MARINE BIOLOGICAL SURVEY OF NORTHERN PONAPE LAGOON

Edited by

Charles Birkeland

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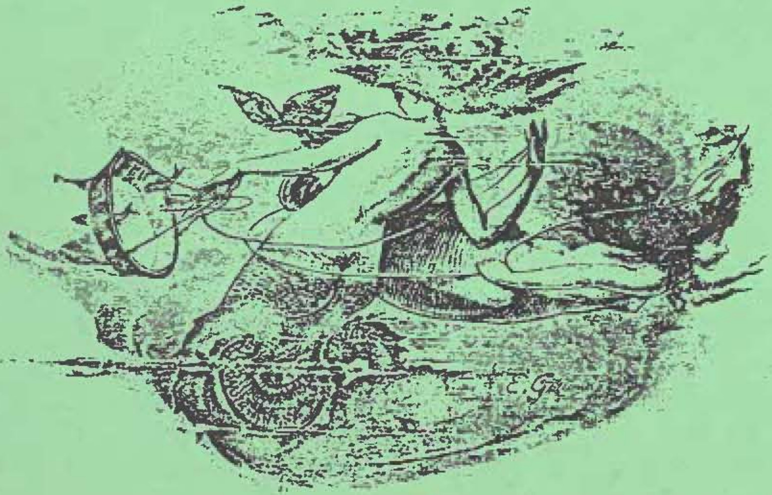

(*From Murray, 1885*)

UNIVERSITY OF GUAM MARINE LABORATORY

Technical Report No. 62

April 1980

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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

In the summer of 1979, Mr. Michael Rody, Director of the Office of Planning and Statistics, Trust Territory of the Pacific Islands, contacted Dr. Roy T. Tsuda, Dean of Graduate School and Research, University of Guam, and requested that a marine survey of Ponape Lagoon be made by the University of Guam Marine Laboratory. The scope of work requested by Mr. Rody involved the following:

1. The physical characteristics of surface and subsurface currents associated with the three major channel areas in northern Ponape (Jokaj, Ponape and Mant Passages) were to be described.

2. The major benthic biological communities or marine habitats were to be described and mapped.

3. A list of marine plants, corals and conspicuous macroinvertebrates were to be made.

4. A coastal bibliography of Ponape was to be compiled.

5. The above material was to be presented in a report which could serve as a reference source for planning in the future economic development in Ponape.

After Roy Tsuda arranged for the Marine Laboratory to undertake this survey, Charles Birkeland agreed to coordinate the mission. Michael Rody instructed Birkeland to present a Conclusions and Recommendations section near the beginning of the report so that planners in Ponape could see some of the major patterns in the collection of data presented in the report. Michael Gawel, also of the Department of Planning and Statistics, Trust Territory of the Pacific Islands, told Birkeland that it would be preferred if a special effort was made to obtain a quantitative analysis of the distribution and abundance of fish eggs and fish larvae. The quantitative analysis of fish eggs and larvae would replace the quantitative survey of macroinvertebrates and adult fishes because the potential baitfish industry on Ponape is likely to be of major concern in future coastal land management decisions.

The field studies were conducted during the first two weeks of 1980 (31 December 1979 to 13 January 1980). Three days were devoted entirely to the current studies. The rest of the days were alloted to the collection of the 90 plankton samples and to the mapping of marine communities at the northern end of Ponape lagoon.

This report was written for the purpose of being a useful source of information on the distribution of marine communities, on the abundance and distribution of fish eggs and fish larvae, and on the current patterns of the lagoon area in northern Ponape lagoon. A complete bibliography on marine-related literature of Ponape, both published and unpublished, is also provided. This report is expected to be of use for those making future decisions concerning planning of resource development and land-management policies near Ponape lagoon.

ACKNOWLEDGEMENTS

We wish to thank Mr. Michael D. Rody, Director of the Office of Planning and Statistics, Trust Territory of the Pacific Islands, for initiating and sponsoring this project. Dr. Roy T. Tsuda, Dean of Graduate School and Research, University of Guam, made all the arrangements for the contract for this project between the Trust Territory of the Pacific Islands and the University of Guam. Mr. Michael J. Gawel advised us of the desired emphasis of this project on the study of larval fish and current patterns. The Honorable Leo Falcam, Governor of Ponape, and Mr. Richard A. Croft, State Fisheries Officer, Marine Resources Division, Ponape, met with us and were very cooperative and encouraging during our stay on Ponape. Dick Croft generously loaned us two of the Marine Resources Division boats for our studies, let us use one of the Marine Resources Division vehicles for transportation, and let us use some Marine Resources Division scuba tanks. We are especially grateful for the help given us by Dick Croft and the Marine Resources Division. Frank Cushing was the general manager of this project. Ersin came with us several times to show us the way through the maze of patch reefs; we could not have made the nighttime plankton tows without his help. Our administrative secretary Terry Balajadia willingly typed this report with all its unreasonable figures and tables.

Barry Smith identified or confirmed identifications of the gastropods listed in this report. Richard Braley identified the bivalves. Roy Kropp identified the invertebrates associated with Pocillopora that were listed in this report.

CONCLUSIONS AND RECOMMENDATIONS

In this report, we found the counts of fish eggs in the lagoonal waters around Ponape to be relatively high when compared to other Pacific Island areas. Richard Croft, Fisheries Officer of the Marine Resources Division of Ponape, informed us of the high harvesting potential of baitfish for the future fisheries industry of the island. Our plankton tows that were taken in baitfish areas off stretches of coastline characterized by mangrove-seagrass associations contained the greatest numbers of larval fishes. Plankton tows were also taken in a variety of habitat types chosen independently of baitfish areas and of these groups of tows, those replicates taken in habitats characterized by mangrove-seagrass associations also contained the greatest numbers of fish larvae. There is strong evidence that the sections of coastline that are characterized by mangrove-seagrass associations are important as nurseries for larval fishes. Future plans for economic development and land management in Ponape should take this into consideration.

Fish eggs were found to be particularly abundant in samples taken over seagrass beds or along the lagoonal margin of the barrier reef. These habitats appear to be important spawning sites for fish and they also appear to be important sites for maintaining a reproductive stock of the fishes that produce the eggs. Any enironmental quality assessment must keep in mind the importance of both the mangrove-seagrass associations as nurseries of fish larvae and the seagrass and lagoonal coral reef habitats as sites for maintaining reproductive stock and a diversity of fishes.

We believe that the relatively rich production of fish eggs and larvae in Ponape lagoon might be a result of phytoplankton productivity which, in turn, might be the direct result of nutrient input from the island. According to calculations in Cowan and Clayshulte (1980:111), the waters with the highest potential phytoplankton biomass yields in Micronesia are waters around the high islands of Ponape and Kosrae. The waters around Truk (Moen, Dublon), Yap, Koror, Kwajalein (Ebeye, Gugeegue) and Majuro were lower in potential phytoplankton biomass yields. The nutrients in the waters around the high islands such as Ponape may be especially great because of the extra heavy rainfall that carries nutrients into the nearshore waters. The lagoonal waters around Ponape may actually have higher phytoplankton production than Kosrae because of longer residence time of the waters in the lagoon. This residence time allows more time for the phytoplankton to reproduce in the presence of nutrients. Around high islands with fringing reefs such as Kosrae, the nutrients may soon be carried away and dispersed before the phytoplankton can build up a large population in the area.

The coral fauna was found to be unexpectedly diverse with 216 species being recorded in our two-week survey of the northern lagoonal area of Ponape. No endangered species were found.

Information concerning currents in the northern lagoon section of Ponape are presented in this report for future use in planning and evaluating future sites of construction and development in areas that may require consideration of local current patterns. These sorts of development might include the construction of such structures as sewer outfalls, small boat harbors, navigation channels, etc. Decisions concerning locations for any silt screens needed during a construction project would be based on the current patterns of the lagoon.

Maps of the distribution of habitats or benthic marine communities around the northern lagoon of Ponape are also given in this report for the purpose of aiding in the future planning of development and coastal land management (Fig. 1). A general guide to the potential development suitability of different habitats, a description of habitats, the natural land and resource management functions of these habitats, the possible consequences of alteration and development of the various habitats, and a glossary of terms are each given in the Appendix for convenience in utilizing the information from the habitat distribution maps in future planning of development and land management.

In conclusion, we believe we should emphasize that the preservation of the marine systems mentioned above, which serve as nursery grounds for larval fishes and spawning grounds for reef fishes, should be given careful consideration in any coastal zone management and development decisions. Ponape has a high potential for a local bait-fishery and the rich and diverse fauna of corals and fishes should be maintained in a healthy state.

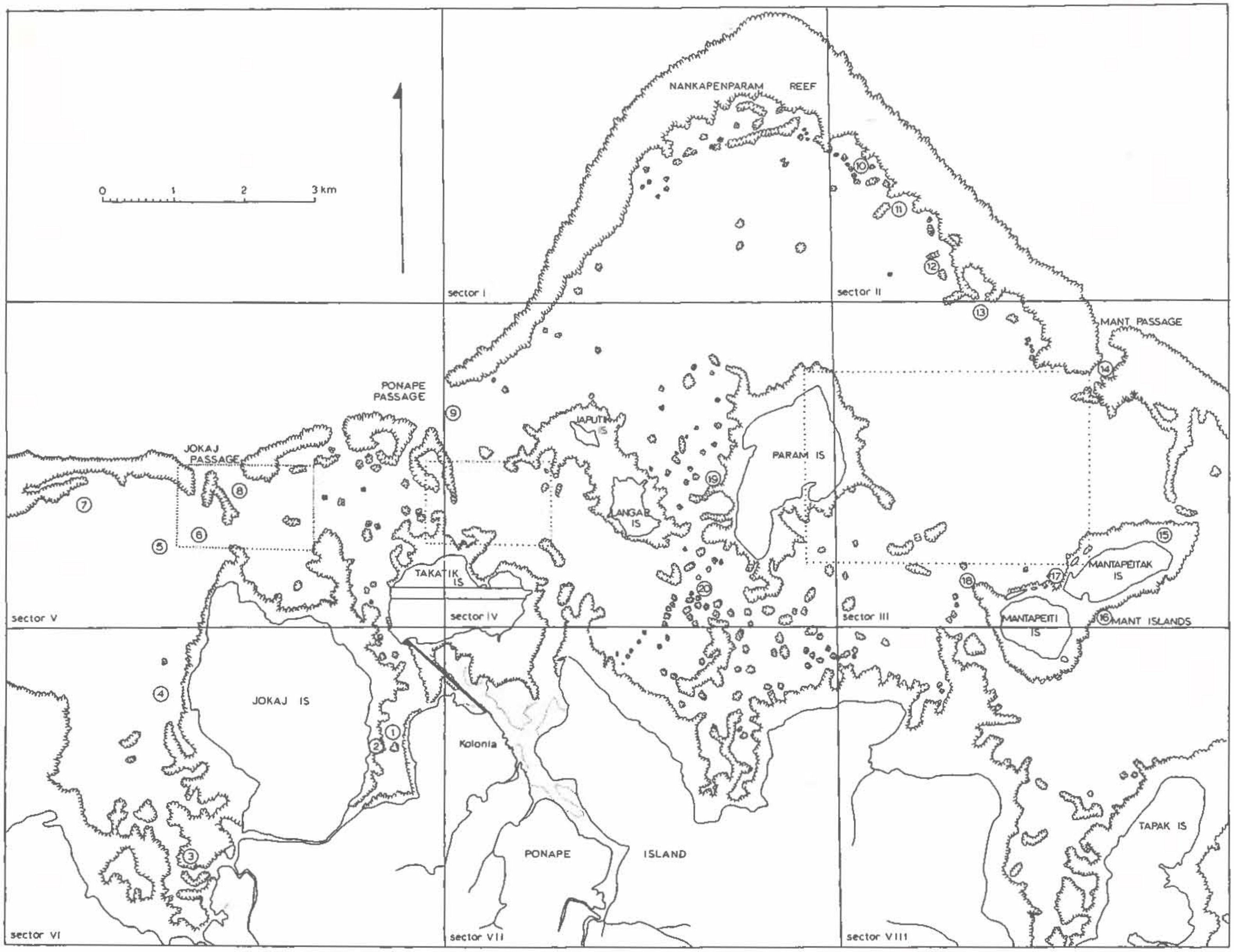

Fig. 1. Northern Ponape Lagoon, showing sector maps I-VIII, plankton tow sites (numbers enclosed in circles), and sites of current studies (within dotted rectangles).

CURRENT PATTERNS IN THE NORTHERN LAGOON OF PONAPE

David Pendleton

INTRODUCTION

At least two previous studies have been carried out on current patterns within the study area. Both focused on the Tuanmokot Channel. Austin, Smith and Associates, Inc. (1968) conducted preliminary studies of tidal action in that area. Tsuda et al. (1974) investigated Tuanmokot Channel current patterns after causeway construction had been completed. No publications were found dealing with current patterns in the lagoon.

METHODS

A pair of drift drogues, 1 m and 5 m deep, were released at three locations within the study area (Figs. 2 through 7). The locations of the study areas are enclosed by dotted lines in Figure 1. After about 45 minutes, their positions were determined with a hand-bearing compass by sighting three fixed points. The drogues were then returned to the starting points and released again. The data were recorded and plotted. This procedure was followed on two separate days, 31 December 1979 and 5 January 1980. On 10 January 1980, both 1-m and 5-m drogues were released at two locations (Figs. 8 and 9). All four drogues were allowed to drift for about seven hours. Drogue positions were determined approximately every hour with a hand-bearing compass. Wind speed and direction were also routinely recorded all three days to ascertain possible correlations between wind direction and drogue movements.

It should be emphasized that accuracy in determining drogue positions is inversely related to fixed point distances. Near Jokaj Passage, the reference points were fairly close and subsequent plottings appeared accurate. The reference points near Ponape Passage were further away and subsequent plottings appeared less accurate. The study conducted near Mant Passage presented another difficulty; the starting point, where the drogues were periodically returned and released, had to be judged using the hand held compass (the other locations had fixed channel markers as starting points). The plotting of drogue positions took the above error factors into consideration and reflect our best estimate of true movement.

Starting points for all three sites, on 31 December and 5 January, were about midway between the lagoon channel entrances and land in order to reflect any lateral movement, since it was felt that water would enter the lagoon through the channels during flood tide and leave during ebb tide, as determined previously for Tuanmokot Channel. On 10 January the drogues were placed so as to determine water movement in that part of the lagoon not directly influenced by channel currents.

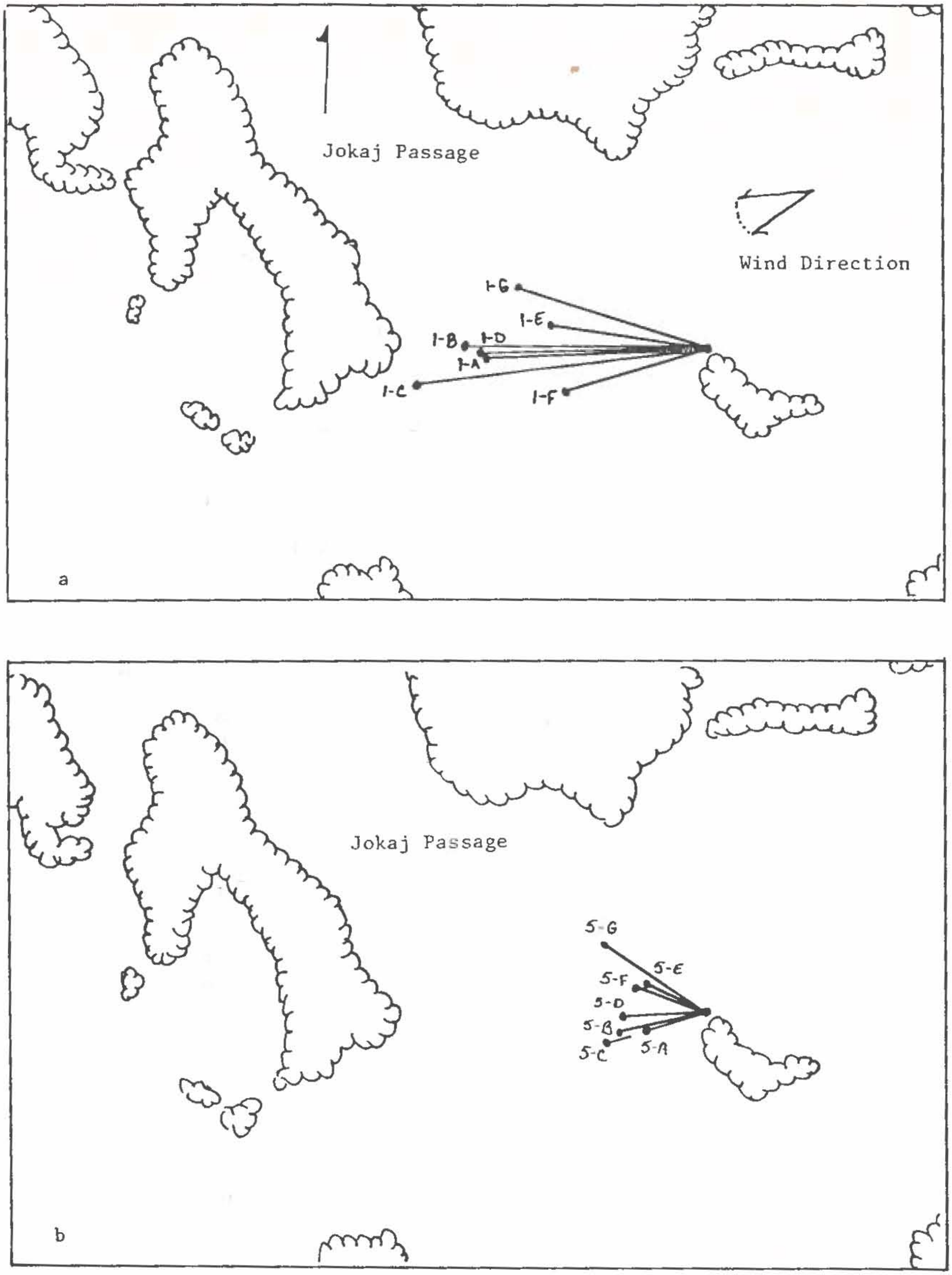

Fig. 2. 1 m (a) and 5 m (b) drift drogue movements, Jokaj Passage, 31 December.

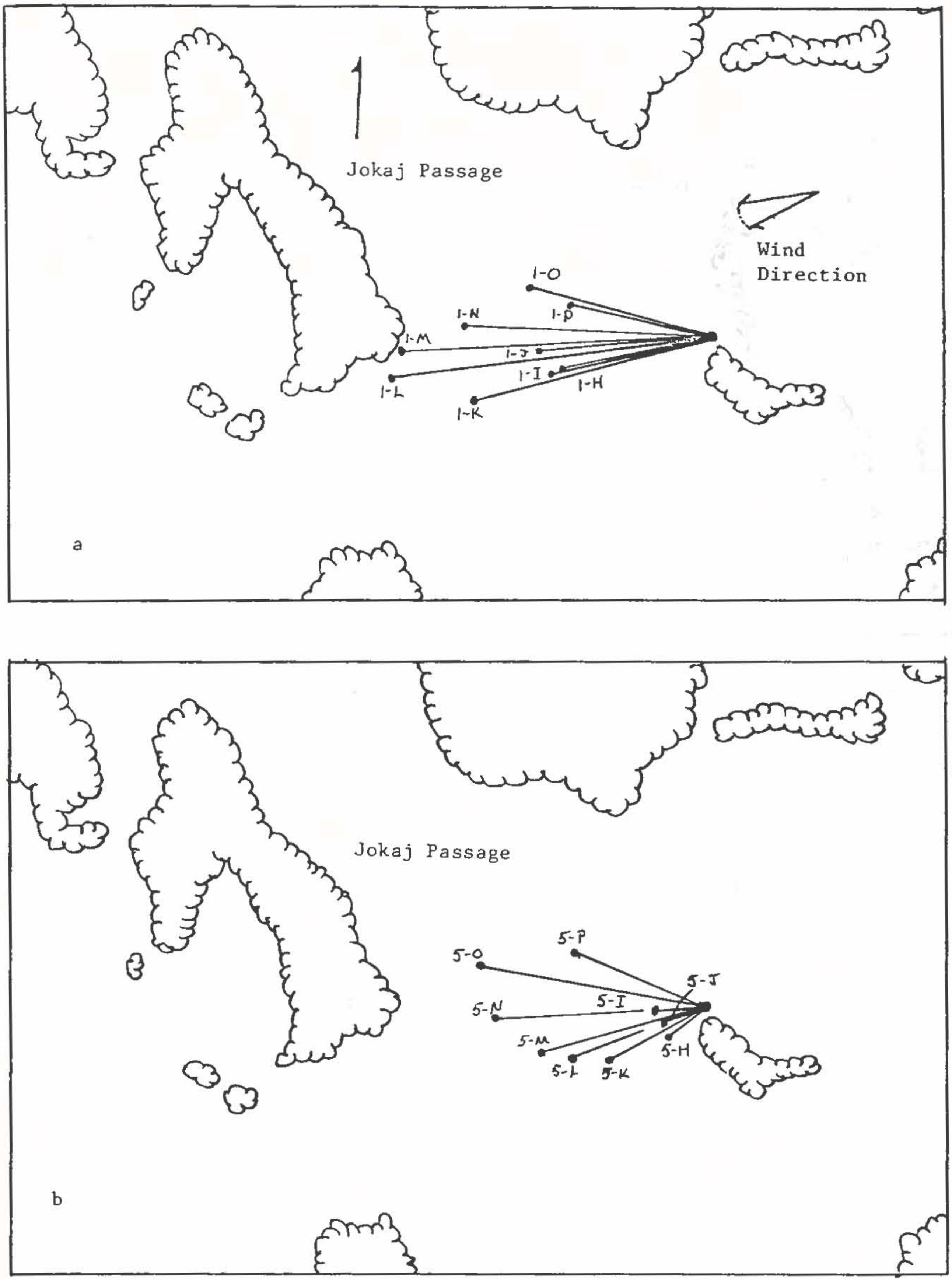

Fig. 3. 1 m (a) and 5 m (b) drift drogue movements, Jokaj Passage, 5 January.

