MANAGEMENT OF REEF RESOURCES:

POHNPEI ISLAND,

FEDERATED STATES OF MICRONESIA

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

CWA	Clean Water Act of 1977
CZM	Coastal Zone Management
CZMA	Coastal Zone Management Act of 1972
DMR	Pohnpei State Division of Marine Resources
EDA	Economic Development Authority
EPB	FSM Environmental Protection Board
FSM	Federated States of Micronesia
GBRMPA	Great Barrier Reef Marine Park Authority
HPO	Pohnpei State Historic Preservation Office
NEPA	National Environmental Protection Act of 1969
NMFS	National Marine Fisheries Service
PLA	Pohnpei State Public Lands Authority
PTA	Pohnpei Transportation Authority
PWC	Pohnpei Public Works Commission
TTPI	Trust Territory of the Pacific Islands
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service

CHAPTER I

INTRODUCTION

Situation

The coastal resources of developing tropical countries are subject to increasing stress as populations expand, development pressures grow, and new technologies are introduced (Stoddart, 1981). On small Pacific islands, this situation is particularly pressing because of the limited amount of land and associated terrestrial resources available. Nearshore marine resources have always played a major role in the sustenance of Pacific island communities. Although some destructive practices of resource use are known to have taken place, the conservation of marine resources was an important part of traditional culture. However, political, socioeconomic, and technological change have eroded this heritage of resource management and gradually replaced it with introduced attitudes and means of resource exploitation (Johannes, 1975, 1978a; Wass, 1982).

In Micronesia in particular, island resources are limited by the restricted amount of flat, arable land on high islands and the lack of soil on low, coral atolls (TTPI, 1979a). The resources of reef and lagoon systems have thus been critical to the livelihood of Micronesians. Micronesia, as elsewhere in the Pacific, is undergoing rapid changes and population growth which affect the condition and use of coastal resources. This situation is exacerbated on Pohnpei where siting of the capital of the recently formed Federated States of

Micronesia (FSM) has stimulated development activities and encouraged migration from outer islands.

The reef and lagoon system of Pohnpei is increasingly subject to degradation from a variety of uses and activities, including: sewage and solid waste disposal associated with urban expansion, reef flat dredging and sand mining, changing land use which results in erosion and reef siltation, and over-exploitation of reef fisheries. There is a need for comprehensive planning for management of reef resources to prevent unnecessary degradation, avoid conflicts in their use, avoid foreclosing future development opportunities, and promote conservation and sustained use.

Statement of Purpose

The purpose of this thesis is to review and evaluate various management approaches and methodologies for application to Pohnpei Island. Based on detailed information on the distribution and abundance of Pohnpei's coastal resources and their uses, specific management recommendaions are provided for Pohnpei's reef and lagoon resources. Formulation of proposals for the management of Pohnpei's reef resources is part of a larger planning process which has been developed for, and applied to, Pohnpei (Holthus, 1985). The goal is that this process and its methods will be applicable to lesser developed island countries elsewhere. In this process, a preliminary survey and literature review are followed by an inventory of physical and biological resources, interviews with resource users, and aerial photographic analysis (Fig. 1). This information provides baseline

data on resource distribution, abundance, and use patterns which have been compiled into a survey report and atlas (see Appendix 1). Following the development of management strategies and recommendations, which are presented in this document, a working draft of the proposals will be presented to government officials, fishermen, and other concerned parties in Pohnpei for discussion in order to refine them and facilitate adoption and implementation of the management plan by the Pohnpei State government.

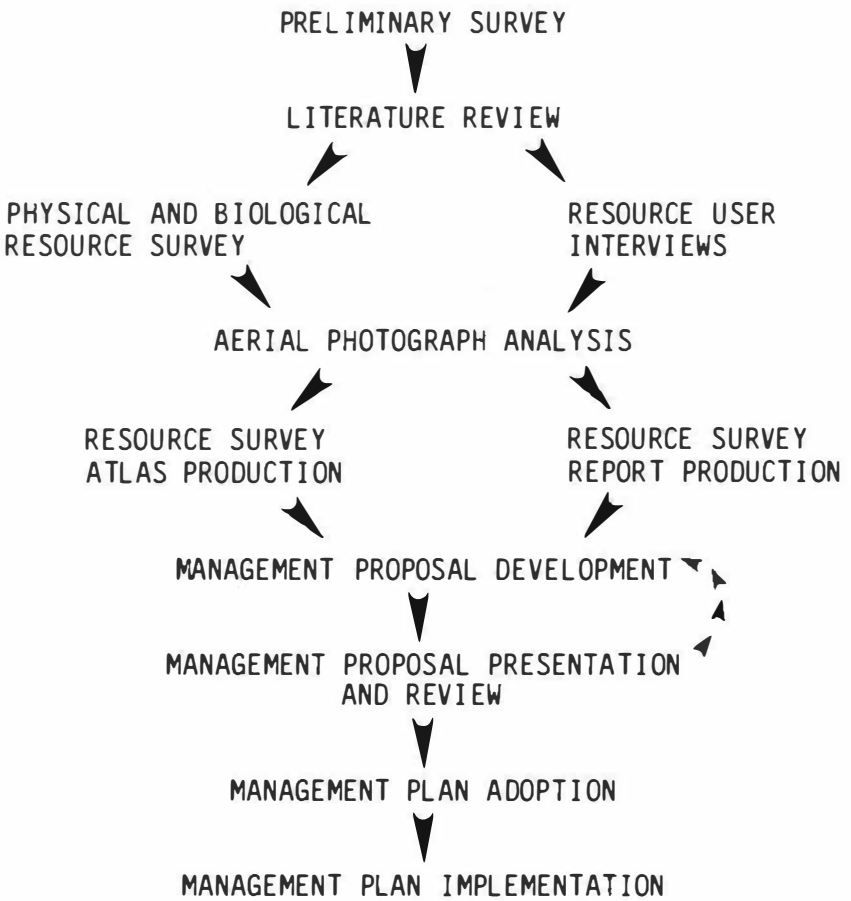
Physical Environment

Pohnpei Island is located in the Caroline Archipelago at approximately 6°45' North and 158° 15' East. The high, basalt, volcanic island is roughly pentagonal in shape with a diameter of 20 km and a land area of about 334 sq km. The rugged, forested interior is dominated by a number of high peaks over 600 m in elevation; the highest reaches over 760 m. Sharp ridges, steep cliffs, and narrow valleys radiate out from the highlands and often reach directly to the shore, with limited foothills or coastal plains (Fig. 2). Rainfall on Pohnpei ranges from almost 500 cm/yr on the northeast windward coast to an estimated 1000 cm/yr in the interior. Numerous streams discharge into nearshore lagoon waters.

Pohnpei Island is surrounded by a complex reef and lagoon system. The highly convoluted fringing reef, which ranges from 20 m to over 2000 m in width, supports a near continuous belt of mangrove around the island. A deep lagoon encircles most of Pohnpei except for a small section along the southeast side where only a wide fringing reef

Figure 1

The Reef Resource Management Planning Process
for Pohnpei Island



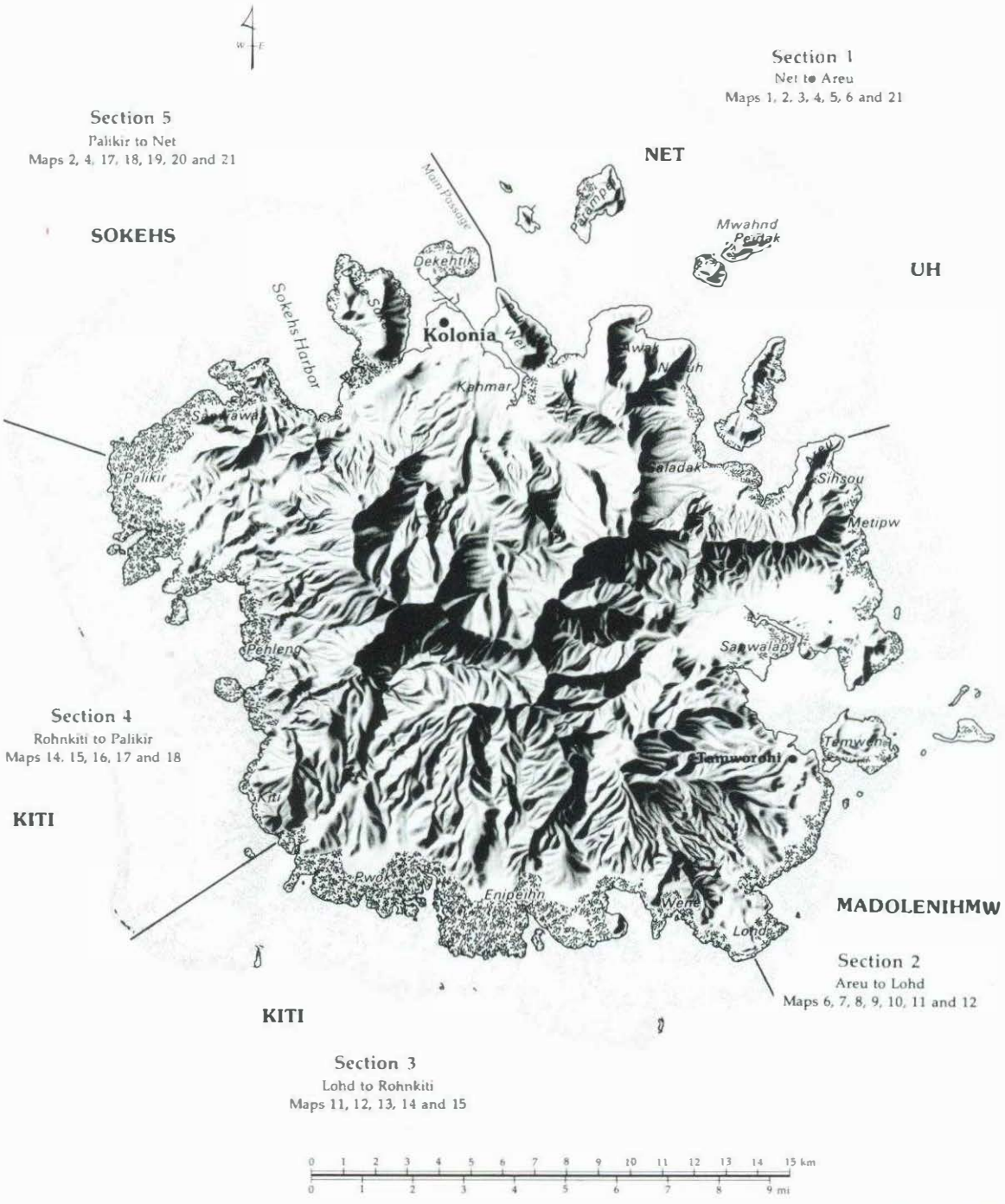
has formed (Fig. 2). The lagoon is dotted with numerous patch reefs of variable size and shape and a number of basalt islands with fringing reefs. Pohnpei's lagoon is enclosed by an extensive barrier reef which supports a number of sand islets and is bissected by over 15 deep passes.

Social, Economical and Political Environment

The population of Pohnpei Island was 23,480 in 1980 and is expected to double in about 20 years. One-quarter of the population resides in Kolonia, the government and commercial center on the north side of the island, while the rest is distributed around the coastal portion of the island within Pohnpei's five municipalities (Net, Uh, Madolenihmw, Kitti, and Sokehs). Pohnpei's economy, especially government employment and capital improvements, is largely subsidized by the U.S. government through the Trust Territory of the Pacific Islands (TTPI). Limited exports include copra, pepper, handicrafts and *Trochus* shell, while the import of food and consumer goods increases each year. A small commercial fishery provides the local market with fresh reef fish, tuna, and mangrove crab. The State of Pohnpei includes 5 outlying atolls: Mokil, Pingelap, Ngatik, Nukuoro, and Kapingamarangi, the latter two of which are inhabited by Polynesians and the rest are inhabited by Micronesians. Pohnpei State, along with Yap, Truk, and Kosrae, is now part of the FSM, whose capital is located on Pohnpei Island. With pending finalization of the FSM's Compact of Free Association with the United States, Pohnpei

Figure 2

Map of Pohnpei Island



Island is becoming the focus of economic development and immigration in Pohnpei State and the FSM.

Resource Management on Pohnpei

The conservation and management of natural resources on Pohnpei is currently a mix of municipal, FSM, Pohnpei State, U.S. Federal and former TTPI programs. Many U.S. Federal programs dealing with the management of environmental resources are applied on Pohnpei. These include the U.S Army Corps of Engineers (USACE) permit program for the discharge of dredged and fill materials in coastal waters and wetlands; U.S. Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS) conservation related assessment, monitoring, and management of selected bird, fish, sea turtle, and other wildlife and vegetation; U.S. Forest Service assistance with the evaluation, development, and conservation of forest resources, including mangroves; and the U.S. Environmental Protection Agency (USEPA) administration of selected federal permits and environmental projects to control solid wastes and water pollution. However, most Federal resource evaluation, conservation, and management programs will terminate when the Compact of Free Association goes into effect. Although the Compact calls for the establishment of counterpart environmental laws and programs, little progress has been made in this direction. The FSM government has taken over most of the former TTPI resource management functions, including the Environmental Protection Board (EPB), which is responsible for monitoring nearshore water quality and public health conditions, and the Marine Resources

Division, which advises state governments on the management of marine resources.

At the state level, the Pohnpei Ministry of Conservation and Resource Surveillance contains the Divisions of Marine Resources (DMR) and Forestry. The DMR is the primary state agency responsible for the conservation and management of reef resources, while the Division of Forestry is responsible for mangrove resources as well as terrestrrial forests. The Economic Development Authority (EDA), which is attached to the governor's office, promotes and supports the economic development of marine, and other, resources. Other state agencies of importance are the Pohnpei Transportation Authority (PTA), which is responsible for constructing roads and for reef flat dredging to obtain fill and aggregate materials for road construction and maintenance; the Public Lands Authority (PLA) which administers all government owned lands, including those below high water mark; the Public Works Department (PWC), which carries out many of the reef dredging and construction activities; and the Historical Preservation Office (HPO), which is responsible for the identifying and promoting the protection of archeological sites and other aspects of Pohnpei's culture. Below the state level, Pohnpei's municipal governments control the use of mangrove forests in each of their districts.

CHAPTER II

METHODS

The methods used in developing management recommendations for Pohnpei's reef resources are described in this chapter as part of the overall planning process (Fig. 1). The process was designed to be adaptable, low cost, rapid, and able to provide the geographically specific information necessary to initiate reef management planning in Pohnpei. It is also a goal that this process will serve as a model for the establishment of reef resource management programs in other developing coral reef coastal regions.

Preliminary Survey

A reconnaissance survey was carried out on Pohnpei to establish the scope of the work, preview the area to be investigated, and attain a commitment by the local government to reef management in general and the Pohnpei study specifically. Key personnel and agencies in Pohnpei were contacted to obtain advance information and establish links for logistical support and local contacts.

Literature Review

Information was gathered from a review of the literature, but the coastal environment of Pohnpei has not been well studied (Eldredge, 1980). Coral reef studies have been limited to the assessment of reef environments adjacent to proposed developments (Tsuda, et al., 1974; Randall, 1977); a multi-faceted survey of Pohnpei's northern lagoon

(Birkeland, 1980); and brief structural and geological investigations (Curray, et al., 1970; Shepard, 1970; Bloom, 1970). The abundance and distribution of some marine organisms have been described for Pohnpei or as part of Micronesia-wide studies, including: mangrove crabs (Dickenson, 1977; Perrine, 1978), sea turtles (DeYoung, 1961; Pritchard, 1981; McCoy, 1981), Trochus (McGowen, 1958), lobster (MacDonald, 1971), Acanthaster (Tsuda, 1971; Wass, 1974) and crocodiles (Allen, 1974). Pohnpei's mangrove forest and other wetlands have been inventoried (Londvai, 1969; Stemmerman and Proby, 1978), and the seagrasses catalogued (Tsuda et al., 1977).

The quality of Pohnpei's nearshore waters has been assessed and pollution sources indicated (Environmental Protection Board (EPB), 1970; Siren and Scheuring, 1970; Cowan and Clayschulte, 1980; Cowan, 1982; Falanruw, 1982). Bascom (1965) briefly documented the traditional use of marine resources in Pohnpei. Other studies on cultural change have mentioned the loss of customs, such as reef tenure and seafood distribution patterns, which influence reef resource use (Coale, 1951; Fischer, 1958; Dahlquist, 1972; Patrick, et al., 1974; Nakayama and Ramp, 1974; Sudo, 1984). Fisheries development and conservation plans have been outlined (Van Pel, 1956; Owen, 1973). Johannes (1978b) made detailed recommendations for improving Pohnpei's reef and lagoon fishery, and the TTPI Office of Planning and Statistics produced a well-illustrated land use guide, which includes nearshore environments (TTPI, 1979b). A survey of natural landmarks was conducted by the U.S. Dept. of Interior (Abbott, et al., 1982). Some results from previous planning reports (Hawaii

Architects, 1968; TTPI, 1971, Patrick et al., 1977) have been incorporated into the current Pohnpei State Development Plan: 1985-1989 (Pohnpei State, 1985a), and environmental considerations associated with the development of the FSM capital complex at Palikir have been described (Brewer and Associates, 1983). Efforts are currently underway to develop island-wide management plans for Pohnpei's mangrove and upland forest resources (Pohnpei State, 1985b, 1985c).

Physical and Biological Resource Survey

The physical and biological resources of Pohnpei's reefs were surveyed by a field team using semi-quantitative inventory methods during six weeks in 1983. Similar methods have been described for broad reef survey work on the barrier reef (Kenchington, 1978) and the same methods have been employed in the gathering of coastal resource inventory data in Hawaii, American Samoa and Micronesia (Maragos and Elliott, 1985). For our work on Pohnpei, 86 survey stations were chosen to obtain adequate geographical coverage and sampling of Pohnpei's variety of reef environments (Fig. 3; Table 1). Sites included fringing reefs, patch reefs, lagoon island reefs, and barrier reef lagoon slopes, ocean slopes, and passes. The range of sampling locations included both windward and leeward, nearshore and offshore, reef flat and reef slope, and shallow (0-5m) and deep (5-35m) reef areas.

Using clipboards and water proof species checklists, each field team member gathered information on a particular portion of the reef's

Figure 3

Coastal Resource Survey Stations

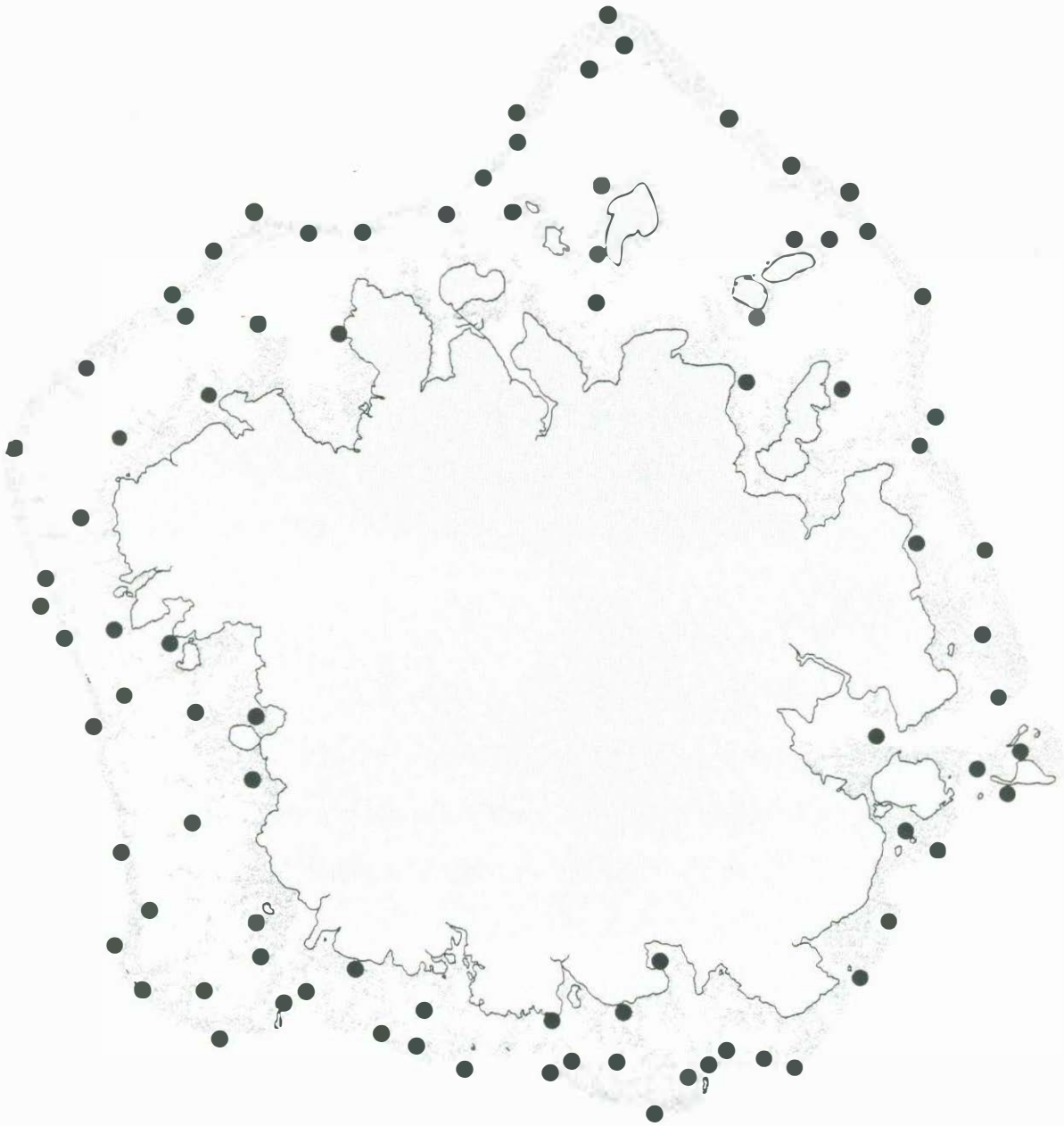


Table 1

Number of Survey Stations,
by Island Section and Reef Area

Island Section	Fringing Reef	Lagoon and Patch Reefs	Barrier Reef	Ocean Reef Slope	Total
I	5	5	12	4	22
II	3	5	-	4	12
III	4	6	5	7	22
IV	5	5	4	3	17
V	3	2	5	3	13
				Total Sites	86

living resources, as well as other features. The relative abundance of organisms was estimated on a 6 category scale (absent, rare, uncommon, common, abundant, dominant). Sketch profiles were drawn to note reef geomorphology, substrate type, and estimated live coral coverage. Additional notes were made by all team members on water quality, oceanography, marine vertebrates, outstanding features, and resource use. Sample checklists for fish, corals, other invertebrates and algae, and a representative sketch profile can be found in Appendix 2. Underwater photographs were also taken and some organisms which could not be identified in the field were collected for later identification. The amount of time spent at each survey station was determined by the complexity of the reef environment, water quality, sea conditions, weather, and safety considerations. The number of survey stations sampled in a day's field work varied from two to seven.

Resource User Interviews

Information on the traditional, subsistence, and artisanal use of Pohnpei's reef resources was gathered by the author during a series of group interviews with experienced reef resource users. Johannes (1978b, 1979, 1981a, 1982) has used methods of ethno-marine biology to obtain information on tropical coastal fisheries in Pohnpei and elsewhere in the Pacific and has described their use for purposes of resource management (Johannes, 1981b, 1981c). An abbreviated form of these methods was employed in Pohnpei whereby the chief magistrate of each of the five municipalities was asked to request people with extensive knowledge and experience regarding reef resources in their

area to attend the meetings. Announcements were distributed, with care taken to stress that the information desired was to be used in planning for the management and wise use of Pohnpei's reef resources. Eight meetings were organized. They were attended by two to fifteen men and women and lasted from two to four hours. Participants were asked, through the translation assistance of a DMR staff member (preferably from the same district), to indicate on a map the abundance and distribution of reef resources and uses in their area. Discussion topics included preferred and productive fishing grounds and methods, areas and means of shellfish and crustacean harvest, and important reef habitats (e.g. reef fish migratory paths and spawning sites, sea turtle nesting sites). Additional information was obtained on the location and cause of reef degradation, special reef features (e.g. areas associated with legends, unique organisms or structures), and reef resource management suggestions.

Information was also gathered on existing, planned, or proposed developments affecting coral reef resources. Interviews were conducted with Pohnpei State government officials from the Division of Marine Resources (DMR), Ministry of Conservation and Resources Surveillance, Economic Development Authority (EDA), Division of Forestry, Transportation Authority (PTA), Public Lands Authority (PLA), Public Works Commission (PWC), Planning Office, Historic Preservation Committee, Health and Sanitation Office, Tourist Commission, and Board of Education. Talks were also held with FSM officials from the Marine Resource Division, Environmental Protection Board (EPB), and Planning Office. Hotel and construction industry

personnel were interviewed, as well as environmental scientists at the Community College of Micronesia, the University of Guam, USFWS, NMFS, and USACE. Officers of the Great Barrier Reef Marine Park Authority (GBRMPA) provided information on incorporating resource user data into the management of reef resources.

Aerial Photograph Analysis

Field survey data on the physical and biological characteristics of Pohnpei's reefs were augmented through the interpretation of low altitude, color, aerial photographs of 1:12,000 scale flown in 1983. Hopley (1978) described applications of aerial photography to interpretation of coral reef features. Field information from known locations served as ground truth for subsequent mapping of reef environments and substrate types onto USGS topographic maps of 1:25,000 scale using the aerial photographs and a stereoscopic zoom transfer scope.

Resource Survey Report and Atlas Production

Information from field surveys, interviews, aerial photograph interpretation, and previous literature is combined in the Pohnpei Coastal Resource Inventory Report (USACE, 1985) and Pohnpei Coastal Resource Atlas (Manoa Mapworks, 1985). In the written report, the island is divided into five geographic sectors (see Fig. 2) within which descriptive information is compiled for the following physiographic units: nearshore terrestrial environment, mangrove forest, fringing reef, lagoon and patch reefs, and barrier reef. The

geomorphology, fish, corals, other invertebrates, algae, water quality, resource uses, and archeology are then described for each of these units. Atlas maps portray reef resources and their uses, employing symbols to represent each use and their locations. The position of reef survey stations are identified by numbered markers which correspond to station numbers referred to in the text. Reef substrate and shoreline characteristics are mapped using a key of various bottom types and depth. Vegetative cover (mangrove, segrass, certain algae) and some bathymetric data are also included. The atlas maps are presented in Appendix 1. As more information becomes available, it can be added to the atlas and report, which are intended to be working documents, not definitive environmental descriptions.

Management Proposal Development

The development of proposals for the management of Pohnpei's reef resources is the main purpose of this thesis. Management of reef resources implies the management of the uses of those resources within the areas where they take place. An overview of Pohnpei's coastal and reef environment and the distribution and abundance reef resources and their uses is provided in Chapter III. The characteristics, value, problems, and management associated with major existing or potential uses of Pohnpei's reef and lagoon resources are described in Chapter IV.

Management which will allow for the continuation of each use and resolve conflicts between reef resource uses become more apparent after documenting the uses of Pohnpei's reef resources. This provides

the basis for the formulation of management goals and objectives. Chapter IV reviews conceptual approaches to coastal resource management and previous or current programs for tropical coastal and coral reef resource management. Chapter V presents strategies which are appropriate for achieving management goals and objectives on Pohnpei. Plans for the management of Pohnpei's reef resources, incorporating preferred strategies and including specific recommendations, are proposed in Chapter VI.

Presentation, Revision and Implementation

A working draft of plans which describe and map strategies for the conservation and management of Pohnpei's reef resources will subsequently be presented and discussed in workshops with Pohnpei's resource management agencies, legislators, fishermen, educators, and other interested parties. Feedback from these sessions will be used to refine management strategies and revise planning proposals. Adoption, implementation, acceptance, and enforcement of a reef management plan requires an informed public, adequately trained and supported government agencies, and the willingness of all parties to cooperate. A program of education on resource conservation aimed both at the general population and specific users, as well as training for reef managers, are critical to successful management of reef resources.

CHAPTER III

SUMMARY OF COASTAL RESOURCE SURVEY AND USER INTERVIEWS

Selected and relevant information from the survey of the physical and biological characteristics of Pohnpei's reef resources are included in this chapter. Complete survey results are contained in the Pohnpei Coral Reef Inventory Report (USACE, 1985). Maps portraying the distribution of reef resources and their uses, compiled by the author in preparing the Pohnpei Coastal Resource Atlas (Manoa Mapworks, 1985), are found in Appendix 1.

Description of Pohnpei's Coastal Resources

Pohnpei's inner reef flat is occupied by a dense belt of mangrove forest which extends up to 2 km from shore. The forest is composed primarily of the mangrove trees Rhizophora and Bruquiera, with scattered Xylocarpus. The latter is preferred for the production of local lumber. The forest provides habitat for the prized mangrove crab (Scylla serrata). The undisturbed mangrove forest stabilizes the shoreline, traps terrestrial sediment, provides a nursery for juvenile reef fish, and supplies nutrient and energy subsidies to lagoon ecosystems. The mangrove forest is under the jurisdiction of the municipal government, which sells permits for the cutting of trees. Small channels have been cut through the mangrove fringe in many places around the island to allow boat access between the shoreline and lagoon. Near population centers, mangrove is cleared along its shoreward edge to provide space for landfill on the reef flat, which

is regulated by EPB and USACE permit procedures. The large mangrove islet (Taketik) near Kolonia has been filled and developed to create Pohnpei's airstrip, commercial port and municipal dump.

The fringing reef platform around Pohnpei consists of a silt and sand covered flat with little coral. It ranges from a narrow strip to wide, expanses punctuated with reef holes. Irregular extensions of the fringing reef reach out into the lagoon. Terrestrial freshwater runoff and silt have progressively more influence closer to shore on the substrate and biota of the fringing reef. Dense seagrass beds cover portions of the reef flat and Halimeda algae is locally abundant. The reef margin consists of a zone of solid reef rock and microatolls with abundant soft coral. The upper reef slope supports very high coral cover dominated by Porites.

The fringing reef flat constitutes a pathway for important fish species, such as mullet and rabbit fish, during their seasonal migration to aggregation sites for spawning. Seagrass beds, reef holes and depressed portions of the reef flat are generally very productive fishing areas. Sea cucumbers and clams (Anadara) are harvested from other parts of the reef flat. With the relatively recent introduction of heavy construction equipment, the fringing reef flat has become an attractive and accessible source of cheap fill material. Dragline dredges are used to obtain the material and the process normally involves the construction of dikes or causeways on the reef flat and inclusion of various types of pollution control. Many causeways, for dredging site access and road transportation, now extend out onto the reef flat, including the long one linking Kolonia

to the airstrip and commercial port at Taketik. Around Kolonia, the reef flat is encroached upon by residential landfills, commercial waterfront development and waste disposal facilities. Pohnpei's major visitor attraction, the prehistoric basalt islet structures of Nan Madol, is situated on the fringing reef flat near Madolenihmw Harbor on the east side of the island.

Lagoon patch reefs and the lagoonward extensions of fringing reefs vary considerably in dimension. The interior of the reef flats here are dominated by sand, rubble and some seagrass, with very little live coral, and are surrounded by a margin of reef rock and microatolls. Reefs surrounding the basaltic lagoon islands exhibit characteristics of both the main island's fringing reef and lagoon patch reefs. Lagoon reef slopes support greater coral diversity and abundance than fringing reefs. Coral development and water quality improve with increasing distance from shore.

Most lagoon patch reefs are heavily used for reef fisheries, and some reefs are the location of fish spawning aggregations. Sea cucumbers and clams are harvested from larger reef flats, and octopus are abundant around certain reefs. Some areas of the adjacent open lagoon bottom are fished for snapper. The lagoon is the main transportation corridor around the island, and safe boat passages through the maze of reefs are identified with numerous reef markers.

The lagoon side of the barrier reef supports ribbon reefs, secondary lagoons, abundant fish, and a depositional slope of sand. The barrier reef platform varies from a few hundred meters wide to over a kilometer across. Low microatolls and prostrate coral patches

are scattered across the sand and rubble reef flat, which becomes a solid pavement at the reef's wide crest. A number of depositional sand and rubble islets have formed on the barrier reef platform. Beyond the reef crest, the reef platform dips gradually into the spur-and-groove zone. At depths of 3 to 15 m, a gradually sloping reef terrace occurs, with high coral abundance and diversity dominated by corymbose Acropora corals. On leeward reefs the terrace ends abruptly with a steep reef wall. On windward reefs the outer edge of the terrace is less distinct and grades into a gradually descending slope. The deep passes which bisect the barrier are flanked by steep, scoured reef walls with little coral cover.

The lagoon side of the barrier reef is heavily fished. Rabbitfish, grouper and parrotfish seasonally aggregate to spawn in a number of reef holes. Sand from lagoon slopes is dredged for government and private construction purposes. Sea turtle nests and coconut crabs occur on the barrier reef islets, a few of which have been developed as destinations for overnight visitors. On the west side barrier reef, small mangrove islets provide an important seabird habitat. Topshell (Trochus), giant clam (Tridacna spp., Hippopus spp.), and lobster (Panulirus sp.) are harvested on the seaward margin of the barrier reef flat. Seven Trochus reserves have been established on portions of the barrier reef where the taking of the topshell is prohibited. The entire northernmost reef section (Nankapenparam) has been identified as an important natural landmark (Abbott, et al., 1982). The outer barrier reef is visited by a few

dive tours which operate on Pohnpei, and the deep ocean reef slope is fished for snapper and grouper. Yellow-fin tuna is caught by handline in the deep water beyond the reef.

CHAPTER IV

REEF RESOURCES: EXISITNG AND POTENTIAL USES

In developing plans for the management of Pohnpei's reef resources, it was necessary to document both the existing and potential "uses" of these resources (Table 2). Reef resource "uses", as described here, include activities, functions, and demands for resources which occur, or may occur, at particular locations in the reef and lagoon system surrounding Pohnpei. The broad distribution of reef resource uses was described in the summary of the inventory of reef resources and user interviews (Chapter III) and their specific distribution has been mapped (see Appendix 1). A more detailed characterization of each reef resource use is presented in this chapter, including a description of the nature and value of each resource; information on problems which are currently or potentially experienced with each reef resource; and a review of existing or previously proposed management measures for the resources and their uses.

Habitat Uses of Special Significance

The coral reefs of Pohnpei are made up of a numerous habitats which are inhabited by a wide variety of organisms. When they remain relatively undisturbed, these habitats have inherent value as locations where reef processes may proceed undisrupted. The habitats of reef fish and sea turtles are particularly suceptible to disturbance by human activities.

Table 2

Existing and Potential Reef Uses

A) Habitat Uses and Functions of Special Significance
1. Reef habitat preservation
2. Fish spawning aggregation
3. Reef fish migration
4. Sea turtle nesting
5. Sea turtle feeding
6. Sea bird nesting
7. *Acanthaster* outbreaks

B) Renewable Resource Harvesting: Traditional and Commercial
1. Shallow reef fish
2. Bottom fish
3. Deep-water handline fish
4. Baitfish
5. Aquarium fish
6. Lobster
7. Mangrove crab
8. Octopus
9. *Trochus*
10. *Anadara* clam
11. Giant clam
12. *Kopil* clam
13. Ornamental shell
14. Sea cucumber
15. Precious coral
16. Mangrove wood

C) Cultural and Recreational
1. Archeological sites
2. Visitor recreation
3. Resident recreation
4. Sport diving
5. Sport fishing

D) Construction and Reef Materials Extraction
1. Reef flat dredging
2. Sand mining
3. Channel dredging
4. Manual sand removal
5. Coral removal
6. Causeway construction
7. Landfill construction
8. Commercial waterfront development and shoreline protection
9. Aquaculture development
10. Navigation aids installation

Table 2 (Continued)

Existing and Potential Reef Resource Uses

E) Lagoon Water Pollution
1. Solid waste disposal
2. Sewage waste disposal: local, treated
3. Land clearing
4. Road construction
5. Pesticide use
6. Oil products storage and transfer
7. Power plant operation

Table 3

Distrbution and Abundance of Reef Resource Use Sites
by Island Section (from Appendix 1)

Reef Resource Use	Island Section (see Fig. 2) I	II	III	IV	V	Total
Reef Fish spawning aggregation	-	4	12	5	2	31
Sea turtle nesting	-	3	5	-	-	8
Sea turtle feeding	-	1	6	-	-	7
Sea bird nesting	-	1	-	6	-	7
Archeological sites	7	9	-	1	1	18
Visitor recreation	-	2	-	-	-	2
Resident recreation	1	-	-	-	1	2
Sport diving	3	-	-	1	-	4
Shallow reef fishing	8	16	18	18	5	65
Bottom fishing	10	2	7	15	8	42
Deep-water handline fishing	5	3	6	2	2	18
Baitfish harvesting	3	-	-	-	-	3
Lobster harvesting	4	4	5	4	-	17
Mangrove crab harvesting	3	7	9	8	4	31
Octopus harvesting	8	-	2	-	-	10
Trochus harvesting	2	4	8	-	-	14
Trochus sanctuaries	2	1	2	1	1	7
Anadara clam harvesting	6	3	2	5	3	19
Giant clam harvesting	9	5	5	4	4	27
Kopil clam harvesting	-	1	2	3	1	7
Sea cucumber harvesting	4	1	1	4	3	13
Mangrove harvesting	-	1	1	-	-	2
Reef flat dredging	7	4	1	3	6	21
Sand mining	4	-	-	-	-	4
Channel dredging	2	3	3	1	many	+9
Manual sand removal	2	-	2	-	-	4
Causeway construction	7	5	-	3	many	+15
Mariculture development	1	1	1	-	-	3
Navigation aids installation (DMR reef markers)	32	24	61	24	19	160

1. Reef Habitat Preservation

Undisturbed unique, valuable, or representative portions of Pohnpei's reef system should be set aside and protected to allow reef processes to take place without the disturbance of human activities. The preserves would serve as refuges for fish and other organisms otherwise subject to heavy harvesting pressure and to allow natural reef conditions to be studied for scientific and educational purposes.

