	ID*	.43	.051	1.14	2.5
	ID	2.24	.096	4.14	1.0
	ID	.20	.105	.59	4.6
	ID	.77	.204	3.33	0.8
Nearshore Shelf	IEc	3.74	2.74	11.74	15.36
Manell Channel Margin	IIAa[1]	.52	.30	.83	.39
Mamaon Channel Margin	IIAb	.16	.07	.27	.45
	IIAc[1]	.10	.03	.69	.04

*Patch reefs IDa-e were not distinguished with certainly. Therefore, comparisons between years cannot be exactly paired for this facies although density and percent cover within years are still matched.

FISHES

By

Steven S. Amesbury

INTRODUCTION

The fishes of Cocos Lagoon were surveyed by R. S. Jones and J. A. Chase in 1974 (see Randall et al., 1975). The present study is a resurvey of fish habitats in Cocos Lagoon to document the present status of fish communities within the lagoon and to determine whether notable changes in the fish fauna have occurred since the previous survey. As was done in the previous survey, fish species were enumerated along transects within certain recognizable biotopes within the lagoon. Because transect locations were chosen to represent certain biotopes rather than being run in exactly the same locations as the previous survey, a conservative bias was introduced into the resurvey in that fish communities within biotopes were likely to be rather similar between the 1974 and the 1982 (present) surveys because of the general ecological stability of fish/habitat relationships whereas the extent of certain biotopes may have changed markedly in the intervening years. In addition, it has been demonstrated (Amesbury et al., 1981) that fish communities show a great deal of variability when censused along transects and that identical areas transected twice within a few days will show considerable differences in species richness and in fish abundance. Thus, variation between the present census results and those of 1974 can be expected to be great even if no significant environmental changes have occurred.

MATERIALS AND METHODS

Biotopes

Five of the six biotopes which were censused for fish in 1974 were resurveyed during this study. The biotope outside the barrier reef was purposefully excluded as we were concerned primarily with biotopes within the lagoon. A seventh biotope (estuarine and freshwater habitats) was not included in the present survey nor in the 1974 survey. See Figure 1 for transect locations.

I. Seagrass Biotope -- Eight 100-m transects were run in the seagrass biotope: transects A through D and their replicates A' through D'. Transects A, A', B, and B' were located in the Halodule uninervis beds around Bikini Island. Transects C, C', D, and D' were placed in beds of Enhalus acoroides southeast of the Geus River mouth.

II. Sand Biotope -- Four transects were run in sandy habitats: transects E and E' in a shallow (3 m) sandy area and transects F and F' in a deeper (8 m) sandy area.

III. Lagoon Patch Reef Biotope -- Six transects were run on lagoon patch reefs, transects G, G', H, H', I, and I'. Each replicate pair was run in a separate patch reef and the transect line was laid to survey both the sides and the tops of the patch reefs.

IV. Barrier Reef Flat Biotope -- Because the barrier reef flat areas were found to be the most heterogeneous of the biotopes surveyed, a total of twelve transects were run to provide an adequate sample of the variety of habitats within this biotope. Transects J, J', K, K', L, L', M, and M' were run in leeward barrier reef flat areas; transects N, N', O, and O' were run on the windward barrier reef flat.

V. Channel Wall Biotope -- Four transects (P, P', Q, and Q') were run along channel walls in a meandering fashion ranging in depth from 7 to 16 m.

An additional pair of transects (R and R') were run on the lagoon fringing reef flat northwest of the Geus River mouth. This biotope was not surveyed in the 1974 study but was added in this survey to more completely sample the range of habitat types within Cocos Lagoon.

Transecting Methods

As in the 1974 study, transects were each 100 m in length and the investigator counted fish by species within 1 m to either side of the transect line (thus censusing 200 m^2 per transect). Replicate transets were run in the same area, but the transect line was reset in each case. Where depth permitted, the investigator used snorkeling gear; on the deeper transects scuba was used. Census data were recorded underwater on a slate.

RESULTS

Thirty-four species of fish were encountered along the 8 transects in seagrass habitats (Table 1). There were considerable differences in species richness among the transects (ranging from 1 to 18 species). Most variation in species richness occurred among the transects in the *Enhalus* beds; in the *Halodule* beds species richness ranged from 13 to 16 species per transect. The overall species richness (34 species) was virtually the same as that recorded in 1974 (32 species).

Fish density within the seagrass biotope was also quite variable, ranging from 0 to 570 fish per 200 m^2 (Table 1). Fish density was notably higher in the *Halodule* beds than it was in the *Enhalus* beds. The overall mean density of fish (178 per 200 m^2) was second only to that of the barrier reef flat biotope (358 fish per 200 m^2; Table 4). This high density was principally the result of a high density of siganids (rabbitfish) in the *Halodule* beds. The fish density measured in the 1974 study (213 fish per 200 m^2) was not significantly greater than that measured during the present study.

The sand biotope had the fewest species of fish (31 species in total; Table 2) and all but 2 of these were associated with isolated coral colonies within the sand biotope. Only *Lethrinus harak* and an unidentified species of trichonotid (sand divers) were found in open sand. Fourteen fish species were censused in the sand biotope in 1974.

Fish density was also very low in the sand biotope, ranging from 0 to 7 fish per 200 m^2. The average density (2.25 fish per 200 m^2) was considerably less than that measured in 1974 (22.7 fish per 200 m^2), principally because of a high density of two species of gobies censused during the earlier study. These results do not indicate that these gobies have become scarcer, only that transect placement was different between the two surveys.

Lagoon patch reefs exhibited an intermediate level of species richness, with a total of 77 species observed. Counts for individual transects ranged from 30 to 49 species (Table 3). Fish density in lagoon patch reef habitats was also at an intermediate level averaging 159 fish per 200 m^2. Most abundant were species of aggregating damselfishes Amblyglyphidodon curacao and Chromis caerulea and juvenile parrotfishes. The number of species and mean diversity measured in 1974 were somewhat higher than those measured during the present surveys but the difference is probably attributable to natural variation.

The fish communities of the barrier reef flat biotope were the highest in species richness (with a total of 103 species) and in fish density (averaging 359 fish per 200 m^2) of all the biotopes surveyed (Table 4). This biotope, while not characterized by great topographic relief, does provide a variety of living spaces and microhabitats for fish within and between the many small- to moderate-sized patches of hard and soft coral which dominate this zone. The Acropora thickets were particularly densely inhabited by farmerfishes of the genus Stegastes (Family Pomacentridae). Butterflyfishes (Family Chaetodontidae) were well represented in this habitat: On a single transect (L'), more than half the butterflyfish species known from Guam were seen. Species richness and fish density measured in ths biotope in 1974 were somewhat lower than those measured during the present study but the difference is negligible.

Neither species richness nor fish density in the channel wall biotope were as high in the present study as they were in the 1974 census (Table 5). This may be explicable by the difference in total effort spent in this biotope during the two surveys and to the presence of some large aggregations of cardinalfishes (Family Apongonidae), damselfishes (Family Pomacentridae), and the blenny Meiacanthus atrodorsalis during the 1974 census. Despite the lower values of species richness and fish density measured during the present survey, there was no evidence of any type of environmental deterioration or damage in this habitat. In fact, this biotope had the only fish stocks with apparent potential for increased harvesting seen during this survey. These were populations of several species of menpachi (Myripristis) living in caves and crevices along the channel walls.

Fish abundance was moderate at the one lagoon fringing reef flat surveyed (Table 5), and species richness on the two transects (both with 34 species) was comparable to that on transects in barrier reef flat biotopes. This biotope was not surveyed during the 1974 study but is included here for completeness.

The 22 most abundant fish species in the patch reef, barrier reef flat, and channel wall biotopes are ranked in Table 6. Thirteen of the 16 most abundant species in the present study were among the 20 most abundant fish species in the 1974 study (Randall et al., 1975, p. 109). This is a strong indication that the fish communities in Cocos Lagoon have undergone no major changes in the years intervening between the two surveys.

DISCUSSION

The results of the fish surveys reported here do not indicate that fish communities in Cocos Lagoon have undergone any significant disturbances since the 1974 survey. This conclusion is consonant with the results of surveys of other biotic groups presented in this report. Although Cocos Lagoon is being developed, particularly along the Merizo shoreline and on Cocos Island, and recreational use of the waters is increasing, the fish communities, except perhaps in localized areas, have not suffered as a result. Nonetheless, because Cocos Lagoon is such an important area for recreation, subsistence fishing, and tourist development, it is essential that efforts to maintain the ecological health of the area be continued.

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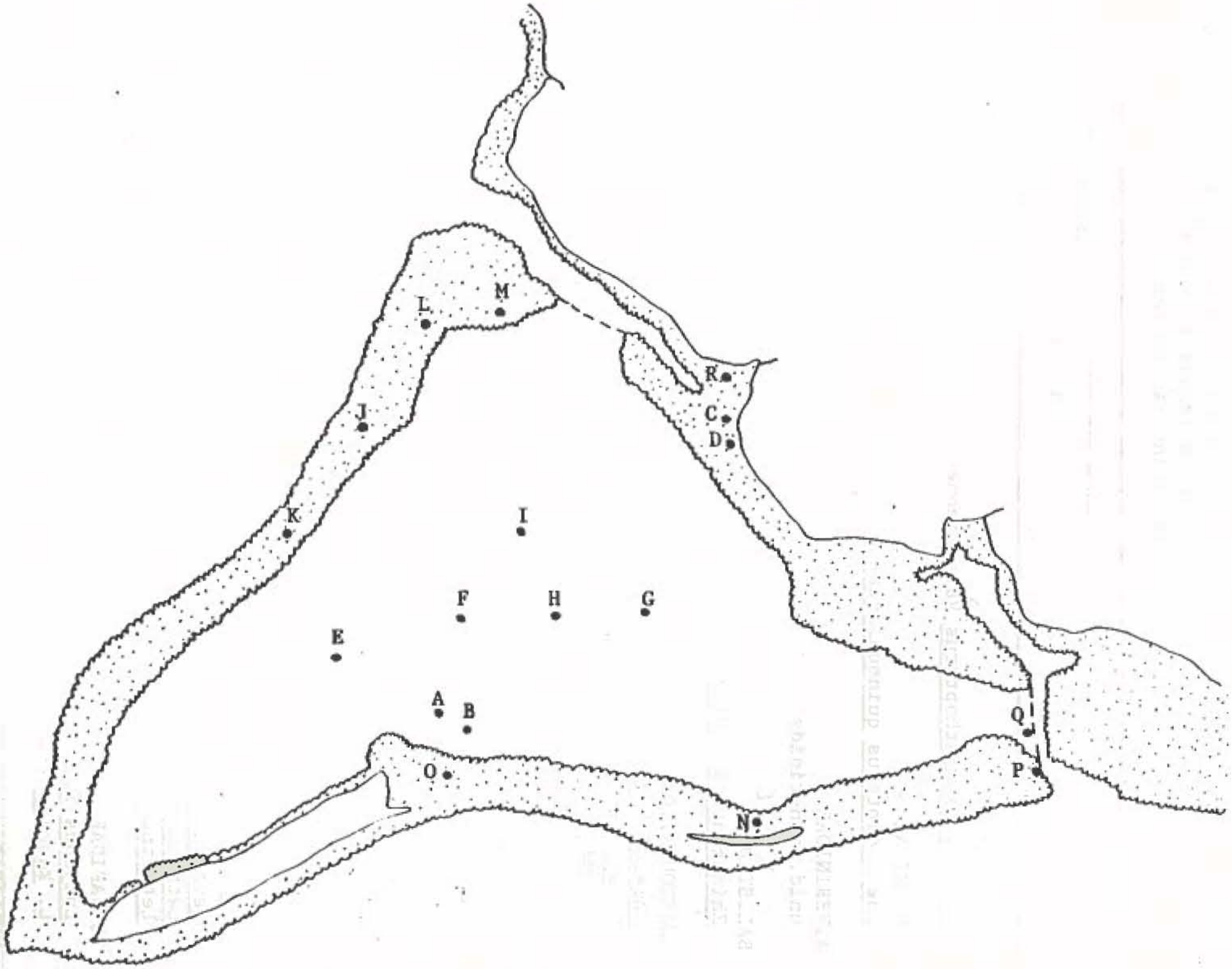

Figure 1. Location of fish transecting stations in Cocos Lagoon.

Table 1. Results of fish survey in seagrass biotope. Numerical entries are number of fish seen per 100-m transect (200 m^2). X indicates additional species seen during random swims.

	TRANSECTS A	A'	B	B'	C	C'	D	D'
ACANTHURIDAE								
Acanthurus xanthopterus Valenciennes	X				1	X		X
APOGONIDAE								
Cheilodipterus quinquelineata (Cuvier)						1		
ATHERINIDAE								
unid. atherinids	X		X					
BALISTIDAE								
Rhinecanthus aculeatus (Linneaus)								X
CHAETODONTIDAE								
Chaetodon auriga Forsskal					2	X		
C. ephippium Cuvier					X			
C. unimaculatus Bloch	X							
GOBIIDAE								
Amblygobius albimaculatus (Ruppell)					1	1		
Gnatholepis sp.					1	1		
unid. gobiids						2		
LABRIDAE								
Cheilio inermis (Forsskal)	2	2	2	3				
Coris variegata (Ruppell)	3	3	2	X				
Halichoeres trimaculatus (Quoy & Gaimard)	1	7	13	5	1	2		9
unid. labrids								6
LETHRINIDAE								
Lethrinus harak (Forsskal)	16	44	9	6	X			X
Lethrinus sp. 1	2	4		2				
Lethrinus sp. 2			X					
LUTJANIDAE								
Lutjanus fulvus (Bloch & Schneider)					X	X		
L. kasmira (Forsskal)					2			
MULLIDAE								
Mulloidichthys flavolineatus (Lacepede)	43	5	X	X				
Parupereus barberinus (Lacepede)	154	7	2	3	2	X	X	
P. chryseredros (Lacepede)	31	16	X	2				
P. trifasciatus (Lacepede)			1	1		1		

Table 1 Continued.