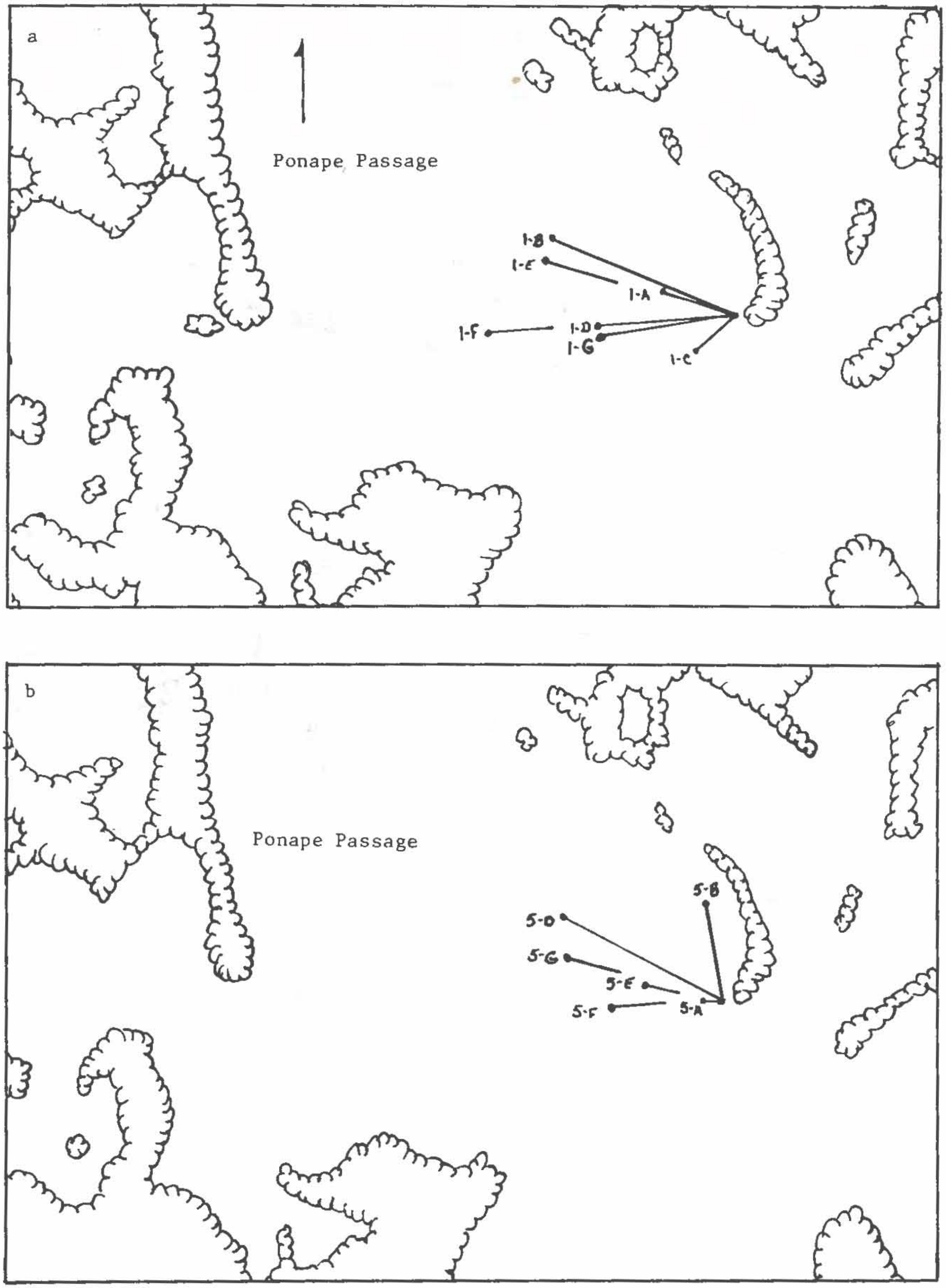

Fig. 4. 1 m (a) and 5 m (b) drift drogue movements, Ponape Passage, 31 December.

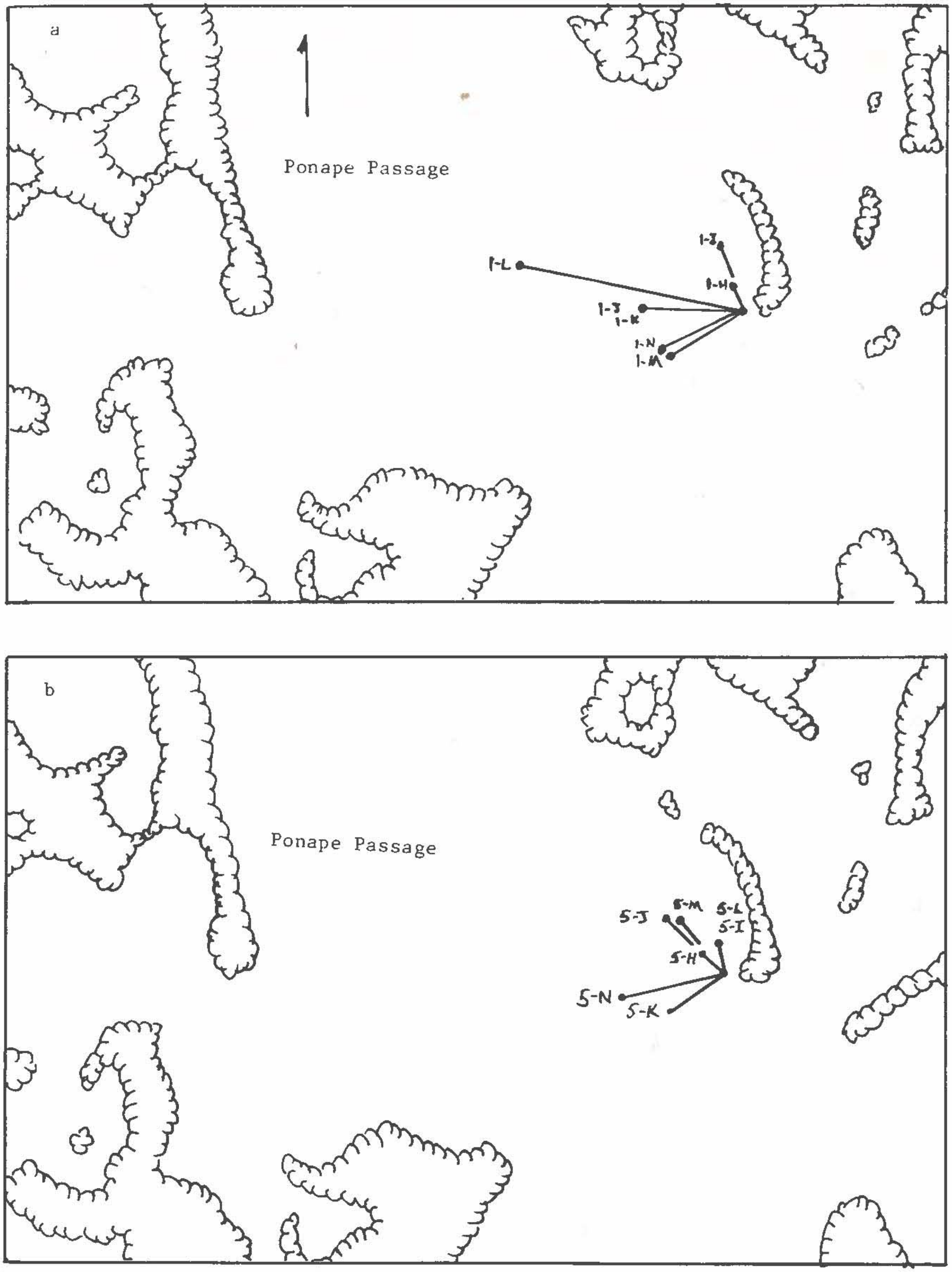

Fig. 5. 1 m (a) and 5 m (b) drift drogue movements, Ponape Passage, 5 January.

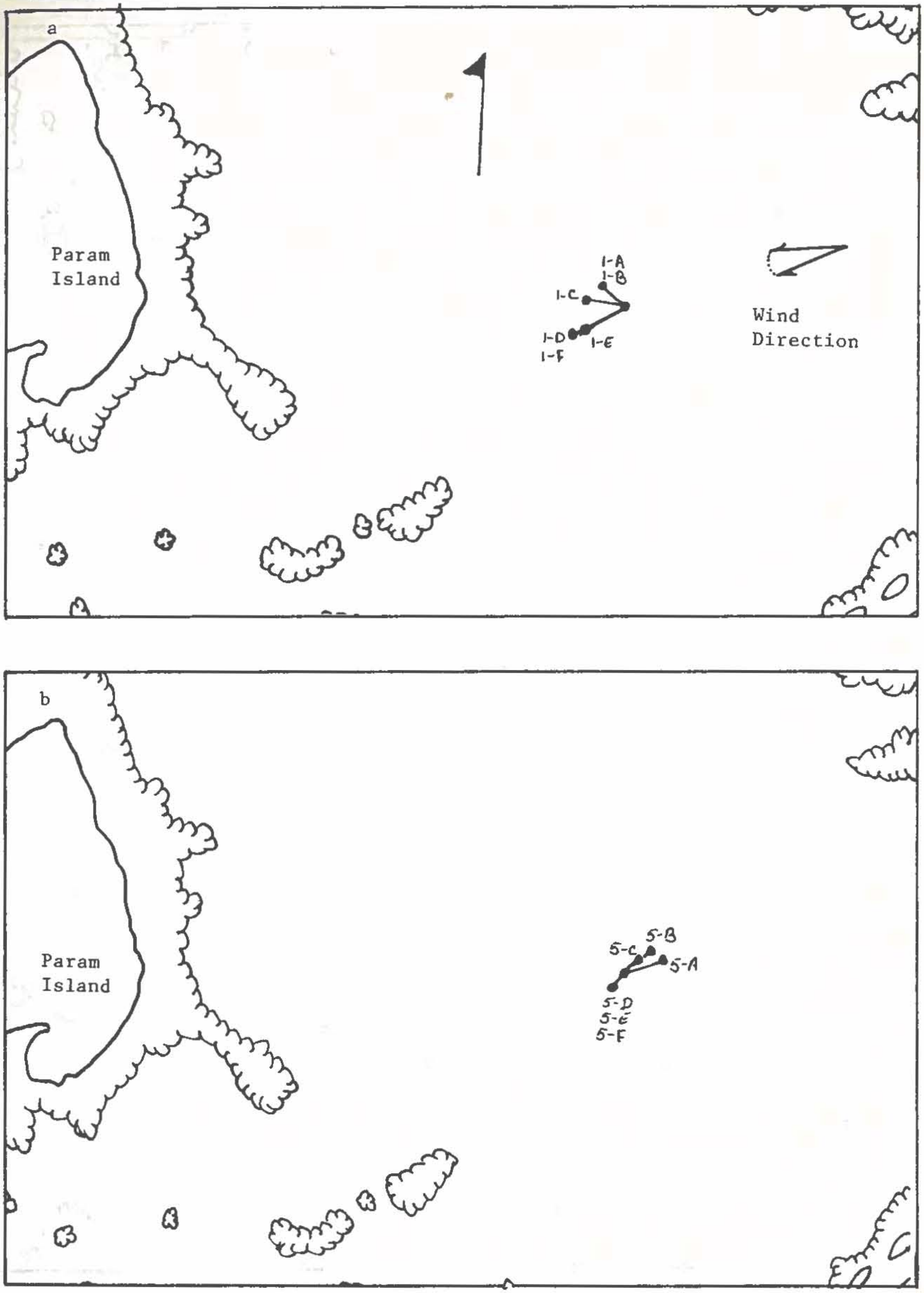

Fig. 6. 1 m (a) and 5 m (b) drift drogue movements, Mant Passage, 31 December.

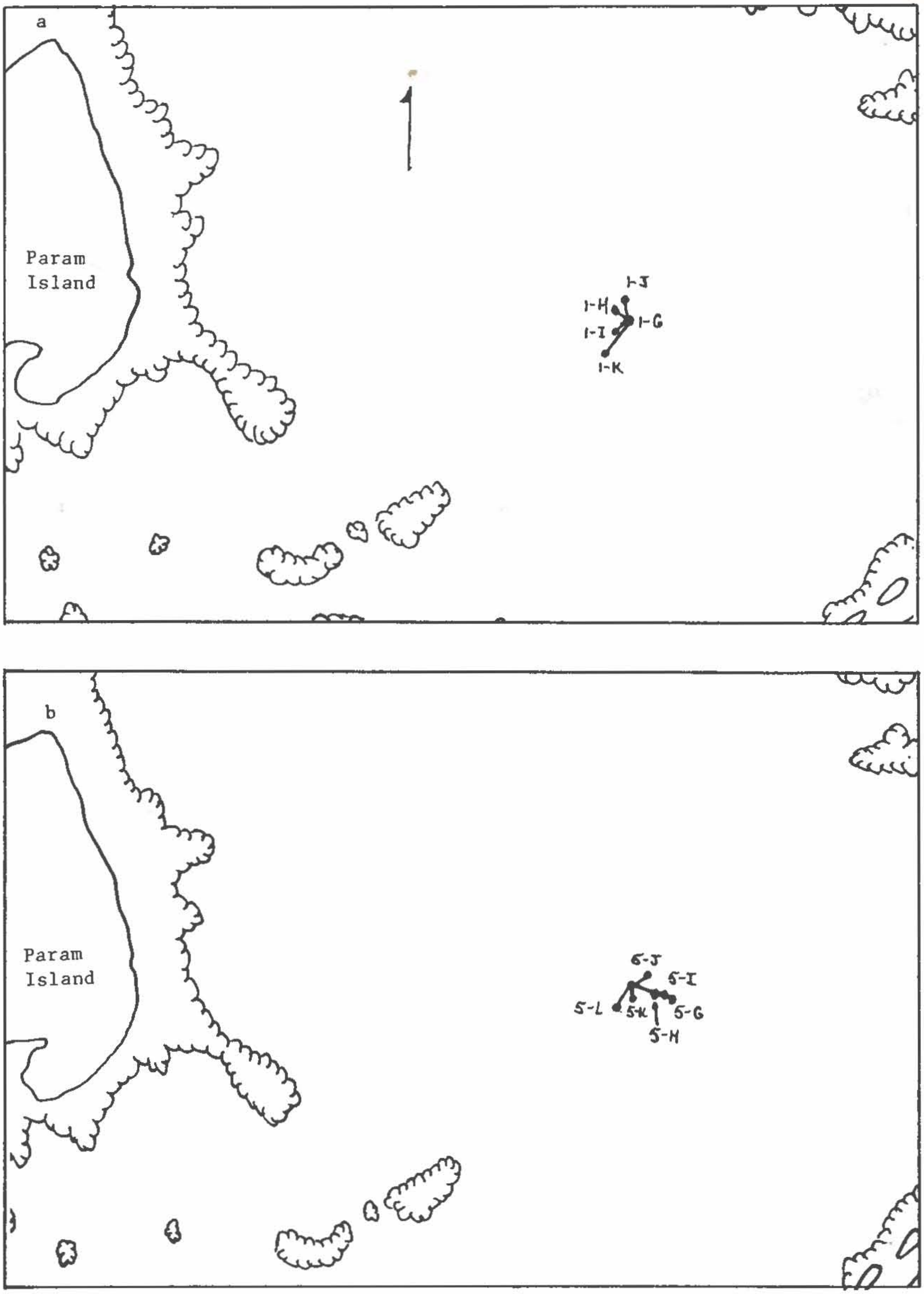

Fig. 7. 1 m (a) and 5 m (b) drift drogue movements, Mant Passage, 5 January.

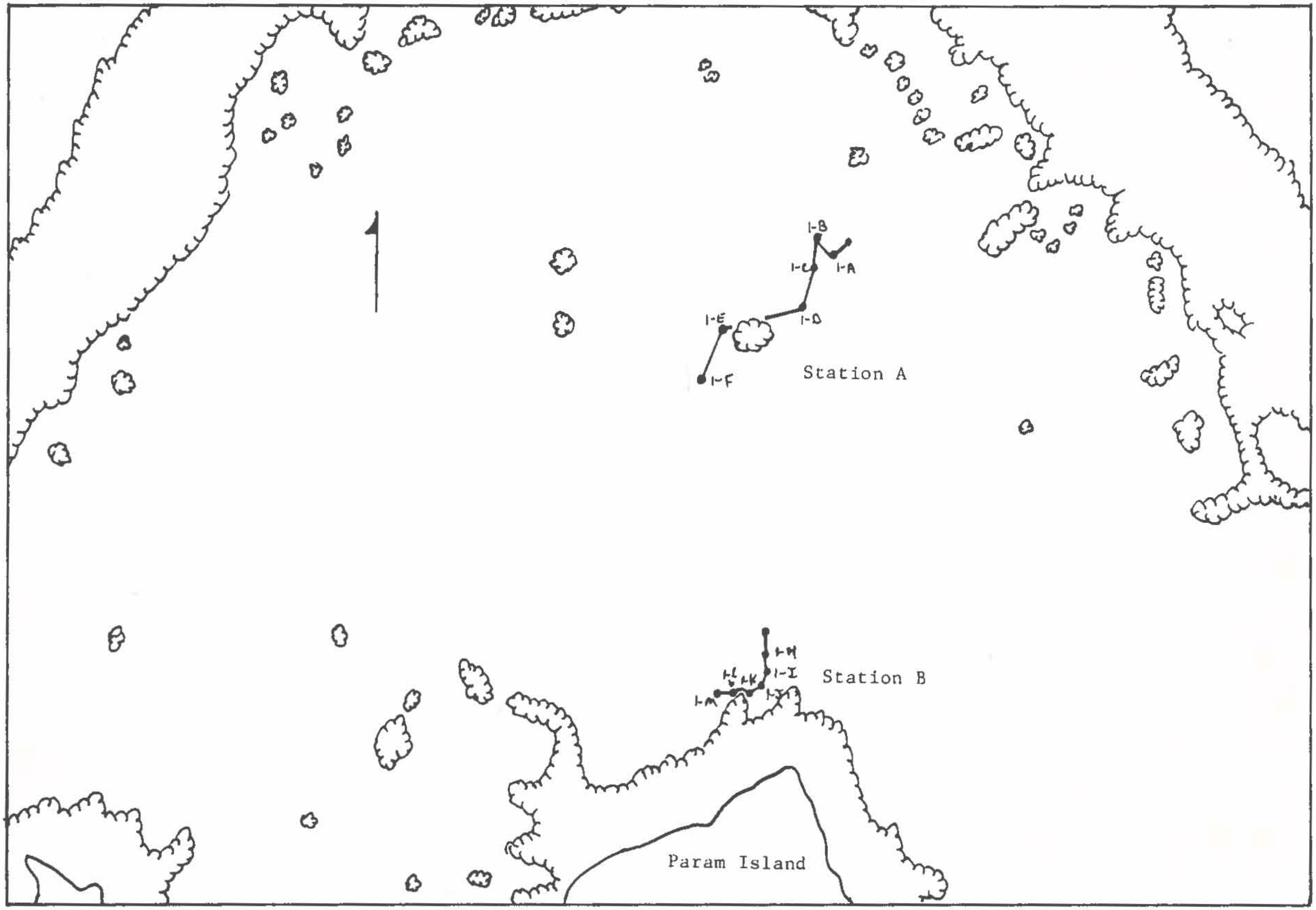

Fig. 8. 1 m drift drogue movements, lagoon north of Param Island, 10 January.