It is difficult to determine the size and location of areas that should be designated as preserves. The removal of reef areas from subsistence use is a potentially unpopular form of management and the enforcement of preserve status on widespread reef areas formerly available for open use presents difficulties. Adequate public support and government enforcement is necessary to establish and protect such areas. The establishment of marine conservation areas to guarantee perpetual replenishment of harvestable marine resources is a main objective of DMR (Pohnpei State, 1985a).

2. Reef Fish Spawning Aggregation

Certain species of reef fish aggregate each year to spawn at specific locations, particularly lagoon patch reefs and reef holes in the barrier reef (Fig. 4). Aggregations occur among grouper, snapper, parrotfish, and rabbitfish and generally take place two weeks before or after new moon between March and May. Some locations are also known as sites for the seasonal aggregation of other kinds of fish,

such as jacks, but it is not clear whether this is part of spawning behaviour.

The aggregations are apparently important in the reproductive behavior and success of these reef fish (Johannes, 1978c). Fishermen know the sites and times where particular fish with value as food can be more easily captured during spawning aggregations. If there is no control on the amount of catch during spawning aggregations, or if the sites are physically altered or degraded, this would then disrupt the reproductive cycle and reduce the abundance and reproductive potential of residual fish populations. Already on Pohnpei, the inadvertant construction of causeways, dredging, and filling at a number of fish aggregation sites has destroyed their use for this function.

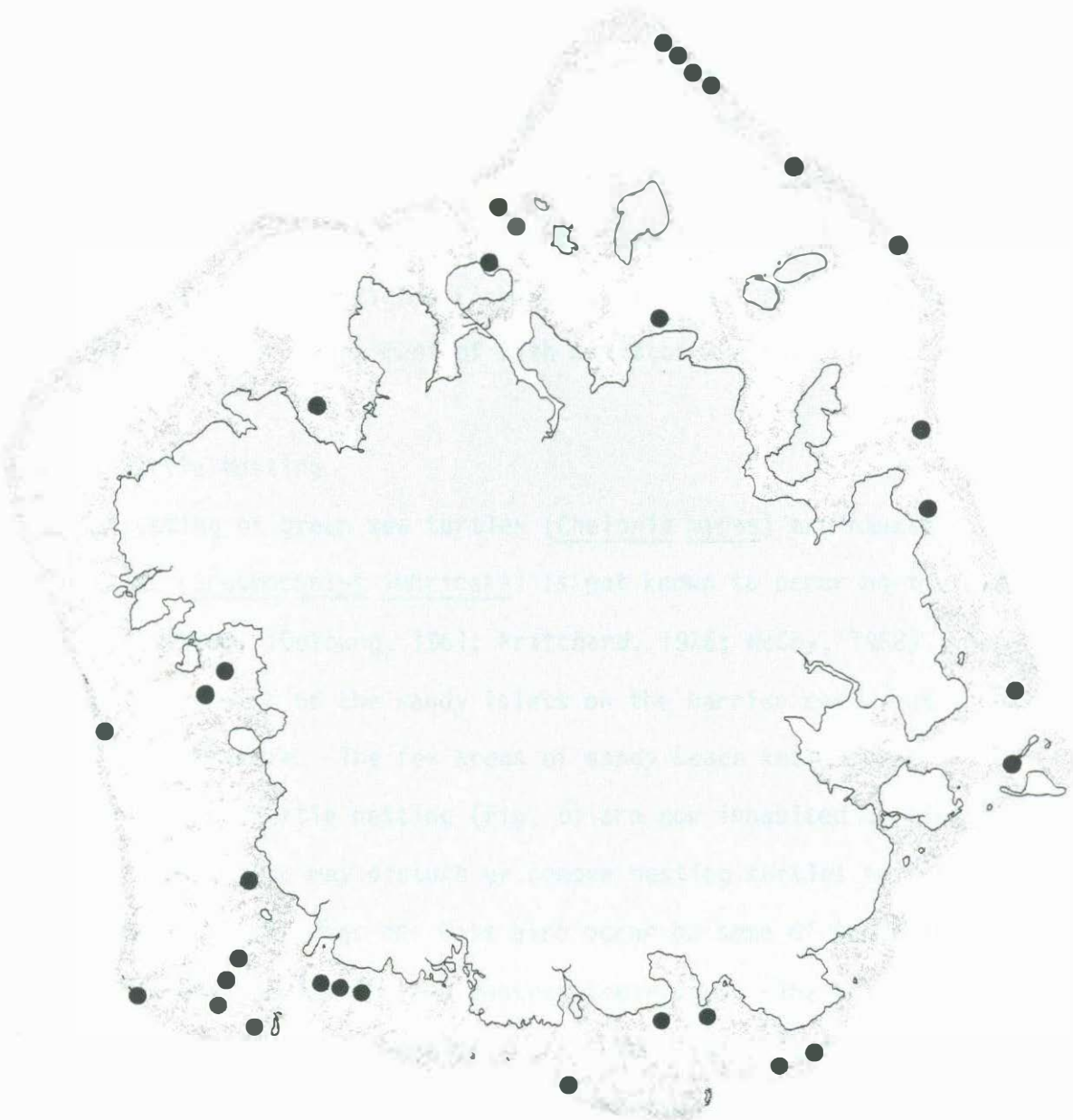
Johannes (1978b) recommended studies be carried out on spawning aggregations of grouper on the reefs of Pohnpei. Subsequently, the taking of grouper by any means for sale during the months of March and April was prohibited under Title V of the Pohnpei State Marine Resource Conservation Act of 1981. It was further recommended by Johannes (1978b) that the sale of rabbitfish during spawning season be banned to avoid the possibility of over-fishing, but this has not been enacted.

3. Reef Fish Migration

Some groups of reef fish have regular patterns and pathways of travel across portions of the reef and lagoon (Fig. 5). These paths are apparently linked to essential activities such as seasonal

Figure 4

Reef Fish Spawning Aggregation Sites



migration to spawning aggregation sites or movement along the fringing reef flat to feeding areas. In a particular area, the direction of fish passage may be one way, seasonally reversed, or occur in both directions over short time periods. The timing and site of the pathways are known by fishermen and exploited to harvest the migrating fish.

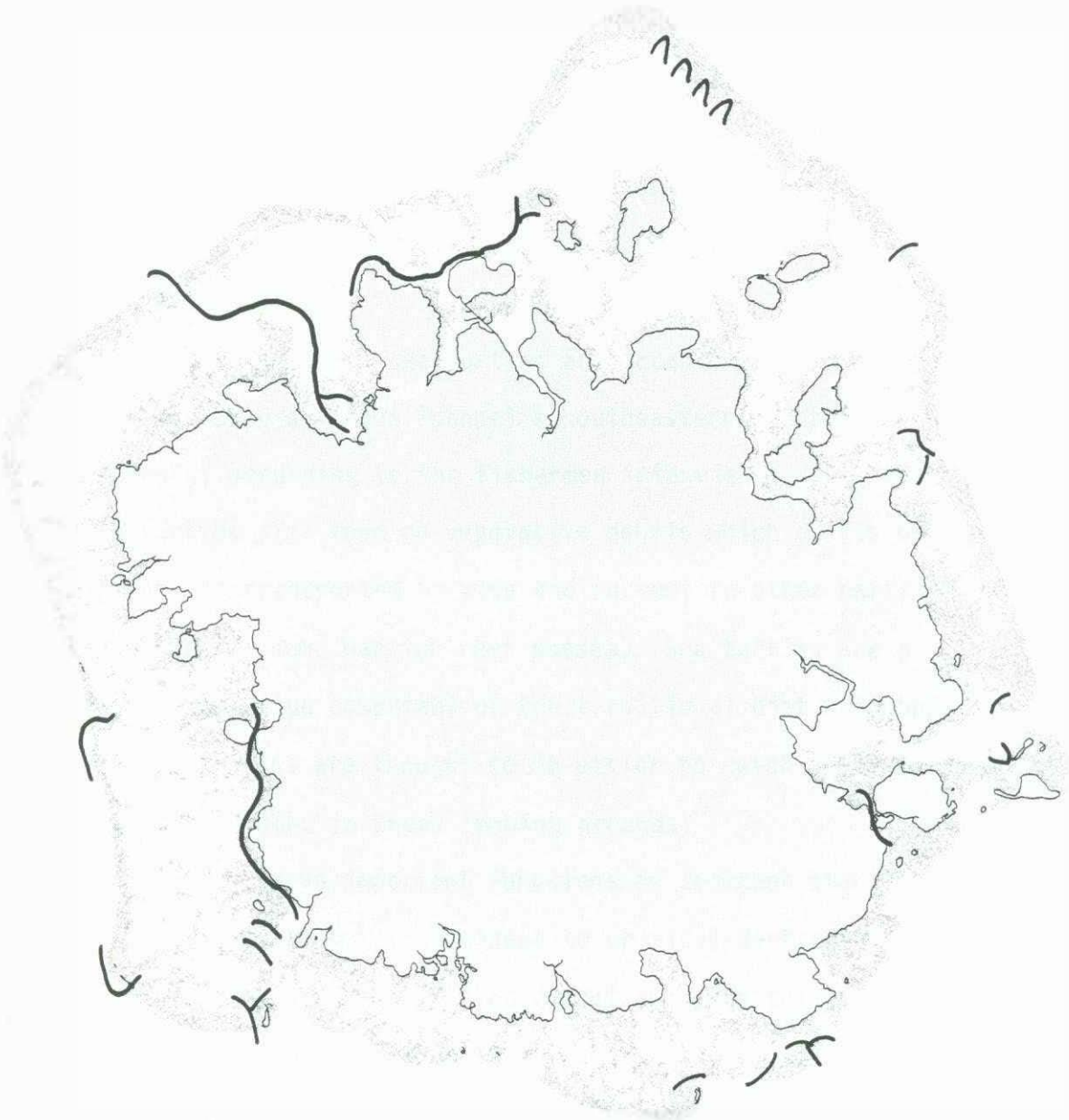
These pathways are easily disturbed by the construction of barriers, such as causeways across the reef flat, dredging, and sand mining. Species which migrate along heavily fished pathways may be over-harvested if unrestricted fishing is allowed. At present, there is no protection or management of fish migratory pathways.

4. Sea Turtle Nesting

The nesting of green sea turtles (Chelonia mydas) and hawksbill sea turtles (Eretmochelys imbricata) is not known to occur on the main island of Pohnpei (DeYoung, 1961; Pritchard, 1976; McCoy, 1982). They once nested on some of the sandy islets on the barrier reef, but rarely do so anymore. The few areas of sandy beach known to be suitable for sea turtle nesting (Fig. 6) are now inhabited or visited often by humans, who may disturb or remove nesting turtles or their eggs. Feral and pet dogs and cats also occur on some of these islets and may disturb the turtles and destroy their eggs. The physical destruction of nesting beaches may result from the extraction of sand, construction of shoreline structures, or through natural processes. Undisturbed nesting areas are necessary for the successful reproduction of rare sea turtles at Pohnpei. Sea turtle is a

Figure 5

Reef Fish Migration Paths



traditional food held in high esteem by the people of Pohnpei and turtles are taken when found.

The green sea turtle is listed as threatened and the hawksbill sea turtle is endangered under the U.S. Endangered Species Act of 1973 which prohibits many activities which may disturb them. In the FSM, however, Micronesians are allowed to harvest green sea turtles for subsistence use, within certain guidelines. Hawksbill turtles are not allowed to be harvested under any circumstances.

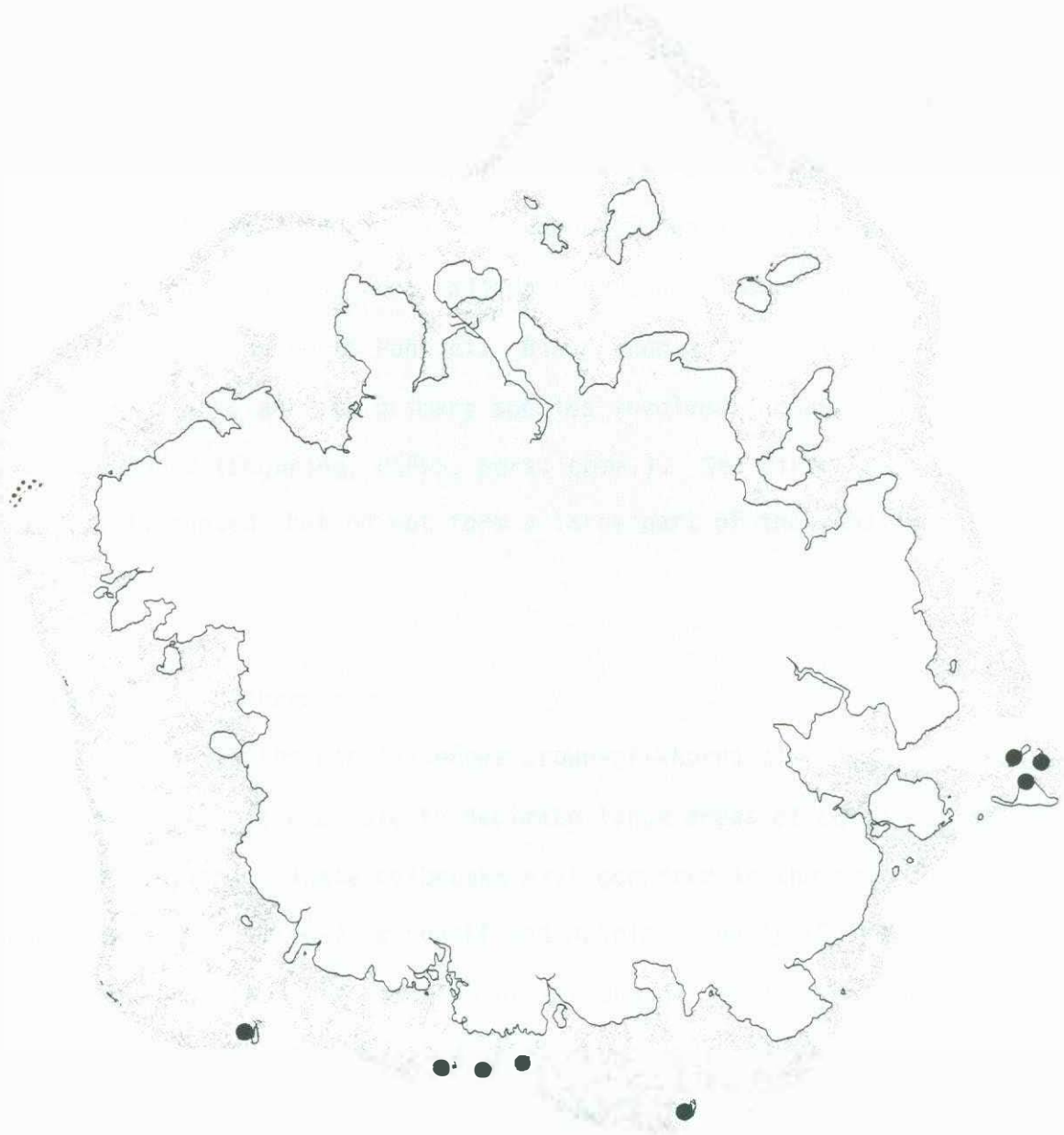
5. Sea Turtle Feeding

Green (Chelonia mydas) sea turtles are occasionally found while feeding on the seagrass beds Pohnpei's southeastern and southern fringing reefs, according to the fishermen interviewed (Fig. 7). Green sea turtles also feed on vegetative debris which drifts off the reef flat and is transported by tide and current to other parts of the lagoon and outside some barrier reef passes. Sea turtles are a favored and high value component of the traditional diet on Pohnpei. The green sea turtles are thought to be easier to catch while feeding and are usually sought in known feeding grounds.

Seagrass beds serve important functions as sediment stabilizers and reef fish habitat, but are subject to physical destruction and degradation as a result of reef flat dredging, terrestrial siltation, causeway construction, and other disturbances. The feeding activities of the turtles may be disrupted by human activities such as reef fishing and noise from outboard motors. As mentioned, green and

Figure 6

Sea Turtle Nesting Sites



hawksbill sea turtles, and their critical habitat, are protected by the Endangered Species Act.

6. Sea Bird Nesting

A large number of seabirds nest in the mangrove trees found on a group of small reef block and rubble islets (Dawahk or Peinantomaea Islands) on the barrier reef off the western coast of Pohnpei (Fig. 8). The Ministry of Conservation and Resource Surveillance has proposed they be declared a wildlife refuge. Seabirds also use the reef rubble islets of Nan Pwil, adjacent to Lohd Harbor, and the Kepara islets of southwest Pohnpei. Black noddys, white terns, and black-napped terns are the primary species involved and are thought to nest year-round (Engbring, USFWS, pers. comm.). Sea birds are occasionally hunted, but do not form a large part of the subsistence diet.

7. Acanthaster Outbreaks

Populations of the coralliverous crown-of-thorns starfish (Acanthaster planci) are able to decimate large areas of coral during large infestations. These outbreaks have occurred in the past on Pohnpei and may be linked to runoff and nutrient supply (Birkeland, 1982). However, this has not been proven and at least some population outbreaks of Acanthaster may be as a result of natural processes and are thus a part of the normal cycle of events on coral reefs. There have not been serious outbreaks of the starfish on Pohnpei since the early 1970's.

Figure 7

Sea Turtle Feeding Areas

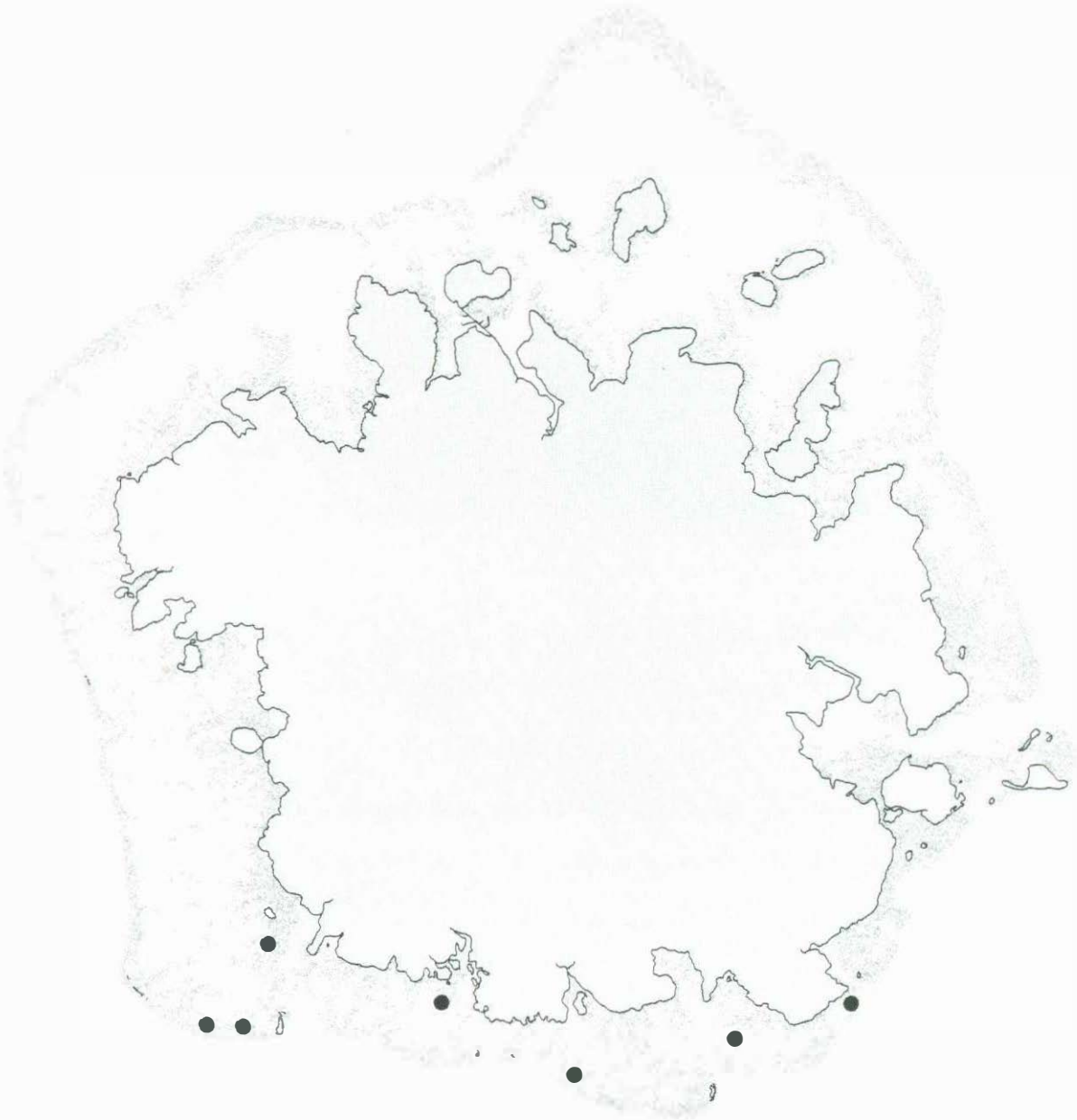
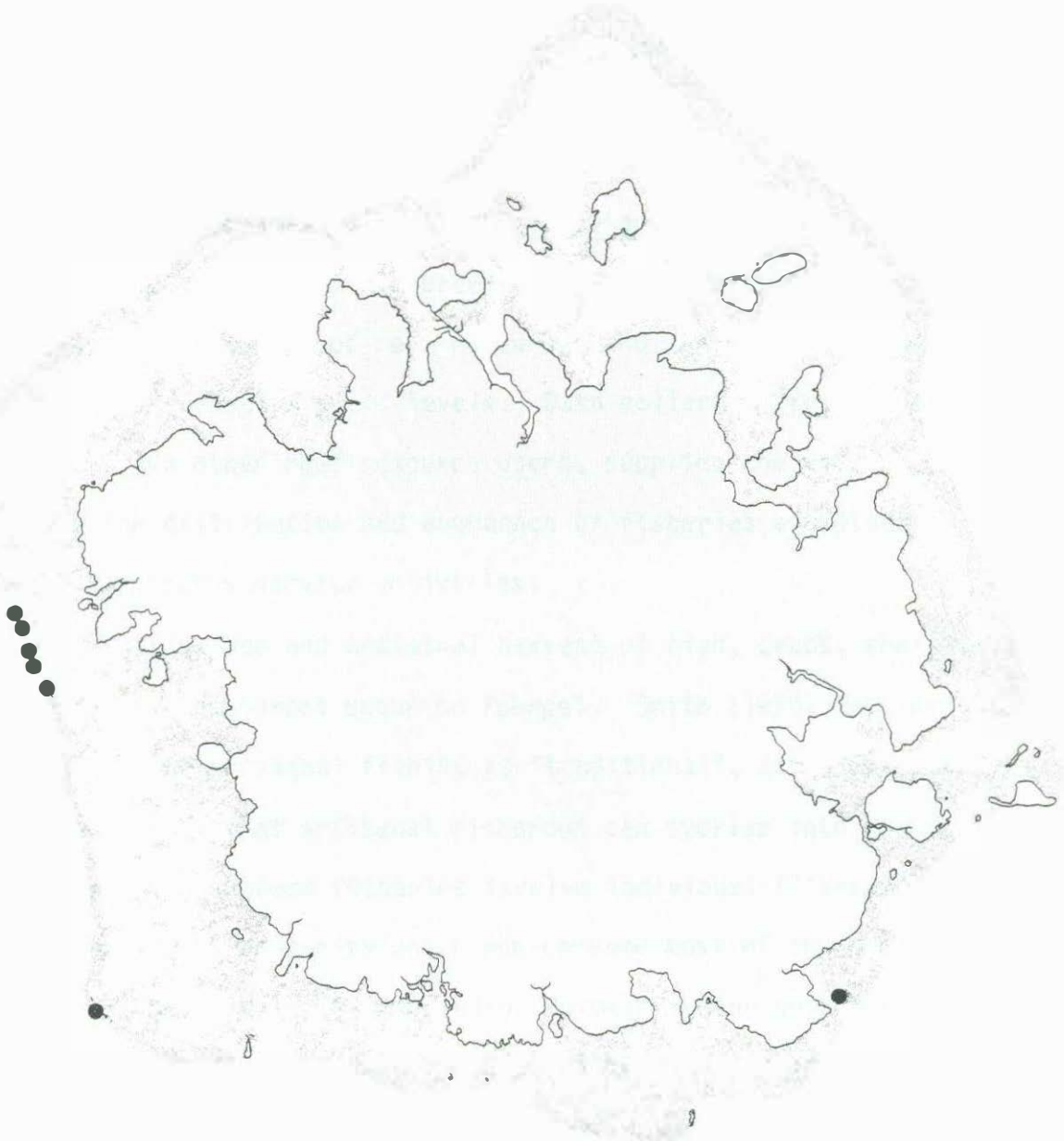


Figure 8

Sea Bird Nesting Areas



In the extreme situation, Acanthaster outbreaks leave much of the coral community lifeless and can result in a gradual decline in fish habitat quality and quantity in the affected area, at least until recovery is completed. The dead coral is susceptible to breakage by wave and storm activity. The DMR maintains an informal monitoring of the Acanthaster situation, and reports of major populations are investigated.

Renewable Resource Harvesting: Traditional and Commercial

Harvest of biological resources from Pohnpei's reef ecosystem is the most widespread use of reef resources and can potentially be managed at sustainable yield levels. Data collected from fishermen, DMR staff, and other reef resource users, supplied the facts to describe the distribution and abundance of fisheries and other renewable resource harvest activities.

Both subsistence and artisanal harvest of fish, crabs, shellfish, and other reef resources occur on Pohnpei. Smith (1979) considers subsistence and artisanal fishing as "traditional", and difficult to separate, except that artisanal fishermen can overlap into commercial fisheries. Subsistence fisheries involve individual fishermen and their families or community group who consume most of their catch directly. They fish part-time, with minimal fishing gear and handmade boats, and have invested small amounts of capital (Smith, 1979). Artisanal fishing is by small, part-time fishing groups which use more manufactured fishing gear than subsistence fishermen and usually have outboard motors. Artisanal fishermen sell some of their catch through

loosely organized sales, but consume most of it themselves, or disperse it within their community group (Smith, 1979). Traditional (subsistence and artisanal) fisheries account for most of the sustainable yield use of Pohnpei's reef biota. Commercial harvest of fish, crabs, and shellfish is beginning to take place to a greater extent on Pohnpei to satisfy growing urban, hotel, restaurant, and tourist industry demands. Industrial level harvest of these resources, for processing and export, has not yet proven feasible or viable on Pohnpei. Although traditional and commercial uses of renewable resources often involve harvest of the same resources from the same areas, it is important to consider them as different forms of sustained yield use of reef resources (Table 2).

1. Shallow Reef Fish

The harvest of fish from the coral reefs around Pohnpei is probably the singlemost important reef use. Bascom (1965) provides a summary of fish commonly caught by traditional fishing and the habitats in which they normally occur. More recent information on the distribution and abundance of common reef fish is found in the Pohnpei Coastal Resource Survey Report (USACE, 1985). Virtually all of Pohnpei's fringing reef, patch reefs and barrier reef are consistently, occasionally, or potentially used for subsistence and artisanal reef fishing, although certain areas were identified as being especially productive or heavily fished (Fig. 9). Different forms of fishing are employed according to the time of day, tide, or season, type of reef habitat, species of target fish, and the number

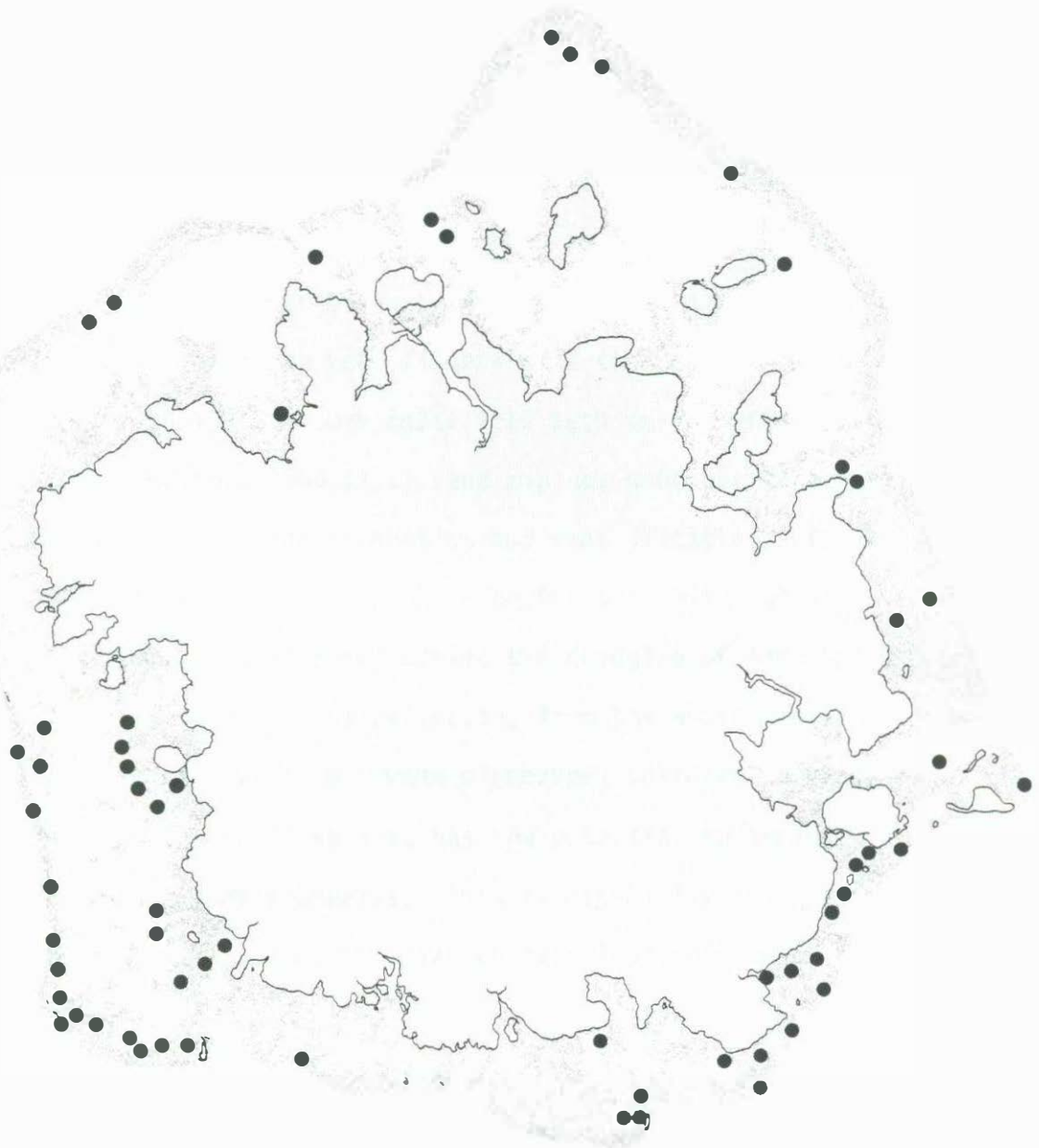
of fishermen involved. A variety of gear and methods, most of which are described by Bascom, are used (1965). Fortunately, there is no evidence of extensive dynamite fishing or the use of poisons for reef fishing on Pohnpei.

Fish, through subsistence, artisanal, and commercial use, provide a critical portion of the diet for much of Pohnpei's population. The number of fishermen continues to increase along with the population, though per capita fresh fish consumption is declining in most households (Dahlquist, 1972). Reef fishing and the resulting catch still play an important role in cultural activities which, in turn, influence the patterns of reef fishing, such as the short periods of heavy fishing which preceed feasts.

Fishing gear and technology are currently a mix of traditional and modern, but the introduction of new equipment and methods is increasing as a part of socio-economic changes. In particular, the government subsidy of new boat purchase for small-scale commercial reef fisheries provides the means to obtain cash income. It is estimated that there are 150 to 200 fulltime and 150 to 200 part-time fishermen on Pohnpei, providing an average of about 320 kg/day of reef fish for sale and a comparable amount for subsistence or artisanal use (Pohnpei State, 1985a). A fishermen's co-operative, established to provide a means of organized marketing of catch, failed but there are efforts being made to revive it.

Figure 9

Shallow Reef Fishing Areas



Potential for over-fishing of some species is growing as the general population expands, the number of fishermen increases, and introduced equipment (e.g. fiberglass boats, outboard motors, nylon gill nets, SCUBA gear, underwater flashlights) becomes available. Preferred species, such as the Bumphead Parrotfish, are subject to excessive fishing pressure, whereas less perferred species may be able to support a greater harvest. Destructive fishing practices common elsewhere in the Pacific, such as dynamite fishing and the use of poisons, could become a problem in Pohnpei as pressures on reef fisheries increase and catch sucess from conventional methods declines.

A continuing threat to reef fisheries is the disruption or destruction of habitat through activities such as reef flat dredging, causeway construction, landfills, sand mining, mangrove clearing, and land clearing, which leads to erosion and reef siltation. Ciguatera poisoning is apparently not a problem on Pohnpei, although its incidence is said to have risen during the dredging of material for airstrip construction. Water pollution, from the above physical disturbances as well as from sewage discharge, solid waste disposal, pesticide runoff, and oil spills, has the potential to seriously degrade Pohnpei's reef fisheries. This is especially true in the heavily fished areas around Kolonia, where pollution sources are also concentrated.

Johannes (1978b) outlined a number of recommendations for improving Pohnpei's reef and lagoon fishery. Some have been adopted, particularly those to protect reef fish when they aggregate for spawning. Other recommendations include a ban on the sale of speared

fish and on the import of gill nets with a stretched mesh size of less than 2.5 inches (6.3 cm). Existing FSM legislation outlaws destructive fishing practices such as dynamite fishing and fish poisoning. The conservation of reef and lagoon fisheries is a primary goal of the DMR and certain species of reef fish are promoted for commercial harvest, and others are considered of particular conservation importance for subsistence fisheries (Pohnpei State, 1985a).

