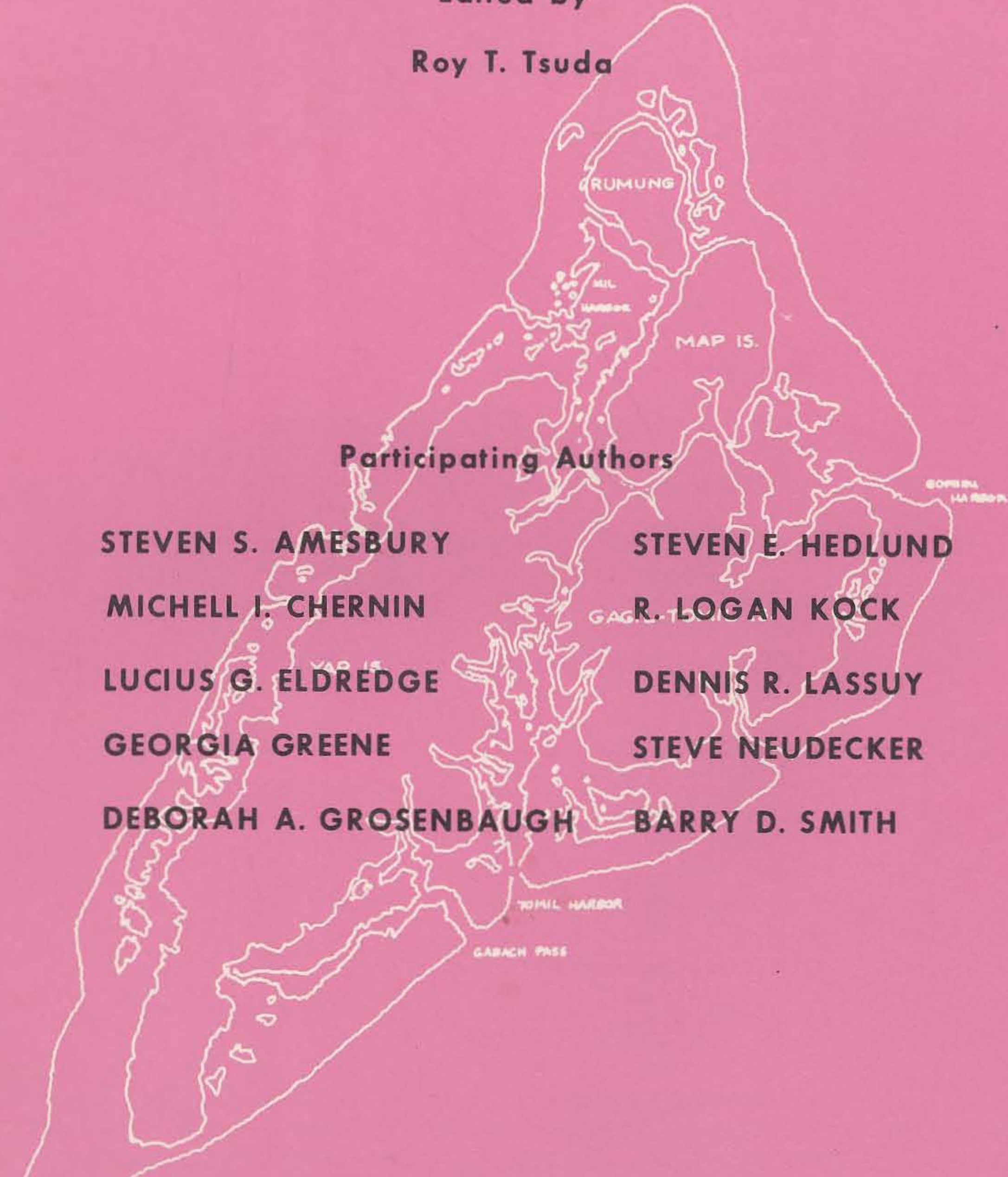
MARINE BIOLOGICAL SURVEY OF YAP LAGOON

Edited by

Roy T. Tsuda



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UNIVERSITY OF GUAM MARINE LABORATORY

Technical Report No. 45

April 1978

This report was financed in part through a federal grant from the Department of Housing and Urban Development, Comprehensive Planning Assistance, Title IV of the Housing and Community Development Act of 1974, as amended. (Grant No. CPA-TQ-09-00-1002).

Cover illustration: Map of Yap, drawn by Leonor Lange-Moore.

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Submitted to

Office of Planning and Statistics

Trust Territory of the Pacific Islands

University of Guam Marine Laboratory

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INTRODUCTION

Roy T. Tsuda

The inception of this study of the Yap Lagoon began about a year and a half ago when Mr. Michael Rody, then the District Planner of Yap, approached the University of Guam Marine Laboratory to undertake a general survey of the water circulation patterns and major biological components of the lagoon. The study was to be fashioned in such a way that the information generated could be used by Government officials or Engineers to better plan future endeavors which could have an impact on the lagoon.

After much discussion on the actual scope of work to be performed within a specified funding level of about $15,000, a contract between the Trust Territory of the Pacific Islands and the University of Guam was finalized on May 24, 1977. The study would determine and map the general current patterns, and biological characteristics and features of the Yap Lagoon. Particular emphasis would be on the following parameters - 1) analyze the extent and magnitude of surface and subsurface currents in the three major harbor areas, i.e., Tomil Harbor, Gofenu Harbor, and Mil Harbor, 2) describe and map the major biological components, i.e., corals, marine plants, and conspicuous macroinvertebrates, 3) describe areas where large populations of fishes occur, and 4) seek the rearing grounds of fishes through the examination of larvae.

The field studies were conducted on July 9-22, 1977 and January 8-13, 1978. The first trip, which consisted of a six-man team, was primarily spent circumnavigating the Yap Islands to obtain a general overview of the marine organisms both on the reef flats and in the deeper lagoonal holes. The lagoonal holes were of particular interest since these were the areas where fishing activities by the local people were concentrated. During this trip, the first set of water circulation data were obtained in the three harbor areas. The second trip of shorter duration, consisted of a four-man team and was primarily made to obtain the second set of water circulation data at the same three sites. This trip also afforded the opportunity to recheck certain observations made on the first trip.

The sections that follow are credited to the individuals who wrote them. Together, they provide a working document on the water circulation patterns and the marine organisms which can be found within the Yap Lagoon. A bibliography on marine-related literature, both published and unpublished, of the Yap District is provided. In addition, a fold-out map of Yap which delineates the major biological components within the lagoon is also provided.

ACKNOWLEDGEMENTS

It is appropriate at this time to acknowledge the various individuals on Yap who made our study a little earier through their cooperation. These individuals are Sam Falanruw, Special Assistant to the District Administrator, and Hilary J. Tacheliol, Deputy District Administrator, who came to our aid when problems arose; Jesse B. Marehalau, then Acting Fishery Officer, who helped on countless occasions; Bob Green, Chief of the Land Commission, who generously loaned us his boat and gasoline cans; Harold Temmy, Chief of Land Management, who provided us with topographic maps; Philip Kloulubak, Chief District Sanitarian, who loaned us his boat; Rev. Heine Hengstler, who saw to our scuba air needs; Silbester Alfonso, Proprietor of the ESA Hotel, who served as a most generous and helpful host during our stay in Yap; Del Arnold, Maintenance Supervisor of Public Works, who streamlined the system for us to obtain gasoline and oil for the boats; Medgeg and Cyril Tman, who served as our guides on the first trip; and Vincent Mareyeg, who served as boat operator and guide on the second trip. Special thanks to our energetic administrative secretary Terry Balajadia for typing this report and to Leonor Lange-Moore for her help in drawing the fold-out map. David Gardner developed our films and printed the photographs. Our sincerest appreciation to the staff of the Trust Territory Liaison Office in Guam for help in establishing communications via telephone or telegrams to both Saipan and Yap.

WATER CIRCULATION PATTERNS IN THE MAJOR HARBORS OF YAP

Mitchell I. Chernin

INTRODUCTION

Prior to this report, four current surveys were done at specific areas in Tomil Harbor, Yap. Austin, Smith and Associates (1967) used floats and dye markers to determine current direction at a point southwest of the Donitsch Island sewer outfall. In January of 1975, Lyon Associates Inc. made a study of water circulation in Tomil Harbor using fixed current meters at various locations within the harbor, and Amesbury et al. (1976) plotted current movement in an area adjacent to the Donitsch Island sewer outfall using drift drogues and fluorescein dye. The fourth study (Gawel and Strong, 1977) plotted water movement with fluorescein dye off Colonia and in Chamorro Bay. There does not appear to be any previous literature on water movement in Gofenu or Mil Harbors.

METHODS

A pair of drift drogues, 1-meter and 5-meters deep, were periodically released at two locations in each of the three study sites (Figs. 1-6). After appropriate time intervals (approximately one hour), the positions of the drogues were determined by sighting three fixed points with a hand-bearing compass. These data were then recorded and plotted. The difficulty in establishing three fixed point positions for Gofenu and Mil Harbors should not be understated. Local topographical features and available maps at times did not coincide; therefore, best estimates were made. This was not the case for Tomil Harbor where fixed buoy positions were used to establish fixed point positions. Wind speed and direction were also recorded to determine possible wind effects on drogue movement. To determine any seasonal variations, this procedure was done in July 1977 and January 1978.

RESULTS AND DISCUSSION

TOMIL HARBOR

Current determinations for 9 July 1977 at Stations A and B (Fig. 1) show definite tidal influence. This is in agreement with Austin, Smith and Associates (1967) and Lyon Associates, Inc. (1975). During a flood tide the 1-meter and 5-meter drogues travelled in a northwest direction. A current reversal was apparent on the ebb tide with drogue movement to the south. Winds throughout these determinations were generally out of the southeast. Ten years of wind direction data indicate winds from the southeast occur 10 percent of the time in 1400 observations for the month of July (Lyon Associates, Inc., 1975).

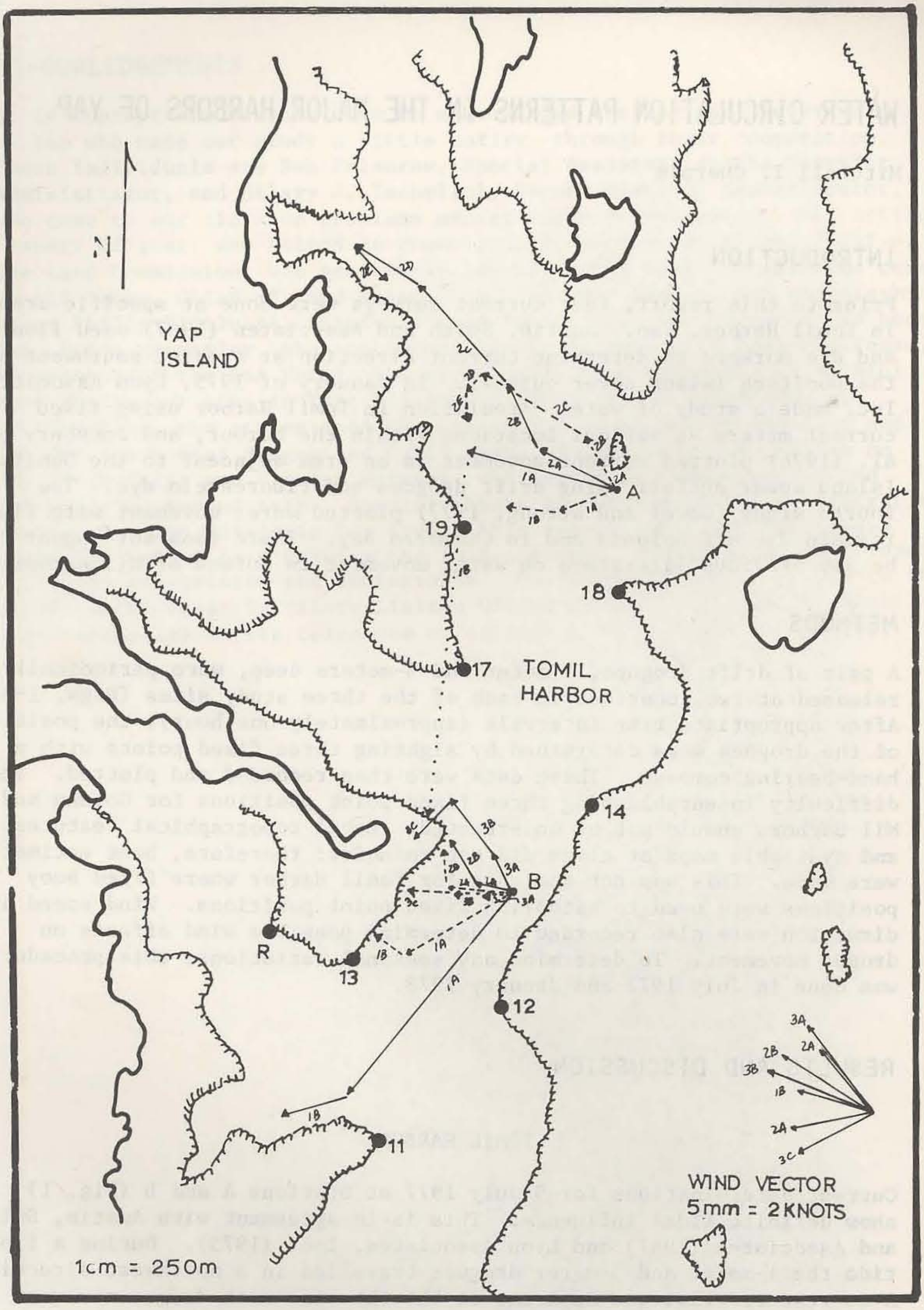

Fig.1. Drift patterns of 1-m and 5-m drogues in Tomil Harbor, 9 July 1978. Solid line represents 1-m drogue, dashed line represents 5-m drogue.

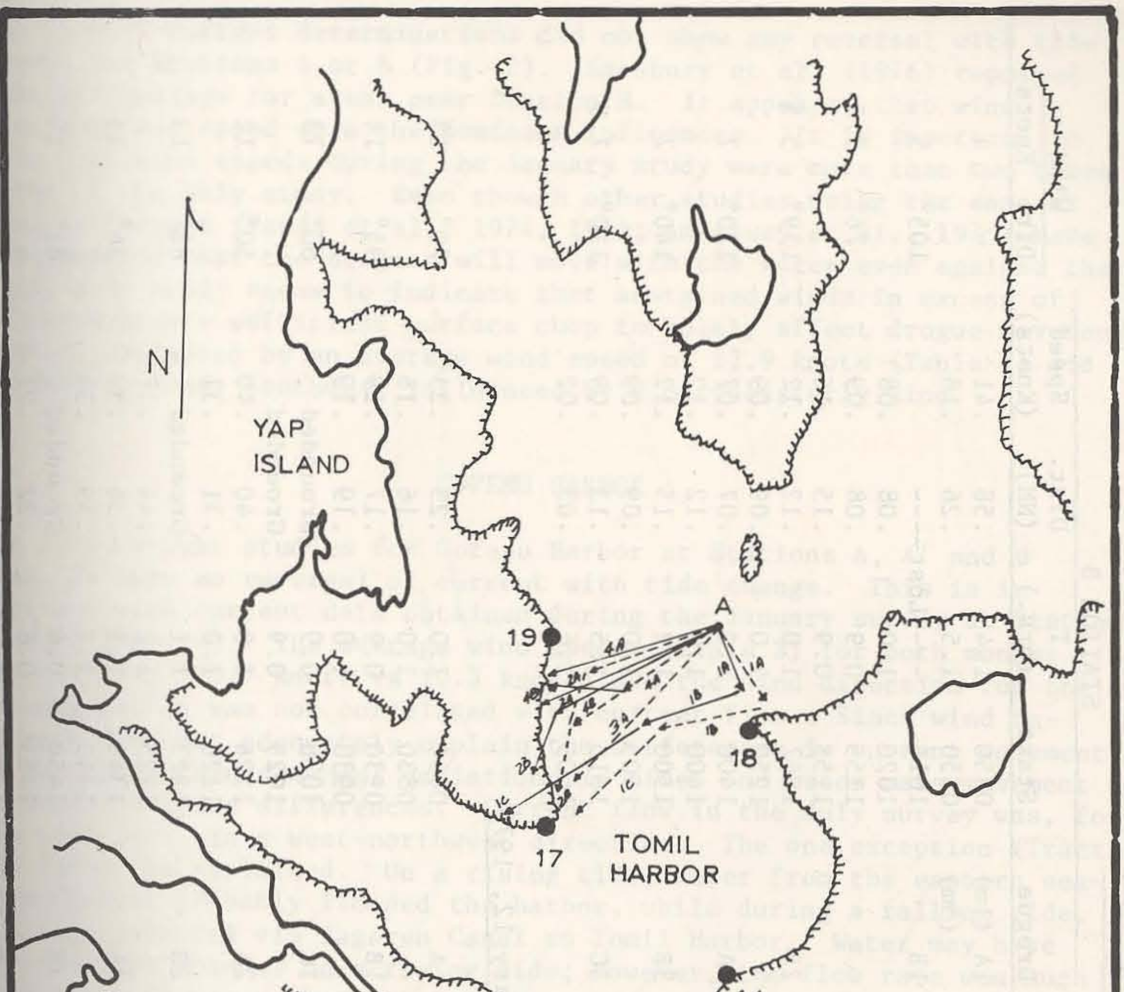

Fig. 2. Drift patterns of 1-m and 5-m drogues in Tomil Harbor, 12 January 1978. Solid line represents 1-m drogue, dashed line represents 5-m drogue.

Table 1. Distance and speed of 1-meter and 5-meter drift drogues, and direction and speed of wind, Tomil Harbor, Yap, July 9, 1977 and January 12, 1978.

STATION A					STATION B					Wind	
Drogue	Start	T (hrs.)	Dist. (NM)	Speed (Knots)	Drogue	Start	T (hrs.)	Dist. (NM)	Speed (Knots)	Dir.	Knots
					July 9, 1977						
1A (1m)	0905	1.6	.34	.21	1A (1m)	0850	1.4	.58	.41	-	4
(5m)	0905	1.6	.13	.08	(5m)	0850	1.5	.26	.18		
1B	1040	0.8	*	*	1B	1015	----Lost----			105°	5
	1043	0.9	.11	.12		1020	1.0	.08	.08		
2A	1140	0.9	.19	.21		1155	0.9	.08	.09	76°	5.5
	1140	1.0	.08	.08		1155	0.9	.15	.16		
2B	1233	1.1	.17	.15	2B	1247	1.0	.12	.12	139°	5.5
	1240	0.9	.05	.06		1250	1.0	.09	.09		
2C	1340	0.9	.28	.31	3A	1400	1.0	.07	.07	120°	7
	1335	1.2	.26	.22		1400	1.0	.12	.12		
2D	1436	1.1	.17	.15	3B	1500	1.2	.15	.12	140°	7
	1445	0.8	.07	.08		1505	1.0	.09	.09		
2E	1545	0.7	.11	.15	3C	1615	1.5	.13	.09	110°	7.5
	1535	----Lost----				1605	1.6	.03	.02		
*Moved by fisherman					**January 12, 1978**						
1A	0845	1.0	.12	.12	1A	0830	1.0	.23	.23	70°	13
	0845	1.0	.16	.16		0830	1.0	.16	.16		
1B	0945	0.9	.05	.06	1B	0930	0.9	.17	.19	95°	14
	0945	0.9	.20	.22		0930	1.0	.19	.19		
1C	1038	1.0	Grounded		1C	1026	0.9	Grounded		60°	13
	1038	1.0	.21	.21		1029	0.9	Grounded			
2A	1140	0.9	.32	.36	2A	1126	1.0	.40	.40	50°	12
	1140	0.9	.24	.27		1126	1.0	.31	.31		
2B	1235	1.3	Grounded		2B	1223	1.1	Grounded		62°	13
	1236	1.3	.23	.18		1225	1.2	.44	.37		
3A	1358	1.0	Grounded		3A	1343	1.1	.56	.52	36°	15
	1358	1.1	.39	.36		1343	1.2	.39	.33		
3B**	1503	0.1	Grounded		3B	1450	0.6	Grounded		81°	12
	1503	0.1	Grounded			1453	0.8	.22	.27		
4A	1512	0.9	.35	.39	4A	1555	1.1	.30	.27		
	1512	0.9	.17	.19		1555	1.2	.17	.15		
4B**	1606	1.1	.15	.13						64	11

The January current determinations did not show any reversal with tide change for Stations A or B (Fig. 2). Amesbury et al. (1976) reported similar findings for areas near Station B. It appeared that wind direction and speed were the dominant influences. It is important to note that wind speeds during the January study were more than two times those of the July study. Even though other studies using the same or similar drogues (Tsuda et al., 1974, 1975; Amesbury et al., 1975) have demonstrated that the drogues will move with the water even against the wind, this study seems to indicate that sustained winds in excess of 12 knots create sufficient surface chop to solely affect drogue movement. This is evidenced by an average wind speed of 12.9 knots (Table 1) and current movement southwest influenced by a northeasterly wind.

GOFENU HARBOR

The July current studies for Gofenu Harbor at Stations A, A' and B (Fig. 3) show no reversal of current with tide change. This is in contrast with current data obtained during the January survey at Stations A and B (Fig. 4). The average wind speeds (Table 2) for both months were similar (10.7 knots vs 10.3 knots) and the wind direction for the January survey was not correlated with current flow. Since wind influence does not adequately explain the differences in current movement, it is likely that seasonal variations in tides and water mass movement account for these differences. Current flow in the July survey was, for the most part, in a west-northwest direction. The one exception (Tract 2B) cannot be explained. On a rising tide, water from the eastern seaward channel probably flooded the harbor, while during a falling tide, drainage occurred via Tageren Canal to Tomil Harbor. Water may have entered this channel on a rising tide; however, the flow rate was much less than the water that entered the eastern seaward channel (Table 2).

Current determinations for January do show a flow reversal with tide change, especially at the head of the eastern seaward channel (Fig. 4). During the flood tide the drogues travelled west away from the channel; and with the onset of a falling tide the drogues travelled east toward the channel mouth. Current movement at Station A shows a similar effect with drogue movement toward the mouth of Tageren Canal on a falling tide. The southerly direction of flow at high tide (Tract 2A, Fig. 4) could be explained by wind influence since no net tidal movement was apparent. Further studies would need to be done to confirm this possible seasonal effect.

MIL HARBOR

The current surveys at Mil Harbor for 15 July 1977 appeared to be influenced by both tidal flow and wind direction and speed. Currents flowed north at Station A (Fig. 5) during a falling tide. It appeared that the water mass should have drained via the channel between Map and Rumung Islands to the northeast. However, a southeast wind with a mean speed of 10.4 knots (Table 3) prohibited the expected northeasterly flow. With the onset of high tide and consequently reduced rates of flow, the

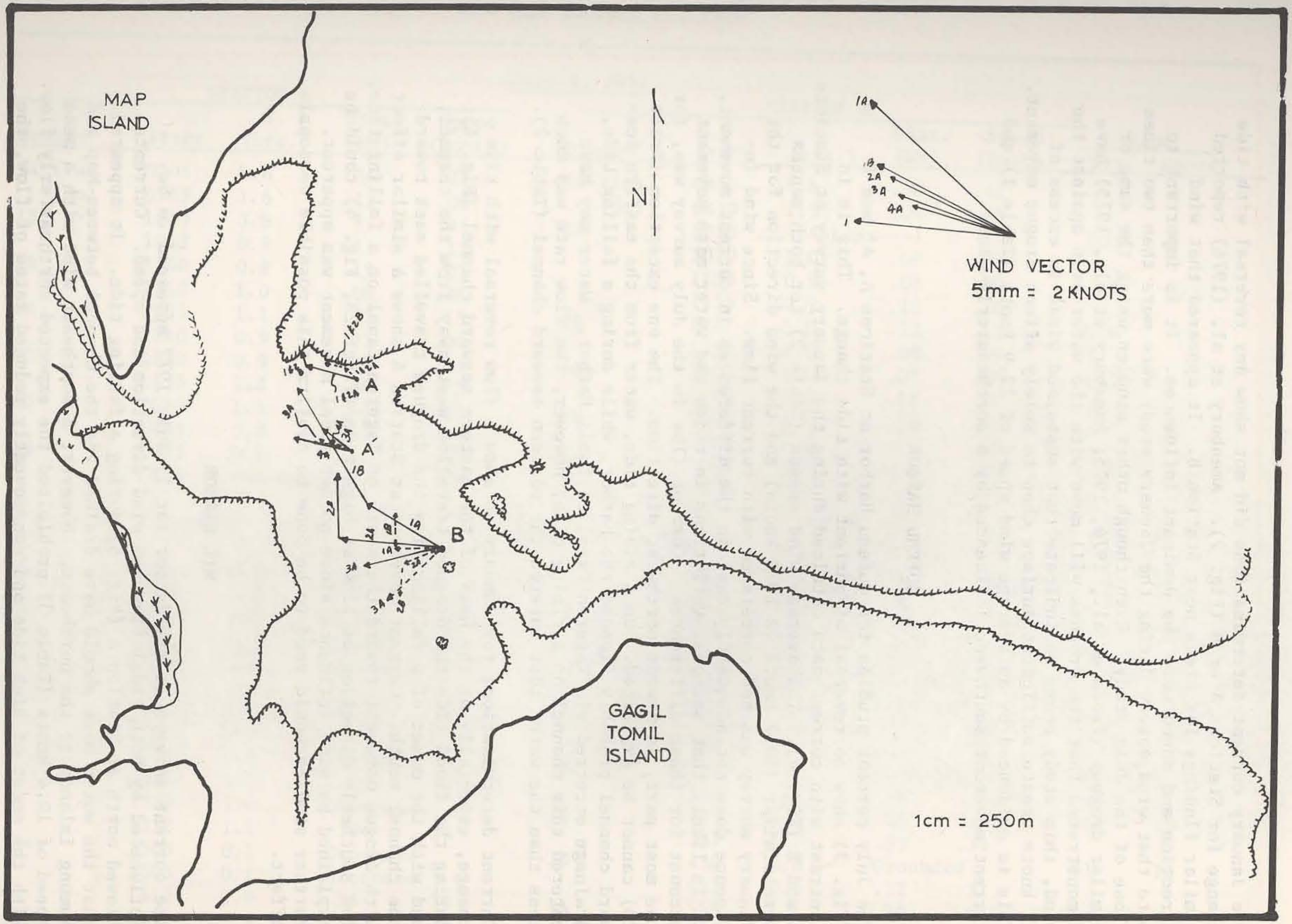

Fig. 3. Drift patterns of 1-m and 5-m drogues in Gofenu Harbor 14 July 1977. Solid line represents

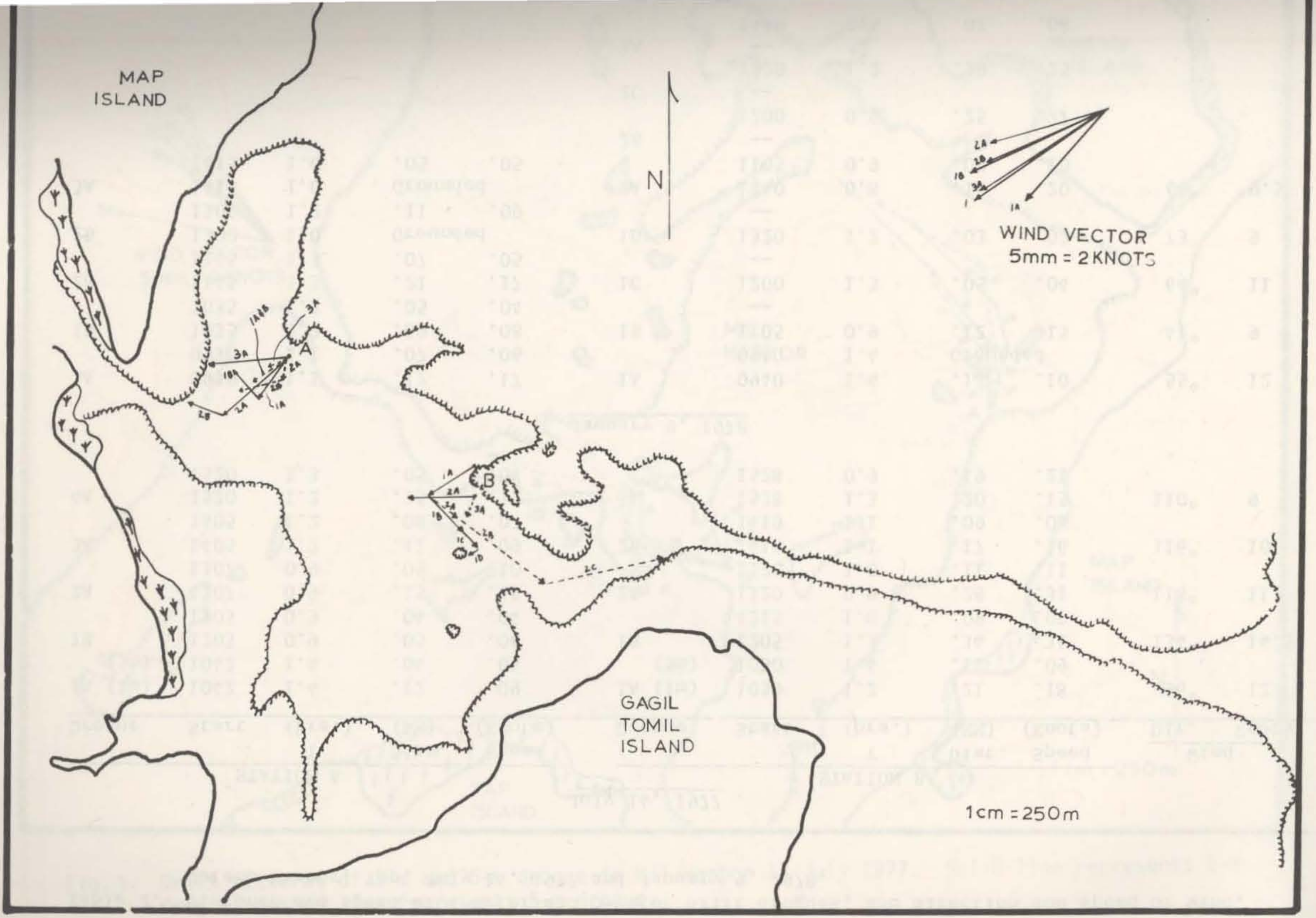

Fig. 4. Drift patterns of 1-m and 5-m drogues in Gofenu Harbor 9 January 1978. Solid line represents 1-m drogue, dashed line represents 5-m drogue.

Table 2. Distance and speed of 1-meter and 5-meter drift drogues, and direction and speed of wind, Gofenu Harbor, Yap, July 14, 1977 and January 9, 1978.

STATION A					STATION B					Wind	
Drogue	Start	T (hrs.)	Dist. (NM)	Speed (Knots)	Drogue	Start	T (hrs.)	Dist. (NM)	Speed (Knots)	Dir.	Knots
July 14, 1977											
1A (1m)	1042	1.4	.12	.09	1A (1m)	1050	1.2	.21	.18	96°	12
(5m)	1042	1.4	.04	.03	(5m)	1050	1.4	.12	.09		
1B	1203	0.9	.05	.06	1B	1205	1.1	.34	.31	134°	14.5
	1203	0.9	.04	.04		1215	1.0	.09	.09		
2A	1307	0.9	.15	.16	2A	1320	0.9	.28	.31	118°	11
	1307	0.9	.09	.10		1320	1.0	.11	.11		
3A	1405	1.2	.11	.09	2B	1416	1.1	.17	.16	116°	10
	1405	1.2	.08	.07		1419	1.1	.09	.08		
4A	1520	1.2	.15	.12	3A	1528	1.3	.20	.15	110°	9
	1520	1.3	.05	.04		1528	0.9	.19	.21		
January 9, 1978											
1A	0930	1.1	.12	.17	1A	0940	1.4	.13	.10	55°	12
	0930	1.1	.07	.06		0940	1.4	Grounded			
1B	1035	1.2	.09	.08	1B	1105	0.9	.12	.13	41°	9
	1035	1.2	.05	.04		--					
2A	1145	1.3	.21	.17	1C	1200	1.3	.05	.04	64°	11
	1145	1.3	.07	.05		--					
2B	1300	1.0	Grounded		1D	1320	1.2	.03	.02	73°	9
	1300	1.2	.11	.09		--					
3A	1415	1.0	Grounded		2A	1440	0.8	.16	.20	66°	9.5
	1415	1.0	.05	.05		1105	0.9	.09	.10		
					2B	--					
						1200	0.9	.25	.27		
					2C	--					
						1320	1.2	.30	.25		
					3A	--					
						1440	0.8	.07	.08		

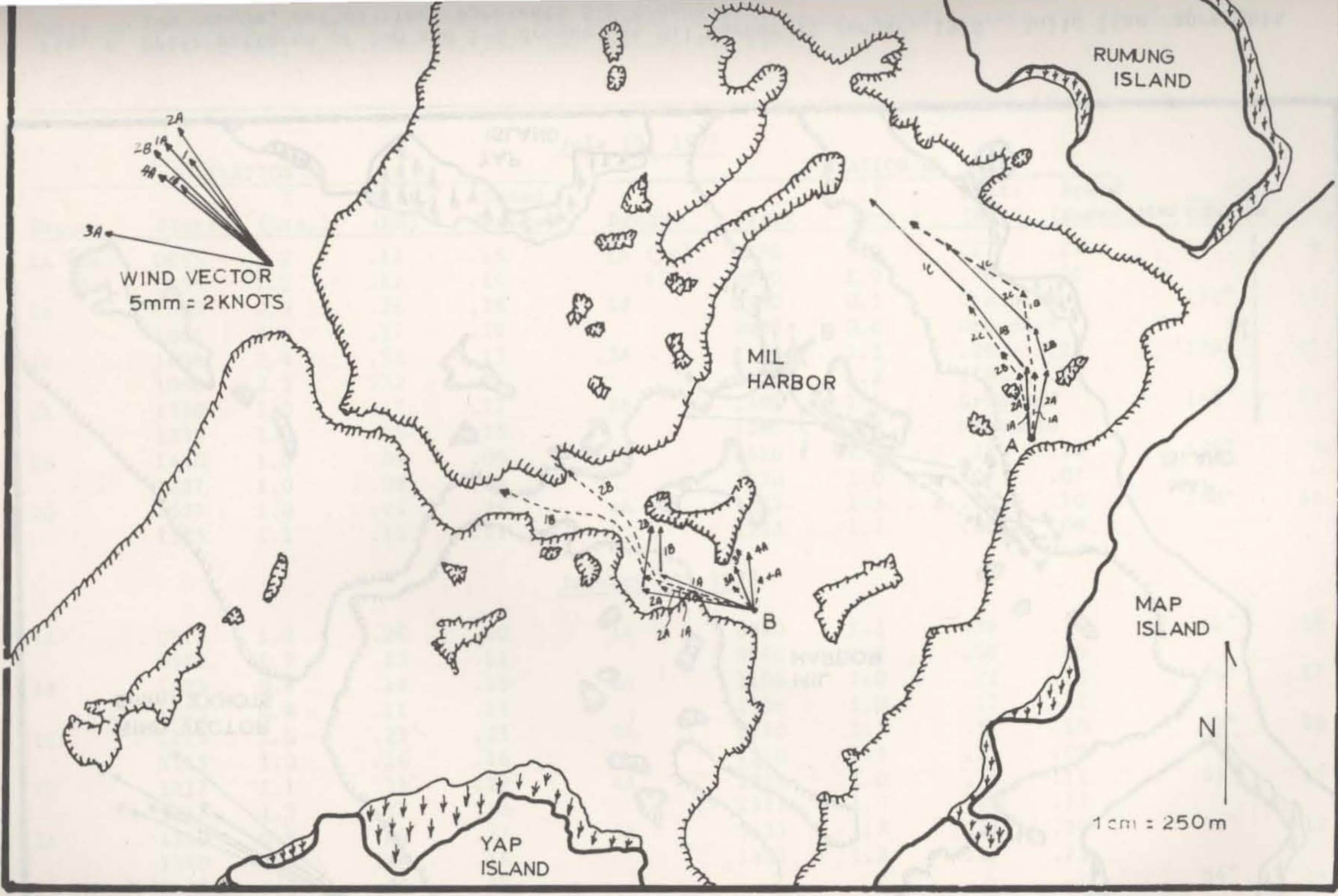

Fig. 5. Drift patterns of 1-m and 5-m drogue in Mil Harbor 15 July 1977. Solid line represents 1-m drogue, dashed line represents 5-m drogue.