	TRANSECTS							
	A	A'	B	B'	C	C'	D	D'
POMACENTRIDAE								
Abudefduf sexfasciatus (Lacepede)	X	3			4	X		
Chromis caerulea (Cuvier)					5			
Dascyllus aruanus (Linnaeus)	X	X			25	1		
Plectroglyphidodon leucozonus (Bleeker)					X			
Pomacentrus pavo (Bloch)					5			
SCARIDAE								
Leptoscarus vaigiensis (Quoy & Gaimard)								X
juvenile scarids		4		1	3	X		
SIGANIDAE								
Siganus argenteus (Quoy & Gaimard)	104	147	10	43				
S. spinus (Linnaeus)	179	186	78	61				
SYNGNATHIDAE								
Corythoichthys intestinalis (Ramsey)						X		
Number Species per Transect	16	14	13	13	18	14	1	6
Fish Abundance per Transect (no./200m^2)	570	502	143	131	53	12	0	15
Total Species per Replicate Pair	17		15		21		7	
Mean Fish Abundance per Replicate Pair (no./200m^2)	536		137		32.5		7.5	

Total Species, Seagrass Biotope:	34(1982)	32(1974)
Mean Fish Abundance (no./200m^2), Seagrass Biotope:	178.25(1982)	212.71(1974)

Table 2. Results of fish survey in sand biotope. Numerical entries are number of fish seen per 100 m transect (200 m^2). X indicates additional species seen during random swims.

	TRANSECTS			
	E	E'	F	F'
ACANTHURIDAE				
Acanthurus triostegus (Linnaeus)		X*		
A. xanthopterus Valenciennes			X*	X*
Ctenochaetus striatus (Quoy & Gaimard)		X*		
APOGONIDAE				
Apogon novemfasciatus Cuvier	X*		X*	
Apogon sp.	X*	X*		
Cheilodipterus quinquelineata (Cuvier)	X*	X*	X*	1*
BALISTIDAE				
Rhinecanthus aculeatus (Linnaeus)			X*	X*
CHAETODONTIDAE				
Chaetodon auriga Forsskal			X*	
C. citriellus Cuvier	X*	X*		
C. ephippium Cuvier		X*	X*	
GOBIIDAE				
Amblygobius albimaculatus (Ruppell)			X*	X*
Gnatholepis sp.				X*
Ptereleotris microlepis Bleeker			X*	X*
unid. gobiids				X*
LABRIDAE				
Cheilinus sp.				X*
Cirrhilabrus sp.			X*	
Halichoeres trimaculatus (Quoy & Gaimard)	X*	1*	X*	X*
Labroides dimidiatus (Valenciennes)				X*
LETHRINIDAE				
Lethrinus harak (Forsskal)		X		
MULLIDAE				
Parupereus barberinus (Lacepede)		X*	X*	X*

Table 2 Continued.

	TRANSECTS			
	E	E'	F	F'
POMACENTRIDAE				
Dascyllus aruanus (Linnaeus)	X*		X*	2*
D. trimaculatus (Ruppell)		X*		
Plectroglyphidodon leucozonus (Bleeker)	X*	1*		X*
Pomacentrus pavo (Bloch)	X*	X*	X*	3*
P. vaiuli Jordan & Seale			X*	1*
SCARIDAE				
Scarus ghobban Forsskal		X*		
S. oviceps Valenciennes		X*		
juvenile scarids	X*			
SERRANIDAE				
Epinephelus sp.	X*			
TRICHONOTIDAE				
unid. trichonotids		X		
ZANCLIDAE				
Zanclus cornutus (Linnaeus)	X*			
Number Species per Transect	11	15	14	15
Fish Abundance per Transect (no./200 m^2)	0	2	0	7
Total Species per Replicate Pair	20		19	
Mean Fish Abundance per Replicate Pair (no./200 m^2)	1		3.5	

Total Species, Sand Biotope: 31(1982) 14(1974)

Mean Fish Abundance (no./200m^2), Sand Biotope: 2.25(1982) 22.7(1974)

* Associated with isolated corals within sand biotope

Table 3. Results of fish survey in lagoon patch reef biotope. Numerical entries are number of fish seen per 100-m transect (200 m^2). X indicates additional species seen during random swims.

	TRANSECTS					
	G	G'	H	H'	I	I'
ACANTHURIDAE						
Acanthurus glaucopareius Cuvier				X		
A. nigrofuscus (Forsskal)	1					X
A. triostegus (Linnaeus)	X	X	X	2	1	10
A. xanthopterus Valenciennes	X	X	1	X		X
Ctenochaetus striatus (Quoy & Gaimard)	X	2	2	2		X
Naso lituratus (Bloch & Schneider)			X	X	X	
N. unicornis (Forsskal)	X		X	1		
Z. flavescens (Bennett)					X	
Z. veliferum (Bloch)			X	X		X
APOGONIDAE						
Cheilodipterus quinquelineata (Cuvier)						1
AULOSTOMIDAE						
Aulostomus chinensis (Linnaeus)						X
BALISTIDAE						
Rhinecanthus aculeatus (Linnaeus)			X	1		2
BLENNIIDAE						
Meiacanthus atrodorsalis (Gunther)	2	2	1	2	4	2
CARANGIDAE						
Caranx melampygus Cuvier				3		
CHAETODONTIDAE						
Chaetodon auriga Forsskal	X		X			X
C. bennetti Cuvier	X					
C. citrinellus Cuvier		1	X	X	2	
C. ephippium Cuvier		X	1	1	X	X
C. kleini Bloch				X		
C. lunula (Lacepede)	1	X	2	1	X	X
C. melannotus Schneider			1	1		X
C. punctatofasciatus Cuvier				X		
C. trifasciatus Park	X				2	
C. ulietensis Cuvier	1	X	X	2		X
C. unimaculatus Bloch	X				X	X
Heniochus chrysostomus Cuvier		X			X	
Megaprotodon trifascialis (Quoy & Gaimard)					X	1
GOBIIDAE						
Amblygobius albimaculatus (Ruppell)	4	1	6	2	1	2
Gnatholepis sp.					X	2
unid. gobids	2	1				1

Table 3 Continued.

	TRANSECTS G	G'	H	H'	I	I'
LABRIDAE						
Cheilinus fasciatus (Bloch)	X		1	X	2	1
C. rhodochrous Gunther			X	X		X
C. undulatus Ruppell	X	1	3	X	X	1
Epibulus insidiator (Pallas)	1	X	X	1	X	X
Gomphosus varius Lacepede	X					
Halichoeres trimaculatus (Quoy & Gaimard)	6	1	3	X	7	1
Hemigymnus melapterus (Bloch)		X	X		2	1
Labrichthys unilineata (Guichenot)				1		
Labroides bicolor Fowler & Bean				1		
L. dimidiatus (Valenciennes)		X	2	5	2	1
Stethojulis bandanensis (Bleeker)	X	X	2	X	10	2
Thalassoma hardwickei (Bennett)			1			
T. lutescens (Lay & Bennett)					X	
LETHRINIDAE						
Ganthodentex aureolineatus (Lacepede)					2	X
Lethrinus harak (Forsskal)					X	
MONACANTHIDAE						
Oxymonacanthus longirostris (Bloch & Schneider)					2	X
Pervagator melanocephalus (Bleeker)					X	
MULLIDAE						
Mulloidichthys flavolineata (Lacepede)	X	X		1	1	X
Parupeneus barberinus (Lacepede)		X		X	X	1
P. chryseredros (Lacepede)	X	X	1	X	1	1
P. trifasciatus (Lacepede)			1	X	1	2
NEMIPTERIDAE						
Scolopsis cancellatus (Cuvier)					X	
OSTRACIONTIDAE						
Ostracion cubicus Linnaeus				X		
POMACANTHIDAE						
Centropyge flavissimus (Cuvier)				X		X
POMACENTRIDAE						
Abudefduf sexfasciatus (Lacepede)			X	X		X
Amblyglyphidodon curacao (Bloch)	65	39	44	33	17	24
Amphiprion melanopus Bleeker			X	X		
Chromis caerulea (Cuvier)			50	111	84	20
Dascyllus aruanus (Linaneus)	5	9	4	8	4	
Plectroglyphidodon leucozonus (Bleeker)						1
Pomacentrus vaiuli Jordan & Seale	1		X	X	X	X
Stegastes lividus (Bloch & Schneider)	X		2		3	

Table 3 Continued.

	G	G'	H	H'	I	I'
	TRANSECTS					
S. nigricans (Lacepede)	X	1	5	2	2	X
SCARIDAE						
Cetoscarus bicolor (Ruppell)						X
Scarus oviceps Valenciennes			X	X		
S. schlegeli (Bleeker)				1	X	
S. sordidus Forsskal	2				15	2
Scarus sp.		X	X	X	X	X
juvenile scarids	19	3	48	66	58	34
SIGANIDAE						
Siganus argenteus (Quoy & Gaimard)	X	X	X	6	1	1
S. chrysospilos (Bleeker)			X			
S. spinus (Linnaeus)	X		X	1	1	X
SYNGNATHIDAE						
Corythoichthys intestinalis (Ramsey)		1	1			
TETRAODONTIDAE						
Arothron nigropunctatus (Bloch & Schneider)	X					
Canthigaster solandri (Richardson)	2	2		X		
C. valentini (Bleeker)		X			1	X
ZANCLIDAE						
Zanclus cornutus (Linnaeus)	X	X	2	X	1	X
Number Species per Transect	34	30	42	48	44	49
Fish Abundance per Transect (no./200 m^2)	112	64	184	255	227	114
Total Species per Replicate Pair	43		54		61	
Mean Fish Abundance per Replicate Pair (no./200 m^2)	88		219.5		170.5	
Total Species, Lagoon Patch Reef Biotope:	77(1982)		94(1974)			
Mean Fish Abundance (no./200 m^2), Lagoon Patch Reef Biotope:	159.33(1982)		265.57(1974)			

Table 4. Results of fish survey in barrier reef flat biotope. Numerical entries are number of fish seen per 100-m transect (200 m^2). X indicates additional species seen during random swims.

	TRANSECTS											
	J	J'	K	K'	L	L'	M	M'	N	N'	O	O'
ACANTHURIDAE												
<u>Acanthurus</u> <u>glaucopareius</u> Cuvier					X							
<u>A.</u> <u>nigrofuscus</u> Valenciennes					X	4			5	1	1	
<u>A.</u> <u>olivaceus</u> Bloch & Schneider		X										
<u>A.</u> <u>triostegus</u> (Linnaeus)	5	1	1	2	X	X	X	1	1	X	X	
<u>A.</u> <u>xanthopterus</u> Valenciennes					X	X	1	X	X			1
<u>Ctenochaetus</u> <u>striatus</u> (Quoy & Gaimard)	17	1	2	14	21	14	6	2	1			
<u>Naso</u> <u>lituratus</u> (Bloch & Schneider)	2	3	1	X	5	1			X			
<u>N.</u> <u>unicornis</u> (Forsskal)	X	X				5					1	
<u>Zebrasoma</u> <u>flavescens</u> (Bennett)			1	1	1	5		X				X
<u>Z.</u> <u>veliferum</u> (Bloch)			1			X			X	X		
APOGONIDAE												
<u>Apogon</u> <u>novemfasciatus</u> Cuvier	7	6	1	1								
<u>Cheilodipterus</u> <u>quinquelineata</u> (Cuvier)				1	X	X	1				1	
ATHERINIDAE												
unid. atherinids	20	40										
AULOSTOMIDAE												
<u>Aulostomus</u> <u>chinensis</u> (Linnaeus)			X		1							
BALISTIDAE												
<u>Balistapus</u> <u>undulatus</u> Park										X		
<u>Rhinecanthus</u> <u>aculeatus</u> (Linnaeus)	X	X		1	X	X	X	X				X
BLENNIIDAE												
<u>Meiacanthus</u> <u>atrodorsalis</u> (Gunther)			2		2	1	3		X			
<u>Plagiotremus</u> <u>tapeinosoma</u> (Bleeker)		X										X
<u>Salarias</u> <u>fasciatus</u> (Bloch)	5	2	1						1			

Table 4 Continued.

	TRANSECTS											
	J	J'	K	K'	L	L'	M	M'	N	N'	O	O'
CHAETODONTIDAE												
Chaetodon auriga Forsskal	1	X	X	X	X	X		X	1	X	2	1
C. bennetti Cuvier						X						
C. citrinellus Cuvier	1	3	2	3	5	2		X		X		3
C. ephippium Cuvier					1	X			2	X		X
C. lunula (Lacepede)	X	1				2			1		1	X
C. melannotus Schneider				X	1	6				X	X	1
C. mertensii Cuvier						X						
C. ornatissimus Cuvier					X	X						
C. punctatofasciatus Cuvier					X	X		1			1	
C. reticulatus Cuvier			X	1	X	X		X				
C. trifasciatus Park			5		5	3			3	1	1	1
C. ulietensis Cuvier						X			X			
C. unimaculatus Bloch						2	2	X				
Heniochus chrysostomus Cuvier					X	X			X		1	
Megaprotodon trifascialis (Quoy & Gaimard)			6	X	6	1		X	1			
FISTULARIIDAE												
Fistularia commersonii Ruppell	X											
GOBIIDAE												
Amblygobius albimaculatus (Ruppell)					1	X	4	X				3
HEMIRAMPHIDAE												
unid. hemiramphids		X			X	X						
HOLOCENTRIDAE												
Adioryx diadema (Lacepede)	X		3	X	1	1			3			
Adioryx sp.												1
Flammeo sammara (Forsskal)			2		1	1			9		1	3
Myripristis sp.			1		1	X			X		2	

Table 4 Continued.