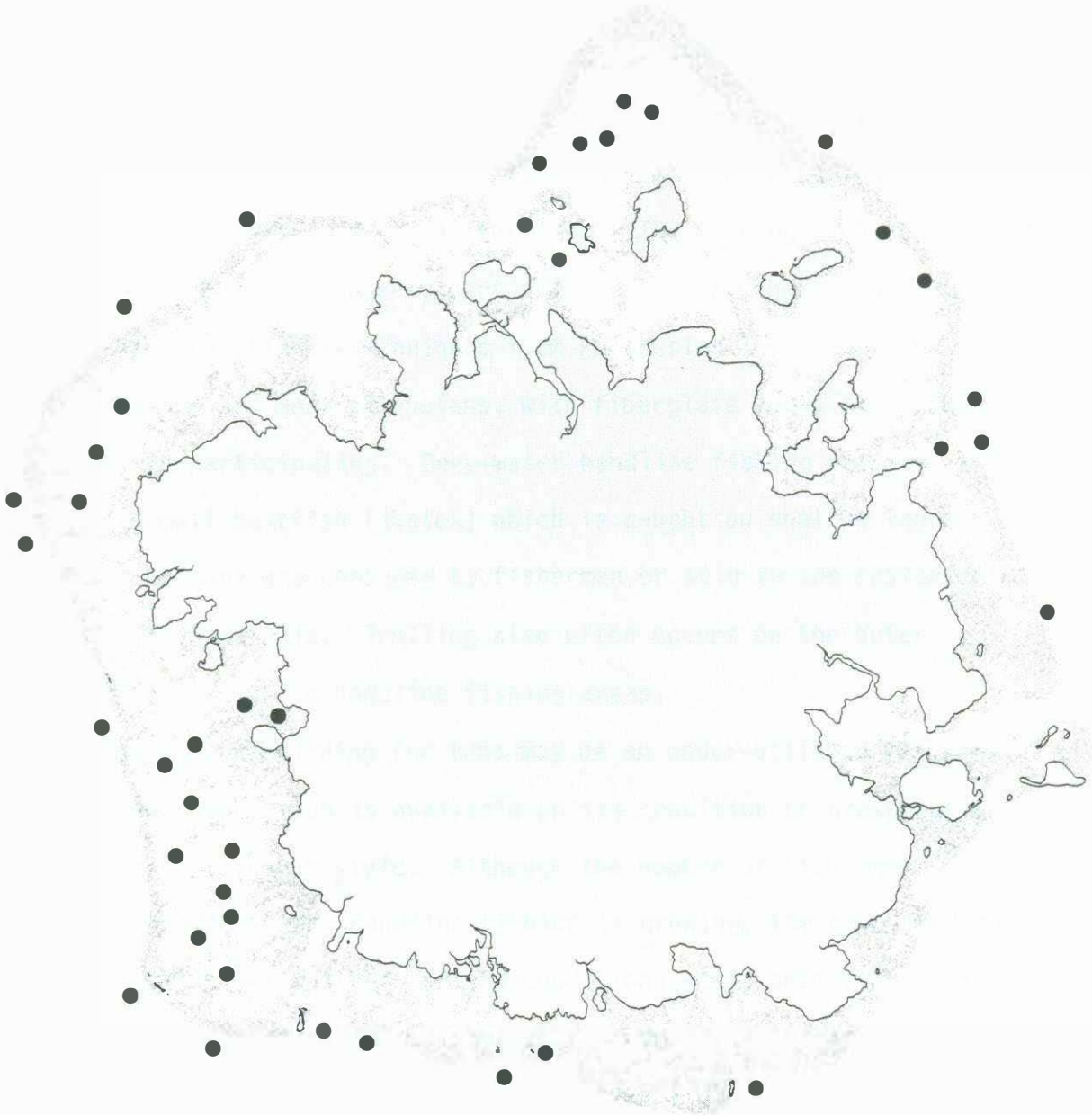
2. Bottom Fish

Bottom fishing is practiced in certain lagoon areas and on the barrier reef, just outside, and to either side, of many reef passes (Fig. 10). Snapper (Lutjanidae) and jacks (Carangidae) are the primary target fish and are fished at depths of 150 to 300m on ocean reef slopes. Although this fishery is underutilized, the number of fishermen involved is apparently growing. Bottom fishing provides an important part of Pohnpei's fish yield by harvesting larger, less sought after, fish than shallow-water reef fishing. Much of the bottom fishing catch goes to the urban population in Kolonia. Snapper and jack stocks are probably under-exploited and can provide more of Pohnpei's food.

At present, there does not appear to be any particular problems associated with this fishery, but little information is available. It has been recommended that use of bottom fish resources be expanded to supplement existing reef fisheries (Johannes, 1978b; Pohnpei State, 1985a).

Figure 10

Bottom Fishing Areas



3. Deep-water Handline Fish

Pelagic fish (not directly associated with the reef) are caught by handline beyond the barrier reef. Yellow-fin tuna (Thunnus albacares) is the primary target species, but other fish are caught as well. The total catch averages over 300 kg/day (Pohnpei State, 1985a). This fishing generally takes place in open ocean waters adjacent to leeward barrier reef passes and where the barrier reef configuration provides protection from wave and swell (Fig. 11). The fishing is done mainly by immigrant outer islanders, particularly from Kapingamarangi, using canoes and traditional techniques from Polynesian low islands. However, more and more Pohnpeians, with fiberglass boats and outboard motors, are participating. Deep-water handline fishing requires the use of a small baitfish (Ikatek) which is caught on shallow lagoon reefs. The tuna are consumed by fishermen or sold to the restaurants and market in Kolonia. Trolling also often occurs on the outer barrier reef slope in handline fishing areas.

Deep-water handlining for tuna may be an under-utilized fishery, but little information is available on its condition or prospects for long-term sustainable yield. Although the number of fishermen involved in deep-water handline fishing is growing, the gear used and the variability of weather and sea conditions would seem to prevent serious over-exploitation. It has been proposed that deep-water handline fishing should be expanded (Pohnpei State, 1985a).

4. Baitfish

The baitfish called Ikatek on Pohnpei is caught on the lagoon fringing and patch reefs (Fig. 11), often using a throw net. As noted above, the fish is used for bait in deepwater handline fishing. Surveys have shown that the baitfish are too few and too short lived to support a baitfish industry in Pohnpei. However, baitfish are essential to deep-water handline fishing and have some local value in pelagic fisheries around Pohnpei. The Ikatek baitfish are as vulnerable to overfishing, degradation of habitat, and pollution problems as other reef fish. State law only allows the harvest of baitfish from Pohnpei's waters by businesses owned or controlled by citizens. All vessels licensed to harvest baitfish are required to provide catch statistics to DMR each month. The DMR proposes that other baitfish (such as anchovy, herring, spats, hardy heads or fusilers) be promoted for commercial harvest (Pohnpei State, 1985a).

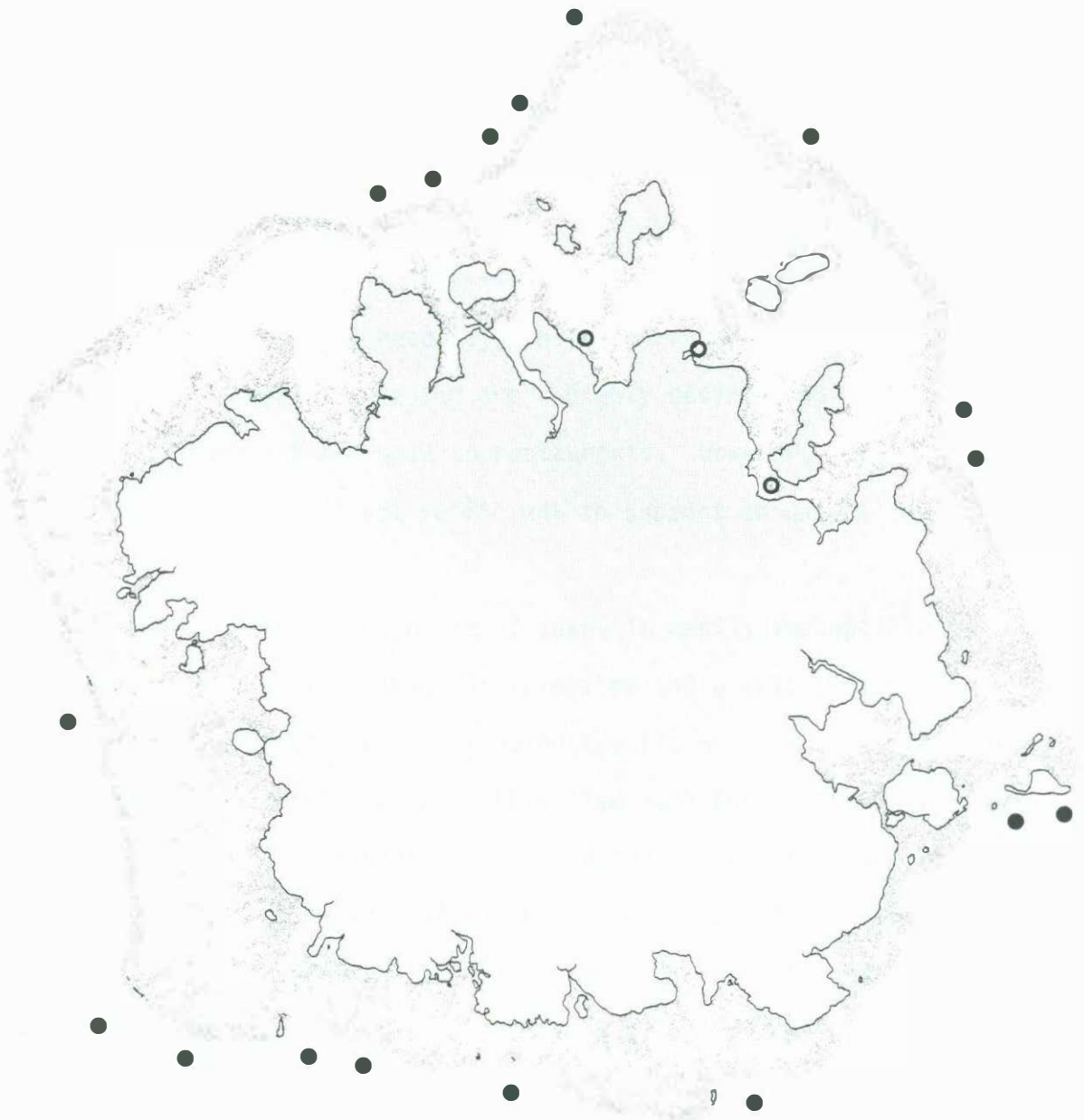
5. Aquarium Fish

Small rare and colorful reef fish are collected for aquarium fish enthusiasts. The export of aquarium fish from Pohnpei was attempted in the recent past, but was unsuccessful due to the lack of regular and reliable air transportation. There may be renewed attempts at developing this export industry in the near future.

There is potential for over-fishing of highly desired species unless the fishery is managed. Coral is destroyed to capture aquarium fish in other parts of the world, and the same practices might be used in Pohnpei. The removal of key species with particularly important

Figure 11

Deep-water Handline Fishing Areas ●
and Baitfish Harvesting Areas ○



ecological functions, such as the cleaner wrasse, may compound adverse effects. For example, Johannes (1978b) recommended that export of the cleaner wrasse (Labroides dimidatus) be banned. However, there is no existing management of the aquarium fish trade on Pohnpei.

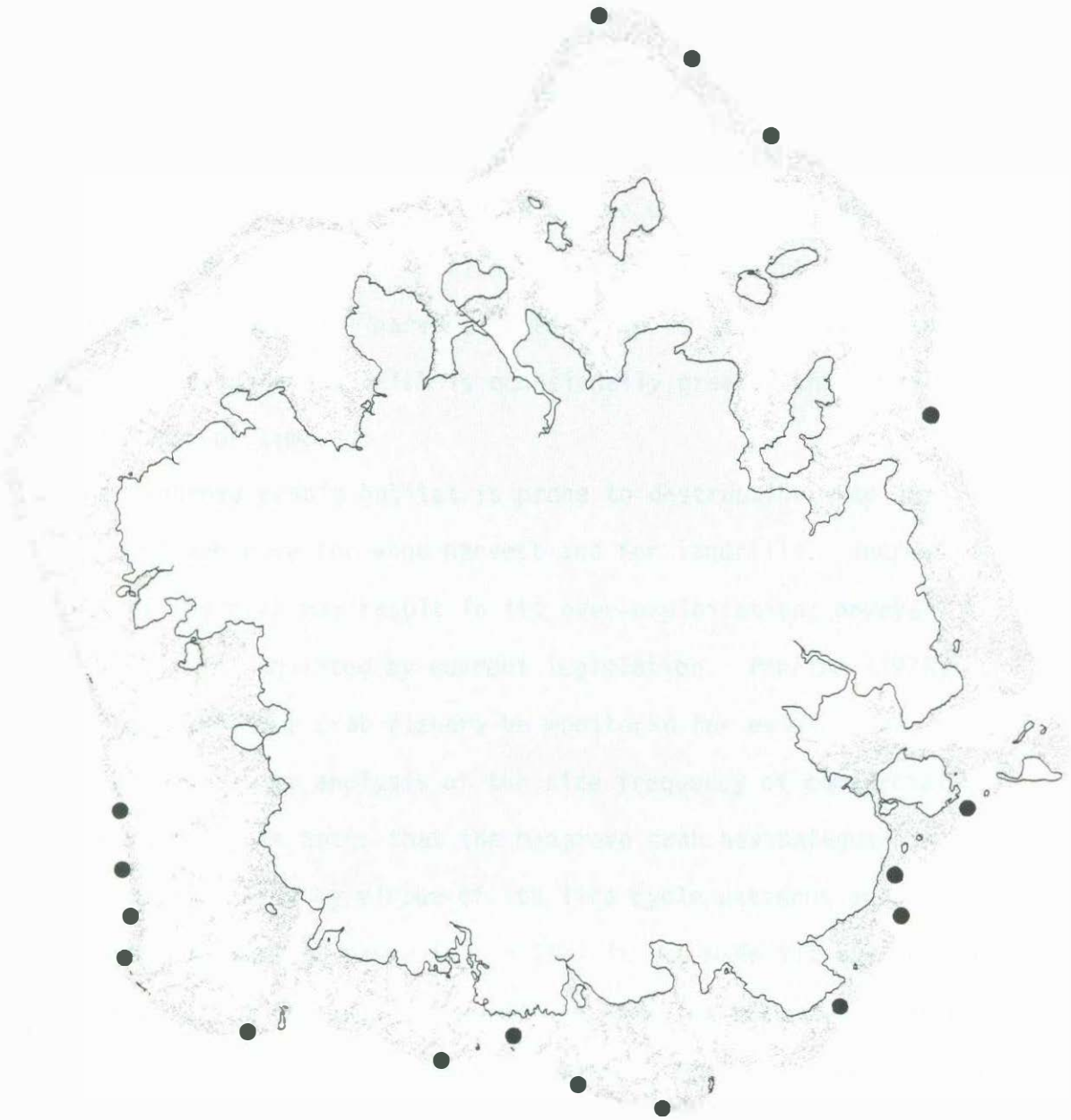
6. Lobster

Both spiny and slipper lobster are found on the ocean edge of the barrier reef around Pohnpei, although the spiny lobster (Panulirus varicolor) is much more abundant (Fig. 12). Lobsters are usually taken by hand at night using torches and flashlights at low tide on the shallow reef or, more recently, while snorkeling using underwater flashlights and spears. Lobster are a highly desired food for both local consumption and for sale to restaurants. However, the quantity of lobster on Pohnpei is not sufficient to support an export industry (MacDonald, 1971).

The small, unregulated lobster fishery is easily susceptible to over-fishing through the taking of juveniles and gravid females. Since no fishing statistics are kept on the fishery, it is difficult to determine its status. Pohnpei state law made the export of lobster illegal in 1971. It has been recommended that the lobster stocks on Pohnpei be conserved because of their low abundance (TTPI, 1971). Johannes (1978b) more specifically proposed a ban on the spearing of lobster to reduce mortality to juveniles and gravid females.

Figure 12

Lobster Harvesting Areas



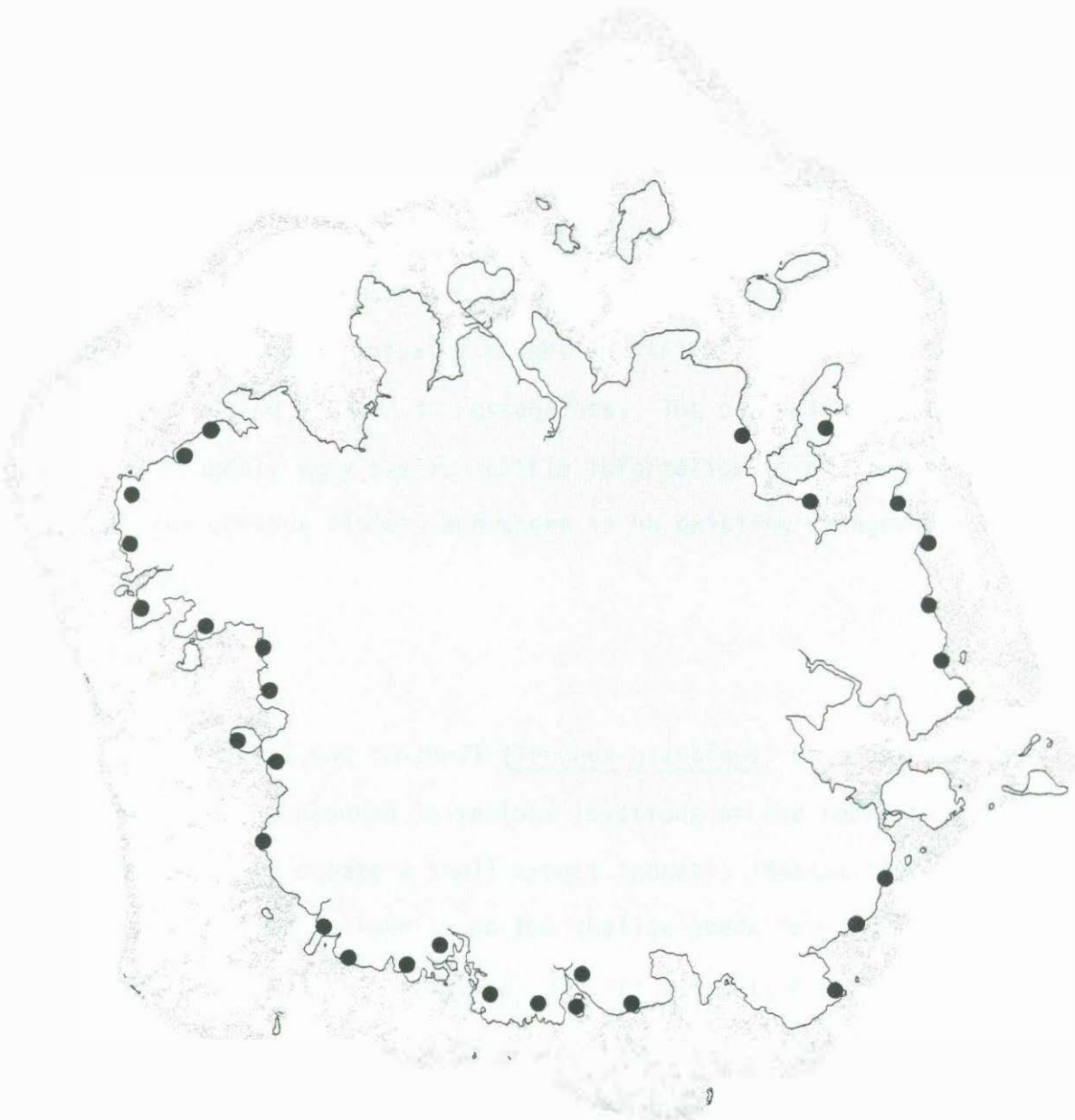
7. Mangrove Crab

The mangrove crab (Scylla serrata), called elemoang, is abundant in the extensive mangrove forest around Pohnpei (Fig. 13). An excellent report (Perrine, 1978) describes the taxonomy, life cycle, natural history, fishery, and conservation of the crab. An estimated 1,000 kg of mangrove crabs are harvested each month. Approximately half of the catch is sold in the market, a large portion of which is shipped to friends and relatives elsewhere in Micronesia (Pohnpei State, 1985a). The mangrove crab, a prized component of the local diet, is found in the Kolonia fish market and is bought by hotels and restaurants. Commercial harvest of the crab is apparently expanding to meet a rising demand which is occasionally greater than supply for short periods of time.

The mangrove crab's habitat is prone to destruction from the clearing of mangrove for wood harvest and for landfills. Increasing harvest of the crab may result in its over-exploitation; however, the crab harvest is regulated by current legislation. Perrine (1978) recommended that the crab fishery be monitored for evidence of over-exploitation by analysis of the size frequency of commercially marketed crabs. He notes that the mangrove crab has safeguards against over-fishing by virtue of its life cycle patterns and traditional methods of harvest. In 1971 it was made illegal to export mangrove crab from Pohnpei. However, in 1977 the export of mangrove crab was permitted on a year-to-year basis by DMR, which requires the exporter to provide catch statistics. In 1981, the Pohnpei State Marine Resources Conservation Act made it illegal to take egg-carrying

Figure 13

Mangrove Crab Harvesting Areas



mangrove crabs, although the enforcement of such a provision is difficult. The capture of crabs with pots, rather than by spearing, is being promoted by DMR, which sees no need for further government involvement in this fishery, except for conservation (Pohnpei State, 1985a).

8. Octopus

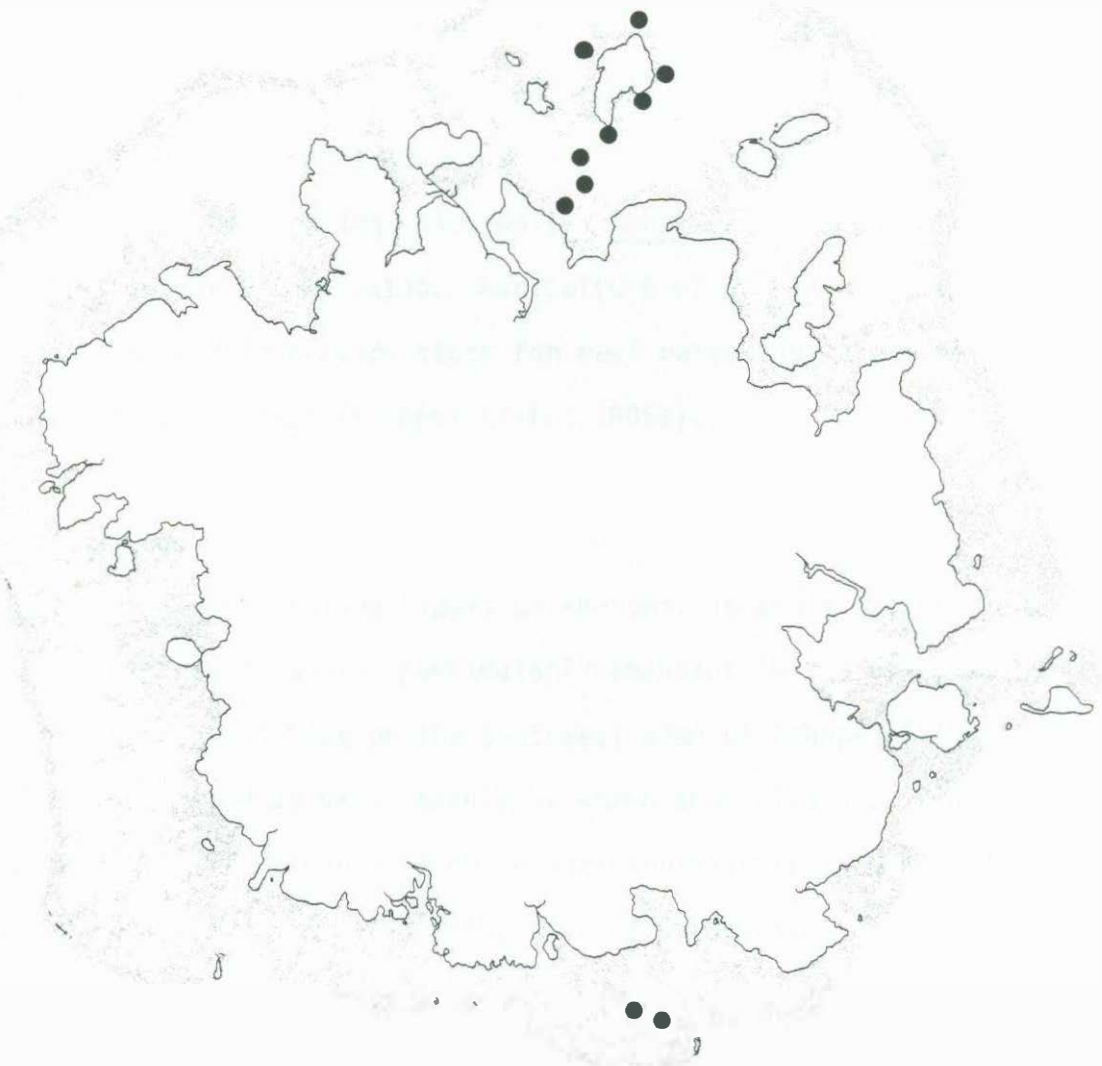
Octopus are widely distributed, in relatively low abundance, around the reefs of Pohnpei. There are groups of patch reefs where they occur in greater number and are more frequently harvested (Fig. 14), though they are not usually sought specifically. Octopus is a speciality food and is used in restaurants. The overall harvest of octopus is probably very small. Little information is available on status of the octopus fishery and there is no existing management or control of it.

9. Trochus

In 1937 about 12,000 topshell (Trochus niloticus) were introduced by the Japanese and planted in various locations on the reefs around Pohnpei in order to create a shell export industry (Bascom, 1965). Topshell is now found primarily on the shallow ocean edges of the barrier reef (Fig. 15). The Trochus are harvested from the reefs once a year, the meat removed for human or livestock food, and the shell exported to Japan for button making. Trochus are easily harvested and recent statistics show a decline in shell exports, indicating over harvest (Pohnpei State, 1985a).

Figure 14

Octopus Harvesting Areas



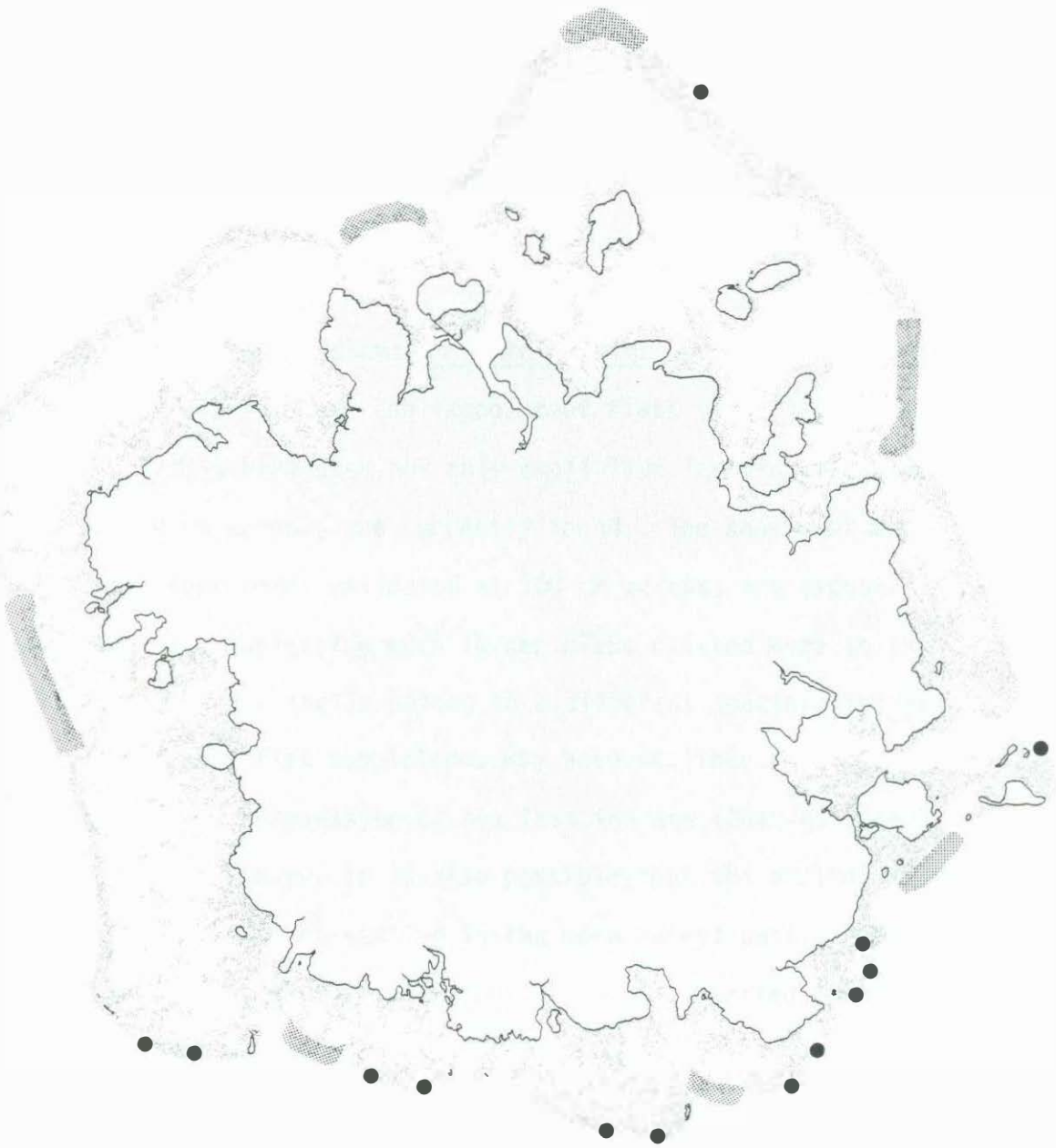
McGowan (1958) recommended the establishment of breeding santuaries for Trochus. The DMR established seven Trochus sanctuaries to provide seed stock for the fishery (Fig. 15). However, it is difficult to enforce sanctuary status on an extensive offshore reef system with limited personnel and funds. Johannes (1978b) recommended that the taking of Trochus while using SCUBA gear be prohibited, but this control has not been pursued. In the Pohnpei State Marine Resources Conservation Act of 1981, the removal of Trochus from closed reef areas (sanctuaries) was prohibited at all times. For the remaining reef areas, the governor declares the season each year on the advice of the DMR, during which only Trochus over 3 inches (7.6 cm) in diameter may be harvested. Mariculture of Trochus has been proposed by the DMR to provide stock for reef reseeding, and a pilot project was begun in 1984 (Pohnpei State, 1985a).

10. Anadara Clam

Anadara antiquata, called Lipwei on Pohnpei, is small cockle found on fringing reef flats and is particularly abundant in the wide, muddy reef flat and seagrass beds on the southwest side of Pohnpei (Fig. 16). It is harvested by hand, mainly by women and children. Lipwei is a much sought after food item on Pohnpei and its use is generally restricted to subsistence and local artisanal purposes.

Figure 15

Trochus Harvesting Areas ●
and Trochus Sanctuaries



The Anadara clam habitat is subject to disturbance and destruction by excessive siltation, dredging, and causeway construction. Although no mention was made of any particular decrease in abundance from these activities, the clams are said to be generally smaller and less plentiful than in the past, possibly due to higher levels of harvest. This shellfish may become unfit for consumption if it is subject to certain kinds of water pollution, but no specific information on this is available. Anadara stocks are presently unmanaged on Pohnpei.

11. Giant Clam

Slow-growing giant clams (Tridacna maxima and Hippopus hippopus) are found on barrier reef and lagoon reef flats (Fig. 17). These clams are easily harvested and only small live individuals, generally less than 30 cm across, are currently found. The shells of much larger dead specimens, estimated at 100 cm across, are exposed in reef flat dredgings, indicating much larger clams existed here in the past. These larger shells belong to a different species, Tridacna gigas, whose reef flat populations may have declined due to habitat changes during the recession of the last ice age (Charles Streck, pers. comm.). However, it is also possible that the decline is attributable to over harvesting in the more recent past. The meat of giant clam, especially the adductor muscle, is a prized delicacy. The shell has value in the ornamental shell trade.

Figure 16

Anadara Clam Harvesting Areas

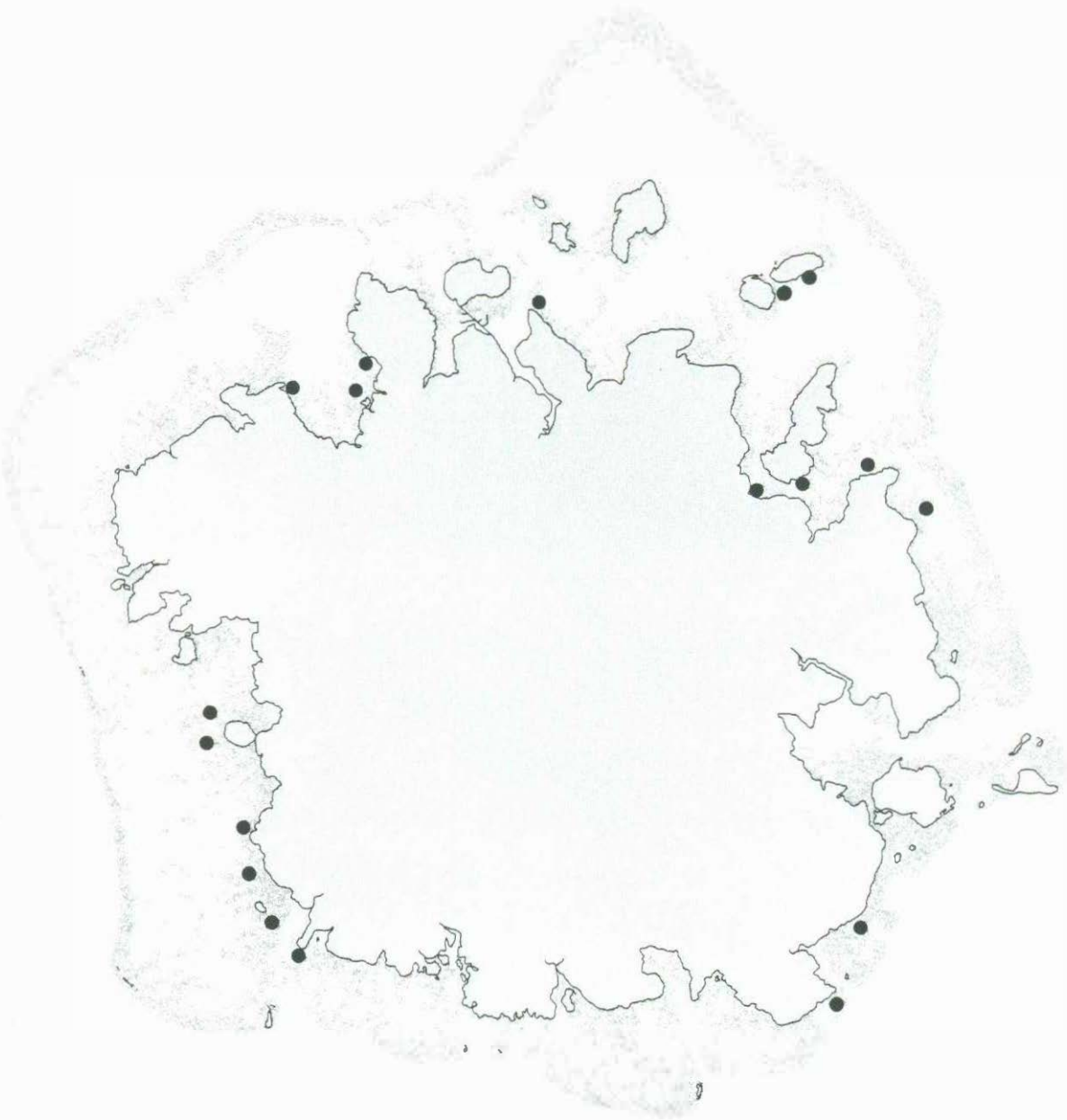
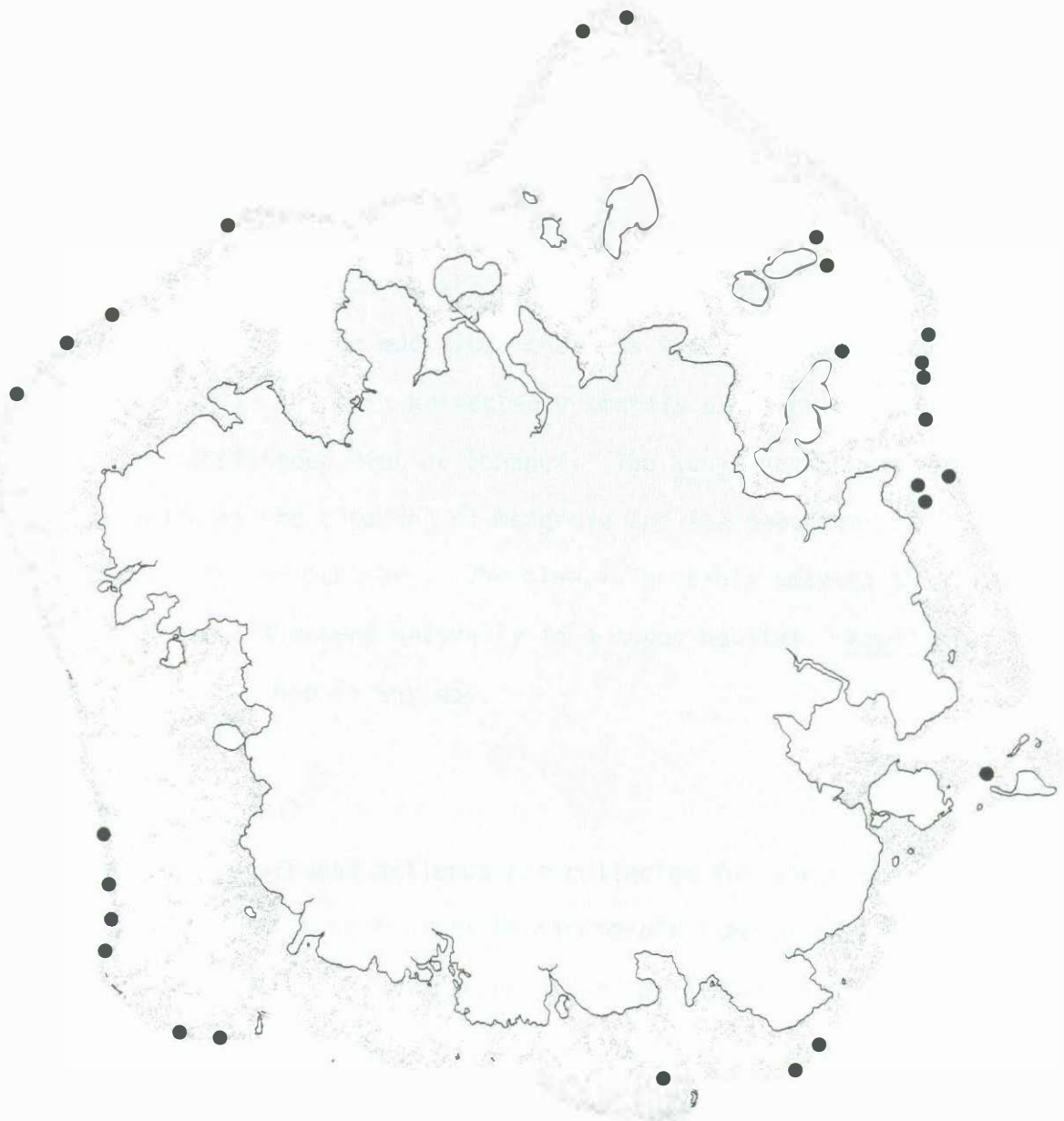


Figure 17

Giant Clam Harvesting Areas



According to the fishermen and DMR staff interviewed, the abundance of giant clam and the size of those harvested is decreasing. This indicates that the clams are being over-harvested relative to their slow reproductive rates. The reef flat habitat of giant clams is also susceptible to disturbance or destruction through activities such as channel dredging. There is no management on Pohnpei of giant clam harvest.