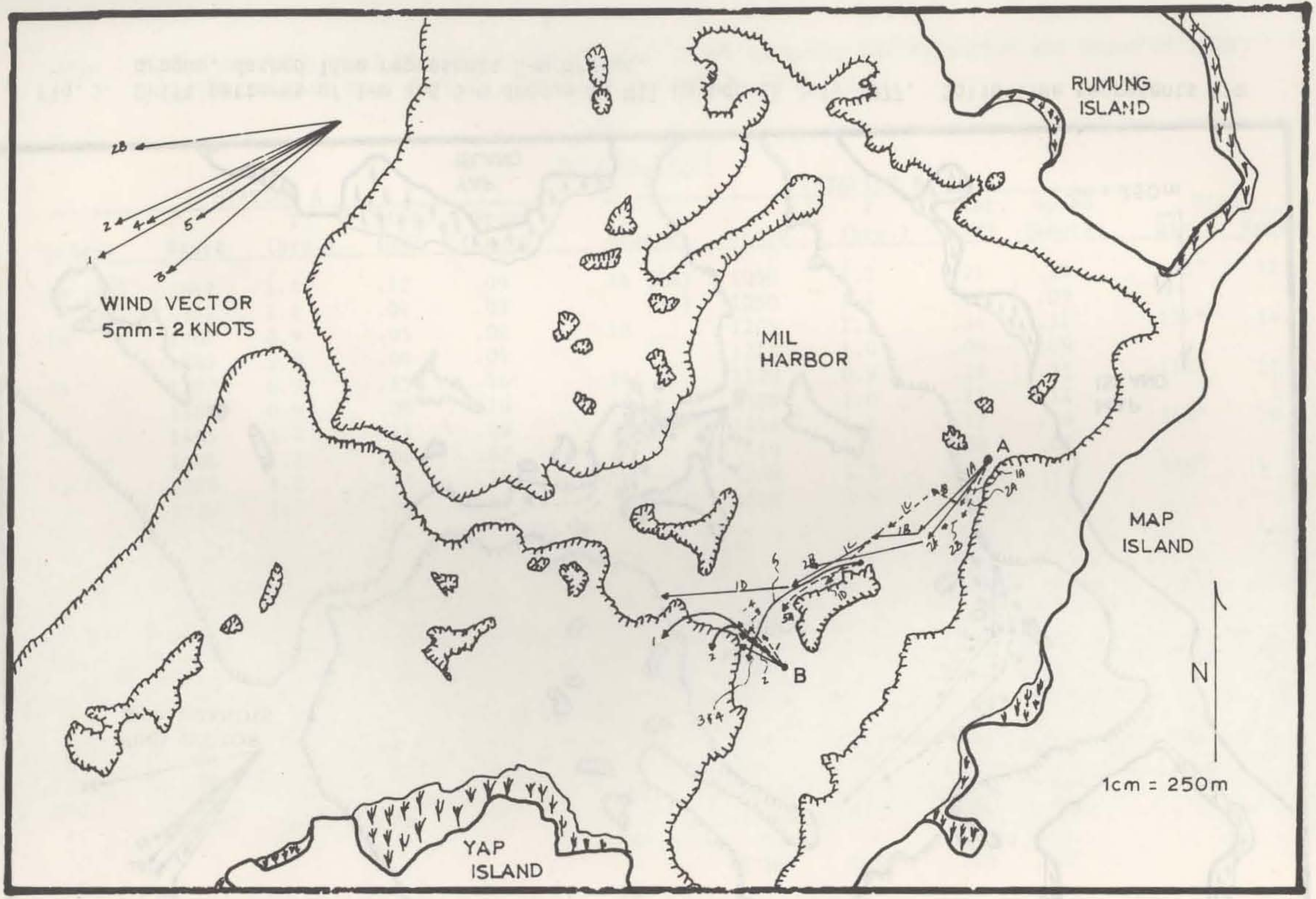

Fig. 6. Drift patterns of 1-m and 5-m drogues in Mil Harbor 11 January 1978. Solid line represents 1-m drogue, dashed line represents 5-m drogue.

Table 3. Distance and speed of 1-meter and 5-meter drift drogues, and direction and speed of wind, Mil Harbor, Yap, July 15, 1977 and January 11, 1978.

					July 15, 1977						
STATION A					STATION B					Wind	
Drogue	Start	T (hrs.)	Dist. (NM)	Speed (Knots)	Drogue	Start	T (hrs.)	Dist. (NM)	Speed (Knots)	Dir.	Knots
1A (1m)	0855	1.2	.17	.15	1A (1m)	0850	1.0	.23	.23	141°	9
(5m)	0855	1.2	.17	.15	(5m)	0850	1.0	.26	.26		
1B	1005	0.9	.26	.28	1B	0950	0.5	Grounded		132°	11
	1004	0.9	.17	.19		0953	0.8	Grounded			
1C	1058	2.4	.32	.13	2A	1150	1.2	.26	.21	138°	11
	1050	2.5	.32	.13		1150	1.2	.19	.16		
2A	1330	1.0	.17	.17	2B	1303	1.1	Grounded		145°	11
	1330	1.0	.15	.15		1305	1.2	Grounded			
2B	1430	1.0	.09	.09	3A	1420	1.0	.11	.11	129°	9.5
	1427	1.0	.08	.08		1420	1.0	.07	.07		
2C	1527	1.0	.29	.29	4A	1523	1.3	.13	.10	100°	11
	1525	1.1	.13	.12		1523	1.3	.08	.06		
					January 11, 1978						
1A	0915	1.2	.24	.20	1A	0940	1.3	.34	.26	61°	19
	0915	1.2	.13	.11		0940	1.3	.08	.06		
1B	1025	0.8	.12	.15	2A	1106	1.0	.22	.22	66°	17
	1025	0.8	.11	.13		1106	1.0	.12	.12		
1C	1115	1.0	.23	.23	3A	1210	1.1	.11	.10	49°	16
	1115	1.0	.16	.16		1210	1.2	.11	.09		
1D	1217	1.1	.31	.28	4A	1322	1.0	.11	.11	63°	15
	1217	1.3	.17	.13		1322	1.0	.13	.13		
2A	1340	0.9	.24	.27	5A	1433	1.2	.36	.30	56°	12
	1340	1.0	.16	.16		1433	1.2	.17	.15		
2B	1436	1.0	.28	.28						84°	14
	1440	0.9	.05	.06							

wind exerted the primary influence with current flow to the northwest. This same phenomenon occurred at Station B (Fig. 5). During a falling tide the drogues travelled westerly toward the mouth of the seaward channel. However, on a rising tide a northerly shift occurred. Again, complete reversal with change in tide did not occur because the wind had sufficient force to prevent such a reversal.

Current studies for 11 January 1978 show a distinct wind effect. Current direction was west-southwest (Fig. 6) regardless of tide movement. The winds throughout these determinations averaged 15.5 knots (Table 3) and were from the northeast. These data further substantiate that wind speeds in excess of 12 knots were responsible for drogue movement during this study.

Observations by Glude (1972) indicate that current movement in Tageren Canal is to the south on both flood and ebb tides. Since this canal connects Gofenu and Mil Harbors with Tomil Harbor, current movements for the two former embayments should have showed this southerly flow throughout the survey. Stations A and B in Gofenu Harbor during the July 1977 determinations did show this trend; however, the January observations for Gofenu Harbor and the July and January observations for Mil Harbor are in disagreement with Glude's findings.

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SEAGRASS ASSEMBLAGES OF YAP, MICRONESIA*

R. Logan Kock and Roy T. Tsuda

INTRODUCTION

The literature is deplete and sorely in need of information on seagrass assemblages which are still in the process of active succession. Studies such as Molinier and Picard (1951), Aleem (1955), and Molinier and Zevaco (1962) are extrapolations made on seagrass assemblages in older coastal ecosystems which den Hartog (1973) warns us against. In these systems, the seagrasses already occupy all the niches which are available under existing ecological conditions. On the other hand, the assemblages of seagrasses in Micronesia are in various stages of development as seen by the diminuation in species diversity (Tsuda et al., 1977), as one moves from the western islands of Palau to the eastern islands of the Marshalls (Fig. 1). One example of a developing seagrass assemblage can be seen on the reef flats of Yap.

In this paper, the distribution of seagrasses on Yap is presented, and the relationship of this assemblage to the recruitment sequence of the different species is discussed.

METHODS

The reef flats of Yap excluding the lagoonal holes and inner channels, were surveyed during July 9-22, 1977. A 12-foot Zodiac raft equipped with a 20 horsepower outboard engine was used to tow two individuals along oblique lines between the shore and barrier reef margin. During low tides, observations in the shallow inshore areas were made by snorkeling or wading. In many instances, it was necessary to tow or wade along a line parallel to shore in order to observe further variations of the seagrass assemblages.

RESULTS

There are seven species of seagrasses reported for Yap (Tsuda et al., 1977). The most frequently encountered species is Thalassia hemprichii (Ehrenb.) Aschers. This species is followed according to abundance by Enhalus acoroides (L.f) Rich., Cymodocea rotundata Ehrenb. & Hempr., Syringodium isoetifolium (Archers.) Dandy, and Halophila ovalis (R. Br.)

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*We acknowledge Professor C. den Hartog's constructive criticisms and suggestions in the final version of this paper which has been accepted for publication in the journal AQUATIC BOTANY.

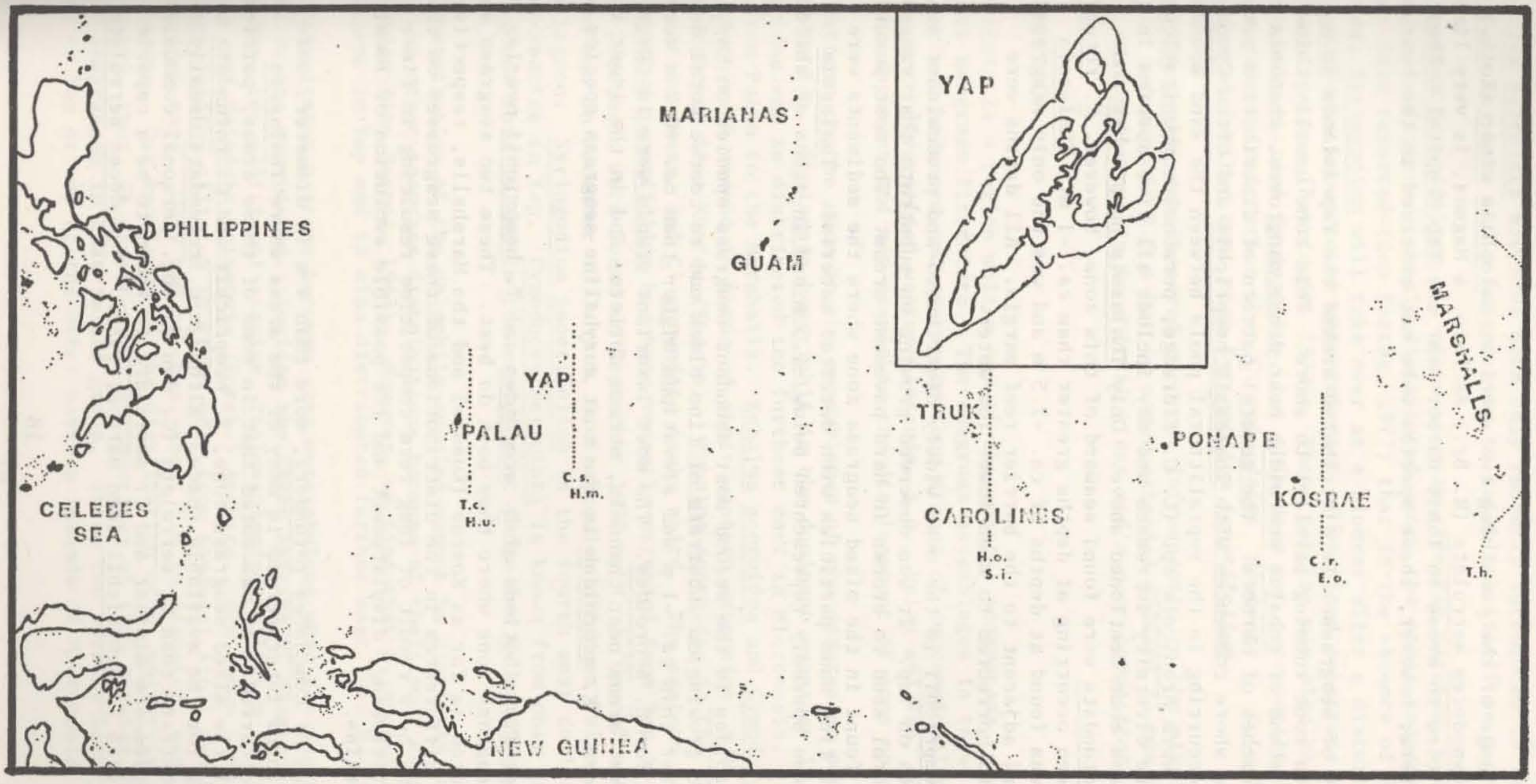

Fig. 1. Map of Micronesia showing eastern range of the nine seagrass species known from Micronesia. The island of Yap is shown as insert. [C. r. = <u>Cymodocea</u> <u>rotundata</u>, C. s. = <u>Cymodocea</u> <u>serrulata</u>, E. a. = <u>Enhalus</u> <u>acoroides</u>, H. u. = <u>Halodule</u> <u>uninervis</u>, H. m. = <u>Halophila</u> <u>minor</u>, H. o. = <u>Halophila</u> <u>ovalis</u>, S. i. = <u>Syringodium</u> <u>isoetifolium</u> T. h. = <u>Thalassia</u> <u>hemprichii</u>, T. c. = <u>Thalassodendron</u> <u>ciliatum</u>.]

Hook. The range of the remaining two species, Halophila minor (Zoll.) den Hartog and Cymodocea serrulata (R. Br.) Aschers. & Magnus, is very limited, being restricted to areas in Tomil Harbor near the Yap Hospital. They may occur elsewhere; however, these species were not observed in the course of this study.

The majority of seagrasses is distributed around the Yap islands in a mixed species zone running parallel to shore. This zone usually thins to a monotypic stand of Enhalus acoroides near dense mangroves, channels or the inner reaches of harbors. The general pattern of distribution perpendicular from shore commences with Thalassia hemprichii and often Cymodocea rotundata, occurring in the supralittoral pools between the sand mounds made by the worm Arenicola sp. (L. G. Eldredge, personal communication). Offshore, the diversity increases and may include all five species in the mixed seagrass zone mentioned above. Only Thalassia hemprichii and Cymodocea rotundata were found seaward of this zone, however, C. rotundata was never seen occurring at depths greater than ca. -1 m. Thalassia hemprichii was found at depths of ca. -2.5 m and was the only seagrass species found adjacent to the barrier reef margin. All depths were estimated and corrected to mean lower low water.

Thalassia hemprichii is the most widely distributed and predominant seagrass species on Yap. It was observed growing on substrata that ranged from fine coral sand to cracks in hard pavement areas. The most luxuriant stands were found in the mixed seagrass zone where the sediments were comprised of fine sand particles with detrital material. Thalassia hemprichii was sparsely represented below -1.5 m and in areas of shifting sand.

Enhalus acoroides is the second most abundant seagrass species on Yap. It was found growing on substrata of fine black mud to coarse coral debris. Depths greater than ca. -1 m and elevations higher than ca. +0.2 m were unfavorable for E. acoroides. The most luxuriant stands were in the mixed seagrass zone, areas near channels, stream outlets, and in the inner reaches of the harbors. E. acoroides is the most euryhaline seagrass species on Yap.

The reef flat distributions of E. acoroides and T. hemprichii overlap in the mixed seagrass zone where they both do best. These two seagrass species are distributed as far as Kosrae (Kusaie) and the Marshalls, respectively. Some of the differences in the distributions of these seagrasses on the reef flat may be a result of long term competition resulting in finer habitat partitioning, displacement and the possible evolution of local seagrass strains.

Large patches of Cymodocea rotundata, more than 4 m in diameter, were frequently found interspersed in many of the areas where Thalassia hemprichii occurred. It was noted that in some of these areas, particularly shoreward of the mixed seagrass zone, T. hemprichii and C. rotundata might be competing for the available space. Although C. rotundata usually occurs on finer substrata than C. serrulata (C. den Hartog, personal communication), their ecologies are similar and C. serrulata is known to be a capable competitor with T. hemprichii (den Hartog, 1970). Cymodocea serrulata is rare on Yap and does not occur as far east in Micronesia as C. rotundata. Cymodocea serrulata may have been only recently introduced to Yap and C. rotundata may have had a longer time to establish itself as a competitor.

Syringodium isoetifolium was often seen as circular patches, usually less than 2 m in diameter, evenly distributed among the other seagrass species. It has been reported (den Hartog, 1977) that in the absence of Halodule species, Syringodium will take over as a pioneer after a disturbance. Syringodium is known to be more tolerant of oxidized substrata than some seagrass species (Patriquin, 1972). These patches may also be a result of recently settled Syringodium, but this does not necessarily indicate a more recent immigration than C. rotundata. However, C. rotundata is distributed further east than Syringodium isoetifolium.

Halophila ovalis was observed to occur infrequently in the mixed seagrass zone to a depth of -2.5 m but it never extended seaward to the barrier reef. Halophila ovalis is a frail plant and a poor competitor.

DISCUSSION

Micronesia is a region unlike any of the coastal ecosystems referred to in past seagrass literature. The seagrass assemblages in these islands are not yet balanced and are in various stages of successional patterns. In the more diversified western islands, i.e., Palau and Yap, competition is more apparent and may result in the displacement of some species.

The pattern can be seen in the assemblages of the seagrasses presently found in Yap. Thalassia hemprichii is the dominant seagrass in Yap at this time and is distributed the furthest east in Micronesia, i.e., ranging from Palau to the Marshalls. Enhalus acoroides and Cymodocea rotundata rank second in terms of their eastern extension, i.e., they are both reported from Kosrae (Kusaie). Enhalus acoroides is the second most dominant seagrass, and C. rotundata ranks third. The eastern range of Syringodium isoetifolium has been recently extended from Yap to Truk where specimens were found in September 1977 by M. J. Gawell off Udot Island and in December 1977 by J. O. Stojkovich off Moen Island in the Truk Lagoon. Syringodium isoetifolium is the fourth most dominant seagrass species in Yap. Cymodocea serrulata is known from only one site in Yap and this island is the easternmost range for C. serrulata.

The distribution of the Halophila species cannot be similarly compared with the other seagrass distributions because of their poor competitive abilities (den Hartog, 1967). However, we find that H. ovalis is more prevalent in Yap and is also distributed further east than H. minor.

The recruitment pattern becomes even more obvious when the seagrasses of Palau are considered. Besides the seven species of seagrasses known from Yap, two additional species, Thalassodendron ciliatum (Forsk.) den Hartog and Halodule uninervis (Forsk.) Aschers., are known from Palau. Thalassodendron ciliatum is known only from Kayangel Atoll and must be considered rare. Only two patches, about 2 m in diameter, were found in the lagoon. Our knowledge of the distribution of H. uninervis in Palau is scanty, thus, we cannot offer a comparison of this species with the other seagrasses in that island group. These two species have yet to be found on Yap or any of the other eastern islands of Micronesia.

Thus, recruitment seems to have set the framework for the competition and succession which in turn has determined the present seagrass assemblage of Yap. Finer habitat partitioning would be expected in areas of greater diversity. Comparative studies of this community with future studies on other Micronesian islands will be useful in realizing the ecological capacities of seagrass species and the true nature of the dynamics of seagrass recruitment and succession.

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OBSERVATIONS ON FRUITING AND GERMINATION OF ENHALUS ACOROIDES AND CYMODOCEA ROTUNDATA IN YAP

R. Logan Kock

INTRODUCTION

The eastern distributional limits of the nine seagrasses recorded for Micronesia (Tsuda et al., 1977) are closely correlated with their individual position of dominance on Yap (Kock and Tsuda, In Press). This implies that some species, e.g., Enhalus acoroides (L.f) Rich. and Cymodocea rotundata Ehrenb. & Hemp. which are distributed as far east as Kosrae, possess propagules which have bridged the islands faster than most of the other seagrass species.

Several dispersal mechanisms are available to seagrasses, e.g., fruits, seeds, seedling fragments and detached mature plants. The success of any of these mechanisms varies with the species. For example, Cymodocea rotundata flowers rarely (den Hartog, 1970) and probably relys more on detached plants as a dispersal mechanism. On the other hand, Enhalus acoroides flowers frequently and the seeds may be the major means of dispersal.

Since the literature lacks recorded observations of the localized fruiting behavior and germination of Micronesian seagrasses, the observations recorded on Yap and laboratory studies undertaken at the University of Guam Marine Laboratory on two species of seagrasses, Enhalus acoroides and Cymodocea rotundata, are presented.

METHODS

The observations on the fruiting behavior and germination of Enhalus acoroides and the seedlings of Cymodocea rotundata were made during a general reef survey of the Yap Lagoon on July 9-22, 1977.

Enhalus acoroides seeds and Cymodocea rotundata seedlings were collected in the field and laid between layers of damp cheese cloth, then transported to Guam in a tupperware container. Fruiting Enhalus acoroides were transported damp in a styrofoam box. Some of the E. acoroides seeds, the C. rotundata seedlings and the fruiting E. acoroides were planted within 72 hrs. of collection in a wooden holding tank (144 x 84 x 13 cm) filled with sand (8 cm deep). The remaining E. acoroides seeds were kept in a plastic (79 x 58 x 50 cm) tank without sand for two months and a half. Both holding tanks were provided with flow-through seawater.

RESULTS AND DISCUSSION

Enhalus acoroides

The seven sites where Enhalus acoroides were observed fruiting are shown in Fig. 1. At each of the sites, fruiting occurred in unison over a rather large area, however, fruiting plants were sparse in the channel area between Rumung and Map (Fig. 1, Site 6).

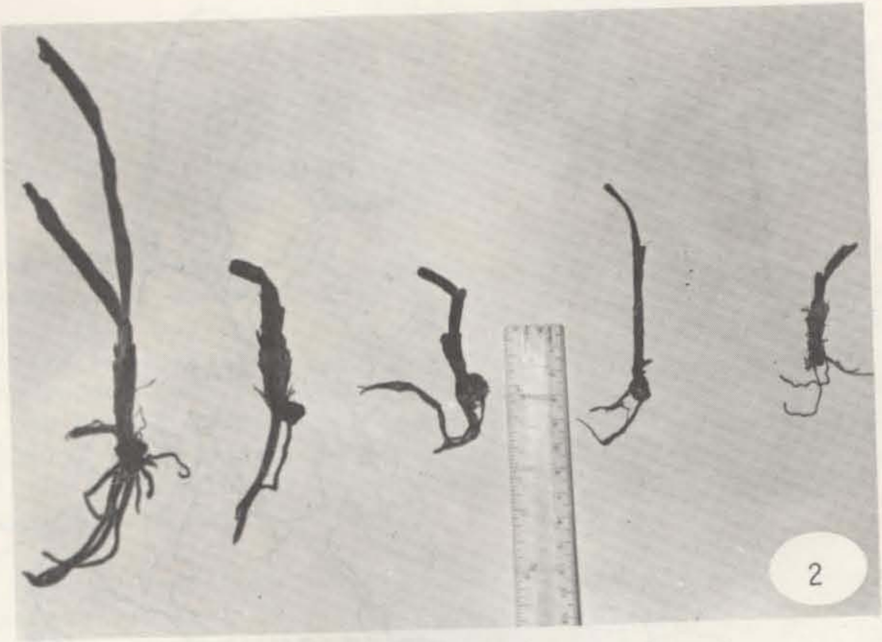
It has been suggested that Enhalus acoroides fruits year round (den Hartog, 1970). Several of our observations suggest that fruiting has been continuous for at least five months on Yap. Female fruits in all stages of development were observed in July 1977. The immature fruits of two Enhalus plants growing in the wooden tank took approximately nine weeks to mature and release seeds in the normal fashion reported previously by Cunningham (1912) and Troll (1931). Since pods were observed releasing seeds on Yap, it would seem that the maturation of the fruits was initiated nine weeks prior to our observations in July.

Eighteen Enhalus seedlings were observed on a 4 m^2 sand scar within the mixed seagrass bed east of Tomil Channel (Fig. 1, Site 2). The size distribution of these seedlings is shown in Fig. 2. In order to obtain some information on the age of the seedlings, seeds were germinated in tanks. It took approximately 10 weeks for these seedlings to reach a length of 4.5 cm, the midrange in Fig. 2. Thus, some of the seeds were released at least 10 weeks previous to our observations on Yap. If it takes a fruit (Fig. 3) nine weeks to mature, fruiting on Yap must have been continuous for no less than 19 weeks or nearly five months. Immature fruits were also observed, so fruiting continued for nine additional weeks beyond July. No fruiting was observed six months later (January 1978) near Bi Island in Tomil Harbor, a site where extensive fruiting was observed in July 1977 (R. T. Tsuda, personal communication). During the same month, however, fruiting was observed in Truk Lagoon (R. N. Clayshulte, personal communication).

Observations on seed release and germination were also observed in the laboratory. The walls of the fruit split and curl back, and the fruit resembles a flower (Fig. 4). The seeds have a thin membrane with air space that enables the seed to float free of its pod and sister seeds. The membrane is quickly lost allowing the seed to sink. Fine root hairs appear over the basal surface of the seeds within 24 hours. The hairs bind sediments until they anchor in an upright position (Fig. 5). Within a week, a central primordial root begins to appear. The leaf shoots are approximately 1 cm long at this point. One to two weeks later, a secondary root begins to grow just below the cotyledons (Fig. 6).

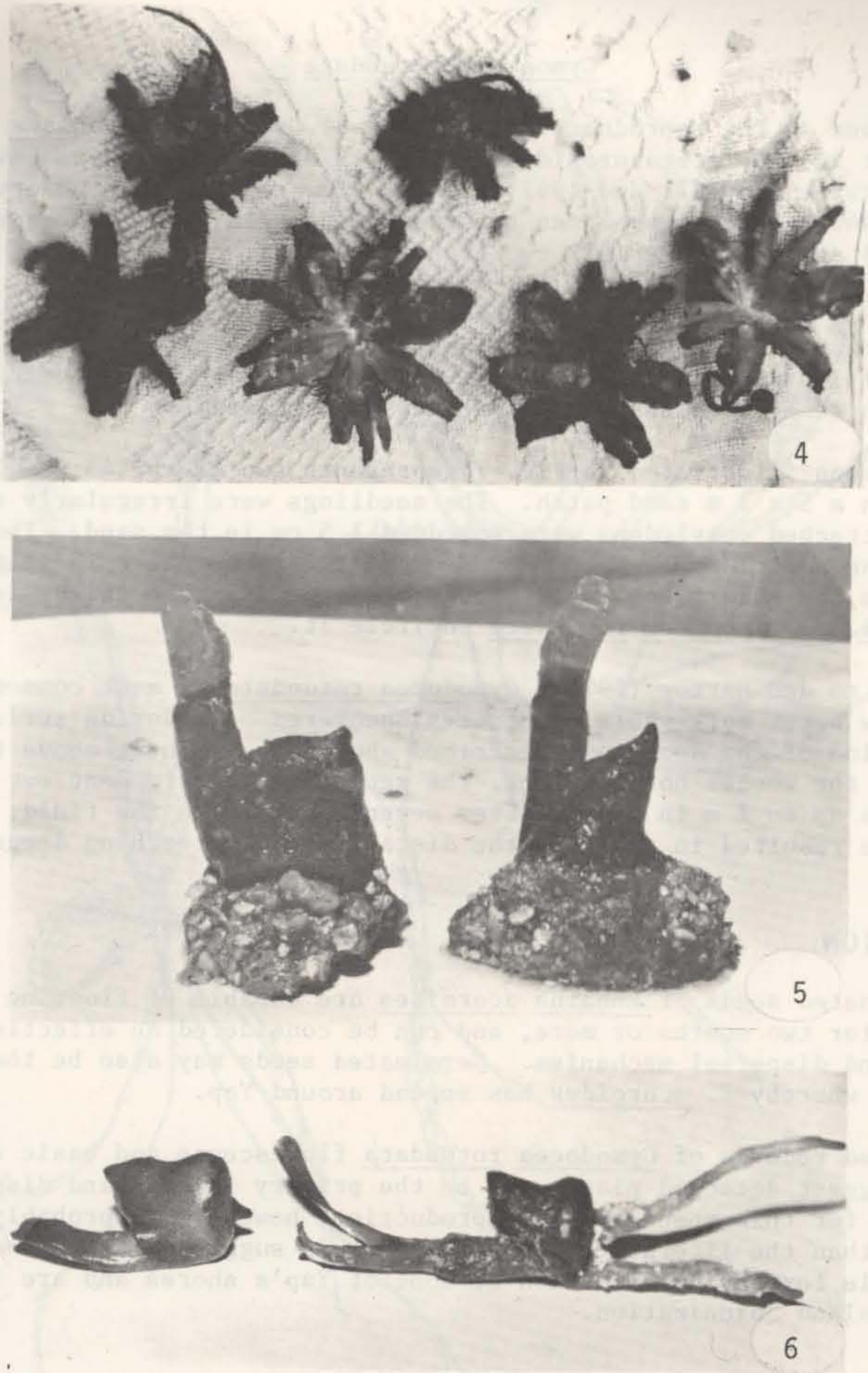
The seeds not planted in sand also germinated. After a period of a few weeks, the seedlings became bouyant due apparently to the accumulation of metabolic gases in the lacunal system of the leaves. These seedlings developed slower than the seedlings planted in sand. The roots grew in a twisted manner. These seedlings, however, appeared healthy even after floating for two months in the tank.

Fig. 1. Map of Yap showing locations of the seven fruiting sites of Enhalus acoroides (1-7) and the two sites (A and B) where seedlings of Cymodocea rotundata were found.



Figs. 2 and 3

Fig. 2. Seedlings of <u>Enhalus</u> <u>acoroides</u>.
Fig. 3. Fruits of <u>Enhalus</u> <u>acoroides</u>.



Figs. 4-6

Fig. 4. Fruits of Enhalus acoroides after release of seeds.
Fig. 5. Germinating seedlings of Enhalus acoroides, 48 hours old, grown in outdoor tank.
Fig. 6. Seedlings of Enhalus acoroides, one week (left) and three weeks (right) old, grown in outdoor tank.

Cymodocea rotundata

Observations on the reproductive processes of Cymodocea rotundata are infrequent in the literature (den Hartog, 1970). Male flowers have been observed twice (in 1871 and 1967); female flowers have been observed only once in 1967. Fruits have been recorded twice - in 1872 by Beccari in New Guinea and again in June 1929 by Setchell in Bali.

Seedlings of C. rotundata were found in two areas - just south of Thilimad Island northeast of Map and at the southeastern tip of Yap Island between Magachaquill and Gorror (see Fig. 1, Sites A and B). The seedlings in both areas were found on high intertidal sand plateaus.

The specimens illustrated in Fig. 7 represents two of the 45 seedlings present in a 5 x 3 m sand patch. The seedlings were irregularly arranged and the attached cotyledons were embedded 1.5 cm in the sand. The roots extended an additional 3-4 cm. These seedlings were the only seagrass growing on the sand patch, even though a sparse stand of Thalassia hemprichii and Cymodocea rotundata encircle it.

According to den Hartog (1970), Cymodocea rotundata is most common at the lowest low water mark where it becomes uncovered only during spring ebbs. The position of the seedlings described above was slightly above this mark. In the wooden holding tank, the seedlings quickly sent out runners which were up to 1 m in length after seven months. In the field, this would have resulted in at least the distal portions reaching deeper water.

CONCLUSION

The germinated seeds of Enhalus acoroides are capable of floating and maturing for two months or more, and can be considered an effective interisland dispersal mechanism. Germinated seeds may also be the mechanism whereby E. acoroides has spread around Yap.

The limited records of Cymodocea rotundata florescence and basic seed design suggest detached plants may be the primary interisland dispersal mechanism for this species. Seed production, however, is probably more frequent than the literature indicates. It is suggested that seeds are responsible for the colonization of some of Yap's shores and are important in intraisland colonization.

ACKNOWLEDGEMENTS

Acknowledgements are extended to Leonor Lange-Moore for illustrating the seedlings of Cymodocea rotundata, David Gardner for photographing the seagrasses and seeds, and Roy T. Tsuda for his help in arranging the manuscript.

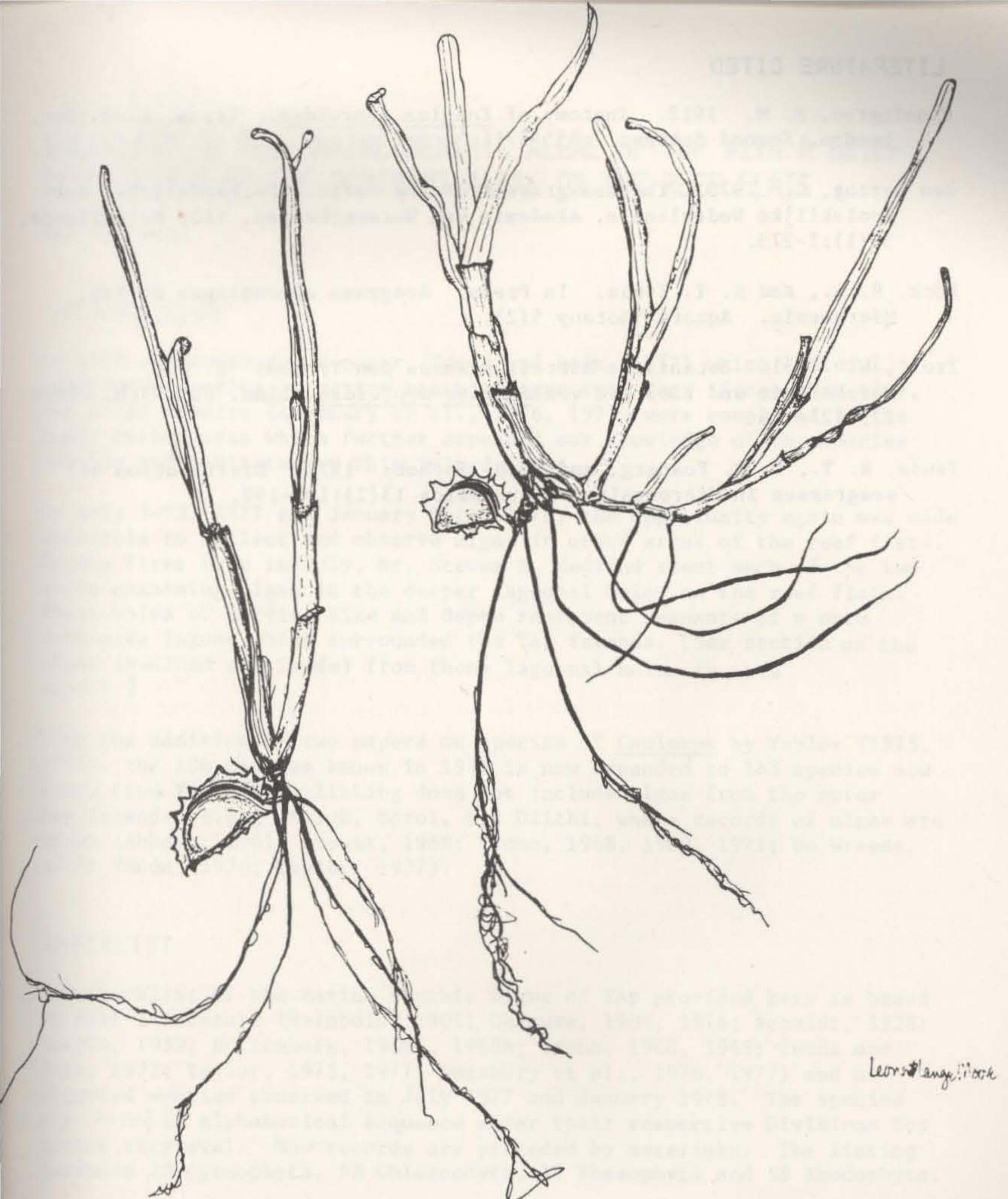


Fig. 7. Seedlings of Cymodocea rotundata.

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CHECKLIST OF THE MARINE BENTHIC ALGAE OF YAP WITH A BRIEF DESCRIPTION OF THE DOMINANT ALGAE ON THE REEF FLATS

Roy T. Tsuda

INTRODUCTION

In 1972, I coauthored a paper (Tsuda and Belk, 1972) which listed 23 additional species of marine benthic algae from Yap. Since that time, two other studies (Amesbury et al., 1976, 1977) were completed in the Tomil Harbor area which further expanded our knowledge of the species complex and habitats for this island group.

On July 9-22, 1977 and January 7-14, 1978, the opportunity again was made available to collect and observe algae in other areas of the reef flats. On the first trip in July, Mr. Steven E. Hedlund spent much of the two weeks examining algae in the deeper lagoonal holes on the reef flats. These holes of varying size and depth represent remnants of a once extensive lagoon which surrounded the Yap islands. [See section on the algae (Hedlund and Tsuda) from these lagoonal holes in this report.]

With the addition of two papers on species of Caulerpa by Taylor (1975, 1977), the 106 species known in 1972 is now expanded to 143 species now known from Yap. This listing does not include algae from the outer Yap Islands, e.g., Ifaluk, Sorol, and Ulithi, where records of algae are known (Abbott, 1961; Drouet, 1968; Trono, 1968, 1969, 1971; De Wreede, 1973; Tsuda, 1976; Taylor, 1977).

CHECKLIST

The checklist of the marine benthic algae of Yap provided here is based on past literature (Reinbold, 1901; Okamura, 1904, 1916; Schmidt, 1928; Tokida, 1939; Hollenberg, 1968a, 1968b; Trono, 1968, 1969; Tsuda and Belk, 1972; Taylor, 1975, 1977; Amesbury et al., 1976, 1977) and unreported species observed in July 1977 and January 1978. The species are listed in alphabetical sequence under their respective Divisions for easier retrieval. New records are preceded by asterisks. The listing includes 10 Cyanophyta, 58 Chlorophyta, 17 Phaeophyta and 58 Rhodophyta.