	TRANSECTS											
	J	J'	K	K'	L	L'	M	M'	N	N'	O	O'
LABRIDAE												
Cheilinus fasciatus (Bloch)	2				1	X		X	1			
C. undulatus Ruppell							X	X	X		X	
Cheilinus sp.			X		1		X	1				X
Cheilio inermis (Forsskal)				X							X	
Coris variegata (Ruppell)	X											
Epibulus insidiator (Pallas)			1	3	1	X		1	5	3	1	
Gomphosus varius Lacepede				X		X			1			
Halichoeres trimaculatus (Quoy & Gaimard)	87	128	48	28	10	3	11	26	20	13	14	44
Hemigymnus melapterus (Bloch)	X	X	X	2	X	X	X	X	2	X	1	X
Labrichthys unilineata (Guichenot)					1	X						
Labroides dimidiatus (Valenciennes)		X		X	X	3	X		1	1	1	
Macropharyngodon meleagris (Valenciennes)	X	1				1						
Novaculichthys taeniourus (Lacepede)												1
Stethojulis bandanensis (Bleeker)	14	16	8	4	4	1	2	10	8	5	6	9
Thalassoma hardwickei (Bennett)	1		X	X		X			1			X
T. lutescens (Lay & Bennett)	X											
T. quinquevittata (Lay & Bennett)						X						
unid. labrids	6	8	3	3	1	4	7	2				
LETHRINIDAE												
Gnathodentex aureolineatus (Lacepede)						14						1
Monotaxis grandoculis (Forsskal)						X					X	X
MALACANTHIDAE												
Malacanthus latovittatus (Lacepede)						X						
MONACANTHIDAE												
Oxymonacanthus longirostris (Bloch & Schneider)			7	X	10	3			3	X		

Table 4 Continued.

	TRANSECTS											
	J	J'	K	K'	L	L'	M	M'	N	N'	O	O'
MULLIDAE												
Mulloidichthys flavolineatus (Lacepede)				X	X	1	11	4	X	3	1	2
Parupeneus barberinus (Lacepede)		1	1	X			1	X	X	X	X	X
P. bifasciatus (Lacepede)	1		X			X						
P. chryseredros (Lacepede)			X	1	3				X	1		
P. trifasciatus (Lacepede)	4	9	3	1	1	X	1	1	1		3	X
NEMIPTERIDAE												
Scolopsis cancellatus (Cuvier)			1	X	4	1	X	X	X	X	X	X
OSTRACIONTIDAE												
Ostracion cubicus Linnaeus						X						
O. meleagris Shaw							X					
PEMPHERIDAE												
Pempheris oualensis Cuvier			X									
POMACANTHIDAE												
Centropyge flavissimus (Cuvier)					X	X						
POMACENTRIDAE												
Abudefduf sexfasciatus (Lacepede)						X						
A. vaigiensis (Quoy & Gaimard)	X											
Amblyglyphidodon curacao (Bloch)					58	107	49	X				
Amphiprion melanopus Bleeker						1		1	1		1	2
Chromis atripectoralis Welander & Schultz	1	1										
C. caerulea (Cuvier)			58	28	105	95	60	15	60	23	93	155
Chrysiptera glaucus (Cuvier)	2	1										
C. leucopomus (Lesson)	2											
Chrysiptera sp.								5			1	15
Dascyllus aruanus (Linnaeus)	16	77	195	138	51	32	46	43	92	76	166	180

Table 4 Continued.

	TRANSECTS											
	J	J'	K	K'	L	L'	M	M'	N	N'	O	O'
Plectroglyphidodon dickii (Lienard)			1		2	4						
P. johnstonianus Fowler & Ball					X							
P. lacrymatus (Quoy & Gaimard)	X											
P. leucozonus (Bleeker)		8		X		1	1	2		1	2	1
Pomacentrus vaiuli Jordan & Seale	5	6	1	5			X		1			2
Stegastes albifasciatus (Ogilby)	10	10	21	9					9		6	X
S. lividus (Bloch & Schneider)			86	47	10	19	X	18	256	148	15	4
S. nigricans (Lacepede)	72	47	52	45	16	10	3	X	19	2	18	20
SCARIDAE												
Scarus oviceps Valenciennes					X	X			X			
S. sordidus Forsskal						X		3				
Scarus sp.						1			X			
juvenile scarids	X		10	8	53	16	45	16	45	13	10	30
SIGANIDAE												
Siganus argenteus (Quoy & Gaimard)		X	X	1	X	X		X	1	1		1
S. spinus (Linnaeus)	3	3		X	X				X	3	1	X
SYNGNATHIDAE												
Corythoichthys intestinalis (Ramsey)				1								
SYNODONTIDAE												
Saurida gracilis (Quoy & Gaimard)					1		1					
Synodus variegatus (Lacepede)		1			1		1					
TETRADONTIDAE												
Canthigaster solandri (Richardson)	4	3	1	4		X	X		1		1	
C. valentini (Bleeker)			X									
ZANCLIDAE												
Zanclus cornutus (Linnaeus)					1	2	X			X	1	X

Table 4 Continued.

	TRANSECTS											
	J	J'	K	K'	L	L'	M	M'	N	N'	O	O'
Number of Species per Transect	36	33	44	40	55	69	30	35	47	28	35	38
Fish Abundance per Transect (no./200m^2)	268	337	527	351	360	378	248	147	560	293	353	481
Total Species per Replicate Pair	44		52		77		43		52		50	
Mean Fish Abundance per Replicate Pair (no./200m^2)	302.5		439		369		197.5		426.5		417	

Total Species, Barrier Reef Flat Biotope: 103(1982) 91(1974)

Mean Fish Abundance (no./200m^2), Barrier Reef Flat Biotope: 358.58(1982) 297.71(1974)

Table 5. Results of fish surveys in channel wall and lagoon fringing reef flat biotopes. Numerical entries are number of fish seen per 100-m transect (200 m^2). X indicates additional species seen during random swims.

	Channel Wall Transects				Lagoon Fringing Reef Flat Transects	
	P	P'	Q	Q'	R	R'
ACANTHURIDAE						
Acanthurus nigrofuscus (Forsskal)	5	1	1	1	1	3
A. olivaceus Bloch & Schneider						1
A. triostegus (Linnaeus)					X	4
A. xanthopterus Valenciennes		X			5	4
Ctenochaetus striatus (Quoy & Gaimard)					2	
N. lituratus (Bloch & Schneider)	3	X			X	
N. unicornis (Forsskal)			X			
Z. flavescens (Bennett)			1	X	1	
Z. veliferum (Bloch)				X		
APOGONIDAE						
Cheilodipterus quinquelineata (Cuvier)					2	1
AULOSTOMIDAE						
Aulostomus chinensis (Linnaeus)			1			
BALISTIDAE						
Balistapus undulatus (Perk)	X					
Rhinecanthus aculeatus (Linnaeus)					X	X
Sufflamen chrysopterus (Bloch & Schneider)	X	3				
BLENNIIDAE						
Meiacanthus atrodorsalis (Gunther)	X	8	5	4	2	4
CHAETODONTIDAE						
Chaetodon auriga Forsskal	X		1			
C. citrinellus Cuvier		1	2	X		2
C. kleini Bloch	1	X	2	2		
C. mertensii Cuvier	3		X	X		
C. ornatissimus Cuvier		X				
C. punctatofasciatus Cuvier	1	X		1	2	1
C. trifasciatus Park		4	X		X	X
C. ulietensis Cuvier		3	1	1		
C. unimaculatus Bloch			X	1	1	X
Forcipiger longirostris (Broussonet)	X	1	2	1		

Table 5 Continued.

	Channel Wall Transects				Lagoon Fringing Reef Flat Transects	
	P	P'	Q	Q'	R	R'
Heniochus acuminatus (Linnaeus)		1	1	1		
H. chrysostomus Cuvier	X	X	X	1		
GOBIIDAE						
Amblygobius albimaculatus (Ruppell)	3	1	X	2	2	10
Gnatholepis sp.				X		
Ptereleotris microlepis Bleeker					2	X
unid. gobiids	5				1	4
HOLOCENTRIDAE						
Adioryx diadema (Lacepede)	X		1			
A. spinifer (Forsskal)			X			
Flammeo sammara (Forsskal)		9	9	5	X	
Myripristis spp.	X	31	67	34	X	
LABRIDAE						
Cheilinus fasciatus (Bloch)		2	X			
C. rhodochrous Guntehr	2	5		1		
C. trilobatus Lacepede			X			
Cheilinus sp.			1			
Epibulus insidiator (Pallas)		2	X	2	1	
Gomphosus varius Lacepede			1			
Halichoeres marginatus Ruppell				X		1
H. trimaculatus (Quoy & Gaimard)	5		3	1	4	4
Hemigymnus melapterus (Bloch)		1	X	X	2	1
Labrichthys unilineata (Guichenot)	X					
Labroides bicolor Fauler & Bean		1	X	X	2	1
L. dimidiatus (Valenciennes)	2	X	2		2	X
Macropharyngodon meleagris (Valenciennes)	X			X		
Stethojulis bandanensis (Bleeker)	5	5		2	11	1
LETHRINIDAE						
Gnathodentex aureolineatus (Lacepede)			1	X		
Monotaxis grandoculis (Forsskal)		X		X		
LUTJANIDAE						
Lutjanus fulvus (Bloch & Schneider)		2	3	1		
L. kasmira (Forsskal)				2		
L. monostigmus (Cuvier)			1	X		

Table 5 Continued.

	Channel Wall Transects				Lagoon Fringing Reef Flat Transects	
	P	P'	Q	Q'	R	R'
MUGILOIDIDAE						
Parapercis cephalopunctata (Seale)	X					
P. clathrata Ogilby	1					
MULLIDAE						
Mulloidichthys flavolineata (Lacepede)		1		X		
Parupeneus barberinus (Lacepede)		3				4
P. bifasciatus (Lacepede)			X	X		
P. chryseredros (Lacepede)		2	2	2		
P. trifasciatus (Lacepede)	3		3	X	1	3
OSTRACIONTIDAE						
Ostracion cubicus Linnaeus						1
PEMPHERIDAE						
Pempheris oualensis Cuvier		2	1	1		
POMACANTHIDAE						
Centropyge flavissimus (Cuvier)		1		1		
POMACENTRIDAE						
Abudefduf sexfasciatus (Lacepede)					5	2
Amblyglyphidodon curacao (Bloch)					6	X
Amphiprion clarkii (Bennett)	X					
Chromis caerulea (Cuvier)		X	28	60	38	3
Chrysiptera traceyi (Woods & Schultz)		1		X		
Dascyllus aruanus (Linnaeus)	X	4	31	27	11	9
D. trimaculatus (Ruppell)	X	1				
Plectroglyphidodon lacrymatus (Quoy & Gaimard)				1		
P. leucozonus (Bleeker)					3	1
Pomacentrus pavo (Bloch)	X	X		2	19	1
P. vaiuli Jordan & Seale	48	28	20	25		1
Stegastes lividus (Bloch & Schneider)			X		4	X
S. nigricans (Lacepede)				X		
SCARIDAE						
Cetoscarus bicolor (Ruppell)				1		

Table 5 Continued.

	Channel Wall Transects				Lagoon Fringing Reef Flat Transects	
	P	P'	Q	Q'	R	R'
Scarus oviceps Valenciennes		X				
S. sordidus Forsskal			1			
Scarus sp.		4	1	X		
juveile scarids	2	6		2	12	14
SCORPAENIDAE						
Pterois volitans (Linnaeus)	X		X			
SIGANIDAE						
Siganus spinus (Linnaeus)						1
SYNGNATHIDAE						
Corythoichthys intestinalis (Ramsey)					X	1
TETRAODONTIDAE						
Canthigaster bennetti (Bleeker)	1					
C. solandri (Richardson)	2	5	2	2	4	1
C. valentini (Bleeker)	X	7	X	X		
ZANCLIDAE						
Zanclus cornutus (Linnaeus)	X	2	3	1		
Number of Species per Transect	35	43	46	49	34	34
Fish Abundance per Transect (no./200m^2)	89	148	198	161	145	83
Total Species per Replicate Pair	57		63		41	
Mean Fish Abundance per Replicate Pair (no./200m^2)	118.5		179.5		114	

Total Species, Channel Wall Biotope: 75(1982) 138(1974)

Mean Fish Abundance (no./200m^2), Channel Wall Biotope: 149(1982) 292(1974)

Total Species, Lagoon Fringing Reef Flat Biotope: 41(1982)

Mean Fish Abundance (no./200m^2), Lagoon Fringing Reef Flat Biotope: 114(1982)

Table 6. Fish species in highest densities in patch reef, barrier reef flat, and channel wall biotopes. Number in parentheses is the numerical rank this species (or equivalent taxon) held in the 1974 survey. Mean density is the mean of all 22 transect counts for the species in these three biotopes, expressed as no. per 200 m^2.

Rank	Species	Mean Density
1	*Chromis caerulea* (1)	115.00
2	*Pomacentrus vaiuli* (6)	71.00
3	*Dascyllus aruanus* (4)	54.73
4	*Stegastes lividus*	27.64
5	juvenile scarids (8)	22.00
6	*Halichoeres trimaculatus* (3)	20.86
7	*Amblyglyphidodon curacao* (2)	18.45
8	*Canthigaster solandri*	14.50
9	*Stegastes nigricans* (9)	14.27
10	*Myripristis* spp. (18)	6.18
11	*Stethojulis bandanensis* (10)	5.14
12	*Ctenochaetus striatus* (12)	3.82
13	*Stegastes albifasciatus* (5)	2.95
14	unidentified atherinids	2.73
15	*Flammeo sammara* (14)	1.82
16	*Meiacanthus atrodorsalis* (13)	1.73
17	*Parupeneus trifasciatus*	1.55
18	*Amblygobius albimaculatus*	1.36
19	*Oxymonacanthus longirostris*	1.14
20	*Mulloidichthys flavolineatus*	1.14
21	*Chaetodon citrinellus*	1.14
22	*Chaetodon trifasciatus*	1.14

MACROINVERTEBRATES

By

Gretchen R. Grimm

INTRODUCTION

The macroinvertebrate survey of Cocos Lagoon was subdivided into three sections; hard corals, soft corals, and holothurians with other miscellaneous macroinvertebrate groups. Hard corals and soft corals are discussed in separate chapters of this text. The holothurians were selected as an indicator group since they are distributed throughout all of the different biotopes and facies found in Cocos Lagoon. Other macroinvertebrates (i.e., gastropods) which are more location specific are not as useful as indicator groups. Holothurians are a visually obvious and very abundant component of the Cocos Lagoon biotic community. They are easily identified in the field, which rarely necessitates collecting them for laboratory analysis. In contrast, many other macroinvertebrates must be removed from the field and identified in the laboratory. Since recruitment and growth may be slow, removal of resident individuals may disturb a habitat enough to effectively bias future surveys.

Statistical comparisons between the 1975 qualitative survey (Randall et al., 1975) and this study were not possible. However, a checklist of miscellaneous groups of macroinvertebrates was compiled for a qualitative comparison between surveys. For the 1982 survey, distribution and density of holothurians were quantified for each biotope and facies.