12. Kopil Clam

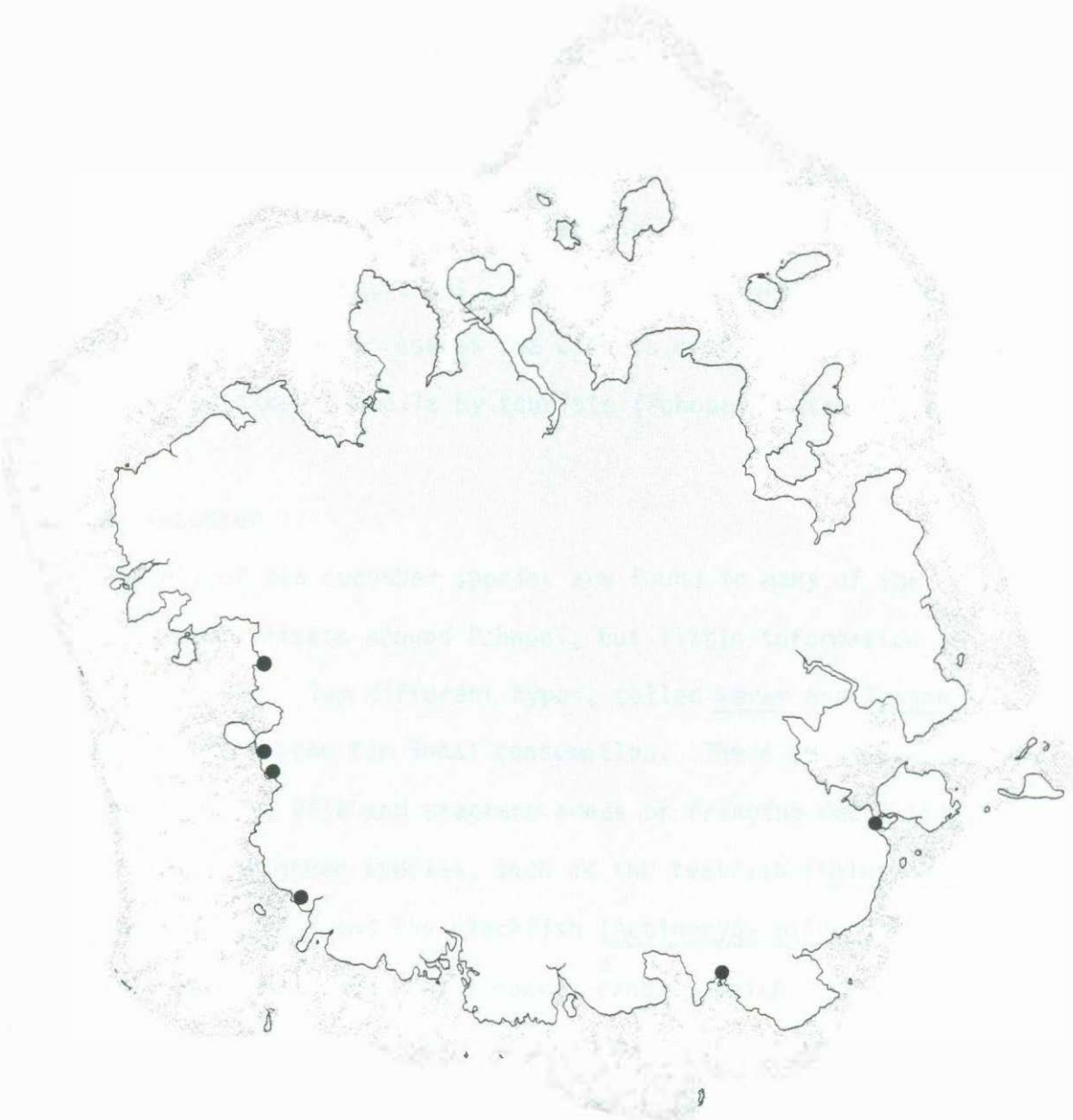
Kopil (Pitar spp.) clams, which are slightly larger than the Anadara, are found in the mud along channels through the mangrove forest (Fig. 18). They are harvested primarily by women and are a part of the subsistence diet on Pohnpei. The kopil habitat is subject to disturbance by the clearing of mangrove and the deepening of channels through the mangrove. The clam is probably adapted to silty conditions since it occurs naturally in a muddy habitat. Kopil clam stocks are not managed in any way.

13. Ornamental Shell

Bivalve and gastropod mollosks are collected for their shells, either for direct sale or for use in handicraft items. Large, striking, or rare shells are preferred for collectors and tourists, while particular species and sizes and are used in handicrafts. At present, shell harvest is mainly limited to supplying the needs of the

Figure 18

Kopil Clam Harvesting Areas



small handicraft industry. The sale of shells and their use in handicrafts contributes to income and employment which tourism generates.

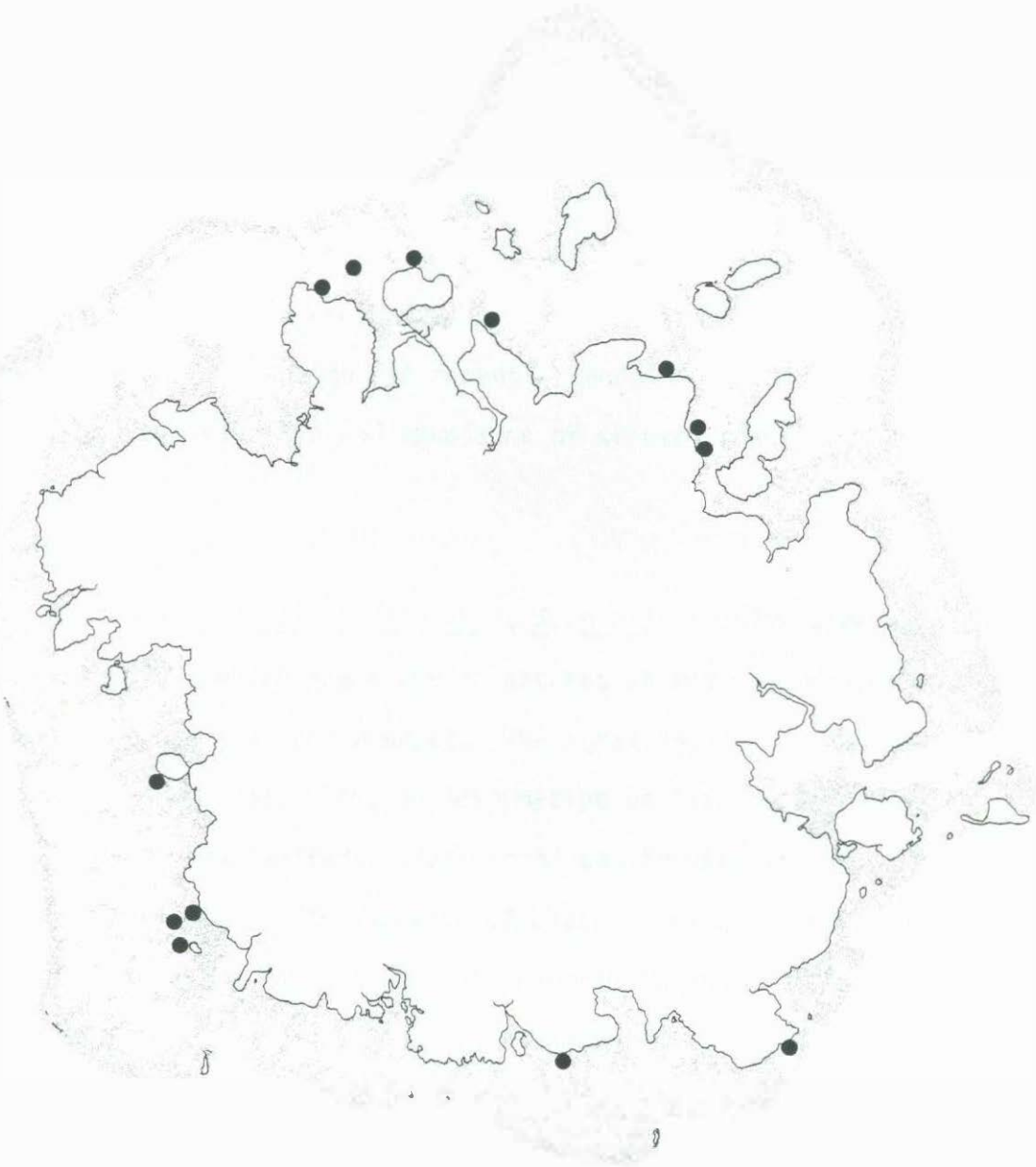
There is potential for the over-harvest of particularly desirable species, but there is little information available on the situation for Pohnpei in particular. In addition, corals are often overturned and broken while searching for shells, resulting in unnecessary disturbance and degradation of reef habitat. The wholesale removal of particular mollusk or gastropod populations from large reef areas has unknown ecological consequences. Conservation programs proposed by DMR include provisions to assess the effects of shell harvesting and to monitor the take of shells by tourists (Pohnpei State, 1985a).

14. Sea Cucumber

A variety of sea cucumber species are found in many of the different reef habitats around Pohnpei, but little information is available on them. Two different types, called werar and longon in Pohnpei, are harvested for local consumption. These sea cucumbers are found on the sand, silt and seagrass areas of fringing reefs (Fig. 19). A number of other species, such as the teatfish (Holothuria (Microthele) nobilis) and the blackfish (Actinopyga miliaris), have potential for beche-de-mer (or trepang) export, which occurred in the past on Pohnpei (Bascom, 1965). The beche-de-mer species have obvious value if there are enough available to again support an export industry, since they are not preferred for consumption in this manner on Pohnpei.

Figure 19

Sea Cucumber Harvesting Areas



The commercially valuable species generally occur on the shallow sandy slopes of the lagoon side of the barrier reef and on patch reefs. Results of survey work by DMR indicate that these species are patchy in distribution and not very abundant overall. The inshore reef flat habitat of the longon and werar is subject to degradation and destruction as a result of dredging, siltation, causeway construction, and other disturbances. The small numbers and limited distribution of the beche-de-mer species could easily allow the population to be over-exploited if unregulated harvest for export were to occur. Sea cucumbers are not subject to any form of management at present in Pohnpei, although EDA recently conducted a survey to determine the distribution and abundance of trepang species.

15. Precious Coral

Black corals (Antipathes dichotoma, A. ulex) are slow growing, ahermatypic corals which are found in patches at moderate depths on various lagoon reefs around Pohnpei. The coral is not very abundant on the reefs of Pohnpei, although information on its abundance and distribution is very limited. Black coral can be used in the manufacture of jewelry. The harvest of black coral and manufacture of jewelry could provide jobs, income and export earnings for Pohnpei. The abundance and distribution of other precious corals are not known for Pohnpei.

Black coral's slow growth pattern increases its susceptibility to over harvest. The Marine Resources Conservation Act of 1981 allows the Department of Resources Conservation and Surveillance to set

seasons or close reef areas to regulate black coral harvest. Annual licenses are required to harvest or process the precious coral and licensees must report quarterly on the amounts, location, and disposition of black coral harvested.

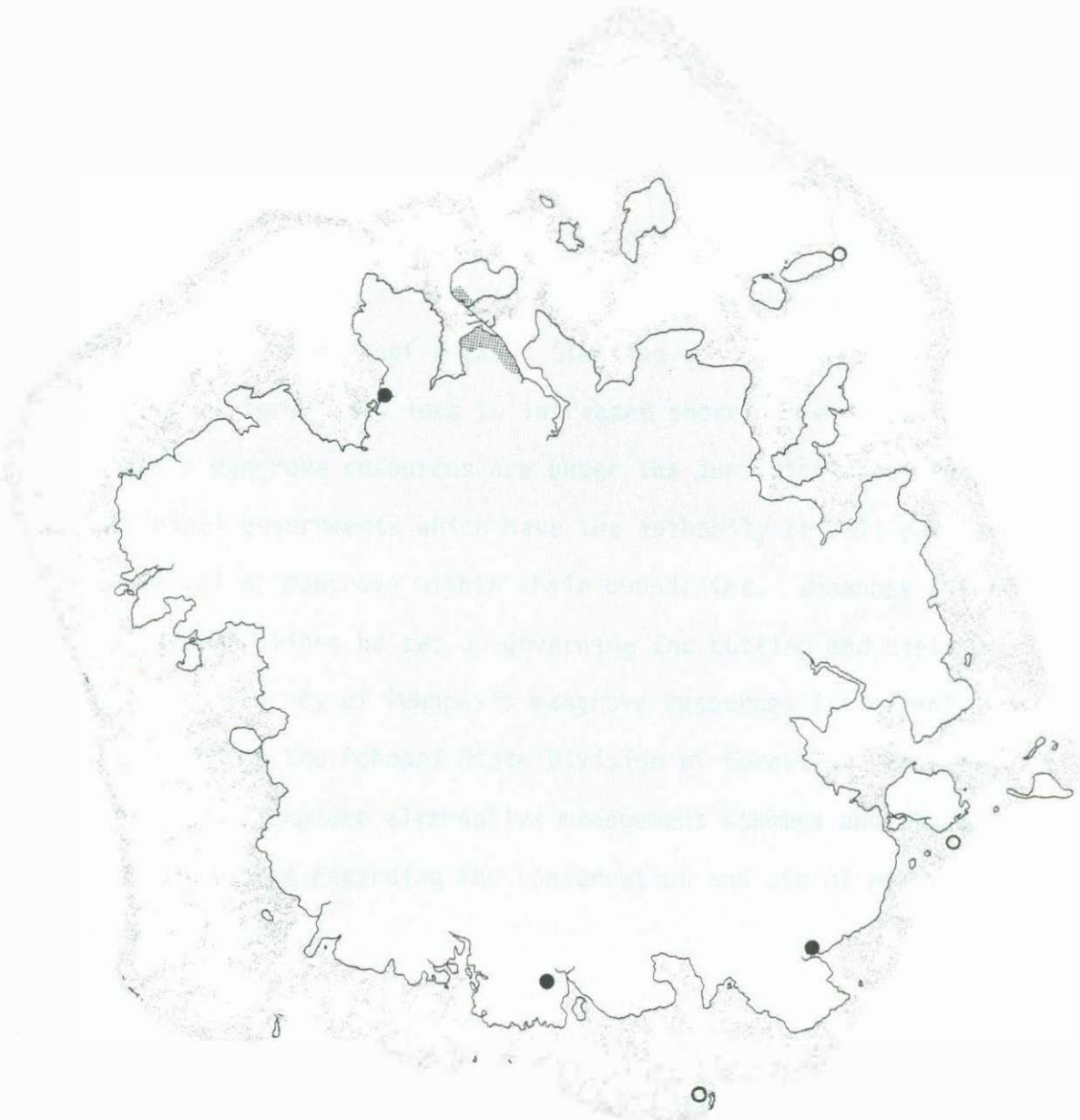
16. Mangrove Wood

Pohnpei is surrounded by an extensive mangrove forest occupying the inner portion of the fringing reef flat. The mangrove forest is composed of several species and covers approximately 10,200 acres (4,128 hectares) (Londvai, 1969; Stemmerman and Proby, 1978). Xylocarpus is logged for local lumber production in small clearcuts and Rhizophora is used for handicraft production (Fig. 20). The extent of fuelwood harvest from the mangrove forest is not known, and is presumed to be minimal, but growing. Clearing for landfills appears to be the major cause of mangrove removal, and occurs around much of Sokeh's Island and in scattered locations elsewhere around Pohnpei.

The intact mangrove forest has ecological value as a filter and trap for terrestrial freshwater and sediment discharge, as a nursery for juvenile reef fish, and as a nutrient supply for adjacent reef communities. The forest is the habitat of the valuable mangrove crab (Scylla serrata) (elemoang) and the smaller black crab (mahsaht). The logging of mangrove provides local employment, a source of building lumber, and raw material for handicraft production. The mangrove forest is a large potential source of fuelwood for Pohnpei's

Figure 20

Mangrove Harvesting Areas ●
Commercial Waterfront Areas
and Aquaculture Sites ○



subsistence economy. The level ground of the nearshore edge of the mangrove forest provides accessible and attractive locations for landfills.

Large-scale removal of mangrove trees entails direct loss of mangrove habitat and its natural ecological functions. Whereas the small scale harvest of mangrove trees allows their potentially sustainable use, the creation of landfills results in irreversible removal of mangrove areas from production. The clear cutting of mangrove is said to cause the elimination of mangrove crab from the area affected and result in the release of previouly entrapped sediment on to adjacent reef areas. Clearing of the lagoonward edge of the mangrove forest may lead to increased shoreline erosion.

Pohnpei's mangrove resources are under the jurisdiction of each of the 5 municipal governments which have the authority to sell permits for the removal of mangrove within their boundaries. Johannes (1978b) recommended regulations be set up governing the cutting and clearing of mangrove. A survey of Pohnpei's mangrove resources is currently being completed by the Pohnpei State Division of Forestry. Efforts are being made to explore alternative management schemes and develop island-wide policies regarding the conservation and use of mangrove (Pohnpei State, 1985b).

Cultural and Recreational

The physical, biological and cultural features of Pohnpei's reef ecosystem create a number of cultural and recreational use opportunities. Visitors and residents use portions of Pohnpei's reef for various recreational activities, and archeological sites are the focus of both tourism and preservation activities.

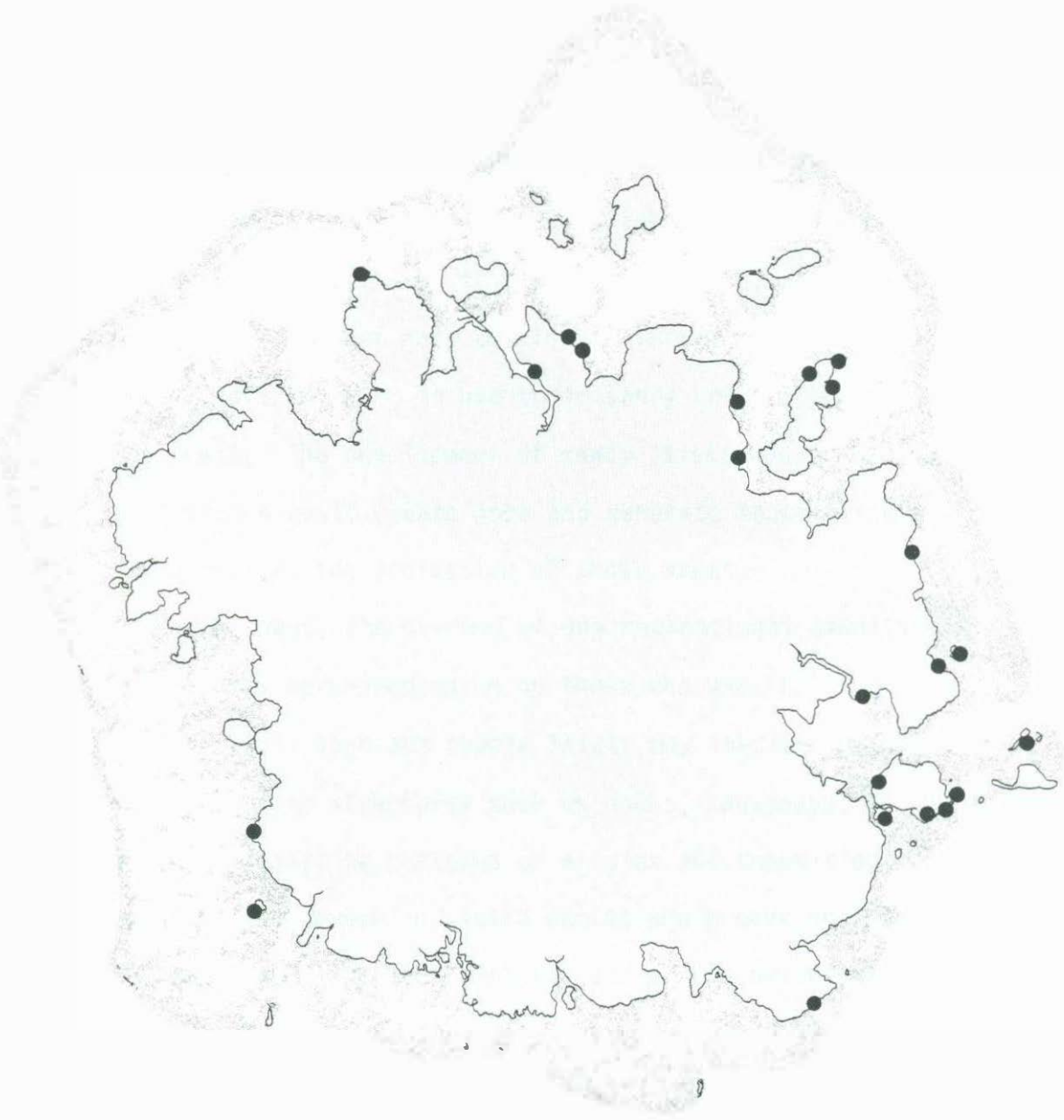
1. Archeological Sites

There are known coastal archeological sites and structures important to the cultural and historical heritage of Pohnpei which require protection from disturbance or destruction (Fig. 21). It is important to preserve these stone structures which were used for living areas and for cultural and religious activities for their continued cultural use and for educational purposes, scientific research, and the benefit of future generations. Some of these areas may be of interest to visitors and may be developed as tourist attractions.

There is a current dilemma in Pohnpei regarding the protection of archeological sites. Some wish to rely upon secrecy to protect generally unknown sites of cultural importance and others propose to identify these areas for official protection. The possibility of inadvertent disturbance or destruction of undisclosed sites is growing as development activities spread around Pohnpei. However, large inputs of time, money, and manpower needed to evaluate, maintain, and protect archeological sites. Provisions for the protection and enhancement of culturally important sites are included in the National

Figure 21

Archeological Sites



Historic Preservation Act of 1966 and the Preservation of Historic and Archeological Data Act of 1974 which are in part administered by the Pohnpei State Historic Preservation Office.

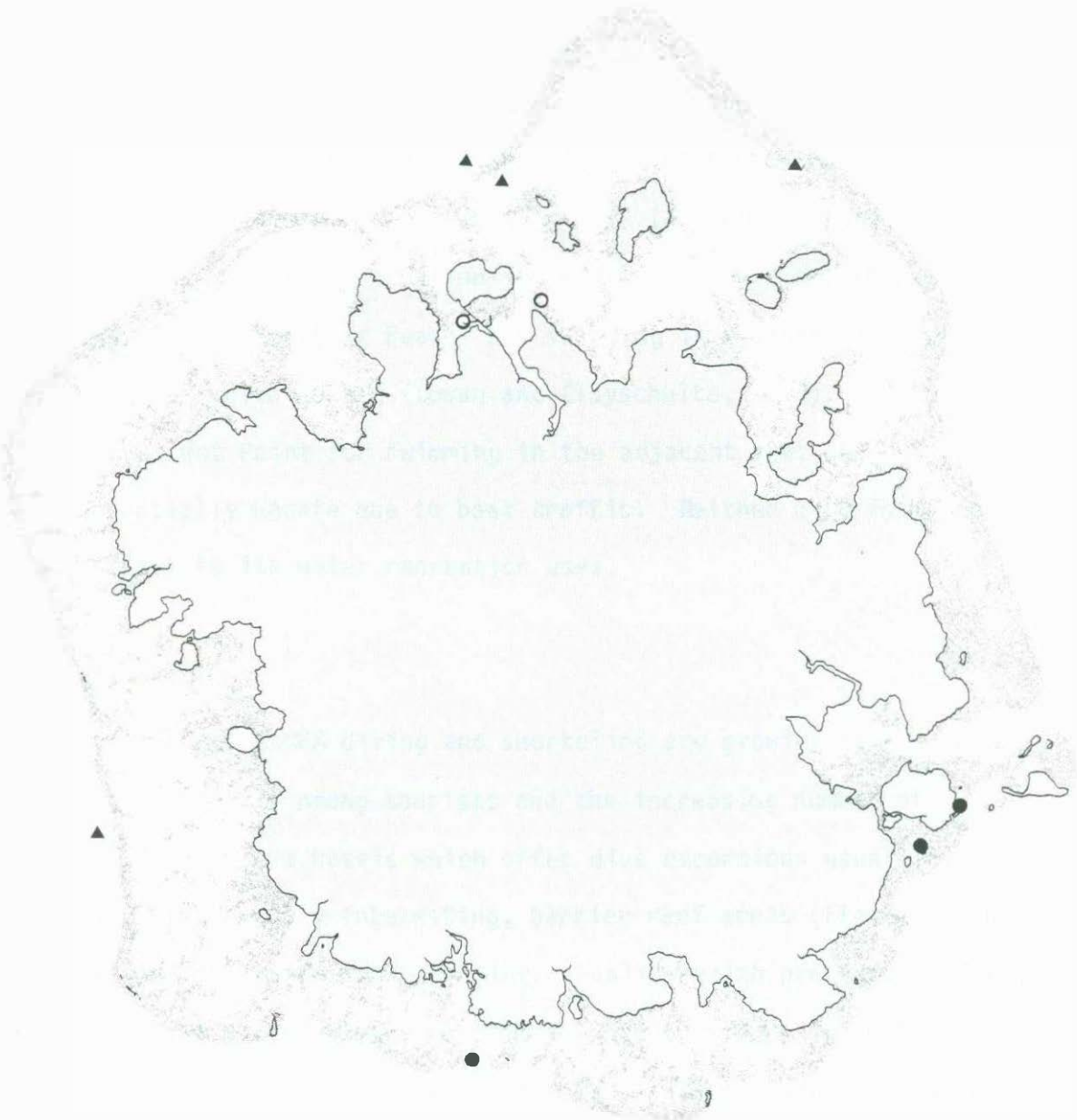
2. Visitor Recreation

A number of coastal areas are used by visitors and residents for leisure activities or because of their archeological and historical interest (Fig. 22). The best example of this is the famous ruins at Nan Madol (Appendix 1, Map 9), parts of which are maintained clear of undergrowth for the benefit of tourists. Elsewhere, a few small coral islets on the barrier reef have developed limited facilities for overnight visitors who wish to use their sandy beaches and nearby snorkeling areas. The development of sandy islets and archeological sites for visitors could create jobs and generate tourism income for Pohnpei, and promote the protection of those areas.

On the other hand, the overuse of any recreational amenity will likely degrade its perceived value by those who use it. The development of small sand and rubble islets may involve the addition of physical shoreline structures such as docks, causeways, or channels which may modify existing patterns of erosion and deposition. In addition, disposing sewage and solid wastes and procuring fresh water on small sandy islets may pose problems and create potential health hazards. Some fishermen allege that the introduction of boating, snorkeling and swimming around a well-visited destination islet (Nahnningi, or "Joy", Island near the Ruins at Nan Madol) (Appendix 1, Map 10) has disrupted subsistence fishing in a very productive area

Figure 22

Visitor Recreation Destinations ●
Resident Recreation Areas ○
and Sport Diving Sites ▲



nearby. The construction of shoreline structures falls under EPB approval and USACE permit procedures.

5. Resident Recreation

An extension of the main Kolonia to Taketik causeway where the government stores sand (called "Lidakika Beach") and the dock at Net Point are popular swimming and picnic sites for the residents of Kolonia. These sites provide accessible lagoon recreation areas for the growing population of Kolonia (Fig. 22) (Appendix 1, Map 4), where there are very limited recreational facilities. However, the use of the causeway at "Lidakika Beach" for swimming in polluted Tuanmokot Channel is a health hazard (Cowan and Clayschulte, 1980). The use of the dock at Net Point for swimming in the adjacent boat channel is also potentially unsafe due to boat traffic. Neither area is managed with respect to its water recreation uses.

6. Sport Diving

Recreational SCUBA diving and snorkeling are growing sports on Pohnpei, especially among tourists and the increasing number of expatriates. Resort hotels which offer dive excursions usually visit pristine, biologically interesting, barrier reef areas (Fig. 22), and generally do not allow sport fishing. Public health problems in Truk, which is usually the primary destination of dive tours through Micronesia, have resulted in a decline in visits to Pohnpei by sport divers. Nevertheless, the growth in sport diving among residents led to plans to open a commercial dive shop on Pohnpei in 1985. Sport

diving has a limited potential for generating jobs and tourism income in Pohnpei. Recreational diving may help promote the protection of marine life, at least in areas with high aesthetic value.

There is concern among some fishermen on Pohnpei that increased sport diving, and accompanying boat traffic, will scare off fish and make them more difficult to catch. Spearfishing during sport dives obviously competes directly with fishermen. The availability of SCUBA equipment may lead to its use in lucrative fisheries and the over-exploitation of those species. There is no management of sport diving on Pohnpei at present.

7. Sport Fishing

Commercial sport fishing is not pursued on Pohnpei and the potential for the activity in surrounding waters is not known. Some small-scale recreational fishing is done by residents and expatriates. The potential for recreational fishing to create jobs and generate tourist income on Pohnpei is undetermined. Commercial sport fishing might result in additional promotion and financial support of fisheries management. On the other hand, sport fishing could possibly result in competition with traditional fisheries for preferred species. Sport fishing activities might also scare off other fish or make them more wary, even if they are not the target species, thus affecting local reef fisheries. Sport fishing is presently unregulated on Pohnpei.

Construction and Reef Materials Extraction

The materials, structure, and accessibility of Pohnpei's fringing reefs make them attractive sites for the dredging of reef rubble. The dredged material is used for landfills, aggregate for cement making, fill for building foundations, surfacing for roads, and other construction purposes. Removal of sand from the lagoon slope of the barrier reef provides valuable material for cement making. Both activities result in considerable modification of reef substrates and their biota. Causeway and landfill construction and channel dredging *permanently alter reefs and water circulation patterns, but provide* important facilities for economic development.

1. Reef Flat Dredging

Reef flat dredging has been carried out to remove abundant fringing reef coral sand and rubble to provide cheap fill material for construction, road building, and maintenance purposes (Fig. 23). The material is easily and economically obtained and transported. Most recent dredging has been carried out by the Pohnpei Transportation Authority (PTA) to obtain surfacing material for the road being built around the island and to stockpile additional material for road maintenance use. Some commercial dredging takes place as well. A dragline dredge is generally used to remove the material, for which a causeway must be built out onto the reef flat to support the machinery. The reef is then dredged on either side of the causeway to a maximum depth of 10 to 12 meters. The material is usually piled into mounds and loaded into trucks after drying.

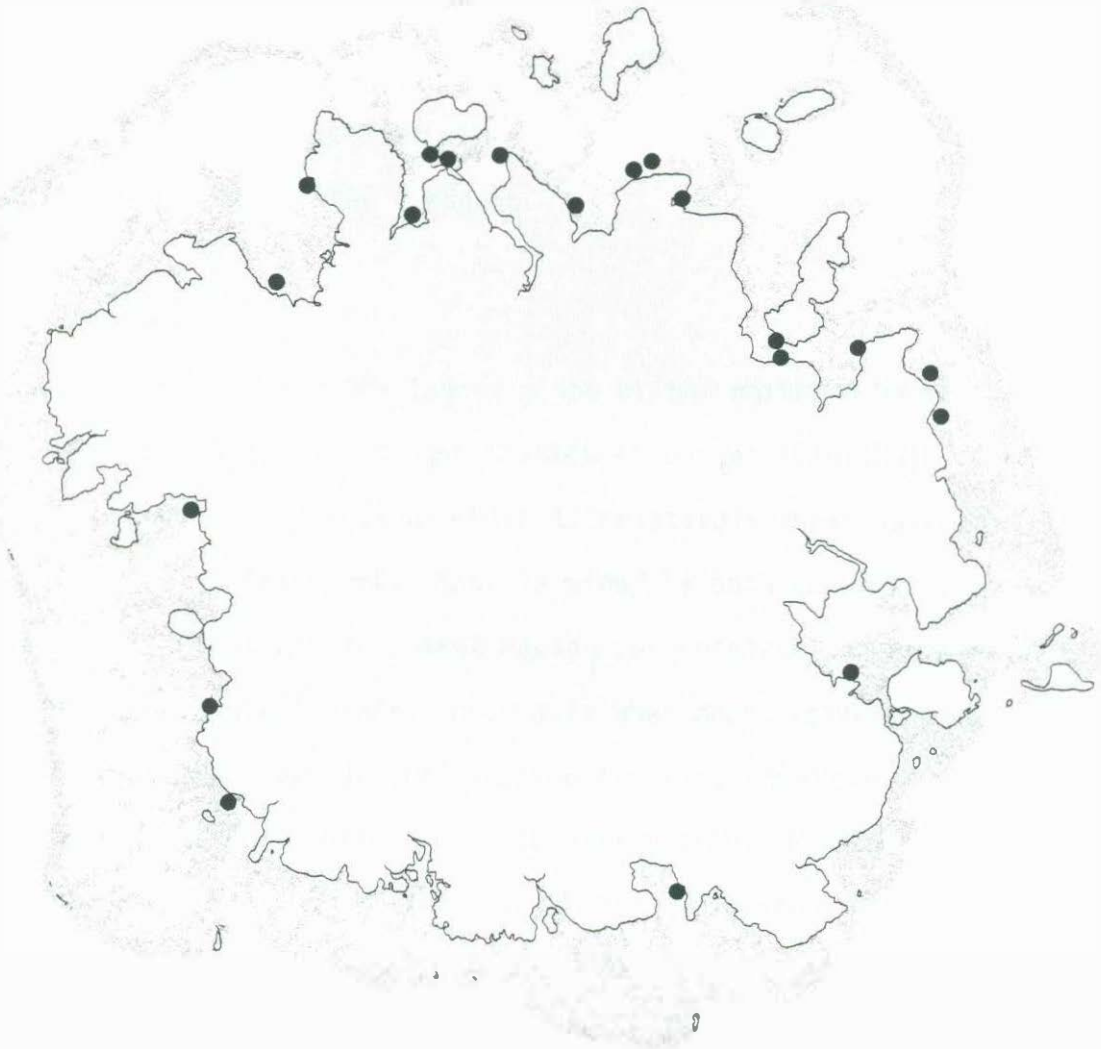
Dredge, or "borrow", sites are limited to accessible reef flat where the mangrove forest is narrow and there is not a hard layer of reef rock just below the reef flat surface. Demand for the material may decline with completion of the circumferential road, but may increase dramatically when the capital complex at Paliker is under construction. In addition, there is a continual need for fill material for road maintenance and shoreline residential and commercial landfills.