Division CYANOPHYTA (blue-green algae)

Brachytrichia quoyi (C. Ag.) B. & Fl.
Calothrix confervicola Ag.
Calothrix crustacea Schousboe & Thuret
Calothrix pilosa Harv.
Dichothrix penicillata Zanard.
Hormothamnion enteromorphoides B. & Fl.
Microcoleus lyngbyaceus (Kutz.) Crouan

Schizothrix calcicola (Ag.) Gomont
Schizothrix mexicana Gomont
Spirulina subsalsa Oersted

Division CHLOROPHYTA (green algae)

Anadyomene wrightii Gray
Avrainvillea lacerata Harvey
Avrainvillea obscura J. Ag.
Avrainvillea papuana (Zanard.) Murray
*Boergesenia forbesii (Harv.) Feldmann
Boodlea coacta (Dickie) Murray & de Toni
Boodlea composita (Harv.) Brand
Boodlea siamensis Reinbold
Boodlea vanbosseae Reinbold
Bornetella sphaerica (Zanard.) Solms-Laubach
Bryopsis pennata Lamx.
Caulerpa antoensis Yamada
Caulerpa brachypus Harv.
Caulerpa cupressoides (West) C. Ag.
Caulerpa elongata W. v. Bosse
Caulerpa filicoides Yamada
Caulerpa freycinetti Ag.
Caulerpa lentillifera J. Ag.
Caulerpa mexicana (Sond.) J. Ag.
Caulerpa peltata Lamx.
Caulerpa pickeringii Harvey & Bailey
Caulerpa racemosa (Forsk.) J. Ag.
Caulerpa serrulata (Forsk.) J. Ag.
Caulerpa sertularioides (Gmel.) Howe
Caulerpa taxifolia (Vahl) C. Ag.
Caulerpa urvilliana Montagne
Caulerpa verticillata J. Ag.
Caulerpa webbiana Montagne
Chaetomorpha crassa (C. Ag.) Kütz.
Chaetomorpha linum (Dan) Kg.
*Chlorodesmis fastigiata (C. Ag.) Ducker
Chlorodesmis hildebrandtii A. & E. S. Gepp
Codium geppii O. C. Schmidt
Dictyosphaeria cavernosa (Forsk.) Boerg.
Dictyosphaeria versluysii W. v. Bosse
*Enteromorpha clathrata (Roth) J. Ag.
Enteromorpha kylinii Bliding
Halimeda cuneata Hering
Halimeda discoidea Decaisne
Halimeda gigas Taylor
Halimeda incrassata (Ellis) Lamx.
Halimeda macroloba Decaisne
Halimeda macrophysa Askenasy
Halimeda opuntia (L.) Lamx.
Halimeda simulans Howe
Halimeda tuna (E. & S.) Lamx.
Microdictyon pseudohaptera A. & E. S. Gepp

Neomeris annulata Dickie
Neomeris dumetosa Lamx.
Neomeris vanbosseae Howe
Rhipilia orientalis A. & E. S. Gepp
Struvea delicatula Kütz.
Struvea tenuis Zanard.
Tydemannia expeditionis W. v. Bosse
*Ulva lactuca L.
*Valonia aegagropila C. Ag.
*Valonia fastigiata Harvey
Valonia ventricosa J. Ag.

Division PHAEOPHYTA (brown algae)

Colpomenia sinuosa (Roth) Derbes & Solier
Dictyota apiculata J. Ag.
*Dictyota bartayresii Lamx.
Dictyota cervicornis Kütz.
Dictyota divaricata Lamx.
Dictyota friabilis Setchell
Feldmannia indica (Sonder) Womersley & Bailey
Hydroclathrus clathratus (Bory) Howe
Lobophora variegata (Lamx.) Womersley
Padina minor Yamada
Padina pavonia (L.) Gaill.
Padina tenuis Bory
Rosenvingea intricata (J. Ag.) Boerg.
Sargassum cristaefolium C. Ag.
*Sargassum polycystum C. Ag.
Sphacelaria tribuloides Meneghini
Turbinaria ornata (Turn.) J. Ag.

Division RHODOPHYTA (red algae)

Acanthophora spicifera (Vahl) Boerg.
Actinotrichia fragilis Boerg.
Amansia glomerata C. Ag.
Amphiroa foliacea Lamx.
Amphiroa fragilissima Lamx.
Asparagopsis taxiformis (Delile) Collins & Hervey
Centroceras clavulatum (C. Ag.) Mont.
Ceramium clavulatum Ag.
Ceratodictyon spongiosum Zanard.
Champia parvula (Ag.) J. Ag.
Chylocladia rigens (Grev.) J. Ag.
Coelothrix irregularis (Harvey) Boerg.
*Dasyphila plumarioides Yendo
Desmia hornemanni Lyngb.
Galaxaura filamentosa Chou
Galaxaura marginata Lamx.
Galaxaura oblongata (E. & S.) Lamx.
Gelidiopsis intricata (Ag.) Vickers
Gelidiopsis pannosa (Grun.) Schmitz

Gelidium intricatum (Kg.) Grun.
Gelidium pulchellum (Turn.) Kütz.
Gelidium pusillum (Stackh.) LeJolis
Gracilaria cacalia (J. Ag.) Grev.
Gracilaria crassa Harv.
*Gracilaria eucheumoides Harv.
Gracilaria minor (Sond.) Grev.
Gracilaria radicans Hauck
Gracilaria salicornia (Mert.) Grev.
Halymenia durvillaei Bory
Halymenia floresia (Chem.) C. Ag.
Halymenia lacerata Sond.
Herposiphonia parca Setch.
Herposiphonia secunda (C. Ag.) Ambronn.
Herposiphonia trichia Hollenberg
*Hemitrema fragilis (Harv.) Dawson
*Hypnea esperi Bory
Hypnea pannosa J. Ag.
Hypnea valentiae (Turn.) Montagne
Jania capillacea Harv.
Jania decussato-dichotoma (Yendo) Yendo
Jania tenella Kütz.
Jania ungulata Yendo
*Laurencia cartilaginea Yamada
Laurencia majuscula (Harv.) Lucas
Laurencia papillosa (Forsk.) Grev.
*Laurencia parvipapillata Tseng
Laurencia perforata (Bory) Mont.
Laurencia yamadana Howe
*Metagoniolithon charoides (Lamx.) W. v. Bosse
*Peyssonnelia rubra (Grev.) J. Ag.
Polysiphonia apiculata Hollenberg
Polysiphonia howei Hollenberg
Polysiphonia scopulorum Harvey
Polysiphonia setacea Hollenberg
*Polysiphonia tepida Hollenberg
*Rhodymenia anastomosans W. v. Bosse
Spyridia filamentosa (Wulf.) Harv.
Tolypiocladia glomerulata (Ag.) Schmidt

DOMINANT ALGAE ON REEF FLAT

The algal assemblages on the reef flats of Yap are quite evident in four major habitats - mixed seagrass beds which encircle the Yap islands, a deeper (to a depth of -3 m) sandy area which may possess scattered coral mounds and seagrass, a reef structure area composed of lush live corals, and a dead reef pavement area near the barrier reef margin.

The most conspicuous alga in the seagrass zone is Caulerpa racemosa which at times comprise 50 percent of the cover in this area. Other algae which are also abundant but in localized areas around the islands are Halimeda opuntia, Laurencia parvipapillata, Gracilaria salicornia and Caulerpa sertularioides. The rare alga Ulva lactuca was found just south of Tomil Harbor.

Caulerpa urvilliana is, by far, the most conspicuous alga in the sandy zone. An unidentified species of Cladophora was abundant on the western reefs south of Gofenu Channel. The blue-green algae Microcoleus lyngbyaceus and Schizothrix calcicola were also present on the sandy areas.

Very few algae were found among the lush live corals which made up the live reef structures. The basal dead portions of the staghorn coral Acropora were inhabited by a turf assemblage of Gelidiopsis intricata, Amphiroa fragilissima and Polysiphonia spp.

The dead reef pavement habitat adjacent to the barrier reef margin is the site which is scoured by waves, especially during the winter period. The most conspicuous algae here are the brown alga Turbinaria ornata and the prostrate blue-green algae Microcoleus lyngbyaceus and Schizothrix calcicola.

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ALGAL ASSEMBLAGES IN ENCLOSED LAGOONAL HOLES ON YAP REEFS

Steven E. Hedlund and Roy T. Tsuda

INTRODUCTION

This paper, which supplements the information on the algae on Yap reef flats (Tsuda, this report), provides a qualitative assessment of the subtidal algal communities which inhabit the enclosed lagoonal holes located on the reef flats of Yap. These lagoonal holes are remmants of a once extensive lagoon system which has been filled in by sedimentation and constructional processes. The holes vary in depth (7 to 35 m) and are the principal areas where large fishes (see Amesbury, this report), congregate within the reef flat system. Thus, these holes serve as a important source of food to the districts or villages which claim ownership of them.

Field observations, by skin diving, to study algal distribution in these lagoonal holes were undertaken on July 12-20, 1977. Each of the 20 enclosed lagoonal holes were surveyed for a period of 20-60 minutes. Qualitative abundance of the algae was estimated and each species present recorded as either dominant (> 30 percent cover), common (2-30 percent cover), or rare (< 2 percent cover). The locations of the 20 lagoonal holes where algae were surveyed are included on Fig. 1 in the section on corals by S. Neudecker (this report).

The authors acknowledge the help extended by both S. S. Amesbury and S. Neudecker during the field study.

ALGAL ASSEMBLAGES

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SE-5 0930-1000

The dominant algae found in this shallow enclosed lagoon were Polysiphonia spp. which covered the bottom portion of the staghorn coral Acropora. Caulerpa racemosa, Halimeda gigas and Tydemannia expeditionis were common.

SE-3 1125-1155

The red algal genus Polysiphonia was again the dominant algae found on the patch reef in this enclosed lagoon. The blue-green alga Microcoleus lyngbyaceus was common as were the two greens Halimeda opuntia and Tydemannia expeditionis. The foliose red alga Halymenia durvillaei was only recorded from this site and SE-2 where it was rare.

SE-2 and SE-4 1340-1540

This enclosed lagoon was surveyed on both the shoreward edge (SE-2) and the seaward edge (SE-4). The shoreward edge had a greater species diversity. Polysiphonia spp. were the dominant algae at both the shoreward and seaward edges of this hole. Both Halimeda gigas and Tydemannia expeditionis were common at the shoreward edge, while H. gigas and Microcoleus lyngbyaceus were common at the seaward edge.

SE-1 [Several 30-min. observations]

The algal community on a patch reef, located in a channel-like strip with sand-rubble substratum in 7-12 m of water, was characterized by having a low number of species but a high algal cover. Caulerpa taxifolia, the dominant alga, formed dense mats with Amphiroa fragilissima.

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E-2 1055-1130

This enclosed lagoonal hole had little algal growth and showed the least species diversity. Halimeda gigas and Valonia ventricosa were common and were the only species present.

E-3 1230-1330

The most dominant algae recorded here were the blue-greens Microcoleus lyngbyaceus and Schizothrix mexicana. Valonia fastigiata, a green alga, was unique to this lagoonal hole. The red calcareous alga Peyssonnelia rubra was recorded here and one other location (NW-1).

E-4 1419-1515

Polysiphonia spp. were the dominant algae on the patch reef in the enclosed lagoonal hole. The green algae Tydemannia expeditionis and Rhipilia sp. were common.

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NE-1 1210-1310

The enclosed lagoonal hole was dominated by the blue-green algae Microcoleus lyngbyaceus and Schizothrix mexicana. Polysiphonia spp. and Halimeda gigas were common.

NE-2 1338-1420

Species of Polysiphonia were the dominant algae here. Both Tydemannia expeditionis and Rhipilia sp. were common.

NE-3 1455-1530

Polysiphonia spp. were the dominant algae covering the lower portion of the staghorn coral Acropora. The green algae Halimeda gigas, Rhipilia sp. and Tydemannia expeditionis were common. The brown alga Lobophora variegata was common here and was also common at one other site (W-8)

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NW-1 1500-1555

The most dominant algae observed here were Caulerpa racemosa and Tydemannia expeditionis. Valonia ventricosa and Polysiphonia spp. were common.

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W-10 0852-0920

Polysiphonia spp. were the dominant algae present in this enclosed lagoonal hole. Halimeda gigas and H. opuntia were common and formed scattered stands among the corals.

W-9 1022-1120

The dominant alga Halimeda gigas formed dense patches among the coral heads. Microcoleus lyngbyaceus and Polysiphonia spp. were common.

W-8 1143-1210

Polysiphonia spp. were the dominant species in this enclosed lagoonal hole. Lobophora variegata, Padina tenuis and Turbinaria ornata were rare, but represented three of the four brown algae recorded in the lagoonal holes during this survey. Padina tenuis was only found at this site.

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NW-4 1120-1136

Polysiphonia spp. were dominant in this enclosed lagoonal hole. Both Schizothrix calcicola and Halimeda gigas were common.

NW-5 1310-1340

Tydemannia expeditionis and Rhipilia sp. were the dominant algae here. Schizothrix calcicola and Halimeda gigas were common.

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W-5 1000-1020

The green algae Caulerpa taxifolia, Halimeda gigas and H. opuntia were the dominant species observed here. These algae formed fairly dense mats on the sandy substratum among the corals.

W-6 1035-1105

Polysiphonia spp. were the dominant algae in this enclosed lagoonal hole. Microcoleus lyngbyaceus and Schizothrix calcicola were common.

W-7 1200-1230

Polysiphonia spp. covered the bottom portion of the staghorn coral Acropora. The other algae present were rare.

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W-3 0905-0930

Halimeda gigas and Valonia ventricosa were the dominant algae in this lagoonal hole. Caulerpa taxifolia and Polysiphonia spp. were common. All of the other species were rare. The highest species diversity occurred here, where 18 species were recorded. The red alga Dasyphila plumarioides was only found here.

DISCUSSION

A total of 30 species of marine benthic algae (Table 1) was found in the 20 lagoonal holes surveyed on the reef flats of Yap. This number represents about 21 percent of the algae known from Yap (see Tsuda, this report). The species composition consisted of 3 blue-greens, 12 greens, 4 browns and 11 reds.

When the reef area of Yap is divided into geographic sectors, the highest species diversity occurred in the northwest (NW) sector where 25 species were recorded (Table 2). The lowest species diversity occurred in the northeast (NE) and east (E) sectors where 13 and 12 species were respectively recorded. In general, the 10 lagoonal holes surveyed in the western half of the islands had a greater species diversity than the 10 lagoonal holes in the eastern half.

Caulerpa urvilliana, Chlorodesmis fastigiata, Padina tenuis, Dasyphila plumarioides and Rhodymenia anastomosans were only found in the west sector. Valonia fastigiata and Halymenia durvillaei were restricted only to the east and northeast sectors, respectively. All seven of these species were considered rare; a more thorough search may reveal these species in other sectors. Caulerpa urvilliana, although rare in the lagoonal holes, was the most dominant alga on the shallow sandy reef flats (< 2 m deep) adjacent to the holes.

Table 1. List of marine benthic algal species collected or observed in each of the 20 enclosed lagoonal holes on the reef flats of Yap.

CYANOPHYTA (blue-green algae)

Microcoleus lyngbyaceus (Kütz.) Crouan -- NE-1, NE-2, NE-3, E-3, E-4, E-5, SE-2, SE-3, SE-4, SE-5, W-3, W-5, W-6, W-7, W-8, W-9, W-10, NW-1.
Schizothrix calcicola (Ag.) Gomont -- NE-2, W-3, W-5, W-6, W-7, W-8, W-9, W-10, NW-4, NW-5.
Schizothrix mexicana Gomont -- NE-1, NE-2, NE-3, E-3, E-4, W-3, W-5, W-6, W-7, W-9, W-10, NW-5.

CHLOROPHYTA (green algae)

Caulerpa racemosa (Forssk.) J. Ag. -- NE-2, E-3, E-5, SE-2, SE-4, SE-5, W-3, W-6, W-7, W-8, W-9, W-10, NW-1.
Caulerpa taxifolia (Vahl) C. Ag. -- SE-1, SE-4, W-3, W-5, W-8, W-10.
Caulerpa urvilliana Montagne -- W-5.
Caulerpa webbiana Montagne -- SE-1, SE-5, W-7, W-9, W-10, NW-1.
Chlorodesmis fastigiata (C. Ag.) Ducker -- W-3, W-5, W-6, W-7, W-8, W-10.
Dictyosphaeria cavernosa (Forssk.) Boerg. -- W-6, W-7, W-8, W-9, NW-1, NW-5.
Halimeda gigas Taylor -- NE-1, NE-3, E-2, E-3, SE-2, SE-4, SE-5, W-3, W-5, W-6, W-7, W-8, W-9, W-10, NW-1, NW-4, NW-5.
Halimeda opuntia (L.) Lamx. -- SE-2, SE-3, SE-5, W-3, W-5, W-7, W-8, W-9. W-10, NW-4.
Rhipilia sp. -- NE-1, NE-2, NE-3, E-3, E-4, W-3, W-6, W-7, NW-1, NW-5.
Tydemannia expeditionis Weber van Bosse -- NE-1, NE-2, NE-3, E-4, E-5, SE-2, SE-3, SE-5, W-3, W-6, W-7, W-9, W-10, NW-1, NW-5.
Valonia fastigiata Harvey -- E-3.
Valonia ventricosa J. Ag. -- NE-1, NE-2, E-2, E-4, SE-3, SE-4, SE-5, W-3, W-5, W-6, W-7, W-8, W-9, W-10, NW-1, NW-5.

PHAEOPHYTA (brown algae)

Dictyota bartayresii Lamx. -- NE-3, SE-2, SE-5, W-5, W-7, W-10, NW-5.
Lobophora variegata (Lamx.) Womersley -- NE-3, W-8.
Padina tenuis Bory -- W-8.
Turbinaria ornata (Turner) J. Ag. -- SE-2, SE-3, W-8, NW-4.

Table 1. continued

RHODOPHYTA (red algae)

- Amphiroa foliacea Lamx. -- NE-2, NE-3, E-3, SE-3, W-3, W-6, W-8.
- Amphiroa fragilissima (L.) Lamx. -- SE-1, SE-2, SE-4, SE-5, W-3, W-5, W-6, W-7, W-8, W-9, W-10, NW-1, NW-4, NW-5.
- Dasyphila plumarioides Yendo -- W-3.
- Gelidiopsis intricata (Ag.) Vickers -- SE-2, NW-1.
- Halymenia durvillaei Bory -- SE-2, SE-3.
- Hypnea esperi Bory -- NE-3, SE-2, SE-3, SE-4, SE-5, W-3, W-5, W-6, W-7, W-8, W-9, W-10, NW-4, NW-5.
- Jania capillacea Harvey -- E-3, SE-4.
- Laurencia sp. -- W-3, W-6, W-9, W-10, NW-4, NW-5.
- Peyssonnelia rubra (Grev.) J. Ag. -- E-3, NW-1.
- Polysiphonia spp. -- NE-1, NE-2, NE-3, E-4, E-5, SE-2, SE-3, SE-4, SE-5, W-3, W-5, W-6, W-7, W-8, W-9, W-10, NW-1, NW-4, NW-5.
- ?Rhodymenia anastomosans Weber van Bosse -- W-3.

Table 2. Number of lagoonal holes where the algae were ranked as dominant or common. "0" indicates that the species was not recorded from any of the lagoonal holes within the geographic sector; "R" denotes that the alga was present but rare.

		EAST		WEST		
		NE	E	SE	NW	W
SPECIES	No. of Lagoonal Holes	3	4	3	3	7
	No. of Species	13	12	17	25	19
Polysiphonia spp.		3	3	3	2	6
Halimeda gigas		2	1	2	2	4
Tydemannia expeditionis		2	1	2	1	R
Microcoleus lyngbyaceus		1	1	2	R	2
Rhipilia orientalis		2	1	0	1	R
Valonia ventricosa		R	1	R	1	1
Halimeda opuntia		0	0	1	0	2
Caulerpa racemosa		R	R	1	1	R
Amphiroa fragilissima		R	0	1	R	R
Caulerpa taxifolia		0	0	1	0	2
Schizothrix calcicola		R	R	0	2	1
Schizothrix mexicana		1	1	0	R	R

The algae (Table 2) which were considered dominant and common reflect a much more accurate overview of the algal communities in each of the lagoonal holes. Polysiphonia spp. and Halimeda gigas were the predominant algae in nearly every lagoonal hole. Polysiphonia covered the dead portion of the staghorn coral Acropora, while H. gigas is one of the few species of Halimeda which inhabit waters rich in silt. Other species which had a fairly continuous distribution around the islands were Tydemannia expeditionis, Microcoleus lyngbyaceus, Caulerpa racemosa and Valonia ventricosa. Seven of the 12 species considered dominant or common belong to the Division Chlorophyta. The four species of brown algae were all considered rare.

When one considers the overall algal composition in the lagoonal holes, the most striking characteristic is the relatively low species diversity. Those algae which were either dominant or common in the lagoonal holes were species not normally eaten by herbivorous fishes or were guarded by territorial fishes (Belk, 1975), as in the case of Polysiphonia. The calcareous nature of Halimeda, Amphiroa and Tydemannia serves as a deterrent to most herbivorous fish. Personal observations indicate that blue-green algae are rarely eaten by fishes. The green alga Valonia is too bulky to be fed upon. Thus, fish grazing seems to be one of the principal factors limiting species diversity and coverage in lagoonal holes. Siltation is also an important factor limiting certain species from inhabiting these holes.

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QUALITATIVE ASSESSMENT OF CORAL SPECIES COMPOSITION OF REEF COMMUNITIES IN YAP LAGOON

Steve Neudecker

INTRODUCTION

Relatively few data have been published on the coral species composition of the diverse barrier reef lagoon of Yap. The first study to publish a species list of reef-building corals was that of Sugiyama (1942). This report included records of Yabe and other Japanese scientists prior to 1942. In total, their list contained 28 genera and 52 species. The only other published species lists are those of Richard H. Randall (Amesbury et al., 1976, 1977) and are composed only of species encountered on quantitative transects run in Tomil Harbor. This work added 13 genera and 62 species records to the list.

Yap consists of four closely approximated islands which are surrounded by a barrier reef and its lagoon (Fig. 1). Most of the lagoon has been filled in by sedimentation and constructional processes and the scattered holes that remain are remnant features of the once extensive lagoon. These enclosed and semi-enclosed lagoon environments are of primary economic importance in that they contain well developed coral communities and thereby provide a habitat for many food fishes.

The purpose of this study was to qualitatively define and map the coral species composition and abundance in lagoon environments. This baseline information will provide planners with an idea of the areas of economic importance for assessment of future development as well as provide additional knowledge on the composition of coral species in Yap Lagoon.

METHODS

While the primary objective of the coral survey was to describe the diversity and abundance of living reef corals of enclosed and semi-enclosed lagoon environments, some adjacent reef-flat platforms, lagoon patch reefs, barrier reef passes and lagoon fringing reefs were also surveyed. These habitats were inventoried by haphazard free-swimming reconnaissance by skin and scuba diving. Estimates of the relative coral genera abundance, and species abundance when possible, were determined for each study site according to Randall's scale (Amesbury et al., 1976) where: D=dominant--the predominant coral within a zone, A=abundant--a species generally distributed throughout a reef zone, C=common--a species generally present but with a patchy distribution within the zone, O=occasional--a species with only localized distribution within a reef zone, and R=rare--a species represented by only one or two occurrences within a reef zone.

Approximately 90 hours of field observation (July 9-20, 1977) were devoted to qualitative appraisal of coral communities. The barrier reef lagoon

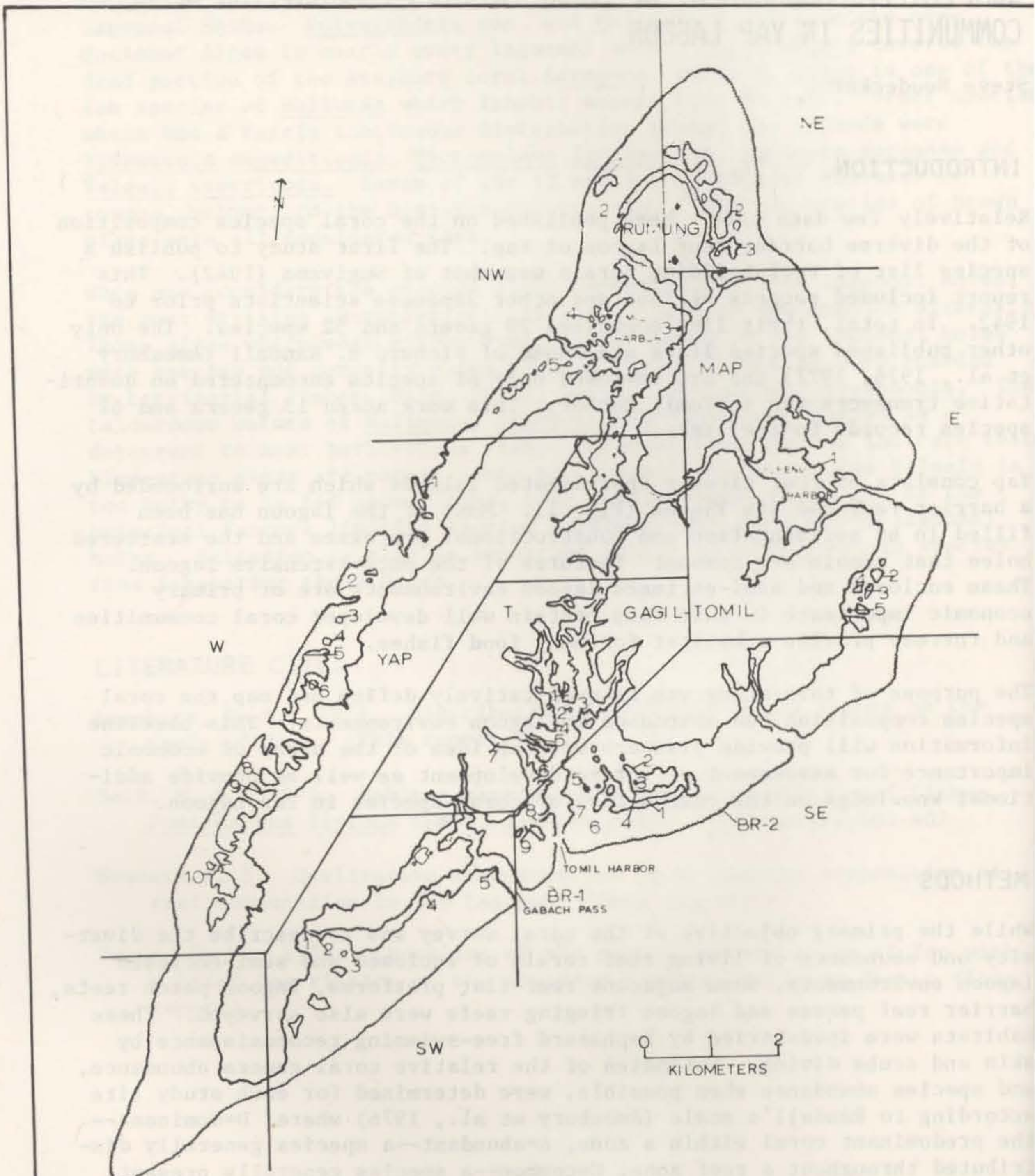

Fig. 1. Map showing geographic sectors and study sites.

was subdivided into seven geographical sectors and study site locations were ordered numerically within each sector. The lagoon-wide survey was designed to thoroughly sample the enclosed and semi-enclosed lagoon environments. These habitats are comprised of the most diverse and structurally complex communities of the barrier reef lagoon and therefore merited detailed study. Regions of sand and seagrass were not sampled for corals and were practically devoid of significant living coral coverage. The Yap barrier reef lagoon has gradually been filled in by sedimentation and constructional processes and the remaining lagoon environments may be classified as remnant lagoons. The coral fauna of a particular site is in part determined by whether or not the lagoon has a barrier reef pass and by how completely the reef rim is surrounded by living coral. These remnant lagoon environments tend to occur in clusters within the barrier reef as those of Tabunifi (W-8 through W-10) and Aringel (W-5 through W-7) on the windward side of the barrier reef and those of Gatjapar (E-2 through E-5) on the lee (Fig. 1). No clear-cut differences exist in the physical conditions between the lagoon reefs of the windward and leeward sides of the barrier reef. Surveys were made at representative sites throughout the lagoon but were somewhat biased in that coral rich areas were generally selected for appraisal. Within the particular lagoon, the exact study location was in part dictated by the direction of prevailing winds which influenced anchorage.

Each study site was classified according to five major physiographic areas, and the date and time of the survey were recorded. The average time of each survey was about 30 minutes although some surveys ran over one hour. The total time spent at a particular reef was in part related to the relative species abundance in that it took longer to record the species present. The reliability of each survey is greatest for the predominant and abundant species and less for the other categories. One is assured of encountering the former on that particular reef. Due to the relatively high species diversity of many of these reefs it was hard to list all common or occasionally occurring species and therefore failure to list a species does not exclude it from the reef. Although 12 sites were also surveyed by scuba diving, most assessment was done while skin diving. Consequently, the lagoon slope beyond -10 m was not adequately surveyed when only skin diving was employed.

Only a few species of the protean genera Acropora, Pocillopora, Porites and Montipora were recognized in the field. Taxonomic problems are paramount in these genera and therefore species and their intergrading growth forms were not separated during field observations. Most of the other genera were classified to the specific level in situ. Specimens of the various coral species encountered were collected for later taxonomic verification and were subsequently deposited in the University of Guam Marine Laboratory Museum. Laboratory determinations were made with Richard Randall's help and according to taxonomic references by Vaughan (1907), Faustino (1927), Yabe, Sugiyama and Eguchi (1936, 1941), Yabe and Sugiyama (1941), Vaughan and Wells (1943), Crossland (1952), Wells (1954, 1956) and Wijsman-Best (1972).

PHYSIOGRAPHIC AREAS

During the qualitative appraisal of the lagoon, five major physiographic areas were recognized and characterized as follows.

1. Enclosed Lagoons. These environments are remnant features of the once extensive lagoon and are now isolated. They are well protected from waves and tidal currents and the resident time of their waters is great. Some of these lagoons are completely surrounded by coral development on their margins (e.g., W-6, Fig. 1) while others lack coral development on their seaward sides (e.g., E-2 through E-5).

2. Semi-Enclosed Lagoons. These lagoons regularly exchange their waters with the open ocean either through a barrier reef pass or channel. The substratum usually consists of reef rock, coarse sand and coral-rubble (e.g., SE-8).

3. Adjacent Reef Flat Platforms. These shallow reef flats occur between lagoons and between the shore and the barrier reef. They are generally protected from strong wave action but are exposed to some tidal currents. The substratum consists primarily of sand and eroded reef rock. An example is the reef flat near shore and the NW-1 lagoon.

4. Lagoon Fringing Reefs. These reefs develop out from the island's shores and are profoundly influenced by the adjacent land. Sedimentation rates are high and the water usually contains large amounts of suspended material (e.g., Tomil-1).

5. Barrier Reef Passes. These passes cut through the barrier reef and are exposed to strong currents. The pass margins and walls contain diverse assemblages of corals while the sand-sediment bottoms are practically devoid of coral development (e.g., SW-5).

In addition to these five major reef types, it was realized that the lagoon environments within Tomil, Gofenu and Mil Harbors were somewhat different from the others. These reefs are strongly influenced by input from the nearby land and mangroves and often have large amounts of suspended material in the water. The Nif channel environments (SW-1 through SW-3) are similar to the harbor environments.

CORAL COMPOSITION

A physical description and coral composition of each reef are presented in the following paragraphs and the location is indicated on Figure 1. Each study site is classified according to the five major physiographic areas recognized and the date, time and corresponding figure numbers are given when applicable. The surveys are reported in chronological order.

9 VII 77

Tomil-1 1005-1111

This lagoon fringing reef was off the southern end of O'Keefe Island. The reef is horseshoe-shaped with coral development on the margin and a reef flat in the center about 200 m at its widest. Acropora formosa and Clavarina scrabicula predominanted the reef flat and reef margin along with Porites andrewsi. Fungia (F.) fungites, Fungia (C.) echinata and Montipora spp. were abundant. Physogyra lichtensteini, Favia spp., Pocillopora spp., Pavona spp. and Alveopora allingi were common.

10 VII 77

SE-8 0840-1030

This semi-enclosed lagoon is connected to Tomil Harbor Channel on its northern side. The adjacent reef flat was predominated by Acropora spp. and corals of the family Fungiidae were locally abundant. Porites andrewsi and massive Porites species predominated the margin and upper lagoon slope. Montipora spp., Favia and Alveopora allingi were common.

SW-1 1420-1440

This lagoon fringing reef was on the side of a small jetty-like peninsula. Water visibility was only a few feet and the coral species diversity was low. This reef margin was predominated by Montipora sp. and massive Porites. Porites andrewsi and Pavona spp. were abundant. Physogyra lichtensteini was common.

SW-2 1456-1506

This reef is a special type of semi-enclosed lagoon in that it is an inward extension of Gabach Channel (SW-5) and like SW-1 the visibility was quite low. Massive Porites and Porites andrewsi predominated the reef crest and the upper 3 m of the lagoon slope. Alveopora allingi predominated the lower lagoon slope to the soft bottom at about -12-15 m. Acropora spp., Fungia (C.) echinata and Fungia (F.) fungites were abundant. Seriatopora hystrix, Pachyseris rugosa, Leptoria phrygia and Pavona spp. were common. Clavarina scrabicula, Acrhelia horrescens, and Montipora spp. were encountered occasionally.

SW-3 1518-1537

This semi-enclosed lagoon is of the same type as SW-2, although the visibility was a bit better. Porites andrewsi and massive Porites predominated the reef crest. Acropora spp., Fungia (C.) echinata, Fungia (F.) fungites and Montipora spp. were abundant. Several species were common including Seriatopora hystrix, Cyphastrea sp., Leptoria phrygia, Physogyra lichtensteini, Clavarina scrabicula, Alveopora allingi, Fungia (H.) actiniformis, Favia spp. and Favites spp., Pavona spp., and Psammocora sp. were found on occasion.

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SE-5 0930-1000

The reef flat adjacent to this enclosed lagoon was predominated by Acropo spp. while the reef margin was predominated by Porites andrewsi, massive Porites and Montipora corals. The lagoon was predominated by encrusting and foliaceous Montipora spp. Acrhelia horrescens was common and Fungia (actiniformis was seen occasionally.

SE-3 1125-1155

This lagoon patch reef was predominated by Porites andrewsi and massive Porites to a depth of -3 m. The lagoon slope beyond -3 m of depth was predominated by foliaceous Montipora and Porites spp., Pachyseris specios and Pavona praetorta. Acropora species, a blue arborescent Acropora and corals of the family Fungiidae were locally abundant. Stylophora mordax, Seriatopora hystrix, Favia spp., Favites spp., Leptoria phrygia, Acrhelia horrescens, Pocillopora damicornis and Millepora dichotoma were common. Pectinia lactva and Millepora exesa were found occasionally.

SE-2 1340-1403

This enclosed lagoon was surveyed on the shoreward side (SE-2) and the seaward side (SE-4). Much of the seaward side was devoid of coral develo ment. Porites andrewsi and massive Porites species predominated the reef crest and lagoon slope. Many of these colonies had been grazed by fish and others were diseased. Branching and encrusting Montipora spp. were abundant. Acropora spp., Seriatopora hystrix, Millepora dichotoma, Pavona spp., Alveopora allingi and Clavarina scrabicula were common. Fav spp., Millepora exesa and Acrhelia horrescens were encountered occasional

SE-4 1515-1540

The southern edge of the seaward side was surveyed. Porites andrewsi and massive Porites species predominated the reef margin and lagoon slope. Acropora spp. were abundant. Stylophora mordax was common and many colonies had been grazed by fish. Favia, Favites and Pavona species, Leptoria phrygia, Alveopora allingi, Pocillopora damicornis, Fungia (C.) echinata, Fungia (F.) fungites, blue arborescent Acropora, a pink Montipora and Acrhelia horrescens were common. Fungia (H.) actiniformis and Cyphastrea microphthalma were encountered on occasion.

Tomil Patch Reefs

SE-1 [Several 30-min. observations] Figure 2

These lagoon patch reefs were located on a long channel-like strip of sand-rubble substratum in 7-12 m of depth. These small reefs (3-20 m diameters) were characterized by having low species diversity and high density and were often monotypic stands of Acropora or massive Porites colonies. Pocillopora damicornis and Seriatopora hystrix were occasionally found on these reefs.

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E-1 0955-1020

This back lagoon slope margin was predominated by massive Porites and Porites andrewsi, some of which had been grazed. Millepora dichotoma was abundant in stands as were Acropora spp. Common at this site were Favia spp., Montipora tuberculosa, encrusting Montipora sp., Stylophora mordax, Fungia (C.) echinata and Fungia (F.) fungites. The lagoon slope was predominated by Pachyseris speciosa, Pavona praetorta and Alveopora allingi. The reef flat surrounding this lagoon area was poorly developed.

E-2 1055-1130

This enclosed lagoon had little coral development on its seaward side. Massive and encrusting Porites spp. predominated the margin along with Porites andrewsi and Clavarina scrabicula in localized stands. Abundant corals at this site were Acropora spp., Pachyseris speciosa, and Montipora species. Alveopora allingi, Cyphastrea microphthalma, Seriatopora hystrix, Merulina ampliata, Fungia (C.) echinata, Fungia (F.) fungites and Pocillopora damicornis were common. Pocillopora spp., Favia spp., Favites spp. and Leptoria phrygia were seen occasionally.

E-3 1230-1330

This enclosed lagoon also lacked coral development on the seaward side and therefore the shoreward side was surveyed. Porites andrewsi, massive Porites and Montipora sp. predominated the reef margin. Abundant corals included a foliaceous Montipora sp. and Acropora spp. Stylophora mordax, Merulina ampliata, Cyphastrea microphthalma and Pavona spp. were common. Leptoria phrygia, Alveopora allingi, Pocillopora damicornis, Pocillopora spp., Fungia (C.) echinata and Fungia (F.) fungites were found on occasion.

E-4 1419-1515

This lagoon patch reef was predominated by Porites andrewsi. Massive Porites, Acropora formosa and other Acropora spp. were abundant. Merulina vaughani was common and abundant in some areas as extensive foliaceous plates. Pavona praetorta was also common to abundant in localized stands on the lagoon slope to -20 m. Other common corals included Pavona spp. and Montipora spp.