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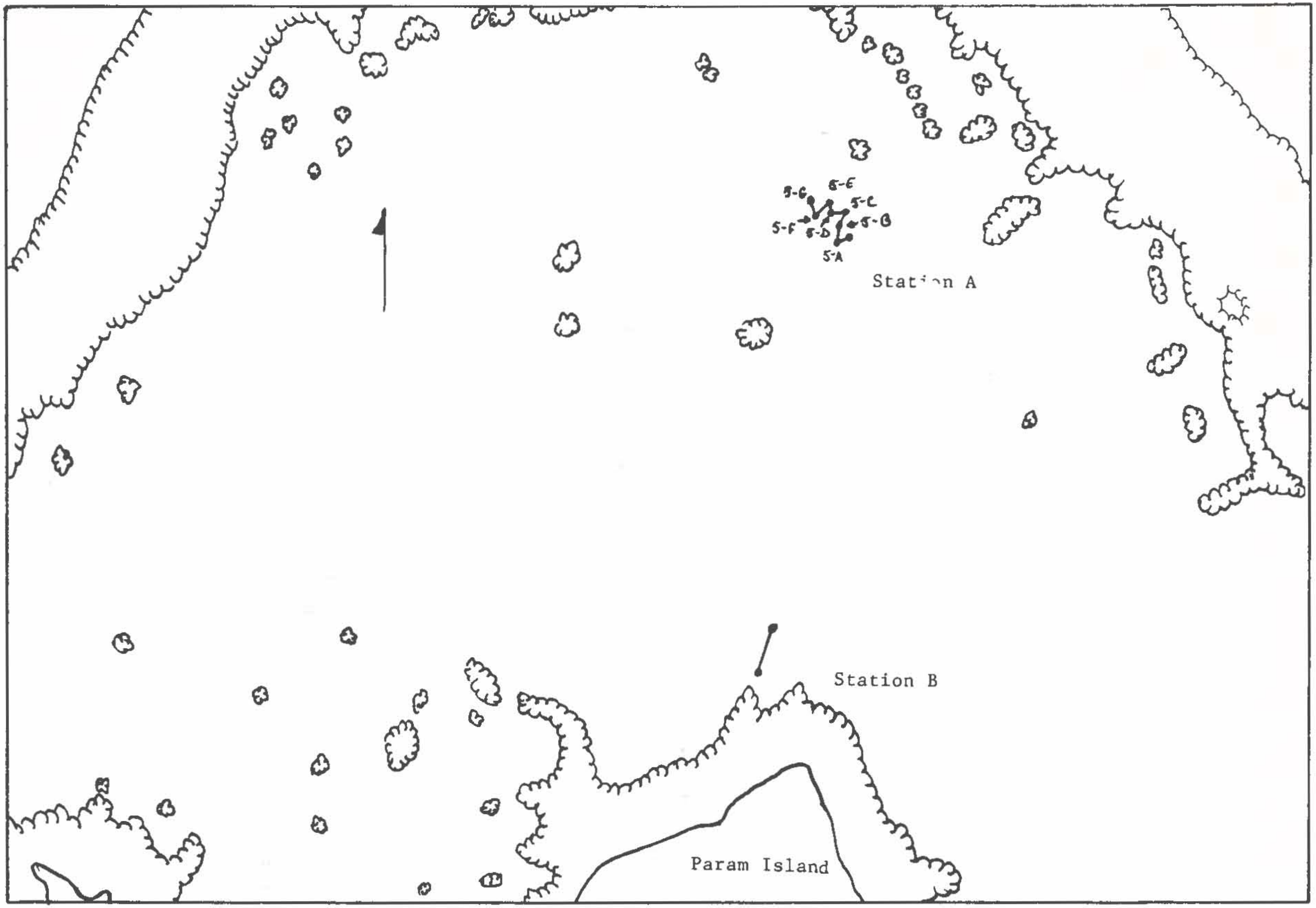

Fig. 9. 5 m drift drogue movements, lagoon north of Param Island, 10 January.

JOKAJ PASSAGE

Two days of current studies near Jokaj Passage showed a significant relationship between wind direction and current direction for both 1-m and 5-m drogues ($X^2 = 30.4^*$ and 24.2^{**}, respectively, cf. Tables 1 and 2 and Figs. 2 and 3). The 1-m drogue moved in a direction between 6° and 56° north of wind direction, averaging 20.6° north of wind direction. The 5-m drogue moved in a direction between 21° south and 64° north of wind direction, averaging 17.4° north of wind direction. Hourly fluctuations in wind direction did not correlate significant with hourly drift direction changes for both drogues. However, average drogue drift direction and average wind direction shifted in the same direction, 10.17° and 6.33° respectively, between 31 December and 5 January. This may indicate drift direction is determined by the generally prevaling wind direction and not hourly fluctuations.

Drift speed measurements gave similar results. There was no correlation found between hourly drogue drift speed changes and wind speed changes. However, wind speed averaged 20.3% higher on 5 January, while drift speeds averaged 17.4% higher on 5 January, indicating drift speeds were determined by long-term wind speeds.

Although the 1-m drogue travelled significantly further during each trial ($F_{[1,12]} = 37.8^{***}$-first day; $F_{[1,16]} = 7.59^*$-second day), there was a positive correlation between 1-m and 5-m drogues in both drift direction and speed ($t_{[\infty]} = 2.746^{**}$ and 2.61^{**}, respectively). That is, they both followed similar patterns; when the 1-m drogue speed increased, the 5-m drogue speed also increased, and when the 1-m drogue shifted directions, the 5-m drogue shrifted in the same direction.

Tidal influence on current patterns near Jokaj Passage was not clearly demonstrated. There was no correlation found between drift directions and tidal changes for both 1-m and 5-m drogues. Also, even though drift speed and tidal changes seemed to be related, no correlation could be found for the 5-m drogues. However, there was a very significant correlation between drift speed and tidal change for the 1-m drift drogues ($t_{[\infty]} = 3.25^{**}$). This is interesting in that the 1-m and 5-m drogues varied together significantly in drift distances, yet only the speed measurements of 1-m drogues correlated significantly with tidal changes. Taken together, it appears that current direction is not influenced by tides, but current speed is slightly increased by a rising tide and decreased by an ebbing tide.

PONAPE PASSAGE

Two days of current studies near Ponape Passage showed a significant relationship between wind direction and current direction, when 1-m and 5-m drogues are included together ($X^2{}_{[25]} = 20.28^{**}$, Tables 3 and 4 and Figs. 4 and 5). The 1-m drogue moved in a direction between 19° south and 94° north of wind direction, averaging 30.0° north of wind direction.

Table 1. Distance, speed, and direction of 1-m and 5-m drift drogues[1], direction and speed of wind[2], and tide change factors[3], Jokaj Passage, Ponape, December 31, 1979.

Drogue	Start	Time (mins.)	Distance (meters)	Speed (meters/hour)	Magnetic Direction	Tide Change Factor	Wind Mag. Dir.	Wind Speed (m/sec)
1-A	1037	42	448	640	266°	↑ 1.1	80°	5.3
5-A	1040	44	127	173	255°			
1-B	1134	38	494	780	269°	↑ .85	75°	5.0
5-B	1134	42	177	253	259°			
1-C	1221	48	594	743	261°	↑ .5	65°	4.0
5-C	1221	43	210	293	245°			
1-D	1321	41	463	678	267°	↑ .2	70°	4.0
5-D	1321	45	167	223	268°			
1-E	1413	46	321	419	270°	↓ .1	65°	5.1
5-E	1413	50	134	161	298°			
1-F	1509	45	303	404	251°	↓ .4	55°	5.8
5-F	1509	49	154	186	292°			
1-G	1603	44	405	552	280°	↓ .7	-	-
5-G	1603	51	250	294	306°			

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[1] Drift direction - opposite of origin (going toward)

[2] Wind direction - origin (coming from)

[3] Tide change factor = difference between high and low tide (in meters) X relative state of the tide, when maximum is between high and low tide and minimum is at high or low tide to reflect tidal influence on current, if any. ↑ is rising tide. ↓ ebbing tide.

Table 2. Distance, speed, and direction of 1-m and 5-m drift drogues, direction and speed of wind, and tide change factors, Jokaj Passage, Ponape, January 5, 1980.

Drogue	Start	Time (mins.)	Distance (meters)	Speed (meters/hour)	Mag. Direction	Tide Change Factor	Wind	
							Mag. Dir.	Speed (m/sec)
1-H	0912	53	319	361	256°	↓ .1	70°	5.0
5-H	0916	53	97	110	229°			
1-I	1014	44	345	470	257°	↑ .1	65°	6.1
5-I	1014	50	108	130	261°			
1-J	1109	47	361	461	263°	↑ .4	65°	5.4
5-J	1109	52	95	110	245°			
1-K	1204	43	503	702	253°	↑ .7	65°	6.3
5-K	1204	47	232	296	237°			
1-L	1255	47	663	846	261°	↑1.0	65°	6.5
5-L	1255	51	297	349	245°			
1-M	1349	42	638	911	265°	↑ .8	65°	4.7
5-M	1349	45	352	469	251°			
1-N	1439	41	510	746	271°	↑ .6	65°	5.4
5-N	1439	44	436	595	263°			
1-O	1529	37	389	631	283°	↑ .3	50°	5.8
5-O	1529	41	473	692	276°			
1-P	1615	29	298	617	281°	↑ .1	45°	7.5
5-P	1615	33	296	538	289°			

Table 3. Distance, speed, and direction of 1-m and 5-m drift drogues, direction and speed of wind[1], and tide change factors, Ponape Passage, Ponape, December 31, 1979.

						Tide	Wind	
Drogue	Start	Time[2] (mins.)	Distance (meters)	Speed (meters/hour)	Mag. Direction	Change Factor	Mag. Dir.	Speed (m/sec)
1-A	1030	46	163	212	287°	↑1.1	80°	5.3
5-A		44	35	48	272°			
1-B	1125	46	413	537	293°	↑ .8	75°	5.0
5-B		44	208	283	349°			
1-C	1215	46	101	131	226°	↑ .5	65°	4.0
5-C		44	not computed-Triangulation error					
1-D	1310	46	285	371	264°	↑ .3	70°	4.0
5-D		44	372	506	296°			
1-E	1405	46	409	532	285°	↓ .1	65°	5.1
5-E		44	162	220	281°			
1-F	1500	46	510	663	265°	↓ .4	55°	5.8
5-F		44	230	313	265°			
1-G	1600	46	294	382	259°	↓ .7	-	-
5-G		44	332	452	284°			

[1] Assumed to be the same as measured at Jokaj Passage.

[2] Time for each 1-meter drogue ∿ 45-47 mins, 5-meter ∿ 43-45 mins.

Table 4. Distance, speed, and direction of 1-m and 5-m drift drogues, direction and speed of wind, and tide change factors, Ponape Passage, Ponape, January 5, 1980.

Drogue	Start	Time (mins.)	Distance (meters)	Speed (meters/hour)	Mag. Direction	Tide Change Factor	Wind	
							Mag. Dir.	Speed (m/sec)
1-H	0920	46	58	75	333°	↓ .1	70°	5.0
5-H		44	60	82	313°			
1-I	1010	46	145	189	339°	↑ .1	65°	6.1
5-I		44	63	86	348°			
1-J	1105	46	212	276	272°	↑ .4	65°	5.4
5-J		44	167	227	312°			
1-K	1200	46	212	276	272°	↑ .7	65°	6.3
5-K		44	141	192	233°			
1-L	1255	46	476	619	281°	↑1.0	65°	6.5
5-L		44	298	406	348°			
1-M	1350	46	179	233	239°	↑ .8	65°	4.7
5-M		44	140	191	320°			
1-N	1445	46	187	243	244°	↑ .6	65°	5.4
5-N		44	213	290	255°			

The 5-m drogue moved in a direction between 12° south and 103° north of wind direction, averaging 52.25° north of wind direction. Hourly fluctuations in wind direction did not correspond with changes in drift directions for either the 1-m or the 5-m drogues during both study days. Also, unlike Jokaj Passage, the average drift direction shifted about 15° north between 31 December and 5 January while average wind direction shifted less than 3° south.

Because of the difficulty in obtaining precise drift drogue positions, any correlations between wind, tide, drift speed or direction near Ponape Passage may have been obscured. Instead, more or less random variations in drift speed and direction was indicated by the data, except the correlation between wind direction and drift direction mentioned above. Even though it was observed that the 1-m drift drogue travelled further than the 5-m drogue during each trial, our data showed no significant difference in drift distances. Also, even though the 1-m and 5-m drogues appeared to travel in corresponding directions, with the 5-m drogue generally moving in a slightly more northerly direction, our data did not support this. That is, no correlation was found between 1-m and 5-m drift direction changes.

With this in mind, the data obtained near Jokaj Passage are probably more indicative of drift patterns. On the spot observations near Ponape Passage tended to confirm patterns found near Jokaj Passage, while the data obtained did not.

MANT PASSAGE

Two days of current studies near Mant Passage indicated a significant $(X^2_{[10]} = 7.2^{**})$ relationship between wind direction and 1-m drogue drift direction (Tables 5 and 6, and Figs. 6 and 7). These 1-m drogue movements corresponded to those found near the other passages studied, averaging 22.3° north of wind direction. However, the 5-m drogue moved in a variable pattern. In general, drogue movement was against the wind and toward the barrier reef. This may have been caused by the proximity of the windward reef. Wave action moves water perpendicular across the reef flat and surface water near the lagoon reef margin may be swept lagoonward, creating an upwelling region near the margin. Lagoon subsurface water would then move toward the upwelling region, replacing that water. Reefs near the other passages, besides having less wave action, are parallel to the prevailing current direction and may not cause this counter-current, while the reef near Mant Passage is more or less perpendicular to the prevailing current. Further studies would be needed to confirm the existence of this pattern.

Near Mant Passage, drift drogue positions were difficult to determine precisely. As was the case near Ponape Passage, any further correlations (besides that mentioned above) between wind direction and speed, drift drogue direction and speed, and tides, may have been obscured. More or less random variations in drogue speeds and direction seemed to be indicated by the data.

Table 5. Distance, speed, and direction of 1-m and 5-m drift drogues, direction and speed of wind, and tide change factors, Mant Passage, Ponape, December 31, 1979.

							Wind	
Drogue	Start	Time (mins.)	Distance (meters)	Speed (meters/hour)	Mag. Direction	Tide Change Factor	Mag. Dir.	Speed (m/sec)
1-A	1044	40	145	218	310°	↑1.1	75°	4.4
5-A		45	178	237	72°			
1-B	1139	40	145	218	310°	↑ .8	60°	7.2
5-B		45	163	217	49°			
1-C	1234	45	173	231	277°	↑ .5	75°	4.4
5-C		50	83	100	46°			
1-D	1334	45	263	351	221°	↑ .3	65°	8.2
5-D		50	80	96	215°			
1-E	1429	43	200	279	220°	↓.1	55°	7.2
5-E		48	80	100	215°			
1-F	1528	46	263	343	221°	↓.4	55°	7.0
5-F		51	80	94	215°			

Table 6. Distance, speed, and direction of 1-m and 5-m drift drogues, direction and speed of wind and tide change factors, Mant Passage, Ponape, January 5, 1980.

Drogue	Start	Time (mins.)	Distance (meters)	Speed (meters/hour)	Mag. Direction	Tide Change Factor	Wind Mag. Dir.	Wind Speed (m/sec)
1-G	0935	48	0	0	-	0	60°	8.8
5-G		48	195	244	112°			
1-H	1028	64	80	75	301°	↑ .2	-	-
5-H		64	108	101	113°			
1-I	1137	44	77	105	226°	↑ .5	60°	-
5-I		44	128	175	110°			
1-J	1226	51	93	109	349°	↑ .8	-	-
5-J		51	85	100	61°			
1-K	1322	43	205	286	213°	↑ .9	60°	-
5-K		46	65	85	170°			
1-L	1413	- - - - - - -	Lost	- - - - - - -	- - - - - -	↑ .7	-	-
5-L		47	125	160	216°			

LAGOON NORTH OF PARAM

Almost 7 hours of drift studies in this area revealed that both the 1-m and the 5-m drogues released just north of Param Island drifted in about the same direction while the 5-m drogue, released near the barrier reef, moved at approximately right angles to the others (Table 7 and Figs. 8 and 9). Drift directions for the 1-m and 5-m drogues released near the barrier reef averaged 11.3° and 84.43° north of the prevailing wind direction, respectively. Drift directions for both drogues released near Param Island avaraged 8.3° and 27.75° south of the prevailing wind direction, respectively. At both sites, the 1-m drogue travelled faster.

The movement of the 5-m drogue released near the barrier reef may have been influenced by wave action at the barrier reef as described previously for the area near Mant Passage. The other drogues appeared to drift more or less with the wind. No tidal influence was demonstrated.

Table 7. Distance, speed, and direction of 1-m and 5-m drift drogues, direction and speed of wind, and tide change factors, lagoon north of Param island, Ponape, January 10, 1980.

						Tide	Wind	
Drogue	Start	Time (mins.)	Distance (meters)	Speed (meters/hour)	Mag. Direction	Change Factor	Mag. Dir.	Speed (m/sec)
Station A								
1-A	1007	39	123	189	219°	↓ .5		
5-A	1007	39	65	100	248°		50°	4.6
1-B	1046	49	115	141	311°	↓ .4		
5-B	1046	64	68	64	001°			
1-C	1135	58	140	145	179°	↓ .2	25°	9.5
5-C	1150	40	65	98	020°			
1-D	1232	33	198	360	188°	↓ .1	20°	6.5
5-D	1230	40	68	102	257°			
1-E	1305	55	383	418	246°	↑ .1		
5-E	1310	45	43	57	342°		60°	6.0
1-F	1400	60	255	255	195°	↑ .4	54°	7.4
5-F	1355	55	80	87	220°			
1-G	1500	- - - - - - - - -	- Lost -	- - - - - - - - - - -		↑ .6		
5-G	1450	45	73	97	333°		45°	8.3
Station B								
1-H	1017	43	105	147	168°	↓ .5	50°	4.6
1-I	1100	44	95	130	161°	↓ .3		
1-J	1144	44	65	89	194°	↓ .2	25°	9.5
1-K	1228	58	63	65	231°	↓ .1	20°	6.5
1-L	1336	54	70	78	263°	↑ .2	60°	6.0
1-M	1430	55	70	76	263°	↑ .5	45°	8.3
5-M	1017	423	215	30—	195°			

MAPPING OF THE REEF HABITAT TYPES ON NORTHERN PONAPE

Richard H. Randall and David Pendleton

Ponape consists of a high volcanic island surrounded by an outer barrier reef which is interrupted at intervals by deep passes. The main island is drained by a radial pattern of rivers and streams which empty into the lagoon. In the lagoon, between the barrier reef and the main island, a complex of both high rocky islands and low mangrove islands are found. Fringing reefs border the main island, as well as most of the smaller lagoon islands. Mangroves border much of the shoreline along both the main island and the smaller lagoon islands. In the lagoon itself, numerous patch reefs reach the surface. These patch reefs range from small isolated pinnacles, a few tens of meters across, to long ribbon-like ridges and intricately curved and branched reefs. Some of these reefs are several kilometers or more in length and sometimes enclose both shallow and deep secondary lagoons.

A complex variety of marine habitats are found on the seaward and lagoon barrier reef terraces and slopes, reef-flat platforms,deep barrier reef passes, fringing island reefs, lagoon patch reefs, coral knolls and mounds, deep and shallow lagoon basins, shallow lagoon shelves, enclosed secondary lagoons, river estuaries, and mangrove swamps.

The reefs of northern Ponape were field-checked at 33 locations by making observations while snorkeling along transects that crossed the reefs at right angles to their lagoon margins. From these reef reconnaissance observations, the relative distribution patterns of corals, sediments, and seagrasses were determined. These data were then used to interpret the distinct zonation patterns discernable on aerial photographic prints of the entire study area. The reef areas and mangrove shorelines and the relative distribution patterns of corals, sediments, and seagrasses were then directly mapped from these aerial prints onto eight sector maps (Figs. 10-17). The location of these sectors are indicated in Figure 1.

More detailed characteristics of the physiographic reef zonation patterns, sediments, and coral and seagrass distributions are shown in vertical profiles of each of the 33 transect locations (Figs. 18-24). These vertical profiles also give percentage estimates of coral surface coverage and the predominant coral genera observed in each of the physiographic zones discerned.

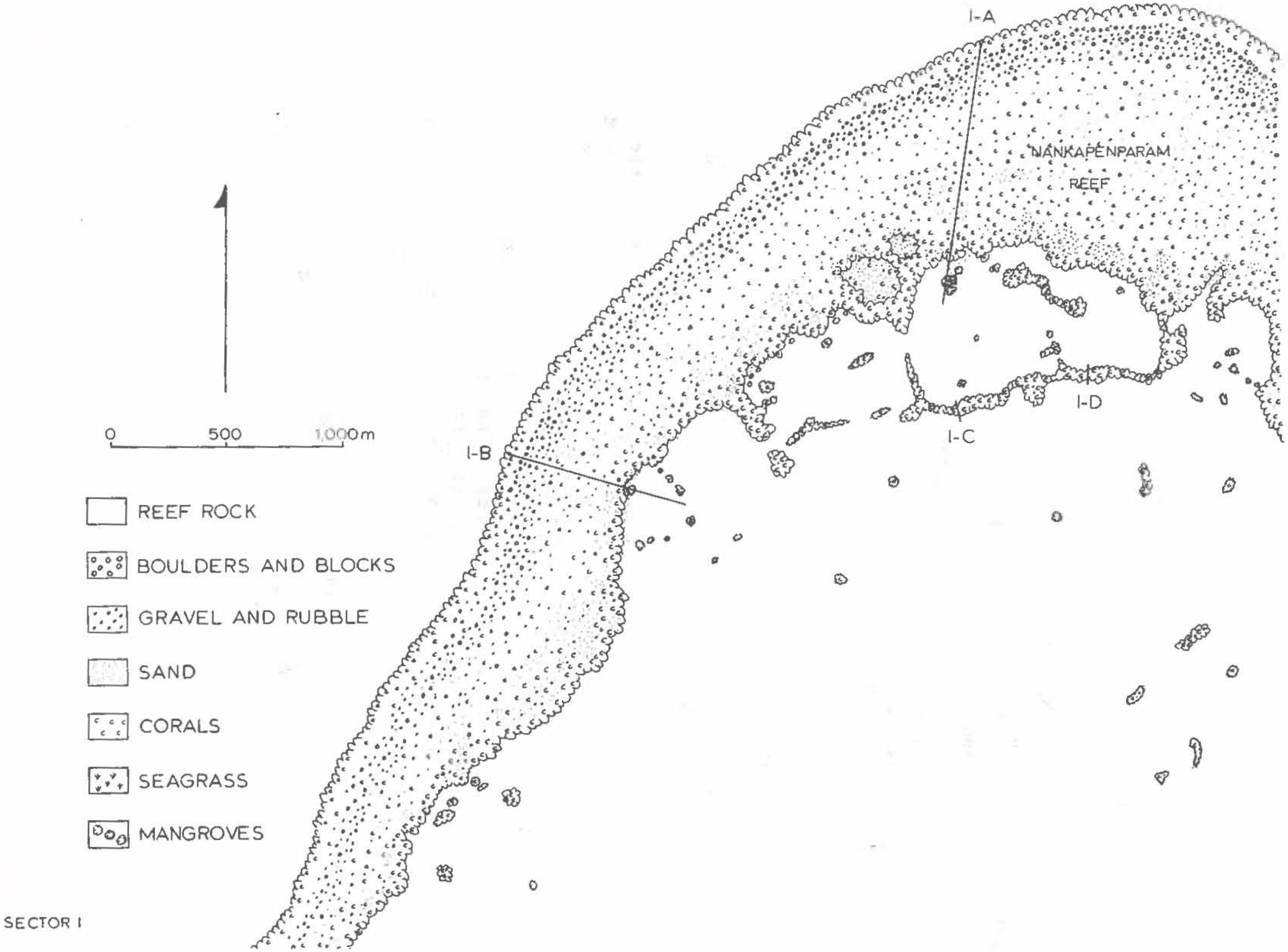

Fig. 10. Sector I map, showing the relative distribution of corals and reef sediments and the locations of Transects I-A, I-B, I-C, and I-D. (See Fig. 10 for map legend.)