Reef flat dredging directly destroys the substrate and the flora and fauna where it takes place. Adjacent reef communities may also be affected by suspended sediments which can be transported by currents. These sediments can settle out on corals and other benthic organisms, smothering them if the amount, rate, and duration of sedimentation is greater than the organism's abilities to remove it. Fish and other motile animals may be driven off by the turbid water and smothered substrate. Use and maintenance of measures to control turbidity and sedimentation, such as silt screens, has been variable and damage that might have been avoided often occurs.

There is only limited planning and management of dredging sites, and one proposed site that would have destroyed a prime fishing area of important cultural significance (Appendix 1, Map 11, Special Reef Area) was successfully opposed by local residents. The discharge of dredged or fill materials into coastal waters, including dredging activities which involve causeway construction, require permits from the USACE (Section 404 permits) and the EPB (earthmoving permits) in

Figure 23

Reef Flat Dredging Sites



compliance with the Clean Water Act of 1977 (CWA) and TTPI environmental laws, respectively.

The use of silt screens or dikes is usually required during dredging to contain suspended sediments, but this does not appear to be consistently enforced. Dredge access causeways are supposed to be removed after the dredging is completed, but this has not been done in most cases. FSM legislation proposed in 1985 will enable the PLA to designate the areas and amounts of dredging allowable and issue licenses for commercial dredging. However, there is no FSM regulation of removal and use of materials for public projects, which are responsible for most of the dredging.

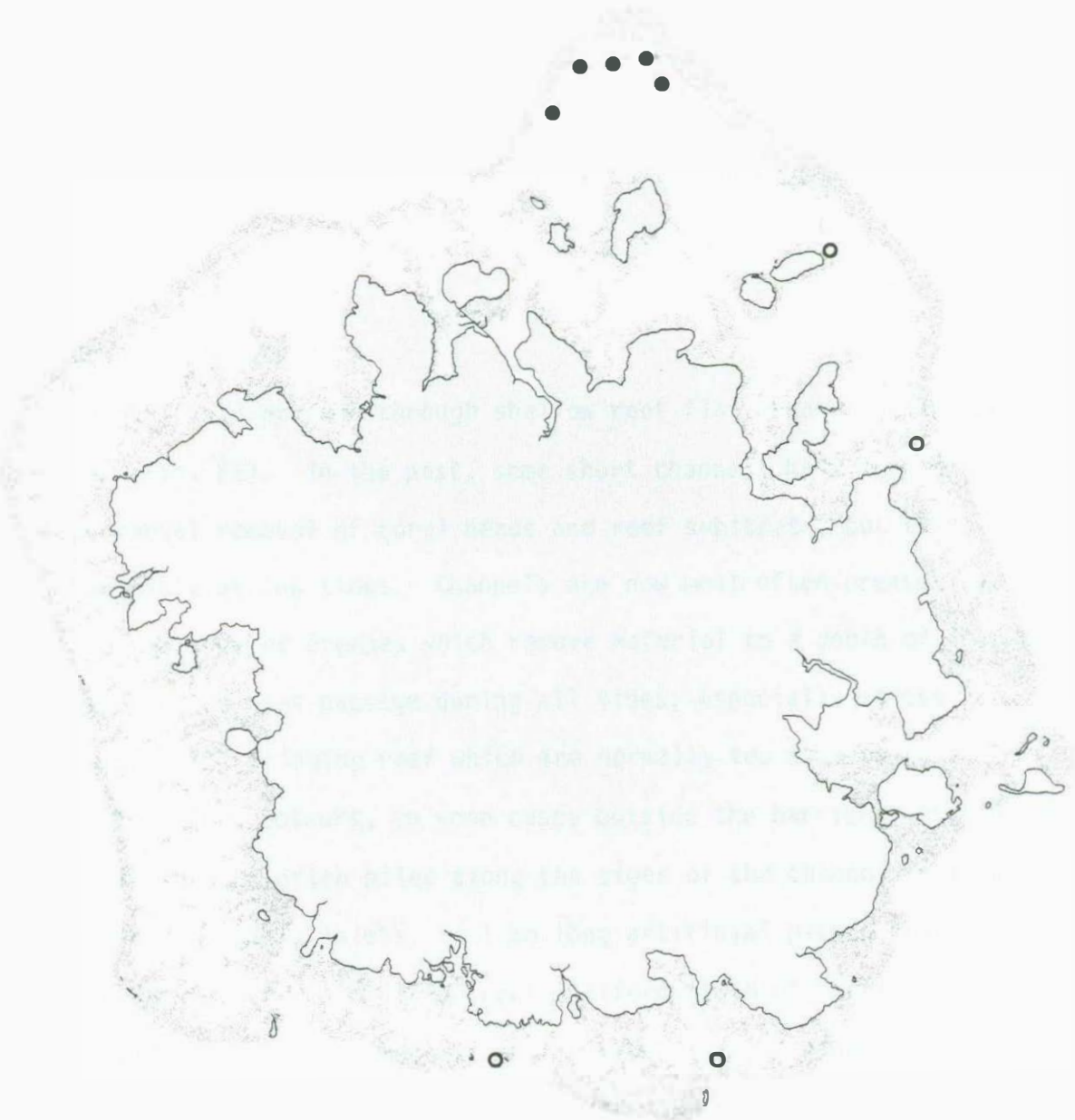
2. Sand Mining

Sand is removed from the lagoon slope of the northern barrier reef by the means of clamshell dredges mounted on barges (Fig. 24). There is abundant sand in these areas which is relatively inexpensive and easy to remove and transport. Sand is mined by both government and private agencies for use in cement making for construction purposes. The demand for sand will increase greatly when construction begins on the capital at Paliker. In anticipation of this, the major commercial sand supplier has apparently been stockpiling sand. Reef sand was sold commercially on Pohnpei for US$9.00 per cubic yard in 1984.

Sand removal destroys the flora and fauna of the substrate at the extraction site. Adjacent coral communities and fish populations can be adversely affected by suspended sediments and turbid water. The unregulated extraction of sand for commercial profit is an undesireble

Figure 24

Sand Mining Sites ●
and Manual Sand Removal Sites ○



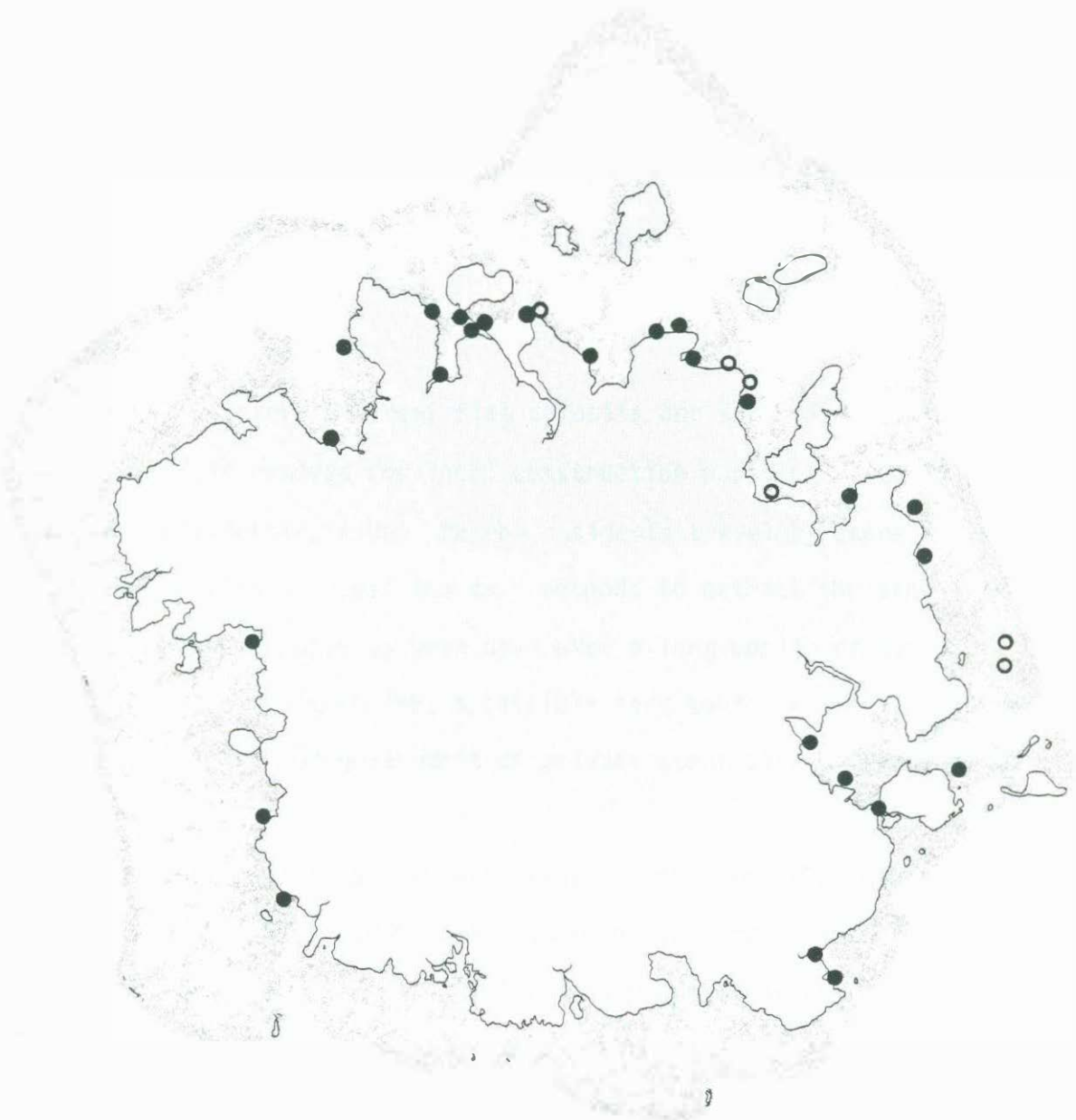
use of public resouces. There are currently no controls, permits, licensing, or planning of site selection required for sand mining. The PLA, which has jurisdiction over this resource, recently requested assistance in designating areas appropriate for sand extraction which could minimize damage to reef fisheries. Legislation was proposed in late 1985 to allow the PLA to designate the areas for and amounts of sand removal by commercial operators, which will be regulated by licensing. However, there is no regulation of sand removal by public agencies.

3. Channel Dredging

Channels are dredged through shallow reef flat areas to allow boat passage (Fig. 25). In the past, some short channels have been created by the manual removal of coral heads and reef substrate, but these are not navigable at low tides. Channels are now most often created by using barge mounted dredges which remove material to a depth of 1 to 2 meters to allow boat passage during all tides, especially across portions of the fringing reef which are normally too shallow or necessitate long detours, in some cases outside the barrier reef. The dredge spoils are often piled along the sides of the channel to form small, linear rubble islets. A 1 km long artificial passage cuts through the continuous fringing reef platform north of Madolenihmw harbor allowing safe passage within the lagoon on the windward side of the island. The rubble islets created from the dredge spoils may be used as temporary fishing camps.

Figure 25

Channel Dredging Sites ●
and Causeway Construction Sites ○



Dredging of channels through formerly solid reef structures alters current patterns and may affect local erosional and depositional processes. Water is funneled through the channel which may make them hazardous or even unnavigable during the rapidly changing tides. The rubble islets created by dredge spoils block the flow of water and passage of marine animals across the reef flat. Generation of suspended sediments during dredging may adversely affect adjacent coral and fish communities. Channel dredging is subject to the same environmental regulation as reef flat dredging.

4. Manual Sand Removal

Sand from intertidal reef flat deposits and sandy islets on the barrier reef is removed for local construction purposes (Fig. 24), usually house construction. Nearby residents travel by canoe or small boat and use simple shovel and sack methods to extract the sand. The same sites have apparently been used over a long period of time. These provide an inexpensive, accessible sand source as an alternative to purchasing it from government or private agencies and transporting it from Kolonia.

Sand removal disturbs or destroys the sandy reef flat habitat where it takes place. Continual removal of sand from reef islets may result in increased erosion. Legislation proposed by the PLA to regulate sand mining allows for individual removal of up to 30 cubic yards per year for use on one's own property.

5. Coral Removal

The removal of coral having ornamental value for sale to tourists is uncommon on Pohnpei, but provides some local income. The extraction and breaking apart of live coral for fill material occurs on a small scale, especially along the west side of Sokeh's Island (Appendix 1, Map 19) where many landfills are being constructed. Reef flat coral supplies a relatively free and accessible source of fill material. Living corals are relatively slow growing colonial organisms which are a primary component of the reef's structure and biological community. Large scale removal of live coral can result in the direct destruction of that portion of the reef ecosystem, although this has not been documented on Pohnpei. Even limited taking of corals may disturb or damage surrounding corals. The DMR has proposed to monitor coral removal by tourists and assess the impacts of such activity (Pohnpei State, 1985a).

6. Causeway Construction

Most causeways are linear, solid fill structures which extend out onto the reef flat for use as docks, dredging platforms, or roadways to join land masses. The causeways often have too few culverts, or none at all, to allow water to pass through. Circulation is thus altered and sediments are trapped by the structure. Numerous causeways have been constructed on Pohnpei, many in association with dredging activities (Fig. 25). The most conspicuous is the 1.4 km link from the Kolonia to the airport and commercial dock at Taketik (Fig. 27), which has only 2 small culverts.

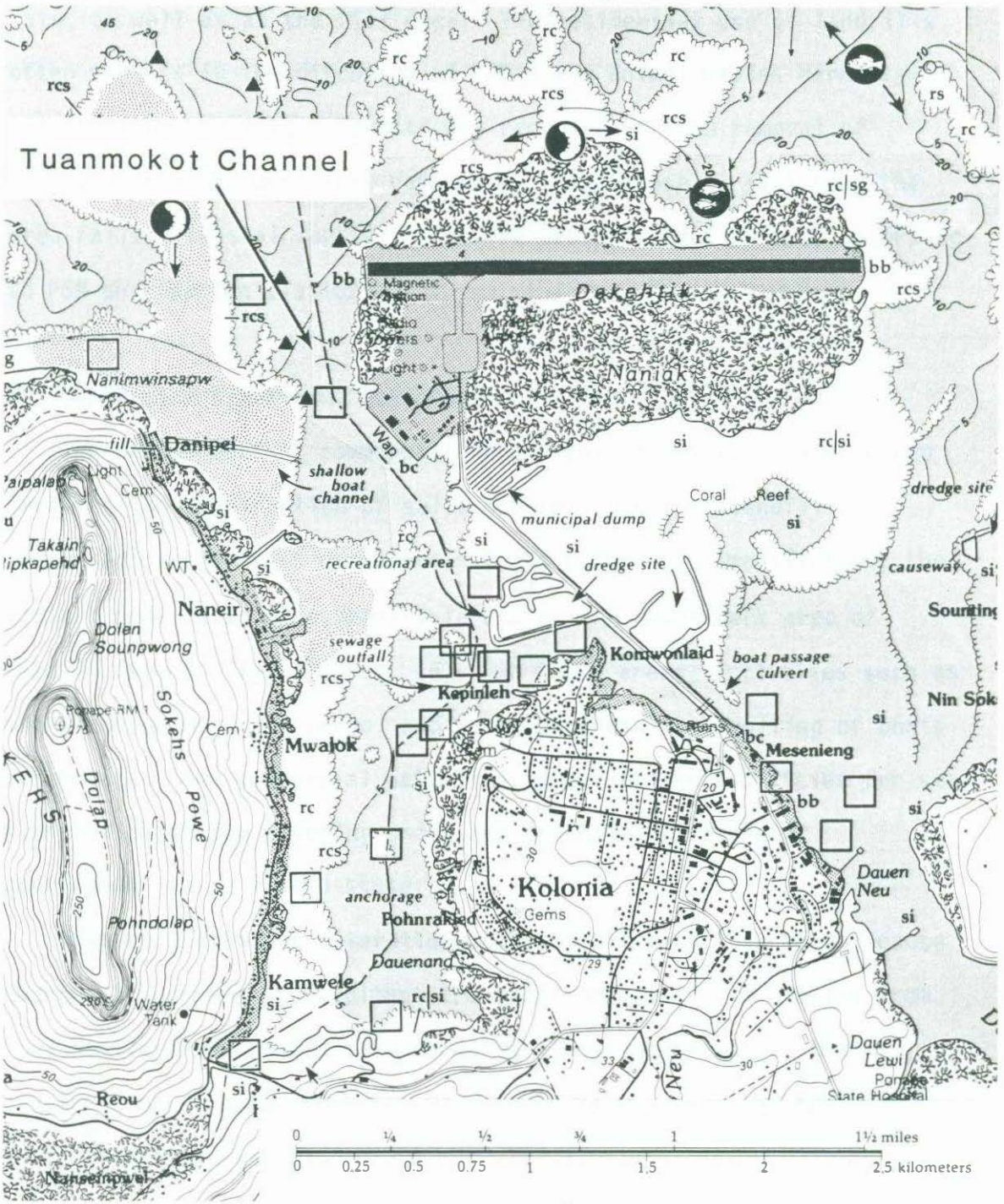
Causeway construction directly destroys a certain amount of reef habitat and disrupts nearby coral reef communities by generating suspended sediments. Dredged reef rubble is usually employed as the fill material. If current patterns are altered, especially when insufficient numbers of culverts are included, normal flushing action is reduced and sediments can accumulate. This can degrade adjacent reef, seagrass, and mangrove areas, as has been the case with the causeway between Kolonia and Taketik. Also, the movement of reef organisms, expecially migrating fish, is disrupted or totally blocked by some structures. The construction of causeways are subject to EPB and USACE permit procedures as required by the CWA.

7. Landfill Construction

Landfills usually require the clearing of shoreward mangrove and the construction of an enclosing dike which is then filled with reef flat material or coral. The creation of new coastal land is needed to accommodate Pohnpei's increasing population, particularly for landless immigrants from the outer islands of Pohnpei State and elsewhere in the FSM. Landfills have mainly been created around Kolonia and on Sokehs Island (Fig. 26), but are also scattered elsewhere around Pohnpei's shoreline. They are usually constructed for residential purposes and often include a latrine over the water and a pigpen at the water's edge. The enormous reef flat landfill, which is now the airstrip and airport for Pohnpei (Fig. 27), replaced much of the mangrove forest of Taketik with fill material dredged from other reef areas.

Figure 26

Tuanmokot Channel, showing:
Landfill Areas
Solid Waste Disposal Site
and Sewage Treatment Plant Outfall Site
(see Appendix 1 for Legend)



Landfills destroy and convert reef and mangrove habitat to fastland. During landfill construction, suspended sediments may degrade adjacent reef areas. Dredged reef materials used for landfills result in reef destruction and disturbance at the dredge site, as well as at the fill area. The residential use of landfills often results in the discharge of human and animal wastes directly into nearshore waters. Permits are required for the removal of mangrove from the municipal government under whose jurisdiction the area falls. Coastal landfills require EPB and USACE permits according to FSM and CWA legislation.

8. Commercial Waterfront Development

The development of commercial waterfront facilities, which often involves the construction of solid concrete docks or landfills protected by sea walls or revetment, has occurred primarily along the eastern side of Kolonia Penninsula and at the newer dock area of Taketik Island (Fig. 20, Fig. 26). In these areas, activities such as the transfer of fish, cargo, and passengers and the fuelling of boats take place. The commercial waterfront provides the facilities for sea transportation and shipping which are essential to economic development in an island state.

However, shoreline alteration and protective structures may cause changes in current and sediment transport processes. Pollution from fuel spillage may result from commercial dock operations. The construction of some shoreline structures is regulated by EPB and USACE permit procedures.

9. Aquaculture Development

In a few locations around Pohnpei, sandy reef flat are used to grow the seaweed Eucheuma. The DMR has two nursery sites and there is one commercial Eucheuma venture underway (Fig. 20), with hopes for further expansion. Eucheuma is generally not eaten, but is exported for processing into agar (Doty, 1981). In the future, the mangrove forests of Pohnpei may be cleared for fishponds, as has occurred in other parts of the tropics. Mariculture has the potential to provide income and employment for people on Pohnpei. The marketing of seaweeds, such as Eucheuma, can contribute to export earnings. It is possible that mariculture of food species would also supply local food requirements and reduce imports.

Seaweed farms on reef flats require areas with suitable natural conditions and lack of conflicting uses. Existing seaweed farms on Pohnpei have had trouble with schools of rabbitfish which devour the crop and with night fishermen whose gear becomes tangled in the stakes. The creation of fishponds in mangrove areas has tradeoffs with the loss of mangrove habitat and juvenile fish habitat and problems with the discharge of pond waste water. The DMR plans to encourage and assist the start of seaweed farms, but remains cautious on the prospects for mariculture (Pohnpei State, 1985a).

10. Navigation Aids Installation

There are official navigation buoys and channel markers approved by the U.S. Coast Guard only between the main barrier reef pass

(Sokeh's Passage) and the commercial dock at Taketik (Appendix 1, Map 21). Elsewhere around Pohnpei, the DMR has placed numerous concrete reef markers on lagoon reefs to mark safe boat passage. The reef markers are invaluable in guiding vessels through the maze of lagoon reefs, especially at low tides and during times of reduced visibility. There is some difficulty maintaining the markers against the ravages of time, weather, and vandals and a modest maintenance program exists.

Lagoon Water Pollution

The lagoon around Pohnpei is subject to a variety of activities which directly and indirectly result in water pollution and degradation of reef resources. These include the intentional discharge of treated and untreated sewage wastes, which often exceed the local environment's capacity to dilute and disperse them, and the dumping of solid wastes. Terrestrial land use activities often release large amounts of sediments into nearshore waters and introduce pesticides and oil products into the lagoon.

1. Solid Waste Disposal

A cleared mangrove area adjacent to the lagoon on Taketik Island provides for the disposal of increasing amounts solid wastes and the creation of a landfill, which may be used as a future power plant site (Fig. 26). The 1.5 acre site has a low, incomplete dike along its lagoon edge. Rubbish from households and businesses in Kolonia, automobiles, machinery, and other disposables are dumped at the site

and periodically compacted. Outside of Kolonia, solid wastes are dumped at informal disposal sites, especially along the inland side of the road where it cuts through the edge of the mangrove forest. These indiscriminate and unplanned dump sites are, at best, convenient only to the local users.

The municipal dump site is unsightly, smelly, and located adjacent to the main road into Kolonia from the airport without any visual screen. It is likely that waste oil and other noxious materials are seeping into the lagoon from the site. Informal dump sites around the island are unsightly health hazards which may also be introducing damaging substances into the coastal environment. Recommendations have been made concerning the disposal of solid wastes, management of the municipal dump, and the need for a new refuse disposal site (EPB, TTPI, 1970). Patrick, et al. (1977) developed a management plan for the disposal of solid wastes on Pohnpei, which included several alternative refuse disposal sites. Informal dumps come under EPB and USEPA jurisdiction, but there is little actual regulation. It is planned that solid waste disposal/landfill sites will be designated for rural areas on Pohnpei (Pohnpei State, 1985a).

2. Sewage Waste Disposal

Raw sewage enters the nearshore waters of Pohnpei from over-water latrines (benjos) and pig pens at the water's edge. These sources of pollution are increasing where new landfills are created. Over water latrines provide an appropriate, traditional, simple, and accepted solutions to household domestic waste disposal at low levels of input

into large bodies of water with sufficient flushing. The discharge of untreated sewage has been eliminated from much of Kolonia by the completion of the sewage treatment plant. However, the sewage treatment plant effluent is discharged into Tuanmokot Channel (Fig. 26), where flushing is weak (Tsuda et al., 1974). Children often swim at nearby "Lidakika Beach", and little or no monitoring of water quality is done in the area (Cowan and Clayschulte, 1980). Kolonia's sewage collection system is inefficiently designed and maintained and storm water runoff is often processed by the plant along with raw sewage. During frequent power failures, lift stations are unable to operate, and raw sewage is bypassed from the stations into streams and the lagoon. Regular operation and maintenance of the sewage treatment plant are also a problem, and chlorine levels in the effluent vary considerably.

The coastal discharge of raw sewage from large numbers of benjos around a confined and poorly flushed water body, such as Tuanmokot Channel, creates water pollution and public health problems. The hazards are exacerbated if the waters are frequented by swimmers and bathers and if marine organisms are harvested for human consumption. This is also true for the discharge of improperly treated effluent from the sewage treatment plant into the same confined embayment. Excess chlorine in the treatment plant effluent is also potentially toxic to marine life.

For the capital complex at Paliker, a sewage disposal system of oxidation ponds and effluent discharge into the mangrove forest along the Sondau River (Appendix 1, Map 17) is proposed (Brewer and Assoc.,

1983). This scheme may be a cost-efficient manner of sewage disposal which utilizes adjacent mangrove forests as a nutrient sink for treatment of sewage. However, the proposal may engender health hazards either directly, through water-borne disease, or through the consumption of mangrove forest fauna harvested in the area.

The discharge of wastewater and the quality of coastal waters are regulated by Federal legislation, including NEPA and the CWA. The CWA includes the National Pollutant Discharge Elimination System (NPDES) permit program (Section 402 of the CWA, administered by the USEPA) and the dredge and fill permit program (Section 404 of the CWA, administered by the USACE). In addition, the EPB is responsible for toilet facility and sewage regulations and marine water water quality standards, through permit and review processes. There are plans to link up more private homes in the Kolonia area to the sewage treatment plant and to extend the sewage outfall 10,000 ft (3,350 m) further into the open lagoon. It has also been proposed that rural areas be provided support to convert from benjos to septic tanks or sanitary privies (EPB, TTPI, 1970; Pohnpei State, 1985a).

3. Land Clearing

The removal of vegetation for agricultural, urban, or commercial land development often exposes bare soil to erosion. Pohnpei's steep slopes and high rainfall usually result in considerable erosion, runoff, and transport of terrestrial sediments. However, the clearing of land is necessary for economic development which provides employment and income.

Exposing soil to excessive erosion reduces its agricultural and ecological value and creates water polluting runoff. The influx of sediment laden water onto coral reefs can result in a number of adverse effects. It can reduce light penetration, smother corals and other benthic organisms, cover hard surfaces necessary for coral planula settlement, and degrade habitat conditions for fish and other motile reef inhabitants. No specific instances of such reef degradation have been documented on Pohnpei, but fishermen remarked upon a general decline of nearshore fisheries in areas where sediment laden runoff began to occur after land use changes.

Land clearing, earthmoving, and erosion control are covered by EPB regulations and permit procedures. Proposals by the Pohnpei State government require runoff control plans and environmental impact statements for major earthmoving activities, and monitoring for compliance with these requirements (Pohnpei State, 1985a). Pohnpei State Division of Forestry is developing guidelines for land clearing and vegetation removal (Pohnpei State, 1985c).

4. Road Construction

A road around Pohnpei is currently being completed, and follows along the coastal lowlands where most population settlements are found. A typical section of the road involves clear-cutting a swath approximately 20 m wide through the forest, grading the road bed with locally available fill, and capping the surface with compacted coral rubble. In places, the road is elevated on a causeway which skirts the inner edge of the mangrove forest and occasionally isolates

pockets of mangrove. Culverts are not usually provided to maintain continued surface water exchange into these pockets of mangrove. Completion of the circumferential road will be a major step in linking much of the population of Pohnpei to the government and commercial center at Kolonia. This will result in improved transport of fish and produce to market, ill people to hospitals, children to schools, and consumer goods to outlying areas. Other roads branch off the main highway and are constructed using bulldozers, often haphazardly with apparently minimal planning or improvements to reduce soil erosion and maintenance requirements. An estimated 60 km of secondary roads are needed and will be constructed over the next ten years (Pohnpei State, 1985a).

The environmental problems associated with land clearing apply to road construction. In addition, the cutting off of mangrove areas by causeways without adequate culverts and the clearing and filling of the mangrove forest's inner fringe for the roadbed permanently remove portions of the mangrove ecosystem from production. Capping the road with coral rubble reduces erosion and terrestrial siltation problems, according to the fishermen interviewed, but necessitates reef flat dredging to supply the material. Road construction is partially controlled by EPB regulations regarding earthmoving, grading, and erosion control.

5. Pesticide Use

Increased use of land on Pohnpei for cash crops involves the application of chemicals to control plant and animal pests. The use of pesticides facilitates the short-term production of crops which provide food, employment, and export earnings for Pohnpei. Pohnpei's high rainfall increases chances that pesticides will be washed off the land and vegetation into nearshore waters. Pesticides may enter the marine food chain and become concentrated in higher level organisms, including those harvested for human consumption. The EPB plans to require registration of all imported pesticides and applicants for their use, and to monitor all pesticide use in the state (Pohnpei State, 1985a).

6. Oil Products Storage and Transfer

There is a large amount of fuel stored near the dock and airfield at Taketik and an increasing amount of shipping and local boating in Pohnpei's lagoon. Fuel and oil are necessary for the operation of Pohnpei's power plant and increasing numbers of trucks, automobiles, and outboard motors. Oil is probably entering lagoon waters from many sites of small spillage and accidents. The potential exists for a major oil spill from a ship colliding with another vessel or the reef. Local authorities have no equipment to respond to an emergency spill.

Spillage of oil products can result in severe damage to many marine and coastal organisms. Mangroves, seagrass, and shallow corals are particularly susceptible to surface oil. Chronic pollution may

result in the contamination of marine organisms harvested for human consumption, especially in the confined embayments around Kolonia. Improperly equipped and untrained local authorities would be ineffective in reducing the impact of a major spill. Consequently, plans call for the continued monitoring of all establishments which store, handle, and sell oil products (Pohnpei State, 1985a). An oil spill containment document is on file in Pohnpei from the USEPA and containment equipment has been allocated for the island. Local agencies have been designated to respond to oil spills, and training is planned (Pohnpei State, 1985). Major oil spills require U.S. Coast Guard assistance, but the nearest facility is on Yap.

7. Power Plant Operation

There is a possibility that a power plant may be constructed on the present municipal dump/landfill site, adjacent to the lagoon, on Taketik Island (Fig. 26). The increasing urban population of Kolonia requires a dependable, adequate supply of electrical power. The landfill site at Taketik is one of the few pieces of level land which is near Kolonia, owned by the government, and adjacent to marine waters which could serve as cooling waters for the power plant, if needed. However, there are plans by the USACE to construct a hydroelectric dam on the Nanpil River in Kitti, beginning in 1985, for the Pohnpei State Government, which would supply much of the island's electricity needs.

It is not known whether the power generation system planned for the lagoon site near Kolonia would involve thermal discharge. However, power plants often discharge heated cooling water into coastal waters, depending upon the type of generation system used, the quantity of heat generated, and other factors. Heated effluent waters can cause serious damage to coral reef biota. Chlorine is also often used as an anti-fouling agent for water intake and outfall pipes, and discharged into the lagoon. Oil-fired power plants consume a considerable amount of fuel oil, increasing the possibility of spills into adjacent waters. Power plant discharges are subject to NPDES (Section 402) permits from USEPA, the discharge structures are subject to USACE permits (CWA Section 404), and receiving water quality standards are administered by the USEPA and the EPB.

CHAPTER V

REEF MANAGEMENT STRATEGIES

Coastal Resource Management

A range of approaches to the management of coastal resources has been developed and applied in many parts of the world and are briefly reviewed here. Many of these programs are applicable to the management of coral reef coastal areas in developing island countries.

Coastal zone management (CZM) has become a major approach to the comprehensive planning of coastal resource use since the passing of the Coastal Zone Management Act in 1972. Through this Act, the U.S. Federal government, by providing funding and guidelines, encourages states to develop programs for coastal resources management and planning in coordination with their local governments (Heikoff, 1980; Mitchell, 1982; Brower and Carol, 1984). Five major approaches to CZM have emerged in the United States: 1) comprehensive planning, involving large-scale surveys of coastal resources and their utilization; 2) functional approaches, responding to development pressures with rapid surveys done within flexible long-term objectives; 3) temporary moratoriums, controlling short-term development during planning for long-range goals; 4) land zoning, regulating coastal development with traditional single-use land zones; and 5) expanding existing administrative agencies to handle coastal planning and some management (U.N., 1982). CZM programs, approved by the Federal government, have been developed in states, territories, and commonwealths with coral reef environments (Hawaii, Florida,

Puerto Rico, Virgin Islands, Guam, American Samoa, Northern Marianas Islands). The CZM authority was not specifically extended to include the TTPI to enable the Caroline Islands to develop CZM programs.

Considerable literature has been published on CZM legislation, administration, methods, and applications. Sorensen (1971) devloped a method to identify and control resource degradation and conflict in the coastal zone and to plan for multiple use. In this method, a series of matrices link resource uses, by causal factors, to the conditions that they create. This process then incorporates the initial and consequent conditions which result from the use and predicts the ultimate effects (of use conflicts or resource changes). This approach was further developed by Neuman (1979). Other notable publications discuss the substantive elements neccessary to develop workable CZM programs (Armstrong, et al., 1974) and provide detailed technical information on the effects of specific human activities in the coastal zone and the importance and conservation requirements of particular ecosystems (Clark, 1977).

The application of CZM-type management programs to other nations, including developing tropical countries with coral reef resources, has been variable (Mitchell, 1982; U.N., 1982). The requirements for a national program of coastal mangement have been described (U.N., 1982), and are: 1) a national policy for the coastal area; 2) defination of physical, environmental, and administrative units; 3) a basic program of scientific observations on the coastal environment; 4) classification of the coastal area; 5) a process of evaluating

coastal development projects; 6) an institutional mechanism for coastal mangaement; and 7) baseline studies of coastal environments.

Ecological guidelines for the management of tropical coastal and island ecosystems have been discussed by Maragos et al. (1983), McEachern and Towle (1974), and Odum (1976). Handbooks are also available on the management of mangroves, with applications to Southeast Asia and the Pacific (Baines, 1981; U.N., FAO, 1982; East West Center, 1984; Teas (ed.), 1984).

However, coastal research aimed specifically at coral reef management has been limited largely to developed nations. In Australia, the Great Barrier Reef Marine Park Authority (GBRMPA) was established in 1975. GBRMPA funds research for analysis of resources, analysis of use, and information management which allows it to develop and refine management stategies through continuous data input (Kelleher, 1981). GBRMPA relies heavily on zoning of the Great Barrier Reef for management of resource use by applying land use planning methods to the tropical marine environment (Cocks, et al., 1983). Although the methods used by GBRMPA may be transferable to developing island countries, the scale and types of information used may not be directly applicable to small countries with intensively used coral reefs.

Similarly, in the U.S., the uninhabited wildlife refuge in the Northwestern Hawaiian Islands was the subject of a five-year, multi-disciplinary, multi-million dollar study to assess the fishery and to develop management plans for preserving unique wildlife and conserving commercial species; an ecosystem model was also created

(Grigg, 1981). The scope and scale of this program can not be applied directly to developing countries with limited funds and expertise.

In developing nations, it is unrealistic to remove large areas of reef resources from use, either temporarily, while studies are conducted, or permanently as preserves, such as is done in Hawaii and Australia. Increasing numbers of indigenous people depend upon coral reefs for their livelihood. However, development pressures often lead to unregulated use of coastal resources for short-term economic gains. Reef management can not ignore economic, social, and political realities in order to remain viable and achieve its primary goal of resource conservation.

Where reef management has occurred in less developed countries, it often focused mainly on fisheries development and marine preserve establishment. Reef fisheries are important resources of immediate concern for subsistence and commercial economies (Gawel, 1981). Johannes (1979, 1978b, 1982) recommended management measures for reef fisheries and coastal resources in some developing Pacific island areas. There are 58 coral reef marine parks in 17 countries (Salvat, 1981), with considerable variation in the ability of developing countries to manage parks and enforce their protective status (White, 1984). Both coral reef parks and fisheries development need to be integrated into a more comprehensive framework of reef management planning. A handbook for the management of coral reefs (Kenchington, 1984) has recently been published which will help to accomplish this.