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NE-1 1210-1310 Figures 6-9

This enclosed lagoon had little coral growth along its seaward edge. The site was predominated by Acropora spp., Porites andrewsi and an encrusting Montipora sp. Acropora formosa, Diploastrea heliopora and massive Porites were abundant. Stylophora mordax, Favia stelligera, Leptoria phrygia, Seriatopora hystrix, Pocillopora damicornis, Millepora exesa, Clavarina scrabicula and Pocillopora spp. were common. Turbinaria sp. (Figure 8) occurred here but was not collected.

NE-2 1338-1420 Figures 10-17

This enclosed lagoon had only scattered coral development on the seaward side. The rest of the reef margin was predominated by Porites andrewsi and Acropora spp. Foliaceous Montipora, massive Porites and Acropora formosa were abundant. Common corals included Stylophora mordax, Pocillopora damicornis, Pocillopora spp., Pachyseris rugosa, Pachyseris speciosa, Fungia (C.) echinata, Fungia (F.) fungites, Merulina vaughani, Millepora dichotoma and Favia spp. Clavarina scrabicula, Millepora exesa, Diploastrea heliopora and Alveopora allingi were observed occasionally.

NE-3 1455-1530

This enclosed lagoon was completely rimmed by coral but development on the seaward side was minimal. The reef crest was predominated by large stands of Acropora spp. and Clavarina scrabicula. Porites andrewsi, Montipora spp. and massive Porites were abundant. Stylophora mordax, Acropora kenti, Pocillopora spp., Merulina ampliata, Seriatopora hystrix, Favia spp. and Favites spp. were common. Pavona spp., Montipora tuberculosa, Galaxea fascicularis, Pachyseris rugosa and Pachyseris speciosa were encountered occasionally.

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NW-3 1016-1100

This lagoon patch reef was predominated by Acropora spp., Porites andrewsi and Alveopora allingi on the lagoon slope. Montipora spp., Pavona praetorta, Pachyseris speciosa, Lobophyllia corymbosa, Lobophyllia costata, Lobophyllia (P.) hataii, Symphyllia nobilis and Symphyllia recta were abundant on the lagoon slope. Leptoria phrygia, Fungia (C.) echinata, Fungia (F.) fungites, Montipora lobulata, Mycedium elephantotus and Pectinia lactva were common to abundant. Psammocora spp., Acropora spp., Fungia (H.) actiniformis and Physogyra lichtensteini were encountered occasionally.

NW-1 1500-1555 Figure 3

This enclosed lagoon was completely rimmed with coral. Huge coral blocks had slumped in places and vertical structure was prominent. Massive Porites, Porites andrewsi, Acropora spp. in localized stands and Pachyseris rugosa in stands predominated the lagoon margin. Alveopora allingi, Goniopora sp. and Pachyseris speciosa predominated the lagoon slope and Tubipora musica was abundant. Montipora sp. and Millepora dichotoma were abundant on the reef crest. Clavarina scrabicula, Seriatopora hystrix, Pavona spp., Psammocora spp., Acropora formosa, Favia spp., Pocillopora damicornis, Turbinaria sp. and Physogyra lichtensteini were common. Millepora exesa, Acrhelia horrescens, Heliopora coerulea and Cyphastrea chalcidicum were found on occasion. Parahalomitra robusta was collected only from this site.

NW-2 [Reef Flat near shore] 1555-1616

Corals were widely scattered on the sand substratum and alcyonaceans were much more abundant than scleractinians. Porites heads, Pocillopora damicornis, Acropora spp., Heliopora coerulea, Cyphastrea chalcidicum, Leptastrea purpurea and Stylocoeniella armata were spread on the sand bottom in -1.5 m of water.

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W-10 0852-0920

This enclosed lagoon was completely ringed with corals on the reef margin. The predominant species were Porites andrewsi, Millepora dichotoma and Acropora formosa. Montipora spp., massive Porites, Favia spp., Seriatopora hystrix and Millepora exesa were locally abundant. Acropora spp., Platygyra daedalea, foliaceous Montipora, Fungia (C.) echinata, Fungia (F.) fungites, Favites spp. and Acrhelia horrescens were common. Stylophora mordax, Psammocora spp., Pocillopora damicornis, Stylocoeniella armata, blue arborescent Acropora and Fungia (H.) actiniformis were found occasionally.

W-9 1022-1120

These enclosed lagoons were nearly completely ringed with coral development and the survey was concentrated between two adjacent holes and the adjoining reef flat. The lagoon margin was predominated by Porites andrewsi and Clavarina scrabicula. Acropora spp. were abundant on the reef flat and Heliopora coerulea was common. Alveopora allingi predominated the lagoon slope and Favites spp. were abundant. Pocillopora damicornis, Pocillopora spp., Acropora spp., Acropora formosa, Montipora spp., Fungia (C.) echinata, Fungia (F.) fungites and Millepora dichotoma were common. Montipora tuberculosa, Fungia (H.) actiniformis and Acrhelia horrescens were encountered occasionally.

W-8 1143-1210

The reef margin and upper slope of this enclosed lagoon was predominated by large stands of Porites andrewsi, Acropora formosa, Clavarina scrabicula and Seriatopora hystrix. Pavona frondifera and Pavona divaricata were abundant. Acropora spp., Montipora spp., ramose Montipora, Pocillopora damicornis, Fungia (C.) echinata and Favia spp. were common. Some fish grazing was noticed on massive Porites. Alveopora allingi, Millepora dichotoma and Acrhelia horrescens were found occasionally.

SW-5 1350-1450 Figure 4

The south wall and adjacent reef flat of Gabach barrier reef pass were surveyed. Porites andrewsi and massive Porites predominated in some places and were interspersed with other abundant species including a foliaceous Montipora, Diploastrea heliopora and Millepora exesa. Acropora spp., Pocillopora spp. and Pocillopora damicornis were abundant on the reef flat. Common species on the channel wall and edge were Leptoria phrygia, Leptoseris solida, Favia spp., Millepora dichotoma, Platygyra daedalea and Fungia (F.) fungites. Species observed only occasionally were those of Pavona, Psammocora, Acropora kenti, blue arborescent Acropora, Pachyseris speciosa, Alveopora allingi, Astreopora myriophthalma, Archelia horrescens and a Goniopora species.

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NW-4 1120-1136

This enclosed lagoon was shallow with a maximum depth of -10 m. Acropora formosa predominated the reef margin while Alveopora allingi predominated the lagoon slope. Porites andrewsi, blue arborescent Acropora, massive Porites and foliaceous Montipora were common. One large head (4 m diameter) of Diploastrea heliopora was encountered. Coral coverage was not great and several species were encountered only on occasion. Those were Favia spp., Favites spp., Acrhelia horrescens, Cyphastrea microphthalma, Galaxea fascicularis, Millepora dichotoma, Hydnophora exesa, Caulastrea furcata, Pavona spp., Stylophora mordax and Seriatopora hystrix.

NW-5 1310-1340

This enclosed lagoon was predominated by stands of Clavarina scrabicula and Porites andrewsi on the reef margin. Massive Porites was abundant and some had been grazed. Pocillopora damicornis was common on the reef margin and abundant on the adjacent reef flat platform. Other common species were those of Favia, Favites, Montipora and Pocillopora. Corals encountered on occasion included Acrhelia horrescens, Alveopora allingi, Diploastrea heliopora, Fungia (H.) actiniformis, Montipora tuberculosa, Psammocora spp., Seriatopora hystrix and Stylophora mordax.

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W-5 1000-1020

Coral coverage was sparse around the reef margin of this enclosed lagoon. Localized stands of Acropora formosa, Acropora spp. and Porites andrewsi predominated the reef margin while Alveopora allingi and Pachyseris speciosa were the predominant corals on the lagoon slope.

Blue Acropora was, in some places, intermixed with Acropora formosa. Massive Porites, some of which were grazed, were abundant. Fungia (C.) echinata, Hydnophora exesa, Merulina laxa, Montipora spp., Pectinia lactva, Pocillopora damicornis and Stylophora mordax were common. Favia, Favites, Heliopora coerulea, Millepora exesa, foliaceous Montipora, Pavona, Pachyseris rugosa, Pachyseris speciosa, Physogyra lichtensteini, Psammocora, Seriatopora hystrix and Stylocoeniella armata were found on occasion.

W-6 1035-1105

The shoreward side of this completely coral-rimmed enclosed lagoon was surveyed. Large stands of Acropora sp. and Acropora formosa predominated this site and massive Porites was abundant. Blue arborescent Acropora, Fungia (F.) fungites, Fungia (C.) echinata, Clavarina scrabicula, Hydnophora exesa, Millepora dichotoma, Montipora spp., Pavona spp., Physogyra lichtensteini, Porites andrewsi, folicaeous Porites, and Pocillopora damicornis were common. Acrhelia horrescens, Alveopora allingi, Favia, Favites, Fungia (H.) actiniformis, Montipora tuberculosa, Pachyseris rugosa, Pachyseris speciosa, Pocillopora species, Psammocora, Seriatopora hystrix, Stylophora mordax and Stylocoeniella armata were found on occasion.

W-7 1200-1230

This enclosed lagoon is near a barrier reef pass and the predominant coral species were Acropora formosa and Alveopora allingi. Acropora spp., Clavarina scrabicula, Porites andrewsi, and massive Porites were abundant. Pachyseris speciosa, Porites sp. and Pocillopora damicornis were common. Acropora kenti, Favia spp., Favites spp., Hydnophora exesa, Lobophyllia costata, Pectina lactva, Physogyra lichtensteini, Seriatopora hystrix and Stylophora mordax were observed occasionally.

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W-3 0905-0930 Figure 5

The reef margin of this enclosed lagoon was predominated by Porites andrewsi and a foliaceous Montipora which sometimes grew together (Figure 5). Millepora dichotoma, Millepora exesa and Montipora spp. were abundant. Common corals at this site were Acrhelia horrescens, Pavona spp., Porites spp., Pocillopora damicornis, Pocillopora spp., Seriatopora hystrix and Stylophora mordax. Species observed occasionally were Acropora kenti, Fungia (F.) fungia, Fungia (C.) echinata, Platygyra daedalea, Stylocoeniella armata and Psammocora spp.

W-2 0943-1030

This barrier reef embayment cuts through the barrier reef but does not connect to a lagoon. The northern pass was partly predominated by a foliaceous Montipora and Porites andrewsi. Millepora dichotoma, Millepora exesa, Hydnophora exesa, Acropora kenti, Acropora spp., Porites spp., Diploastrea heliopora, Favia spp., Favites spp., Montipora spp., Pachyseris speciosa, Psammocora sp., and Pocillopora spp. were common.

Heliopora coerulea, Galaxea fascicularis, Goniastrea retiformis, Goniopora arbuscula, Leptoseris solida, Lobophyllia costata, Platygyra daedalea, Pocillopora damicornis, Seriatopora hystrix and Stylophora mordax were found occasionally.

W-1 1050-1130

This barrier reef embayment is very similar to W-2 in its structure and species composition. No species was clearly dominant and Acropora spp. were abundant. Heliopora coerulea, Diploastrea heliopora, Galaxea fascicularis, Leptoseris solida, Lobophyllia costata, Montipora spp., Pavona spp., Pocillopora spp., Psammocora sp., Stylophora mordax, Favia spp., Favites spp. and Leptoria phrygia were common. Corals occurring occasionally included Alveopora sp., Cyphastrea microphthalma, Fungia (H.) actiniformis, Distichopora violacea, Goniastrea retiformis, Platygyra daedalea, Hydnophora exesa, Clavarina scrabicula, Pectinia lactva, Porites andrewsi, massive Porites, Seriatopora hystrix, Stylophora mordax and Fungia (F.) fungites.

Of the 32 study sites, 18 were enclosed lagoons and three more were semi-enclosed. The remaining surveys were made on four lagoon patch reefs, two barrier reef embayments, two lagoon fringing reefs, one barrier reef pass, one back lagoon slope and one separate reef flat. Other reef flat surveys were included in the description of their nearby lagoons.

A systematic classification of the corals encountered during these surveys and including the previously published records of Sugiyama (1942) and Randall (in Amesbury et al., 1976, 1977) is presented in Table 1. Over 100 representative specimens were collected by this author and deposited in the University of Guam Marine Laboratory Museum. A complete breakdown of the species records is presented in Table 2. Distribution of these records according to author is given in Table 3.

DISCUSSION

When considering the total species diversity of the Yap reefs it is important to realize that the outer barrier reefs are not included. Complete collections on the barrier reef as well as additional work in the lagoon will probably increase the total species diversity nearly twofold. While the species list is not a complete one for the lagoon environments, further field studies will not add species which are predominate or are abundant on lagoon reefs. As shown in Tables 2 and 3, this report adds 12 genera and 56 species to the list and yields a total diversity of 53 genera and 170 species. Although the number of genera and species of ahermatypes is small, it will probably not be increased significantly by further collection in the lagoon.

It is interesting to note that four of the genera recorded by Sugiyama (1942) were not found by Randall or this author. These were Barbattoria, Coscinaria [=Coscinastrea], Halomitra and Polyphyllia. It is also interesting that Coeloseris, Herpentoglossa, Plerogyra and Stylaster have not been recorded from the lagoon. It is likely that some of these occur elsewhere in the lagoon.

Table 1. Coral fauna of the Yap Lagoon.

This systematic classification of the Scleractinia generally follows that of Vaughan and Wells (1943). All existing records from Yap are included except those reported only to the generic level (unless the only record for that genus). Existing records are those of Sugiyama (1942)-S and those of Richard Randall-R, in Amesbury et al. (1976,1977). A species name followed by two author's initials indicates that the first record was only to the generic level. The numbers following species names are those of specimens collected by this author and deposited in the Marine Laboratory Museum collection.

CLASS ANTHOZOA
ORDER SCLERACTINIA
SUBORDER ASTROCOENIINA
FAMILY ASTROCOENIIDAE
Stylocoeniella armata (Ehrenberg) R

FAMILY THAMNASTERIIDAE
Psammocora contigua (Esper) R
Psammocora obtusangula (Lamarck) R
Psammocora (Stephanaria) togianesis (Umgrove) R

FAMILY POCILLOPORIDAE
Stylophora mordax (Dana) S 00622-3
Stylophora sp. 00624
Seriatopora angulata Klunzinger S 00625-6
Seriatopora hystrix Dana S 00627-8
Seriatopora sp. 00629
Pocillopora damicornis (Linnaeus) R 00630
Pocillopora damicornis caespitosa Dana S
Pocillopora danae Verrill 00636
Pocillopora ligulata Dana S
Pocillopora meandrina Verrill 00632-4
Pocillopora meandrina nobilis Verrill S
Pocillopora cf. P. molokensis Vaughan S
Pocillopora verrucosa (Ellis and Solander) 00631
Pocillopora sp. [bottlebrush] 00637-8

FAMILY ACROPORIDAE
Acropora abrotanoides (Lamarck)? S
Acropora arbuscula (Dana)S
Acropora corymbosa (Lamarck) S
Acropora digitifera (Dana) S
Acropora echinata (Dana) 00639
Acropora exigua (Dana) R
Acropora formosa (Dana) S
Acropora formosa gracilis Dana S

Acropora formosa brachiata (Dana) S
Acropora hebes (Dana) R
Acropora humilis (Dana) R
Acropora hyacinthus (Dana) S
Acropora kenti (Brook) 00640
Acropora palifera (Lamarck) S 00641
Acropora polymorpha (Brook) S
Acropora procumbens (Brook) 00646
Acropora cf. A. secunda (Dana) S
Acropora smithi (Bernard) S
Acropora teres Verrill R
Acropora [blue] R
Acropora sp. 1 00647
Acropora sp. 2 00648
Astreopora myriophthalma (Lamarck) S, R 00649
Montipora acanthella Bernard R
Montipora annularis Bernard R
Montipora berryi Hoffmeister R
Montipora caliculata Dana 00650
Montipora carinata Nemenzo R
Montipora circumuallata (Ehrenberg) R
Montipora sp. cf. M. colei Wells 00651
Montipora danae Milne-Edwards and Haime 00652
Montipora divaricata Brueggemann R 00654
Montipora sp. cf. M. mehrenbergii Verrill R
Montipora foliosa (Pallas) S
Montipora foveolata (Dana) R
Montipora informis Bernard S 00655
Montipora cf. M. intricata Milne-Edwards and Haime S
Montipora levis Quelch S
Montipora lobulata Bernard R 00656
Montipora spumosa (Lamarck) 00657
Montipora tuberculosa (Lamarck) 00658
Montipora turgescens Bernard R
Montipora verrilli Vaughan R
Montipora verrucosa (Lamarck) 00659
Montipora sp. 1 00660
Montipora sp. 2 00661
Montipora sp. 3 00684

SUBORDER FUNGIIDAE

FAMILY AGARICIIDAE

Pavona decussata Dana S 00661
Pavona divaricata (Lamarck) 00662
Pavona frondifera Lamarck S 00663-4
Pavona praetorta (Dana) R
Pavona varians Verrill S
Pavona (Polyastrea) obtusata 00665
Pavona (Polyastrea) venosa (Ehrenberg) 00666
Leptoseris columna Yabe and Sugiyama 00731
Leptoseris scabra Vaughan R
Leptoseris solida (Quelch) R

Pachyseris rugosa (Lamarck) R 00667-8
Pachyseris speciosa (Dana) R 00669-10

FAMILY SIDERASTREIDAE
Coscinaraea columna [Coscinastrea] (Dana) S

FAMILY FUNGIIDAE
Fungia (Heliofungia) actiniformis Quoy and Gaimard S 00671
Fungia actiniformis palauensis Doederlein S
Fungia (Verrillofungia) concinna Verrill R
Fungia costulata Ortmann S
Fungia (Ctenactis) echinata (Pallas) S 00672-3
Fungia (Fungia) fungites (Linnaeus) R 00674-7
Fungia fungites haimei Verrill S
Fungia (Pleuractis) paumotuensis Stuchbury R
Fungia (Pleuractis) scutaria Lamarck R
Herpolitha limax (Esper) S
Halomitra irregularis Gardiner S
Parahalomitra robusta (Quelch) 00678
Polyphyllia talipina Lamarck S

FAMILY PORITIDAE
Goniopora arbuscula Umbgrove S, R 00679
Goniopora lobata Milne-Edwards and Haime R
Goniopora sp. 1 00680
Goniopora sp. 2 00681
Porites andrewsi Vaughan S 00682
Porites australiensis Vaughan R
Porites cocosensis Wells R
Porites cf. P. crassatellata Quelch S
Porites lobata Dana R
Porites lutea [haddoni] Milne-Edwards and Haime R
Porites murrayensis Vaughan R
Porites nigrescens Dana 00685
Porites cf. P. tenuis Verrill S
Porites (Synarea) convexa Verrill R
Porites (Synarea) horizontalata Hoffmeister R
Porites (Synarea) iwayamaensis Eguchi R 00686
Porites (Synarea) monticulosa (Dana) R
Porites (Synarea) sp. 00687
Alveopora allingi Hoffemeister R 00688

FAMILY FAVIIDAE
Barbattoia mirabilis Yabe and Sugiyama S
Caulastrea furcata Dana 00689
Favia danae Verrill R
Favia favus (Forskaal) 00690
Favia matthaii Vaughan R
Favia pallida Dana S
Favia rotumana (Gardiner) S 00691
Favia speciosa (Dana) R 00692

Favia stelligera (Dana) 00693
Favites abdita (Ellis and Solander) 00694
Favites acuticollis (Ortmann) R 00695
Favites chinensis (Verrill) 00696
Favites cf. F. complanata (Ehrenberg) S 00697
Favites melicerum (Ehrenberg) R
Favites virens (Dana) S
Favites sp. 00698
Goniastrea parvistella (Dana) R
Goniastrea pectinata (Ehrenberg) S
Goniastrea retiformis (Lamarck) 00699
Platygyra daedalea (Ellis and Solander) S, R 00700
Platygyra lamellina (Ehrenberg) R 00701
Diploastrea heliopora (Lamarck) S 00702
Leptoria phrygia (Ellis and Solander) 00703-4
Hydnophora exesa (Pallas) 00705
Hydnophora rigida (Dana) 00706
Leptastrea bottae (Milne-Edwards and Haime) 00707
Leptastrea purpurea (Dana) R 00708
Chyphastrea chalcidicum (Forskaal) 00709
Chyphastrea microphthalma (Lamarck) R 00710
Echinopora lamellosa (Esper) R 00711
Echinopora sp. 1 00712
Echinopora sp. 2 00713
Montastrea sp S

FAMILY RHIZANGRIDAE
+*Culicia rubeola (Quoy and Gaimard) 00714

FAMILY OCULINIDAE
Galaxea fascicularis (L.) S 00715
Galaxea sp. [explanate] 00716
Acrhelia horrescens (Dana) S, R. 00717

FAMILY MERULINIDAE
Merulina ampliata (Ellis and Solander) 00732
Merulina vaughani Var der Horst 00727
Clavarina scrabicula Dana 00726

FAMILY MUSSIDAE
Lobophyllia corymbosa (Forskaal) 00718
Lobophyllia costata (Dana) R 00719
Lobophyllia (Palauphyllia) hataii Yabe, Sugiyama and Eguchi R 00720
Symphyllia nobilis [=recta] Dana S 00721
Symphyllia valenciennsi Milne-Edwards and Haime R 00722

FAMILY PECTINIIDAE
Echinophyllia aspera (Ellis and Solander) R
Oxypora lacera Verrill 00723
Mycedium elephantotus Pallas R 00724

Pectinia lactva (Pallas) S 00725
Pectinia sp. 00635

SUBORDER CARYOPHYLLIINA
FAMILY CARYOPHYLLIIDAE
Euphyllia glabrescens Chamisso and Eysenhardt R 00728
Physogyra lichtensteini Milne-Edwards and Haime R 00729

SUBORDER DENDROPHYLLIINA
FAMILY DENDROPHYLLIIDAE
*Dendrophyllia micranthus (Ehrenberg) R
*Tubastrea aurea (Quoy and Gaimard) 00714
Turbinaria sp. [observed only]

ORDER COENOTHECALIA
FAMILY HELIOPORIDAE
°Heliopora coerulea (Pallas) S 00730

SUBCLASS OCTOCORALLIA
ORDER STOLONIFERA
FAMILY-TUBIPORIDAE
°Tubipora musica (L.) 00642

CLASS HYDROZOA
ORDER MILLEPORINA
FAMILY-MILLEPORIDAE
+Millepora dichotoma Forskaal 00643
+Millepora exesa Forskaal S 00644
+Millepora intricata [≐confentissima] Milne-Edwards and Haime S

ORDER STYLASTERINA
FAMILY-STYLASTERIDAE
+*Distichopora violacea (Pallas) 00645

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*Ahermatype

+Hydrozoan

°Octocoral

Table 2. Tabulation of all species records from Yap Lagoon.

Corals		Previous Records	New Records
Scleractinians			
Hermatypic	Genera	38	8
	Subgenera	9	0
	Species	109	52
Ahermatypic	Genera	1	2
	Species	1	2
Nonscleractinians			
	Genera	2	2
	Species	3	3
TOTAL	GENERA	53	
	SPECIES	170	

Table 3. Distribution of coral records from Yap Lagoon according to author.

Authors	Genera	Species
Sugiyama (1942)	28	52
Amesbury et al. (1976, 1977)	13	62
Neudecker (this report)	12	56
TOTAL	53	170

When all of the enclosed lagoons are considered, no major or clear-cut differences exist in coral fauna between the reefs throughout the entire lagoon. Porites andrewsi is a predominant species in parts of nearly every site and often shares this role with massive Porites, Acropora spp. and Montipora spp. Other abundant corals included Acropora formosa, Millepora dichotoma, Clavarina scrabicula, Alveopora allingi, Pachyseris speciosa, Fungia (C.) echinata and Fungia (F.) fungites. Therefore, the species composition of all the lagoon reefs is much more similar than dissimilar even though some coral species were unique to certain sites (e.g., Parahalomitra robusta at NW-1). Perhaps this similarity is just a reflection of the fact that most of the lagoons were interconnected at one time. Qualitatively, it appeared that the enclosed lagoons on the leeward side (W-1 through W-10) were a little richer in total species diversity.

Differences do appear in species composition when the different reef environments are compared. The most diverse reefs overall were those of the barrier reef passes. This was in part due to the large amount of water exchange, low turbidity and close proximity to the barrier reefs. The NW-1 enclosed lagoon was one of the most diverse of its type which was in part due to the high structural complexity provided by the slumping of huge coral blocks and partly to its relatively close proximity to the windward barrier reef. The least diverse and poorly developed sites were the lagoon fringing reefs. The terrestrial input does not appear to facilitate active reef development in these areas. The NW-3 patch reef was unique in its high abundance of mussid corals.

Fish feeding on corals was observed throughout the lagoon by direct observations of certain corallivorous chaetodontids and indicated by the many white lesions visible on several coral species. Coral is an important food resource for many of its associated fish species and also provides shelter.

Space for coral settlement was often the primary factor restricting further reef development. Intraspecific competition for space was observed (e.g., Figure 5) in many of the barrier reef lagoons.

A general attenuation of species diversity was noticed from the barrier reefs to the island shores. This diversity gradient was particularly evident in the Nif-Gabach channel (SW-1 through SW-3) where the site nearest land (SW-1) had only a few species; the SW-5 barrier reef pass was one of the most diverse sites studied.

When future development is considered in the Yap Lagoon, particular attention should be given to the large enclosed lagoons. These reefs, which harbor diverse coral and fish assemblages, are of major economic importance as food resources.

ACKNOWLEDGEMENT

Dr. Roy T. Tsuda and Steve Amesbury gave many helpful suggestions and assistance in the field. Steve Hedlund and Logan Kock also assisted in the field. Many thanks go to our field guides Medgeg the fisherman and Cyril Tman.

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PLATE I

Fig. 2. *Acropora formosa* stand forming a patch reef in Tomil Harbor. *A. formosa* was common on nearly every reef surveyed and was often the predominant species. Patch reefs, such as this one, were composed of only a few species.

Fig. 3. Two colonies of *Parahalomitra robusta* lay on *Porites* rubble in -10 m of water at NW-1. *P. robusta*, a new record for Yap, occurred only at this site.

Fig. 4. This photograph shows the channel edge (-3 m) at barrier reef pass SW-1. *Acropora* and *Pocillopora* species are abundant. Barrier reef passes were among the most diverse of the communities sampled.

Fig. 5. A colony of *Montipora informis* (also upper right) has settled and begun to grow on a large *Porites andrewsi* colony on the reef edge of enclosed lagoon W-3.

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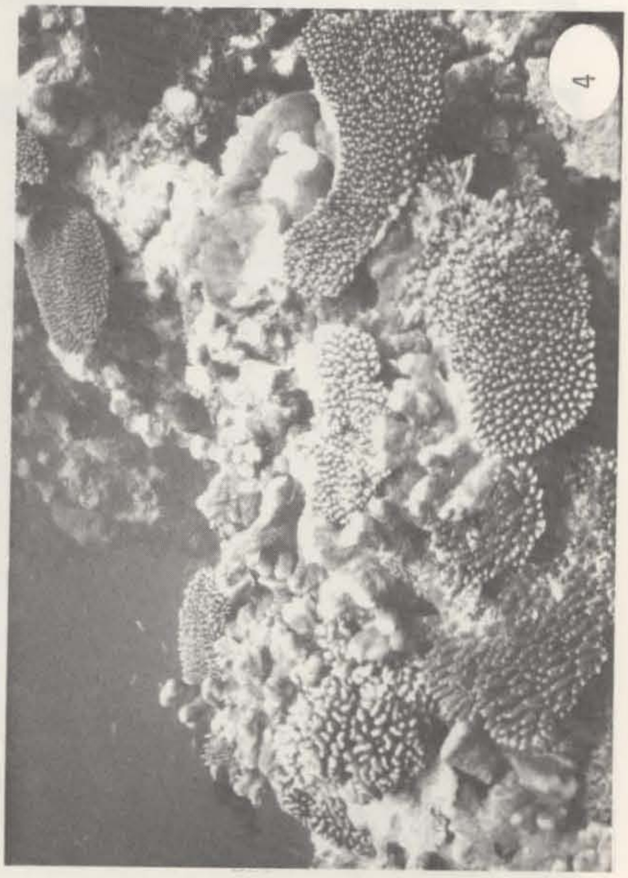

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PLATE II

Fig. 6. Leptoria phrygia in enclosed lagoon NE-1. This species occurred on many reefs throughout the lagoon.

Fig. 7. Porites andrewsi was found on nearly every reef surveyed in the lagoon. The lemon-lime green and grey color varieties were prevalent.

Fig. 8. Foliaceous Turbinaria sp. and Clavarina scrabicula (ramose species) were observed at NE-1.

Fig. 9. Stylophora mordax (center), Acropora sp. (right and left) and Favia stelligera (in front of S. mordax) were found at NE-1. S. mordax was a common species on many reefs and was often grazed by fish.

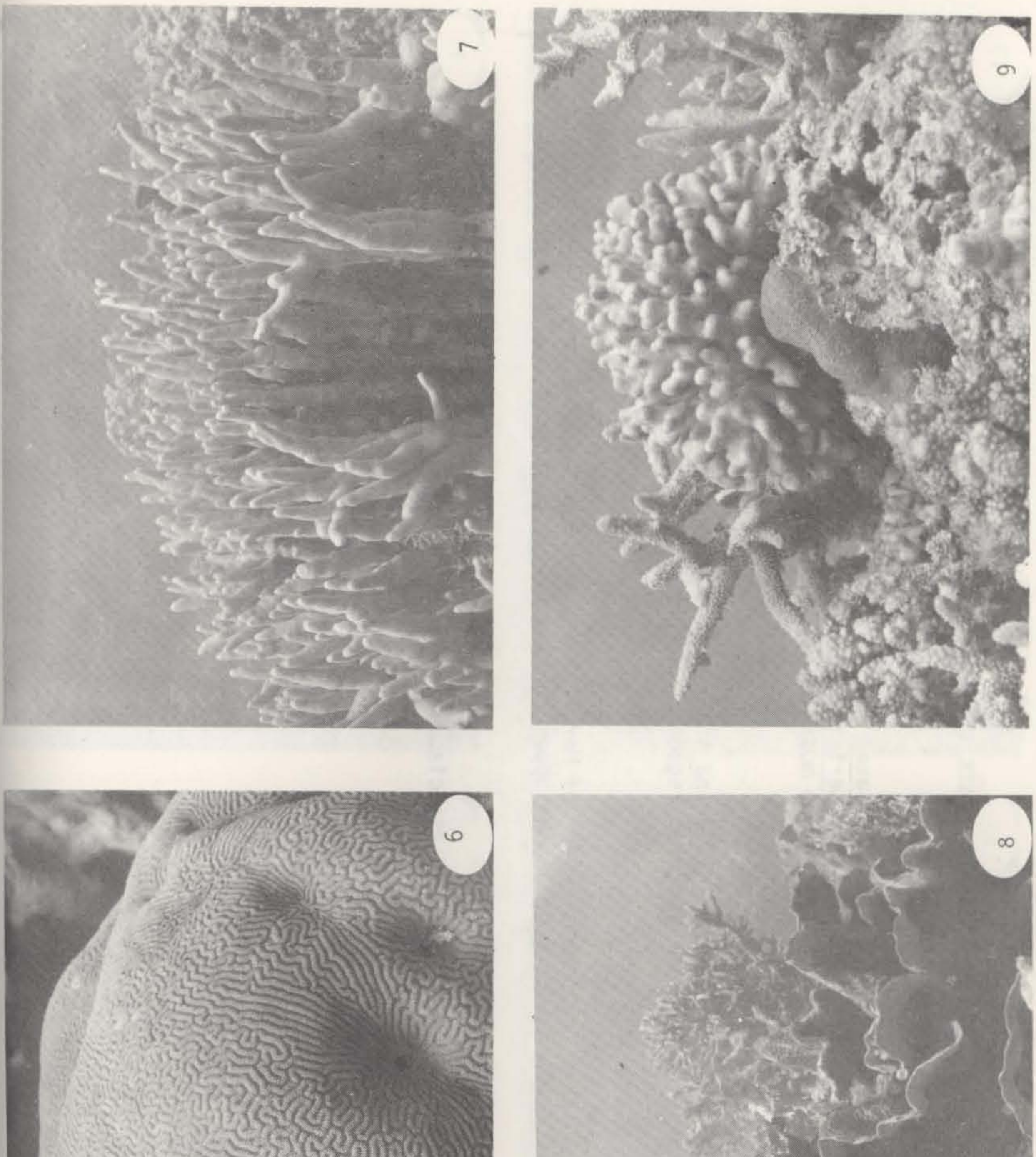
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PLATE III

Fig. 10. *Seriatopora hystrix* and *Galaxea fascicularis* (lower left) occurred in enclosed lagoon NE-2. *Seriatopora hystrix* was a common to locally abundant species on most lagoon reefs.

Fig. 11. Localized stands of *Clavarina scrabicula* were common on reef flats near many of the enclosed lagoons.

Fig. 12. A large foliaceous colony of *Merulina vaughani* at NE-2. Massive *Porites* can be seen in the upper portion of the photograph.

Fig. 13. *Acropora kenti* and its associate *Dascyllus reticulatus* at NE-2.

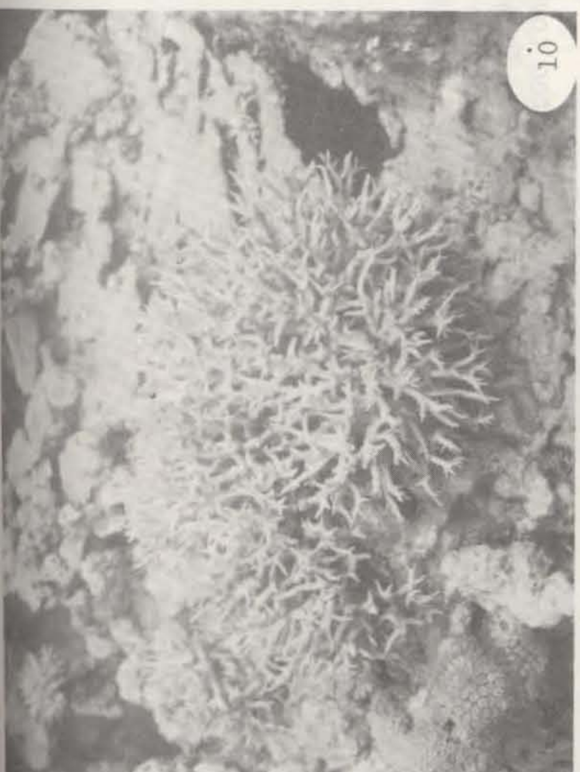
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PLATE IV

Fig. 14. *Porites andrewsi*, a massive *Porites* sp. and *Diploastrea heliopora* (upper left) in enclosed lagoon NE-2.

Fig. 15. *Millepora dichotoma* and associated *Chromis caerulea* were common on most reefs in the lagoon. The photo was taken in NE-2.

Fig. 16. A large colony (4 m diameter) of *Diploastrea heliopora* at NE-2. Although *D. heliopora* was not common on all reefs, the few colonies encountered were always large.

Fig. 17. Alcyonacean corals often covered large areas of reef flat surface near the lagoon holes. These soft corals of the genus *Sinularia* were photographed on the reef flat near NE-2.


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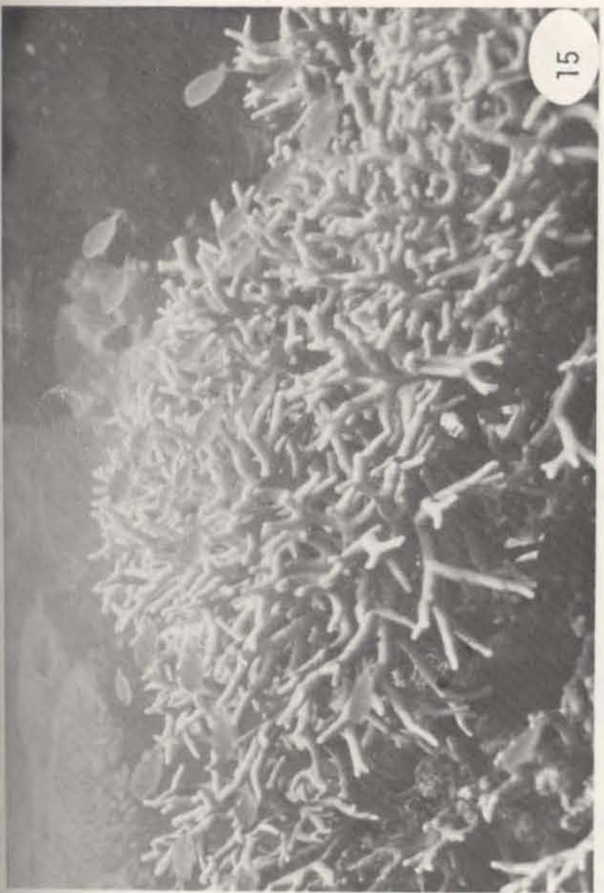
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FIELD OBSERVATIONS OF THE GASTROPOD AND BIVALVE MOLLUSCS OF YAP

Barry D. Smith

INTRODUCTION

Field observations of gastropod and bivalve molluscs were carried out in coordination with studies of corals, fishes, algae, and plankton. Specimens were observed or collected by means of snorkeling in shallow areas of the reef flat and by means of snorkeling or scuba diving in deeper holes and channels. Specimens are deposited at the Marine Laboratory.

FIELD OBSERVATIONS

Various areas within the Yap reef system were sampled. For purposes of living gastropods (Table 1), the reef was divided into five habitats. These areas were coral sand, live coral, seagrasses, rocky subtidal, and mangrove.