MATERIALS AND METHODS

Macroinvertebrate survey areas were selected to represent the range of habitat and substrate types found in each biotope and facies which were established by Randall et al. (1975). A total of 18 locations was surveyed in Biotope I Facies A, B, C, D, and E, and Biotope II Facies A and B (Figure 1). Areas were surveyed by swimming with snorkel gear or scuba equipment along a 100 m transect line and recording the number of holothurians and other macroinvertebrates within 1 m of the line. The more cryptic or visually less obvious macroinvertebrates were recorded during a 20-minute random swim in the adjacent area. Two replicate transects were run in each area except Biotope I Facies D (ID) where 4 separate transects were surveyed. Replicate transect lines were laid in a random, unbiased fashion in each area. Four transects and replicates were run in area IA. Three transects and replicates were run in areas IB and IIA. Two transects and replicates were run in area IIB. One transect and a replicate was run in areas IC, IE and IIB. The 1982 transects were run on coral, coral rubble, rock and sand substrates in Biotopes I and II. Facies C in Biotope I was only surveyed by random swims to establish a species checklist, since suitable habitat for invertebrate occupation was very limited. Statistical comparisons between replicates were made using a t-test for paired comparisons (Sokal and Rohlf, 1969). Holothurians were identified according to Rowe and Doty (1977).

RESULTS AND DISCUSSION

Holothurians

Species distribution for the 1975 and 1982 surveys were very similar. The following discussion refers to the species checklist (Table 1). Holothurians were observed in both biotopes and every facies. A total of 17 holothurian species was observed in the 1975 study and 16 species in 1982. Four species recorded in 1975 were not observed in the 1982 study: *Bohadschia bivitata*, *Holothuria inhabilis*, *Holothuria* sp. 1, and *Holothuria* sp. 2. Three species recorded in 1982 were not recorded for the 1975 survey: *Bohadschia graeffei*, *Bohadschia marmorata* and *Holothuria pervicax*. *Bohadschia argus* was found in every biotpe and facies for both surveys. *Holothuria atra* was found in every location in 1982. In 1974 *Stichopus chloronotus* was found in every loation. Biotope I Facies A had the greatest number of species in 1974 (14) and 1982 (13). There is no significant difference between the number of species found per transect in 1975 and 1982 ($p>0.05$) (Table 3). Since holothurians were not quantified in the 1974 survey, no other statistical comparisons can be made.

Table 2 represents the mean density of holothurians per transect for each facies. No significant difference was found between replicate transects ($p>0.05$). Since the number of individuals per transect and the number per m^2 differ by a factor of 100, the discussion will concern the number of individuals per transect ($100m^2$). Table 3 presents the density of holothurians for each transect.

The greatest holothurian density occurs in Biotope I Facies E. In the other facies of Biotope I, the density of holothurians decreases along a gradient from the barrier reef platform (Facies A), and lagoon terrace (Facies B), to the patch reefs and knolls on the lagoon floor (Facies D, Figure 2). A similar trend occurs in Biotope II, Mamaon and Manell Channels with greater holothurian densities occurring in Facies A (shallow margin shelf) than in Facies B (steep channel slope). A complete description of biotopes and facies can be found in Randall et al., 1975.

In Biotope I Facies A, the barrier reef platform was a high energy habitat which was continually wave washed, especially the southern windward reef. Sediments were subject to scouring and shifting by wave, current and wind assault. Five transects and replicates were run in this area. Holothurians were found in places where sediments collected and in slightly sheltered areas near corals and rocks. Seven species of holothurians were quantified along transect lines in this facies (Table 1). Six additional species were observed during random swims (Table 1). *Holothuria atra* was the most abundant holothurian in this area with an average density of 60.8 individuals per $100m^2$ (Table 2). *H. atra* often covers itself with a thin cloak of sand but does not burrow into the sediment. Therefore it does not require a constantly stable substrate.

Bohadschia argus was the second most abundant holothurian. It occurred considerably less frequently than H. atra, with a mean density of 3.0 individuals per $100m^2$. Other holothurians were quantified infrequently with densities >3.0 indiviuals per $100m^2$.

Facies B was a shallow terrace extending lagoonward from the barrier reef-flat to the 3m submarine contour. Acropora thickets covered extensive areas of the terrace floor. Three transects and replicates were run in this area (Figure 1). Distribution of holothurians along transects was patchy, depending on the availability of suitable substrates. Nine holothurian species were recorded from this facies. Holothuria atra was the most abundant species with a mean density of 33.5 individuals per $100m^2$. Holothuria edulis was quantified with a mean density of 6.3 individuals per $100m^2$. Other holothurians, Bohadschia argus, Stichopus chloronotus, Actinopyga mauritiana, Holothuria leucospilota, Holothuria hilla, Synapta maculata, and Holothuria nobilis were with mean densities <1.0 individual per $100m^2$. Bohadschia marmorata was observed buried or partially exposed on sand and fine gravel. Synapta maculata and Holothuria hilla were observed partially hidden under boulders and small coral heads. Other holothurians were observed fully exposed on sand.

Facies C was located in the center of the lagoon with depths consistently deeper than 3m. The area was relatively barren in terms of topographic relief. The substrate consists of fine sands marked by numerous cone-like mounds produced by an unidentified worm. Widely scattered coral mounds, knolls and patch reefs offer the only large topographical relief. These features attract invertebrates to the adjacent area. During random swims, 11 species of holothurians (Table 1) were observed. Stichopus variegatus and Bohadschia graeffei were found only in this location for the 1982 survey.

Facies E consists of patchreefs, mounds and knolls on the lagoon floor of Facies C. Since no holothurians were observed on coral substrates, 4 separate transects were run along the base of these features. Three species were found in this facies: Holothuria edulis with a mean density of 20.3 individuals per $100m^2$; Holothuria atra with a mean density of 7.3 individuals per $100m^2$, and Stichopus chloronotus with a mean density of 3.0 individuals per $100m^2$.

Facies E on the shoreward side of the lagoon consisted of the nearshore shelf or fringing reef platform. Sediments were mainly of terriginous material washed into the lagoon by surface runoff and river deposits. One transect and replicate were run at this location. Four species of holothurians were found, three along the transect line and one during a random swim. Holothuria atra and Holothuria edulis were exposed on open sediment while Holothuria hilla was found under rocks. Bohadschia argus was observed during a random swim on open sediment. The mean density per $100m^2$ of each species was 83.0 for Holothuria atra, 62.5 for Holothuria edulis, and 1.5 for Holothuria hilla.

Facies A and B of Biotope II (Mamaon and Manell Channels) were surveyed. Facies A contained a greater diversity and density of holothurians than facies B. Facies A was the shallow margin shelves which form the upper lip of the channel slopes or walls. One transect and replicate were run in Mamaon Channel, shoreward side. This area, located near the channel mouth, was subject to continuous wave assault and swell action. One transect and replicate were run at the Geus River mouth, shoreward side. The Mannell Channel transect and replicate are located at the channel head. The Geus River and Manell

Channel survey locations had only minimal water movement. The Manell and Mamaon Channel transects were comparatively depauperate of holothurians. The unstable sediments at Mamoan Channel and the heavily silted substrate at Manell Channel provide less suitable environments for holothurian habitation compared to Geus River location. A total of six species was observed in this facies: Holothuria atra, Holothuria edulis, Bohadschia argus, Actinopyga mauritiana, Stichopus chloronotus, and Stichopus horrens (Table 1). All six species were observed at the Geus River location. Four species were observed at Mamoan Channel: Holothuria atra, Stichopus chloronotus, Actinopyga mauritiana, and Bohadschia argus (Table 1). These same species, except Bohadschia argus were observed at Manell Channel. The most abundant holothurian in Facies A was Holothuria edulis with a mean density of 13.0 individuals per $100m^2$. The mean density of Holothuria atra was 4.2 individuals per $100m^2$. Other holothurians occurred with mean densities of less than 2.0 individuals per $100m^2$.

Facies B was the steep channel slopes located between the channel margin and the contour of the channel floor. Water in this facies at Manell Channel was turbid with a high sedimentation rate. At Mamaon Channel the substrate was subject to severe scouring by gravel size sediments driven by waves and heavy surge. These conditions may account for the paucity of holothurians in these locations. One transect and replicate was run at Mamaon Channel. Two transects and replicates were run at Manell Channel. Five species were observed at Mamaon Channel (Table 1). Holothuria edulis was the most abundant species with a mean density of only 1.3 individuals per $100m^2$. Stichopus chloronotus had a mean density of 1.2 individuals per $100m^2$ and Holothuria atra had a mean density of 0.2 individuals per $100m^2$. Two species were observed during random swims, Bohadschia argus and Thelonota ananas. No holothurians were quantified or observed at the Manell Channel location.

In general, for both 1975 and 1982 surveys, the areas of highest species diversity were Facies A of both Biotope I and II. The greatest number of individuals occurred on the reef flat platforms (Figure 2). Aside from the richness of individuals at Facies E, the number of individuals varies inversely with distance from high energy, low turbidity areas with sand or gravel substrates.

In conclusion, a qualitative assessment of species observed in the 1974 and 1982 surveys reveals no apparent change in the holothurian diversity within the surveyed areas of Cocos Lagoon. No assessment can be made concerning changes in population density.

Other Miscellaneous Groups

A checklist of commonly observed macroinvertebrates other than holothurians, soft corals and hard corals is found in Table 4. The group most well represented in both surveys is the molluscs. This group was observed in every facies in Biotope I and most abundantly in Facies A. Few species were observed in Biotope II. Many gastropods and bivalves prefer a substrate of sand or very fine gravel. The substrates of Biotope II are scoured rock at Mamaon Channel and fine silt at Manell Channel which do not offer a suitable substrate for molluscs to inhabit.

The echinoderms which inhabit sand as well as hard substrates were also well represented. Individuals were observed in every facies of both habitats in 1975 and 1982. The coralivores, Culcita novaeguineae and Acanthaster planci, observed in observed in Biotope I, were present in numbers sufficient to indicate a healthy coral reef environment.

The "sea urchins", Class Echinoidea, were observed in every biotope and facies. These species are found on hard substrates under coral heads in holes and under rock ledges. Echinometra mathaei was the species most often encountered.

The most notably abundant species, the "jelly fish" Cassiopea andromeda, was observed at Facies E Biotope I. Great clusters of individuals rested on the silty substrate.

Many species of macroinvertebrates prefer sheltered habitats therefore, observation of individuals is greatly a matter of chance. Additionally, these species tend to be most cryptic during daylight hours, emerging to feed in the protection of darkness. Since all fieldwork was conducted in the day many species were undoubtedly missed.

ACKNOWLEDGEMENT

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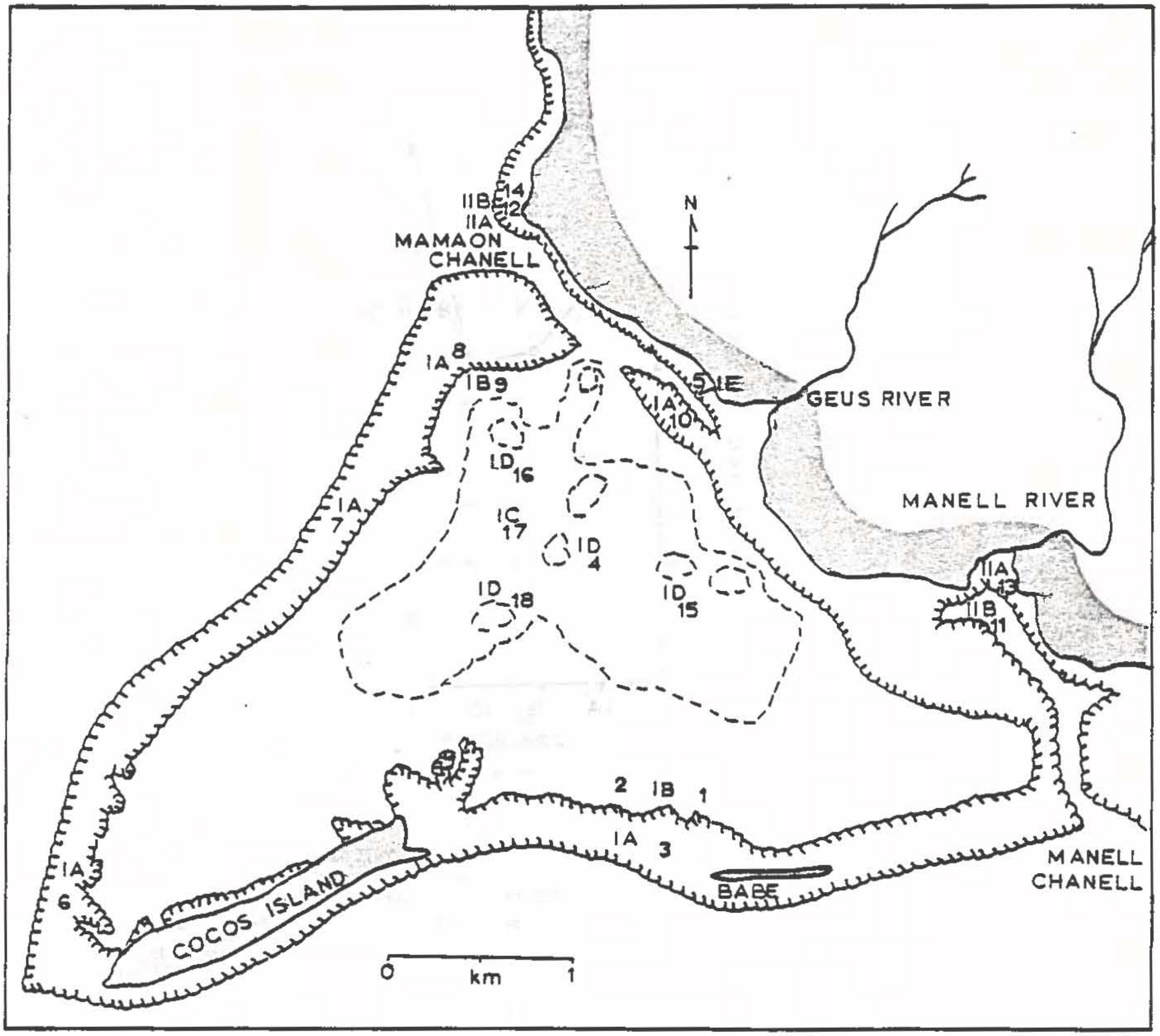

Figure 1. Transect locations for the 1982 survey.