Community-based reef management has been used in the Philippines to enforce the protective status of coral reef preserves (Castaneda

and Miclat, 1981). This relies on a program of marine conservation education which helps local fishermen to understand the benfit of maintaining some reef areas free from harvest pressures (Cabanban and White, 1981). Dahl (1981) proposed that residents of coral reef areas can also monitor the health of local reefs using standard, simplified techniques.

Traditional Resource Management

Traditional forms of reef resource conservation and management still exist in parts of Oceania (Johannes, 1977). Although these practices have been considerably degraded, there is potential for their application, or revival, to support and complement current management of reef resources by government agencies. Johannes (1978a) describes the ecological value of reef and lagoon tenure in conserving reef resources. When local reef users control access to their own resources through marine tenure, they are likely to manage them for sustained use. It is in the best interests of those who control a given area to harvest it in moderation and thereby maintain high sustained yield, the returns from which benefit the owners. When resources are available to all users in a region, no one is responsible for, or concerned about, their continued availability. Reef and lagoon tenure systems in Oceania have usually not survived the introduction of monetary economies; the breakdown of traditional authority; and the imposition of foreign concepts, laws and practices of land, sea, and resource ownership (Johannes, 1977, 1978a). However, where reef and lagoon tenure is still strong in Oceania,

legislation has sometimes formalized traditional management so that local municipalities control and police their own reef areas and resources, protecting them from degradation and over-exploitation.

Resource management practices to conserve Pohnpei's coastal resources are a part of traditional Pohnpeian use of reef and lagoon areas, and include reef and lagoon tenure, preferential allocation of marine food harvests, and special reef areas associated with legends and cultural activities. Until recently, very little was known of these traditional methods of reef management, which have declined or disappeared along with the general changes occurring in Pohnpeian culture.

Ownership of the coral reefs and lagoon surrounding Pohnpei was tradionally divided among the island's five major clan groups. Political boundaries extended from the central highlands to the shore and continued out beyond the barrier reef (Nakayama and Ramp, 1974). The ultimate control of each reef area and its resources belonged to the clan head, or Nanmwarki (Sudo, 1984). However, each village within a clan district had rights to specific inshore areas which its residents were free to exploit (Fischer, 1958).

With the advent of foreign control of Pohnpei, reef tenure began to be replaced with Western concepts of sea rights. During the German period, from 1899 to 1914, all areas seaward of the mangrove forest were specifically declared common property, a condition which was reinforced during the Japanese era (Sudo, 1984). Common ownership of reef and lagoon areas was not changed during the U.S administration from 1945 to the present and today all lands below high water mark

fall under the jurisdiction of the Pohnpei State Public Lands Authority (PLA) with open access for all Pohnpeians to all reef and lagoon areas and their resources.

The reestablishment of a modern form of local reef tenure, drawn along the lines of current municipal government districts, has been proposed (Johannes, 1978b). There are benefits to reef and lagoon tenure, but, according to the fishermen interviewed, it would not be workable to revive these practices which were lost generations ago on Pohnpei, and have not been used since. There are many problems associated with attempting to revive this traditional form of reef mangement and incorporate it into modern coastal resource management. These include: determining appropriate enforcement measures; regulating bait fishing, which utilizes large lagoon areas; and allowing use of leeward reef areas by members of windward districts whose resources may be inaccessible during bad weather. The recommendation to reestablish reef and lagoon tenure did not receive support from marine resources agencies on Pohnpei and has not been pursued.

Johannes (1978a) described the value of chiefly controls on marine food harvest and allocation in conserving reef and lagoon resources. On Pohnpei, the harvest of certain fish during periods of scarcity was declared forbidden by chiefs in the past. In addition, chiefs had preferential rights to certain marine food resources, particularly sea turtles, when they were caught by commoners (Coale, 1951). Some fish and other marine foods were, and in many cases still are, presented to high ranking members of Pohnpeian society during feasts (Reisenberg,

1968), but the degree to which this practice persists has not been documented. The process of cultural change in Pohnpei has resulted in the breakdown of traditional patterns of marine food resource use and allocation (Coale, 1951), and there are no investigations into the application of this traditional form of resource management to the present situation.

According to the fishermen interviewed, there are particular patch reefs and portions of the fringing and barrier reef of Pohnpei which were established as special reef areas. These continue to have cultural significance to Pohnpeians and are considered off-limits for certain kinds of use. These reef areas are important links between traditional Pohnpeian society and its reef environment, and their cultural importance serves to protect them from major disturbance. Information on these sites is very limited because their value is strongly linked to cultural practices, legends, and traditional knowledge of resource use which is not readily divulged to outsiders. These special reef areas are important as sites of traditional cultural activities (e.g. testing of newly made gill nets) or as traditional fishing grounds which are especially productive and associated with legends.

Although little is known of these areas and few of them have been mapped, a number of instances in which modern development has threatened culturally important reef sites have been met with very strong opposition from local residents. However, because the location and relative importance of these special reef areas are not widely

known, they are liable to be inadvertently disrupted or destroyed by unplanned development activities.

Goals and Objectives for the Management of Pohnpei's Reef Resources

With growing island populations, expanding urban centers, increasing coastal development, and the continuing need for subsistence use of reef resources, Pohnpei's coral reefs require management that integrates traditional knowledge and uses, modern marine scientific research, and the necessity for development. Information and analysis presented in Chapter IV on the characteristics, values, problems, and status of exisitng management of Pohnpei's reef resources and their uses, reveals the problems and needs for management planning. To address these problems and needs, four main goals have been identified:

1. To provide for maximum multiple use of Pohnpei's reef resources with minimum conflict in use;
2. To conserve the biological resources and ecological integrity of Pohnpei's reef and lagoon ecosystem;
3. To maximize sustainable human use of reef resources for traditional pursuits, subsistence requirements, and development activities consistent with conservation goals; and
4. To prevent conflicting uses of Pohnpei's reef resources, both between different human uses and between human uses and natural uses which require undisturbed reef habitats.

Given the wide range of traditional, special habitat, cultural, recreational, renewable resource, materials extraction, construction, and polluting uses of Pohnpei's reef and lagoon resources, it is neccesary to establish priority objectives to achieve management goals. The most important of these objectives are:

1. To provide for the conservation of reef food resources for continued subsistence use;
2. To protect reef areas of particular biological, ecological, or cultural importance from degradation;
3. To preserve especially significant unique, representative, and pristine reef habitats from disturbance and degradation;
4. To provide for the protection and viability of rare, threatened, or endangered species;
5. To designate appropriate locations for continued reef flat dredging, sand mining, filling, and construction uses; and
6. To develop specific management recommendations for reef areas where serious degradation or conflicts in use already exist.

Reef Management Approaches and Strategies for Pohnpei

To implement these goals and objectives, approaches and strategies for reef management must be identified from among the many that are available. The comprehensive approach of CZM planning should be applied to the management of reef resources on Pohnpei, because the entire island is effectively within the coastal zone. However, the small size of land areas and governments in Micronesia does not always allow CZM models developed for countries with larger resource and

administrative bases to work. Hence the emphasis is better placed on coastal resources management, rather than CZM. General features of CZM which are applicable to Pohnpei are the initiation of coastal resource surveys and monitoring, the integration of various levels of government resource management, and the comprehensive management of terrestrial and nearshore environments as interacting ecosystems.

In general, ecological principles for the management of tropical coastal and island ecosystems (Maragos, et al., 1983; McEachern and Towle, 1974; Odum, 1975), and mangroves (Baines, 1981; U.N. FAO, 1982; East West Center, 1984; Teas (ed.), 1984) should be adhered to on Pohnpei. These guidelines should be integrated into existing and newly developed resource management programs. At present, the Compact of Free Association provides no funds or programs for coastal resource management or CZM program development in the FSM, and the prospects for U.S. support in these fields are low.

Specific management approaches, particularly avoidance, amelioration, and monitoring measures (Maragos, et al., 1983), provide the basis for developing detailed management plans. Stategies for avoidance, especially reef zoning, preempt the unnecessary degradation of resources or conflicts in their use by assigning compatible uses to the same zone. Reef zoning provides a hierarchy of progressively more protected areas and designates areas for construction, materials extraction, or polluting activities. Reef zones also provide a framework for the more specific application of amelioration and monitoring, and for more specific avoidance measures. Amelioration seeks to reduce or correct problems associated with a particular use

through regulation. Monitoring refers to the repeated assessment of resource qualities or conditions to determine if a resource is being degraded or if remedial actions to correct degradation are effective. Amelioration and monitoring measures include: permit procedures, water quality monitoring, environmental quality monitoring, fisheries monitoring, seasonal and species closures, and facilities siting (Table 4). Reef zoning for Pohnpei and additional reef management measures are discussed in more detail in the following section.

Some forms of traditional reef management may be incorporated into modern governmental coastal resource management. Johannes (1978b) proposed that reef and lagoon tenure be re-established in Pohnpei, but the length of time which has passed since it was actively practiced on Pohnpei seems to preclude its formal, or informal, incorporation into modern reef management. However, mangrove resources are currently managed at the municipal level. Within island-wide guidelines for coastal resource management, it is possible that reef resources can be managed at this level as well. If marine tenure in particular is found to be a viable management practice in certain areas or instances, it should be cultivated and integrated within overall reef management.

Reef management zones

Five types of reef zones have been defined for the management of Pohnpei's reef resources, ranging in a hierarchy from the least to the greatest amount of protection: 1) General Use, 2) Sustainable Use, 3) Seasonal Preserves, 4) Species Preserves, and 5) Marine Parks. Reef

Table 4

Reef Management Strategies

Reef management zones

1. General Use
2. Sustainable Use
3. Seasonal Preserve
4. Species Preserve
5. Marine Park

Reef management measures

a. Permit Procedures
b. Water Quality Monitoring
c. Environmental Quality Monitoring
d. Fisheries Monitoring
e. Seasonal and Species Closures
f. Facilities Siting
g. Emergency Planning
h. Land Use Management
i. Hazardous Substances Management

management zones delineate specific reef areas within which resource uses are regulated and other management strategies are applied. Each zone and its complementary management activities will be described more fully. Within a zone, multiple reef uses which do not conflict with each other, or with the level of protection desired for that zone, are allowed. Some uses are provisionally allowed by permits from regulating agencies, while others are prohibited entirely. Depending upon the uses which are allowed in each zone, specific amelioration and monitoring activities may, or may not, be necessary to complement the management of the area. Detailed application of reef zoning to Pohnpei is described in the next chapter.

The zoning plan requires guidelines and criteria to assist in the delineation of reef management zones. Many of the guidelines developed by the Great Barrier Reef Marine Park Authority (Kenchington, 1984; GBRMPA, 1985) in its reef zoning experience have been adapted for the zoning of Pohnpei's reefs. These are that:

1. Zone boundaries should be as simple as practical and rely on prominent geographical features to aid their recognition;
2. Zone areas should include discrete reefs or reef sections to aid in zone boundary delineation and identification;
3. Zones which permanently remove reef resources from human use, or reduce their yield, should be carefully considered and kept to a minimum;

4. Zones should provide for adequate conservation of reef habitat, especially of those areas and species important for subsistence use; and
5. Highly protected areas should be separated from zones of relatively little protection by buffer areas.

The objectives of each type of reef zone are described below beginning with the least restrictive type.

1. General Use Zone

Existing and planned shoreline and water-dependent commercial and industrial facilities and activities should be located in general use zones, as should other facilities or activites which are likely to result in acceptable levels of water pollution and reef degradation which cannot be sited outside the coastal area. Even so, most general use zone activities require permits, with stipulations to ensure pollution control and minimal environmental effects. Reef areas recommended for particularly important or destructive reef uses, such as sand mining and reef flat dredging, will only be allowed in specifically designated general use zones.

2. Sustainable Use Zone

The primary purpose of sustainable use zones is to provide for the maximum sustainable yield of renewable reef resources, especially subsistence fish. In this zone, harvest of renewable resources is permitted by means, and at rates, which will not permanently deplete the resources. Most other non-extractive, non-destructive uses of

reef resources are also allowed in sustainable use zones, although some activities require consent and are regulated by permit. Sustainable use zones are intended to provide buffer areas around seasonal preserves, species preserves, and marine parks. All reef areas not otherwise zoned (marine parks, preserves, general use) will be zoned for sustainable use.

3. Seasonal Preserves

Seasonal reserves allow for particular reef areas to be closed for specific time periods to replenish stock or to protect important habitats during critical times (e.g. during spawning aggregations of reef fish). During the rest of the year, seasonal preserves should be designated as part of the sustainable use zone which surrounds them.

4. Species Preserves

In species preserves, the removal or disturbance of specific organisms which have been identified for protection is prohibited. Other uses which do not conflict with this objective are allowed. Species preserves thus serve as sanctuaries for particular plants or animals which are rare, threatened, endangered, or of special use value. For all other organisms, species preserves function as sustainable use zones.

5. Marine Parks

Marine parks protect reef areas for the replenishment of fish and other renewable resources and maintain them free from major dirtubances and harvest pressures. Fishing, collecting, or other harvest activities are prohibited in marine parks. Scientific, educational, and recreational uses of a non-disruptive, non-extractive nature are allowed. Marine parks also allow opportunities for the monitoring of reef habitats, biological communities, and resources in relatively undisturbed conditions. Marine parks serve as critical or important habitat for rare, threatened, or endangered species, supplementing the protection these organisms may receive in species preserves.

Reef management measures

A variety of management measures are required to complement and reinforce the reef management provided by reef zones, which alone do not ensure adequate resource conservation. Some of these measures are already employed to some extent on Pohnpei by various agencies. Detailed application of these measures to Pohnpei's reef resources and their uses is described in the next chapter.

a. Permits

Many reef activities require permits to ensure that the proposed use is consistent with environmental and social goals, as determined by the permitting agency. Permits also give the controlling agency the ability to gather data on the reef uses, to encourage responsible

reef resource use, to separate conflicting uses, and to assess appropriate fees for particular reef uses. However, the granting agency should be responsible for the monitoring and consequences of the permitted use.

b. Water Quality Monitoring

Monitoring of reef and lagoon water quality is neccessary in areas where sewage or solid waste might create a public health hazard. This is especially true where waters receiving wastes are adjacent to recreational and subsistence use areas. Regular sampling, in key locations throughout Pohnpei's reef and lagoon waters, would determine if water quality is deteriorating. Selected marine park and preserve waters might also be monitored to assure that they remain free from significant pollution.

c. Environmental Quality Monitoring

Monitoring of reef environmental parameters, other than water quality, would reveal reef ecosystem degradation. Indicator organisms, such as certain algae, corals, mollusks, or reef fish, or physical conditions such as turbidity or terrestrial sediment accumulation could be monitored at a series of representative stations to track reef conditions over extended periods of time. Dahl (1981) developed methods by which local residents may accomplish some of this monitoring with a minimal amount of training. Monitoring of environmental quality in marine parks and preserves would provide information on whether these areas are being disturbed. Monitoring at

locations of potential major reef degradation (e.g. dredge sites, sewage outfalls, causeways) could indicate whether environmental impact controls are effective.

d. Fisheries Monitoring

Populations of important harvested species of reef fish, aquarium export fish, and other target species should be monitored to determine if stocks are maintaining themselves or are becoming depleted by over-harvest or habitat loss. Marine parks offer opportunities to census unexploited fish populations and to determine if these populations help replenish depleted stock outside the parks. Catch statistics, determination of catch per unit effort, and other stock asessment techniques, can provide information on the condition of fish populatons. However, it is very difficult to obtain accurate data for subsistence and artisanal fisheries.

e. Seasonal and Species Closures

Seasonal preserves and species preserves, respectively, temporarily close specific reef areas and protect specific species from harvest pressures. Sites of reef fish aggregations for spawning would be particularly suited to this form of management. Other reef areas where fishing pressure is especially heavy, and where stocks have become locally depleted, might be temporarily closed to allow populations of exploited species to recover. Particular species, which are subject to depletion, may be declared protected in a given area but other sustainable yield uses will be allowed to continue.

f. Facilities Siting

Facilities which are potentially major point sources of pollution should be sited away from marine parks, seasonal and species preserves, and important fisheries in sustainable use zones, to prevent degradation of valuable reef habitat and biological resources.

g. Emergency Planning

Plans, training, and equipment should be maintained to enable appropriate agengies to respond, contain, and clean up emergency pollution situations (e.g. oil spills, sewage plant overflows, pesticide spills).

h. Land Use Management

Land use changes should be regulated to ensure that vegetation is not unneccessarily removed and that proper erosion controls are maintained during land clearing and road construction. Major land use changes, land clearing, and earthmoving should require permits to ensure that adequate planning, erosion control, and runoff reduction measures are included.

i. Hazardous Substances Management

All storage and transfer facilities for oil products should be maintained at standards which reduce the possibility of chronic or disastrous spillage, and personnel should be trained to properly handle these substances. Use of pesticides and other dangerous chemicals should be carefully controlled, and the users of such chemicals adequately trained.

CHAPTER VI

REEF RESOURCE MANAGEMENT PLAN: ZONES AND RECOMMENDATIONS

This chapter presents details of the proposed reef management zones as applied to Pohnpei and portrayed on maps from the Pohnpei Coastal Resource Atlas (Manoa Mapworks, 1985) (Appendix 1). The location, rationale, and allowed uses for each zone are discussed. Use specific recommendations for the management of activities allowed in each zone follow. Comparing reef resource uses (Table 2) with reef management strategies (Table 4), forms a matrix which shows the management strategies which are appropriate for each use (Table 5).

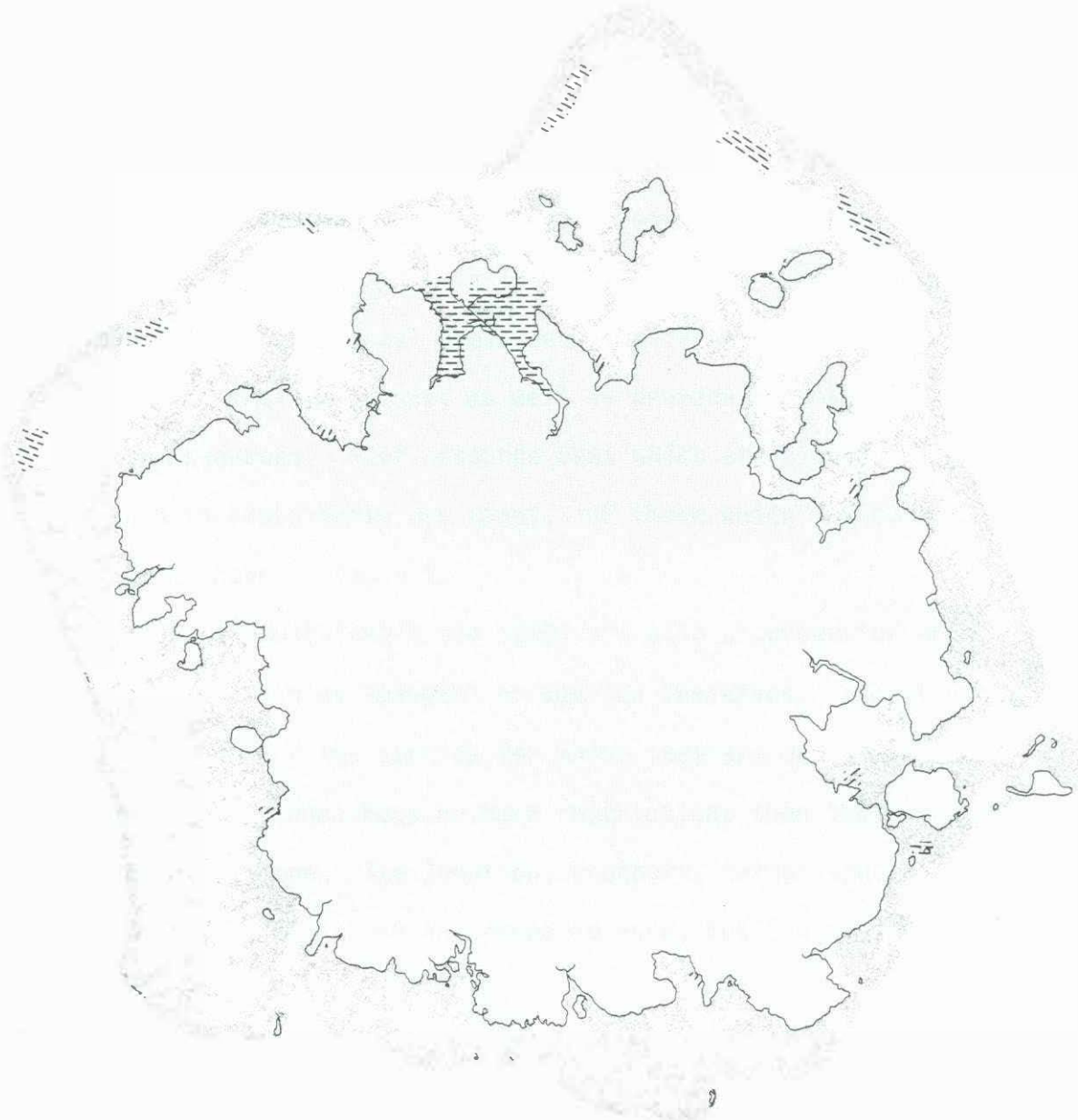
Application of Reef Management Zones

1. General Use Zone

Designation of zones for general use are proposed around Kolonia and Taketik Island, and in Tuanmokot and Daukosele Channels (Fig. 27) (Appendix 1, Maps 4, 19, 21). A general use zone has also been delineated around Nahnningi Islet (Appendix 1, Map 10), which is developed as a recreational and overnight visitor destination. General use zones for dredging are proposed around Pohnpei at previously or currently used dredging sites (Appendix 1, Maps 4, 6, 8, 11, 15, 19). These sites should be used fully before new dredging areas are opened. General use zones for sand mining are proposed in areas where sand deposits on the lagoon slope of the barrier reef are

Figure 27

Proposed General Use Zones



found near to Kolonia, but away from major subsistence use areas (Appendix 1, Maps 1, 3, 5, 18, 20, 21). Sand extraction from some currently used sand mining sites should be discontinued because they are near to, and cause disruption of, subsistence reef fisheries (Appendix 1, Map 1). Uses which are allowed, prohibited, or allowed by permit only in general use zones are indicated in Table 5.

2. Sustainable Use Zone

Proposed sustainable use zones cover most of Pohnpei's reef and lagoon area (Fig. 28) (Appendix 1, Maps 1-21). These zones are designed to buffer seasonal preserves, species preserves, and marine parks from general use zones, as well as provide for harvest of renewable resources. Reef resource uses which are allowed or prohibited in sustainable use zones, and those which may be allowed by permit, are shown in Table 5.

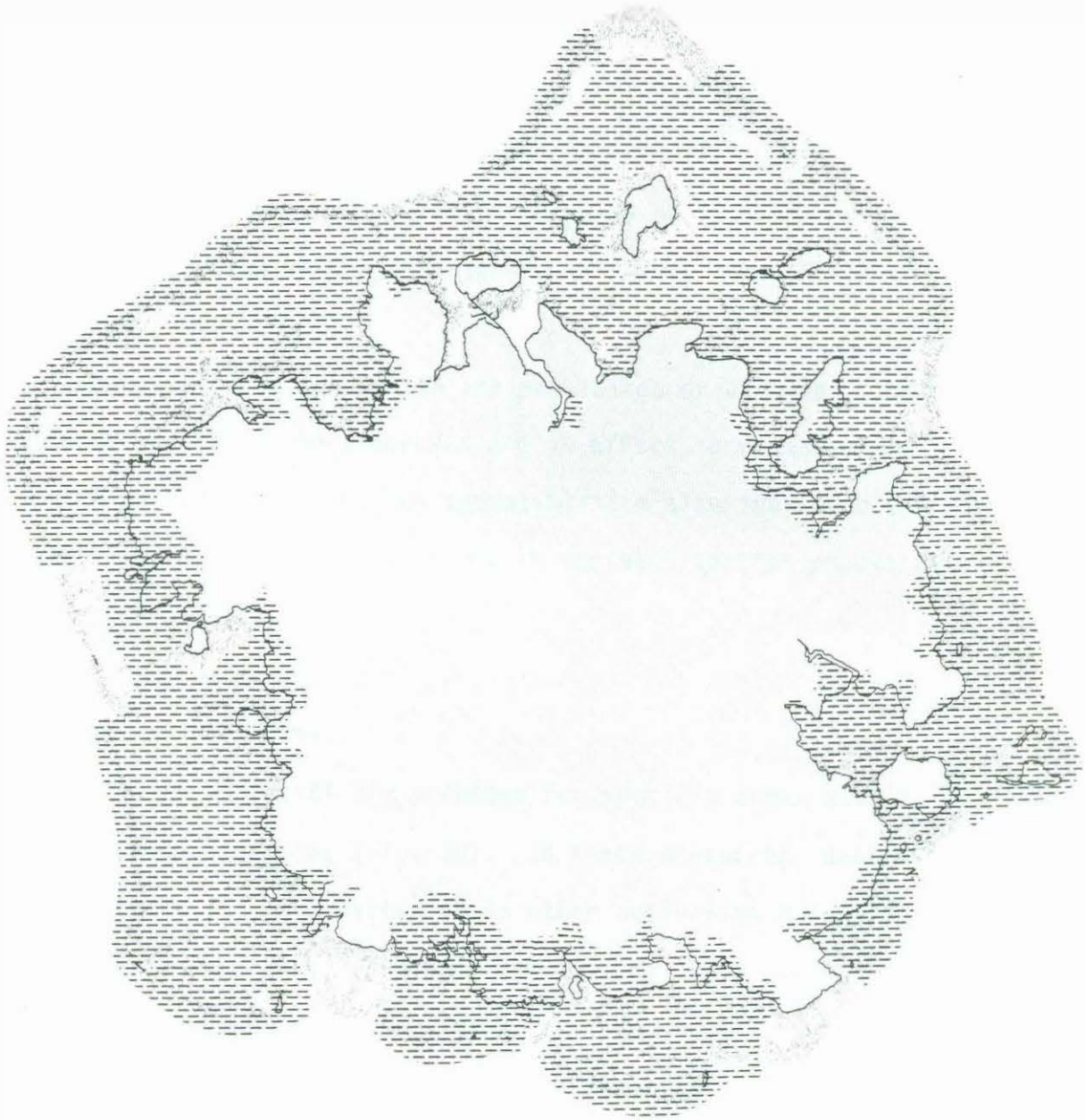
Portions of sustainable use zones are also proposed for more specific protection as seasonal or species preserves. Except for the time period, or for the species for which they are designated as preserves, these zones have no more restrictions than the surrounding sustainable use zone. The location, boundary, target species, and seasons for such preserves are proposed here, but DMR may see fit to propose others.

3. Seasonal Preserves

Seasonal preserves are designated in sustainable use zones to protect small areas from all use for specific time periods (Fig. 29).

Figure 28

Proposed Sustainable Use Zones



Seasonal preserves are proposed for reef fish spawning aggregation sites which are not otherwise protected in species preserves or marine parks (Appendix 1, Maps 8-9, 14). The timing of seasonal preserves should be set by DMR to correspond with documented spawning aggregation periods (USACE, 1985). Additional information on spawning periods should be sought from fishermen as necessary. The declaration of seasonal preserves should be widely publicized over the radio and to fishermen encountered by DMR reef patrols to ensure the user population is aware of the areas and time periods involved. DMR should designate seasonal preserves as needed in addition to those proposed here.

Reef resource uses which are prohibited or allowed in seasonal preserves, while the preserves are in effect, are summarized in Table 5. Other uses which may be compatible are also indicated and more specific information is provided in the next section on use specific recommendations.

4. Species Preserves

Species preserves are proposed for specific areas within sustainable use zones (Fig. 30). In these preserves, designated species are fully protected while other activities normally allowed in sustainable use zones, which do not disturb the protected species or its habitat, are permitted. Mant Pass (Appendix 1, Map 3) is proposed as a species preserve for the black trigger fish (Melichthys niger) which is only known from that area on Pohnpei.

Figure 29

Proposed Seasonal Preserves

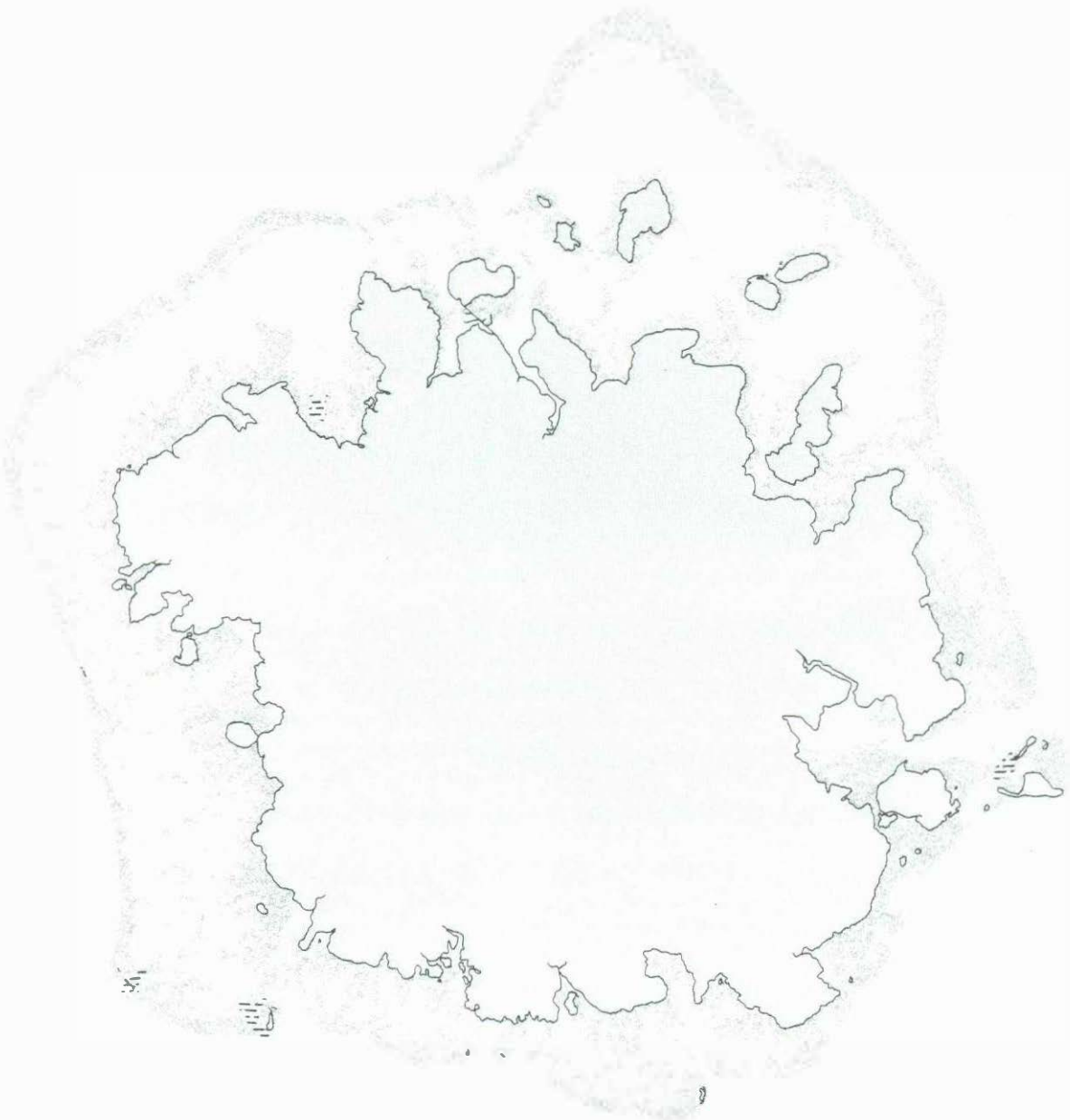
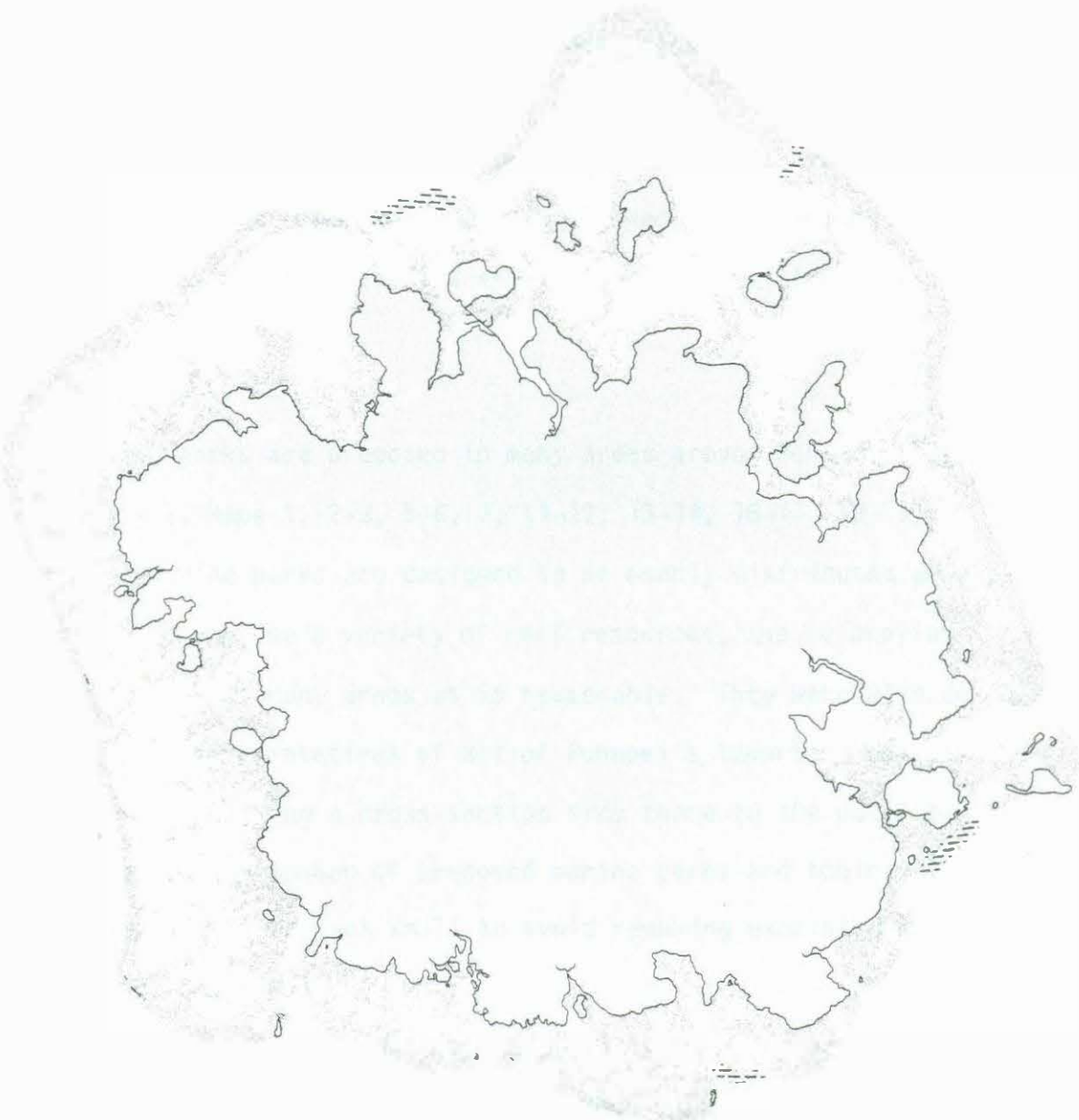


Figure 30

Proposed Species Preserves



Elsewhere, existing Trochus sanctuaries that have not been included in marine parks are proposed as species preserves (Appendix 1, Maps 9-12, 21). It is also proposed that giant clams (Tridacna spp. and Hippopus spp.) and lobsters (Panulirus sp.) be designated as protected species within these preserves. The DMR should administer the species preserves and consider other areas and species for similar protection as warranted.

Uses which are allowed or prohibited in species preserves are shown in Table 5. Uses which may be allowed, depending on their interaction with the protected species, are also listed.