The coral sand habitat is characterized by a layer of sand 5 cm or more in depth. The most abundant sand-dwellers appeared to be ceriths (Family Cerithiidae). *Rhinoclavis aspera* and *R. fasciata* were noted in all sandy locations. Cones (Family Conidae), augers (Family Terebridae), and mitres (Family Mitridae) were commonly observed in the sand.

Cowries (Family Cypraeidae) and muricids (Family Muricidae) were commonly found in association with live corals. The cowries seemed to be more common on corals of patch reefs than on corals of shallower reef flat areas.

Grazing gastropods were predominant in seagrass beds. *Pyrene scripta* was very abundant on the seagrasses and on the sandy substratum. The tiger cowrie *Cypraea tigris* and the humped conch *Strombus gibberulus gibbosus* were commonly observed. Shells of *Atys cylindricus* and *A. naucum* were abundant among the seagrasses, but few live specimens were found.

Various species of cones were found under coral rocks and in holes of the rocky subtidal habitat. *Conus rattus*, *C. miles*, and *C. lividus* were common. The topshell *Trochus niloticus* and the vase shell *Vasum turbinellus* were also commonly noted.

Mangrove areas were characterized by an abundance of several species of ceriths and by the periwinkle *Littorina scabra*. These gastropods are intertidal on mangrove roots, and they were found above and below the water level. Several juvenile *Lambis lambis* were observed on the substratum among the mangrove roots.

Table 1 . Gastropods collected or observed on the reef flats of Yap. Asterisk (*) denotes dead specimen.

Table 1. Gastropods collected or observed on the reef flats of Yap. Asterisk (*) denotes dead specimen.

Species	HABITAT				
	Coral Sand	Live Coral	Sea-Grasses	Rocky Subtidal	Mangrove
Haliotidae					
**Haliotis* sp.					
Trochidae					
Chrysostoma paradoxum (Born)				X	
Tectus pyramis (Born)				X	
Trochus maculatus Linnaeus				X	
T. niloticus Linnaeus				X	
Stomatellidae					
**Pseudostomatella papyracea* (Gmelin)					
Turbinidae					
Turbo chrysostomus Linnaeus				X	
Neritidae					
Nerita polita Linnaeus				X	
Littorinidae					
Littorina scabra (Linnaeus)					X
Cerithiidae					
Cerithium coralium (Kiener)					X
C. echinatum (Lamarck)		X			
C. morus Bruguiere					X
C. patulum (Sowerby)					X
C. suturale Philippi			X		
C. zonatus (Wood)			X		
C. nodulosum Bruguiere				X	
Pseudovertagus aluco (Linnaeus)	X				
Rhinoclavis fasciata (Bruguiere)	X				
R. aspera (Linnaeus)	X				
R. vertagus (Linnaeus)	X				

Table 1. Continued.

Species	HABITAT				
	Coral Sand	Live Coral	Sea-Grasses	Rocky Subtidal	Mangrove
Strombidae					
Lambis lambis Linnaeus	X		X		X
Strombus gibberulus gibbosus (Roeding)			X		
*S. luhuanus Linnaeus					
*S. mutablis Swainson					
*S. urceus Linnaeus					
Hipponicidae					
Hipponix conicus (Schumacher)				X	
Cypraeidae					
Cypraea annulus Linnaeus		X			
C. caputserpentis (Linnaeus)		X			
C. cylindrica Born		X			
C. erosa Linnaeus		X			
*C. helvola Linnaeus					
*C. isabella Linnaeus					
*C. lynx Linnaeus					
C. moneta Linnaeus		X			
C. stolida (Linnaeus)		X			
C. tigris Linnaeus		X	X		
Naticidae					
Natica fasciata (Roeding)			X		
N. violacea Sowerby			X		
*Policines melanostomus Gmelin					
*P. tumidus (Swainson)					
Cymatiidae					
Cymatium muricinum (Roeding)	X	X			
*C. nicobaricum Roeding					
Gyrineum gyrinum (Linnaeus)	X	X			
Bursidae					

Table 1. Continued.

Bursidae
Bursa granularis (Roeding)

Table 1. Continued.

Species	HABITAT: Coral Sand	Live Coral	Sea-Grasses	Rocky Subtidal	Mangrove
Conidae cont'd					
Conus rattus (Hwass)		X		X	
C. sponsalis Hwass				X	
Terebridae					
Terebra affinis Gray	X				
T. dimidiata (Linnaeus)	X				
T. maculata (Linnaeus)	X				
T. subulata (Linnaeus)	X				
Architectonicidae					
Philippia radiata Roeding	X				
Pyramidellidae					
Pyramidella acus (Gmelin)	X				
Acteonidae					
Pupa solidula (Linnaeus)	X				
Bullidae					
*Bulla vernicosa Gould	X				
Atyidae					
Atys cylindricus (Helbling)			X		
*A. naucum (Linnaeus)					

Table 1. Continued.

Species	HABITAT				
	Coral Sand	Live Coral	Sea-Grasses	Rocky Subtidal	Mangrove
Colubrariidae					
Colubraria tortuosa (Reeve)	X				
Muricidae					
Chicoreus brunneus (Link)		X			
Drupa ricinus (Linnaeus)				X	
D. rubusidaeus Roeding				X	
Drupella cornus (Roeding)		X			
D. ochrostoma (Blainville)		X			
Morula biconica (Blainville)		X			
M. fiscella (Gmelin)		X			
M. granulata (Duclos)		X			
M. margaritacola (Broderip)		X			
M. spinosa (H. & A. Adams)		X	X		
**Nassa serta* (Bruguiere)					
Magilidae					
Coralliophila violacea (Kiener)		X			
Columbellidae					
**Mitrella ligula* (Duclos)					
**Pyrene deshayesii* (Crosse)					
P. scripta (Lamarck)			X		
Buccinidae					
Cantharus fumosus (Dillwyn)					X
Nassariidae					
Nassarius graniferus (Kiener)	X				
**N. papillosus* (Linnaeus)					
Fasciolariidae					
Latirus polygonus barclayi (Reeve)				X	

Table 1. Continued.

Species	HABITAT: Coral Sand	Live Coral	Sea-Grasses	Rocky Subtidal	Mangrove
Olividae					
Oliva annulata Gmelin	X				
Vasidae					
Vasum turbinellus (Linnaeus)				X	
Harpidae					
**Harpa amouretta* (Roeding)					
Mitridae					
Imbricaria olivaeformis (Swainson)	X				
I. punctata (Swainson)	X				
Mitra imperialis Roeding				X	
Neocancilla papilio (Link)	X				
**Pterygia* sp.					
Vexillidae					
Vexillum cruentatum Gmelin			X		
V. gruneri (Reeve)			X		
**V. plicarium* (Linnaeus)					
**V. rugosum* (Gmelin)					
Conidae					
Conus arenatus (Hwass)	X				
C. capitaneus Linnaeus				X	
C. coronatus Gmelin				X	
C. distans Hwass				X	
**C. ebraeus* Linnaeus					
**C. eburneus* Hwass					
C. lividus Hwass				X	
C. leopardus Roeding			X		
C. magus Linnaeus		X			
C. marmoreus Linnaeus	X	X			
C. musicus Hwass				X	
C. miles Linnaeus				X	
C. pulicarius Hwass	X				

Table 2 presents a checklist of bivalve molluscs observed or collected during this study. Bivalve habitats were designated as free-swimming, sand, attached to the substratum, and unattached.

Free-swimming and sand-dwelling bivalves appeared to be scarce. This impression may be caused by the difficulty of locating them. Free-swimming species, such as Limea fragilis, live under rocks. When disturbed, they propel themselves through the water by rapid open-and-close movements of their valves.

The sand-dwelling species are active burrowers in sandy areas of the reef flat. Several species of cockles (Family Cardiidae), sunset shells (Family Tellinidae), and Venus shells (Family Veneridae) were found, but they were not abundant.

Among the bivalves, those attached to the substratum were most conspicuous. Lopha cristagalli was widespread and common under coral ledges. Several small specimens of Tridacna spp. were noted on patch reefs, but no large ones were observed. Other species of attached bivalves were present in only small numbers.

A single specimen of Hippopus hippopus was found in shallow water on a patch reef. Adults of this species have no means of attachment to the substratum. As a result they are especially vulnerable to removal by man.

ECONOMIC VALUE

Many of the molluscs observed in this study are of some economic value. Some are important as food, while others are valued in tourism and in industry.

Edible species include the giant clams (Family Tridacnidae) and the topshell Trochus niloticus. While several small tridacnids were seen on patch reefs, only one large specimen was found. Glude (1972) reported that local residents collect large tridacnids when they find them, but that due to their scarcity these clams are not considered a staple article of food or of commerce. The relatively high mortality and slow growth rate of giant clams (Yamaguchi, 1977) plus collecting pressure on the population may make it desirable to impose a catch limit for these species. Other bivalves of Yap are edible, but their small sizes and low densities restrict their importance.

Yap is one of only three island groups of Micronesia in which Trochus niloticus is indigenous (McGowan, 1956). The animal may be eaten raw or cooked, but the shell is the portion of greater economic importance. Because of the thickness and strength of its shell, Trochus is valuable in the mother-of-pearl industry, in which it is processed into buttons for clothing.

Table 2. Bivalves collected or observed on the reef flats of Yap.

SPECIES	HABITAT			
	Free-Swimming	Sand	Attached to Substratum	Unattached
Arcidae				
Barbatia bicolorata (Dillwyn)			X	
Barbatia sp.			X	
Mytilidae				
Mytilus sp.			X	
Pteriidae				
Pinctada maculata (Gould)			X	
Pectinidae				
Chalamys squamosa (Gmelin)			X	
Pecten spp.	X			
Pedum spondyloideum (Gmelin)			X	
Spondylidae				
Spondylus spp.			X	
Limidae				
Limea fragilis (Gmelin)	X			
Ostreidae				
Dendostraea sp.			X	
Lopha cristagalli (Linnaeus)			X	
Cardiidae				
Vasticardium alternatum (Sowerby)		X		
Vasticardium spp.		X		
Tridacnidae				
Hippopus hippopus (Linnaeus)				X
Tridacna maxima (Roeding)			X	
T. squamosa Lamarck			X	
Tellinidae				
Quidnipagus palatum Iredale		X		
Veneridae				
Lioconcha fastigiata (Sowerby)		X		
L. ornata (Dillwyn)		X		
Paphia exarata Philippi		X		
Periglypha puerpera (Linnaeus)		X		

When cleaned properly, most gastropod and bivalve shells are prized by tourists as souvenirs of their visit. This is especially true of brightly colored and nacreous shells, such as cowries, cones, and pearl oysters (Family Pteriidae). If collection data is provided with the individual shells, they are also avidly sought by malacologists throughout the world.

Other species, especially cowries, are important as ornaments on handcrafted items. These articles are, in turn, an asset to the promotion of tourism.

The lists of gastropods and bivalves observed in this study are incomplete at best. Further studies should add more species and should provide estimates of the population densities of the predominant species.

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QUALITATIVE ASSESSMENT OF THE ECHINODERMS IN YAP LAGOON

Deborah A. Grosenbaugh

INTRODUCTION

A limited amount of work has been done on the echinoderm population of Yap. Two previous technical reports (Amesbury et al., 1976, 1977) list 16 echinoderms observed in two localized areas: one at the Donitsch Island sewer outfall site and the other at a proposed dock site in Colonia, Yap. No other observations on this group of macroinvertebrates have been reported for Yap (L. G. Eldredge, pers. comm.). This paper provides a qualitative assessment of the echinoderm population in the Yap Lagoon, with particular reference to the holothurians.

The author wishes to acknowledge L. G. Eldredge and C. E. Birkeland for their aid in the identification of some of the echinoderms encountered in this study and for reviewing the manuscript, and R. L. Kock for providing the data concerning the stomach contents of Mespilia globulus and Tripneustes gratilla. Identification of most holothurians was obtained from Rowe and Doty (1977).

METHODS

The observations made here were done during the course of a general reef survey, conducted during July 9-20, 1977, which covered a major portion of the reef flat in the Yap Lagoon. Most observations were made as a result of towing the observerfrom a small boat in a zigzag pattern from the seagrass beds near shore to the barrier reef margin. When unusually conspicuous populations of echinoderms (particularly holothurians) were noted, a closer examination was made by snorkeling in the area. Periodically, more detailed observations of randomly chosen areas were made in order to note less conspicuous species.

Two 30 m transects were run in a Thalassia hemprichii bed just east of Bik Island in Tomil Harbor. In this case, all echinoderms 0.5 m on either side of a 30 m long transect line were enumerated.

RESULTS AND DISCUSSION

Four zonal habitats (seagrass, seagrass-live corals, live corals, and dead coral pavement) characterize the reef flats in the Yap Lagoon. The seagrass zone is characterized by thick beds of Thalassia, Enhalus, and Cymodocea adjacent to shore, becoming patchy and interspersed with live coral heads (predominately Porites) as one progresses out toward the reef margin. This transitional zone is referred to as the seagrass-live coral zone in this paper. As the seagrass becomes less dominant, other corals (notably Acropora) along with the Porites form a live coral zone. Near the reef margin, the live corals become replaced by dead coral pavement. Table 1 lists the various echinoderms found in these

Table 1. Checklist of echinoderms observed in the various reef flat zones and other habitats in Yap Lagoon. (1. seagrass zone, 2. seagrass-live coral zone, 3. live coral zone, 4. dead coral pavement zone, 5. patch reefs in Tomil, Mil, and Gofenu Harbors, 6. holes in reef flat, 7. Tomil Harbor Channel).

	Reef Flat Zones				Other Habitats		
Species	1	2	3	4	5	6	7
Class Asteroidea							
Acanthaster planci (Linnaeus)					X		
Culcita novaeguineae Müller & Troschel		X		X	X	X	
Echinaster luzonicus (Gray)			X	X			
Fromia milleporella (Lamarck)						X	
Linckia laevigata (Linnaeus)				X			
Linckia multifora (Lamarck)			X				
Protoreaster nodosus (Linnaeus)	X						
Class Echinoidea							
Diadema setosum (Michelin)			X		X	X	
Echinothrix calamaris (Pallas)				X			
Heterocentrotus mammillatus (Linnaeus)				X			
Mespilia globulus (Linnaeus)	X					X	
Tripneustes gratilla (Linnaeus)	X						
Class Holothuroidea							
Actinopyga echinites (Jaeger)	X						
Bohadschia argus Jaeger					X		X
Bohadschia sp.	X						
Holothuria atra Jaeger	X	X		X	X		
Holothuria axiloga Clark							X
Holothuria edulis Lesson	X	X			X	X	
Holothuria hilla Lesson	X						
Holothuria flavomaculata Semper	X	X	X		X	X	
Holothuria leucospilota Brandt		X	X		X	X	
Holothuria nobilis (Selenka)		X					
Stichopus chloronotus Brandt	X	X			X	X	
Stichopus variegatus Semper	X				X		
Thelenota ananas (Jaeger)							X
Class Ophiuroidea				X			

four habitats, as well as those found on patch reefs, holes, and channel.

The densest populations of echinoderms on the reef flat occur in the seagrass beds adjacent to land, though not all of the seagrass beds surveyed exhibited obvious numbers of echinoderms. Holothurians in the seagrass beds were either absent, rare (1-2 seen per hour of snorkeling), or unusually abundant.

Table 2 presents the results of the two 30 m long transects (1-m wide) run in the seagrass bed. Transect A was located adjacent to Tomil Harbor channel and southeast of Bik Island. Transect B was situated just east of the island. The major components in both cases were the echinoid Mespilia globulus (Fig. 1) and the holothurian Actinopyga echinites (Fig. 2). The unusually large numbers of M. globulus present had covered themselves with seagrass detritus. Examination of the stomach contents of 25 M. globulus and four Tripneustes gratilla that were also present, revealed that Thalassia was the only food item ingested. Actinopyga echinites seemed to be feeding primarily on the detritus. In some cases. A. echinites could be seen feeding on the detritus that was attached to M. globulus . Actinopyga echinites exhibited the clumped distribution referred to by Amesbury et al. (1976), being found often in "piles" of five or more in close association. One small dark red holothurian, which the author could not identify, was observed in Transect A.

In another Thalassia bed off Pekel Island in Tomil Harbor, Actinopyga echinites was also abundant, exhibiting the same tendency toward clumping that was observed earlier. Also present but not as abundant were Stichopus variegatus and S. chloronotus and a variety of occasionally observed holothurians such as Holothuria hilla, H. atra, and the asteroid Protoreaster nodosus (Fig. 3), along with the scyphozoan medusa Cassiopeia sp. Large population densities of H. atra were also noted in an Enteromorpha bed west of Thilimad Island, near the northern tip of Map Island. Only one synaptid was observed during the entire survey, in a seagrass bed off the northeast corner of Map.

As one progresses out toward the reef margin into the seagrass-live coral zone, Holothuria edulis replaces Actinopyga echinites as the predominant holothurian species. Stichopus chloronotus was usually present in this zone, but, as in the seagrass zone, was not particularly common. It was seen mostly in sandy areas between coral heads. Holothuria leucospilota was occasionally seen with the anterior part of its body extended out from under the Porites heads. Other holothurians observed in the seagrass-live coral zone were an occasional Holothuria atra, H. nobilis, H. flavomaculata. The "cushion starfish" Culcita novaeguineae was also seen.

In the live coral zone, the asteroids Linckia multifora, Fromia milleporella, and Echinaster luzonicus, along with the echinoid Diadema setosum, were common in among the Acropora, and under Porites heads. Holothuria leucospilota was seen, as in the seagrass-live coral zone, extending out from under Porites heads, whereas H. flavomaculata was common in close association with stands of Acropora.

Table 2. Density of echinoderms along two 30-m long transects (1-m wide) in a *Thalassia* bed off Bik Island, Tomil Harbor, Yap.

	A	B
Actinopyga echinites	164	450
Mespilia globulus	34	245
Holothuria edulis	11	3
Protoreaster nodosus	9	4
Holothuria atra	4	2
Stichopus chloronotus	2	4
Holothuria hilla	1	1
Unidentified holothurian	1	-
Holothuria flavomaculata	-	4
Tripneustes gratilla	-	1

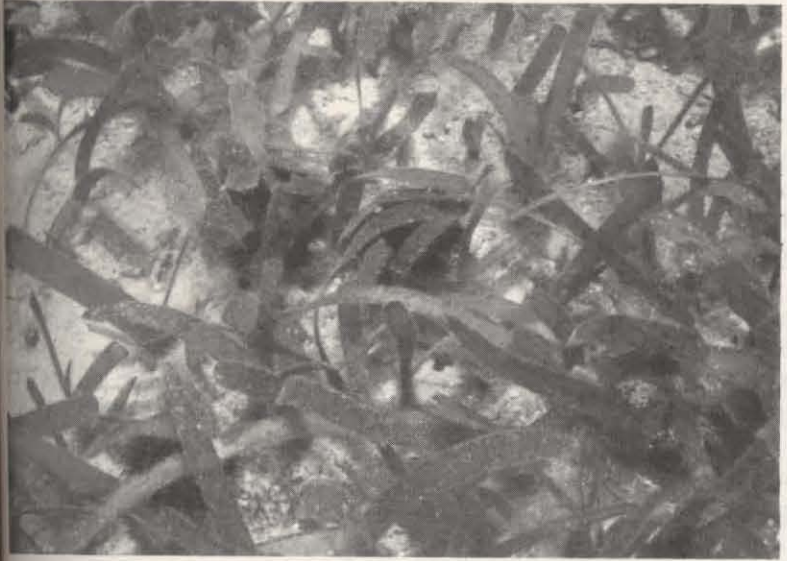

Fig. 1. Mespilia globulus in Thalassia bed.

Fig. 2. Actinopyga echinites in Thalassia bed.

Fig. 3. Protoreaster nodosus in Thalassia bed.

In the dead coral pavement zone out near the reef margin, only an occasional Holothuria atra represented the holothurians. The only other obvious echinoderms were Linckia laevigata and Culcita novaeguineae. The majority of the echinoderms in this zone were found in coral rubble and under rocks. These include an unidentified ophiuroid, Echinaster luzonicus, Echinothrix calamaris, and Heterocentrotus mammillatus.

Besides the general zonation across the reef flat, there exist distinct echinoderm populations in the deep holes that occur on the reef flat, and on patch reefs in the various harbor entrances. The holes are surrounded by a Porites-Acropora type community and the echinoderm fauna corresponds thusly. As the sides of the holes slope downward to a sandy bottom, those holothurians which inhabit sandy substrate are seen, e.g., Holothuria edulis and Bohadschia argus.

Patch reefs in the three major harbors (Tomil, Mil, Gofenu) provide a diverse environment for a variety of echinoderms. Sandy areas with some seagrass are interspersed between areas of high coral density. The sandy areas of these reefs include the holothurians Holothuria edulis, H. atra, Stichopus chloronotus, S. variegatus, and Bohadschia argus. The holothurians H. flavomaculata and H. leucospilota were found associated with the corals Acropora and Porites, respectively. The echinoid Diadema setosum and the asteroid Fromia milleporella were found in the coral while Culcita novaeguineae was often observed in sandy patches between corals. On the downward slope of these patch reefs and along channels, the larger detritus-feeding holothurians, i.e., Thelenota ananas, Bohadschia argus, and Holothuria axiloga, were located.

While holothurians of major economic importance were identified within the reef flat (Thelenota ananas, Bohadschia argus, Holothuria nobilis), they were not observed to be present in such quantities that would made their export profitable. The Yapese, themselves, are not overly fond of the delicacy, but the Palauan community of Yap does occasionally utilize the above-mentioned species as a food source as well as Actinopyga echinites which is found in considerable abundance in some of the seagrass areas. Since the Palauan community is situated in the Colonia area, only edible holothurians in the Tomil Harbor area are likely to be harvested because of the strict reef tenure on Yap, where the various villages have exclusive fishing rights on designated areas of the reef.

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DISTRIBUTIONAL ANALYSIS OF THE FISHES ON THE REEFS OF YAP

Steven S. Amesbury

INTRODUCTION

Tropical reefs are typically inhabited by a large number of species of reef fishes. The species richness of a particular reef system can be decomposed into three separate components:

1) point diversity--the number of fish species that can coexist in an arbitrarily small area of the reef within which interspecific interaction commonly occur;

2) Intrazonal diversity--the number of species that live within a given environmental zone or subdivision of a reef; this is greater than point diversity because of environmental heterogeneity within zones and because of the occurrence of more or less ecologically equivalent species at different locations within the same zone; and

3) Interzonal diversity--the combined diversity of all the ecologically distinct subdivisions of the reef system.

The first two components, point diversity and intrazonal diversity, can be considered to be aspects of "within habitat" diversity and have recently been discussed by Smith and Tyler (1972), Sale and Dybdahl (1975), and Sale (1977). The third component, interzonal or "between-habitat" diversity, has been investigated by Goldman and Talbot (1976) at One Tree Island Reef in the Great Barrier Reef. They recognized five distinct zones on this reef and found that each zone had a relatively distinct fish fauna. Of the 395 species collected, only 7% were found in all five zones and 49% were restricted to one or another of the five zones. The high degree of between-habitat diversity of the fish community at the One Tree Island Reef was contrasted with Tutia Reef on the East African coast (Talbot, 1965, and unpublished data) where more species of fishes were shared between samples collected in different reef habitats. The work of Chave and Eckert (1974) at Fanning Island indicates that high between-habitat diversity is an important feature of the reef fish fauna on this reef system with only 6.5% of the species observed being broadly distributed among reef zones. Hiatt and Strasburg (1960) stated that certain characteristic associations of fishes were ecologically tied to particular habitats on Marshall Island reefs, and they listed species which were characteristically found in several reef environments. Hobson (1974) noted that distinctive assemblages of fishes are found within various reef habitats in his study area in Kona, Hawaii, and he listed the ten most frequently seen species in each of five reef habitats.

The present study examines the distributional ranges of reef fish species among physiographic/biotic zones of the reef system of Yap in the Western

Caroline Islands. The reef zones surveyed (barrier reef front, barrier reef embayments, barrier reef pass, lagoon, reef flat, and seagrass-dominated areas) are major subdivisions of the reef system and provide characteristic combinations of environmental conditions to which resident species must be adapted.

METHODS

STUDY AREA

The four main islands of Yap are nearly contiguous and are surrounded by a single, continuous reef system (Figure 1). A conspicuous feature of this reef is the extent to which the lagoon has been filled in by sedimentation and reef development so that, at the present time, the lagoon consists largely of many completely enclosed remnant lagoons, isolated from one another by reef flat areas. As a result of lagoon filling, the fringing reef, extending outward from the shores of the islands, has become confluent with the landward margin of the barrier reef. The enclosed remnant lagoons are of various sizes and depths, and all except the very smallest have sandy floors. The margins of many of these enclosed lagoons are completely rimmed with coral, and there is no noticeable demarcation between the landward and seaward margins. Other enclosed lagoons have coralliferous shoreward margins and sandy seaward rims. The barrier reef in some locations is sharply indented forming barrier reef embayments. These embayments lack deep water connections with lagoon areas, but are somewhat more protected than is the barrier reef front itself. At several places the barrier reef is penetrated by passes which directly connect the lagoons with the oceanic water outside the barrier reef. The reef flat exhibits a broad pattern of zonation. An extensive belt of seagrass, dominated by _Thalassia hemprichii_ and _Enhalus acoroides_ occupies the shoreward portion of the reef flat. This gives way to a sand and coral zone which may extend out to the barrier reef or it may give way to a predominantly sandy zone with scattered algae and corals. In the areas surrounding the lagoon remnants the reef flat supports luxuriant coral growth. There were rather extensive lagoon areas on the southeast reef in which the substrate was almost entirely made up of sand, with occasional scattered mounds of coral (_Acropora_, _Porites_, and _Pocillopora_). These areas were approximately 10 to 15 m deep and were located seaward of the coral-rimmed enclosed lagoons.

FISH SURVEY

Between July 7 and July 21, 1977, a visual survey of the fishes of the Yap reef was made. During dives of 20-to 60-minutes duration at each of 54 sites throughout the reef system, lists were made of all fish species observed. Additional information from other sites where incomplete species lists were made, as well as information from two previous studies on Yap (Amesbury et al., 1976; Amesbury et al., 1977), has also been included to provide more complete information on species distributions. All surveys were performed with snorkeling gear, with the exception of one barrier reef front dive in which scuba gear was used, and for this reason fishes living deeper than 15 meters were not adequately surveyed. The

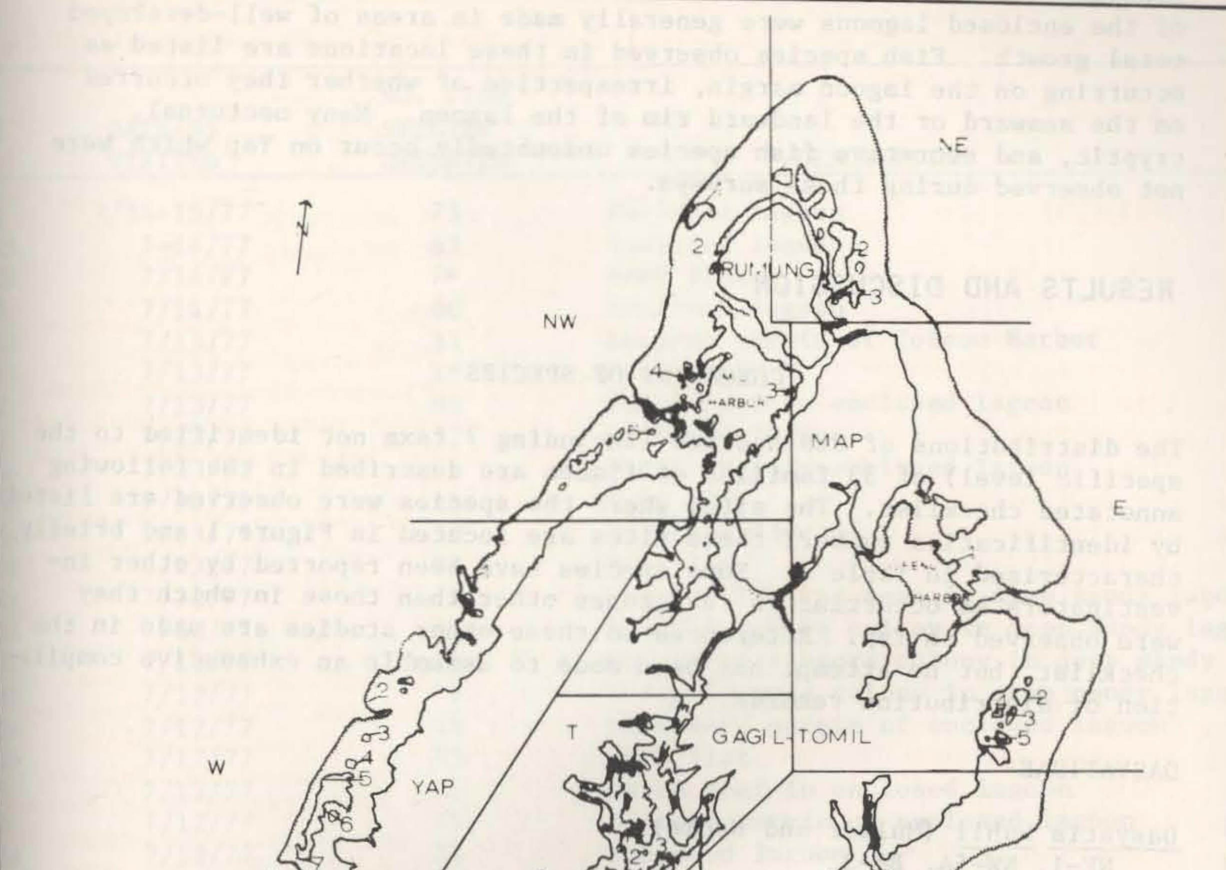

Fig. 1. Locations of fish survey sites on Yap. The reef system is divided into seven sectors (NE, E, SE, SW, NW, W, and T=Tomil Harbor area). Sites are numbered separately within each sector as are the sites on the barrier reef front (BR).

preponderance of the surveys were made in lagoon and reef flat areas, and only two surveys each were made in barrier reef pass, barrier reef embayment, and barrier reef front environments. Surveys of the margins of the enclosed lagoons were generally made in areas of well-developed coral growth. Fish species observed in these locations are listed as occurring on the lagoon margin, irrespective of whether they occurred on the seaward or the landward rim of the lagoon. Many nocturnal, cryptic, and secretive fish species undoubtedly occur on Yap which were not observed during these surveys.

RESULTS AND DISCUSSION

CHECKLIST OF SPECIES

The distributions of 208 species (including 7 taxa not identified to the specific level) of 33 families of fishes are described in the following annotated checklist. The sites where the species were observed are listed by identification number; these sites are located in Figure 1 and briefly characterized in Table 1. Some species have been reported by other investigators as occurring in reef zones other than those in which they were observed on Yap. References to these other studies are made in the checklist, but no attempt has been made to assemble an exhaustive compilation of distribution records.

DASYATIDAE

Dasyatis kuhli (Muller and Henle)
NE-1, NW-5A, BR-2

Large individuals of this species were seen lying in sandy areas in lagoons and on the barrier reef front. The individuals seen were not apparently engaged in feeding activities and were lying motionless, partially covered by a thin layer of sand.

MYLIOBATIDAE

Aetobatus narinari (Euphrasen)
NE-1

A school of 42 large individuals was seen swimming "in formation" in one of the lagoons.

SYNODONTIDAE

Saurida gracilis (Quoy and Gaimard)
SE-2A, SW-2A, SW-5A

This cryptic species was no doubt more common than the few observations reported here would suggest. It was seen among the corals of the lagoon margin and in the Gabach barrier reef pass. It is likely that further observations in Yap will disclose additional lizard fish species.

Table 1. Fish survey sites on Yap. Asterisk denotes fish counts at sites where enumeration of species was not attempted.

SITE NO.	DATE(S) VISITED	NO. FISH SPECIES OBSERVED	DESCRIPTION
NE-1	7/14-15/77	73	Enclosed lagoon
NE-2A	7-14/77	62	Enclosed lagoon
NE-2B	7/14/77	7*	Reef flat
NE-3	7/14/77	60	Enclosed lagoon
E-1A	7/13/77	51	Seaward margin of Gofenu Harbor
E-1B	7/13/77	1*	Reef flat
E-2	7/13/77	66	Patch reef in enclosed lagoon
E-3	7/13/77	52	Enclosed lagoon
E-4A	7/13/77	61	Patch reef in enclosed lagoon
E-4B	7/13/77	16	Reef flat
E-5A	7/13/77	50	Enclosed lagoon
E-5B	7/13/77	29	Reef flat
SE-1A	7/12/77	5	Massive _Porites_ head in deep sandy lagoon
SE-1B	7/12/77	10	Large _Acropora_ colony in deep sandy lagoon
SE-1C	7/12/77	9	Large _Pocillopora_ colony in deep sandy lagoon
SE-1D	7/12/77	7	Large _Acopora_ colony in deep sandy lagoon
SE-2A	7/12/77	46	Shoreward margin of enclosed lagoon
SE-2B	7/12/77	35	Reef flat
SE-3	7/12/77	62	Patch reef in enclosed lagoon
SE-4	7/12/77	61	Seaward margin of enclosed lagoon
SE-5A	7/12/77	31	Enclosed lagoon
SE-5B	7/12/77	49	Shallower enclosed lagoon
SE-6	7/13/77	61	Coral-rich reef flat with considerable topographic relief
SE-7	7/16/77	38	Reef flat
SE-8	7/ 9/77	54	Enclosed lagoon
SE-9A	7/ 9/77	38	Enclosed lagoon
SE-9B	7/ 9/77	34	Reef flat
SW-1	7/10/77	19	Nearshore lagoon margin; poor visibility
SW-2A	7/10/77	24	Lagoon margin; poor visibility
SW-2B	7/10/77	5*	Reef flat and seagrass; poor visibility
SW-3A	7/10/77	43	Lagoon margin
SW-3B	7/10/77	2*	Seagrass area on reef flat
SW-4	7/10/77	45	Lagoon margin
SW-5A	7/16/77	67	Barrier reef pass
SW-5B	7/16/77	43	Barrier reef pass
SW-5C	7/16/77	35	Coral rich reef flat with sand channels
NW-1	7/15/77	64	Enclosed lagoon
NW-2	7/15/77	21	Reef flat
NW-3A	7/15/77	62	Patch reef in Mil Harbor-margin
NW-3B	7/18/77	40	Patch reef in Mil Harbor-reef flat
NW-4A	7/18/77	51	Enclosed lagoon
NW-4B	7/18/77	60	Enclosed lagoon
NW-5A	7/18/77	55	Enclosed lagoon

Table 1. continued

SITE NO.	DATE(S) VISITED	NO. FISH SPECIES OBSERVED	DESCRIPTION
NW-5B	7/18/77	1*	Reef flat
W-1	7/20/77	59	Barrier reef embayment
W-2A	7/20/77	39	Barrier reef embayment
W-2B	7/20/77	6*	Reef flat
W-3	7/20/77	63	Enclosed lagoon
W-4	7/19/77	56	Enclosed lagoon
W-5	7/19/77	53	Enclosed lagoon
W-6	7/19/77	65	Enclosed lagoon
W-7A	7/19/77	52	Enclosed lagoon
W-7B	7/19/77	45	Enclosed lagoon
W-8	7/16/77	51	Enclosed lagoon
W-9A	7/16/77	55	Enclosed lagoon
W-9B	7/16/77	20	Reef flat
W-10	7/16/77	76	Enclosed lagoon
T-1A	7/ 9/77	9*	Lagoon fringing reef margin
T-1B	7/ 9/77	15*	Lagoon fringing reef margin
T-1C	7/ 9/77	6*	Reef flat
T-1D	7/ 9/77	5*	Reef flat
T-1E	7/ 9/77	7	Seagrass
T-2	7/ 9/77	1*	Patch reef in Tomil Harbor
T-3	7/21/77	5	Seagrass
T-4	3/ 6/77	26	Lagoon fringing reef margin
T-5A	3/4-6/77	5*	Seagrass
T-5B	3/4-6/77	16*	Reef flat
T-5C	3/4-6/77	9*	Lagoon fringing reef margin and slope
T-6A	1/3-5/76	14*	Seagrass
T-6B	1/3-5/76	24*	Reef flat
T-6C	1/3-5/76	28*	Lagoon fringing reef margin and slope
T-7	7/10/77	1*	Bank of Chamorro Bay
BR-1	7/16/77	49	Barrier reef front
BR-2	7/21/77	84	Barrier reef front

HOLOCENTRIDAE

Adioryx caudimaculatus (Ruppell)
BR-2

This species was only observed once under a ledge on the barrier reef front. Chave and Eckert (1974) saw it in the barrier reef pass at Fanning Island.

Adioryx spinifer (Forskal)
E-1A, E-2, E-5A, SE-2A, SE-4, SE-8, SE-9A, W-3, W-4, W-5, W-6, W-10

All observations of this species were on lagoon margins where plentiful cover was available. Jones and Chase (1975) observed this species in association with the barrier reef on Guam as did Chave and Eckert (1974) at Fanning Island.

Flammeo sp.
NE-2A, E-2, E-3, E-4A, E-5A, SE-1D, SE-2A, SE-8, SE-9A, NW-1, W-1, W-2A, W-3, W-4, W-6, W-7A, W-8, W-9A, W-10, BR-1

There are probably several species of this genus in Yap. Individuals were seen in lagoon margin, barrier reef embayment, and barrier reef front environments, sheltered within protected holes and coral formations.