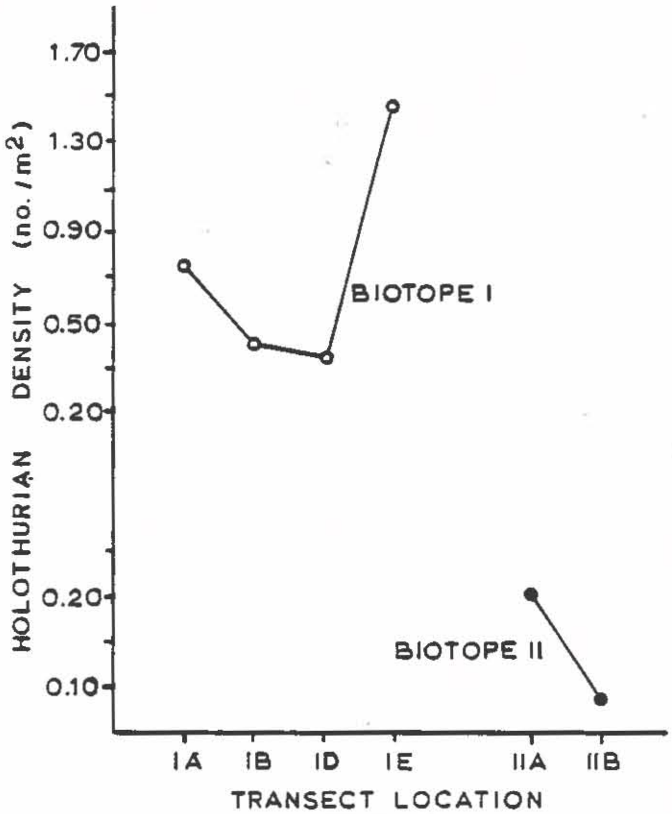

Figure 2. Density of holothurians in each biotope for the 1982 survey.

Table 1. Checklist of holothurians observed along or adjacent to transects during 1975 and 1982 surveys.

SPECIES	BIOTOPE I										BIOTOPE II									
	A		B		C		D		E		A		B		C		D		E	
	75	82	75	82	75	82	75	82	75	82	75	82	75	82	75	82	75	82	75	82
Actinopyga echinities	X	X																		
Actinopyga mauritiana	X	X		X		X	X				X	X	X		X					
Bohadschia argus	X	X	X	X	X	X	X	X	X	X	X	X		X						
Bohadschia bivitata	X		X		X		X		X		X									
Bohadschia greaffei						X														
Bohadschia maurmorata		X				X		X												
Holothuria atra	X	X	X	X		X		X		X		X		X						
Holothuria edulis	X	X	X	X	X	X	X	X	X	X	X	X		X						
Holothuria hilla	X	X	X	X			X	X	X	X	X		X		X					
Holothuria inhabilis			X																	
Holothuria leucopilota	X	X	X	X	X		X		X		X		X							
Holothuria nobilis	X	X	X	X	X		X	X			X									
Holothuria pervicax		X																		
Holothuria sp. 1									X											
Holothuria sp. 2	X																			
Stichopus chloronotus	X	X	X	X	X	X	X	X	X		X	X	X	X	X					
Stichopus horrens	X	X					X					X								
Stichopus variegatus	X		X			X	X		X		X									
Synapta maculata	X	X	X	X				X												
Thelenota ananas						X								X	X					
Total number of species	14	13	11	9	6	9	10	8	8	4	9	6	4	5	4					

Table 2. Mean density/transect for holothurians in each biotope in the 1982 survey.

SPECIES	BIOTOPE I A	BIOTOPE I B	BIOTOPE I D	BIOTOPE I E	BIOTOPE II A	BIOTOPE II B
Holothuria atra	60.8	33.5	7.3	83.0	4.2	0.2
Holothuria edulis	-	6.3	20.3	62.0	13.0	1.3
Bohadschia argus	3.0	1.0	-	-	0.8	-
Stichopus chloronotus	1.1	0.2	3.0	-	1.3	1.2
Actinopyga mauritiana	2.8	-	-	-	0.2	-
Holothuria leucospilota	2.0	-	-	-	-	-
Holothuria hilla	0.1	-	-	1.5	-	-
Synapta maculata	0.5	0.2	-	-	-	-
Holothuria nobilis	-	0.3	-	-	-	-
Bohadschia maurmorata	-	0.2	-	-	-	-

Table 3. Holothurian density per 100 m transect for the 1982 survey.

	SPECIES		DENSITY/TRANSECT
Biotope I			
Facies A			
Transect 3a			
	Holothuria atra		49
	Holothuria leucospilota		8
	Bohadschia argus		1
	Total number species	- 3	
	Total density/m^2	- 0.58	
Transect 3b	*Bohadschia argus*		1
	Bohadschia maculata		1
	Stichopus chloronotus		1
	Total number species	- 3	
	Total density/m^2	- 0.03	
Transect 8a	*Holothuria atra*		62
	Actinopyga mauritiana		9
	Bohadschia argus		5
	Stichopus chloronotus		3
	Total number species	- 4	
	Total density/m^2	- 0.79	
Transect 8b	*Holothuria atra*		29
	Bohadschia argus		7
	Actinopyga mauritiana		4
	Stichopus chloronotus		1
	Total number species	- 4	
	Total density/m^2	- 0.41	
Transect 6a	*Holothuria atra*		50
	Stichopus chloronotus		1
	Total number species	- 2	
	Total density/m^2	- 0.51	
Transect 6b	*Holothuria atra*		43
	Total number species	- 1	
	Total density/m^2	- 0.43	
Transect 7a	*Holothuria atra*		62
	Bohadschia argus		2
	Actinopyga mauritiana		1

Table 3 Continued.

	SPECIES	DENSITY/TRANSECT
	Synapta maculata	1
	Total number species - 4 Total density/m^2 - 0.66	
Transect 7b	Holothuria atra	70
	Bohadschia argus	3
	Actinopyga mauritiana	3
	Synapta maculata	1
	Total number species - 4 Total density/m^2 - 0.77	
Facies B		
Transect 1a	Holothuria atra	57
	Total number species - 1 Total density/m^2 - 0.57	
Transect 1b	Holothuria atra	55
	Holothuria hilla	2
	Holothuria nobilis	1
	Bohadschia marmorata	1
	Stichopus chloronotus	1
	Synapta maculata	1
	Holothuria edulis	1
	Total number species - 7 Total density/m^2 - 0.62	
Transect 2a	Holothuria atra	21
	Holothuria nobilis	1
	Total number species - 2 Total density/m^2 - 0.22	
Transect 2b	Holothuria atra	25
	Bohadschia argus	1
	Total number species - 2 Total density/m^2 - 0.26	
Transect 9a	Holothuria atra	50
	Holothuria edulis	7
	Total number species - 2 Total density/m^2 - 0.57	

Table 3 Continued.

	SPECIES	DENSITY/TRANSECT
Transect 9b	*Holothuria atra*	43
	Holothuria edulis	30
	Bohadschia argus	5
	Total number species - 3	
	Total density/m^2 - 0.78	
Facies C		
Transect 17a/b	Holothurians not quantified	
Facies D		
Transect 4	*Holothuria edulis*	8
	Stichopus chloronotus	8
	Holothuria atra	6
	Total number species - 3	
	Total density/m^2 - 0.22	
Transect 15	*Holothuria edulis*	33
	Holothuria atra	11
	Stichopus chloronotus	2
	Total number species - 3	
	Total density/m^2 - 0.46	
Transect 16	*Holothuria edulis*	21
	Holothuria atra	5
	Stichopus chloronotus	1
	Holothuria nobilis	1
	Total number species - 4	
	Total density/m^2 - 0.28	
Transect 18	Holothurians not quantified.	
Facies E		
Transect 5a	*Holothuria edulis*	86
	Holothuria atra	67
	Total number species - 2	
	Total density/m^2 - 1.53	
Transect 5b	*Holothuria atra*	99
	Holothuria edulis	38
	Holothuria hilla	3
	Total number species - 3	
	Total density/m^2 - 1.40	

Table 3 Continued.

	SPECIES	DENSITY/TRANSECT
Biotope II		
Facies A		
Transect 10a	Holothuria edulis	23
	Stichopus chloronotus	5
	Actinopyga mauritiana	1
	Bohadschia argus	1
	Total number species - 4	
	Total density/m^2 - 0.30	
Transect 10b	Holothuria edulis	54
	Holothuria atra	20
	Total number species - 2	
	Total density/m^2 - 0.74	
Transect 12a	Holothuria atra	4
	Actinopyga mauritiana	3
	Stichopus chloronotus	1
	Total number species - 3	
	Total density/m^2 - 0.08	
Transect 12b	Stichopus chloronotus	2
	Bohadschia argus	1
	Holothuria atra	1
	Total number species - 3	
	Total density/m^2 - 0.04	
Transect 13a	Holothuria atra	4
	Bohadschia argus	3
	Total number species - 2	
	Total density/m^2 - 0.07	
Transect 13b	Holothuria atra	1
	Holothuria edulis	1
	Total number species - 2	
	Total density/m^2 - 0.02	
Facies B		
Transect 14a	Stichopus chloronotus	6
	Holothuria edulis	3
	Total number species - 2	
	Total density/m^2 - 0.09	

Table 3 Continued.

	SPECIES	DENSITY/TRANSECT
Transect 14b	*Holothuria edulis*	5
	Holothuria atra	1
	Stichopus chloronotus	1
	Total number species - 3	
	Total density/m^2 - 0.07	
Transect 11a/b	No holothurians observed.	

Table 4. Checklist of common macroinvertebrates other than hard corals and soft corals observed along or adjacent to transects during the 1975 and 1982 surveys.

SPECIES	BIOTOPE I										BIOTOPE II									
	A		B		C		D		E		A		B		C		D		E	
	75	82	75	82	75	82	75	82	75	82	75	82	75	82	75	82	75	82	75	82
Phylum Protozoa																				
Class Sarcodina																				
Marginopora vertibralis		X	X	X		X		X		X		X		X						
Phylum Cnidaria																				
Class Scyphozoa																				
Cassiopea andromeda									X	X										
Class Anthazoa																				
Anemone sp. 1		X				X		X												
Anemone sp. 2				X				X												
Phylum Porifera																				
Class Demospongiae																				
Terpious sp.		X		X				X				X		X						
Phylum Annelida																				
Class Polychaeta																				
Sabella sp.		X				X		X				X		X						
Spirorbis sp.		X		X			X	X												
Sedentaria sp.		X		X						X										
Phylum Chordata																				
Class Acidiacea																				
Yellow				X				X												
Blue								X		X										
Phylum Echinodermata																				
Class Asteroidea																				
Acanthaster planci						X		X												

Table 4 Continued.

SPECIES	BIOTOPE I										BIOTOPE II									
	A		B		C		D		E		A		B		C		D		E	
	75	82	75	82	75	82	75	82	75	82	75	82	75	82	75	82	75	82	75	82
<u>Culcita novaeguineae</u>		X		X		X		X		X										
<u>Linckia laevigata</u>		X				X		X						X		X				
<u>Linckia multiflora</u>																X				
<u>Echanster</u> sp.								X												
Class Ophiuroidea																				
Unidentified sp.		X																		
Class Echinoidea																				
<u>Diadema savignyi</u>																				
<u>Diadema setosum</u>		X												X						
<u>Echinometra mathaei</u>		X						X		X				X		X				
<u>Echinothrix diadema</u>		X				X										X				
<u>Tripneustes gratilla</u>														X						
Phylum Mollusca																				
Class Gastropoda																				
<u>Arca ventricosa</u>	X	X																		
<u>Arca</u> sp. 1				X																
<u>Arca</u> sp. 2						X														
<u>Atys cylindricus</u>			X																	
<u>Cantharus undosus</u>	X							X												
<u>Cerithium columna</u>	X			X																
<u>Cerithium mutatum</u>				X																
<u>Cerithium nodulosum</u>	X	X	X	X		X		X		X										
<u>Chicoreus brunneus</u>			X	X		X														
<u>Cheilea</u> sp. 1						X														
<u>Conus arenatus</u>	X			X																
<u>Conus distans</u>	X	X																		

Table 4 Continued.

SPECIES	BIOTOPE I										BIOTOPE II									
	A		B		C		D		E		A		B		C		D		E	
	75	82	75	82	75	82	75	82	75	82	75	82	75	82	75	82	75	82	75	82
Conus ebreus	X	X		X																
Conus flavidus			X	X																
Conus imperialis		X	X																	
Conus litteratus			X							X										
Conus lividus	X	X																		
Conus marmoreus			X	X																
Conus miles				X																
Conus miliaris		X		X		X			X											
Conus pulicaris	X	X	X	X	X				X											
Conus rattus	X	X		X																
Conus sponsalis									X	X										
Conus virgo	X																			
Conus sp. 1				X																
Cymatium hepaticum										X										
Cyprea annulus		X																		
Cyprea corneola	X			X																
Cyprea erosa		X		X																
Cyprea helvola				X																
Cyprea isabella				X																
Cyprea lynx								X												
Cyprea moneta	X	X	X	X		X		X		X										
Cyprea tigris			X	X			X	X												
Distorsio anus		X																		
Drupella cornus	X	X																		
Drupina grossularia		X																		
Imbricoria conularis					X	X														
Lambis chiragua		X																		
Lambis chrocata										X										
Lambis lambis		X						X		X		X								
Lambis truncata		X		X																

Table 4 Continued.