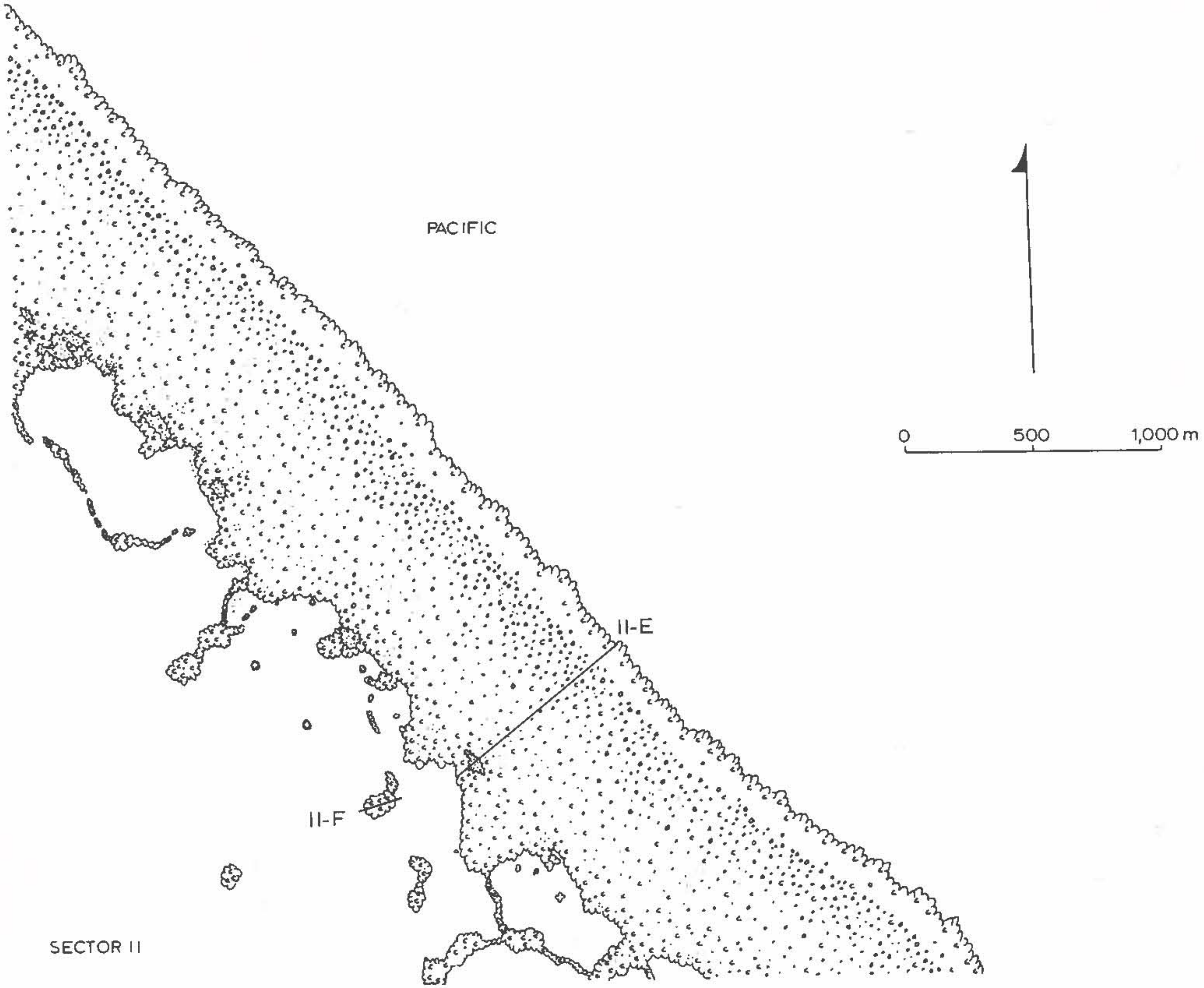

Fig. 11. Sector II map, showing the relative distribution of corals and reef sediments and the locations of Transects II-E and II-F. (See Fig. 10 for map legend.)

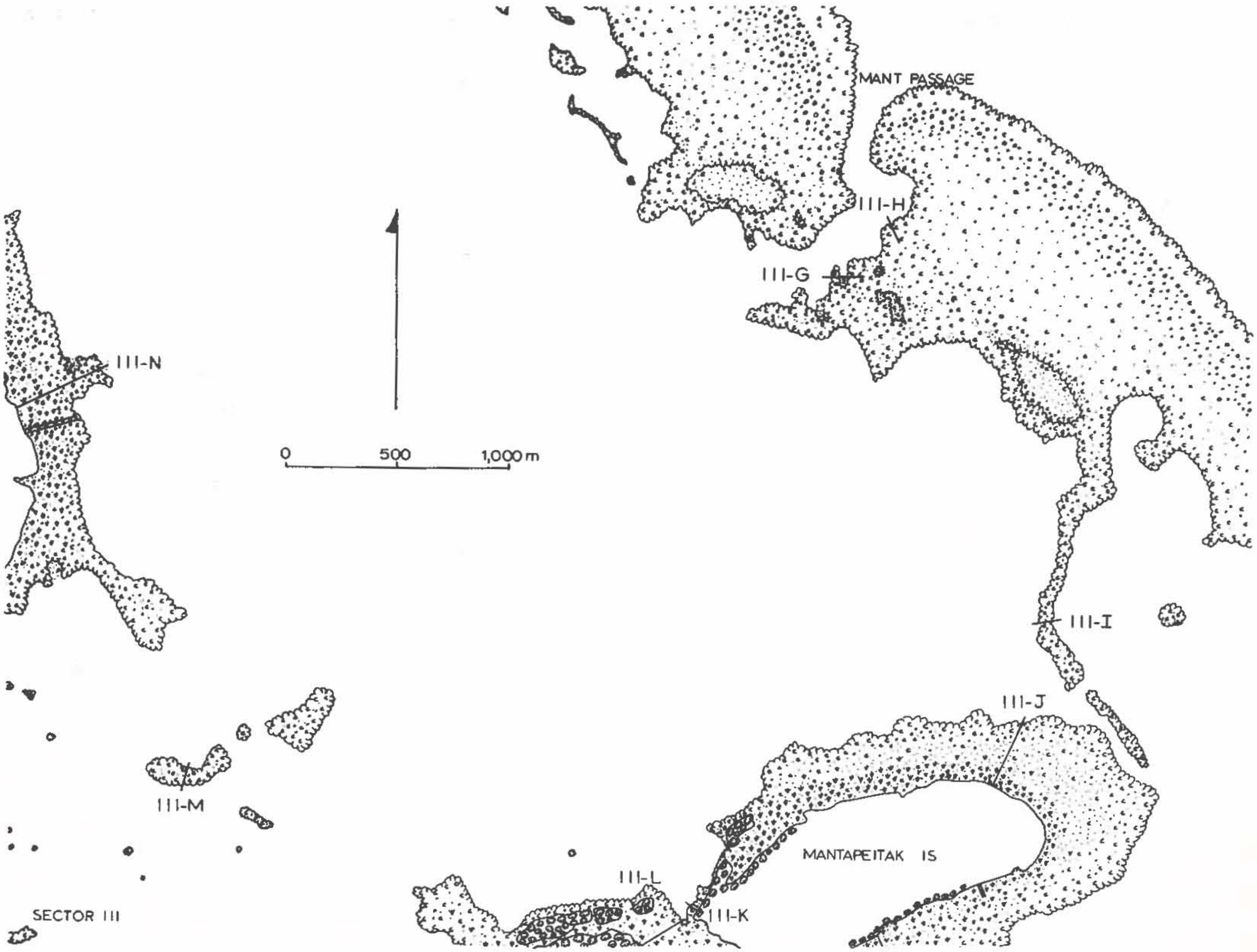

Fig. 12. Sector III map, showing the relative distribution of corals, seagrasses, reef sediments, mangrove shorelines, and the locations of Transects III-G, III-H, III-I, III-J, III-K, III-L, III-M, and III-N. (See Fig. 10 for map legend.)

shorelines, and the locations of Transects
III-N. (See Fig. 10 for map legend.)

Fig. 13. Sector IV map, showing the relative distribution of corals, seagrasses, reef sediments, mangrove shorelines, and the locations of Transects IV-O, IV-P, IV-Q, and IV-R. (See Fig. 10 for map legend.)

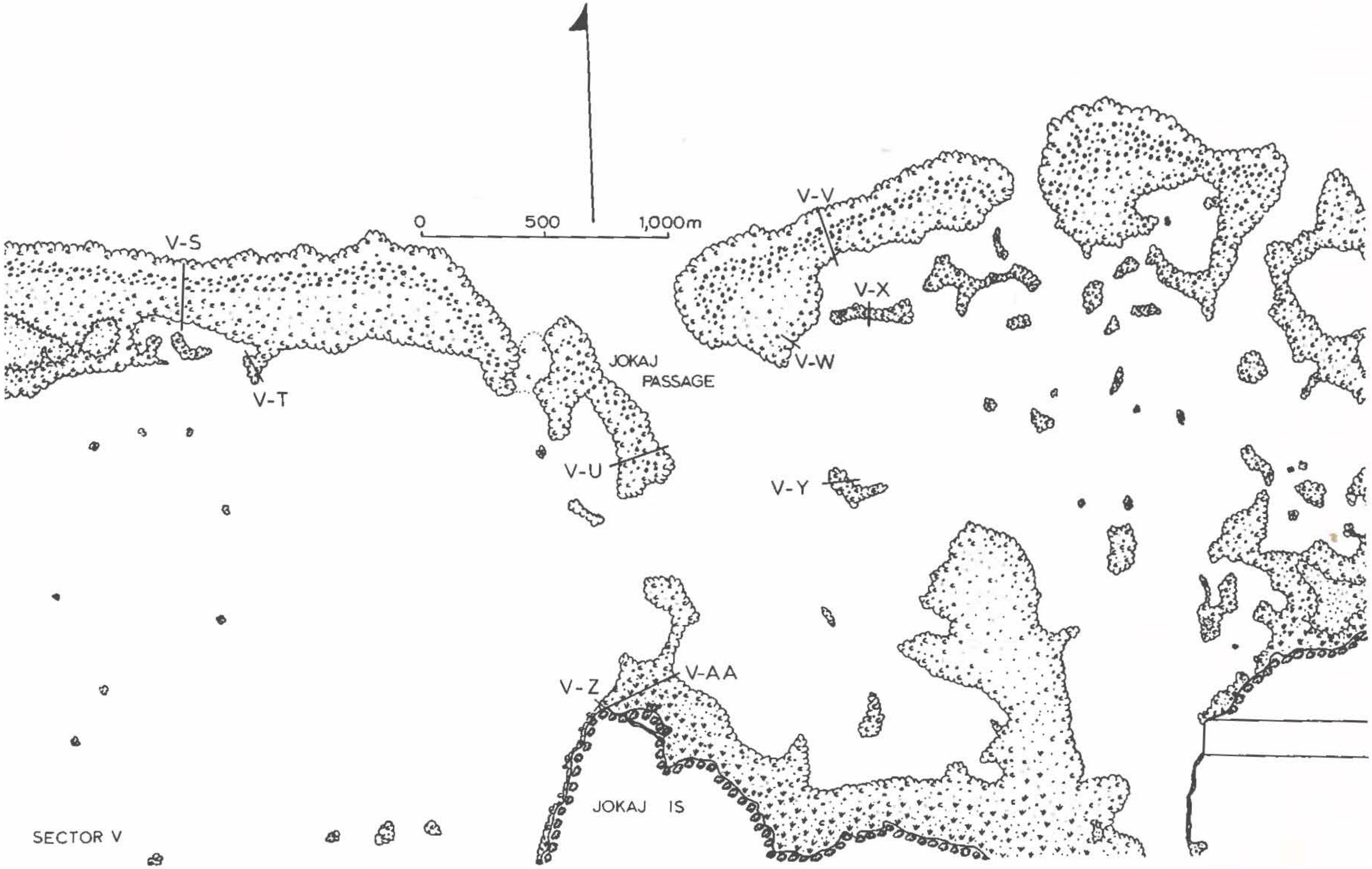

Fig. 14. Sector V map, showing the relative distribution of corals, seagrasses, reef sediments, mangrove shorelines, and the locations of Transects V-S, V-T, V-U, V-V, V-W, V-X, V-Y, V-Z, and V-AA. (See Fig. 10 for map legend.)

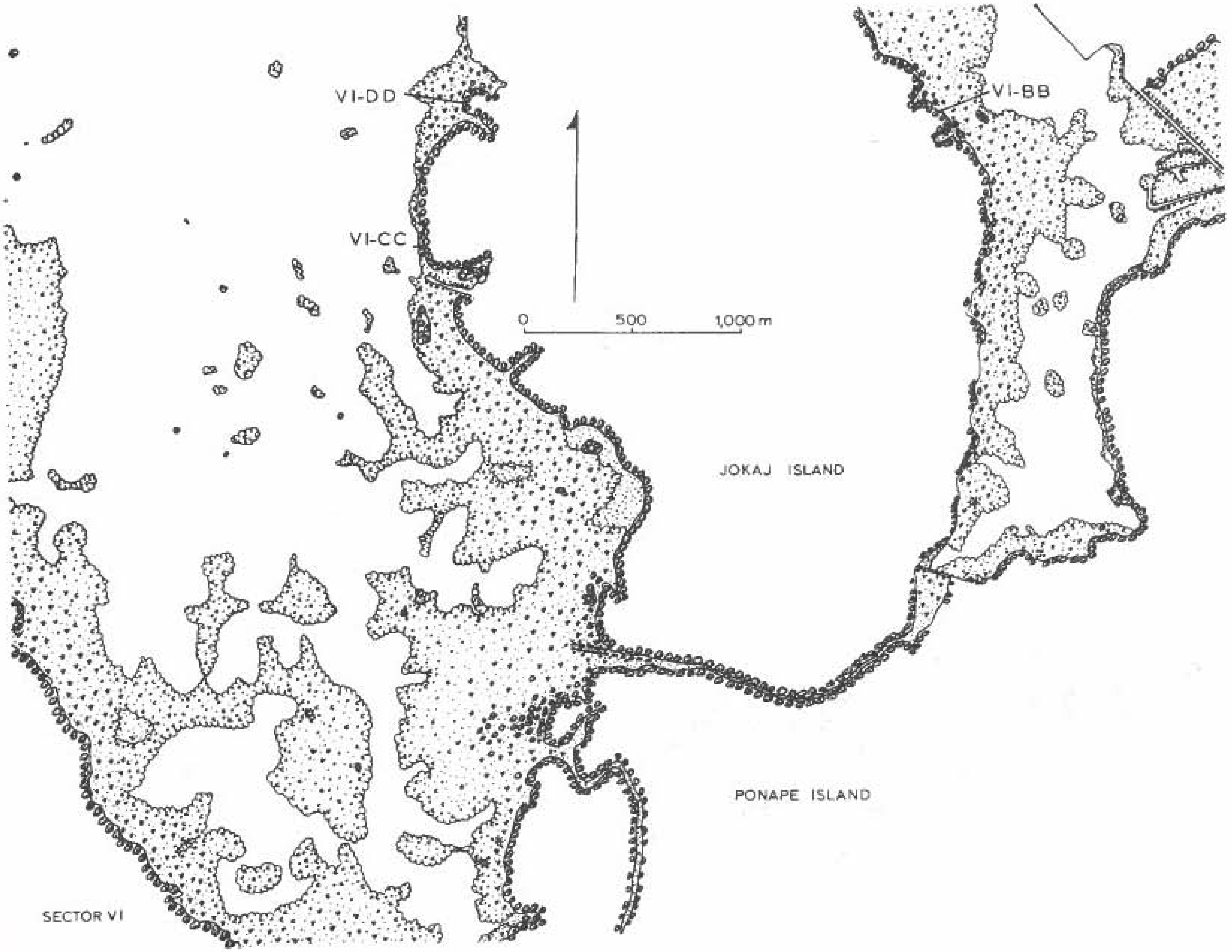

Fig. 15. Sector VI map, showing the relative distribution of corals, seagrasses, reef sediments, mangrove shorelines, and the locations of Transects VI-BB, VI-CC, and VI-DD. (See Fig. 10 for map legend.)

Fig. 16. Sector VII map, showing the relative distribution of corals and reef sediments. (See Fig. 10 for map legend.)

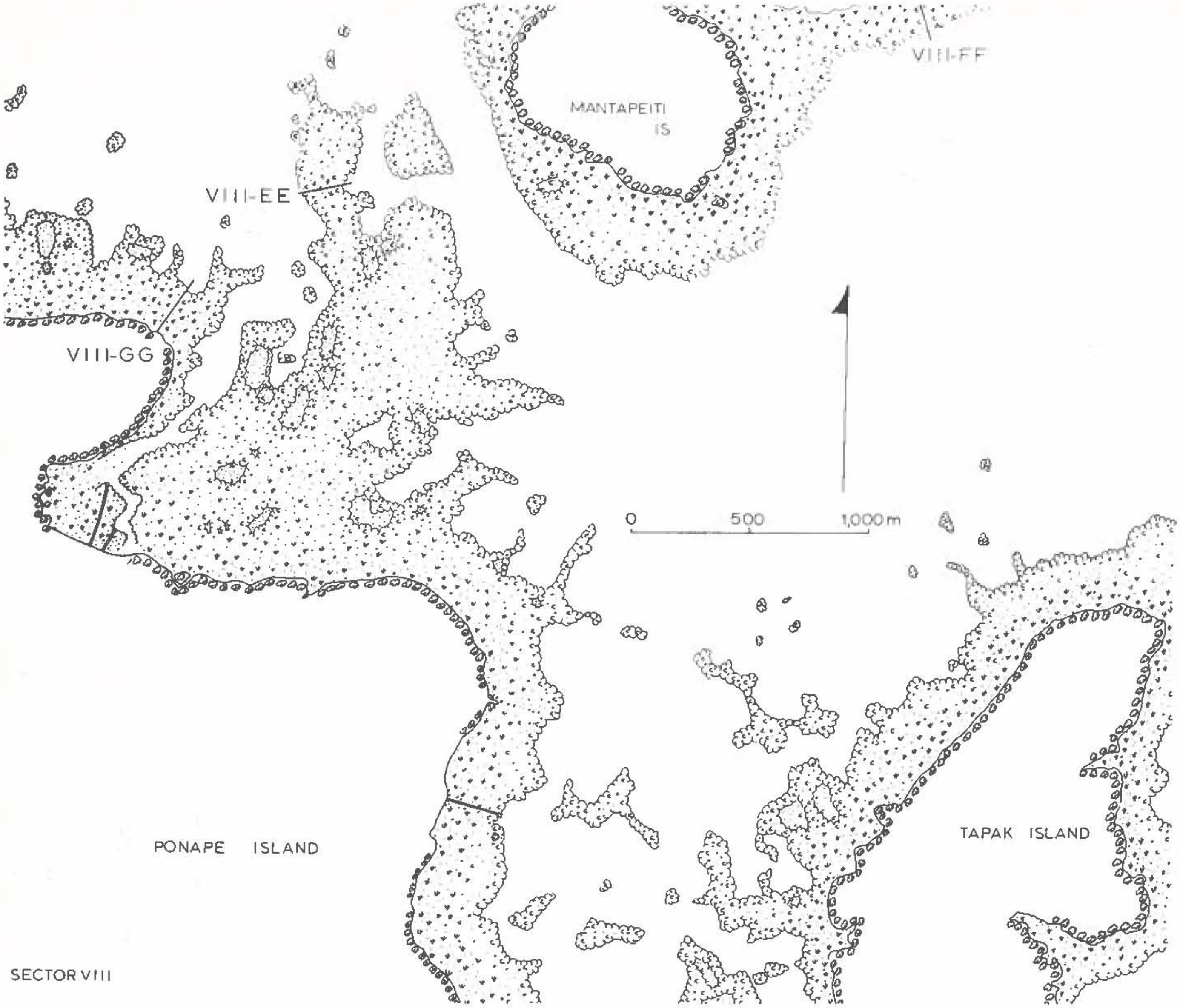

Fig. 17. Sector VIII map, showing the relative distribution of corals and reef sediments and the locations of Transects VIII-EE, VIII-FF, and VIII-GG. (See Fig. 10 for map legend.)