Myripristis sp.
NE-1, NE-3, E-2, E-5A, SE-2A, SE-3, SE-4, SE-6, SE-8, SE-9A, SW-5A, SW-5B, NW-1, NW-4A, NW-4B, NW-5A, W-1, W-5, W-6, W-7A, W-8, W-9A, W-10, BR-1, BR-2

This genus is also represented by several species on Yap. During the day they are sheltered in the reef in lagoon margin, barrier reef pass, barrier reef embayment, and barrier reef front environments. The reef flat observation was made in an area of rich coral growth and considerable topographic relief.

Holocentrid species are generally active nocturnally, retreating into crevices and protected holes in the reef during the daylights hours (Hiatt and Strasburg, 1960; and others). Nighttime observations are required to ascertain their ranges of activity among reef zones.

AULOSTOMIDAE

Aulostomus chinensis (Linnaeus)
NE-1, NE-3, SE-5A, SE-9A, NW-1, NW-4A, W-3, W-4, BR-1

Individuals of this species were seen associated with lagoon margins and on the barrier reef front. Jones and Chase (1975) observed this species in seagrass environments on Guam.

FISTULARIIDAE

Fistularia petimba Lacepede
E-4A

This species was observed once on a patch reef in an enclosed lagoon. Randall (1955) observed this species in a somewhat broader range of habitats in the Gilbert Islands, including seagrass flats, lagoon area, and outer reef flat tide pools. It was seen on a barrier reef flat on Guam (Jones and Chase, 1975) and in the barrier reef pass at Fanning (Chave and Eckert, 1974).

SCORPAENIDAE

Pterois lunulata Temminck and Schlegel
NW-5A

A single individual was seen under a reef overhang on one of the lagoon margins.

With the notable exception of Pterois, most scorpionfishes tend to be camouflaged and are not readily noticed in coralliferous environments. Some species are active nocturnally (Hobson, 1974). This probably accounts for the low number of scorpaenid species observed during this survey; undoubtedly many more occur in Yap.

SERRANIDAE

Cephalopholis argus Bloch and Schneider
SW-5B

This was seen only once in the Gabach barrier reef pass. Randall (1955) reported it as occurring in many different habitats in the Gilbert Islands. Chave and Eckert (1974) observed it in lagoon and barrier reef habitats at Fanning, and it occurred outside the barrier reef at Canton Island (Grovhoug and Henderson, 1976).

Cephalopholis urodelus (Bloch and Schneider)
SE-3, SW-4, W-3, BR-1, BR-2

This species was observed on the lagoon margin and barrier reef front.

Epinephelus merra Bloch
E-2, E-5A, SE-2A, SW-5A, W-4, W-9A, W-10

This species was seen in lagoon margin habitats and in the Gabach barrier reef pass. It occurred in many habitats at Fanning (Chave and Eckert, 1974) and Canton (Grovhoug and Henderson, 1976).

Plectropomus leopardus (Lacepede)
SW-5B, BR-2

The two observations of this species were in the Gabach barrier reef pass and on the barrier reef front.

Variola louti (Forskal)
T-5C

This species was seen once near the lagoon fringing reef margin on the north side of Colonia peninsula. It was associated with the barrier reef at Fanning (Chave and Eckert, 1974).

Groupers tend to conceal themselves during the day, lying in ambush for unwary prey (Hiatt and Strasburg, 1960). They are probably represented by more species in Yap than were recorded during this survey.

APOGONIDAE

Apogon cf. lateralis Valenciennes
T-6A, T-6B

This species was seen in the reef flat and seagrass zone off Donitsch Island in Tomil Harbor. Occasionally, large groups of up to 100 fishes were seen.

Apogon leptacanthus Bleeker
NE-1, E-1A, E-4A, SE-2A, SE-8, SE-9A, SW-2A, SW-4, NW-3A, NW-5A, W-4, W-6, W-8, W-9A, T-1A, T-4

This species was found in deeper water areas in lagoon reef margin environments where large groups were seen surrounding colonies of branching corals into which the fish would withdraw if disturbed.

Apogon trimaculatus Cuvier
SW-1, T-1C, T-1E, T-3, T-5A

This species was observed quite frequently, and almost exclusively, in seagrass environments.

Archamia zosterophora (Bleeker)
NE-2A, E-1A, SE-5B, SE-8, SE-9A, NW-3A, W-6, W-9A, T-4

The distribution and habits of this species are similar to those of Apogon leptacanthus and Sphaeramia nematoptera. On occasions, these three species were seen occupying various parts of the same large coral colony.

Cheilodipterus quinquelineatus Cuvier and Valenciennes
E-1A, SE-5A, SE-8, SE-9B, SW-1, NW-2, NW-3A, W-6, T-1C

This species was seen on reef flats and lagoon margins and was generally partially hidden beneath coral colonies. In Guam it also occurs in seagrass and in barrier reef passes (Jones and Chase, 1975). This species is broadly distributed at Canton Island (Grovhoug and Henderson, 1976).

Sphaeramia nematoptera (Bleeker)
E-1A, SE-2A, SE-5A, SE-8, NW-3A, NW-3B, W-8, T-1A, T-1C, T-1E

This species had a distribution similar to that of Apogon leptacanthus and was additionally found associated with a coral colony in a seagrass environment.

Sphaeramia orbicularis (Cuvier and Valenciennes)
T-4

Several individuals of this species were seen associated with branching coral colonies on the lagoon fringing reef margin north of Colonia Peninsula.

As most cardinalfish are nocturnally active, taking cover during the day, there are quite likely considerably more apogonid species in Yap than were seen during the surveys.

CARANGIDAE

Caranx melampygus Cuvier and Valenciennes
NE-3, E-2, SW-5A, NW-1, NW-3A, W-6, W-8, W-9A

Individuals were observed swimming in the water column in several lagoon areas and in the Gabach barrier reef pass. This species quite likely also occurs outside the barrier reef as it occurs in this type of environment in the Gilberts (Randall, 1955), Marshalls (Hiatt and Strasburg, 1960), and on Guam (Jones and Chase, 1975) and Fanning Island (Chave and Eckert, 1975).

Scomberoides sanctipetri (Cuvier and Valenciennes)
NE-1, BR-1

Small groups of 5 to 10 individuals were observed in one of the enclosed lagoons and at a location on the barrier reef front.

Jacks are generally roving predators, cruising over various parts of the reef in search of prey. In some species, periods of activity are related to time of day (Hobson, 1974) and tidal phase (Hiatt and Strasburg, 1960), and the likelihood of observing them in various reef zones depends upon the time when the survey is made.

LUTJANIDAE

Aphareus furcatus (Lacepede)
SW-5A, BR-1, BR-2

This species was seen in the Gabach barrier reef pass and on the barrier reef front. On Guam it was seen on lagoon patch reefs (Jones and Chase, 1975).

Caesio caerulaureus Lacepede
NW-3A, BR-2

Schools of this species were seen in the water column near a lagoon patch reef and outside the barrier reef.

Caesio xanthonotus Bleeker
T-5C, T-6C

This schooling species was seen off the lagoon slopes to the north and east of Colonia peninsula. Randall (1955) collected it on the outer reef terrace in the Gilbert Islands, and it was seen in this environment at Fanning by Chave and Eckert (1974).

Gaterin orientalis (Bloch)
NE-1, E-2, E-3, SE-3, SE-4, SE-5B, W-1, W-4, W-5, W-8, W-9A, W-10, BR-2

This fish was seen in deeper water lagoon and barrier reef environments.

Gaterin cf. chaetodonoides (Lacepede)
E-3, NW-1, W-6, BR-2

This species was less frequently seen than G. orientalis but generally occurred in the same types of environments.

Gnathodentex aureolineatus (Lacepede)
NE-3, E-1A, E-5A, SE-2A, SE-5B, SE-6, SE-9A, SW-5A, SW-5B, SW-5C, NW-1, NW-4A, NW-5A, W-4, W-5, W-7A, W-10, T-1B

This fish was generally observed in groups of 10 to 50. It was seen most frequently in lagoon environments and was also seen in coral-rich reef flat areas and in the Gabach barrier reef pass. This species was observed on the outer reef in the Marshalls (Hiatt and Strasburg, 1960) and in the Gilberts (Randall, 1955), and in a barrier reef pass on Guam (Jones and Chase, 1975).

Lethrinus sp. A
E-2, SE-6, NW-5A, W-3, W-7B, W-8, W-9A

This species is pale with a dark oval spot on the side. It was seen on the lagoon margin and on the reef flat.

Lethrinus sp. B
NE-T, E-2, E-3, W-4, W-5, W-9A, W-10

This was a pale fish with a mottled brown pattern on its sides. It was seen in association with the lagoon margin.

Lutjanus fulvus (Bleeker)

NE-1, NE-2A, NE-3, E-1A, E-2, E-3, E-4A, SE-1C, SE-2A, SE-5B, SE-8, SW-4, SW-5A, SW-5B, NW-3A, NW-4B, W-1, W-3, W-4, W-5, W-6, W-7A, W-8, W-9A, W-10, T-6B, BR-1, BR-2

This species was seen most frequently in lagoon environments. It was also observed in barrier reef embayments, on the barrier reef front, and, on one occasion, on a reef flat.

Lutjanus kasmira (Forskal)

NE-3, SE-1B, SE-1D

This was among the few species seen associated with deep coral mounds in sandy bottom lagoon areas. It was also seen on the lagoon margin.

Lutjanus cf. monostigmus (Cuvier and Valenciennes)

NE-1, E-3, E-5A, SE-2A, SE-2B, SE-7, SE-9B, SW-1, SW-3B, NW-4A, W-1, W-4, W-6, W-7A, W-8, W-9A, T-5A, T-6A, T-6B

Individuals referred tentatively to this species may represent more than one species which exhibit a dark oval spot on a grey body. They were seen on the reef flat, occasionally in seagrass, in lagoon environments, and in a barrier reef embayment. Chave and Eckert (1974) saw this species in barrier reef pass and front environments.

Macolor niger (Forskal)

NE-1, NE-3, E-2, E-3, NW-4B, W-1

This species was seen in association with the lagoon margin and in a barrier reef embayment.

Monotaxis grandoculis (Forskal)

NE-1, NE-2A, E-2, E-4A, SE-2B, SE-5B, SW-5A, NW-1, NW-4B, NW-5A, W-1, W-3, W-4, W-5, W-10, T-6A, BR-1, BR-2

This species occurred on the reef flat (once in association with seagrass), on the lagoon margin, in a barrier reef embayment, and on the barrier reef front. Hobson (1974) observed this species moving into shallower water at night to feed in Kona.

Scolopsis bilineatus (Bloch)

NE-1, NW-3, E-2, E-3, SE-1C, SE-6, SE-7, SW-1, SW-4, SW-5B, SW-5C, NW-4A, NW-4B

This species was seen in lagoon environments and in some coral-rich reef flat areas.

Scolopsis cancellatus (Cuvier and Valenciennes)

NE-1, NE-2B, E-2, E-4A, E-4B, E-5A, E-5B, SE-2A, SE-2B, SE-3, SE-5B, SE-7, SE-9B, SW-1, SW-2A, SW-3A, SW-4, NW-3B, NW-4B, W-5, W-7A, W-7B, W-9A, W-9B, W-10, T-5B, T-5C, T-6A, T-6B

This frequently observed species is a lagoon margin and reef flat resident, occurring occasionally in seagrass environments.

Scolopsis xenochrous Gunther
SE-2B, SE-3, SE-4, SE-5B, SE-9B, NW-3B, T-4

This species occurred in reef flat and lagoon margin environments.

MULLIDAE

Mulloidichthys auriflamma (Forskal)
NE-1, NE-2A, NE-3, E-4A, SE-5B, SE-7, SE-9A, SW-3A, SW-4A, SW-4B, W-3, W-4, W-7A, W-9A, W-10, BR-1, BR-2

This is predominantly a lagoon species although it was also seen outside the barrier reef. Randall (1955) collected a small specimen, tentatively identified as this species, in a seagrass flat.

Mulloidichthys samoensis (Gunther)
NE-1, NE-2A, NE-3, E-3, SE-1B, SE-1D, SE-4, SE-5B, SE-9A, SW-4, SW-5A, SW-5B, NW-4B, W-3, W-4, W-5, W-6, W-7A, W-8, W-9A, W-10, T-6B

This species is also most frequently found in lagoon environments, including the deep lagoon coral mound areas. Additional observations of this species were made in the Gabach barrier reef pass and on the reef flats adjacent to Colonia peninsula. It occurs in seagrass in Guam (Jones and Chase, 1975).

Parupeneus barberinoides (Bleeker)
T-5B

A single individual was seen on the reef flat near the fringing reef margin on the north side of Colonia peninsula.

Parupeneus barberinus (Lacepede)
NE-3, E-5A, SE-2B, SE-5B, SW-4, SW-5A, NW-4A, W-2A, W-9A, T-6A, BR-2

This species was observed in a variety of environments including seagrass, lagoon margin, barrier reef pass, and barrier reef front.

Parupeneus pleurostigma (Bennett)
SE-6, SW-5A, SW-5B, T-5A

Although infrequently observed, this species was seen in seagrass, reef flat, and barrier reef pass environment.

Parupeneus trifasciatus (Lacepede)
NE-1, NE-2A, NE-3, E-2, E-4A, SE-3, SE-4, SE-6, SE-8, SW-3B, SW-4, SW-5A, SW-5C, NW-1, NW-2, NW-3A, NW-3B, NW-4A, NW-4B, W-1, W-2A, W-3, W-4, W-5, W-6, W-10, T-1E, T-6A, BR-1, BR-2

This species occurred on the reef flat and in seagrass, on the lagoon margin, in the Gabach barrier reef pass, in barrier reef embayments, and on the barrier reef front. It was the most frequently observed goatfish in Yap as it was in Onotoa in the Gilberts (Randall, 1955).

PEMPHERIDAE

Pempheris sp.
NW-3A, BR-2

This species was seen in protected locations on the barrier reef front and on a lagoon patch reef. Randall (1955) has suggested that P. oualensis is nocturnal, in which case the pempherids on Yap may be more widespread on the reef than the two sightings here indicate. P. oualensis occurs in barrier reef passes on Guam (Jones and Chase, 1975).

TOXOTIDAE

Toxotes jaculator (Shaw)
T-7

Archerfish were seen along the margin of Chamorro Bay, a slightly brackish body of water subject to raw sewage discharge (Amesbury et al., 1976). This species is not a true reef fish, but rather a resident of fresh and brackish water environments.

KYPHOSIDAE

Kyphosus cinerascens (Forskal)
NE-1, NE-2A, E-1A, E-4A, SE-5A, SW-5A, SW-5B, W-1, W-2A, W-4, W-6, W-7A, W-8, W-10

This schooling species was seen in lagoon, barrier pass, and barrier reef embayment environments. It was seen on the barrier reef flat at Fanning (Chave and Eckert, 1974).

EPHIPPIDAE

Platax orbicularis (Forskal)
NE-2A, E-3, SE-5A, NW-3A

The four sightings of this species were in areas of high topographic relief in lagoon environments.

CHAETODONTIDAE

Centropyge bicolor (Bloch)
T-2, T-5C, T-6C

This species was observed in lagoon margin and lagoon slope environments within Tomil Harbor.

Centropyge tibicen Cuvier
NE-1, W-3, T-5C, T-6C

Individuals were seen associated with the lagoon margin.

Centropyge vroliki (Bleeker)
E-4A, E-5A, SE-8, SE-9A, SW-5A, SW-5B, NW-5A, W-2A, W-8, T-4, BR-2

This species was seen in lagoon margin, barrier reef embayment, and barrier reef front environments.

Chaetodon auriga Forskal
NE-1, NE-2A, NE-3, E-1A, E-2, E-3, E-4A, E-4B, E-5B, SE-1A, SE-2B, SE-3, SE-4, SE-6, SE-7, SE-8, SE-9B, SW-1, SW-2B, SW-3A, SW-4, SW-5A, SW-5C, NW-1, NW-2, NW-3A, NW-3B, NW-4A, NW-4B, NW-5A, W-2A, W-3, W-4, W-5, W-6, W-7A, W-7B, W-8, W-9A, W-9B, W-10, T-4, T-5B, T-6C, BR-2

This ubiquitous species was seen in every type of environment surveyed, including seagrass and in deep lagoon areas associated with isolated Acropora mounds. Its range of tolerance to water quality is apparently great as it was found in very silty waters as well as on the barrier reef front.

Chaetodon bennetti Cuvier and Valenciennes
NW-4B, W-8, BR-2

This rather uncommon species was seen in coral-rich lagoon margin areas and on the barrier reef front. Randall (1955) reported that this species was found in all major regions of the Onotoa Atoll, although it was not common in any. It was similarly wide-spread but uncommon at Fanning (Chave and Eckert, 1974).

Chaetodon citrinellus Cuvier and Valenciennes
NE-1, NE-2A, NE-3, E-1A, E-4A, E-5B, SE-2B, SE-6, SE-7, SW-4, SW-5A, SW-5C, NW-1, NW-2, NW-4A, NW-4B, W-1, W-2A, W-6, W-7A, W-7B, T-5B, T-6B, BR-1, BR-2

This species occurs in a variety of environments including reef flats, lagoon margins, barrier reef passes, and barrier reef front.

Chaetodon ephippium Cuvier and Valenciennes
NE-1, NE-2A, NE-3, E-1A, E-2, E-3, E-4A, E-5A, SE-2A, SE-3, SE-4, SE-5A, SE-5B, SE-6, SE-7, SE-8, SE-9A, SE-9B, SW-1, SW-4, SW-5A, SW-5B, NW-1, W-2A, W-3, W-4, W-5, W-6, W-7A, W-7B, W-8, W-9A, W-9B, W-10, T-1B, T-4, BR-1, BR-2

Although as frequently observed as C. auriga, this species did not occur in as wide a range of environments. It was not seen in seagrass areas or associated with deep isolated coral mounds, although individuals were seen in all other types of environments surveyed. Randall (1955) found it only in the lagoon at Onotoa.

Chaetodon kleini Bloch

NE-1, NE-2A, E-2, E-3, E-4A, E-4B, SE-3, SE-4, SE-5A, SE-6, SE-8, SE-9B, SW-3A, SW-5B, SW-5C, NW-1, NW-2, NW-3A, NW-4B, W-3, W-4, W-5, W-7A, W-7B, W-10, T-1B, T-4, T-5B, T-5C, T-6B, T-6C, BR-2

This species was seen in reef flat, lagoon margin, lagoon slope, barrier reef pass, and barrier reef front environments. Although widespread in Yap, this species was rare at Onotoa (Randall, 1955).

Chaetodon lineolatus Cuvier and Valenciennes

E-1A, SE-2A, SE-4, SE-5A, SE-5B, SE-6, BR-1

Although infrequent, this species was seen in several environments: reef flat, lagoon margin, and barrier reef front. It was also seen in barrier reef passes at Fanning (Chave and Eckert, 1974).

Chaetodon lunula (Lacepede)

NE-2A, NE-3, E-1A, E-2, E-3, E-4A, SE-5A, SE-8, SE-9A, SW-5A, NW-1, NW-3A, NW-4A, NW-5A, W-1, W-2A, W-3, W-5, W-6, W-8, BR-1, BR-2

This species was seen in lagoon margin, barrier reef pass, barrier reef embayment, and barrier reef front environments. It was never observed on the reef flat at Yap, but occurs in this habitat on Fanning (Chave and Eckert, 1974).

Chaetodon melannotus Bloch and Schneider

NE-2A, E-2, E-3, E-4A, E-5A, E-5B, SE-2A, SE-2B, SE-3, SE-4, SE-6, SE-7, SE-8, SE-9B, SW-3A, SW-4, SW-5A, SW-5C, NW-1, NW-3A, NW-3B, NW-4A, NW-4B, NW-5A, W-1, W-2A, W-4, W-5, W-7A, W-7B, W-8, W-10, BR-1, BR-2

This species was found in a variety of environments: reef flat, lagoon margin, barrier reef pass, barrier reef embayment, and barrier reef front.

Chaetodon mertensii Cuvier

W-7A

This species was observed only once, associated with a lagoon margin, although Mr. S. Neudecker (pers. comm.) reported seeing it in other lagoon areas below 15 m. Jones and Chase (1975) observed it in association with the barrier reef on Guam.

Chaetodon meyeri Bloch and Schneider

E-4A, W-2A, W-7A

This uncommon species was seen in two lagoon margin locations and in a barrier reef embayment. It occurred on the outer reef slope at Fanning (Chave and Eckert, 1974).

Chaetodon ornatissimus Cuvier and Valenciennes

E-5A, SW-5A, W-1, BR-2

Each of the four sightings of this species was in a somewhat different environment: lagoon margin, barrier reef pass, barrier reef embayment, and barrier reef front. Randall (1955) observed it only on the outer reef terrace at Onotoa.

Chaetodon punctatofasciatus Cuvier
NE-3, SW-5A, NW-1, BR-2

This species was observed associated with the lagoon margin, in the Gabach barrier reef pass, and outside the barrier reef.

Chaetodon rafflesi Bennett
SE-2A, SE-5B, SE-6, SE-7, SW-3A, SW-4, SW-5A, SW-5B, NW-4A, NW-5A, W-1, W-2A, W-3, W-7B, W-9A, W-9B, W-10, BR-2

This species was found on coral-rich reef flats, on the lagoon margin, in barrier reef passes and embayments, and on the barrier reef front.

Chaetodon reticulatus Cuvier and Valenciennes
SW-5B, W-1, W-2A, W-7A, BR-2

This appears to be primarily a barrier reef species in Yap, occurring in barrier reef passes and embayments and on the barrier reef fronts. It was seen once in an enclosed lagoon. Hiatt and Strasburg (1960) reported it to be common in the lagoons in the Marshall Islands. Jones and Chase (1975) observed this species on lagoon patch reefs on Guam.

Chaetodon semeion Bleeker
SE-4, SE-5B, SE-7, SE-8, SE-9A, NW-1, NW-3B, W-6, W-8, BR-2

This was a moderately common species which occurred in reef flat, lagoon margin, and barrier reef front environments.

Chaetodon speculum Cuvier and Valenciennes
SE-9A, NW-5A, W-10, BR-1

This species was seen infrequently on lagoon margins and on the barrier reef front.

Chaetodon triangulum Cuvier and Valenciennes
SW-5A, BR-1

The two sightings of this species were in the Gabach barrier reef pass and on the barrier reef front.

Chaetodon trifascialis Quoy and Gaimard
NE-1, NE-2A, NE-3, E-1A, SE-1B, SE-4, SE-5B, SE-7, SW-3A, SW-4, SW-5A, SW-5B, NW-1, NW-3A, NW-4A, NW-4B, NW-5A, W-1, W-2A, W-3, W-4, W-7A, W-7B, W-10, BR-1, BR-2

This is primarily a lagoon margin and barrier reef species which was occasionally seen on the reef flat. It was also one of the few species associated with isolated Acropora colonies in deep lagoon areas.

Chaetodon trifasciatus Mungo Park

NE-1, NE-2A, NE-3, E-1A, E-2, E-3, E-4A, E-5B, SE-2A, SE-2B, SE-3, SE-4, SE-5A, SE-5B, SE-6, SE-7, SE-8, SE-9A, SE-9B, SW-3A, SW-4, SW-5A, SW-5B, SW-5C, NW-1, NW-3A, NW-4A, NW-4B, NW-5A, W-1, W-2A, W-3, W-6, W-7A, W-7B, W-8, W-9A, W-10, T-1A, T-1B, T-4, T-6C, BR-1, BR-2

This was among the most frequently observed Chaetodon species, occurring in all environments surveyed except seagrass and deep isolated coral mounds. It was not seen in areas of very silty water as were C. auriga and C. ephippium, the other two most abundant Chaetodon species.

Chaetodon ulietensis Cuvier

NE-1, NE-2A, NE-3, E-1A, E-2, E-3, E-5A, SE-2A, SE-8, SE-9A, SW-5A, NW-1, NW-3A, NW-3B, NW-4B, NW-5A, W-1, W-2A, W-4, W-5, W-6, W-7A, W-8, W-9A, W-10, T-6C, BR-2

This is primarily a lagoon margin and barrier reef species, appearing only infrequently on the reef flat.

Chaetodon unimaculatus Bloch

E-1A, SE-3, SE-5B, SE-6, SE-7, SW-4, SW-5A, NW-1, NW-2, NW-5A, NW-7A, W-4, BR-1, BR-2

This species was observed on the reef flat in coral-rich areas, on lagoon margins, in the Gabach barrier reef pass, and on the barrier reef front.

Chaetodon vagabundus Linnaeus

NE-2A, E-4A, E-5B, SE-2B, SE-4, SE-5A, SE-6, SE-7, SE-9B, SW-1, SW-2B, SW-5A, SW-5B, NW-3B, W-1, T-5B, BR-1, BR-2

This species was seen rather frequently on the reef flat as well as in lagoon margin, barrier reef pass, barrier reef embayment, and barrier reef front environments. Randall (1955) found this species only in the lagoon at Onotoa. Hiatt and Strasburg (1960) did not observe it at all in the northern Marshall Islands, although it occurs at Arno Atoll.

Because of their bright coloration and nonsecretive habits, Chaetodon species are generally quite conspicuous on the reef. It seems unlikely that many more species of this genus will be found in shallow waters in Yap than were seen during these surveys.

Euxiphipops sexstriatus (Cuvier)

SE-2A, NW-1, NW-3A, NW-4B, NW-5A, W-5, W-10

This appears to be a strictly lagoon-dwelling species.

Forcipiger flavissimus Jordan and McGregor

NE-1, NE-3, E-3, E-4A, SE-3, SE-6, SE-8, SW-4, SW-5A, SW-5B, NW-1, W-2A, W-3, W-7B, T-6C, BR-1, BR-2.

The identity of several individuals referred to this species was verified by close observation of the mouth opening, but not all individuals were so examined and it is possible that some sightings were of the very similar F. longirostris. Forcipiger was seen in lagoon margin, barrier reef pass, barrier reef embayment, and barrier reef front environments predominantly. It was infrequently observed on the reef flat.

Heniochus acuminatus (Linnaeus)
E-1A, SE-8, NW-1, NW-4B, W-5, W-10, BR-2

This species was seen in lagoon margin and barrier reef front environments. It was not common.

Heniochus chrysostomus Cuvier and Valenciennes
NE-1, NE-3, E-1A, E-3, E-4A, SE-2A, SE-4, SE-8, SE-9A, SW-5A, NW-3A, NW-5A, W-3, W-4, W-5, W-6, W-7A, W-7B, W-8, W-9A, W-10, T-6C, BR-1, BR-2

This is principally a lagoon margin and barrier reef species. It was seen only once on the reef flat.

Heniochus varius (Cuvier)
SW-5A, SW-5B, BR-1, BR-2

This appears to be strictly a barrier reef species in Yap, occurring in the Gabach barrier reef pass and on the barrier reef front. Randall (1955) collected this species from the lagoon at Onotoa.

Pomacanthus imperator (Bloch)
SE-8, NW-3A, W-1, BR-2

This species was seen on the lagoon margin, in a barrier reef embayment, and on the barrier reef front. At Fanning it also occurs in barrier reef passes (Chave and Eckert, 1974),

Pygoplites diacanthus (Boddaert)
NE-1, NE-2A, NE-3, E-4A, E-5A, SE-6, SE-8, SW-4, SW-5A, SW-5B, NW-1, NW-3A, NW-5A, W-1, W-2A, W-3, W-4, W-6, W-7A, W-10, T-6C, BR-1, BR-2

This species was most frequently seen in lagoon margin and barrier reef environments. It was observed once on the reef flat in an area of rich coral development and relatively high relief.

POMACENTRIDAE

Abudefduf coelestinus (Cuvier)
NE-1, NE-2A, E-2, E-3, E-5A, SE-4, SE-6, SW-3A, SW-5B, W-1, W-5, W-6, W-8, W-9A, W-10

This schooling species was seen most frequently around the lagoon margin. It also occurred on coral-rich reef flats, in the Gabach barrier reef pass, and in a barrier reef embayment.

Abudefduf saxatilis (Linnaeus)
BR-1

A group of fishes of this species was observed on the barrier reef front.

Abudefduf septemfasciatus (Cuvier and Valenciennes)
T-6B

A small group of six individuals was seen on the reef flat off Donitsch Island in Tomil Harbor. Randall (1955) found this species associated with the outer reef at Onotoa, and Allen (1975) lists it as occurring on shallow reef flats of outer reefs. Jones and Chase (1975) observed this species on the barrier reef in Guam.

Abudefduf sordidus (Forskal)
NW-3B, T-6B

Both observations of this species were in reef flat environments. Hiatt and Strasburg (1960) found this species to be abundant on all the reefs they visited, and Randall (1955) and Hobson (1974) found it in association with the outer reef in Onotoa and Kona.

Amblyglyphidodon curacao (Bloch)
NE-1, NE-2A, NE-3, E-1A, E-2, E-3, E-4A, E-5A, SE-2A, SE-2B, SE-3, SE-4, SE-5A, SE-5B, SE-8, SE-9A, SE-9B, SW-2A, SW-3A, SW-4, SW-5A, SW-5B, NW-1, NW-3A, NW-3B, NW-4A, NW-4B, NW-5A, W-3, W-4, W-5, W-6, W-7A, W-7B, W-8, W-9A, W-10, T-1A, T-1B, T-4, T-6C

Aggregations of 5 to 50 individuals were seen around colonies of branching coral. This species was very frequently encountered on lagoon margins and reef flats. It was seen in the Gabach barrier reef pass, but was not otherwise observed in association with the barrier reef. Allen (1975) reports this species to inhabit a broad range of reef habitats including outer reefs.

Amblyglyphidodon ternatensis (Bleeker)
NE-1, NE-2A, E-1A, E-3, E-4A, SE-2A, SE-2B, SE-3, SE-4, SE-5A, SE-5B, SE-6, SE-7, SE-8, SE-9A, SE-9B, SW-3A, NW-3A, NW-3B, NW-4A, NW-4B, NW-5A, W-3, W-4, W-5, W-6, W-7B, W-8, W-9A, W-10, T-1B, T-1C, T-4

This species is ecologically very similar to A. curacao, and aggregations of both species were often seen intermingled or in very close association. This species was only seen in lagoon margin and reef flat environments.

Amphiprion melanopus Bleeker
SE-8, SE-9A, SW-4, SW-5A, NW-1, NW-3A, NW-5A, W-1, W-3, T-1B

This species, which was only observed in the presence of its host anemone, occurred in lagoon margin and barrier reef embayment environments.

Amphiprion perideraion Bleeker
NE-3

This anemonefish was seen only once in an enclosed lagoon off Rumung Island. Its habitat includes outer reef slopes according to Allen (1975).

Chromis atripectoralis Welander and Schultz
NE-1, NE-3, E-1A, E-2, E-3, E-4A, E-5A, SE-1B, SE-1D, SE-3, SE-4, SE-5A, SE-5B, SE-6, SW-6C, NW-1, NW-3A, NW-4A, NW-1B, W-1, W-7A, W-7B, W-10, T-4, BR-1, BR-2

Although it closely resembles C. caerulea (see below) in its appearance, C. atripectoralis is rather distinct from that species behaviorally. C. atripectoralis was usually seen individually or in groups of up to 40 members. These fishes were often swimming in the water column at some distance from the coral substratum. Most observations of this species were in lagoon margin environments, with additional sightings on deep lagoon coral mounds, in coral-rich reef flat areas, in one barrier reef embayment, and on the barrier reef front.

Chromis caerulea (Cuvier and Valenciennes)
NE-1, NE-2A, NE-3, E-2, E-3, SE-1B, SE-2A, SE-3, SE-4, SE-5B, SE-6, SE-7, SE-8, SE-9A, SE-9B, SW-2A, SW-3A, SW-4, SW-5A, SW-5B, SW-5C, NW-2, NW-3B, NW-4A, NW-4B, NW-5A, W-3, W-6, W-7A, W-8, W-9A, W-10, T-1B, T-4, T-6C

This species occurs in aggregations of five to up to several hundred members. It was always seen in close association with branching coral colonies into which it would withdraw upon the approach of a diver. On some occasions it was observed actively feeding on zooplankton. This is primarily a lagoon margin species, with some additional sightings made on the reef flat and in the Gabach barrier reef pass. Hiatt and Strasburg (1960) and Allen (1975) report this species as also occurring on outer reefs.

Chromis margaritifer Fowler
NE-1, NE-3, SW-5A, SW-5B, NW-1, NW-4A, W-1, W-2A, BR-1, BR-2

This species was frequently observed in barrier reef environments (barrier reef pass, embayment, and front). It was also seen in some deep lagoon environments. In all areas where it was observed, this species was associated with considerable topographic relief.

Dascyllus aruanus (Linnaeus)
NE-1, NE-2A, NE-3, E-1A, E-2, E-3, E-4A, E-5A, E-5B, SE-1B, SE-1C, SE-1D, SE-2A, SE-2B, SE-3, SE-4, SE-5B, SE-6, SE-7, SE-8, SE-9A, SE-8B, SW-1, SW-2A, SW-3A, SW-5A, SW-5B, SW-5C, NW-1, NW-2, W-3, W-4, W-5, W-6, W-7A, W-7B, W-8, W-9A, W-9B, W-10, T-1A, T-1B, T-1D, T-4, T-6B, T-6C

Aggregations of this species were found associated with colonies of branching coral in almost every lagoon margin area surveyed. This species was also seen with some frequency on the reef flat. Its only association with the barrier reef was its occurrence in the Gabach barrier reef pass.

Dascyllus reticulatus (Richardson)
NE-3, SE-6, SW-4, SW-5A, SW-5B, SW-5C, W-7A, BR-2

This species was much less frequently seen than D. aruanus. It occurred in a few lagoon margin locations, two coral-rich reef flat areas, in the Gabach barrier reef pass, and on the barrier reef front.

Dascyllus trimaculatus (Ruppell)
NE-1, SE-1B, SE-8, SW-5A, NW-1, NW-2, NW-4A, W-1, W-3, W-5, T-6C, BR-2

Like species of the genus Amphiprion, this species is often found associated with a sea anemone. It was seen on the lagoon margin and slope, associated with a deep lagoon Acropora mound, and in barrier reef pass, embayment, and front environments.

Dischistodus chrysopoecilus (Schlegel and Muller)
SE-9B, SW-3A, W-9B

Two of the three observations of this species were on the reef flat and one was on the lagoon margin.

Dischistodus notopthalmus (Bleeker)
NE01, NE-2A, NE-3, E-2, E-3, E-4A, E-5A, SE-2B, SE-3, SE-4, SE-5B, SE-6, SE-7, SE-9A, SW-3A, SW-4, NW-1, NW-4A, NW-4B, NW-5A, W-4, W-6, W-7B, W-10

This appears to be primarily a lagoon margin species which was also seen occasionally on the reef flat.

Dischistodus perspicillatus (Cuvier)
NE-1, E-1A, E-2, E-5B, SE-1A, SE-1C, SE-2A, SE-2B, SE-5B, SE-9B, SW-1, SW-2A, SW-2B, SW-3A, SW-4, SW-5C, NW-1, NW-3A, NW-3B, NW-4B, W-3, W-4, W-5, W-6, W-8, W-9A, W-9B, W-10, T-1A, T-1B, T-1C, T-1D, T-1E, T-4, T-5A, T-5B, T-5C, T-6A, T-6B

This species was common on the lagoon margin and reef flat and was also seen in seagrass environments. It occurred on deep lagoon coral mounds. It was not observed in association with the barrier reef.

Eupomacentrus albifasciatus (Schlegel and Muller)
NE-1, NE-3, E-2, E-5A, E-5B, SE-3, SE-4, SE-6, SE-7, SE-9B, SW-1, SW-2A, SW-3A, SW-4, SW-5C, NW-2, NW-3B, NW-4A, W-3, W-4, W-6, W-7B, W-9B, W-10

This territorial species is found on the reef flat and lagoon margin. It occupies mounds of dead Acropora or other branching coral where individual fishes protect their living areas from intruders. Allen (1975) lists this species as an inhabitant of outer reef flats, and it was seen in that environment at Fanning (Chave and Eckert, 1974).

Eupomocentrus lividus (Bloch and Schneider)
NE-1, NE-2A, NE-3, E-2, E-3, E-4A, E-5B, SE-1B, SE-1C, SE-1D, SE-2A, SE-2B, SE-3, SE-4, SE-5B, SE-6, SE-9B, SW-1, SW-2A, SW-3A, SW-4, NW-1, NW-2, NW-3A, NW-4A, NW-4B, NW-5A, W-3, W-4, W-5, W-6, W-7B, W-8, W-10, T-6B, T-6C

This is also a territorial species which protects a living space within areas of branching coral. It occurs on the reef flat and lagoon margin and in deep lagoon coral mounds. Jones and Chase (1975) found it in barrier reef passes on Guam.

Eupomacentrus nigricans (Lacepede)
SE-4, SE-6, SE-7, SE-9A, SW-3A, SW-4, SW-5C, NW-1, NW-4B, W-6, W-7B, W-8, W-10

This territorial species has habits similar to its congeners described above. It occurs on the reef flat and lagoon margin. On Guam it also occurs in barrier reef passes (Jones and Chase, 1975). Grovhoug and Henderson (1976) reported that this species was ubiquitous at Canton Island.

Glyphidodontops cyaneus (Quoy and Gaimard)
NE-2B, NE-3, E-1A, E-2, E-4B, E-5A, E-5B, SE-2B, SE-3, SE-4, SE-6, SE-7, SE-9B, SW-3A, SW-5C, NW-5B, W-7B, W-8, W-9B, W-10

This species is primarily a reef flat resident that is occasionally seen on the lagoon margin.

Glyphidodontops leucopomus (Lesson)
W-2B, T-6B

Both color forms of species were seen. It is a reef flat resident. On Guam this species was observed in association with the barrier reef (Jones and Chase, 1975).

Paraglyphidodon melanopus (Bleeker)
SE-6, SE-7, SW-5A, SW-5C, W-9A

This species was observed on the reef flat and lagoon margin and in the Gabach barrier reef pass.