SPECIES	BIOTOPE I										BIOTOPE II									
	A		B		C		D		E		A		B		C		D		E	
	75	82	75	82	75	82	75	82	75	82	75	82	75	82	75	82	75	82	75	82
Lambis sp. 1				X																
Mitra mitra						X														
Mitra sp. 1						X														
Mitra sp. 2						X														
Oliva annulata		X				X														
Polinices auranatus						X														
Pusia patriarchalis								X												
Rhinoclavis aspera	X	X	X	X	X				X											
Rhinoclavis pharus				X																
Rhinoclavis sinensis		X		X																
Strombis gibberulus		X	X	X	X															
Strombis letiginosus				X																
Strombis luhuanus		X		X						X										
Strombis mutabilis		X				X														
Terebra babylonia				X	X															
Terebra maculata				X																
Thais aculaeata		X																		
Tonna perdix		X										X								
Trochus fenestratus				X																
Trochus niloticus		X		X							X	X	X							
Trochus pyramis				X																
Trochus tubiferus		X																		
Turbo chrysostoma		X								X										
Turbo pethalatus				X																
Vasum ceramicum	X		X																	
Vasum turbinellum		X	X	X				X		X										
Vexillum coronotum								X												

Table 4 Continued.

SPECIES	BIOTOPE I										BIOTOPE II									
	A		B		C		D		E		A		B		C		D		E	
	75	82	75	82	75	82	75	82	75	82	75	82	75	82	75	82	75	82	75	82
Class Pelycepoda																				
Chama sp.						X														
Chlamys sp.				X																
Codakia divergens							X	X												
Codakia punctata		X				X														
Codakia sp. 1					X															
Gafrarium sp.				X																
Isognoman perna				X																
Lima sp. 1				X																
Lima sp. 2				X																
Fragram fragram	X	X	X	X	X	X		X		X										
Pinctata margaritifera						X														
Pinna sp.																				
Scutargopagia scobinata		X		X																
Spondylus nicobaricus				X																
Spondylus sp. 1				X																
Tridacna maxima		X		X				X		X		X		X						
Tridacna squamosa		X																		

WATER CURRENTS

By

James A. Marsh, Jr., and Richard H. Randall

INTRODUCTION

Observations of direction and speed of water currents were made repeatedly at the five stations shown in Figures 1-4. The number of stations thus exceeded the specified Scope of Work and gave a reasonable coverage of the western portion of the lagoon with its deeper basin. Most tidal states were well represented; but there was a bias toward light surf conditions and fewer observations during heavy surf, as might be expected for the months of the study period.

Observations were made by releasing patches of fluorescein dye from a small boat at temporary marker buoys placed at each station. After a suitable interval the compass bearing from marker buoy to dye patch (i.e., the direction of movement) was determined. The distance covered by the dye patch during the specified time interval was measured by running the boat between the patch and the marker buoy while paying out a transect line attached to a floating bucket, which thus served as a sea anchor and maintained its position in the dye patch during this operation. Current speed could then be determined by dividing the distance covered by the moving dye by the measured time. Observations of wind speed and direction were taken concurrently with a hand-held anemometer.

At all stations except D, which was the shallowest (ca. 1 m deep at low tide), dye released at the surface of the water occasionally showed noticeable vertical mixing downward into the water column, and the recorded flow represented both surface and deeper movement. The more usual pattern was for the dye to remain in the upper 0.5 m, thus representing a surface flow only. In some cases we had the impression that there was a wind-driven surface flow moving faster than the underlying water mass, which nevertheless was probably moving in the same direction as the surface flow.

A temporary tide staff was placed on a patch reef near Sta A during the latter part of the field work. Observations of tidal level indicated that the time of low tide coincided with that predicted for Apra Harbor. Insufficient information was obtained to make a statement about high tide.

All current and wind data are recorded in Table 1 and are presented graphically in Figures 1-4. Current speeds at all stations were usually slower than 0.25 m sec^{-1} during most tidal states and surf conditons and did not generally exceed 0.15 m sec^{-1} at Sta C, D, and E. Occasional values exceeding 0.25 m sec^{-1} were found during heavy surf conditions on spring tides.

The most constant directions of flow were found at Sta A and were generally within 90° of magnetic north, usually being more northeasterly than northwesterly. The major exception was an opposite flow toward the southwest on flooding spring tides.

The direction of flow was much more variable at the other stations. At Sta B, as at Sta A, flows toward the southwest tended to occur only during spring tides; and relatively few observations showed movement toward the southeast. At Sta C, flow direction toward the southwest likewise occurred only during spring tides; and for all such observations the surf again was light. At Sta D, the most common direction of water movement was toward the northeast, and only one observation showed movement toward the southeast. At Sta E, the most common direction of movement was toward the northwest, or away from the nearest barrier reef and toward Mamaon Channel.

The general picture that emerges is that much of the water entering the lagoon comes across the barrier reefs, particularly when the surf is moderate to heavy. Much of the drainage is toward Mamaon Channel, with movement toward Manell Channel being partially inhibited by the large expanses of shallow seagrass flats that occupy the eastern portion of the lagoon. On rising spring tides, when the surf is light and the western barrier reef has no water coming across it, water flooding into the lagoon enters through Mamaon Channel. The highest current speeds generally occur at sta A, nearest Mamaon Channel. This station also has the most constant direction of flow, toward Mamaon Channel, except with the reversals that occur on rising spring tides.

A shallow (2-m depth) channel through the western barrier reef near Cocos Island, may have flows either into or out of the lagoon, depending on tidal state. It thus serves as an incurrent and excurrent area for the shallow part of the lagoon near the western end of Cocos Island.

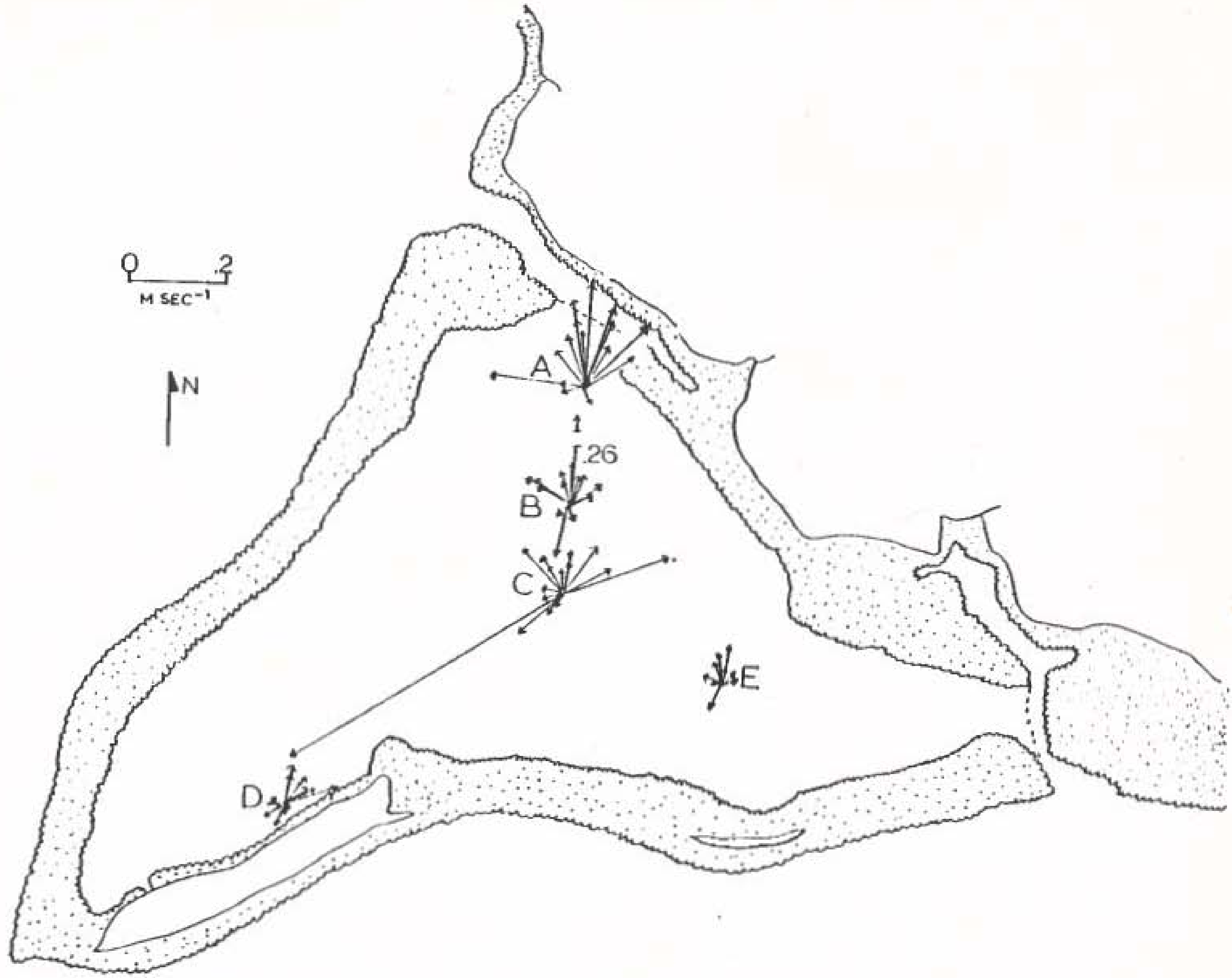

Figure 1. Water current observations for low tides. Length of the arrows is proportional to current speed. Arrows with open heads represent neap tides and those with closed heads represent spring tides.

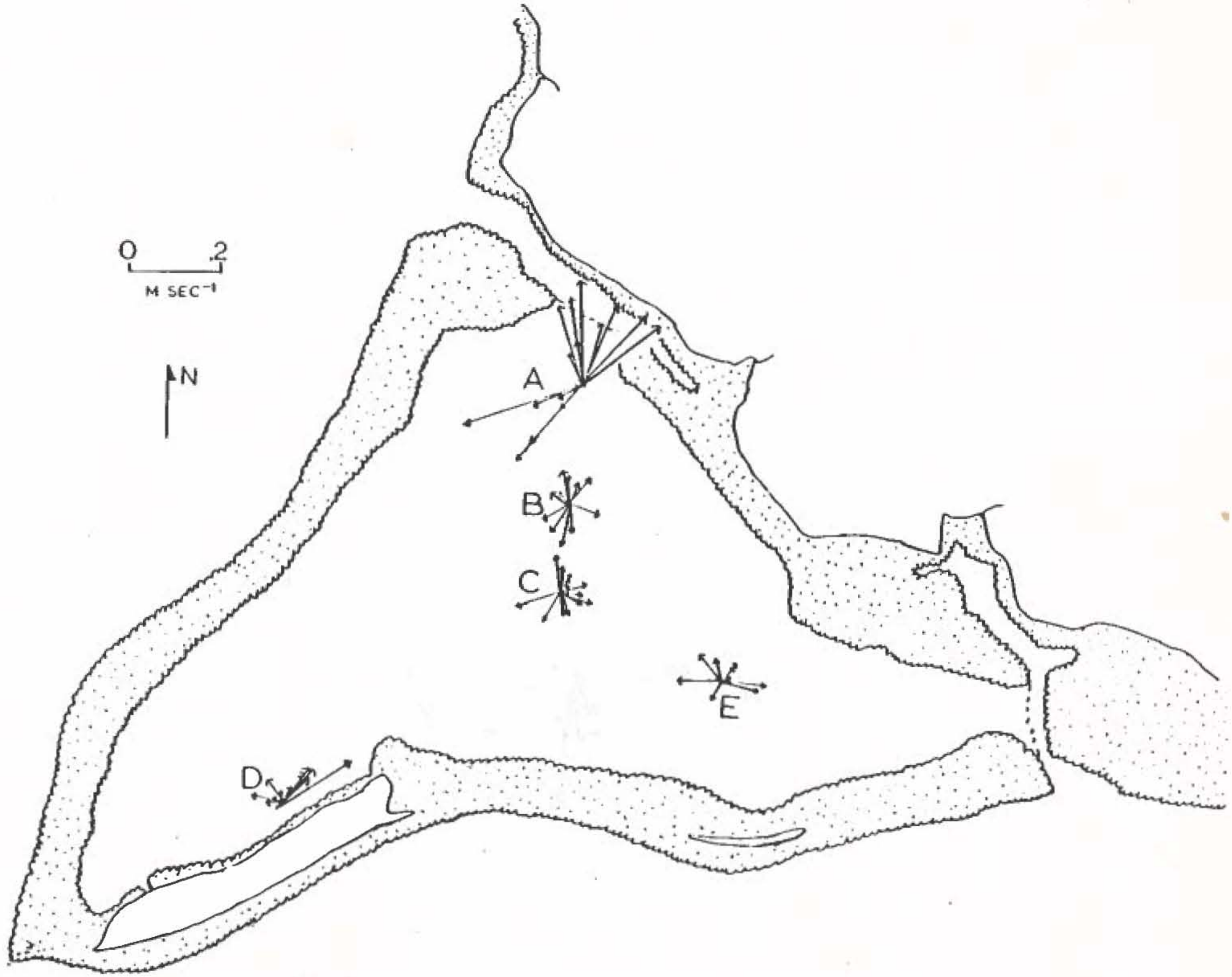

Figure 2. Water current observations for flooding tides. Length of the arrows is proportional to current speed. Arrows with open heads represent neap tides and those with closed heads represent spring tides.