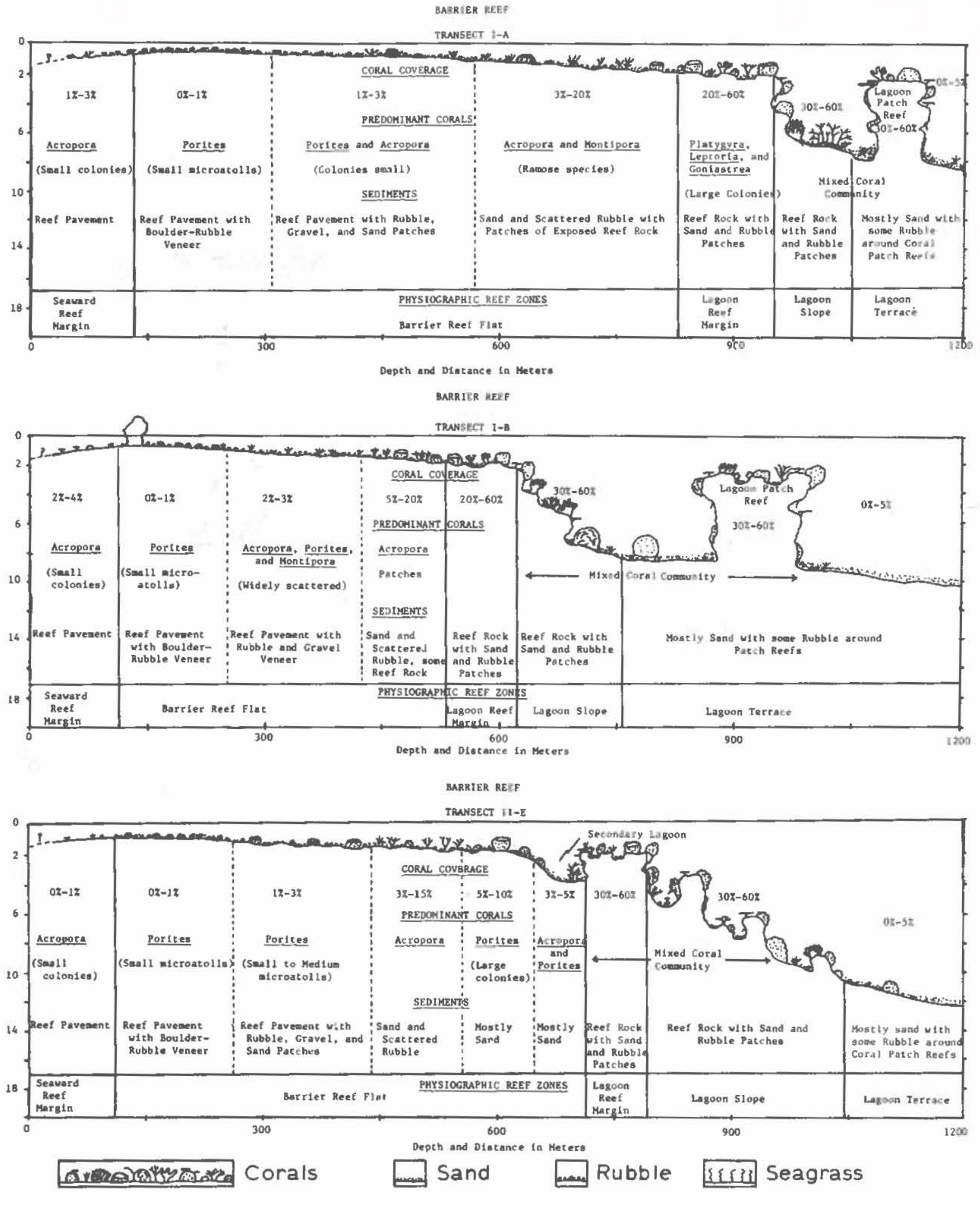

Fig. 18. Vertical profiles of Transects I-A, I-B, and II-E. Transect locations are shown on Figs. 10 and 11.

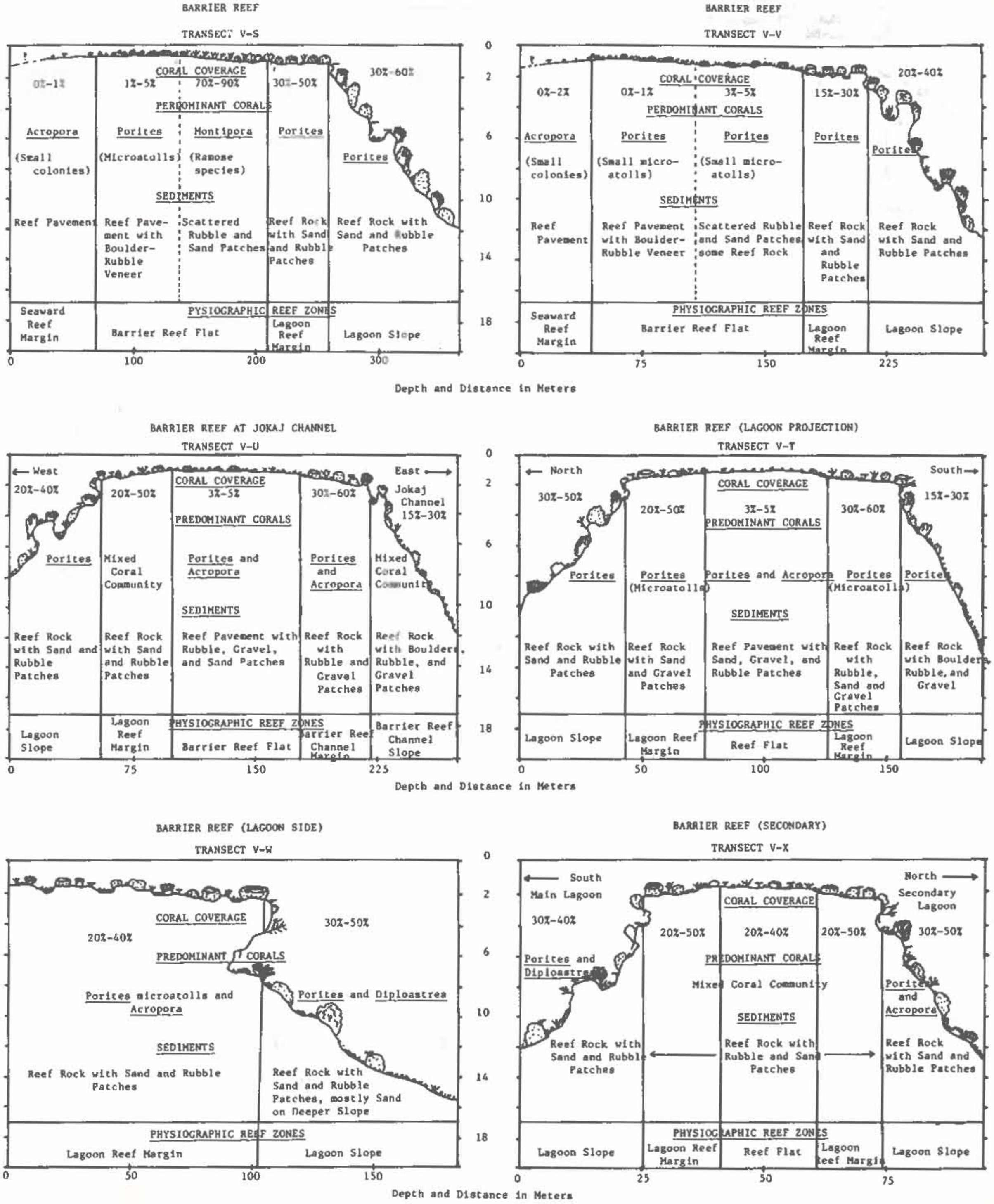

Fig. 19. Vertical profiles of Transects V-S, V-V, V-T, V-U, V-W, and V-X. Transect locations are shown on Fig. 14. (See Fig. 18 for map legend.)

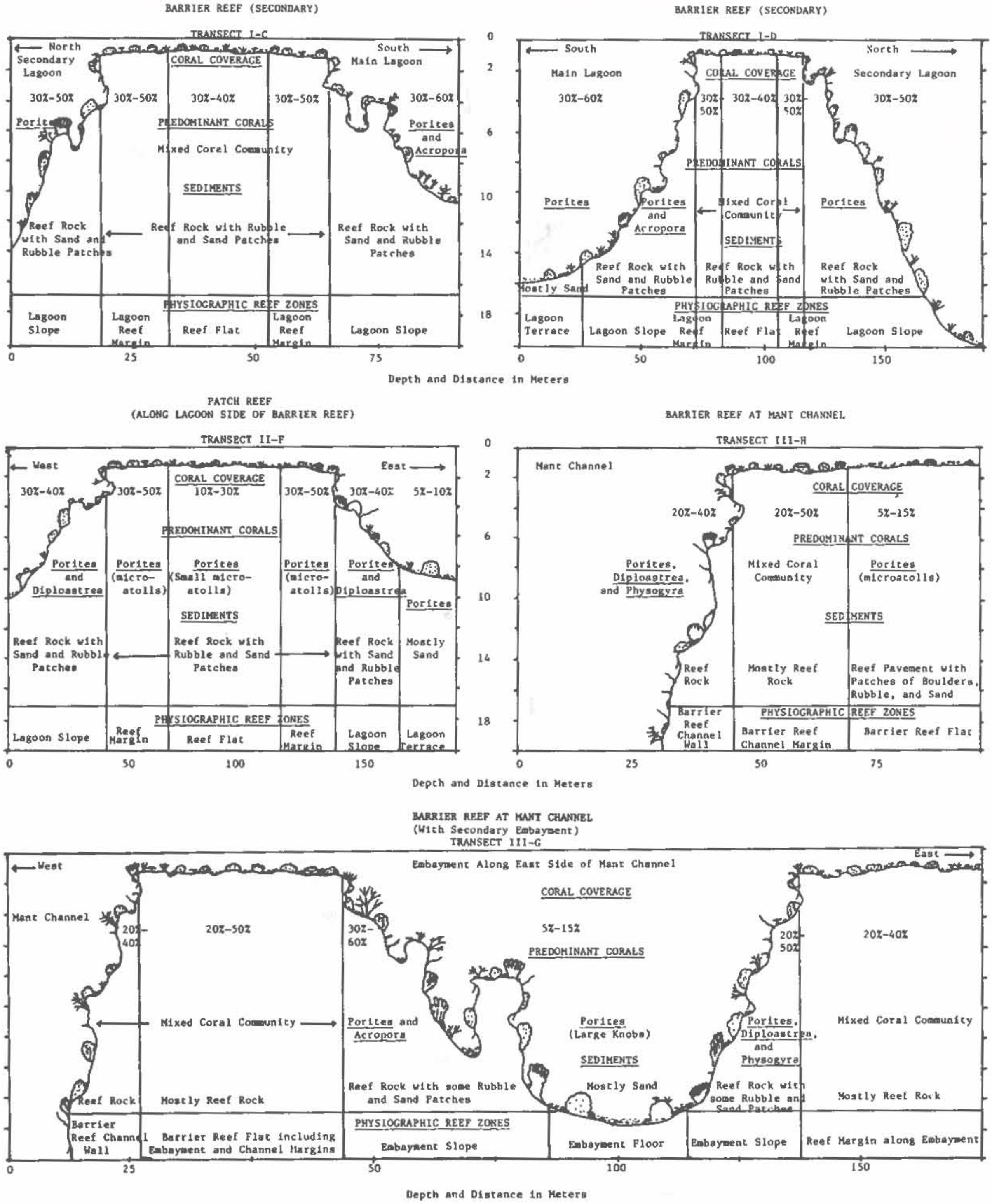

Fig. 20. Vertical profiles of Transects I-C, I-D, II-F, III-H, and III-G. Transect locations are shown on Figs. 10, 11, and 12. (See Fig. 18 for map legend.)

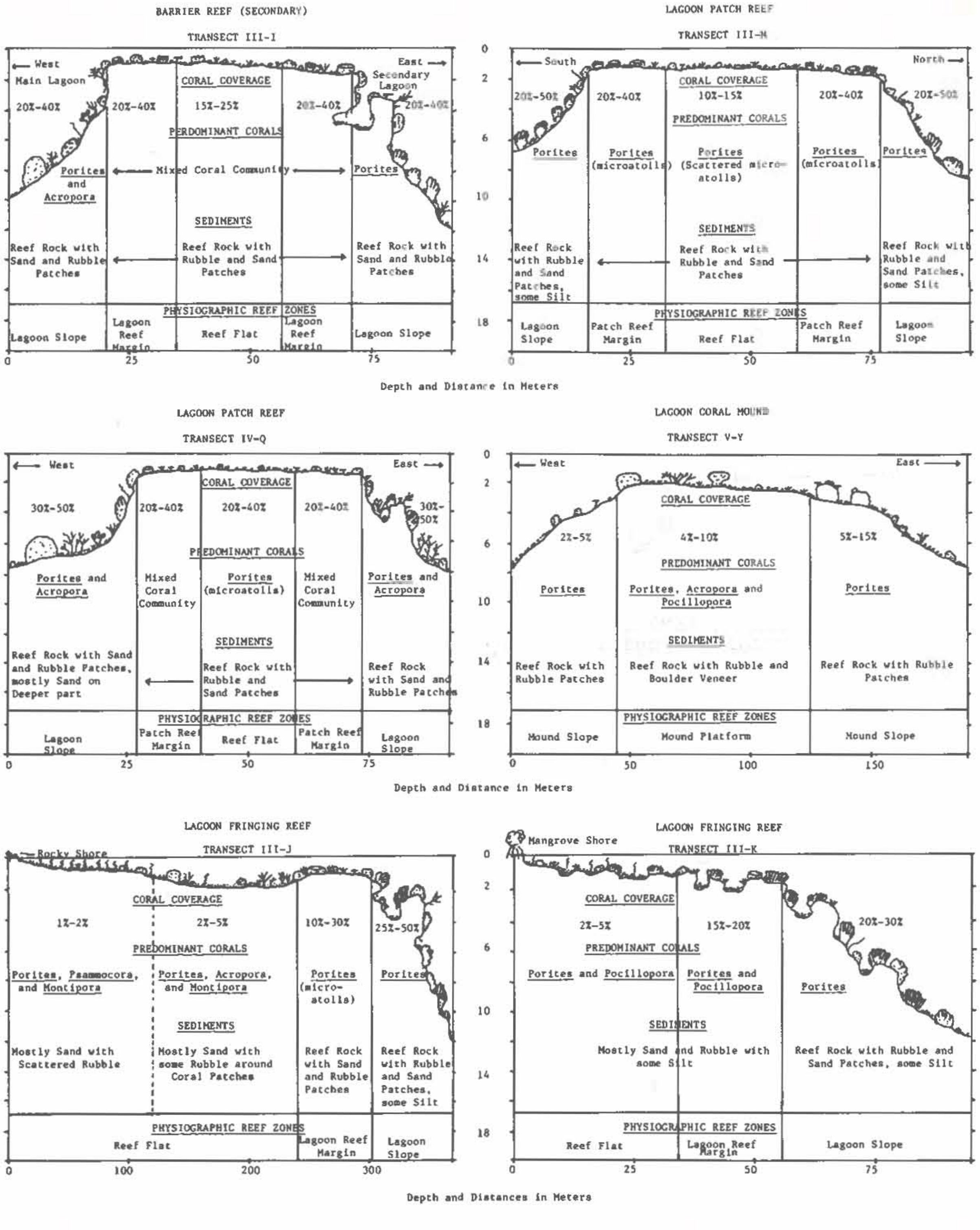

Fig. 21. Vertical profiles of Transects III-I, III-J, III-K, III-M, IV-Q, and V-Y. Transect locations are shown on Figs. 12, 13, and 14. (See Fig. 18 for map legend.)

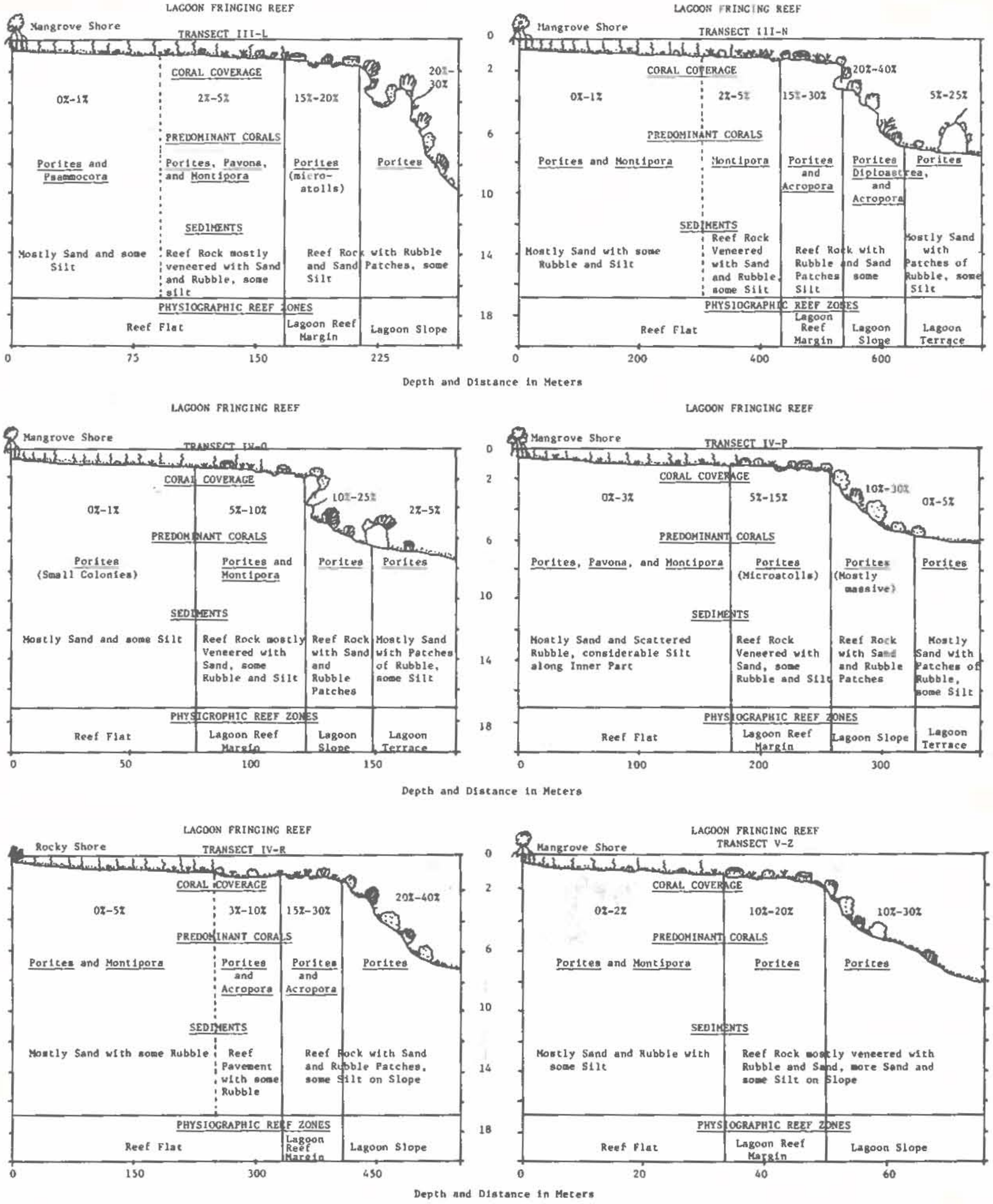

Fig. 22. Vertical profiles of Transects III-L, III-N, IV-O, IV-P, IV-R, and V-Z. Transect locations are shown on Figs. 12, 13, and 14. (See Fig. 18 for map legend.)