Plectroglyphidodon dickii (Lienard)
SW-5C, W-1, W-2B, T-6C, BR-1, BR-2

Observations of this species were made on the barrier reef front, in a barrier reef embayment, and on reef flat areas. It occurred in a variety of environments including lagoon areas at Fanning (Chave and Eckert, 1974).

Plectroglyphidodon johnstonianus Fowler and Ball
BR-2

This species was observed once outside the barrier reef. It occurred on outer reef flats at Fanning (Chave and Eckert, 1974).

Plectroglyphidodon lachrymatus (Quoy and Gaimard)
NE-2A, NE-3, E-1A, E-2, E-5A, E-5B, SE-3, SE-4, SE-6, SW-3B, SE-5A, NW-4B, W-1, W-10, T-6C, BR-2

This species was seen in a variety of environments including reef flat, lagoon margin, barrier reef pass, barrier reef embayment, and barrier reef front.

Plectroglyphidodon leucozona (Bleeker)
NE-2B, E-1A, E-4B, E-5B, SE-2B, SE-3, SE-4, SE-9B, NW-2, NW-3A, W-5, W-7B, W-9B, W-10, T-5B, T-6A, T-6B

Individuals referred to this species are dark with a pale vertical band on the sides of the body. It is possible that more than one species is combined in this group. These fishes were seen primarily in reef flat environments, including seagrass areas, and were also seen along the lagoon margin.

Pomacentrus bankanensis Bleeker
SE-6

The only observation of this species was on a coral-rich reef flat area near Tomil Harbor.

Pomacentrus coelestis Jordan and Starks
BR-2

This species was seen only once outside the barrier reef. It was broadly distributed at Fanning (Chave and Eckert, 1974) and Canton (Grovhoug and Henderson, 1976).

Pomacentrus pavo (Bloch)
NE-1, NE-3, E-1A, SE-1A, SE-2A, SE-2B, SE-7, SE-8, SW-1, SW-2A, SW-3A, SW-4, SW-5B, SW-5C, NW-1, NW-2, NW-3A, NW-4A, NW-5A, W-3, W-5, W-6, W-8, W-9A, W-9B, W-10, T-6C

This species was often seen in the water column off the lagoon margin. It occasionally also occurred on the reef flat and was seen in the Gabach barrier reef pass.

Pomacentrus popei Jordan and Seale
E-1A, SE-2A, NW-5B, W-4

This species occurred on the lagoon margin and was seen once on a patch reef in Mil Harbor. Allen (1975) indicates that it is also a resident of outer reef slopes.

Pomacentrus vaiuli Jordan and Seale
NE-2A, NE-3, SE-3, SW-5B, NW-1, W-2A, BR-2

This species was seen on the lagoon margin, in the Gabach barrier reef pass, in a barrier reef embayment, and on the barrier reef front.

Allen (1975) has stated that tropical pomacentrids usually show definite preferences for particular depth ranges and substrate types, and thus individual species are generally restricted to particular reef zones. Many of the species listed in this account do indeed show rather restricted distributional ranges among reef zones, including some species (e.g., Amblyglyphidodon curacao and A. ternatensis) which were quite frequently observed.

CIRRHITIDAE

Paracirrhites arcatus (Cuvier and Valenciennes)
SE-6, W-1

This species was observed only twice: on a reef flat and in a barrier reef embayment. It occurs on the barrier reef front on Guam (Jones and Chase, 1975) and Fanning (Chave and Eckert, 1974).

Paracirrhites forsteri (Bloch and Schneider)
W-2A

A single sighting of this species was made in a barrier reef embayment. On Guam it occurs in barrier reef front and pass areas (Jones and Chase, 1975).

Few cirrhitids were observed during the survey. It seems probable that fishes of this family are more abundant than the number of sightings would suggest, but that their habits of sitting motionless on the reef waiting for prey to happen by made them somewhat inconspicuous.

LABRIDAE

Anampses caeruleopunctatus Ruppell
NE-1, SE-4, NW-3A, NW-3B, W-1, W-3, W-7A

This species was most frequently observed on the lagoon margin, but was also seen once on the reef flat and once in a barrier reef embayment. It was seen on the barrier reef front on Guam (Jones and Chase, 1975).

Anampses twisti Bleeker
W-7A, W-10, BR-2

This species was seen twice on the lagoon margin and once on the barrier reef front.

Bodianus axillaris (Bennett)
W-2A

The single sighting of this species was in a barrier reef embayment. It occurred on the barrier reef front at Fanning (Chave and Eckert, 1974).

Cheilinus fasciatus (Bloch)
NE-1, NE-3, E-1A, E-2, E-4A, E-5A, SE-3, SE-4, SE-5B, SE-9A, NW-1, NW-3A, NW-4B, NW-5A, W-3, W-4, W-6, BR-2

This is predominantly a lagoon margin species. It was also seen on the barrier reef front. Jones and Chase (1975) observed this species in barrier reef passes and flats on Guam.

Cheilinus trilobatus Lacepede
SE-4, W-1

This species was seen once on the lagoon margin and once in a barrier reef embayment. On Guam it was seen in barrier reef front, pass, and flat environments (Jones and Chase, 1975).

Cheilinus undulatus Ruppell
NE-1, NE-2A, NE-3, E-2, E-3, E-4A, E-5A, SE-2A, SE-4, SE-5B, SE-8, SE-9A, NW-3A, NW-3B, NW-4A, NW-4B, NW-5A, W-1, W-3, W-4, W-5, W-6, W-8, W-9A, W-10

Although this species was frequently observed, none of the very large adults were seen. It predominantly occurred in lagoon environments, but was also seen on the reef flat and in a barrier reef embayment. Jones and Chase (1975) observed this species in barrier reef front, pass, and flat environments on Guam.

Cheilio inermis (Forskal)
NW-4A, NW-4B, W-4, T-3

This species was seen on the lagoon margin and in the seagrass.

Choerodon anchorago (Bloch)
NE-2A, E-1A, E-2, SE-2A, SE-3, SE-5B, SE-7, SE-8, SE-9B, SW-1, SW-2A, SW-2B, SW-3A, NW-3A, NW-3B, NW-4A, NW-4B, W-3, W-5, W-6, W-7B, W-8, W-9A, W-9B, W-10, T-1B, T-1D, T-1E

This is a broadly distributed species occurring in seagrass, on the reef flat, and in lagoons. It was not observed in association with the barrier reef.

Coris aygula Lacepede
SE-6

A juvenile of this species was seen in a coral-rich reef flat area. It occurs in barrier reef passes at Fanning (Chave and Eckert, 1974).

Coris gaimardi (Quoy and Gaimard)
SE-4, SE-6, NW-2

Juveniles of this species were seen twice on the reef flat and once in a lagoon margin environment. Jones and Chase (1975) observed this species in association with the barrier reef on Guam.

Epibulus insidiator (Pallas)
NE-2A, E-2, SE-3, SE-4, SE-5A, SE-6, SE-8, SW-5A, SW-5C, NW-1, NW-3A, NW-4A, NW-4B, NW-5A, W-1, W-2A, W-4, W-5, W-6, W-7A, W-8, W-9A, W-10, T-1B, T-6C, BR-2

This widespread species was seen on reef flats, in association with the lagoon margin, in the Gabach barrier reef pass, in barrier reef embayment, and on the barrier reef front.

Gomphosus varius Lacepede
NE-2A, NE-2B, NE-3, E-2, E-3, E-4A, E-4B, E-5A, E-5B, SE-1C, SE-2A, SE-3, SE-4, SE-8, SE-9B, SW-2A, SW-3A, SW-5A, SW-5B, NW-1, NW-3A, NW-4A, NW-5A, W-1, W-2A, W-2B, W-5, W-6, W-7A, W-7B, W-9A, W-10, BR-1, BR-2

This is another widespread species which was seen in every type of environment surveyed with the exception of seagrass areas.

Halichoeres centiquadrus (Lacepede)
NE-1, NE-2A, E-1A, E-2, SE-3, SE-6, SW-4, SW-5A, SW-5B, SW-5C, NW-1, NW-5A, W-2A, BR-1, BR-2

This species was seen most frequently associated with the lagoon margin, and also occurred on coral-rich reef flat areas, and in association with the barrier reef.

Halichoeres margaritaceous (Cuvier and Valenciennes)
E-4B, E-5B, NW-2, T-5A, T-5B

All observations of this species were made on the reef flat, one in association with seagrass. Hiatt and Strasburg (1960) reported it to be especially abundant on outer reefs and surge channels. It was seen on the barrier reef front on Guam (Jones and Chase, 1975).

Halichoeres marginatus Ruppell
NE-2A, SE-3, SE-5B, SE-6, SW-2A, W-2A, BR-2

This species occurs on the reef flat, on the lagoon margin, and in barrier reef embayment and barrier reef front environments.

Halichoeres trimaculatus (Quoy and Gaimard)
NE-1, E-1A, E-4B, E-5B, SE-1A, SE-1C, SE-2B, SE-3, SE-4, SE-6, SE-7, SE-9B, SW-2B, SW-4, SW-5C, NW-1, NW-2, NW-3A, NW-3B, W-7B, T-6A, T-6B

This is predominantly a reef flat species occurring in coral, sand, and seagrass environments. It was also seen on the lagoon margin and in association with deep coral mounds in the lagoon. It was seen in a barrier reef pass on Guam (Jones and Chase, 1975) and Fanning (Chave and Eckert, 1974).

Hemigymnus fasciatus (Bloch)
NE-1, NE-3, E-2, E-4A, E-5A, SE-4, SE-5A, SW-4, NW-4A, W-1, W-3, W-10

All observations of this species were made on the lagoon margin with the exception of one barrier reef embayment sighting. Jones and Chase (1975) observed it in barrier reef pass and front environments on Guam, and Chave and Eckert (1974) saw it in these environments on Fanning.

Hemigymnus melapterus (Bloch)

NE-1, NE-2A, NE-3, E-1A, E-2, E-3, E-4A, E-5A, SE-2A, SE-2B, SE-3, SE-4, SE-5B, SE-6, SE-7, SE-8, SE-9A, SW-2A, SW-3A, SW-4, SW-5A, NW-3A, NW-4A, NW-4B, NW-5A, W-1, W-3, W-4, W-5, W-6, W-7A, W-7B, W-8, W-9A, W-10, BR-1, BR-2

This species was most frequently seen in association with the lagoon margin, but also occurred on the reef flat, in barrier reef passes and embayments and on the barrier reef front.

Labrichthys unilineata (Guichenot)

NE-2A, SE-9B, SW-5A, NW-1, NW-5A

This rather uncommonly seen species occurred on the reef flat, lagoon margin, and in the Gabach barrier reef pass.

Labroides bicolor Fowler and Bean

NE-2A, NE-3, E-2 E-3, E-4A, SE-5A, SE-8, SE-9A, SW-5A, NW-4A, NW-4B, NW-5A, W-1, W-5, W-6, W-7A, W-9A, W-10, BR-1, BR-2

This species of cleaner wrasse was seen most frequently in lagoon margin environments, and was also seen in association with the barrier reef.

Labroides dimidiatus (Cuvier and Valenciennes)

NE-1, NE-3, E-1A, E-2, E-3, E-4A, E-5A, E-5B, SE-1B, SE-1D, SE-2A, SE-2B, SE-3, SE-4, SE-5B, SE-5, SE-7, SE-8, SE-9A, SE-9B, SW-1, SW-3A, SW-4, SW-5A, SW-5B, SW-5C, NW-1, NW-3A, NW-4A, NW-4B, NW-5A, W-1, W-2A, W-3, W-4, W-5, W-6, W-7A, W-7B, W-8, W-9A, W-9B, W-10, T-1B, T-4, BR-1, BR-2

This very common species was seen in every type of environment surveyed except seagrass.

Macropharyngodon meleagris (Cuvier and Valenciennes)

SE-6, SE-7, NW-4A, W-2B, W-4, T-4

This species was observed in reef flat and lagoon margin environments. Both sexes were seen. This species was seen in association with the barrier reef on Guam (Jones and Chase, 1975).

Pseudocheilinus hexataenia (Bleeker)

NE-2A, E-3, E-5A, E-5B, SE-3, SE-8, SE-9A, SE-9B, SW-3A, SW-5A, SW-5B, NW-3A, NW-3B, W-7A, W-7B, T-1A, T-1B, T-4

This is principally a lagoon margin and reef flat species. It was also observed in the Gabach barrier reef pass. Chave and Eckert (1974) observed this species in many environments at Fanning, including the barrier reef front.

Stethojulis bandanensis (Bleeker)

NE-2B, E-4B, E-5B, SE-1C, SE-2B, SE-3, SE-4, SE-6, SE-7, SE-9B, SW-3A, SW-4, SW-5A, NW-1, NW-2, NW-3B, NW-4A, W-2B, W-4, W-7B, W-9B, W-10, T-3, T-4, T-6A, T-6C

This species occurred most frequently on the reef flat and was not uncommon in seagrass environments. It was also seen associated with the lagoon margin, with deep coral mounds, and in a barrier reef pass.

Thalassoma hardwicki (Bennett)

NE-1, NE-2A, NE-3, E-1A, E-2, E-3, E-4A, E-4B, E-5A, E-5B, SE-1B, SE-2A, SE-2B, SE-3, SE-4, SE-5A, SE-5B, SE-6, SE-7, SE-8, SE-9B, SW-1, SW-2A, SW-3A, SW-4, SW-5A, SW-5B, SW-5C, NW-1, NW-2, NW-3A, NW-3B, NW-4A, NW-4B, NW-5A, W-1, W-2A, W-3, W-4, W-5, W-6, W-7A, W-7A, W-8, W-9A, W-9B, W-10, T-4, T-6C, BR-1, BR-2

Among the most common fishes seen, this species occurred in every type of environment surveyed except seagrass.

Thalassoma lunare (Linnaeus)

SE-2A, SE-2B, SE-3, SE-5B, SW-5B, NW-1, NW-3A, NW-4A, W-5, W-9A, W-10, BR-1

This species occurred most frequently on the lagoon margin. It was also seen on the reef flat, in the Gabach barrier reef pass, and on the barrier reef front.

Thalassoma lutescens (Lay and Bennett)

E-1A, T-6C, BR-2

This species was seen on the lagoon margin and lagoon slope and outside the barrier reef. It also occurred in passes at Fanning (Chave and Eckert, 1974).

Thalassoma quinquevittata (Lay and Bennett)

NE-2B, E-1A, E-4B, SE-3, SW-3A, NW-3A, NW-3B, NW-4B, W-1, W-7B, BR-2

Observations of this species were made on the reef flat, on the lagoon margin, in a barrier reef embayment, and on the barrier reef front.

Xyrichthys taeniourus (Fowler)

SE-2A, SE-2B, SW-3A, W-7B

Young of this species were seen on the reef flat and lagoon margin. Jones and Chase (1975) observed this species in a barrier reef pass on Guam, as did Chave and Eckert (1974) at Fanning.

SCARIDAE

Bolbometopon bicolor (Ruppell)

NE-1, NE-2A, E-2, E-4A, E-5A, SE-3, SE-4, NW-3, W-1, W-2A, W-3, W-4, W-6, W-9A, BR-1

This species was seen associated with the lagoon margin, barrier reef embayments, and off the barrier reef front.

Bolbometopon muricatus (Cuvier and Valenciennes)
NE-1, SE-5A, NW-1, NW-3A, BR-2

These were very large (greater than 1 m SL) humphead forms that occurred in open water areas in lagoons and on the barrier reef front.

Scarus chlorodon Jenyns
NE-1, E-1A, E-2, E-5A, SE-4, SE-5B, SW-5A, SW-5B, NW-3A, NW-4B, W-1, W-3, W-4, W-5, W-6, W-7A, W-7B, W-8, W-9A, BR-1

Most observations of this species were in association with the lagoon margin, although it was also seen in a barrier reef embayment and on the barrier reef front. Smaller individuals were seen infrequently on the reef flat.

Scarus dimidiatus Bleeker
NE-1, N E-3, E-1A, E-4A, E-5A, SE-2A, SE-3, SE-8, SW-5A, NW-1, NW-3A, NW-4A, NW-4B, W-2A, W-3, W-4, W-5, W-6, W-7A, W-7B, W-9A

This is a lagoon margin form that was seen in a barrier reef embayment and infrequently on the reef flat.

Scarus ghobban Forskal
W-5, W-8

Both observations of this species were made in waters near the lagoon margin. It occurred in association with the barrier reef at Fanning (Chave and Eckert, 1974).

Scarus pectoralis Cuvier and Valenciennes
NE-1, NE-2A, NE-3, E-1A, E-2, E-3, E-4A, E-5A, SE-2A, SE-3, SE-4, SE-5B, SW-2A, SW-3A, SW-4, SW-5A, NW-1, NW-3A, NW-4B, W-1, W-4, W-6

This species occurred in lagoon margin environments and in a barrier reef embayment.

Scarus scaber Cuvier and Valenciennes
NE-1, NE-2A, NE-3, E-1A, E-2, E-3, E-4A, E-4B, E-5A, E-5B, SE-2A, SE-2B, SE-3, SE-4, SE-5A, SE-5B, SE-6, SE-8, SE-9A, SE-9B, SW-2A, SW-3A, SW-4, SW-5A, SW-5B, SW-5C, NW-1, NW-3A, NW-3B, NW-4A, NW-4B, NW-5A, W-1, W-2A, W-3, W-4, W-5, W-6, W-7A, W-8, W-9A, W-10, BR-1, BR-2

This species was one of the most frequently seen scarids. It occurred in all types of environments surveyed except seagrass and associated with deep lagoon coral mounds.

Scarus sordidus Forskal

NE-1, NE-2A, NE-3, E-1A, E-2, E-3, E-4A, E-5A, E-5B, SE-2A, SE-2B, SE-3, SE-4, SE-5A, SE-5B, SE-6, SE-7, SE-8, SE-9A, SE-9B, SW-2A, SW-3A, SW-5C, NW-1, NW-3A, NW-4A, NW-4B, NW-5A, W-3, W-4, W-5, W-6, W-7A, W-7B, W-8, W-9A, W-9B, W-10, T-6B, BR-2

This species occurred most commonly on the lagoon margin, but aggregations of young individuals were frequently seen on the reef flat as well. The species was also observed on the barrier reef front. It occurs in many environments including seagrass on Guam (Jones and Chase, 1975).

Scarus venosus Cuvier and Valenciennes

W-7B

This species was seen only once on a reef flat. It occurs in barrier reef and lagoon environments on Guam (Jones and Chase, 1975).

Scarus sp.

NE-1, NE-2A, E-1A, E-2, E-4A, SE-3, SE-8, SW-3A, NW-3A, NW-3B, NW-4B, W-3, W-5, W-6, W-9A, W-10

The individuals included here were grey with yellow unpaired fins. They may be immature individuals. Most observations of this species were around the lagoon margin, with infrequent sightings on the reef flat.

juvenile scarids

NE-2A, E-2, E-3, E-4B, SE-2B, SE-3, SE-6, SW-2A, SW-3A, SW-5A, NW-2, NW-3A, NW-3B, NW-4A, NW-5A, W-3, W-4, W-5, W-6, W-7A, W-7B, W-8, T-1E, T-3, T-6B

Aggregations of small scarids of various species were commonly seen on the reef flat and in seagrass areas. They also occurred in lagoon margin environments, but were not observed associated with the barrier reef, although Chave and Eckert (1974) observed them in passes and on the barrier reef front at Fanning.

MUGILOIDIDAE

Parapercis cephalopunctatus (Seale)

T-3

A single observation of this species was made in the seagrass area near Tomil Harbor. This species lies in ambush for its prey, its mottled coloration serving to camouflage it. It is probably more numerous than these survey results indicate. On Guam it was observed in association with the barrier reef (Jones and Chase, 1975).

BLENNIIDAE

Meiacanthus atrodorsalis (Gunther)

E-4A, SW-5A, NW-1, W-10

This species was seen hovering in the water column associated with the lagoon margin. It occurs in association with the barrier reef on Guam (Jones and Chase, 1975).

Meiacanthus grammistes (Valenciennes)
NE-1, NE-2A, E-5B, SE-2B, SE-3, SE-8, SE-9B, NW-3A, NW-3B, NW-5A, W-6, W-9A, W-10

Groups of 5 to 15 individuals were seen on reef flats and associated with the lagoon margin.

Plagiotremus tapeinosoma (Bleeker)
NE-3, SE-7

This species was seen once associated with the lagoon margin and once on the reef flat. On Guam it occurs in association with the barrier reef (Jones and Chase, 1975).

Many more species of blennies, particularly those belonging to the subfamily Salariinae, are present on Yap. The three species listed above were the most conspicuous, free-swimming forms observed.

GOBIIDAE

Amblygobius albimaculatus (Ruppell)
NE-2, E-4B, E-5B, SE-3, W-3, W-7B, T-5B, T-6A

This large goby is primarily a reef flat dweller, sometimes occurring in seagrass environments. It was also observed on the reef margin. Jones and Chase (1975) observed this species in association with the barrier reef on Guam.

Gobiodon citrinus (Ruppell)
SE-4, NW-3A, W-3, T-1C

This species was seen among corals on the lagoon margin.

As is the case with the blennies, only the most conspicuous gobies are included in this account. Many more species are also present on the Yap reefs.

ELEOTRIDAE

Nemateleotris magnificus Fowler
BR-2

Two small individuals of this species were seen on the barrier reef front.

Ptereleotris tricolor Smith
NE-1, NE-2A, NE-3, E-2, E-3, E-5A, SE-1A, SE-2A, SE-3, SE-4, SE-5B, SE-6, SE-8, SW-3A, SW-5A, SW-5B, NW-1, NW-3A, NW-4B, W-1, W-3, W-6, W-10, T-5B, BR-2

This species occurred most frequently on the lagoon margin and in association with the barrier reef. It was seen infrequently on the reef flat.

ACANTHURIDAE

Acanthurus gahhm (Forskal)
SE-4, SW-5C, NW-4B, W-4, W-6

This species occurred in groups of 5 to 15 individuals and was seen in lagoon margin and coral-rich reef flat areas. It occurred in many environments including the barrier reef front at Fanning (Chave and Eckert, 1974).

Acanthurus glaucopareius Cuvier
NE-1, NE-2A, NE-3, E-1A, E-2, E-3, E-4A, E-5B, SE-3, SE-4, SE-5B, SE-6, SW-3A, NW-1, NW-4B, W-1, W-2A, W-3, W-4, W-5, W-6, W-7A, W-7B, W-10, BR-1, BR-2

This widespread species was found in lagoon margin, reef flat, and barrier reef front environments. It was seen individually and in groups of up to 50 members. In the Marshall Islands, Hiatt and Strasburg (1960) found this species rather restricted in its habitat, occurring only on the outer seaward reef and in surge channels. Jones (1968) classified this species as a surge zone resident on Hawaiian and Johnston Island reefs.

Acanthurus lineatus (Linnaeus)
NE-2A, E-1A, E-5A, SE-3, SE-4, SW-5A, SW-5C, NW-1, W-1, W-2A, W-7B, T-6C, BR-1, BR-2

This species occurred in association with the lagoon margin and barrier reef and was seen once in a coral-rich reef flat area. Individuals and aggregations of various sizes were seen.

Acanthurus mata (Cuvier)
E-3, SE-2B, SE-5A, SE-8, SW-1, SW-2A, SW-3A, SW-4, NW-3B, NW-4B

This species was seen occasionally in lagoons and on reef flats and was among the relatively few species seen in silt-laden lagoon waters near shore.

Acanthurus nigrofuscus (Forskal)
NE-2B, SE-6, SE-7, T-6B, T-6C, BR-2

This species was generally confined to reef flat areas and was also observed outside the barrier reef. In Hawaii and Johnston Island, this species occupies subsurge habitats (Jones, 1968), such as would be provided within lagoons and off the barrier reef front. It occurs in lagoon and barrier reef pass environments on Guam (Jones and Chase, 1975).

Acanthurus nigroris Cuvier and Valenciennes
T-5C

The only observation of this species was on the relatively featureless lagoon slope north of Colonia Peninsula. Randall (1955) collected it from the outer reef at Onotoa. Schultz et al. (1953) and Hiatt and Strasburg (1960) found this species abundant in a variety of habitats in the Marshalls. In Hawaii and Johnston Island it characteristically occurs in subsurge habitats (Jones, 1968).

Acanthurus olivaceous Bloch and Schneider
W-2A

The only observation of this species was made in a barrier reef embayment. It is common on lagoon and outer reefs in the Marshalls (Hiatt and Strasburg, 1960). Jones (1968) found it associated with sand patches in Hawaii and Johnston Island. It occurred in passes at Fanning (Chave and Eckert, 1974).

Acanthurus pyroferus Kittlitz
E-2, E-3, SE-8, NW-2, NW-5A, W-5, BR-2

This species was seen infrequently and in small numbers. Most sightings were in lagoons, but it was also seen on the reef flat and outside the barrier reef.

Acanthurus triostegus (Linnaeus)
NE-1, NE-2A, E-2, E-4A, E-4B, E-5B, SE-2A, SE-2B, SE-3, SE-4, SE-7, SE-8, SE-9A, SE-9B, SW-1, SW-2A, SW-3A, SW-5C, NW-2, NW-3B, NW-4B, NW-5A, W-1, W-3, W-5, W-7A, W-7B, W-9B, W-10, T-6B

A very widespread surgeonfish species, occurring solitarily or in groups of up to several hundred members, this fish was found in all habitats surveyed at Yap except seagrass and outside the barrier reef. It occurs outside the barrier reef at Fanning (Chave and Eckert, 1974) and Canton (Grovhoug and Henderson, 1976).

Acanthurus xanthopterus Cuvier and Valenciennes
NE-1, NE-2A, NE-3, E-1A, E-2, E-3, E-4A, E-5A, E-5B, SE-2A, SE-4, SE-5A, SE-5B, SE-6, SE-9A, SW-4, SW-5B, SW-5C, NW-1, NW-3B, NW-4A, NW-4B, NW-5A, W-1, W-2A, W-3, W-5, W-6, W-8, W-9A, W-10, T-4, T-5B, T-6A, T-6B, BR-2

Another widespread surgeonfish, this species occurred in all types of environments surveyed including seagrass and outside the barrier reef. It generally occurred in groups of 5 to 50.

Ctenochaetus striatus (Quoy and Gaimard)
NE-1, NE-2A, NE-3, E-1A, E-2, E-3, E-4A, E-5A, E-5B, SE-1C, SE-2A, SE-2B, SE-3, SE-4, SE-5A, SE-5B, SE-6, SE-7, SE-8, SE-9B, SW-2A, SW-3A, SW-4, SW-5A, SW-5B, SW-5C, NW-1, NW-3A, NW-4A, NW-4B, NW-5A, W-1, W-2A, W-3, W-4, W-5, W-6, W-7A, W-7B, W-8, W-9A, W-10, T-1B, T-1D, T-4, T-6B, T-6C, BR-1, BR-2

The most frequently observed surgeonfish, this species was seen in every type of environment except seagrass. It was generally observed individually or in small groups of 5 to 15 members.

Naso annulatus (Quoy and Gaimard)
NE-1, E-4A

Solitary individuals were seen on two occasions cruising in lagoon waters.

Naso literatus (Bloch and Schneider)
NE-2A, E-2, E-4A, E-5A, SE-3, SE-5A, SE-5B, SW-4, SW-5A, NW-1, NW-3A, NW-5A, W-1, W-2A, W-6, W-7A, W-10, BR-1, BR-2

This species was observed almost exclusively in deeper water areas in lagoons, barrier reef embayments, and off the barrier reef front. It generally occurred in aggregations of 5 to 15 individuals.

Naso tuberosus Lacepede
NE-1

A single large individual was observed in a lagoon.

Naso unicornis (Forskal)
BR-1, BR-2

Large solitary individuals were seen at each of the two barrier reef front locations surveyed. Jones and Chase (1975) observed it in barrier reef passes and in the lagoon on Guam.

Zebrasoma flavescens (Bennett)
E-2, E-4A, SE-4, W-8

The four sightings of this species were in lagoons. It was observed in association with the barrier reef on Guam (Jones and Chase, 1975).

Zebrasoma scopas (Cuvier)
NE-1, NE-2A, NE-3, E-1A, E-2, E-3, E-4A, E-5A, SE-2A, SE-3, SE-4, SE-5A, SE-6, SE-7, SE-8, SE-9A, SW-2A, SW-3A, SW-4, SW-5A, SW-5B, SW-5C, NW-1, NW-3A, NW-4A, NW-4B, NW-5A, W-1, W-3, W-4, W-7A, W-7B, W-8, W-9A, W-10, T-1A, T-1B, T-4, T-6C

This species was observed principally on lagoon margins, and occasionally on reef flats and in one of the barrier reef embayments. It occurs in barrier reef passes on Guam (Jones and Chase, 1975) and Canton (Grovhoug and Henderson, 1976).

Zebrasoma veliferum (Bloch)
NE-1, NE-2A, NE-3, E-2, E-4A, E-5A, SE-2A, SE-2B, SE-3, SE-4, SE-5A, SE-5B, SE-8, SE-9A, SW-5A, NW-3A, NW-3B, NW-4B, NW-5A, W-1, W-2A, W-3, W-4, W-7A, W-7B, W-8, W-9A, W-10, T-4, BR-1, BR-2

This species occurred in a variety of habitats: reef flats, lagoon margin and lagoon patch reef, barrier reef embayment, and barrier reef front.

ZANCLIDAE

Zanclus cornutus (Linnaeus)
NE-1, NE-2A, NE-3, E-1A, E-2, E-3, E-4A, E-5A, SE-2A, SE-3, SE-4, SE-5A, SE-5B, SE-6, SE-7, SE-8, SE-9A, SW-2A, SW-3A, SW-4, SW-5A, SW-5B, NW-1, NW-3A, NW-3B, NW-4A, NW-4B, NW-5A, W-1, W-2A, W-3, W-4, W-5, W-6, W-7A, W-7B, W-8, W-9A, W-10, T-4, BR-2

This species was frequently seen on the lagoon margin and in association with the barrier reef. Its reef flat occurrences were in areas of rich coral cover and considerable topographic relief.

SIGANIDAE

Siganus argenteus (Quoy and Gaimard)
E-5A, W-6, W-7A, BR-1

This species was seen in the water column off the lagoon margin and on the barrier reef front. Jones and Chase (1975) observed it in seagrass on Guam.

Siganus canaliculatus (Park)
E-2, W-9A, W-10, T-1A, T-6B

This species occurred on the lagoon margin and on the reef flat.

Siganus guttatus (Bloch)
E-4A, SE-4, SE-5B

This species was seen associated with the lagoon margin.

Siganus lineatus (Cuvier and Valenciennes)
NW-3B, W-5, W-8, W-9A, W-10

The principal habitat of this species appears to be the lagoon margin, although some were seen passing across the reef flat.

Siganus puellus (Temminck and Schlegel)
NE-1, NE-2A, NE-3, E-1A, E-2, E-3, E-4A, E-5A, SE-3, SE-4, SE-5A, SE-5B, SE-6, SE-7, SE-8, SW-4, SW-5A, SW-5B, NW-1, NW-3A, NW-3B, NW-4A, W-4, W-6, W-7A, W-8, W-9A, W-10, T-6A, T-6C, BR-2

This frequently observed siganid occurred in seagrass, on the reef flat, on the lagoon margin, in the Gabach barrier reef pass, and on the barrier reef front.

Siganus spinus (Linnaeus)
T-6A, T-6B

The two observations of this species were on the reef flat, one in the seagrass.

Siganus virgatus (Cuvier and Valenciennes)
NE-1, NE-2A, NE-3, E-2, E-3, E-4A, SE-2B, SE-3, SE-5A, SE-5B, SE-9A, SW-5A, NW-1, NW-3B, NW-5A, W-1, W-3, W-6, W-7A, W-8, W-9A, W-10, BR-2

This species was seen on the reef flat and lagoon margin, in the Gabach barrier reef pass, in barrier reef embayments, and on the barrier reef front.

Siganus vulpinus (Schlegel and Muller)
E-2, E-3, E-4A, E-5A, NW-4B, NW-5A, W-7B, W-10, BR-2

This was primarily a lagoon margin species that was also seen on the barrier reef front and infrequently on the reef flat.

BALISTIDAE

Balistapus undulatus Mungo Park
NE-1, NE-2A, SE-5B, SE-6, SE-8, SW-5A, NW-1, NW-4A, NW-4B, NW-5A, W-3, W-5, W-6, W-9A, W-10, T-4, BR-2

This was the most commonly seen balistid species, and occurred around lagoon margins, reef flats, barrier reef passes, and outside the barrier reef. As was the case with all the balistid species observed, only solitary individuals were seen.

Melichthys niger (Bloch)
BR-1

The only observation of this species was on the barrier reef front.

Melichthys vidua (Solander)
W-1, BR-1, BR-2

This species was only seen on the barrier reef front and in a barrier reef embayment. It occurs in passes at Fanning (Chave and Eckert, 1974).

Pseudobalistes flavimarginatus (Ruppell)
E-4A, T-5B

A large individual was seen in an enclosed lagoon and a juvenile was found occupying a discarded beverage can on the reef flat fringing Colonia Peninsula.

Pseudobalistes viridescens (Bloch and Schneider)
E-3, W-5, BR-2

Large individuals were infrequently seen in the water off the lagoon margin and off the barrier reef front. It occurs in passes at Fanning (Chave and Eckert, 1974).

Rhinecanthus aculeatus (Linnaeus)
SW-1, SW-5C, W-6, W-9B, T-1D, T-5B

This is primarily a reef flat species, although it was also observed in association with the lagoon margin. It was seen in passes at Fanning (Chave and Eckert, 1974).

Rhinecanthus rectangulus (Block and Schnedier)
W-2B

This species was observed once in a reef flat environment. Randall (1955) and Hiatt and Strasburg (1960) observed this species on outer reef environments.

Rhinecanthus verrucosus (Linnaeus)
E-4B, W-9B, T-5B, T-5C

This balistid is primarily a reef flat dweller.

Sufflamen bursa (Bloch and Schneider)
BR-2

The only observation of this species was on the barrier reef front.

Sufflamen chrysoptera (Bloch and Schneider)
SE-6, W-3, T-6C

This species was seen on the reef flat and associated with the lagoon margin. Jones and Chase (1975) observed it in association with the barrier reef on Guam.

MONACANTHIDAE

Alutera scripta (Osbeck)
SW-5B

This species was seen once at the Gabach barrier reef pass.

Amanses scopas (Cuvier)
BR-1

The single observation of this species was made on the barrier reef front.

Oxymonacanthus longirostris (Bloch and Schneider)
NE-3, E-3, SE-4, SE-5B, NW-1, NW-4A

This species, which often occurs in pairs, appears to be primarily restricted to the lagoon margin environment. It was observed in association with the barrier reef on Guam (Jones and Chase, 1975).

OSTRACIONTIDAE

Ostracion cubicus Linnaeus
E-2, E-4A, E-5A, W-1, W-6, W-9B, W-10

This species was seen on the lagoon margin and reef flat and in a barrier reef embayment. Jones and Chase (1975) saw this species in barrier reef passes on Guam.

Ostracion meleagris Shaw
SE-6, SW-5A, W-1, BR-1

This species occurred on a coral-rich reef flat, in the Gabach barrier reef pass, in a barrier reef embayment, and on the barrier reef front.

TETRAODONTIDAE

Arothron nigropunctatus (Bloch and Schneider)
E-4A, E-5B, BR-2

The three sightings of this species were each in a different environment: reef flat, lagoon margin, and barrier reef front.

CANTHIGASTERIDAE

Canthigaster valentini (Bleeker)
NE-2A, E-1A, E-3, E-4A, SE-3, SE-6, SW-5C, NW-4B, W-3, W-6, T-1B

Single individuals were seen in reef flat and lagoon margin environments.

PATTERNS OF FISH DISTRIBUTION AMONG REEF ZONES

The reef zones that have been recognized in this survey can be arranged in an environmental continuum from seagrass-dominated reef flat, to other reef flat area (dominated by sand, coral pavement, and coral), to lagoon habitats, to barrier reef passes, to barrier reef embayments, to the barrier reef front. It has been assumed for the following analysis that a fish species seen in more than one type of environment on this continuum (e.g., lagoon and barrier reef front) probably also occurs in the intervening environmental types (e.g., in this case, barrier reef pass and barrier reef embayment). Table 2, then, indicates the number of species actually observed within a given environmental zone, as well as those species presumed to occur there based on their occurrence in environments lying to the two extreme of the given environment on the continuum.

The data in Table 2 indicate that the reef species observed on Yap are generally rather widely distributed among environmental zones. Of the 207 reef species observed (the archer fish Toxotes jaculator is omitted from this analysis), only 48 (23%) are restricted to a particular zone.

Table 2. Distribution of fish species among reef zones.

Reef Zone	No. Sites Examined	No. Species (and Percent of Total Species) Occurring in Zone	No. Species Restricted to Zone (and Percent of Species Occurring in Zone that are Restricted to Zone)
seagrass	6	23 (11.1)	1 (4.3)
reef flat	19	121 (58.5)	8 (6.6)
lagoon margin	38	176 (85.0)	26 (14.8)
barrier reef pass	2	119 (57.5)	1 (0.8)
barrier reef embayment	2	107 (51.7)	3 (2.8)
barrier reef front	2	97 (46.9)	9 (9.3)

Fifty three species (25.6%) occur in all zones from barrier reef front to reef flat, and six of these are also found in the seagrass.