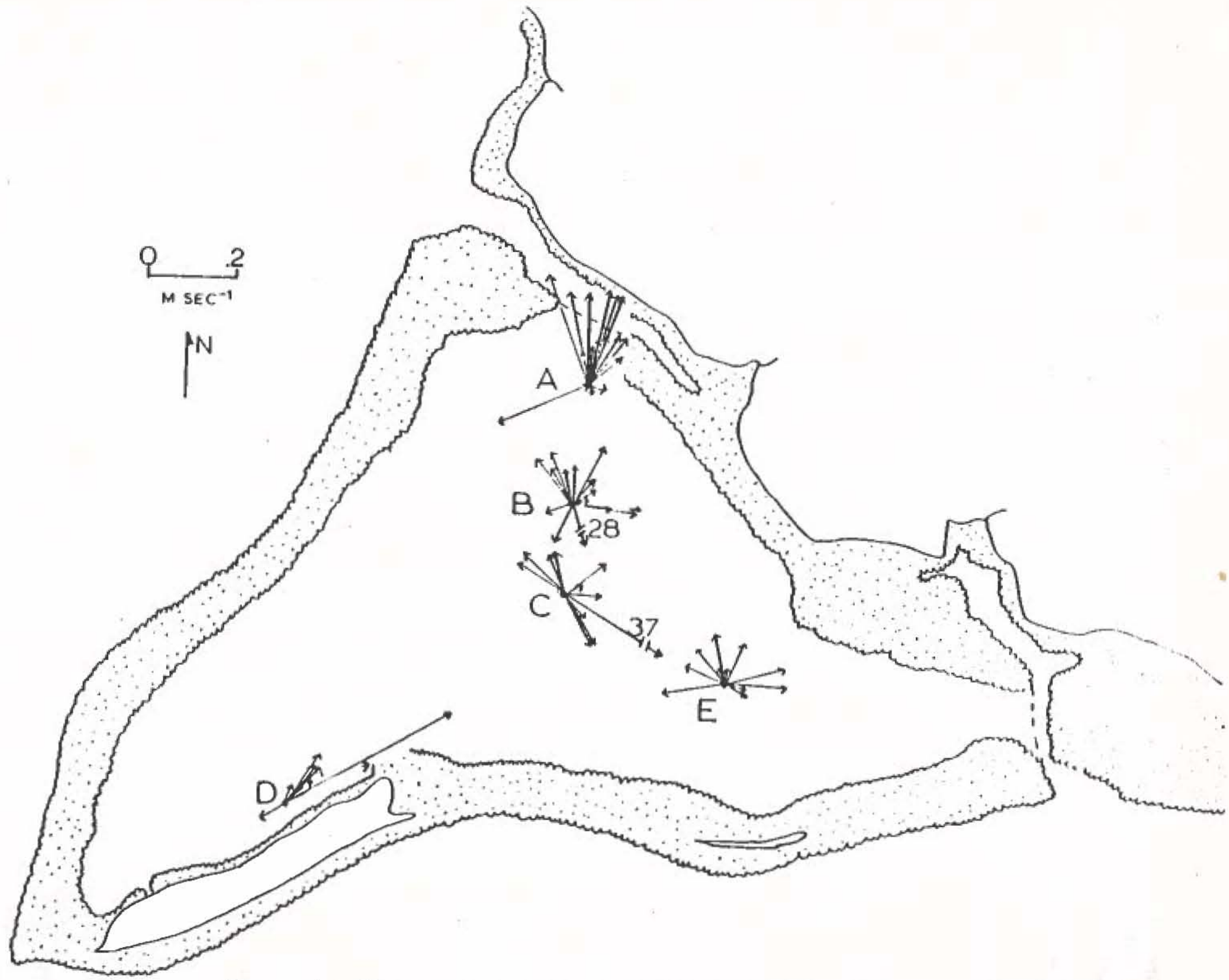

Figure 3. Water current observations for high tides. Length of the arrows is proportional to current speed. Arrows with open heads represent neap tides and those with closed heads represent spring tides.

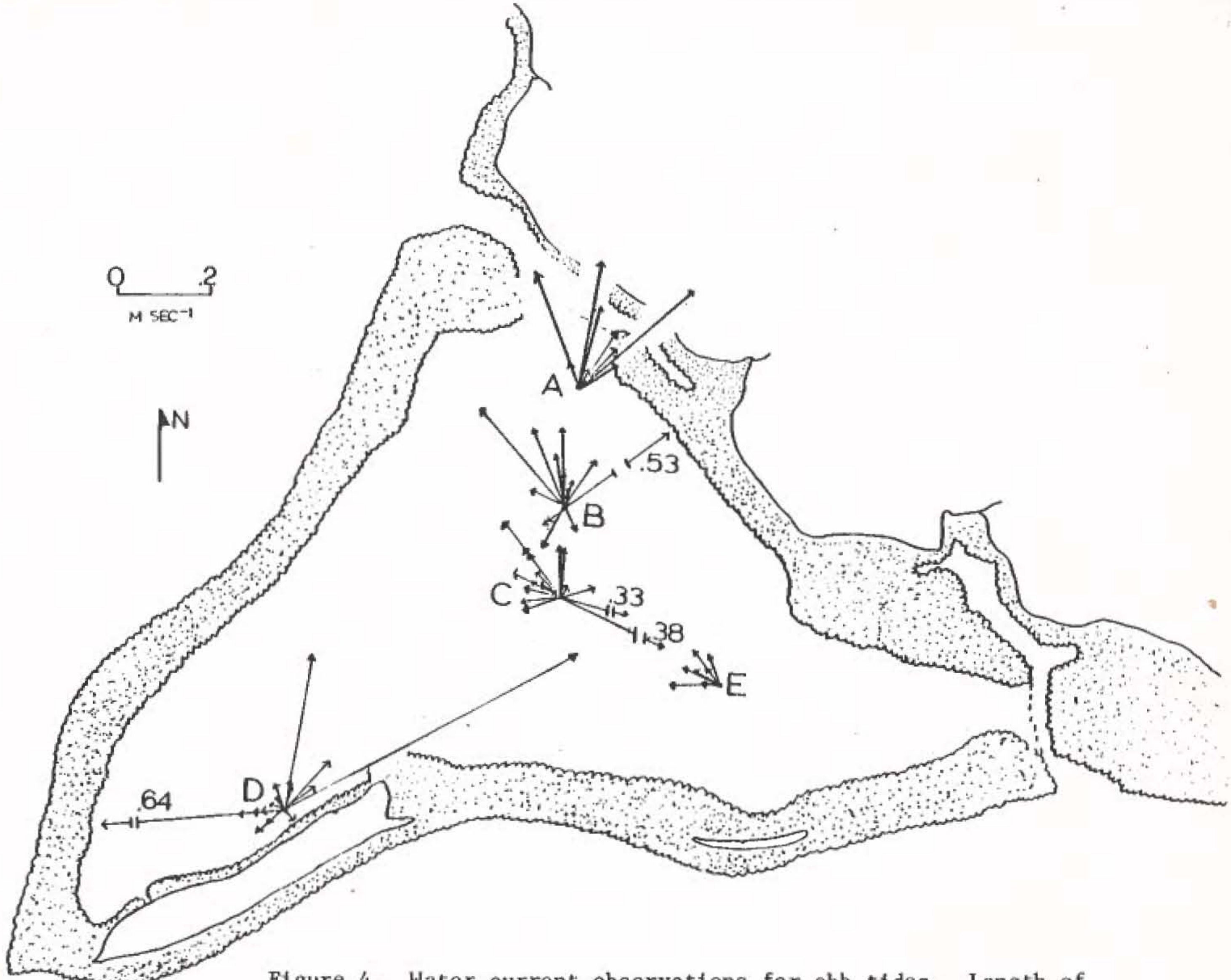

Figure 4. Water current observations for ebb tides. Length of the arrows is proportional to current speed. Arrows with open heads represent neap tides and those with closed heads represent spring tides.

Table 1. Current flows in Cocos Lagoon. The designated current bearing is the direction toward which the current was flowing. The designated wind bearing is the direction from which the wind was blowing. See Figure 1 for station locations.

Station	Time	Current Bearing	Current Speed (m/sec)	Wind Bearing (knots)	Tide
	June 22	Surf moderate (tropical storm Ruby approaching and passes south of Guam)			
B	1112	336°	0.18	140° (12)	spring-ebb
	1137	318°	0.29	140° (12)	-ebb
	1409	307°	0.09	130° (12)	-low
	1445	345°	0.08	140° (12)	-low
C	1103	324°	0.20	140° (12)	spring-ebb
	1131	327°	0.12	130° (12)	-ebb
	1402	326°	0.12	125° (12)	-ebb
	1446	320°	0.13	142° (12)	-low
D	1046	332°	0.02	155° (12)	spring-ebb
	1125	228°	0.04	140° (12)	-ebb
	1356	028°	0.03	125° (12)	-low
	1422	285°	.01	125° (12)	-low
	June 24	surf heavy, large swells			
B	1015	035°	0.15	245° (13)	spring-high
	1129	032°	0.12	230° (13)	-ebb
	1304	054°	0.53	230° (13)	-ebb
	1410	004°	0.26	215° (13)	-low
C	1023	122°	0.37	250° (13)	spring-high
	1122	115°	0.38	230° (13)	-ebb
	1310	105°	0.33	215° (13)	-ebb
	1354	070°	0.25	234° (13)	-low
D	1041	062°	0.42	230° (13)	spring-high
	1114	063°	0.72	235° (13)	-ebb
	1318	010°	0.35	217° (13)	-ebb
	1402	062°	0.25	215° (13)	-low
F	1342	068°	0.68	246° (13)	spring-ebb
G	1418	024°	1.09	215° (13)	spring-low
	June 28	surf light			
A	1017	360°	0.23	128° (10.3)	neap-flood
	1144	343°	0.26	176° (10.8)	-high
	1210	252°	0.26	126° (8.2)	-high
	1432	352°	0.22	130° (13.6)	-high
	1532	338°	0.26	124° (13.6)	-ebb

Table 1 Continued.

Station	Time	Current Bearing	Current Speed (m/sec)	Wind Bearing (knots)	Tide
B	1024	320°	0.02	126° (11.3)	neap-flood
	1140	354°	0.08	111° (13.4)	-high
	1217	333°	0.04	145° (11.5)	-high
	1422	330°	0.03	105° (10)	-high
	1528	328°	0.02	110° (13.4)	-ebb
C	1040	076°	0.05	112° (18.3)	neap-flood
	1135	068°	0.05	115° (10.8)	-high
	1220	072°	0.05	115° (11.5)	-high
	1418	095°	0.09	110° (12.4)	-high
	1525	075°	0.08	115° (13.4)	-ebb
D	1049	048°	0.10	075° (8.9)	neap-flood
	1126	064°	0.10	110° (9-11)	-high
	1243	048°	0.11	122° (10.5)	-high
	1411	055°	0.08	102° (8.7)	-high
	1518	058°	0.09	094° (11.7)	-ebb
	June 29	Surf light			
A	0948	002°	0.19	165° (10.5)	neap-low
	1148	353°	0.20	103° (5.0)	-flood
	1245	004°	0.22	129° (6.0)	-high
	1439	353°	0.08	094° (8.0)	-high
B	0952	007°	0.10	186° (10.0)	neap-low
	1144	314°	0.04	131° (6.0)	-flood
	1250	012°	0.08	118° (7.0)	-high
	1434	058°	0.08	117° (8.5)	-high
C	1004	327°	0.09	186° (15)	neap-low
	1140	112°	0.06	116° (9.0)	-flood
	1256	062°	0.03	114° (6.5)	-high
	1430	058°	0.08	117° (8.5)	-high
	June 30	Surf light			
A	0939	352°	0.15	088° (10)	neap-low
	1131	350°	0.19	112° (6.5)	-low
	1215	344°	0.18	115° (5.5)	-flood
	1432	025°	0.20	130° (7.5)	-flood
B	0945	294°	0.07	076° (10)	neap-low
	1124	237°	0.10	121° (6.5)	-low
	1222	319°	0.03	129° (9.0)	-flood
	1425	360°	0.06	130° (7.0)	-flood
C	0952	256°	0.03	076° (5.5)	neap-low

Table 1 Continued.

Station	Time	Current Bearing		Speed (m/sec)	Wind Bearing (knots)	Tide
	1112	291°	1st run	0.04	105° (6.0)	neap-low
			2nd run	0.02		
	1228	042°		0.03	110° (5.0)	-flood
	1417	125°		0.07	134° (5.5)	-flood
D	1000	047°		0.07	095° (5.5)	neap-low
	1103	018°		0.06	094° (7.5)	-low
	1237	050°		0.06	094° (6.5)	-flood
	1405	039°		0.08	120° (4.0)	-flood
	July 1	Surf light				
A	0950	021°		0.17	000° (3.0)	neap-low
	1123	018°		0.15	calm	-low
	1355	020°		0.14	136° (4.5)	-flood
B	0958	035°		0.12	253° (4.0)	neap-low
	1117	018°		0.07	calm	-low
	1345	352°		0.07	121° (5.5)	-flood
C	1006	035°		0.12	281° (3.5)	neap-low
	1106	061°		0.12	000° (1.0)	-low
	1327	026°		0.05	127° (5.0)	-flood
D	1013	069°		0.08	291° (3.5)	neap-low
	1100	073°		0.11	calm	-low
	1335	042°		0.10	152° (5.0)	-flood
E	1136	043°		0.04	calm	neap-low
	1320	322°		0.07	124° (6)	-flood
	July 12	Surf light				
A	0940	007°		0.07	158° (5.0)	neap-high
	1230	348°		0.06	calm	-ebb
	1317	010°		0.28	146° (5.0)	-ebb
	1426	014°		0.16	135° (2.0)	-ebb
B	0950	331°		0.07	178° (3.5)	neap-high
	1216	021°		0.06	calm	-ebb
	1310	357°		0.16	145° (1.0)	-ebb
	1421	354°		0.13	145° (5.5)	-ebb
C	1005	348°		0.06	calm	neap-high
	1210	035°		0.03	140° (2.5)	-ebb
	1305	360°		0.11	147° (4.0)	-ebb
	1415	004°		0.07	125° (4.0)	-ebb

Table 1 Continued.

Station	Time	Current Bearing	Current Speed (m/sec)	Wind Bearing (knots)	Tide
D	1024	027°	0.04	153° (3.0)	neap-high
	1240	265°	0.64	calm	-ebb
	1400	340°	0.05	150° (3.0)	-ebb
	1455	140°	0.04	156° (4.5)	-ebb
E	1050	028°	0.02	140° (3.5)	neap-high
	1200	015°	0.03	142° (2.0)	-high
	1445	324°	0.09	132° (5.0)	-ebb
	July 13	Surf light			
A	0926	025°	0.23	calm	neap-high
B	0945	100°	0.08	239° (1)	neap-high
	July 14	Surf light			
A	0940	018°	0.10	074° (6.0)	neap-flood
	0945	355°	0.07	140° (2.5)	-flood
	1113	360°	0.05	141° (1)	-flood
	1300	055°	0.14	325° (2)	-high
	1420	058°	0.11	272° (1)	-high
B	0955	032°	0.04	153° (2)	neap-flood
	1122	360°	0.05	141° (0.1)	-flood
	1318	065°	0.05	344° (2)	-high
	1430	068°	0.06	165° (0.5)	-high
C	1005	360°	0.05	158° (3)	neap-flood
	1130	355°	0.08	143° (2)	-flood
	1325	152°	0.08	322° (1.5-2)	-high
	1440	153°	0.08	101° (3)	-high
D	1018	030°	0.04	133° (1-2)	neap-flood
	1140	324°	0.06	124° (1)	-flood
	1332	-	0	002° (0.5)	-high
	1455	234°	0.06	095° (2)	-high
E	1036	285°	0.03	156° (2)	neap-flood
	1200	334°	0.04	143° (2-2.5)	-high
	1347	128°	0.04	calm	-high
	July 22	Surf light			
A	1038	042°	0.05	055° (15)	spring-ebb
	1230	055°	0.09	070° (15)	-ebb
B	1113	212°	0.10	038° (15)	spring-ebb

Table 1 Continued.