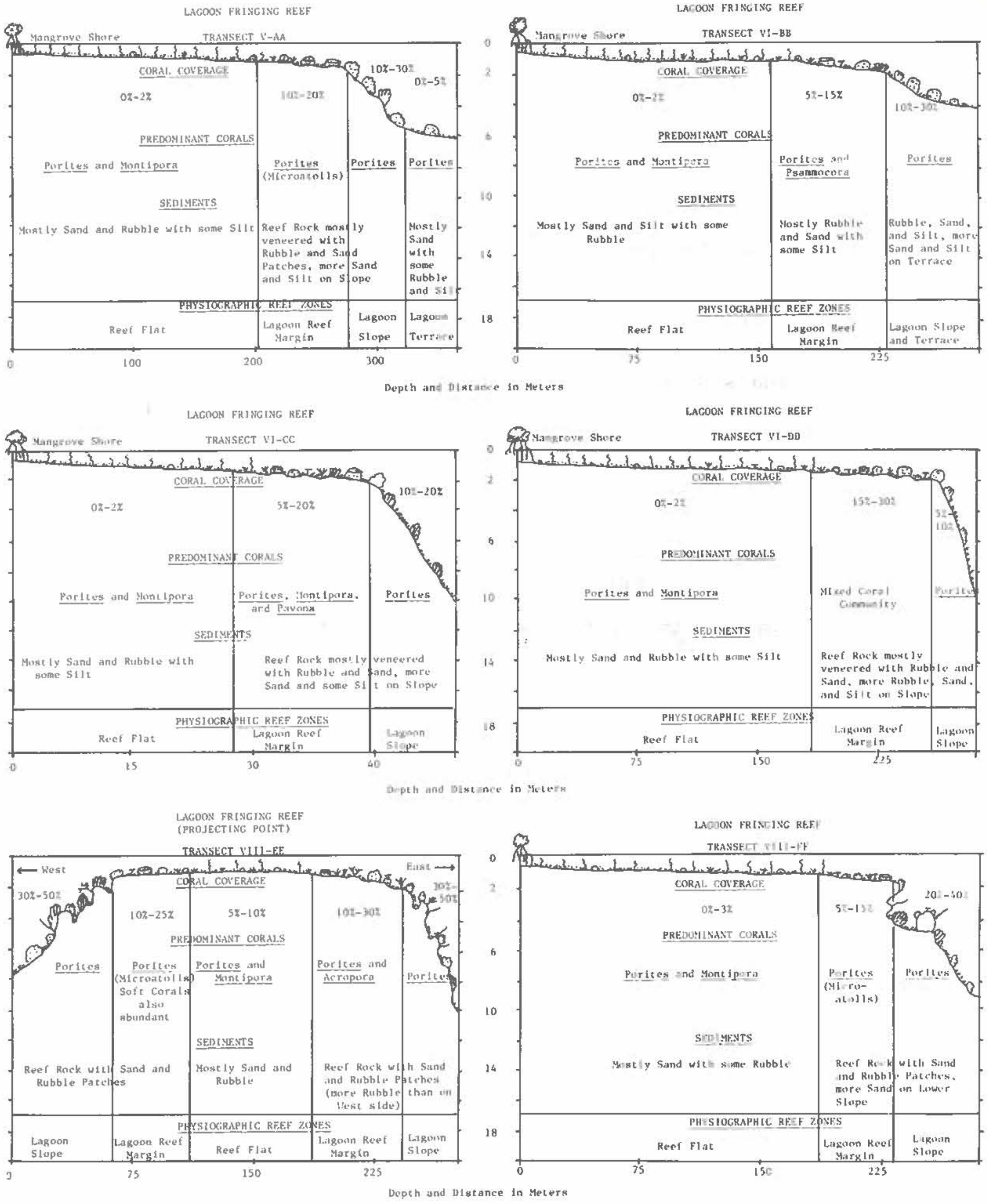

Fig. 23. Vertical profiles of Transects V-AA, VI-BB, VI-CC, VI-DD, VIII-EE, and VIII-FF. Transect locations are shown on Figs. 14, 15, and 17. (See Fig. 18 for map legend.)

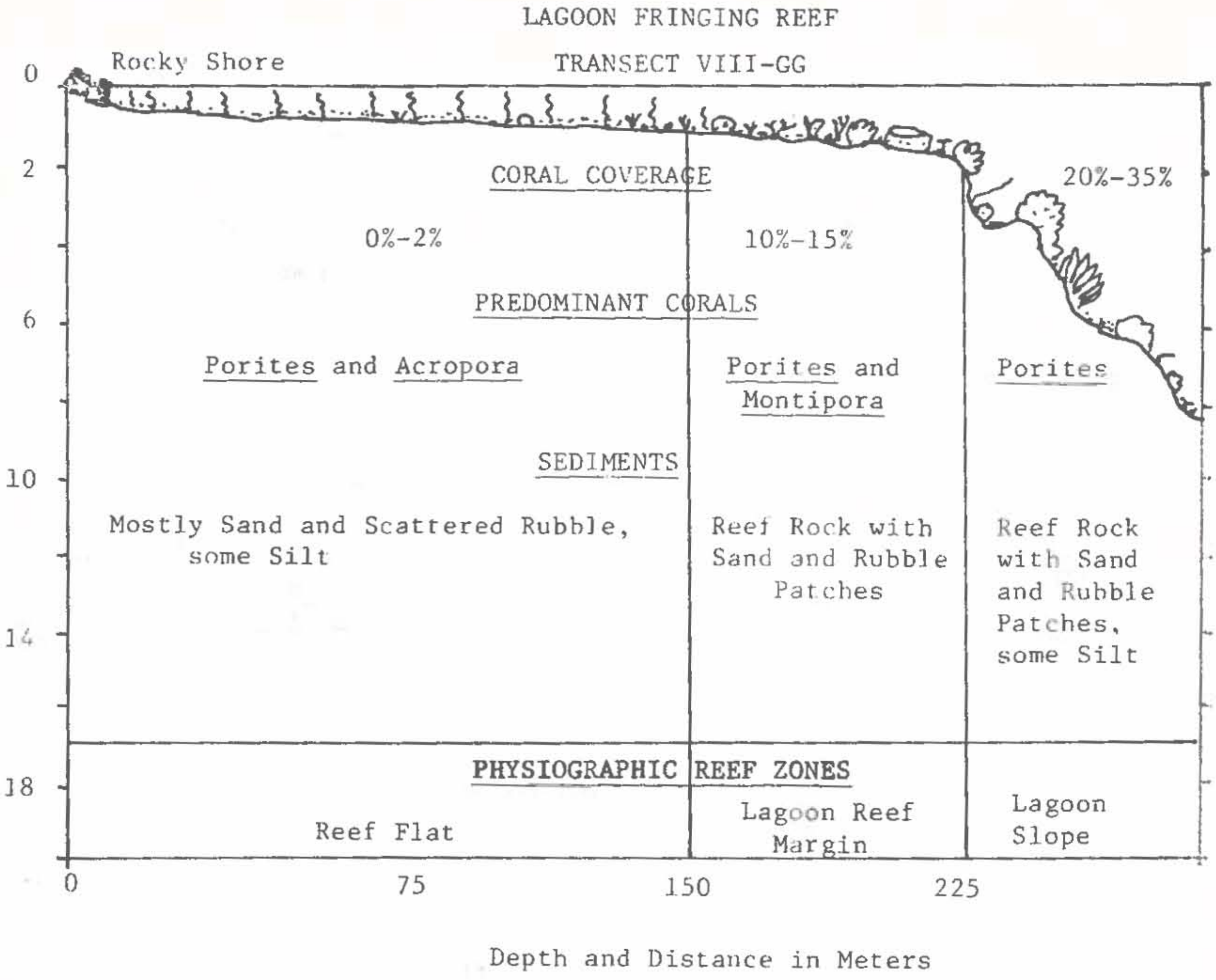

Fig. 24. Vertical profiles of Transect VIII-GG. Transect location is shown on Fig. 17. (See Fig. 18 for map legend).

CORALS

Richard H. Randall

The reefs of northern Ponape Lagoon can be broadly divided into three types consisting of the outer barrier reefs, lagoon patch reefs, and fringing reefs developed around the lagoon islands. The coral communities of these three reef types were investigated at 33 locations by making snorkel observations along transects that crossed the reefs normal to their lagoon margin edges. Specific locations of these transects are shown on Sector Maps I-VIII (Figs. 10-17) in the "Reef Habitat Mapping Section" of this report. Data collected along these transects included the physiographic reef zonation patterns discerned; distribution of corals, seagrasses, and sediments; and an estimation of the reef surface covered by corals and the predominant coral genera encountered in each zone. These data are presented on representative vertical profiles for each transect (Figs. 18-24). Coral species observed from the barrier reefs, lagoon patch reefs, and fringing island reefs are listed in Table 8. The forereef slope zones of the barrier reefs and lagoon slopes deeper than 10 meters were not investigated.

BARRIER REEFS

The barrier reefs are characterized as having distinct physiographic reef zones and coral distribution patterns. In a seaward to lagoonward direction, the reef zones recognized are a narrow seaward reef margin, a broad reef-flat platform, a relatively narrow lagoon reef margin, and a steep lagoon slope which at most places grades into a more gentle sloping lagoon terrace.

The seaward reef margin is a wave-swept reef pavement that slopes gently downward in a seaward direction. Although algal ridge development is absent in this zone, the pavement surface is predominantly veneered by encrusting red algae. Corals may be absent or form a widely scattered community dominated by small Acropora colonies. Even though this zone is located in a region of breaking surf and strong currents, many of the Acropora colonies consist of fragile-branched corymbose and arborescent species.

The seaward part of the reef-flat platform generally coincides with the reef crest and consists of a relatively flat reef pavement veneered with abundant boulders and rubble. At places the boulders and rubble form long ridges aligned normal to the reef margin edge. During low spring tides this part of the reef flat is commonly exposed and corals are mostly absent except for a few small Porites and stunted Acropora colonies located in depressions and holes. Lagoonward from the boulder and rubble veneered reef crest the middle part of reef flat platform gradually deepens. The reef pavement surface is somewhat more irregular and is veneered with patches of rubble, gravel, and coarse sand. The coral community is scattered to patchy and mostly dominated by small Porites microatolls and low arborescent clumps of Acropora and Montipora.

Table 8. List of corals observed in the various habitats of northern Ponape Lagoon.

	Barrier Reefs	Lagoon Patch Reefs	Fringing Reefs
CLASS - ANTHOZOA			
ORDER - SCLERACTINIA			
SUBORDER - ASTRCOENIINA			
FAMILY - ASTROCOENIIDAE			
Styloccenielia armata (Ehrenberg)	X	X	X
FAMILY - THAMNASTERIIDAE			
Psammocora contigua (Esper)	X	X	X
Psammocora digitata Edwards and Haime	X	X	X
Psammocora haimeana Edwards and Haime	X		X
Psammocora neirstraszi van der Horst	X		
Psammocora profundacella Gardiner	X		
Psammocora samoensis Hoffmeister			X
Psammocora stellata Verrill	X		X
Psammocora superficialis Gardiner	X		
FAMILY - POCILLOPORIDAE			
Pocillopora ankeli Scheer and Pillai		X	
Pocillopora damicornis (Linnaeus)	X	X	X
Pocillopora danae Verrill	X		X
Pocillopora elegans Dana	X		
Pocillopora eydouxi Edwards and Haime	X		
Pocillopora ligulata Dana	X		
Pocillopora meandrina Dana	X		
Pocillopora setchelli Hoffmeister	X	X	
Pocillopora verrucosa (Ellis and Solander)	X		
Seriatopora hystrix Dana	X		X
Stylophora mordax (Dana)	X		
FAMILY - ACROPORIDAE			
Acropora aculeus (Dana)	X		
Acropora acuminata Verrill	X		
Acropora affinis (Brook)	X	X	
Acropora aspera (Dana)	X		X
Acropora cerealis (Dana)	X		
Acropora cymbicyathus (Brook)	X	X	X
Acropora eytherea (Dana)	X		
Acropora delicatula (Brook)	X		X
Acropora divaricata (Dana)	X	X	
Acropora diversa (Brook)	X		
Acropora echinata (Dana)	X	X	
Acropora elesyi (Brook)	X		
Acropora exigua (Dana)			X
Acropora formosa (Dana)	X	X	X
Acropora grandis (Brook)	X		

Table 8. Continued

	Barrier Reefs	Lagoon Patch Reefs	Fringing Reefs
ACROPORIDAE - continued			
Acropora granulosa (Edwards and Haime)	X		
Acropora haimei (Edwards and Haime)		X	X
Acropora hebes (Dana)	X	X	X
Acropora horrida (Dana)	X	X	
Acropora humilis (Dana)	X		
Acropora hyacinthus (Dana)	X	X	
Acropora intermedia (Brook)	X		
Acropora irregularis (Brook)	X		
Acropora longicyathus (Edwards and Haime)	X		
Acropora nasuta (Dana)	X	X	X
Acropora palifera (Lamarck)	X	X	
Acropora rotumana (Gardiner)	X		
Acropora squarrosa (Ehrenberg)	X	X	X
Acropora striata Verrill	X	X	X
Acropora subglabra (Brook)	X		X
Acropora tenuis (Dana)	X	X	X
Acropora teres Verrill	X	X	
Acropora variabilis (Klunzinger)	X		
Acropora vaughani Wells	X	X	
Acropora virgata (Dana)	X		
Acropora (arborescent sp. 1)			X
Acropora (arborescent sp. 2)	X	X	
Acropora (arborescent sp. 3)	X		
Acropora (corymbose sp. 1)			X
Acropora (corymbose sp. 2)	X		
Anacropora (sp. 1)	X		
Astreopora myriophthalma Edwards and Haime	X		X
Montipora berryi Hoffmeister	X		
Montipora caliculata (Dana)	X	X	
Montipora cocosensis Vaughan	X		X
Montipora composita Crossland	X		
Montipora compressa Bernard	X	X	X
Montipora conicula Wells	X	X	
Montipora danae Edwards and Haime	X		X
Montipora digitata (Dana)	X	X	X
Montipora divaricata Brueggemann	X	X	X
Montipora ehrenbergii Verrill	X	X	
Montipora erythraea Marenzeller	X	X	X
Montipora foliosa (Pallas)			X
Montipora foveolata (Dana)	X	X	
Montipora hispida (Dana)	X		
Montipora hoffmeisteri Wells	X	X	
Montipora lobulata Bernard	X	X	X

Table 8. Continued

	Barrier Reefs	Lagoon Patch Reefs	Fringing Reefs
ACROPORIDAE - continud			
Montipora minuta Bernard	X		
Montipora ramosa Bernard	X	X	X
Montipora strigosa Nemenzo			X
Montipora trabeculata Bernard	X		
Montipora tuberculosa (Lamarck)	X	X	
Montipora venosa (Ehrenberg)	X		X
Montipora verrilli Vaughan	X		X
Montipora verrucosa (Lamarck)	X	X	
Montipora (foveolate sp. 1)		X	X
Montipora (papillate sp. 1)	X	X	
Montipora (papillate sp. 2)	X		
Montipora (tuberculate sp. 1)		X	X
Montipora (tuberculate sp. 2)	X		
SUBORDER - FUNGIINA			
FAMILY - AGARICIIDAE			
Agariciella planulata (Dana)	X		
Leptoseris columna Yabe and Sugiyama	X		
Leptoseris incrustans (Quelch)	X		
Leptoseris mycetoseroides Wells	X	X	
Leptoseris solida (Quelch)	X		X
Pachyseris rugosa (Lamarck)	X	X	X
Pachyseris speciosa (Dana)	X	X	X
Pavona decussata (Dana)	X	X	X
Pavona divaricata Lamarck	X	X	X
Pavona frondifera Lamarck			X
Pavona maldivensis (Gardiner)	X		
Pavona praetorta (Dana)	X		
Pavona varians Verrill	X	X	X
Pavona (*P.*) *obtusata* (Quelch)	X	X	X
Pavona (*P.*) *venosa* Ehrenberg	X	X	X
Pavona (foliaceous sp. 1)	X		
Pavona (*P.*) (encrusting sp. 1)	X	X	X
Pavona (*P.*) (encrusting sp. 2)	X		
FAMILY - SIDERASTREIDAE			
Coscinaraea columna (Dana)	X		
FAMILY - FUNGIIDAE			
Fungia (*Verrillofungia*) *concinna* Verrill	X		
Fungia (*Danafungia*) *danai* Edwards and Haime	X		X
Fungia (*Ctenactis*) *echinata* (Pallas)	X		X
Fungia (*Fungia*) *fungites* (Linnaeus)	X	X	X

Table 8. continued

	Barrier Reefs	Lagoon Patch Reefs	Fringing Reefs
FUNGIIDAE - continued			
Fungia (*Pleuractis*) *paumotuensis* Stutchbury	X		
Fungia (*Verrillofungia*) *repanda* Dana	X		X
Fungia (*Pleuractis*) *scutaria* Lamarck	X		
Halomitra philippinensis Studer		X	
Herpolitha limax (Esper)			X
Polyphyllia talpina (Lamarck)	X		X
FAMILY - PORITIDAE			
Alveopora verrilliana Dana	X		
Goniopora arbuscula Umbgrove	X		X
Goniopora columna Dana	X	X	
Goniopora lobata Edwards and Haime	X		X
Goniopora somaliensis Vaughan	X	X	X
Goniopora stokesi Edwards and Haime	X		
Goniopora tenuidens (Quelch)	X	X	
Goniopora (massive sp. 1)	X		X
Porites andrewsi Vaughan	X	X	X
Porites annae Crossland	X	X	X
Porites australiensis Vaughan	X	X	X
Porites cocosensis Wells			X
Porites fragosa Dana			X
Porites lichen Dana	X	X	X
Porites lobata Dana	X	X	X
Porites lutea Edwards and Haime	X	X	X
Porites murrayensis Vaughan	X	X	X
Porites nigrescens Dana	X	X	X
Porites (*S.*) *convexa* Verrill	X	X	X
Porites (*S.*) *iwayamaensis* Eguchi	X	X	X
Porites (*S.*) *monticulosa* (Dana)	X		X
Porites (*S.*) *horizontalata* Hoffmeister	X	X	X
Porites (massive sp. 1)	X		
Porites (massive sp. 2)		X	
Porites (ramose sp. 1)	X		
Porites (explanate sp. 1)		X	X
Porites (*S.*) (massive sp. 1)			X
Stylaraea punctata Klunzinger			X

Table 8. Continued

	Barrier Reefs	Lagoon Patch Reefs	Fringing Reefs
SUBORDER - FAVIINA			
FAMILY - FAVIIDAE			
Caulastrea echinulata (Edwards and Haime)	X		
Cyphastrea chalcidicum Klunzinger			X
Cyphastrea microphthalma (Lamarck)	X		
Diploastrea heliopora (Lamarck)	X	X	X
Echinopora lamellosa (Esper)	X		
Favia amicorum Edwards and Haime			X
Favia favus (Forskaal)	X	X	X
Favia matthai Vaughan	X		
Favia pallida (Dana)	X		X
Favia pentagona (Esper)	X		
Favia rotumana (Gardiner)	X	X	
Favia speciosa (Dana)			X
Favia stelligera (Dana)	X		
Favites abdita (Ellis and Solander)	X		
Favites complanata (Ehrenberg)	X		X
Favites flexuosa (Dana)	X	X	
Favites virens (Dana)	X		X
Goniastrea aspera Verrill	X	X	X
Goniastrea australiensis Edwards and Haime			X
Goniastrea edwardsi Chevalier	X		
Goniastrea favulus (Dana)	X	X	
Goniastrea pectinata (Ehrenberg)	X	X	
Hydnophora exesa (Pallas)		X	
Hydnophora microconos (Lamarck)	X	X	
Hydonphora rigida (Dana)	X		X
Leptastrea bottae Edwards and Haime	X		X
Leptastrea purpurea (Dana)	X	X	X
Leptoria phrygia (Ellis and Solander)	X		
Montastrea curta (Dana)	X		
Oulophyllia crispa (Lamarck)			X
Platygyra daedalea (Ellis and Solander)	X	X	X
Platygyra lamellina (Ehrenberg)	X		X
Plesiastrea versipora (Lamarck)	X		

Table 8. Continued

	Barrier Reefs	Lagoon Patch Reefs	Fringing Reefs
FAVIIDAE - continued			
FAMILY - OCULINIDAE			
Acrhelia horrescens (Dana)	X		
Galaxea fascicularis (Linnaeus)	X	X	
Galaxea clavus (Dana)	X		
FAMILY - MERULINIDAE			
Merulina ampliata (Ellis and Solander)	X		
Merulina laxa Dana	X	X	X
FAMILY - MUSSIDAE			
Lobophyllia corymbosa (Forskaal)	X		
Lobophyllia hemprichii (Ehrenberg)	X	X	
Lobophyllia pachysepta Chevalier	X		
Symphyllia agaricia Edwards and Haime	X		
Symphyllia nobilis (Dana)	X	X	X
Symphyllia radians Edwards and Haime	X		
Symphyllia valenciennesii Edwards and Haime	X		X
FAMILY - PECTINIIDAE			
Echinophyllia aspera (Ellis and Solander)	X	X	X
Mycedium elephantotus (Pallas)	X		
Mycedium tenuicostatum Verrill	X		
Oxypora lacera (Verrill)	X		X
Pectinia lactuca (Pallas)	X		
SUBORDER - CARYOPHYLLIINA			
FAMILY - CARYOPHYLLIIDAE			
Euphyllia glabrescens Chamisso and Eysenhardt			X
Plerogyra sinuosa (Dana)	X		
Physogyra lichtensteini Edwards and Haime	X	X	X
SUBORDER - DENDROPHYLLIINA			
FAMILY - DENDROPHYLLIIDAE			
Dendrophyllia (sp. 1)	X		
Endopsammia (sp. 1)	X		
Rhizopsammia (sp. 1)	X		X

Table 8. Continued

		Barrier Reefs	Lagoon Patch Reefs	Fringing Reefs
DENDROPHYLLIIDAE - continued				
Tubastraea aurea (Quoy and Gaimard)		X		X
Tubastrea micranthus (Ehrenberg)		X	X	X
Turbinaria foliosa Bernard		X		
Turbinaria reniformis Bernard		X	X	X
Turbinaria (massive sp. 1)		X		
ORDER - COENOTHECALIA				
FAMILY - HELIOPORIDAE				
Heliopora coerulea (Pallas)		X		
ORDER - STOLONIFERA				
FAMILY - TUBIPORIDAE				
Tubipora musica (Linnaeus)		X		
CLASS - HYDROZOA				
ORDER - MILLEPORINA				
FAMILY - MILLEPORIDAE				
Millepora exaesa Forskaal		X		
Millepora dichotoma Forskaal		X	X	X
Millepora platyphylla Hemprich and Ehrenberg		X	X	X
ORDER - STYLASTERINA				
FAMILY - STYLASTERIDAE				
Distichopora violacea (Pallas)		X		
	GRAND TOTAL			
TOTAL FAMILIES	19	19	15	14
TOTAL GENERA	57	52	28	35
TOTAL SPECIES	215	189	87	104

The reef-flat platform continues to deepen in a lagoonward direction and is veneered by increasing amounts of coarse sand and scattered rubble. Corals become more abundant and diverse, but at most places are dominated by ramose Acropora and Montipora thickets. On Transect II-E (Fig. 18) the inner part of the reef-flat platform is occupied by a large sand-floored hole (secondary lagoon) about four meters deep. Although few corals were found on the sandy floor of this hole, forty-five species of corals were observed on the coral-dominated peripheral slopes of the hole.