Although differences in techniques of data collection and analysis make precise comparisons with other studies difficult, it appears that fish species at Yap are generally more widely distributed among reef zones than they are at One Tree Island Reef and at Fanning Island. At One Tree Island Reef (Goldman and Talbot, 1976) nearly half of the reef fish species were restricted to one or another of the reef zones and only 7% were found in all major habitats (which on that reef did not include a zone of seagrass). Of the total of 214 reef fish species seen at Fanning, Chave and Eckert (1974) observed only 14 species (6.5%) more than once in at least six of the seven recognized habitats, whereas 61 species (28.5%) were seen only within one zone.

Of the six environmental zones recognized on the Yap reefs, the lagoon margin zone is the most distinctive in its fish fauna, with almost 15% of the fishes occurring there being seen nowhere else. To some extent, this is a reflection of the greater amount of time spent in surveying this zone, and more time in other zones might disclose the presence of some species which are here recorded only from the lagoon margin environment. Least distinctive was the barrier reef pass zone, in which only one species, of the 119 presumably occurring there, was not seen in another zone.

The distinctness of the various zones is shown in a somewhat different way in Table 3 which shows the number of species which are no longer encountered (are "lost") as one progresses from seagrass to barrier reef front, the number of species newly encountered ("gained"), and the percent faunal change which occurs as the zone boundaries are crossed. The greatest faunal change occurs between the seagrass and reef flat zones and is due to the relatively large number of species which occur in the latter zone but not in the former. The seagrass zone itself has only one species (based on the present survey results) which does not also occur on other reef flat environments. Many additional species are encountered as one progresses from the reef flat to the lagoon margin, as well as some species being lost. More than 40% of the total number of species occurring in these two zones are not common to both. Few new species are encountered in the barrier reef pass while the ranges of many lagoon margin species do not extend into this zone, resulting in a 37% faunal change. Between the three barrier reef zones, the percent of faunal change is rather low.

The overall pattern of fish distribution across the Yap reefs which these data suggest is one in which seagrass and reef flat species also occur commonly on the lagoon margin, but relatively few extend into the barrier reef environments (Figure 2). Species of the three barrier reef zones also occur in the lagoon margin zone, but many are excluded from the reef flat and very few occur in the seagrass. The lagoon margin zone accommodates species from both ends of the continuum as well as a significant number which are found only in this zone.

Table 3. Faunal change which occurs between reef zones along the seagrass--barrier reef front gradient. Percent faunal change (D) = $[(A+B)/C] \times 100$

Reef Zones	A No. Species Lost	B No. Species Gained	C Total Species in Adjacent Zones	D Percent Faunal Change
Seagrass				
↓	1	99	122	82.0
Reef Flat				
↓	12	67	188	42.0
Lagoon Margin				
↓	62	5	181	37.0
Barrier Reef Pass				
↓	16	4	123	16.3
Barrier Reef Embayment				
↓	19	9	116	24.1
Barrier Reef Front				

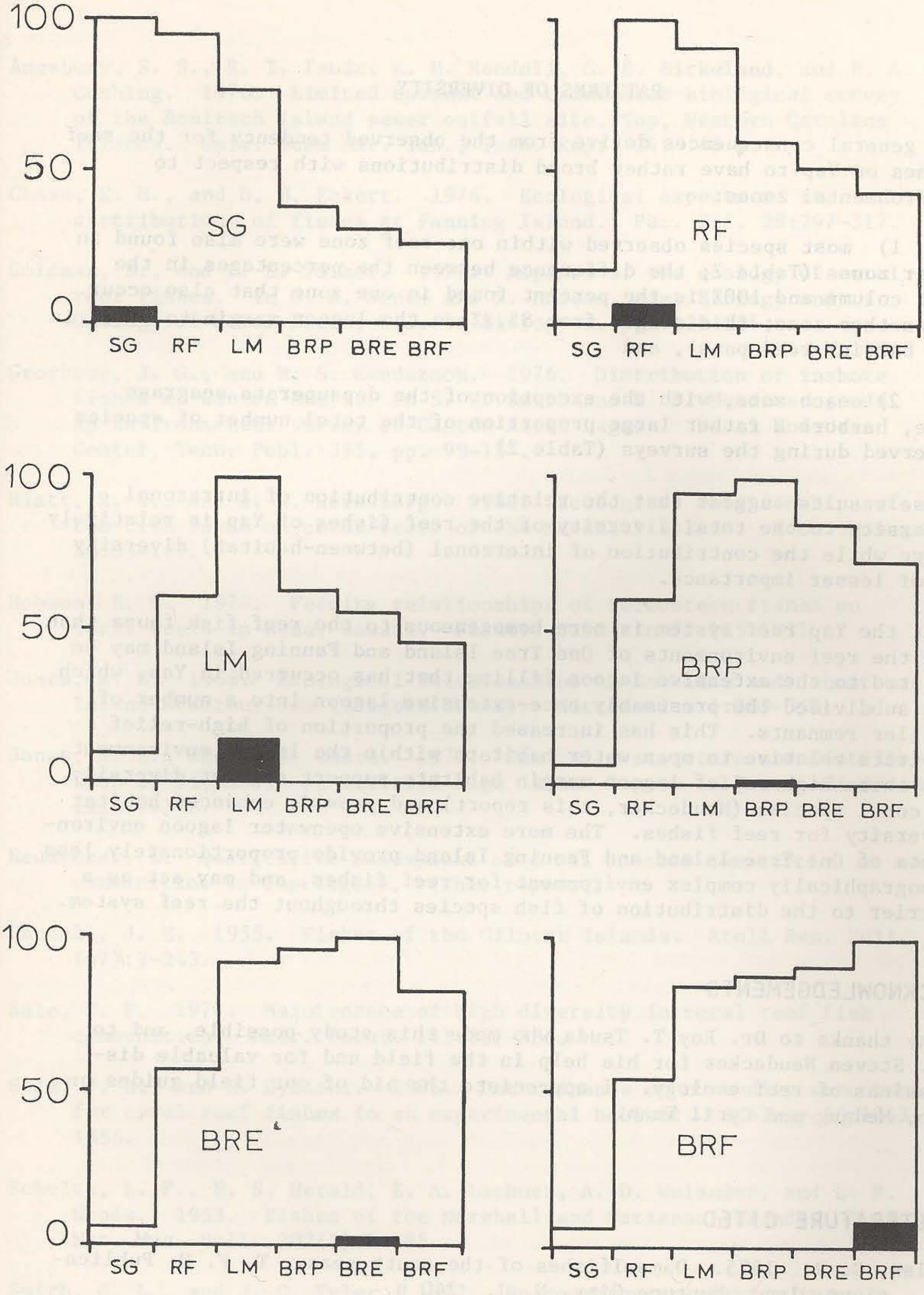

Fig. 2. Percentage of those species occurring within one reef zone that also occur in the other reef zones. Dark bar shows percentage of species occurring in a zone that are restricted to that zone. SG=seagrass, RF=reef flat, LM=lagoon margin, BRP=barrier reef pass, BRE=barrier reef embayment, BRF=barrier reef front.

PATTERNS OF DIVERSITY

Two general consequences derive from the observed tendency for the reef fishes on Yap to have rather broad distributions with respect to environmental zones:

1) most species observed within one reef zone were also found in other zones (Table 2; the difference between the percentages in the last column and 100% is the percent found in one zone that also occur in another zone; this ranges from 85.2% on the lagoon margin to 99.2% in the barrier reef pass), and

2) each zone, with the exception of the depauperate seagrass zone, harbors a rather large proportion of the total number of species observed during the surveys (Table 2).

These results suggest that the relative contribution of intrazonal diversity to the total diversity of the reef fishes of Yap is relatively large while the contribution of interzonal (between-habitat) diversity is of lesser importance.

That the Yap reef system is more homogeneous to the reef fish fauna than are the reef environments of One Tree Island and Fanning Island may be related to the extensive lagoon filling that has occurred in Yap, which has subdivided the presumably once-extensive lagoon into a number of smaller remnants. This has increased the proportion of high-relief habitats relative to open water habitats within the lagoon environment, and these high-relief lagoon margin habitats support a great diversity of coral species (Neudecker, this report) and provide enhanced habitat diversity for reef fishes. The more extensive openwater lagoon environments of One Tree Island and Fanning Island provide proportionately less topographically complex environment for reef fishes, and may act as a barrier to the distribution of fish species throughout the reef system.

ACKNOWLEDGEMENTS

Many thanks to Dr. Roy T. Tsuda who made this study possible, and to Mr. Steven Neudecker for his help in the field and for valuable discussions of reef ecology. I appreciate the aid of our field guides on Yap, Medgeg and Cyril Tman.

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QUANTITATIVE ASSESSMENT OF THE ZOOPLANKTON ASSEMBLAGES IN YAP LAGOON

Dennis R. Lassuy

INTRODUCTION

The tropical plankton community has been the subject of relatively few extensive surveys (Johnson, 1954; Wickstead, 1965) and, as such, is not well known. Amesbury et al. (1976) is the only previous work available which specifically refers to zooplankton in Yap. This survey, then, represents perhaps the most extensive assessment of the zooplankton community in Yap Lagoon to date.

The duration of the study and the range of environments sampled within the lagoon make possible the discussion of seasonality and the presence of various "community types" within Yap Lagoon as a whole. Observations on the occurrence of the developmental stages of potentially economically important resource species can, therefore, be discussed in terms of these community-types and the seasonal consistency within them.

I wish to thank Deborah A. Grosenbaugh and Dr. Steven S. Amesbury for their assistance in the counting and identification of the zooplankton samples.

METHODS

Quantitative samples of the plankton community within Yap Lagoon were taken during July, 1977 and January, 1978. Zooplankton was sampled with a 50 cm diameter conical net with .35 mm mesh apertures. In all cases, the net was towed behind a small boat for five minutes at an approximate speed of two knots (1 m/sec.) immediately below the surface; thus, each tow sampled a constant water volume of about 59 m^3. Deeper horizontal towing in areas such as the mangrove canal or the shallower reef pockets was hazardous because of the irregularity of the substrate. Horizontal tows with a smaller, somewhat finer mesh net for sampling the phytoplankton community were taken simultaneously or alternately over the same path. Analysis of these tows, however, will not be presented in this report. Samples were preserved in 5% formalin and examined with a binocular microscope in the laboratory.

Previous to any census, the total volume of zooplankton in the samples was estimated by measuring the displacement of water subsequent to refiltration of the sample. For those samples with less than 1,000 individual organisms the total sample was counted. Those samples with greater than 1,000 individuals were subsampled (1/6 to 1/60 of total sample) and estimates of density were drawn from these counts. In order to discern any major seasonal changes in the plankton community, the

January 1978 samples were taken, as often as possible, from the same sites as those in July 1977. The positions of the tows are shown in Fig. 1. All tows were made in the daytime.

RESULTS AND DISCUSSION

ZOOPLANKTON COMMUNITY STRUCTURE

The composition of the zooplankton community in nearly any aquatic environment is the result of contributions from a very wide variety of animal Phyla and may contain both holoplankton and meroplankton, i.e., those which spend all or part of their life cycles, respectively, as plankton. The complexity of such communities is overwhelming and obviously does not facilitate detailed taxonomic analysis. The range of environments sampled in this study, varying from protected mangrove canals and deep lagoon holes to harbor-like channels with open ocean exposures, further complicates such efforts. Therefore, any discussion of diversity will be in terms of the number of categories, taxa, recorded per tow, which may or may not be an adequate reflection of actual species diversity.

Copepods, brachyuran zoea and shrimp larvae were recorded in every tow and appear to be the most consistent contributors to the numbers and probably to the biomass of the zooplankton community. These three taxa, as a group, form the bulk of the numbers at all sites, comprising from 50.5% to 97.7% of the total number of organisms in the tows. Fish eggs and fish larvae also occur in every tow, however, usually in smaller numbers. Chaetognaths were recorded from every tow except 8A and often contributed significantly to community numbers. These six taxa, as a group, comprise from 71.1% to 99.8% of the total number of organisms in the tows. This would seem to indicate some degree of homogeneity in the community composition between sites. However, the relative proportions of these six taxa are quite variable.

There seem to be three somewhat distinct types of zooplankton communities discernable within the Yap Lagoon as a whole - the mangrove canal community, the harbor communities and the lagoon pocket or hole communities. Brachyuran zoea were the numerically dominant organisms in the mangrove canal, followed secondly by the copepods. Other consistently important taxa were the chaetognaths and larval fish. The only taxon recorded strictly from the mangrove canal was the insects. No significant seasonality in the composition of the mangrove community was found. The harbors investigated, Mil and Gofenu, were dominated in all cases by copepods followed secondly by either brachyuran zoea or shrimp larvae. Chaetognaths consistently comprised a major portion of the Mil Harbor zooplankton community but were never especially important in the Gofenu Harbor tows. The only taxon recorded solely from the harbors was the echinoderm larvae. Again no distinct seasonality was observed in the composition of the zooplankton communities of the harbors.

Dominance in the deep lagoon holes, when averaged for the entire study period, is shared very closely by the copepods, brachuran zoea and shrimp

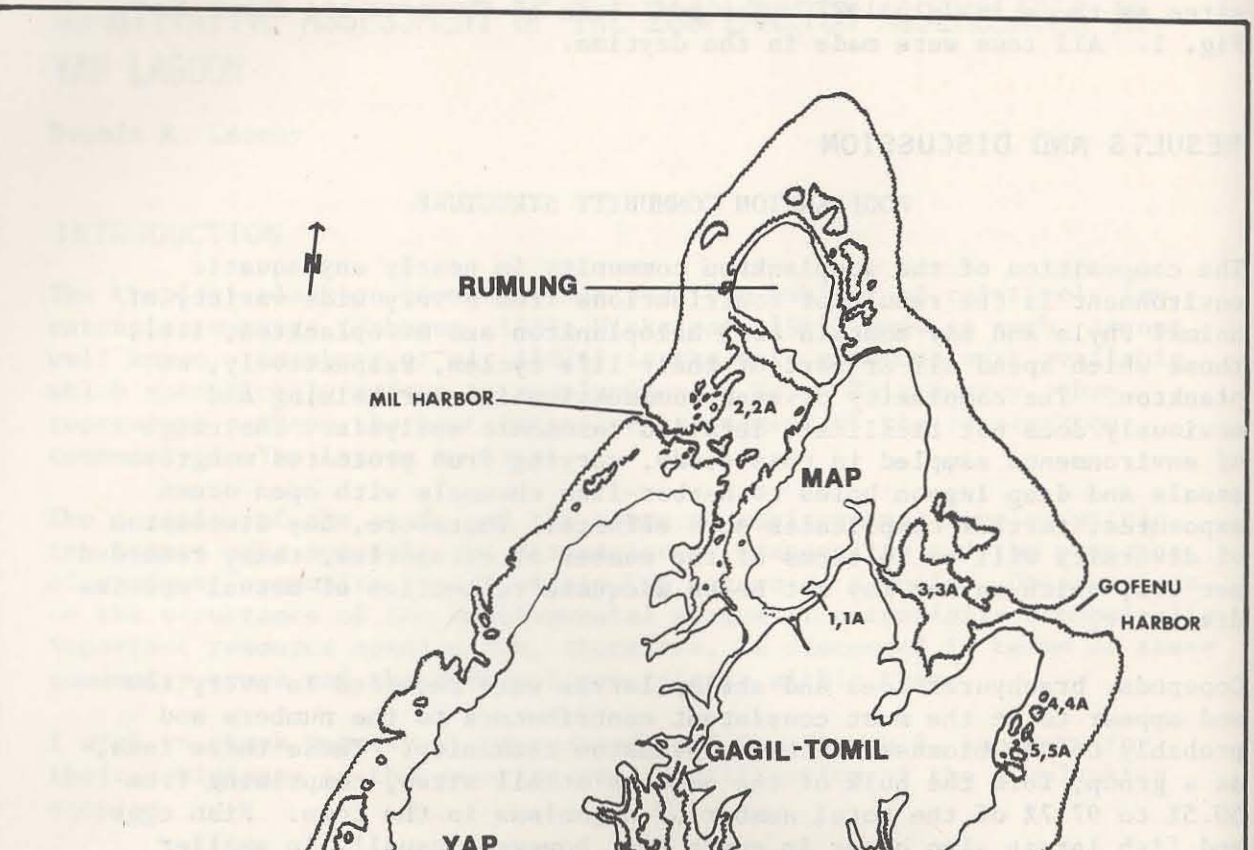

Fig. 1. Locations of plankton tows in Yap Lagoon (1-9=July, 1977, 1A-9A= January, 1978).

larvae which comprised 30.6, 30.2 and 24.6%, respectively, of the total numbers of organisms. When compared seasonally, however, the copepod populations were of significantly less numerical importance in January 1978 than in July 1977 ($t = 3.23^{**}$) averaging 49.6% of the total organisms in July and only 6.6% in January. Other zooplankters occasionally important in the lagoon holes include fish eggs, fish larvae, chaetognaths and foraminifera. Taxa recorded only from the lagoon holes include isopods, nauplii and radiolarians.

A total of 31 taxa were recorded from 18 horizontal tows and varied from a low of 9 to a high of 22 for any one tow (Table 1). Significantly higher diversities were observed in samples from the mangrove canal than either the harbors ($t = 6.11^{*}$) or the lagoon holes ($t = 7.78^{***}$). Although no salinity values are known for the canal separating Map and Gagil-Tomil, data collected from nearby Tageren Canal, separating Yap and Gagil-Tomil, in January, 1978 indicated nearly oceanic conditions with salinity varying only from 33.3 to 33.8 parts per thousand (ppt). However, Glude (1972) reported salinity values from Tageren Canal of 19 ppt after heavy rains. Occasionally, then, these mangrove canals may become somewhat estuarine in nature.

Elevated taxonomic diversity is not usually associated with estuarine environments (Friedrich, 1973, Teal, 1962). Mangrove areas are usually known to have a rich faunal diversity (Friedrich 1973). Lagler et al. (1962) state that estuarine ecosystems, as transitional zones between two environments, i.e., freshwater and saltwater, are properly termed ecotones. The tendency of such transition zones, ecotones, to have an increased variety and/or density of organisms is called the "edge effect". The rather abrupt transition from aquatic to terrestrial environments along the mangrove canals in Yap adds yet another dimension to this ecotonal community. Odum (1959) demonstrates that the diversity of ecotonal communities increases as the number of dimensions, i.e., types of transition zones, increases. The combination of at least three such transitions along the mangrove canals in Yap apparently, then, encourages this increase in taxonomic diversity.

ZOOPLANKTON DENSITY AND VOLUME

The mean zooplankton density for all tows in the study was 257.7 organisms/m^3 ($n = 18$, $s = 372.4$) and ranged from a low of 1.8/m^3 in tow 8A to a high of 1300.8/m^3 in tow 3A (Table 2). The zooplankton density found in this study for the whole of Yap Lagoon is not significantly different, then, from the value found by Amesbury et al. (1976) for daytime tows in the vicinity of Donitsch Island, Yap ($\bar{X} = 375.0/m^3$, $n = 2$, $s = 37.5$). Similar zooplankton densities ($\bar{X} = 402.3/m^3$, $n = 3$, $s = 633.7$) have also been found for Apra Harbor, Guam (Lassuy, unpubl. data). Measurements of the volume of zooplankton from Yap Lagoon varied from .01 ml/m^3 to .39 ml/m^3 (Table 2) with a mean value of .16 ml/m^3 ($n = 18$, $s = .10$). Very few studies of the zooplankton community on Yap have been done and those reports available either neglected to measure zooplankton volume or did not present the data. However, values found in Apra Harbor, Guam ($\bar{X} = .09$ ml/m^3, $n = 3$, $s = .10$) are, again, quite

Table 1. Percent composition of zooplankton taxa in horizontal tows in Yap, Lagoon (1-9=July, 1977, 1A-9A= January, 1978).

Taxon	Percent of Total Samples																	
	1	1A	2	2A	3	3A	4	4A	5	5A	6	6A	7	7A	8	8A	9	9A
Copepods	7.8	21.6	51.5	30.1	48.8	64.4	4.0	13.4	75.7	1.4	79.7	4.4	42.5	1.2	95.1	12.1	0.6	6.8
Brachyuran zoea	52.6	39.9	17.7	13.0	41.0	22.9	75.0	42.0	15.7	41.4	2.5	38.4	4.7	46.2	0.8	25.3	43.7	26.3
Shrimp larvae	3.0	5.7	7.0	28.7	6.5	8.6	10.9	23.8	2.2	49.6	3.1	41.5	37.0	30.2	1.8	13.1	44.4	37.1
Chaetognaths	4.6	13.6	14.9	15.9	1.9	2.3	1.4	0.5	0.9	0.5	13.2	1.5	1.2	3.1	1.4		0.1	0.5
Fish eggs	4.1	0.4	4.9	2.5	0.3	0.4	1.5	11.4	2.7	2.5	0.3	1.7	3.1	5.1	0.3	17.8	9.8	4.8
Fish larvae	5.9	3.2	0.1	4.1	0.4	0.2	0.7	0.5	0.4	0.2	0.3	2.0	0.8	3.8	0.1	2.8	1.2	18.8
Brachyuran megalops	0.5				0.5					0.1	0.1				0.1		0.1	0.2
Mysids	1.2	1.6	1.5		0.5		1.9	1.0	0.2	0.1	0.1	4.9	0.4	4.0	0.1	4.7		0.2
Foraminifera	0.2	1.7	0.1	0.2		0.1	4.2	0.5	1.6	0.5		0.6	6.7	1.0		15.9		1.7
Larvaceans	0.2	2.7		3.5			0.1		0.2		0.1	4.6		0.9	0.3			
Stomatopod larvae				1.2	<.1	1.1		5.9		2.6		0.2		0.1				1.7
Gastropod larvae	0.4	0.1				<.1	0.1					0.2	0.4	0.6		2.8		0.5
Polychaete larvae	0.7	1.1						0.5										
Anomuran zoea	0.5	0.1	0.1							0.5				0.2				
Heteropods		0.1								0.1			1.6	3.5				0.7
Amphipods	0.2	0.7	0.1	0.3			0.1			0.4	0.1					1.9		
Isopods																0.9		
Medusae	0.7	2.2	0.2	0.5							<.1							0.2
Misc. worms	1.1	1.4							0.2									
Lucifer		0.1	0.5								0.5		0.4					
Misc. crustacean larvae	8.0	0.6			0.1												0.1	
Siphonophores	1.1	1.2	0.2															
Ostracods	0.5	0.9	0.6										0.4			0.9	<.1	
Ascidian tadpole larvae	0.7															0.9		
Insects	0.5																	
Nauplii							0.1											
Echinoderm larvae			0.1															
Radiolarians														0.1				
Misc. egg mass																0.9		
Misc. larvae													0.8					
Misc. unknowns	5.5	1.1	0.5				0.5		0.2	0.1								0.5

Table 2. Volume, density and taxonomic diversity of zooplankton in horizontal tows in Yap Lagoon (1-9=July, 1977, 1A-9A=January, 1978).

	1	1A	2	2A	3	3A	4	4A	5	5A	6	6A	7	7A	8	8A	9	9A
Volume of zooplankton (ml/m^3)	.01	.03	.12	.13	.39	.17	.01	<.01	.02	<.01	.12	.01	.02	.01	.03	<.01	.07	<.01
Density of zooplankton # of individuals/m^3)	9.58	183.2	691.7	166.6	920.6	1300.8	98.7	3.4	47.1	14.4	497.4	55.8	32.4	73.7	91.6	1.8	442.6	7.0
Taxonomic diversity (# of taxa recorded/tow)	22	20	15	11	10	10	12	11	10	13	12	11	10	14	9	13	9	13

similar (Lassuy, unpubl. data).

A more detailed picture of the zooplankton community of Yap Lagoon is possible by again splitting it into the three community types - mangrove canals, lagoon holes and harbors. Of these three communities, the harbors are by far the most concentrated. The mean density of zooplankton organisms in the samples from Mil and Gofenu Harbors was $769.9/m^3$ (n = 4, s = 474.2), similar to the density found near Ebeye in Kwajalein Atoll of $617/m^3$ (Amesbury et al., 1975), with Gofenu consistently showing slightly higher densities than Mil. This is a significantly higher density than the lagoon holes (t = 2.71*) whose density was estimated as $113.8/m^3$ (n = 12, s = 170.0). Although the mangrove canals showed a mean density of $96.4/m^3$, even lower than that of the lagoon holes, the small number of tows in this community and the proportionately higher fluctuations in density yield a statistically insignificant t-value of 2.667 (.10 > P > .05). No significant seasonality in zooplankton densities was observed for the mangrove canals, harbors or lagoon holes although in the lagoon holes all but one pair of tows (7/7A) the density was lower in January 1978 than was found in July 1977. Tows 7 and 7A were not run in precisely the same position and perhaps should not have been included for statistical purposes.

Inspection of Table 1 reveals that between July 1977 and January 1978 the composition of the zooplankton community in the vicinities of tows 7 and 7A changed from primarily a copepod-dominated community to a brachyuran zoea-dominated one. This shift to a taxon of generally much smaller animals is reflected in the total volume per m^3 (See Table 2). Thus, in every case, the January 1978 tows showed a lower zooplankton volume than July 1977, strongly suggesting some degree of seasonality in the production of zooplankton biomass in the deeper holes of Yap Lagoon.

FISHERIES IMPLICATIONS

In order to more efficiently protect and develop a fisheries resource one must know not only the distribution of the exploited portion of the population, usually the adults, but also that of the developmental, larval, stages. As mentioned in the discussion of zooplankton community structure, the early developmental stages of a very wide variety of animal taxa are planktonic in nature. Probably the most economically important single taxon whose larval stages appeared in consistent numbers in the zooplankton tows from Yap Lagoon was the fish. Therefore, in examining the samples particular attention was given to the analysis of the distribution of larval fish.

Fish larvae were observed from all tows made during this study. Their range in the percent of the total composition was from 0.1 to 18.8%, with a mean value of 2.5% (n = 18, s = 4.4). This range is similar to values being found in zooplankton tows with this same net in the nearshore waters of Guam of 0 to 15.4% (Lassuy, unpubl. data). No seasonality in the distribution or density of larval fish was apparent.

Mean values for the mangrove canal, lagoon hole and harbor communities were 4.6%, 2.6% and 1.2%, respectively. Statistical comparison of the three communities, however, reveals no significant difference in terms of percent composition or density of larval fish. In fact, the three highest densities for larval fish came from each of the three community types. The highest single value for density of larval fish came from Gofenu Harbor, tow 2A, ($6.83/m^3$), the next highest from the mangrove canal, tow 1A, ($5.86/m^3$) and the third highest from tow 9, a deep lagoon hole near the village of Nif ($5.31/m^3$).

This data can, however, be misleading as a closer examination of Table 1 reveals that most of the values for the lagoon holes are quite low (7 of 12 are less than or equal to 0.8%) as are those for the harbors (3 of 4 are less than or equal to 0.4%). In both cases, one exceptionally high value tends to inflate the mean. Although no attempt at specific identification of the larval fish was made, it was apparent while counting that all larvae in tows 2A and 9 were nearly identical and may have represented a "unispecific" school or swarm. The patchiness of zooplankton is well documented (Wiebe, 1970, 1971) and as suggested by Lagler et al. (1962) such schooling in fishes may be to facilitate feeding upon these patches.

The values of percent composition for larval fish within the mangrove canals range only from 3.2% to 5.9%. These consistently high values indicate quite clearly that such areas are active nursery grounds for the rearing of larval fish and thus should be considered an important community to manage for the development and protection of this resource in Yap.

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COASTAL BIBLIOGRAPHY OF YAP DISTRICT

Lucius G. Eldredge and Georgia Greene

INTRODUCTION

The numerous islands of the Yap District have rarely been studied. This bibliography is an attempt to draw together the published and unpublished literature of the entire district. The bibliography is composed primarily of marine-related information; however, some additional pertinent material, such as geological, anthropological, and physical information is included.

The articles are listed alphabetically. A cross-reference index follows. The reference scheme is not exhaustive but is intended to help locate major items of interest. Articles with a strong emphasis on a given island are referenced to that island individually.

Some of the citations are translations from Japanese which sometimes vary from translator to translator. The journal series titles are also translated.

The major portion of this bibliography was compiled through the efforts of the University of Guam Sea Grant Program (Grant Nos. 04-4-158-4 and 04-5-158-45). Special acknowledgements are extended to Majorie V. C. Falanruw (Yap Institute of Natural Science), R. E. Johannes (Hawaii Institute of Marine Biology), R. T. Tsuda (University of Guam Marine Laboratory), and Emilie G. Johnston and Albert Williams (Micronesian Area Research Center).

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CROSS REFERENCE INDEX

APPENDIX

REEF DEVELOPMENT GUIDE

Roy T. Tsuda, Michael J. Gawel* and Michael D. Rody*

Based on the information obtained from the biological studies presented in the previous sections, a reef development guide is presented which we hope will be of some use to planners and other governmental agencies responsible for developing, interpreting or commenting on developments proposed for coastal and reef areas.

Figure 1 depicts a generalized cross section of the Yap reef showing all of the possible zones which can be encountered as one travels from the shore to the outer reef slope. Some of the areas of the reef may be dominated by only one of these zones, e.g., the seagrass zone, or by all of these zones. The fold-out map which accompanies this report provides a generalized view of the zones around the four major islands of Yap. It should be emphasized that the zones portrayed in the fold-out map are very general. Thus, before any development is planned for any area, a detailed study must be undertaken in the selected area. The various zones depicted on the cross-section profile (Fig. 1) and the fold-out map are described in Table 1 along with their potential functions and consequences of alteration and development.

The proposed developments which are considered in this section are listed and defined in Table 2. Table 3 provides one interpretation of the development suitability of the various reef areas or zones shown on the fold-out map and the cross-section profile. Our interpretation will no doubt differ from others but our overall philosophy is based on the premise that coastal development will take place in Yap. We are simply providing guidelines on where these developments should or should not occur.

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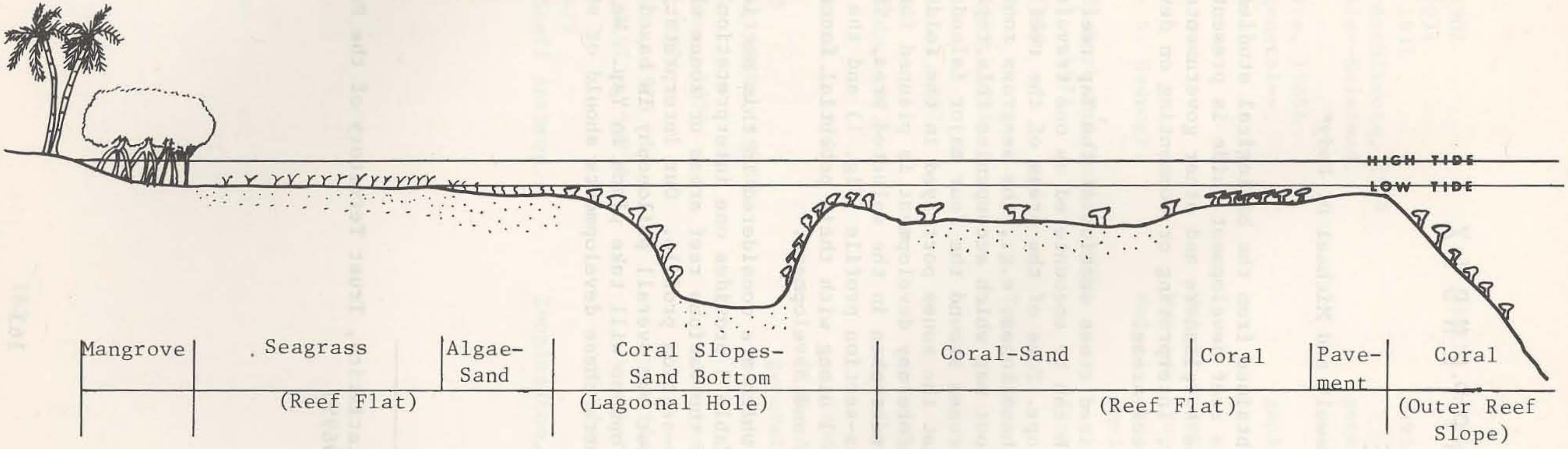

Fig. 1. General cross section of Yap reef.

Table 1. Description, functional aspects and consequences of alteration and development of the various reef areas in Yap.

Table 1. Description, functional aspects and consequences of alteration and development of the various reef areas in Yap.

Reef Areas	Description	Function	Consequences of Alteration & Development
MANGROVE	Mud substrate; dominated by mangrove trees; habitat for larval fish, shellfish, crabs, jellyfish.	Protect shoreline from erosion and land from storm wave flooding; trap sediments; build-up land; firewood and lumber; recycle pollutants.	Erosion of shore; flooding of land in storms; siltation, damage to corals; loss of crabs and shellfish; loss of rearing ground for fishes; loss of firewood and lumber.
REEF FLAT			
Seagrass	Sand substrate; dominated by seagrasses and benthic algae; habitat for juvenile fishes, sea cucumbers, worms and shells.	Bind loose sediments; trap sediments from land run-off; shelter and feeding grounds for fishes, shells, crabs and other animals; food source for turtles; high biological productivity.	Loose sand; silt from land will not be trapped and may affect corals; loss of fishes, shells, and crabs.
Sand-Algae	Sand substrate; dominated by benthic algae; few fishes.	Shelter some animal life, such as, worms, crabs, and few fishes; bind loose sediments; trap sediments; limited boat passage.	Loss of worms, crabs and few fishes; silt will not be trapped.
Coral Area	Reef rock serves as substrate; many types of corals and few algae present; many fishes.	Actively growing portion of reef; shelter for numerous large food fish, lobsters and crabs; habitat for small aquarium-type fishes.	Hinder growth of reef; loss of food fish, lobsters and crabs.
Pavement	Smooth reef rock and rubble caused by abrasive action of waves; coralline and turf algae present; few fishes.	Protects live coral zone from wave action.	Live coral zone may be destroyed by wave action.

Reef Areas	Description	Function	Consequences of Alteration & Development
LAGOONAL HOLE	Hole in reef of various size usually with sand bottom; rich coral growth; inhabited by many types of food fish, crabs, and shellfish.	Most reliable source of protein for local people; attractive scénic area for divers; deep water passage for boats; serve as site for sediment deposits.	Loss of edible fish and shellfish; loss of possible tourist attraction; loss of natural boat passage.
OUTER REEF SLOPE	Reef rock substrate; numerous types of corals, food fish, and shellfish.	Source of edible fish and shellfish; attractive underwater scenery for divers.	Loss of edible fish and shellfish; loss of possible tourist attraction.

Table 2. Definitions of the terms used for the proposed developments considered in Table 3.

Preservation: protection from alteration or change.

Water Sports: swimming, snorkeling, diving, sailing, motor boating, water skiing, fishing, shelling.

Aquaculture: intensive controlled production of commercially valuable plants and animals, usually requiring pens, ponds, and cages; farming of prawns, eels, turtles, rabbitfish, milkfish, oysters and others.

Resorts: hotels, inns, or similar developments to be used by the tourist industry; including swimming pools, tennis courts, golf courses, shopping arcades and restaurants.

Docks and Piers: building or improving facilities for mooring, berthing, docking, and loading or unloading from ships and boats; included are solid jetties as well as raised structures on pilings.

Light Industry: clean industries producing little pollution or environmental impact; examples include bakeries, copra drying, printing, and manufacture of furnitures, handicrafts and clothings.

Heavy Industry: manufacturing and processing industries which tend to have hazardous or badly polluting effluents or large impact on environment; examples include fish processing plants, cement plants, copra mills, canneries, power plants, desalination plants, oil storage and transhipment facilities, boat building and repairs, refineries, slaughterhouses, etc.

Stormwater Runoff Disposal: discharge of rainwater through pipes, drains, ditches or by sheet runoff.

Domestic Sewage Disposal: discharge of treated or untreated wastewater from a large public system or from individual homes or buildings.

Industrial Sewage Disposal: discharge of treated or untreated wastewater from heavy industries.

Solid Waste Disposal: permanent storage, destruction or recycling of garbage, refuse, junk, and unwanted solid materials.

Channel Building and Enlarging: construction, improving, deepening, or widening boat channels; usually requires dredging or blasting, increasing siltation temporarily and increasing use of the channel as a long-term impact.

Dredging: excavations, digging, scraping, dragline dredging, suction dredging, or other means of removing rubble, rock, sand, silt, coral or other bottom materials in areas below water level.

Filling: building up of land by deposits of excavated, dredged, or waste materials.

Table 3. Development suitability of reef areas. Key: Unsuitable = ●, Partially Suitable = ◐, Suitable = 0.

PROPOSED DEVELOPMENT \ REEF AREAS	Mangrove	Seagrass	Algae-Sand	Coral (Lagoon & Reef Flat)	Reef Pavement	Coral (Outer Reef Slope)	Enclosed Lagoon	Semi-Enclosed Lagoon	Harbor	Barrier Reef Pass
Preservation	0	0	0	0	0	0	0	0	◐	0
Water Sports	◐	0	0	0	◐	0	0	0	0	0
Aquaculture	0	0	0	◐	●	●	0	0	◐	●
Resorts	◐	0	0	0	0	●	0	0	0	●
Docks and Piers	0	0	0	◐	0	●	◐	◐	0	●
Light Industry	◐	◐	◐	●	◐	●	◐	◐	0	0
Heavy Industry	●	●	●	●	●	●	●	●	◐	●
Stormwater Runoff Disposal	0	0	◐	●	0	●	◐	●	0	0
Domestic Sewage Disposal	◐	●	●	●	●	◐	●	◐	◐	◐
Industrial Sewage Disposal	●	●	●	●	●	◐	●	●	●	◐
Solid Waste Disposal	●	●	●	●	●	●	●	●	●	●
Channel Building and Enlarging	◐	0	0	◐	●	●	◐	◐	0	0
Dredging	◐	●	●	◐	◐	●	0	0	◐	◐
Filling	◐	◐	◐	●	0	●	●	●	◐	●