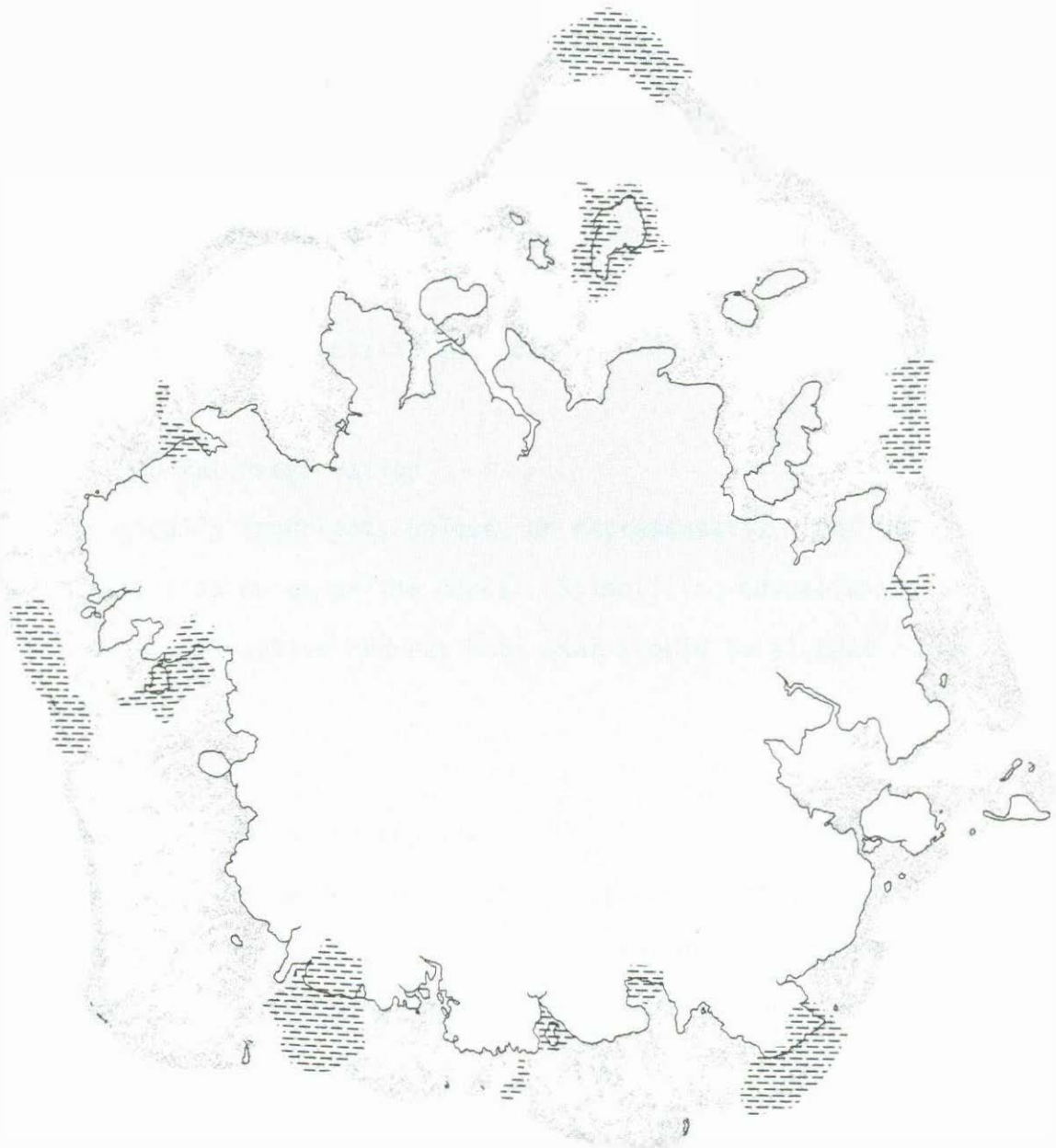
5. Marine Parks

Marine parks are proposed in many areas around Pohnpei (Fig. 31) (Appendix 1, Maps 1, 2-3, 5-6, 7, 11-12, 13-14, 16-17, 18-19). Proposed marine parks are designed to be evenly distributed around Pohnpei, to include a variety of reef resources, and to provide protection to as many areas as is reasonable. They were also designed to include representatives of all of Pohnpei's important coastal habitats by covering a cross-section from shore to the outer barrier reef slope. The number of proposed marine parks and their minimum essential size were kept small to avoid removing excessive reef areas from sustainable use.

Trochus sanctuaries not designated as species preserves were included in marine parks (Appendix 1, Maps 1, 5-6, 16-17). Seabird nesting areas on the mangrove islets on the west barrier reef were included in a marine park zone (Apendix 1, Maps 16-17). In addition,

Figure 31

Proposed Marine Parks



all special reef areas (Appendix 1, Maps 11-12) and all fish spawning aggregation sites not designated as seasonal preserves (Appendix 1, Maps 1, 6, 11, 13-14) were included in marine parks. Reef resource uses which are prohibited or allowed in marine parks are listed in Table 5. Uses which may be compatible with marine parks, if they include appropriate regulation, are also shown in the table and are discussed in the next section on use recommendations.

Application of Reef Management Measures

A. Habitat Uses of Special Significance

1. Reef Habitat Preservation

Ecologically important, unique, or representative reef habitats should be set aside as marine parks. Scientific, educational, and selected non-disruptive recreational uses should be allowed by permit from DMR.

2. Reef Fish Spawning Aggregation

Important sites where reef fish aggregate to spawn sites should be included in marine parks or preserves. Fish populations which may be over-fished during spawning aggregations should be monitored by DMR to determine if seasonal preserves are needed during their spawning periods. Particular species may also be protected by declaring their spawning sites as species preserves. Prohibiting the commercial sale, during spawning season, of fish which are subject to over-fishing

Table 5

Reef Resource Use / Management Strategy Matrix

KEY: Reef Management Zones
+ = zone should probably allow this use
0 = zone could possibly allow this use, with regulation
- = zone should probably not allow this use
no symbol = reef management zones do not apply to this use

Reef Management Measures
+ = management measure should probably be applied to this use
0 = management measure could possibly be applied to this use
- = management measure should probably not be applied
no symbol = management measure does not apply to this use

Reef Uses	Reef Management Stratgegies (see Table 4) Zones					Measures								
	1	2	3	4	5	a	b	c	d	e	f	g	h	i
A) Habitat Uses of Special Significance														
1. Reef habitat preservation	-	-	0	0	+	0	+	+	+	0	-	-	-	-
2. Fish spawning aggregation	-	+	+	+	+	-	0	+	+	+	-	-	-	-
3. Reef fish migration	-	+	0	0	+	-	0	+	+	0	-	-	-	-
4. Sea turtle nesting	-	+	+	0	+	-	-	+	+	+	-	-	-	-
5. Sea turtle feeding	-	+	0	0	+	-	0	+	+	0	-	-	-	-
6. Sea bird nesting	-	+	0	0	+	-	-	+	-	0	-	-	-	-
7. Acanthaster outbreaks						-	-	+	-	-	-	+	-	-

Table 5 (Continued)

Reef Resource Use / Management Strategy Matrix

Reef Uses		Reef Management Strategies (see Table 4) Zones 1 2 3 4 5	Measures a b c d e f g h i
B) Renewable Resource Harvesting: Traditional and Commercial			
1. Shallow reef fish	traditional	+ + 0 0 -	- - 0 + 0
	commercial	+ + 0 0 -	0 - 0 + +
2. Bottom fish	traditional	+ + 0 0 -	- - - + 0
	commercial	+ + 0 0 -	0 - - + +
3. Pelagic fish	traditional	+ + 0 0 -	- - - + -
	commercial	+ + 0 0 -	0 - - + 0
4. Baitfish	traditional	+ + 0 0 -	- - - + -
	commercial	+ + 0 0 -	0 - 0 + 0
5. Aquarium fish		+ + 0 0 -	+ - 0 + +
6. Lobster	traditional	+ + 0 0 -	- - - + 0
	commercial	+ + 0 0 -	0 - - + +
7. Mangrove crab	traditional	+ + 0 0 -	- - - 0 0
	commercial	+ + 0 0 -	0 - - + +
8. Octopus		+ + 0 0 -	- - - 0 -
9. Trochus		+ + 0 0 -	- - - + +
10. Anadara clam		+ + 0 0 -	- - - 0 -
11. Giant clam		+ + 0 0 -	- - - + +

Table 5 (Continued)

Reef Resource Use / Management Strategy Matrix

Reef Uses		Reef Management Strategies (see Table 4) Zones 1 2 3 4 5	Measures a b c d e f g h i
12. Kopil clam		+ + 0 0 -	- - - 0 -
13. Ornamental shell		+ + 0 0 -	0 - 0 + 0
14. Sea cucumber	traditional	+ + 0 0 -	- - - 0 -
	commercial	+ + 0 0 -	0 - - + +
15. Precious coral		+ + 0 0 -	+ - - + +
16. Mangrove wood	handicraft	+ + 0 0 -	- - 0 - -
	lumber	+ + 0 0 -	+ 0 + 0 0 +
C) Cultural and Recreational			
1. Archeological sites		- + - +	0 - + - - - - - -
2. Visitor recreation		+ + 0 0 0	+ + + 0 - + 0 0 -
3. Resident recreation		+ + 0 0 0	- + + 0 - + - 0 -
4. Sport diving		0 + 0 0 0	0 - 0 0 0 - - - -
5. Sport fishing		+ + - - -	+ - 0 + 0 - - - -

Table 5 (Continued)

Reef Resource Use / Management Strategy Matrix

Reef Uses	Reef Management Strategies (see Table 4) Zones 1 2 3 4 5	Measures a b c d e f g h i
D) Construction and Reef Materials Extraction		
1. Reef flat dredging	+ - - - -	+ + + + - + - - -
2. Sand mining	+ - - - -	+ + + + - + - - -
3. Channel dredging	+ 0 - - -	+ + + + - + - - -
4. Manual sand removal	+ + 0 0 0	- - 0 0 - - - - -
5. Coral removal	+ 0 - - -	0 - 0 + 0 - - - -
6. Causeway construction	+ 0 - - -	+ + + + - + - - -
7. Landfill construction	+ 0 - - -	+ + + + - + - + -
8. Commercial waterfront development	+ - - - -	+ 0 + 0 - + 0 0 0
9. Aquaculture development	+ 0 - - -	0 - 0 0 - + - - -
10. Navigation aids installation	+ + 0 0 0	- - - - - - 0 - - -

Table 5 (Continued)

Reef Resource Use / Management Strategy Matrix

Reef Uses		Reef Management Strategies (see Table 4) Zones 1	2	3	4	5	Measures a	b	c	d	e	f	g	h	i
E) Lagoon Water Pollution															
1. Solid waste disposal		+	-	-	-	-	+	+	+	-	-	+	0	+	+
2. Sewage waste disposal	local	+	0	-	-	-	-	+	0	0	-	0	-	+	-
	treated	+	-	-	-	-	+	+	+	0	-	+	+	+	+
3. Land clearing							+	+	+	0	-	0	-	+	-
4. Road construction							+	+	+	0	-	+	-	+	-
5. Pesticide use		+	-	-	-	-	+	+	+	0	-	-	+	0	+
6. Oil products storage and transfer		+	-	-	-	-	+	+	+	0	-	+	+	-	+
7. Power plant operation		+	-	-	-	-	+	+	+	+	-	+	0	-	+

during spawning was proposed by Johannes (1978b) for rabbitfish and grouper, and enacted for the latter. Similar legislation should be proposed by DMR if it determines that rabbitfish, or other species, are over-harvested during spawning aggregations.

3. Reef Fish Migration

Major pathways for reef fish migration should be included in sustained use zones or marine parks. Permits for landfills, construction, or dredging activities on reef flats should be required. Consultation with local resident reef users and the DMR should be part of the permit stipulations, to determine whether important reef fish migration paths would be affected, culverts, or bridged openings are needed, and relocation of fill projects is warranted.

4. Sea Turtle Nesting

Green sea turtles and their nests should be monitored by DMR or FSM Marine Resources Division to establish population levels and determine if continued subsistence harvest is a threat to survival of local sea turtle populations. One or more of the sandy barrier reef islets should be designated as a marine park or species preserve for sea turtles, or as seasonal preserve during nesting periods.

5. Sea Turtle Feeding

Sea turtle feeding areas, particularly the extensive seagrass beds on the southern and southeastern fringing reefs, should be included in

sustainable use zones. Existing forms of protection for green and hawksbill turtles should be supported by DMR research and monitoring of population levels, feeding activity, movements, and subsistence harvest.

6. Sea Bird Nesting

The Peinantomaea (or Dawahk) islets on the barrier reef west of Paliker should be included in a marine park to protect the nesting seabirds. Other seabird nesting locations should be examined by USFWS for possible inclusion in marine park or preserve zones. Seabirds should be censused by USFWS to estimate and monitor their populations.

7. Acanthaster Outbreaks

Periodic monitoring of Acanthaster populations should be continued by DMR. Local reef users should be encouraged to assist by reporting unusually large aggregations of the starfish. Control measures should be considered by DMR only if large scale infestations threaten important reef resources.

B. Renewable Resource Harvesting: Traditional and Commercial

1. Shallow Reef Fish

Subsistence reef fishing areas should be included in sustainable use zones to preclude depletion of stocks and degradation or destruction of important reef habitat. Marine parks, seasonal preserves, and species preserves should be established in sufficient

areas to ensure the continued availability of important subsistence reef fish. Particular attention should be given to the protection of spawning aggregation sites and important species which are already depleted.

Monitoring of preferred subsistence reef fish and commercially exploited species should be expanded by DMR to determine if stocks are being over fished. Examination and testing of reef fish harvested from disturbed or polluted areas should be undertaken regularly to check for public health hazards. Gear restrictions suggested by Johannes (1978b), including a ban on the sale of speared fish and the import of gill nets less than 2.5 inches (6.3 cm) stretched mesh size, should be implemented.

It is recommended that the role which traditional practices of marine food resource allocation play in the harvest of reef and lagoon food resources be investigated. In particular, information should be collected on which food species continue to be preferred and in what amounts fish are harvested for cultural events (e.g. feasts, funerals).

2. Bottom Fish

Bottom fishing areas should be included in sustainable use zones and commercial fishing of target species should be authorized only by permit from DMR. To aid fisheries management, permit conditions should require users to report catch statistics. Bottom fishing should be promoted to reduce pressures on already heavily harvested shallow water reef fisheries.

3. Pelagic Fish

Areas where pelagic fish are harvested by deep-water handlining should be included in sustainable use zones. Subsistence use of deep-water fishery resources should be expanded to reduce pressures on over-exploited reef and lagoon fisheries.

4. Baitfish

Baitfish harvest areas should be included in sustainable use zones. Protecting existing natural supplies of baitfish for subsistence pelagic fishing should be given priority over other uses of baitfish or development of commercial baitfish ventures.

5. Aquarium Fish

If the collection and export of aquarium fish resumes on Pohnpei, all exporters should be licensed by DMR or EDA and required to submit data on location, kinds, and amounts of fish collected. Destructive collecting practices, such as breaking up coral colonies, and the harvest of cleaner wrasses should be prohibited, as suggested by Johannes (1978b). Monitoring of catch statistics by DMR should provide enough information to determine if seasonal or species preserve status is needed to protect particular areas or species from over harvest.

6. Lobster

Since it appears impractical to prohibit all lobster spearing, as suggested by Johannes (1978b), commercial sale of lobster harvested by

spearing should be banned. Lobster harvest areas should be included in sustainable use zones. The harvest of egg bearing female lobsters and juveniles below a certain size limit (as set by DMR) should be prohibited. Lobster catch should be monitored by DMR to determine the condition of the fishery and evaluate the need for seasonal or species preserve status to allow stock replenishment.

7. Mangrove Crab

Mangrove crab harvest areas should be included in sustainable use zones and integrated with Pohnpei State Division of Forestry mangrove management plans. Permits for mangrove clearing should not allow exploitation of important mangrove crab habitat. Harvest levels should not exceed maximum sustained yields as set by DMR. The DMR should monitor mangrove crab harvest and assess the need for seasonal or species preserves to provide replenishment areas.

8. Octopus

Octopus harvest areas should be included in sustainable use zones.

9. Trochus

Existing Trochus sanctuaries that are not included in marine parks should be maintained by designation and management as species preserves. In these preserves the sustainable use of reef resources is permitted, except for the disturbance or removal of Trochus. A ban on the use of SCUBA gear while harvesting Trochus, proposed by DMR and supported by Johannes (1978b), should be enacted. Trochus harvest

areas outside the species preserves should be included in sustainable use zones. In sustainable use zones, Trochus habitat would be protected, and the controlled harvest of Trochus would be permitted during open season.

10. Anadara Clam

Major Anadara clam harvest areas should be included in sustainable use zones. Clams harvested in polluted areas should be tested by EPB to determine if they are contaminated.

11. Giant Clam

Species preserves should be established to protect giant clams and allow them to reach maturity and reproduce free from over-harvest pressure. Giant clams in the preserves would provide seed stock for other reef areas. Species preserves for giant clams could be included within the existing Trochus species preserves. Remaining giant clam harvest areas should be included in sustainable use zones.

12. Kopil Clam

Kopil harvest areas should be included in sustainable use zones. Permits should not allow clearing of mangrove adjacent to important Kopil harvesting areas. Kopil clams harvested in polluted areas should be periodically checked by EPB for contamination.

13. Ornamental Shell

The kinds and amounts of shells harvested for sale to tourists and collectors and for use in handicrafts should be periodically assessed to determine if management measures are required. Locations and methods of harvest might also be monitored to ascertain if destructive shell harvesting practices are used. If so, educational programs aimed at informing shell harvesters about the detrimental effects of destructive harvest practices should be developed by DMR.

14. Sea Cucumber

Werar and longon sea cucumber harvesting areas should be included in sustainable use zones. Populations of beche-de-mer species of sea cucumbers should be monitored by DMR or EDA if an export industry develops. Maximum sustainable yield levels and the need for seasonal preserves or species preserves should then be determined.

15. Precious Coral

Analysis of black coral harvest statistics by DMR or EDA should provide the basis for determining whether existing laws, which allow DMR to set seasons or close areas to black coral harvest, are adequate. If other precious coral beds are found on Pohnpei, similar legislation may be needed. Representative black coral areas should be given maximum protection by inclusion in marine parks.

16. Mangrove Wood

The bulk of Pohnpei's mangrove forest should be included in sustainable use zones in cooperation with Pohnpei State Division of Forestry. Certain forest areas should be provided with additional protection by inclusion in marine parks. The clear-cutting of large areas of mangrove forest where there is only a narrow band along the shore, or along the lagoon edge of the mangrove forest, should be prohibited. Landfills and other permanent removal of mangroves should be discouraged. Permits for the harvest of mangrove or the removal of mangrove for landfills should require evaluation of mangrove crab habitat, potential sediment release onto adjacent reefs, and alternative landfill sites in non-mangrove areas. Maximum area and rate restrictions for clear-cutting should be established to maintain maximum sustainable yield and reduce habitat loss. Existing and future demands for mangrove timber and fuelwood should be determined by the Division of Forestry to guide management planning.

C. Cultural and Recreational

1. Archeological Sites

The Pohnpei State Historic Preservation Office should continue and expand efforts to locate important archeological and historical sites and gather information on them. Significant archeological sites should be included in marine parks or sustainable use zones to protect them from extractive, contruction, and other degrading activities. In addition, it is recommended that studies be conducted, with the

assistance of, or by qualified Pohnpeians, to determine the location and relative value of traditionally significant reef areas so that they may be protected from inadvertant disruption. Known reef areas of cultural significance should be included in marine parks, preserves, or sustainable use zones.

2. Visitor Recreation

Development of archeological and historical sites as visitor destinations should preserve the integrity of the sites, the dignity of the culture, and encourage appropriate educational and scientific use.

Development of barrier reef islets with overnight accomodations and other facilities should be carefully planned due to the small size and ephemeral nature of sandy islets. Particular attention should be paid to sewage and solid waste disposal, fresh water supply and storage, and shoreline structures. In addition, local residents should participate in siting and design decisions to avoid conflicts in use and inadvertant disruption of subsistence reef activities by recreational uses. Islets which have already been, or will be, developed as visitor recreation destinations should be included in general use zones.

3. Resident Recreation

Use of "Lidakika Beach" for swimming in Tuanmokot Channel ought to be strongly discouraged, or prohibited, until water quality is improved and maintained at healthy levels through improvements in

waste water quality and disposal practices. Water quality in this area should be monitored by EPB to verify continued safe conditions.

Recreation on the otherwise unused dock at Net Point should be encouraged by properly developing it as a public park. Rubbish and accumulated machinery should be removed and toilet facilities installed by the PWC. Use of the adjacent boat channel for diving and swimming is probably difficult to discourage, but the DMR should post warnings to both swimmers and boaters.

Possibilities for other lagoon side recreational sites should be explored by the Pohnpei State Planning Office for aquisition and development as state or municipal parks with appropriate facilities.

4. Sport Diving

Hotel and tour operators which offer recreational diving should become informed of important subsistence reef use areas, especially fisheries, and plan excursions to avoid them. Spearfishing or harvest of other marine organisms while SCUBA diving should generally be discouraged or prohibited. SCUBA assisted harvest of species designated by DMR as vulnerable or over-exploited should be made illegal. Recreational divers should be encouraged, through DMR educational programs, to report incidents of reef degradation (e.g. Acanthaster outbreaks, dynamite fishing) to DMR.

5. Sport Fishing

Development of sport fishing on Pohnpei should not be allowed to compete with or disturb subsistence fisheries. If sport fishing operations do develop, licenses and fees should be used by DMR to encourage and enforce proper resource use.

D. Construction and Reef Materials Extraction

1. Reef Flat Dredging

Dredging of reef flat sand and rubble should be confined to designated dredging sites within general use zones. Existing dredge sites should be used to their fullest before new areas are dredged. Dredging zones should be sited to avoid marine parks, preserves, and important sustainable use areas. Environmental protection measures required in permits for dredging should be actively enforced. Coral and fish communities adjacent to dredging areas should be monitored by DMR to ascertain whether polution control measures are effective or need to be strengthened. Availability of suitable sources of fill and aggregate should also be examined by PTA and PWC.

2. Sand Mining

Mechanical removal of sand should be confined to designated sand mining sites within general use zones. Sand mining areas which are already officially designated and used should be used fully before new areas are mined. New sand mining locations should avoid marine parks, preserves, and important subsistence use areas in sustainable use

zones. License and permit procedures recently proposed by PLA should include provisions requiring the use of silt screens, or other barriers, to prevent the dispersal of turbid waters from the mining areas. Coral and fish communities adjacent to sand mining areas should be monitored by DMR to determine if pollution control measures are effective.

3. Channel Dredging

Permits for the mechanical dredging of reef channels should require the use of silt screens or barriers to contain suspended sediments. Permits should also require monitoring of water flow characteristics and nearshore processes to prevent alterations in erosional or depositional processes. Channel dredging proposed for sustainable use zones should minimize reef habitat and subsistence use losses and involve local reef users in decision making. Evaluation of less valuable sites for the proposed channels should be required. Channel dredging should be prohibited in marine parks and preserves.

4. Manual Sand Removal

Manual removal of moderate amounts of sand for local construction purposes should be allowed to continue, providing that sustainable subsistence harvest areas are not disrupted and material is not removed from barrier reef islets at rates which will create shoreline erosion problems. Manual sand removal should be prohibited from preserves and marine parks.

5. Coral Removal

Removal of coral of ornamental value for sale should be monitored by DMR to determine if the amounts and types of coral being taken warrant regulation. The removal of live coral for fill material should be prohibited and further discouraged through educational programs.

6. Causeway Construction

Permits for causeways should require assessment of local circulation patterns and the need, size, and location for culverts or bridged openings. Construction permits for causeways should require evaluation of sustainable reef resource use in the area, paying particular attention to fish migration paths. Permits should also require measures to control water pollution during construction and adjacent coral and fish communities should be monitored by DMR to determine the effectiveness of such measures. Causeways proposed in sustainable use zones should require participation of local residents in the decision making process. Causeways should not be permitted near or in preserves or marine parks.

7. Landfill Construction

Permits for landfills should require a full consideration of alternative non-coastal sites, and should only be allowed when all upland alternatives have been evaluated and exhausted. Major landfills should not be allowed where the mangrove forest is only a narrow band along the shore. Area-wide permits should be considered

for landfills in general use zones. Permits for landfills in sustainable use zones should require assessment of reef habitat and subsistence uses and require participation of local resident reef users in decision making. Permits should also require measures to control water pollution during construction and monitor adjacent coral and fish communities to determine the effectiveness of such measures. Landfills should be prohibited from marine parks and preserves. New landfills with over water latrines or pig pens should not be allowed in waters with inadequate circulation. Landfills for uses not dependent on access to the water should be strongly discouraged or prohibited.

8. Commercial Waterfront Development

Permits for commercial waterfront facilities should include assessment of possible changes in shoreline configuration which may affect water circulation patterns and natural processes of erosion and deposition. Commercial development not requiring siting on, or in proximity to, the lagoon should not be located on the shoreline.

9. Aquaculture Development

Reef flat seaweed farms should require permits from DMR. The permit process should include site evaluation to avoid disruption of local reef fish populations and subsistence harvest. Conversion of mangrove forest to mariculture should be prohibited or strongly discouraged and require evaluation of alternative sites.

Serious consideration should be given to the environmental and economic costs and benefits of mangrove conversion to aquaculture.

10. Navigation Aids Installation

The DMR should continue to maintain local reef markers and solicit advice on the need for additional markers. Damage or destruction of official U.S. Coast Guard approved channel markers and buoys should be reported for repairs.

E. Lagoon Water Pollution

1. Solid Waste Disposal

The EPB, PLA, and PWC should promptly evaluate and select an alternative to the municipal dump site on the lagoon side of Taketik Island, giving consideration to the recommendations of Patrick, et al. (1977). Prospects for private or government refuse collection service for Kolonia should be investigated by EDA. Proper waste disposal sites should be designated by EPB, PLA, and PWC in rural areas away from mangrove forests, and efforts should be made to clean up unauthorized mangrove and reef flat dumps. Penalties for indiscriminate dumping should include requirements to clean up the improperly disposed solid wastes. The current dumpsite at Taketik should be screened with vegetation and the lagoon edge diked by PWC to contain any runoff from the rubbish.

2. Sewage Waste Disposal

The construction of additional over-water latrines and the disposal of animal wastes should be discouraged in densely populated rural areas and prohibited along waters determined by EPB to be at or above their capacity to assimilate such wastes. Where hook up to the sewage treatment plant is not possible, water seal latrines, cesspools, or septic tanks should be constructed. Composting, methane digesting and alternative disposal methods for animal wastes should be developed and promoted by EDA in areas unable to cope with additional raw sewage.

The collection system for the sewage treatment plant should be upgraded and maintained by PWC so that storm water does not infiltrate the pipes. Sewage treatment plant operations should maintain proper treatment of waste waters, with acceptable chlorine levels in discharged effluent. Power outages at the sewage treatment plant should be investigated by PWC and prevented, if possible, to avoid dumping of raw sewage into lagoon waters around Kolonia. Installation of a back-up generator should be considered by the Pohnpei State Government. Monitoring of lagoon water quality adjacent to the sewage treatment plant outfall and in congested areas with over-water latrines and adjacent pig stys should be carried out on a regular basis by EPB.

Plans to extend the sewage treatment plant outfall should include water circulation studies to determine where the effluent will end up and the amount of mixing which will occur at the proposed discharge site. Alternative discharge sites through a deep pass outside the

barrier reef should be evaluated if studies indicate that extension of the outfall to the outer lagoon does not adequately dilute the effluent.

Plans to use mangrove swamp waters adjacent to the new capital complex at Paliker as sewage receiving waters should be based on a review of current literature on the subject, especially case studies elsewhere. A pilot project or on-site test should be conducted before proceeding further. If it is workable to discharge sewage treated in oxidation ponds into mangrove swamp waters, test studies on dilution and mixing should be conducted to estimate effects on water quality. If the system is implemented, water quality monitoring and bioassay testing of potential food resources in the area should be carried out by EPB at regular intervals.

3. Land Clearing

Proposals by EPB to require environmental impact statements for major earthmoving activities and to monitor these activities for compliance with soil erosion and runoff control standards should be adopted and expanded to include any form of major land clearing or land use change which involves vegetation removal. Streams and reefs adjacent to land clearing and earthmoving activities should be monitored by EPB and DMR for excessive suspended sediment loads. Downstream fish and coral communities should also be monitored by DMR for impacts from siltation. Permits for land clearing should have strict limits on slope clearing and require buffer strips of vegetation along watercourses and other erosion control measures.

4. Road Construction

Major road construction should require environmental impact statements. Permits for road construction should require an evaluation of alternative alignments; and that all proposed roads be surveyed and engineered to certain minimum standards set by EPB, PTA, and PWC. Cutting off of mangrove forest sections by road fills should be kept to a minimum and require culverts to maintain surface water exchange when it is unavoidable. Monitoring of road construction by EPB for compliance with erosion and runoff controls should be included in permit procedures. Stream and reef areas adjacent to watersheds disturbed by road construction, and their biota, should be monitored by EPB and DMR for excess suspended sediments and their impacts.

5. Pesticide Use

Plans by EPB to require registration of all imported pesticides and their users, and to monitor pesticide use should be adopted. Training programs for users should be required as part of the registration process. Water quality and edible organisms should be monitored by EPB for toxic pesticide levels in areas of heavy pesticide use or suspected abuse.

6. Oil Products Storage and Transfer

Plans to monitor all establishments which store, handle and sell oil products should be carried out by EPB. Training for those whose responsibility it is to contain oil spills should be conducted by

appropriate agencies with U.S. Coast Guard assistance, using best available technology and equipment. Oil spill prevention and contingency plans should be developed and periodically practiced.

7. Power Plant Operation

Operation of an oil or diesel fired power plant should require controls on the transfer and storage of oil products. Plans for the discharge of thermal effluents should require study of reef biota, subsistence uses and current and mixing patterns in the receiving waters. Levels and effects of thermal effluent discharge should be monitored by EPB and DMR.

CHAPTER VII

CONCLUSIONS

Zoning Plan Presentation and Revision

A working draft of plans which describe and map zones for the management of Pohnpei's reef resources should be circulated among appropriate agencies on Pohnpei. Discussion workshops should be held with representatives from these agencies, and other concerned government officials, to solicit their suggestions and criticisms. Detailed discussion of the reef management plans should be sought from persons who provided information during the resource user interviews. In addition, a series of public hearings should be conducted to familiarize reef users with proposals for the management of Pohnpei's reef resources and to receive their feedback. In all of these gatherings, emphasis should be placed on soliciting constructive criticism of planning proposals. Feedback on the general plan outline, overall strategies, and broad recommendations should be encouraged, as well as specific suggestions on the location and boundaries of zones and the use of additional management measures.

Plans for the management of Pohnpei's resources should be revised based on the information gathered during government and public hearings. General criticisms and specific suggestions should be evaluated and incorporated into the plan when appropriate. The revised plan should include the reasons why other criticisms and

suggestions were not inccorporated. The revised plan should be circulated among government agencies and concerned parties for further comment.

Reef Management Implementation

Implementation of the reef zoning plan and other management strategies is constrained by their acceptance and limits on manpower, expertise, and funding which reflect the social and political realities of resource management on Pohnpei. The specific recommendations presented in Chapter VI represent a broad range of needed management measures which might be implemented under ideal conditions. However, to initiate the proposed management plan, these recommendations must be prioritized to identify the critical issues. To accomplish this, reef management recommendations are divided into a series of stages, beginning with those which are most urgently needed. At all stages of evaluating, adopting, and implementing legislation for reef resource management, public participation should be required and encouraged.

Stage I - First priority management measures:

- Upgrade operations of sewage treatment plant to ensure proper treatment of wastes and discharge of treated effluent with proper coloform and chlorine levels;
- Monitor the water quality of sewage effluent and of lagoon waters in the discharge area;

- Discourage or prohibit recreational use of lagoon waters near sewage treatment plan outfall ("Lidakika Beach") until water quality is improved;
- Prohibit further construction of over-water latrines and near-water pig pens along Tuanmokot Channel;
- Require environmental impact statements for all proposed major earthmoving and land clearing activities;
- Require permits for all major earthmoving and land clearing which stipulate the use of erosion and runoff controls;
- Prohibit break up and removal of live coral for fill use;
- Develop permit program for proposed landfills, causeways, channel dredging, and commercial waterfront development which includes consideration of habitat loss and disruption, subsistence use of resources, water quality, current patterns, and sedimentation processes, and requires public hearings;
- Prohibit clear cutting of mangrove along the lagoonward edge of the mangrove forest, and in areas where the mangrove forest is less than 0.25 km wide;
- Develop license and permit procedures for commercial sand mining and dredging which include public hearings, and consideration of reef habitat loss and disturbance, water quality, reef fisheries, and subsistence use of resources, and require use of sediment confining devices (i.e. silt screens, dikes);
- Declare giant clams (Tridacna spp. and Hippopus spp.) and lobster (Panulirus sp.) as protected species within Trochus sanctuaries, prohibiting their removal or habitat disturbance.

Stage II - Zoning plan implementation:

At the second stage, the mechanism for reef management zoning should be established. They should be a high priority for legislative action since it serves as the foundation for the specific management measures applied to each zone. Enabling legislation should be drafted to grant DMR the authority to set up and manage the proposed reef management zones. The supportive management measures can then be phased in as the zones become accepted and laws are enacted. Enforcement legislation allowing DMR, EPB, and other appropriate agencies to enforce the management plan and specifying penalties for violations of laws concerning reef resources should be enacted. The reef uses which should be allowed, prohibited, or allowed with regulation (i.e. permits) in each of the 5 zone types are described in Chapter VI. Once DMR has obtained the authority to declare management zones in Pohnpei's reef and lagoon areas, the following sequence of zoning steps is suggested.

Step 1: Declare Marine Park status for Trochus sanctuaries which have been identified for this level of protection (Appendix 1, Maps 1, 5-6, 16-17). This will include protection of important seabird nesting areas (Appendix 1, Map 16-17). In one case, the Marine Park area extends beyond the current Trochus sanctuary and the boundary must be re-defined (Appendix 1, Map 1).

Step 2: Declare remaining Trochus sanctuaries as Species Preserves for Trochus, giant clams, and lobster (if this did not occur in Stage I) (Appendix 1, Maps 9-10, 11-12, 13-14, 21).

Step 3: Declare identified General Use Zones for sand mining (Appendix 1, Maps 1, 3, 5, 18, 20, 21) and reef flat dredging (Appendix 1, Maps 4, 6, 8, 11, 15, 19) as the only areas where extraction of these reef materials may take place.

Step 4: Declare a General Use Zone around Kolonia (Appendix 1, Maps 4, 19, 21) and Nahnningi Islet ("Joy Island") (Appendix 1, Map 10).

Step 5: Declare all reef, lagoon, and mangrove areas not included in Marine Parks, Species Preserves, or General Use Zones as Sustainable Use Zones (Appendix 1, Maps 1-21).

Step 6: Declare additional Marine Parks to include mangrove forest and ecosystem cross sections from shore to the outer barrier reef (Appendix 1, Maps 11-12, 13-14, 18-19).

Step 7: Declare Seasonal Preserves for the areas identified (Appendix 1, Maps 8-9, 14) for the months of March, April, and May.

Step 8: Declare a Species Preserve in Mant Pass for the black trigger fish (Appendix 1, Map 3).

Step 9: Declare a final series of Marine Parks to ensure protection of mangrove, reef, and lagoon habitat, and provide for replenishment of renewable resources in locations throughout Pohnpei's reef and lagoon system (Appendix 1, Maps 2-3, 7, 12-13, 16-17).

Step 10: Declare a Species Preserve for Green Turtles, or a Seasonal Preserve during nesting periods, on Ros Islet (Appendix 1, Map 13), if this area was not included in a Marine Park.

Stage III - Second priority management measures:

- Select and develop an alternative upland dump site for the Kolonia area, and develop upland dump sites in rural areas;
- Prohibit the sale of reef fish, for those species which are over exploited during their spawning aggregations, during the months of March, April, and May;
- Establish a program to monitor oil products storage and transfer facilities and their operations;
- Prohibit the use of SCUBA for the harvest of Trochus;
- Prohibit the sale of speared fish or lobster;
- Develop program to register all pesticides and certify users through a pesticide user training course;
- Establish State-wide mangrove management program, including limits on the extent and rate of clear cutting;
- Promote bottom fish and pelagic fish resources for subsistence use;
- Maintain the lagoon edge dikes of the municipal dump, and sceen the dump from the road with vegetation;
- Clean up, or stabilize with fill, the unofficial rural dump sites;
- Prohibit the import of gill nets with less than a 2.5 inch (6.3 cm) stetched mesh size.