The lagoon reef margin is a distinct zone dominated by large massive Porites species or a more mixed assembage of corals. At places arborescent and corymbose species of Acropora are also abundant in the zone. At Transect I-A (Fig. 18) large massive colonies of Platygyra, Leptoria, and Goniastrea dominate the lagoon reef margin. At most places barren reef rock and patches of sand and rubble occupy the floor between the large coral colonies of this zone.

The lagoon slope zone at most places is generally steep to locally vertical. Overhanging ledges and cavernous fissures and chutes are common at places. The slope surface is generally irregular because of coral growth or slumping which gives it considerable local relief and provides a variety of exposed and shaded horizontal to vertical surfaces and cryptic habitats. Such a variety of habitats generally support a rather diverse mixed coral community at most places. Sediments on the upper part of the lagoon slopes are restricted to pockets and depressions, but become increasingly more abundant on the lower part where the degree of slope decreases. Where the lagoon slope grades outward onto an adjacent lagoon terrace or floor the surface is dominated by fewer corals and more sand-sized sediment. Small patch reefs, such as the one shown in Transect I-B (Fig. 18), are common physiographic features where the lagoon slope grades out onto shallow lagoon terraces. Larger patch reefs, a hundred or more meters across, are also found on the lagoon terrace at places (Transect II-F, Fig. 20).

At a number of locations narrow ridgelike reefs enclose or partially enclose deep and shallow secondary lagoons on the lagoon side of the wide barrier reefs (see Figs. 10-12 and 14 and Transects I-C, I-D, III-I, and V-X in Figs. 19, 20, and 21). These secondary reefs and their enclosed lagoons are similar to some of the faro reefs described by Purdy (1974) in the Indian Ocean. Except for the narrow reef-flat platforms, which are slightly more submergent during low spring tides and covered by more corals, the reef zonation and coral distribution patterns on these narrow ridgelike reefs are similar to those described for the lagoon side of the wide barrier reefs.

At three locations deep passes or channels bisect the barrier reefs (Fig. 1). Transects III-H, III-G, and V-U (Figs. 19 and 20) at Mant and Jokaj Channels show the general characteristics of these channel habitats. The reef walls along these channels are generally steep to precipitous and at places are commonly overhanging and cavernous. The channel walls consist for the most part of algal-veneered reef rock that supports a somewhat scattered to locally abundant community of mixed corals. Sediments are generally scarce except for minor amounts trapped in holes and on ledges, but may dominate the surface where steep slopes replace the vertical walls (Transect V-U, Fig. 19). At Mant channel the precipitous wall is interrupted by a shallow embayment (Transect III-G, Fig. 20). The steep slopes along the sides of this embayment support an exceptionally diverse community of corals.

A total of 189 coral species representing 52 genera were recorded from the barrier reef habitats (Table 8).

LAGOON PATCH REEFS

Lagoon patch reefs are somewhat isolated habitats that are located in the lagoon proper between the peripheral barrier reefs and the island fringing reefs. Here they rise up from the deep lagoon floor to or near the surface. Transect profiles III-M, IV-Q, and V-Y (Fig. 21) show the general physiographic zonation and coral distribution patterns of these small reef habitats.

The reef flat zone on lagoon patch reefs generally support scattered to abundant coral growth on surfaces that remain covered by water during low spring tides and little to no coral growth where the surface is mostly emergent during such times. Where corals were present the community was commonly dominated by _Porites_ species that formed flat-topped microatolls.

The patch reef margin forms a narrow peripheral zone around the central reef-flat platform that is slightly deeper and supports more abundant coral growth.

Physiographic structure and sediment distribution patterns on the lagoon slopes and adjacent terraces of patch reefs are quite similar to that described earlier for the same zones on barrier reefs, but the coral community structure is quite different. The patch reef slopes and terraces are conspiciously dominated by _Porites_ species, whereas a more diverse coral community was generally found on the barrier reef slopes. An exception to this pattern of domination by _Porites_ species was found on Transect V-Y (Fig. 12), where the patch reef surface was deeper and subject to considerable wave assault from swells that enter the lagoon through Jokaj Channel.

A total of 87 coral species representing 28 genera were recorded from the lagoon patch reefs (Table 8).

LAGOON FRINGING REEFS

Lagoon fringing reefs are located around island land masses and are thus subject to a greater influence by surface drainage from the adjacent land than the peripheral lagoon patch reefs and barrier reefs. Differences in the composition of sediments are especially noticeable from the presence of varying amounts of dark colored volcanic detrital grains that are intermixed with the lighter colored grains of reef origin. It appears that seagrass communities are also restricted to the fringing reefs where there is a source of detrital sediments from the land.

The reef-flat platforms appear to be quite flat but actually slope very gently downward from a mangrove or rocky shoreline to the outer periphery where the slope increases somewhat, forming a slightly deeper and distinct, but narrow lagoon reef margin. At most places the reef-flat platforms are veneered by sand and scattered rubble and support extensive seagrass beds at many locations. During low spring tides the inner part of the reef-flat platform is for the most part exposed while the outer part is partly exposed or covered by only a few centimeters of water. During high tide the water on the inner reef-flat platform is approximately a meter deep and up to a meter-and-a-half deep on the outer reef margin fringe. Corals are mostly absent on the reef-flat platforms except for a few widely scattered small colonies found in depressions and holes which retain water during low spring tides. Seagrasses diminish in abundance near the lagoon reef margin fringe and corals are somewhat more common, but still widely scattered and irregular in distribution.

At the lagoon reef margin coral abundance and diversity sharply increases, but at most locations the coral community is dominated by *Porites* species. Where the lagoon reef margin grades into the shallow reef-flat platform thickets of ramose *Montipora* were commonly found.

The steep lagoon slope zone is sharply defined at most places along the outer lagoon reef margin fringe. At most places the upper slopes are steep to vertical with overhanging walls and cavernous regions common. The slope surface is irregular from local coral growth that forms mounds, knobs, and pinnacles. Mass slumping of large coral colonies and parts of overhanging walls adds to the irregular topography and relief which characterizes much of the lagoon slope zone. Sediments are patchy and restricted to local ledges, holes, and depressions along the upper slope, but may dominate the more gentle sloped lower part, particularly where it grades outward onto sandy lagoon terraces. Without exception, the lagoon slopes at most places were dominated by massive, ramose, and columnar species of *Porites*. Corals found on the lagoon slope zone represent 80 to 90 percent of the 104 species recorded from all the zones of the fringing reefs; however, all but *Porites* species were widely scattered, rare, or restricted to cryptic habitats.

Possibly the high abundance of *Porites* species on the fringing reef slopes, and to some extent on the lagoon patch reef and barrier reef slopes, is due to the frequent occurrence of *Acanthaster planci* predation. *Acanthaster planci* were more prevalent on the island fringing reefs than on the lagoon slopes of the barrier reefs. *Porites* species, as a group, are rather low in the hierarchy of preferred species eaten by *A. planci*. Thus, with rather frequent predation the abundance of more preferred species, such as *Acropora* and *Montipora* species, would be reduced. Selection of this sort by *A. planci* could account for the scattered, rare, or cryptic occurrence of the more preferred coral species and a high occurrence and abundance of the less preferred species. It could also account for the increasing occurrence and abundance of the more preferred food species as the distance increases from the fringing reefs, where *A. planci* are common, to the peripheral barrier reef.

MARINE PLANTS OF NORTHERN PONAPE

Bruce Best and David Pendleton

INTRODUCTION

In conjunction with our marine biological survey of northern Ponape reefs, the marine plants were recorded from the transect areas (Fig. 1). Previous work in the area is referenced in Tsuda and Wray (1977) and Tsuda, Fosberg, and Sachet (1977) for benthic algal and seagrass distributions, respectively. Previous studies from this laboratory have centered mainly around the Takatik and Kolonia areas. These data will add to the knowledge of the unique barrier, fringing and patch-reef system of northern Ponape.

METHODS

Marine plants were quantified by a modified point-quadrat method (Tsuda 1972). A 25 x 25 cm gridded quadrat with 16 internal cross-points was tossed haphazardly and the substratum cover directly under each point was recorded.

Percent cover for each transect was calculated by taking the total points at which a species occurred, divided by the total points per transect. Similarly, frequency of occurrence was calculated by taking the number of quadrat tosses in which a species occurred, divided by the number of tosses per transect. Both cover and frequency values were converted to percentages by multiplying by 100. In addition, any other plants noted in the study areas were also recorded.

RESULTS AND DISCUSSION

In this limited survey, a total of 46 taxa of marine plants were recorded along the reefs of northern Ponape. Table 9 reflects not only cover by plants, but also other common biotic and abiotic substratum cover. In general, the live coral estimates from the barrier reef transects are probably slightly exaggerated because the quadrat was not thrown near the outer wave-washed margin (an area lacking corals).

The 37 genera of plants recorded in Table 10 indicate a good diversity, especially when considering that microturfs were not keyed out because of time or resource limitations.

Two range extensions were recorded from this study. The collection or <u>Turbinaria decurrens</u> from the barrier-reef transects greatly increases the known range of this brown algae. Previously it was only recorded from Pulo Anna Island in the Palau district (Trono 1969). Also, <u>Cymodocea</u> (seagrass) was noted along fringing reefs of the Mant Islands. This seagrass was previously recorded from Kosrae and Truk, but not from Ponape (Tsuda, Fosberg, and Sachet 1977).

Table 9. Estimates of percent cover and frequency of occurrence along selected transects of 10 biotic and abiotic substratum categories. Numbers indicate percent cover/frequency. "+" or "-" indicate the category was observed or not observed, respectively, along the transect.

	TRANSECTS*					
	I-A	III-N	IV-O	VIII-EE	VIII-FF	VIII-GG
Live Coral	40.6/75	26.6/50	3.1 /25	11.9/60	37.5 /66.6	25 /33.3
Leafy Algae	3.1/25	+	14.1 /75	8.1/20	21.9 /50	8.3/50
Filamentous Algae	10.9/25	12.5/25	3.1 /25	14.4/30	+	1.0/16.6
Coralline Algae	9.4/25	+	+	0.6/10	1.0 /16.6	14.6/16.6
Dead Coral Rubble	10.9/25	12.5/25	+	11.9/20	5.21/50	21.9/50
Seagrass	-	21.9/25	32.8 /75	47.5/60	5.2/16.6	11.5/33.3
Sand	25 /25	25 /25	32.8 /75	3.1/20	10.4/16.6	14.6/50
Holothurians	+	1.6/25	1.56/25	1.9/20	1.0/16.6	1.0/16.6
Sponge	+	+	3.1 /50	0.6/10	+	2.1/16.6
Bivalves	+	+	9.3 /25	+	+	+
Total Points Sampled	64	64	64	160	96	96

*Transect numbers refer to those positions given in Figure 1.

Table 10. Checklist of marine plants found on the reefs of northern Ponape.

	Barrier Reefs	Lagoonal Patch Reefs	Island Fringing Reefs
Cyanophyta (blue-greens)			
Hormothamnion enteromorphoides Bornet & Flahault	X	X	X
Microcoleus lyngbyaceus (Kütz.) Crouan	X		X
Schizothrix calcicola (Ag.) Gomont	X	X	X
Schizothrix mexicana Gomont	X		
Chlorophyta (greens)			
Boergesenia forbesii (Harv.) Feldmann	X		
Boodlea composita (Harv.) Brand	X	X	
Caulerpa racemosa (Forskal) J. Ag.	X	X	X
Caulerpa serrulata (Forskal) J. Ag.		X	X
Chlorodesmis cf. *fastigiata*	X	X	X
Dictyosphaeria sp.	X	X	
Halimeda cf. *discoidea*	X	X	
Halimeda cf. *incrassata*		X	
Halimeda macroloba Decaisne	X	X	X
Halimeda opuntia (L.) Lamx.	X	X	X
Neomeris vanbosseae Howe	X		
Rhipilia orientalis A. & E. S. Gepp	X		X
Tydemannia expeditionis Weber van Bosse	X	X	X
Valonia fastigiata Harvey	X		
Valonia ventricosa J. Ag.	X	X	X
Phaeophyta (browns)			
Dictyota cf. *bartayresii*	X	X	X
Ectocarpus cf. *breviarticulatus*	X		
Hydroclathrus clathratus (C. Ag.) Howe			X
Lobophora variegata (Lamx) Womersley	X	X	X
Padina sp.		X	X
Ralfsia pangoensis Setchell	X		X
Sargassum polycystum C. Ag.			X
Turbinaria ornata (Turner) J. Ag.	X	X	X
Turbinaria decurrens Bory	X		
Rhodophyta (reds)			
Acanthophora spicifera (Vahl) Boerg.			X
Actinotrichia fragilis (Forskal) Boerg.	X	X	X
Amansia cf. *glomerata*	X		
Amphiroa foliacea Lamx.	X	X	X
Amphiroa fragillissima (L.) Lamx.	X		X
Ceramium sp.			X
Coralline algae	X	X	X
Gelidium sp.			X
Gracilaria salicornia (Mert.) Grev.	X	X	X
Gracilaria sp.		X	X
Halymenia durvillaei Bory	X		

Table 10. continued

	Barrier Reefs	Lagoonal Patch Reefs	Island Fringing Reefs
Hypnea sp.	X	X	X
Jania sp.	X		X
Laurencia sp.	X	X	X
Tolypiocladia glomerata (Ag.) Schmitz			X
Seagrasses			
Enhalus acoroides (L.F.) Royle		X	X
Thalassia hemprichii (Ehrenb.) Aschers		X	X
Cymodocea sp.			X
Number of Species/Area	33	26	34
Total Species	46		

Overall, cover by algae was low. This was probably in part because of the luxuriant coral coverage and in part because of the abundance of scarid, acanthurid and siganid fishes. Areas of recent disturbance, either by *Acanthaster*, storm action, or siltation, had greater proportions of coverage by filamentous algal growth. Large beds of seagrass commonly fringed the extensive mangrove export systems.

COMMON CRUSTACEANS, MOLLUSKS AND ECHINODERMS OF NORTHERN PONAPE LAGOON

Thomas Smalley

In association with the current and ichthyoplankton surveys conducted on the northern lagoon of Ponape, the common macroinvertebrates were recorded and/or collected from the transect areas (Fig. 1) or similar habitats. Table 11 includes only the more common, conspicuous, or most easily collected macroinvertebrates in the habitats. Probably the most conspicuous of the motile macroinvertebrates observed were the holothurians.

Two suspension-feeding forms, the sponges and the crinoids, appeared particularly prevalent within the lagoon as compared with the seaward margin of the barrier reef. The abundance of suspension-feeders may be the result of nutrient input from the island and its long residence time within the lagoon.

A rich diversity of mollusks is indicated by over 100 species recorded from this study without any intensive sampling techniques. Sixteen species of crustaceans were collected, with eight of these being recorded from 8 <u>Pocillipora</u> <u>damicornis</u> colonies from the lagoon margin of the barrier reef.

Table 11. Some of the more commonly encountered macroinvertebrates (crustaceans, mollusks and echinoderms) of the northern lagoon of Ponape. * indicates dead individuals.

	Barrier Reefs	Lagoon Patch Reefs	Island Fringing Reefs
Arthropoda			
Crustacea			
Decapoda			
Alpheidae			
Alpheus lottini Guerin	X		
Diogenidae			
Calcinus laevimanus Randall			X
C. minutus Buitendijk	X		
Dardanus lagopodes (Forskal)			X
Hapalocarcinidae			
Hapalocarcinus marsupialis Stimpson	X		
Calappidae			
Calappa hepatica (Linnaeus)			X
Portunidae			
Thalamita crenata (Latreille)			X
Xanthidae			
?*Epixanthus dentatus* (White)			X
Tetralia glaberrima (Herbst)	X		
Trapezia cymodoce (Herbst)	X		
T. ?*davaoensis* Ward	X		
T. digitalis Latreille	X		
T. ferruginea Latreille	X		
T. intermedia Miers	X		
T. ?*reticulata* Stimpson	X		
Grapsidae			
?*Metopograpsus messor* (Forskal)			X
Mollusca			
Gastropoda			
Haliotidae			
Haliotis sp.	X		
Trochidae			
Euchelus atratus (Gmelin)			X
Trochus maculatus Linnaeus	X	X	
T. niloticus Linnaeus	X	X	
Turbinidae			
Turbo argyrostomus Linnaeus	X		

Table 11. Continued

	Barrier Reefs	Lagoon Patch Reefs	Island Fringing Reefs
Neritidae			
Nerita grayana Recluz			X
N. plicata Linnaeus	X		X
N. reticulata Karsten			X
N. cf. *squamulata* LeGuillou			X
**N. undata* Linnaeus			X
Littorinidae			
Littorina undulata Gray			X
Planaxidae			
Planaxis sulcatus (Born)			X
Cerithiidae			
Bittium sp.	X		
Cerithium columna Sowerby			X
C. nodulosum Bruguiere	X		X
C. planum Anton			X
C. cf. *ravidum* Philippi			X
Cerithium sp.	X		
Rhinoclavis aspera (Linnaeus)	X		
R. fasciatus (Bruguiere)	X		
R. sinensis (Gmelin)	X		
Strombidae			
Lambis lambis (Linnaeus)	X		
Strombus gibberulus (Roeding)	X		
S. luhuanus Linnaeus	X	X	X
S. microurceus (Kira)	X		
S. mutabilis Swainson	X		
S. urceus Linnaeus			X
Cypraeidae			
Cypraea carneola Linnaeus	X		
C. erosa Linnaeus	X		X
C. helvola Linnaeus	X	X	
C. isobella Linnaeus	X		
C. lynx Linnaeus	X		X
C. moneta Linnaeus	X		
C. talpa Linnaeus	X		
C. tigris Linnaeus	X	X	X
C. vitellus Linnaeus			X
Naticidae			
Polinices tumidus (Swainson)	X		

Table 11. Continued

	Barrier Reefs	Lagoon Patch Reefs	Island Fringing Reefs
Cymatiidae			
**Cymatium nicobaricum* Roeding		X	
Muricidae			
Chicoreus brunneus Link		X	X
Chicoreus sp.		X	
Drupa rubusidaea Roeding	X		
Drupella cariosa (Wood)	X		
D. cornus (Roeding)	X		
Morula margariticola (Broderip)			X
Thais armigera Link	X		
T. hippocastanum (Philippi)	X		
Coralliophilidae			
Coralliophila violacea (Kiener)			X
Quoyula madreporarum Sowerby	X		
Columbellidae			
Mitrella ligula (Duclos)	X		
Pyrene sp.	X		
Buccinidae			
Cantharus fumosus (Dillwyn)			X
Nassariidae			
Nassarius quadrasi Hidalgo	X		
Fasciolariidae			
Latirus sp.	X		
Peristernia cf. *incarnata* (Kiener)			X
Vasidae			
Vasum turbinellus Linnaeus	X		X
Mitridae			
Cancilla filaris Linnaeus	X		
Imbricaria punctata Swainson	X		
Mitra emeritarum Roeding	X		
M. mitra Linnaeus	X		
M. nigricans (Pease)	X		
Neocancilla papilio Link	X		
Costellariidae			
Vexillum granosum Gmelin	X		
V. plicarium Linnaeus			X
Turridae			
**Lophiotoma* cf. *acuta* (Perry)			X

Table 11. Continued

	Barrier Reefs	Lagoon Patch Reefs	Island Fringing Reefs
Conidae			
Conus balteatus Sowerby	X		
C. distans? Hwass	X		
C. eberneus Hwass	X		
C. flavidus Lamarck	X		
C. litteratus Linnaeus	X		
C. magus Linnaeus	X		
C. marmoreus Linnaeus	X		X
C. virgo Linnaeus			X
Terebridae			
Terebra affinis Gray	X		
**T. cingulifera* Lamarck			X
T. felina Dillwyn	X		
T. guttata Roeding	X		
T. maculata Linnaeus	X		X
T. subulata Linnaeus	X		
Pyramidellidae			
Pyramidella sulcata (A. Adams)	X		
Bivalvia			
Arcidae			
Anodara cf. *nodifera* VonMartens			X
Arca ventricosa Lamarck			X
Barbatia tenella Reeve			X
Pinnidae			
Atrina vexillum (Born)		X	
Pteriidae			
Pinctada margaritifera Linnaeus	X		
Pinctada sp.			X
Pteria sp.			X
Isognomonidae			
Isognomon perna Linnaeus			X
Spondylidae			
Spondylus tenebrosus Reeve			X
Spondylus sp.	X		
Ostreidae			
Lopha cristogalli (Linnaeus)			X
Lopha sp.		X	
Chamidae			
Chama cf. *reflexa* Reeve			X
Chama sp.		X	

Table 11. Continued

	Barrier Reefs	Lagoon Patch Reefs	Island Fringing Reefs
Cardiidae			
Acrosterigma cf. *elongatum* Bruguierre			X
Fragum fragum Linnaeus	X		
Tridacnidae			
Hippopus hippopus (Linnaeus)			X
Tridacna maxima (Roeding)			X
Tellinidae			
Tellina cf. *vigato* Linnaeus			X
Scutarcopagia scobinata Linnaeus	X		
Echinodermata			
Asteroidea			
Acanthaster planci (Linnaeus)		X	X
Culcita novaeguineae Muller & Troschel		X	X
Linkia laevigata (Linnaeus)		X	
L. multifora (Lamarck)	X		X
Echinaster luzonicus (Gray)	X	X	
Echinoidea			
Diadema cf. *setosum* (Michelin)	X		
Heterocentrotus mammillatus (Linnaeus)		X	
Holothuroidea			
Stichopus chloronotus Brandt	X		
S. hermanni	X	X	X
Actinopyga mauritiana (Quoy & Gaimard)	X		
Bohadschia graeffei (Semper)	X		
B. argus Jaeger	X		
B. marmorata Jaeger	X		
Holothuria atra Jaeger	X		X
H. edulis Lesson	X		
H. nobilis (Selenka)	X		
H. leucospilota (Brandt)	X		
Synapta sp.		X	

FISH EGGS AND FISH LARVAE

Thomas Smalley, Bruce Best and Charles Birkeland

INTRODUCTION

For continued harvesting of fish populations, it is necessary to not overexploit the resource and to preserve the nursery areas. Even heavily overexploited stocks can often recover if adequate nursery areas are available for the production of larval fishes. It is therefore of interest to determine the nature of the major fish nursery areas in order to be able to assess the relative importance of different habitat types. This information would be of use in developmental planning for the island community. The relative importance of different habitat types for fisheries development should be taken into account if changes in land management are to be made in future agricultural and industrial development.