Station	Time	Current Bearing	Current Speed (m/sec)	Wind Bearing (knots)	Tide
	1220	155°	0.06	090° (>15)	spring-ebb
C	1123	240°	0.09	072° (15)	-ebb
	1210	252°[b]	0.09	045° (10-12)	-ebb
D	1150	230°	0.07	060° (>15)	spring-ebb
	August 2	Surf heavy			
A	1048	050°	0.36	200° (1-2)	spring-low
	1200	045°	0.20	200° (1)	-low
	1320	030°	0.10	190° (2)	-low
	1412	250°	0.11	200° (2)	-flood
B	1118	030°	0.05	218° (1)	spring-ebb
	1208	342°	0.05	170° (1)	-low
	1326	062°	0.05	180° (2)	-low
	1417	045°	0.08	205° (2.5)	-flood
C	1128	359°	0.06	170° (1)	spring-low
	1215	332°	0.06	190° (1)	-low
	1335	010°	0.07	170° (1)	-low
	1423	105°	0.07	155° (2)	-flood
D	1140	063°	0.06	230° (1)	spring-low
	1225	045°	0.06	205° (<0.5)	-low
	1343	069°	0.06	155° (2.5)	-low
	1430	045°	0.07	195° (1.5)	-flood
E	1152	360°	0.07	120° (1)	spring-low
	1233	355°	0.06	285° (1.7)	-low
	1350	350°	0.05	175° (2)	-flood
	1439	040°	0.05	185° (2)	-flood
	August 4	Surf light			
A	1025	041°	0.14	300° (1.5)	spring-ebb
	1128	065°	0.18	275° (0.5)	-ebb
	1312	058°	0.12	268° (0.5)	-low
	1400	150°	0.03	299° (6.5)	-low
B	1035	005°	0.04	290° (0.5)	spring-ebb
	1133	011°	0.06	289° (0.5)	-ebb
	1322	341°	0.05	309° (0.2)	-low
	1406	165°	0.03	359° (4.5)	-low
C	1045	303°	0.04	305° (0.5)	spring-ebb
	1140	005°	0.05	265° (0.5)	-ebb
	1328	063°	0.03	285° (2)	-low

Table 1 Continued.

Station	Time	Current Bearing	Current Speed (m/sec)	Wind Bearing (knots)	Tide
	1414	143°	0.08	289° (4.5)	spring-low
D	1055	060°	0.04	305° (0-0.5)	-ebb
	1153	025°	0.03	268° (0+)	-ebb
	1337	276°	0.02	265° (4.2)	-low
	1424	171°	0.02	340° (4)	-low
E	1113	280°	0.03	248° (0.5)	spring-ebb
	1210	342°	0.05	280° (0+)	-low
	1350	068°	0.03	289° (3.5)	-low
	<u>August 5</u>	Surf light			
A	0938	032°	0.14	230° (2)	spring-ebb
	1050	045°	0.07	330° (2.5)	-ebb
	1310	355°	0.12	255° (2.5)	-low
	1404	030°	0.03	330° (3)	-low
B	0954	360°	0.08	198° (1)	spring-ebb
	1055	352°	0.12	145° (2.5)	-ebb
	1315	009°	0.07	218° (3.5)	-low
	1412	360°	0.09	260° (3)	-low
C	1000	-	0	140° (2)	spring-ebb
	1106	005°	0.11	290° (2)	-ebb
	1321	005°	0.09	150° (0+)	-low
	1416	335°	0.04	160° (3)	-low
D	1017	054°	0.04	225° (1)	spring-ebb
	1117	013°	0.06	218° (2)	-ebb
	1330	045°	0.05	150° (3.5)	-low
	1424	018°	0.08	150° (3)	-low
E	1038	328°	0.05	210° (2.5)	spring-ebb
	1124	344°	0.1	143° (2)	-ebb
	1338	005°	0.04	191° (2)	-low
	1434	007°	0.08	189° (2)	-low
	<u>August 9</u>	Surf light			
A	0935	105°	0.05	055° (11-15)	neap-high
	1035	150°	0.02	060° (10)	-high
	1310	053°	0.08	050° (14)	-ebb
	1413	005°	0.04	078° (14)	-ebb
B	0945	207°	0.11	055° (10)	neap-high
	1044	255°	0.06	050° (19)	-high
	1317	236°	0.05	045° (7)	-ebb
	1420	231°	0.04	075° (9)	-ebb

Table 1 Continued.

Station	Time	Current Bearing	Current Speed (m/sec)	Wind Bearing (knots)	Tide
C	0952	301°	0.12	060° (14)	neap-high
	1049	310°	0.03	040° (13)	-high
	1329	300°	0.12	115° (15)	-ebb
	1426	301°	0.05	090° (10)	-ebb
D	1020	231°	0.09	055° (13)	neap-high
	1215	267°	0.09	060° (7)	-ebb
	1347	265°	0.07	080° (12)	-ebb
	1442	264°	0.06	035° (9.5)	-ebb
E	1010	290°	0.09	096° (13)	neap-high
	1059	261°	0.13	080° (10)	-high
	1340	300°	0.09	080° (14)	-ebb
	1434	304°	0.06	080° (9.5)	-ebb
	August 11	Surf moderate to heavy			
A	0945	011°	0.09	100° (7)	neap-high
	1053	029°	0.08	080° (7.5)	-high
	1240	031°	0.13	100° (5)	-high
	1404	045°	0.12	120° (7.5)	-ebb
B	0955	320°	0.12	110° (6)	neap-high
	1105	325°	0.09	100° (7)	-high
	1245	337°	0.11	075° (5.5)	-high
	1410	020°	0.06	119° (5.5)	-ebb
C	1004	311°	0.10	100° (8)	neap-high
	1111	322°	0.09	115° (6.8)	-high
	1248	343°	0.09	120° (6)	-high
	1415	320°	0.05	122° (7)	-ebb
D	1024	038°	0.14	103° (7)	neap-high
	1130	044°	0.10	080° (5)	-high
	1305	065°	0.11	110° (4)	-high
	1431	045°	0.11	080° (5.5)	-ebb
E	1015	321°	0.09	115° (7.5)	neap-high
	1120	321°	0.08	125° (7)	-high
	1254	345°	0.11	120° (6)	-high
	1420	352°	0.06	110° (7)	-ebb
	August 12	Surf moderate to heavy			
A	0940	337°	0.08	290° (3)	neap-flood
	1129	019°	0.11	240° (2.5)	-high
	1317	035°	0.14	340° (4.5)	-high
	1417	053°	0.15	340° (6)	-high

Table 1 Continued.

Station	Time	Current Bearing	Current Speed (m/sec)	Wind Bearing (knots)	Tide
B	0944	029°	0.05	168° (3)	neap-flood
	1132	095°	0.15	271° (3)	-high
	1321	093°	0.16	341° (4.5)	-high
	1421	165°	0.82	293° (9)	-high
C	0953	070°	0.02	250° (1)	neap-flood
	1137	090°	0.09	240° (0+)	-high
	1326	091°	0.09	064° (4)	-high
	1426	137°	0.07	221° (9)	-high
D	1015	063°	0.12	175° (1)	neap-flood
	1152	064°	0.11	289° (0+)	-high
	1339	065°	0.09	000° (4)	-high
	1439	054°	0.07	350° (9)	-high
E	1005	045°	0.02	268° (2)	neap-flood
	1145	077°	0.14	285° (2.5)	-high
	1331	094°	0.15	106° (4)	-high
	1431	031°	0.10	351° (8)	-high
	August 16	Surf light			
A	1040	302°	0.10	095° (8-10)	spring-low
	1148	244°	0.05	130° (10-12)	-low
	1343	223°	0.23	115° (8-10)	-flood
	1430	225°	0.16	115° (6-8)	-flood
	1540	226°	0.07	122° (6)	-flood
	1616	245°	0.05	128° (4)	-flood
B	1046	041°	0.07	110° (8-10)	spring-low
	1153	243°	0.04	138° (10-12)	-low
	1343	211°	0.08	083° (8-10)	-flood
	1435	243°	0.07	125° (10-12)	-flood
	1545	181°	0.07	111° (6)	-flood
	1623	180°	0.06	119° (4)	-flood
C	1053	228°	0.12	115° (8-10)	spring-low
	1200	208°	0.03	120° (12-14)	-low
	1348	165°	0.05	100° (8)	-flood
	1439	170°	0.05	114° (8)	-flood
	1549	252°	0.09	115° (6-7)	-flood
D	1108	244°	0.01	141° (5-6)	spring-low
	1217	200°	0.04	128° (6-7)	-low
	1406	290°	0.02	104° (6)	-flood
	1450	281°	0.06	063° (>15)	-flood
	1607	352°	0.01	115° (6)	-flood

Table 1 Continued.

Station	Time	Current Bearing	Current Speed (m/sec)	Wind Bearing (knots)	Tide
E	1058	328°	0.04	114° (8-10)	spring-low
	1203	088°	0.01	129° (11-13)	-low
	1358	-	0	101° (6-7)	-flood
	1444	273°	0.09	070° (15)	-flood
	1553	040°	0.04	117° (6-7)	-flood
	August 18	Surf light			
A	1006	341°	0.09	030° (7)	spring-ebb
	1120	340°	0.12	070° (4.5)	-low
	1315	273°	0.05	083° (9.5)	-low
	1419	273°	0.20	120° (9)	-low
	1516	261°	0.27	029° (5)	-flood
B	1011	299°	0.07	340° (8)	spring-ebb
	1125	299°	0.06	062° (4.5)	-low
	1320	222°	0.03	063° (8)	-low
	1423	191°	0.11	060° (7)	-low
	1522	192°	0.11	051° (7.5)	-flood
C	1022	286°	0.08	071° (6)	spring-ebb
	1131	269°	0.04	063° (4)	-low
	1325	238°	0.02	090° (11)	-low
	1427	214°	0.09	030° (8)	-low
	1526	212°	0.07	331° (3)	-flood
D	1037	281°	0.03	089° (9.5)	spring-ebb
	1144	245°	0.04	070° (5.5)	-low
	1328	233°	0.04	072° (8)	-low
	1440	180°	0.04	040° (6)	-low
	1539	272°	0.03	043° (9)	-flood
E	1028	271°	0.08	068° (6)	spring-ebb
	1137	295°	0.04	080° (8)	-low
	1330	290°	0.01	035° (9)	-low
	1431	198°	0.06	060° (11)	-low
	1531	214°	0.04	054° (7)	-flood
	August 26	Surf heavy			
A	1011	045°	0.21	297° (4)	neap-flood
	1103	053°	0.21	271° (4)	-flood
	1308	020°	0.16	268° (3)	-high
	1405	023°	0.22	calm	-high
B	1020	-	0	270° (6)	neap-flood
	1107	113°	0.07	280° (0+)	-flood

Table 1 Continued.

Station	Time	Current Bearing	Current Speed (m/sec)	Wind Bearing (knots)	Tide
	1313	094°	0.08	279° (2)	neap-high
	1409	083°	0.04	282° (0.5)	-high
C	1029	123°	0.05	287° (4.5)	neap-flood
	1110	111°	0.07	293° (3.5)	-flood
	1317	147°	0.16	295° (3)	-high
	1415	148°	0.12	271° (3.5)	-high
D	1046	065°	0.17	312° (3.5)	neap-flood
	1143	060°	0.17	282° (2)	-flood
	1330	065°	0.24	297° (4)	-high
	1437	070°	0.21	325° (7)	-high
E	1037	098°	0.10	282° (4.5)	neap-flood
	1115	107°	0.09	290° (3)	-flood
	1323	111°	0.05	082° (4.5)	-high
	1426	123°	0.06	240° (5)	-high

RECOMMENDATIONS

By

Richard H. Randall

General Summary of Resurvey

With the exception of algae and seagrass, and to some extent the hard corals, the results of this study indicate that little to no significant changes have occurred in the biologic communities of Cocos Lagoon and its associated barrier and patch reefs and deep channels between the 1975 survey and present time. Discussion of differences found in the community structure of the various biologic communities between the 1975 survey and the 1982 survey are discussed in each of the appropriate sections.

In general the additional current data collected during the present 1982 resurvey period from the lagoon proper substantiates the general current patterns suggested by Emery (1962) and Randall et al. (1975).

Although there has been a substantial increase in tourism in the Cocos Lagoon/Island area between 1975 and 1982, with relatively few noticeable changes taking place in the marine plant and animal communities, the study does not suggest or indicate that continued increases of tourism and other traditional uses will not cause noticeable effects in the future. Possibly there is a threshold of stress that must be reached in the lagoon system before significant or noticeable effects will be detected. Although the lagoon system has so far shown to be amazingly stable in spite of increased use, the need for a "Comprehensive Cocos Lagoon/Island Use Plan" is by no means diminished. We have a situation in Cocos Lagoon/Island area where a "use plan" is being developed, not in response to noticeable environmental degradation, but as a vehicle to prevent such from becoming a reality.

Although the resurvey revealed little change between 1975 survey and 1982 resurvey the following recommendations are listed below as mitigating or measures against increased stress or activities that could enhance the marine communities of the Cocos Lagoon area.

1. Plans for a small-boat harbor should proceed as rapidly as possible to localize the present proliferation of individual anchorage moorings being placed in reef and navigational channel areas. The head of Mamaon Channel in the vicinity of the mouth of the Géus River appears from a biological and users viewpoint to be the best location.

2. Because of the unstable nature and periodic inundation by storm waves of the small sand islet at the eastern end of Cocos Island development there should be discouraged.

3. Self-guiding underwater scuba and or snorkeling trails at several appropriate locations in the lagoon should be considered.

4. The Guam Environmental Protection Agency should continue their water monitoring program in the lagoon area, and possibly expand it to high-use areas as development proceeds.

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