The purpose of this study is to determine the relative abundance and distribution of fish eggs and fish larvae among the different habitats of northern Ponape.

METHODS

Fish eggs and larvae were sampled with 50 cm diameter plankton nets of 0.35 mm mesh. Most of the tows were made during daylight hours at a constant speed of 2 knots (1 m/sec) for 10 minutes. Approximately 0 to 5 cm of the net protruded above the surface of the water. Eight tows were made at a speed of 4 knots for 5 minutes and eight tows were made at night at 2 knots for comparative purposes. In all cases, the volume filtered remained approximately constant at 118 m^3.

Most sites were sampled in replicate with 4 consecutive tows retracing the same route. Exceptions were the second day of collections at the sites in the passages and the collections at Palang and at sites 5 and 6 (Fig. 1) where only two replicates were taken. Four samples taken on the lagoon margin at Nankapenparam Reef were in a linear series (sites 10-13, Fig. 1) rather than replicates over the same site.

As two nets of the same dimensions were utilized concurrently at different locations in much of our sampling, two cod ends were also employed. These cod ends were of different mesh size, one being 0.33 mm in diameter and the other 0.25 mm. In order to determine whether these cod ends would be responsible for significant differences among our samples, one site was sampled in replicate by towing both cod ends at the same time from the boat, twice over the same route, for a total of 4 samples. Both cod ends were also towed at the same time in two linear series tows for a total of another 4 samples. The data were then compared (Table 12) and no significant differences were found between the counts in the samples taken by the two cod ends. No significant differences were found between the replicate tows over the

Table 12. An analysis of variance between replicates, between cod ends, and between linear series tows from nighttime tows in baitfish areas.

FISH EGG COUNTS

	Cod End		
Replicate	Grey	White	
tow no. 1	287	40	327
tow no. 2	42	3	45
	329	43	372

$F_{\text{cod ends}}$ = 1.89 ns

$F_{\text{replicates}}$ = 1.84 ns

FISH LARVA COUNTS

	Cod End		
Replicate	Grey	White	
tow no. 1	133	214	347
tow no. 2	49	45	94
	182	259	441

$F_{\text{cod ends}}$ = .821 ns

$F_{\text{replicates}}$ = 8.86 ns

Linear series tows	Grey	White	
Area 5 (Fig. 1)	165	188	353
Area 6 (Fig. 1)	2322	2116	4438
	2487	2304	4791

$F_{\text{cod ends}}$ = .639 ns

F_{areas} = 318.2*

Linear series tows	Grey	White	
Area 5 (Fig. 1)	119	81	200
Area 6 (Fig. 1)	126	112	238
	245	193	438

$F_{\text{cod ends}}$ = 1.334 ns

F_{areas} = .715 ns

same area, but a significant difference was found between tows in a linear series. These results validate our sampling methods.

Samples were transferred from the cod end into 60 ml sample bottles with a volume of approximately 50 ml seawater, and approximately 3 ml of 100% buffered formalin were added. This yielded an approximately 5% formalin solution. Some samples, particularly those from seagrass areas, were rather clogged with seagrass blades and were difficult to handle. These samples were transferred to 350 or 500 ml plastic sample bottles and preserved by adding 100% buffered formalin to bring the concentration to 5%.

Samples were analyzed for fish eggs and larvae in the laboratory with a binocular Wild MS5 stereomicroscope. In all cases, the entire sample was counted for fish larvae. Where feasible, the entire sample was counted for fish eggs. Those samples that contained high densities of eggs were aliquoted (1/16 or 1/32), with 4 replicate fractions being counted. The mean of the 4 replicates was multiplied times 16 or 32, as appropriate.

RESULTS AND DISCUSSION

Fish larvae were found to be most abundant in baitfish areas and near mangrove-seagrass areas (Table 13). The baitfish areas with the most fish larvae in daytime counts (Uoten and Metalanim [Table 14]) were in close proximity to mangrove-seagrass areas. In comparable daytime plankton tows, the mangrove-seagrass areas (Uoten and Metalanim) had very significantly ($t_{s[70]}$ = 9.77***) greater counts of larval fish (78.1 ± 15.5 [12], range 22-190) than did all the other areas (7.93 ± 1.12 [60], range 0-43). Mangrove areas bordering corals, and seagrass areas away from mangroves, each had less than a third the abundance of larval fishes than did the mangrove-seagrass combination areas (Table 1). The combination of mangroves and seagrasses in a habitat appeared to produce the richest nursery area for larval fishes.

The abundance of larval fishes (Table 14) and fish eggs (Table 15) showed no significant correlation in our plankton samples (r_s = -.295 ns). Fish eggs were relatively scarce in our samples that were taken near mangroves (Table 13); they were abundant near corals and seagrass beds. Fish egg counts were especially high in samples taken along the lagoon margin of the barrier reef and in the channels leading from the lagoon margin through the barrier reef (Table 13). Fish eggs were also abundant in seagrass beds away from mangroves (Table 13). The general picture that emerges from these data is that a great many eggs are spawned by the abundant and diverse fish community on the lagoon side of the barrier reef, but fish larvae are most abundant in the mangrove-seagrass areas.

Few fish larvae or fish eggs were found on the seaward margin of the barrier reef at Ponape (Table 13). A review of the literature suggested a general tendency towards a greater abundance of larval fishes in lagoons than on seaward margins of coral reefs (Table 16). The waters in lagoons around high islands may be more productive

Table 13. Number of fish eggs and fish larvae per 1 m^3 in different habitats around Ponape. All estimates were calculated from data for daytime tows at 2 knots in Tables 14 and 15.

Habitat	Number of Samples (n)	$\bar{Y} \pm S_{\bar{Y}}$ Eggs	Larvae
Baitfish areas	16	2.29 ± .69	1.24 ± .13
Passages through the barrier reef	18	13.0 ± 2.3	.11 ± .02
Lagoon margin of the barrier reef	10	29.1 ± 5.0	.033 ± .008
Seaward margin of the barrier reef	2	0.82 ± .09	0
Coral point in lagoon	4	4.1 ± 2.6	.026 ± .018
Reef with few living corals	4	.15 ± .02	.004 ± .004
Mangrove-coral	8	.98 ± .42	.094 ± .031
Mangrove-seagrass	4	.021± .009	.33 ± .06
Seagrass	8	23.6 ± 8.7	.076 ± .027

Table 14. Counts of larval fish in plankton tow samples (approximately equivalent to number per 118 m^3).

Location	Special situation[1]	Number given the site in Fig. 1	Counts from replicate tows				$\bar{Y} \pm S_{\bar{Y}}$ of replicates	CV
			BAITFISH AREAS					
Uoten		1	69	41	82	29	55.2 ± 12.2	44.3
Uoten	night	1	133	49	214	45	110 ± 40.1	72.7
bay west of Jokaj		4	10	5	3	2	5.0 ± 1.78	71.2
bay west of Jokaj	4 knots	4	1	2	7	16	6.5 ± 3.43	105.5
bay west of Jokaj	night	5	81	119			100 ± 19.0	26.9
bay west of Jokaj	night	6	112	126			119 ± 7.0	8.3
channel south of Param		20	1	4	3	4	3.0 ± .71	47.1
Metalanim		-	163	97	110	190	140 ± 21.9	31.3
			PASSAGES					
Jokaj Pass	2 Jan	8	19	11	13	11	13.5 ± 1.89	28.0
Jokaj Pass	2 Jan at 4 knots	8	7	6	3	4	5.0 ± .91	36.5
Jokaj Pass	9 Jan	8	16	5			10.5 ± 5.50	74.1
Ponape Pass	2 Jan	9	2	8	13	43	16.5 ± 9.12	110.5
Ponape Pass	9 Jan	9	13	25			19.0 ± 6.00	44.7
Mant Pass	2 Jan	14	6	1	2	3	3.0 ± 1.08	72.0
Mant Pass	9 Jan	14	17	22			19.5 ± 2.50	18.1
			LAGOON MARGIN OF BARRIER REEF AREAS					
west of Jokaj Pass		7	3	4	5	4	4.0 ± .41	20.4
Nankapenparam Reef		10	2				2	
Nankapenparam Reef		11	4				4	
Nankapenparam Reef		12	4				4	
Nankapenparam Reef		13	11				11	
Palang-lagoon margin of barrer reef		-	1	1			1	

Table 14. continued

Location	Special situation	Number given the site in Fig. 1	Counts from replicate tows				$\bar{Y} \pm S_{\bar{Y}}$ of replicates	CV
			OTHER CORAL AREAS					
Palang-seaward margin of barrier reef		-	0	0			0	
Coral point		18	9	3	0	0	3.0 ± 2.1	141.4
Reef with few living corals[2]		16	0	0	2	0	.5 ± .5	200.0
			MANGROVE-CORAL AREAS					
west edge of Mantapeitak Island		17	3	2	6	0	2.75 ± 1.25	90.9
west side of Param Island		19	13	13	26	26	19.5 ± 3.75	38.5
			MANGROVE-SEAGRASS AREAS					
Uoten		2	38	39	57	22	39.0 ± 7.15	36.7
			SEAGRASS AREAS					
off mouth of Mokota River		3	14	20	11	22	16.8 ± 2.56	30.6
northeast end of Mantapeitak Island		15	1	2	2	0	1.25 ± .48	76.6

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[1] Unless a difference is noted in this column, all tows were daytime at 2 knots.

[2] Corals were apparently killed by Acanthaster a few months previous.

Table 15. Counts of fish eggs in plankton tow samples (approximately equivalent to number per 118 m^3).

Location	Special situation[1]	Number given the site in Fig. 1	Counts from replicate tows				$\bar{Y} \pm S_{\bar{Y}}$ of replicates	CV
			BAITFISH AREAS					
Uoten		1	9	32	24	41	26.5 ± 6.79	51.2
Uoten	night	1	287	42	40	3	93.0 ± 65.3	140.4
bay west of Jokaj		4	59	53	58	47	54.2 ± 2.75	10.1
bay west of Jokaj	4 knots	4	18	22	17	22	19.8 ± 1.31	13.3
bay west of Jokaj	night	5	188	165			176 ± 11.5	9.2
bay west of Jokaj	night	6	2116	2322			2219 ± 103	6.6
channel south of Param		20	114	579	203	374	318 ± 103	64.6
Metalanim		-	1006	664	202	853	618 ± 174	51.2
			PASSAGES					
Jokaj Pass	2 Jan	8	1683	1342	1195	3275	1874 ± 478	51.0
Jokaj Pass	2 Jan at 4 knots	8	1516	1845	692	1197	1312 ± 246	37.4
Jokaj Pass	9 Jan	8	1077	670			874 ± 204	32.9
Ponape Pass	2 Jan	9	1692	2675	4656[3]	2396[4]	2855 ± 635	44.5
Ponape Pass	9 Jan	9	2020	1294			1657 ± 363	31.0
Mant Pass	2 Jan	14	505	338	669	757	567 ± 92.6	32.6
Mant Pass	9 Jan	14	635	680			658 ± 22.5	4.8
			LAGOON MARGIN OF BARRIER REEF AREAS					
west of Jokaj Pass		7	2601	3290	3984[3]	6176[3]	4013 ± 774	38.6
Nankapenparam Reef		10	5664[4]				5664	
Nankapenparam Reef		11	5196[4]				5196	
Nankapenparam Reef		12	3500[4]				3500	
Nankapenparam Reef		13	704[4]				704	
Palang-lagoon margin of barrier reef		-	1316	1902			1609 ± 293	25.8
			OTHER CORAL AREAS					
Palang-seaward margin of barrier reef		-	725	911			818 ± 93.0	16.1
Coral point		18	273	2871	1253	11816[3]	4053 ± 2642	130.4
Reef with few living corals[2]		16	111	131	182	168	148 ± 16.4	22.1

Table 15. Continued

Location	Special situation[1]	Number given the site in Fig. 1	Counts from replicate tows				$\bar{Y} \pm S_{\bar{Y}}$ of replicates	CV
			MANGROVE-CORAL AREAS					
west edge of Mantapeitak Island		17	3	11	8	13	8.75 ± 2.17	49.7
west side of Param Island		19	408	148	195	139	222 ± 63.0	56.7
			MANGROVE-SEAGRASS AREAS					
Uoten		2	4	7	32	41	21.0 ± 9.16	87.2
			SEAGRASS AREAS					
off mouth of Mokota River		3	104	155	71	147	119 ± 19.6	32.9
northeast end of Mantapeitak Island		15	5736[3]	6112[3]	5928[3]	3944[3]	5430 ±501	18.5

[1] Unless a difference is noted in this column, all tows were daytime at 2 knots.

[2] Corals were apparently killed by <u>Acanthaster</u> a few months previous.

[3] Calculated by averaging 4 aliquots of 1/32 samples and multiplying the mean by 32.

[4] Calculated by averaging 4 aliquots of 1/16 samples and multiplying the mean by 16.

Table 16. Number of fish eggs and fish larvae per 1 m^3 from surveys around Micronesia and Hawaii. Only daytime data are included.

Location	No. of Tows (n)	$\bar{Y} \pm S$		Reference
		Egg	Larvae	
Caroline Islands				
Ponape				
lagoon	72	12.5 ± 2.2	.17 ± .03	this report
seaward of barrier reef	2	.82 ± .09	0	this report
Truk				
Tol Island	4	1.57 ± .32	.28 ± .20	Clayshulte et al. 1978
Dublon Island		4.9 ± 2.2	.08	Amesbury et al. 1977
Palau				
Arakabesan Island	5	.77 ± .57	.33 ± .26	Randall et al. 1978
Malakal Island	1	.9	.3	Birkeland et al. 1976
Yap				
all around	18	5.7 ± 2.9	1.9 ± .5	Lassuy 1978
Tomil Harbor	2	7.8	.25	Amesbury et al. 1976
Mariana Islands				
Guam				
west coast	36	44.2 ± 8.6	1.14 ± .19	Amesbury 1978
Apra Harbor	8	1.03 ± 1.66	.68 ± .79	Univ. of Guam Marine Lab. 1977
Saipan	2	1.4	.4	Amesbury and Doty 1977
Marshall Islands				
Bikini				
lagoon	25	1.45	.61	Johnson 1954
seaward of barrier reef	18	.66	.16	Johnson 1954
Enewetak		.09	1.15	Johnson 1954
Rongelap		2.27	3.64	Johnson 1954
Rongerik		.73	1.43	Johnson 1954
Kwajalein*	2	19	6	Amesbury et al. 1975a
Majuro	4	8.0	.5	Amesbury et al. 1975b
Hawaii				
Kauai	33		.066 ± .011	Miller et al. 1979
Oahu	49		.121 ± .015	Miller et al. 1979
Maui	31		.095 ± .019	Miller et al. 1979

*The Kwajalein samples were taken at Ebeye, in an area possibly being influenced by nutrient input from a sewer outfall.

because of a longer residence time for the nutrient rich rainwater runoff containing nutrients. The long residence time for nutrients in the water column may allow time for the production of phytoplankton which in turn serves as food for the higher trophic levels. This might ultimately provide for nourishment of larvae and the production of eggs by adult fishes.

We found a significantly greater concentration of fish eggs (Table 15, daytime counts were 40 ± 6, nighttime counts were 645 ± 346, $t_{s[14]} = 2.32$*) and especially fish larvae (Table 14, daytime counts were 30 ± 11, nighttime were 109 ± 19, $t_{s[14]} = 4.77$***) in nighttime tows as compared to daytime tows in the same areas. Our plankton tows were taken at the surface, so these results would seem to imply a vertical movement of eggs and larvae into the surface waters at night. It's hard to imagine how fish eggs are moved, but the data in Table 15 definitely require an explanation. Perhaps the nocturnal environment triggers spawning in adult fishes which might move into the surface waters to spawn at night. The abundance of eggs at night would then be a result of recent spawning rather than a result of vertical drift of eggs per se.

BIBLIOGRAPHY OF COASTAL PONAPE

Lucius G. Eldredge

INTRODUCTION

The island of Ponape has not been well studied. This bibliography is an attempt to draw together published and unpublished literature about the island. This bibliography is composed primarily of marine-related information; however, some additional pertinent material, such as anthropological, geological, and physical, is included. For the truly terrestrial botany and vegetation literature, "Island Bibliographies" and "Island Bibliographies Supplement" (Pacific Science Board, U. S. National Academy of Sciences 1955, 1971) should be consulted.

The following articles are listed alphabetically by author. Some of the citations are translations from Japanese which often vary from translator to translator. Many 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 acknowledgments are extended to Georgia Greene and Barbara Simmons who assisted during the compilation of this bibliography. John Byrne (U. S. Fish. and Wildlife Science, Portland) provided a computer printout concerning Ponape from the Pacific Island Ecology project. R. E. Johannes (CSIRO, Western Australia) and E. H. Bryan, Jr., (Pacific Scientific Information Center) reviewed a preliminary list and suggested additions.

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APPENDIX

REEF DEVELOPMENT GUIDE

(Modified from Roy T. Tsuda, Michael J. Gawel* and Michael D. Rody* 1978)

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.

Figures 18 to 24 in the section of the report entitled Mapping of the Reef Habitat Types in Northern Ponape depict cross-sections of the reefs showing areas which can be encountered as one travels from the shore to the outer reef slope. The maps (Figs. 10-17) which are presented in the same section of this report give a view of the distribution of habitat types around the northern lagoon of Ponape. The various areas depicted on the cross-sectional profiles (Figs. 18-24) and the maps (Figs. 10-17) are described in Table 17 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 18. Table 19 provides one interpretation of the development suitability of the various reefs areas or zones shown on the maps and the cross-sectional profiles. This interpretation is based on the general pattern of recommendations presented by Tsuda, Gawel and Rody (1978). Their overall philosophy is based on the premise that coastal development will take place. These guidelines are simply presented to advise the readers as to where these developments should or should not occur.

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Table 17. Description, functional aspects and consequences of alteration and development of the various reef areas in Ponape (adopted from Tsuda, Gawel and Rody 1978).

Reef Areas	Description	Function	Consequences of Alteration or Development
MANGROVE	Mud substratum; 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 substratum; dominated by seagrasses and benthic algae; habitat for juvenile fishes, sea cucumbers, worms and shells.	Bind loose sediments; trap sediments from land runoff; 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 substratum; 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 (barrier reef, lagoon patch reefs, lagoon fringing reefs)	Reef rock serves as substratum; many types of corals and few algae present; many fishes.	Actively growing portion of reef; shelter for numerous large food fishes, 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.

Table 17. continued

Reef Areas	Description	Function	Consequences of Alteration or Development
BARRIER REEF PASS	Rich growth of sea fans, corals and big sponges; inhabited by many types of food fish, crabs, and shellfish; very large and abundant food fishes, sharks.	Most reliable source of protein for local people; attractive scenic area for divers; deep water passage for boats.	Loss of best site for edible fish; loss of possible tourist attraction; loss of natural boat passage.
OUTER BARRIER REEF SLOPE	Reef rock substratum; numerous types of corals, food fishes, 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 18. Definitions of the terms used for the proposed developments considered in Table 19 (from Tsuda, Gawel and Rody 1978).

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.

Table 18. continued

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 19. Development suitability of reef areas. Key: Unsuitable = ●, Partially Suitable = ◐, Suitable = 0.
(Adapted from Tsuda, Gawel and Rody 1978.)

PROPOSED DEVELOPMENT / REEF AREAS	Mangrove Shoreline	Seagrass	Sediment (sand-algae)	Coral (Barrier Reef)	Reef Pavement	Outer Barrier Reef Margin	Lagoon Patch Reefs	Lagoon Fringing Reefs	Harbor Areas and Estuaries	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	●	●	●	◐	●