- Prohibit the harvest of egg-bearing female lobsters and juvenile lobsters, with minimum size limit determined from experience elsewhere in Micronesia;
- Monitor mangrove crab, lobster, and beche-de-mer commercial fisheries;

Stage IV - Additional reef management, monitoring, and research needs:

- Establish a water quality monitoring program for lagoon waters around the island;
- Establish a monitoring program for environmental quality at reef dredging, sand mining, and construction sites, and in streams and lagoon areas adjacent to earthmoving and land clearing activities;
- Determnine extent of ornamental shell and coral harvest, and needs for management;
- Monitor heavily fished species of reef fish;
- Determine future uses and needs of mangrove resources;
- Prohibit export of the cleaner wrasse;
- Clean up and improve recreational facilities at Net Point;
- Study sites for potential extension of the sewage outfall;
- Study methods and sites proposed for discharge of sewage treated by oxidation ponds in Paliker region;
- Establish guidelines for use and development of sandy barrier reef islets;
- Search for, and develop, additional public recreation sites near Kolonia;

- Monitor fish and shellfish harvested from polluted areas for potential health hazards;
- Determine and monitor population levels of sea turtles;
- Develop permit program for commercial bottom and pelagic fishing;
- Encourage development of a private refuse collection system for Kolonia;
- Establish license and permit program for the export of aquarium fish, if neccessary;
- Establish license program for sport fishing, if neccessary.

Mangement proposals must be forged into workable legislation, which, in turn, must be supported by surveillance programs and enforcement measures. Permit programs need an administrative system to issue, review, and enforce the permit's requirements. Environmental and water quality monitoring programs require an infrastructure of field scientists, laboratories, and technicians. In summary, all of the management recommendations involve substantial amounts of funding, facilities, and qualified personnel. All of these necessities would be required over extended time periods to implement the recommendations, but are in short supply in the developing Pacific.

After the Compact of Free Association goes into effect, the State of Pohnpei, and the FSM, will be dependent upon their own resources to continue the conservation efforts which began under the TTPI administration. However, as part of the Compact, the FSM will receive a guaranteed amount of U.S. financial support for many years, much of which will go to needed economic development. The FSM should be able

to invest a significant portion of this support in the conservation of its natural resources to provide for the long-term sustenance of much of its population. In addition, the FSM should request U.S. and international resource management agencies for technical and advisory assistance in the conservation and management of coastal resources. Research by scientists from developed countries, into topics with management applications should be encouraged by the FSM to add to the information on the area's natural resources.

Training and Education

Long term prospects for the success of reef management planning rely on an informed, educated, and supportive public and government. Government staff involved with resource planning, management, and enforcement should be required to have a minimum level of training and be encouraged and supported to take advantage of opportunities to increase their level of expertise. General education regarding marine conservation principles and practices should be carried out by DMR in the schools and for the public through extension services. Specific information on the effects of particular reef use activities, the need for management, and the benefits associated with management should be communicated to specific resource user groups. In this way, community supported reef management should come into being as resource users realize the benefits from effective management of their reef resources.

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APPENDIX 1

Detailed Maps of Reef Resources and Resource Use,
From Pohnpei Coastal Resource Atlas (Manoa Mapworks, 1985),
With Reef Management Zones Superimposed

Key to Proposed Reef Management Zones:

Proposed General Use Zones . . . . . 

Proposed General Use Zones (Sand Mining) . 

Proposed General Use Zones (Dredging). . . 

Proposed Sustainable Use Zones . . . . . [no pattern]

Proposed Seasonal Preserves. . . . . 

Proposed Species Preserves . . . . . 

Proposed Marine Parks. . . . . 

Pohnpei Coastal Resource Atlas Legend:
Resource Use Symbols

Resource Use

RELATED TO BIOTA


Deep water handlining (primarily for yellowfin tuna).


Bottom fishing (primarily for groupers and snappers).


Reef fishery (very productive and/or heavily fished areas).


Stone fishtrap.


Seasonal fish aggregation area.


Baitfish (ikatek).


Sea turtle nesting area (historical).


Sea turtle feeding area.


Mangrove crab.


Lobster.


Freshwater shrimp.


Giant clams (*Hippopus* and/or *Tridacna*).


Lipwei clam (*Anadara antiquata*).


Other clams (primarily kopil clams).


Top shell (*Trochus niloticus*), outside of preserves.


Octopus.


Sea cucumbers.


Sponge collecting (historical).


Recreational diving.


Trochus preserve.


Fish migration path.


Seagrass bed.

NOT RELATED TO BIOTA


Sand mining.


Manual sand removal.


Archaeological site.

Channel buoy.

▲ Channel marker.

Reef marker.

Field Stations

1 PCRI Stations.

Other stations.

Pohnpei Coastal Resource Atlas Legend:
Scale and Substrate Symbols

Aerial Photograph Based Classification System

OFFSHORE

s — Sediment.

- **sc** — Sand bottom, in water depths less than 10 meters.
- **sd** — Sand bottom, in water depths greater than 10 meters.
- **si** — Silt.

rc — Reef complex.

- **rc** — Mixed bottom types consisting of reef rock (limestone) associated with shallow reef formations.
- **rcl** — Consolidated limestone, lacking sediment.
- **rcp** — Consolidated limestone with a smooth, pavement-like surface.
- **rcg** — Consolidated reef with well defined groove-and-spur system.
- **rcs** — Mostly consolidated limestone with some (25–50%) sediment bottom.
- **rct** — Complex reef bottom type (**rc**, **rcs**, or **rs**) with loose materials formed into tracts by waves or currents.
- **rs** — Complex reef bottom type consisting mostly of sand, but with some limestone outcrops or boulders.
- **co** — Areas of greater than 50 percent live coral cover.

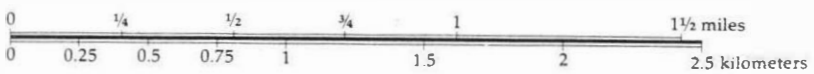
SHORELINE

- **ba** — Volcanic rock shoreline (basalt).
- **bb** — Man-made boulder shoreline.
- **bc** — Concrete/cement masonry seawall and shoreline.
- **sb** — White sand beach of predominately calcareous material.
- **sbc** — Calcareous rubble and/or shingle beach.

VEGETATION COVER

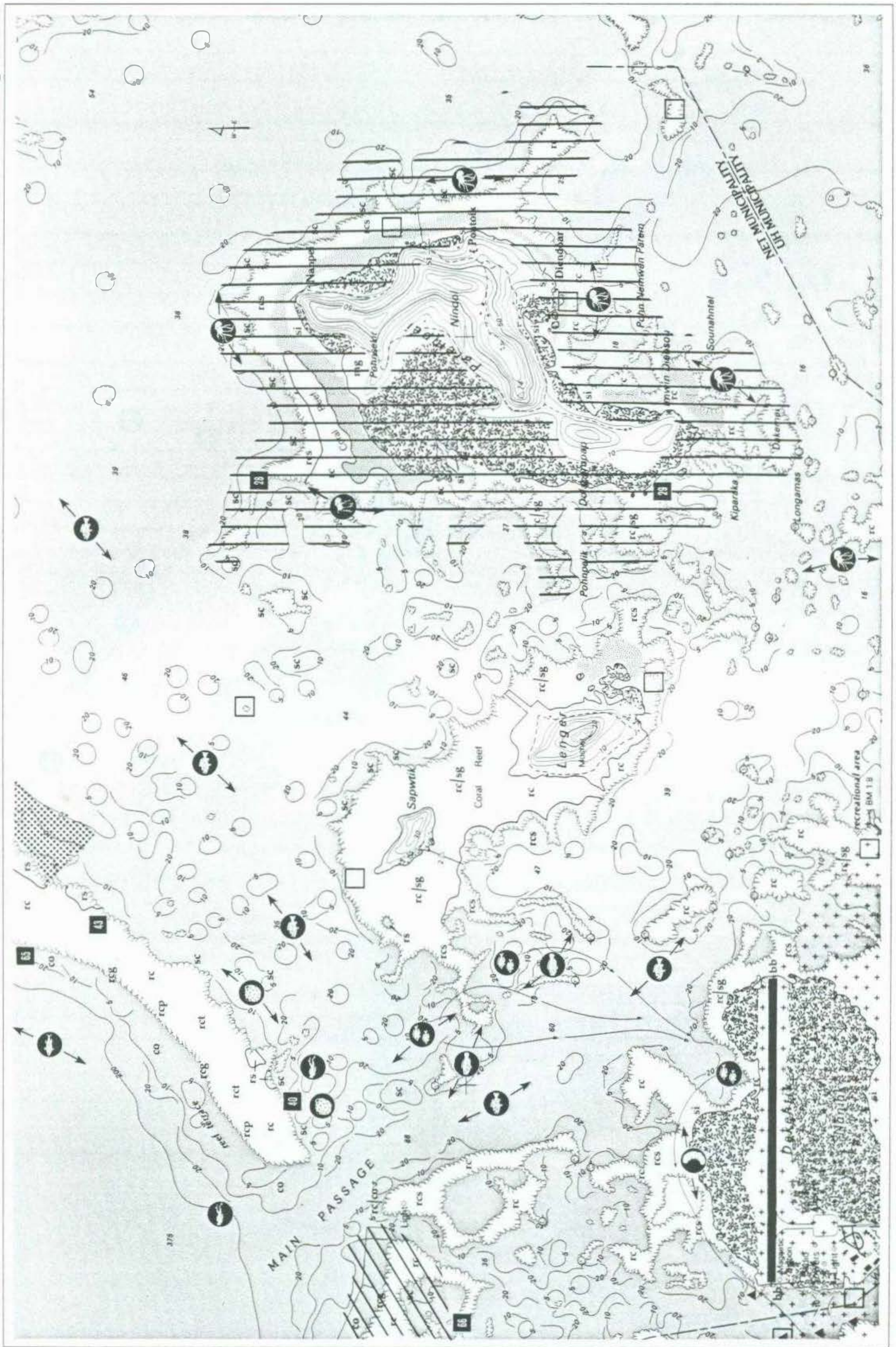
- **mg** — Mangrove forest (where not otherwise indicated on basemap).
- **sg** — Seagrass bed.
- **ag** — Algae bed.

Note: All patch reef surfaces are substrate type **rc** unless otherwise designated.

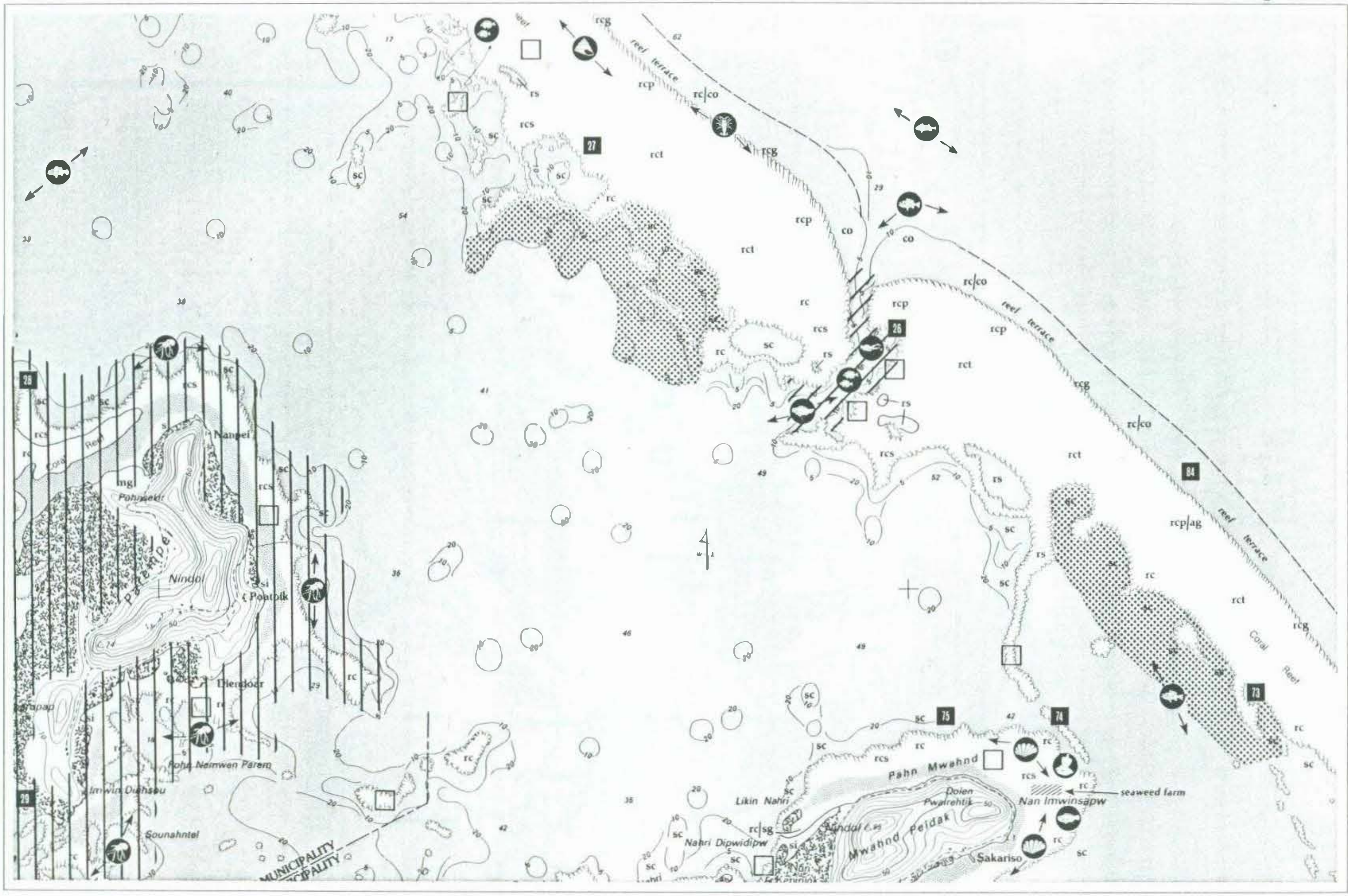


Map 1

Map 2

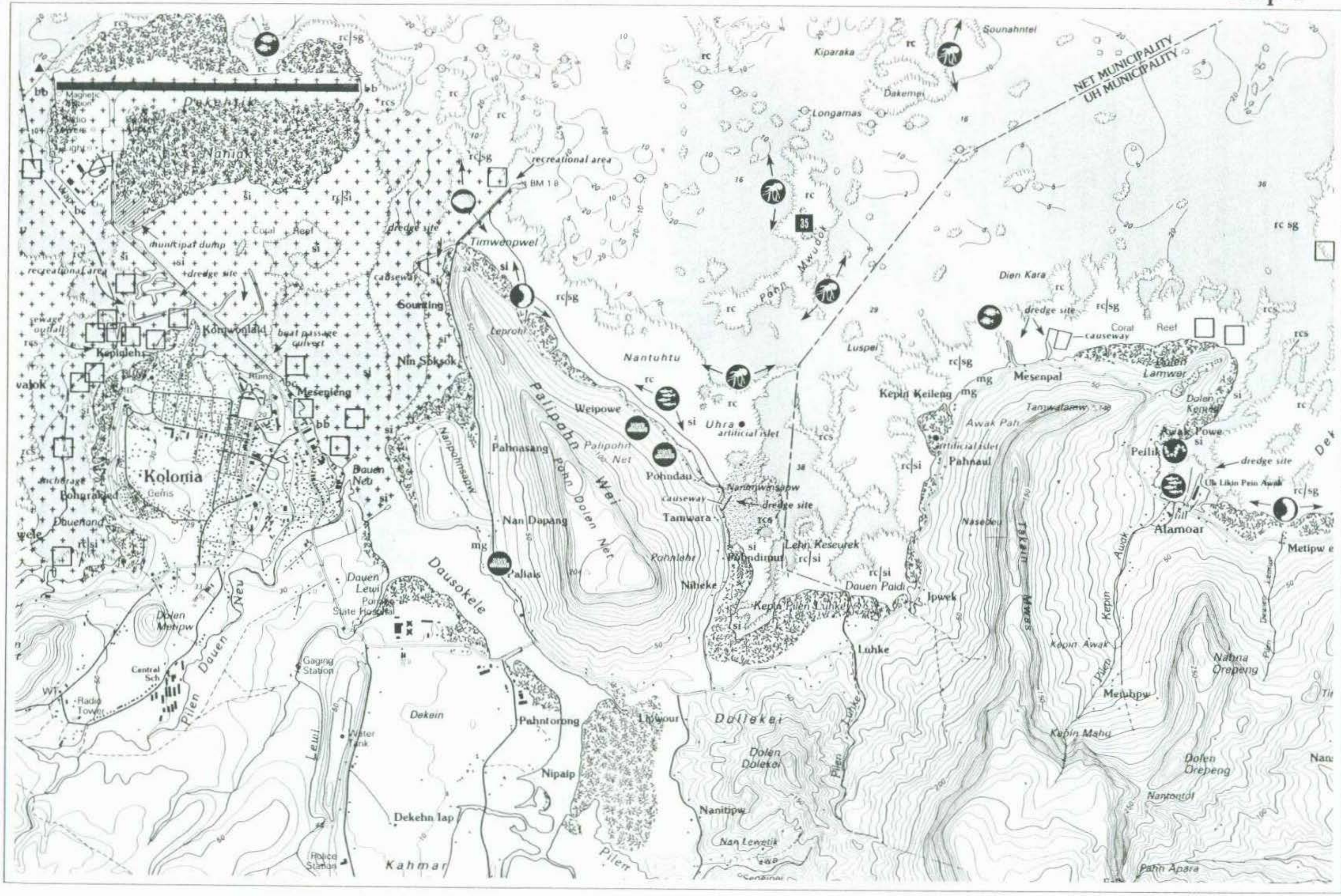

MAIN PASSAGE
NET MUNICIPALITY
UH MUNICIPALITY
Coral Reef
Sapwtik
Lenger
Nanpei
Pohnpei
Kiparska
Longamas
recreational area

Map 3



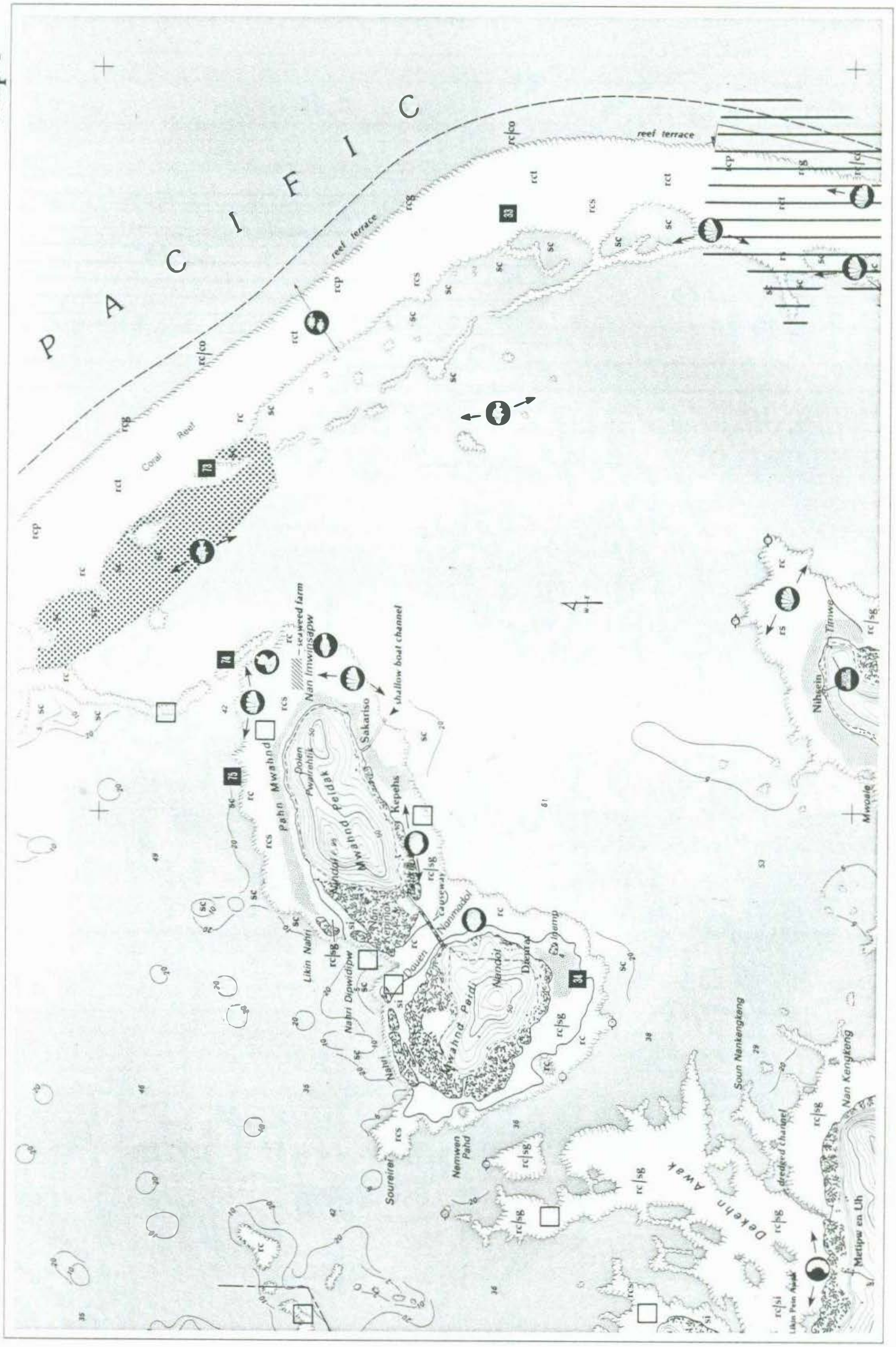
reef terrace
Coral Reef
seaweed farm
Nan Imwinsapw
Pahn Mwahnd
Mwahnd Peidak
Doien
Pwairehtik
Sakariso
Likin Nahri
Nahri Dipwidipw
Nanpei
Pohnsakar
Palampel
Nindol
Si Pontolk
Diendoar
Pohn Neimwen Parem
Imwin Diahsou
Sounahntel
MUNICIPALITY

Map 4

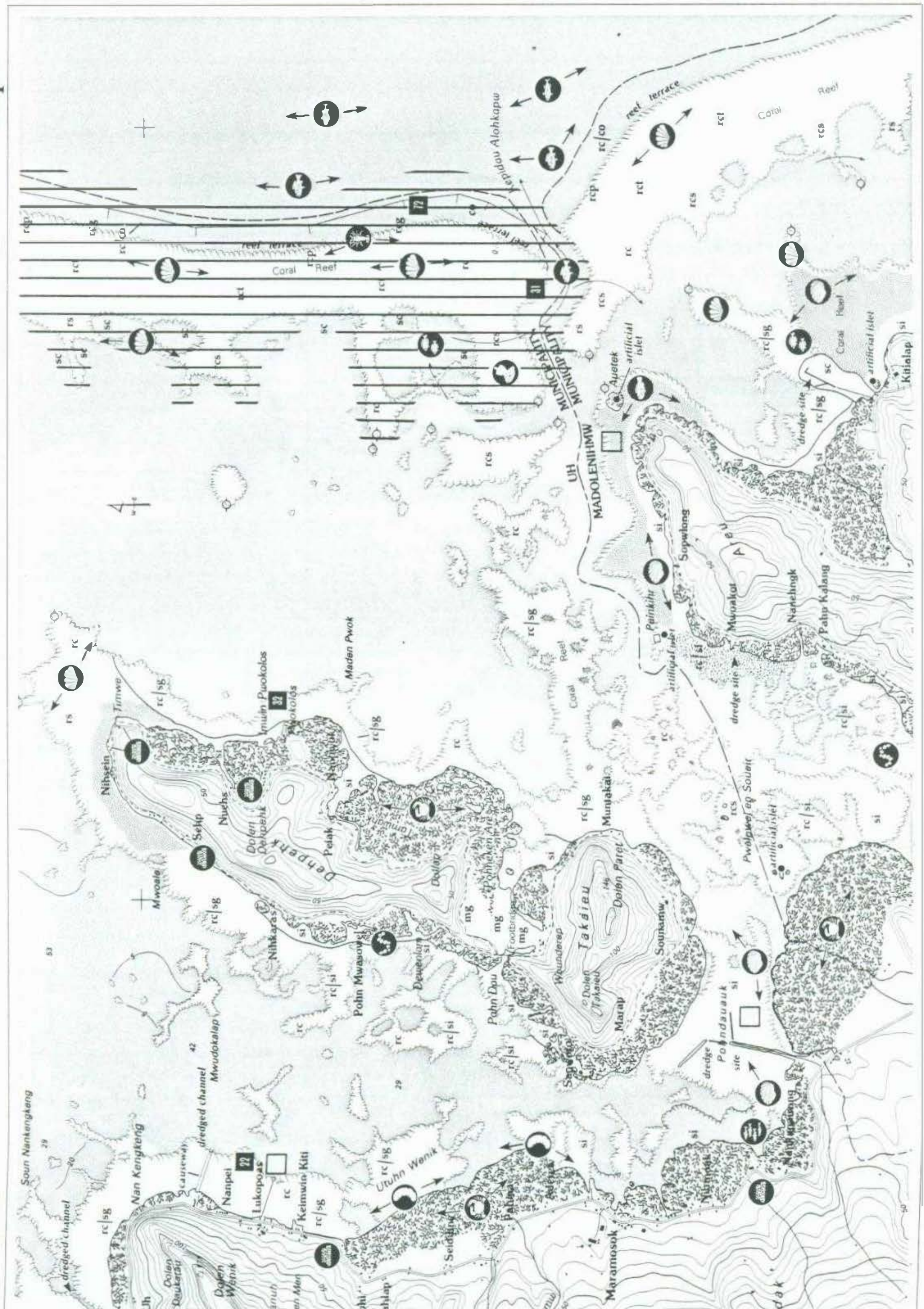


NET MUNICIPALITY
UH MUNICIPALITY
Sounahntel
Kiparaka
Dakemei
Longamas
Pohn Mwudok
Dien Kara
dredge site
Coral Reef
causeway
Luspei
Mesenpal
Dolen Lamwer
Kepin Keileng
Tamwatamw
Awak Pah
artificial islet
Pahnaul
Pelik
Awak Powe
dredge site
Uh Likin Pein Awak
Alamoar
Metipw
Nantuhtu
Uhra
artificial islet
Weipowe
Palipohn Net
Pohndau
Nanmwinsapw
causeway
dredge site
Tamwara
Pohnlahr
Pohndimul
Lehn Keseurek
Nihieke
Kepin Pilen Luhke
Dauen Poidi
Ipwek
Luhke
Takain Mwas
Nasedeu
Kepin Awak
Kepin Mahu
Nahna Orepeng
Dolen Orepeng
Nantontol
Pahn Apara
Dollekei
Dolen Dolekei
Nanitipw
Nan Lewetik
Pilen
Palipohn Wei
Pohn Dolen Net
Pahnasang
Nan Dapang
Palias
Nanpohnsapw
Leprohi
Timwenpwel
recreational area
BM 1.8
dredge site
causeway
Sounting
Nin Soksok
Dausokele
Dauen Lewi
State Hospital
Gaging Station
Dekein
Water Tank
Lewi
Pahntorong
Nipaip
Dekehn Iap
Kahmar
Police Station
Lipwour
Dekehtik
Naniak
Magnetic Station
Radio Towers
municipal dump
dredge site
recreational area
sewage outfall
Kapinlehs
Konwonlaid
boat passage culvert
Mesenieng
Dauen Neu
Kolonia
Ruins
Bohnrakied
Dauenond
Central Sch
Radio Tower
Dolen Metipw
Pilen Dauen Neu

Map 5

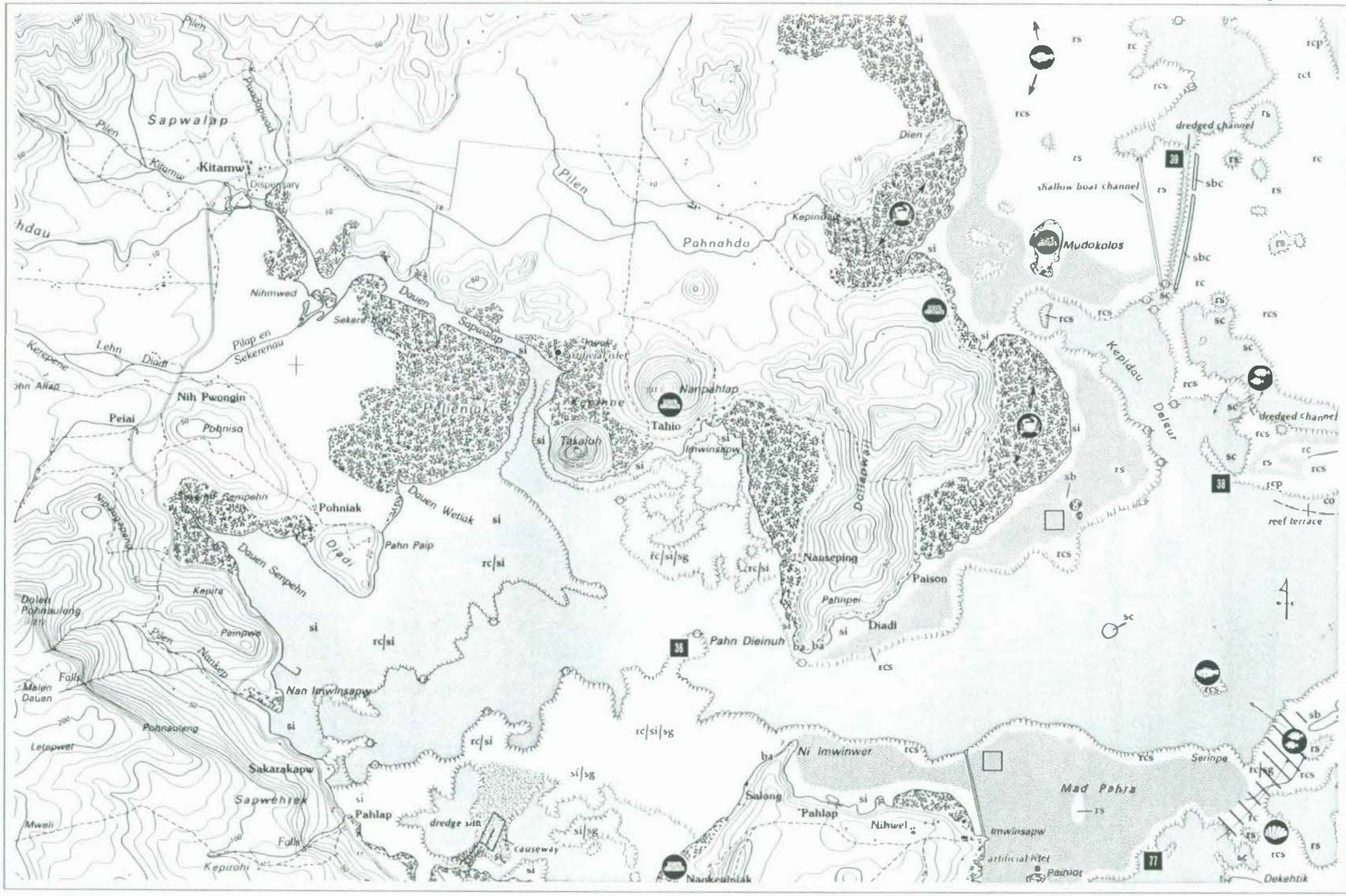

P A C I F I C
reef terrace
Coral Reef
seaweed farm
shallow boat channel
Nan Imwinsapw
Sakariso
Pahn Mwahnd
Mwahnd Peidak
Pwulahlik
Doien
Kepehs
Likin Nahri
Nahri Dipwidipw
Dauen Nanmadol
Mwahnd Peidi
Nandoi
Dieinai
Soureirei
Nemwen Pahd
Dekehn Awak
dredged channel
Soun Nankengkeng
Nan Kengkeng
Metipw en Uh
Likin Pein Awak
Nihsein
Timwe
Mwosie

Map 6

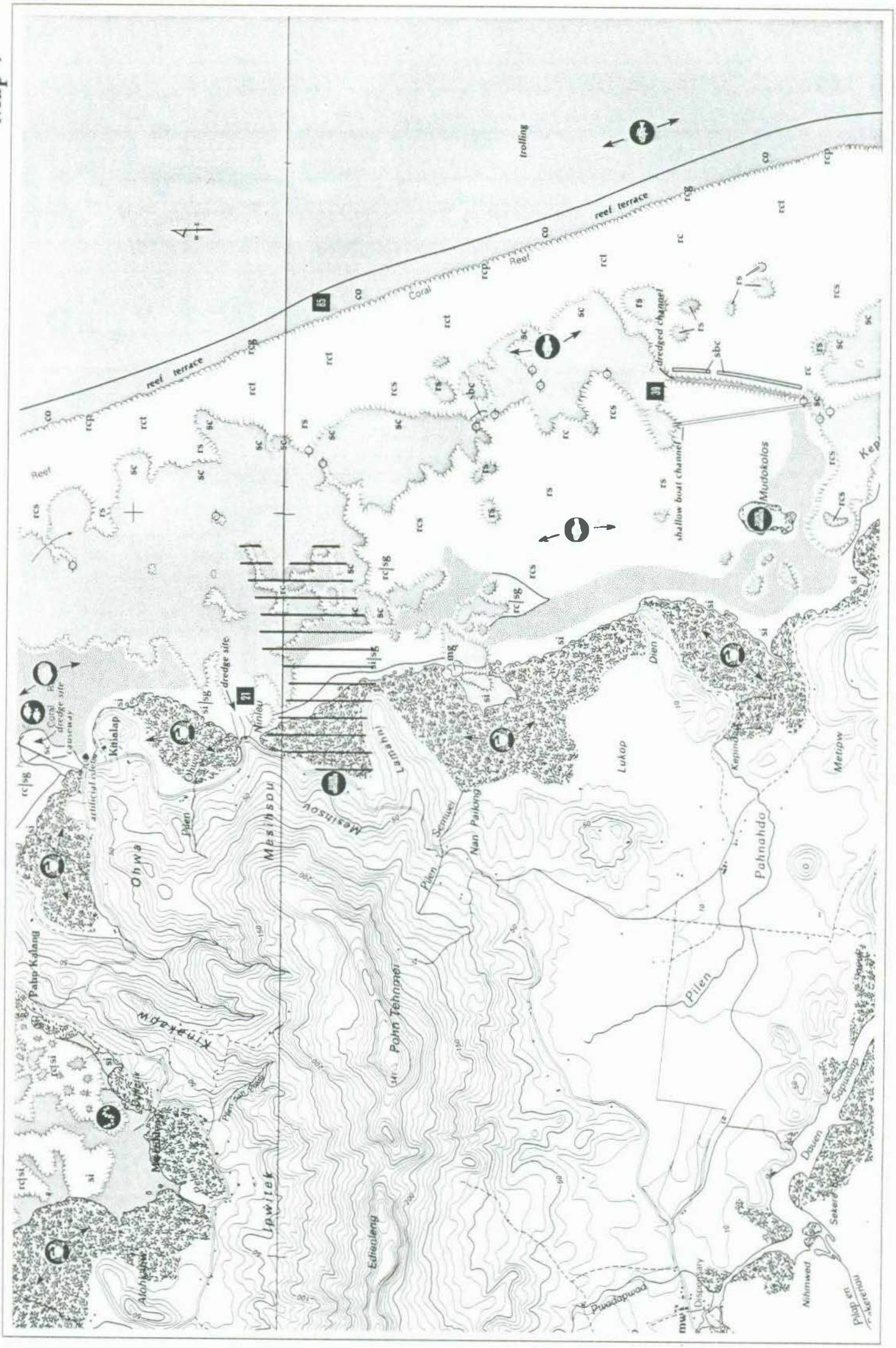


Metipw en Uh
dredged channel
Nan Kengkeng
Soun Nankengkeng
Mwudokalap
Nanpei
Lukopoas
Keimwin Kiti
Nausalohi
Pahlap
Maramosok
Saladak
Takaieu
Dolen Parat
Sounsamw
MADOLENIHMW
UH
MUNICIPALITY
reef terrace
Coral Reef
artificial islet
dredge site
Supwilong
Nanehngk

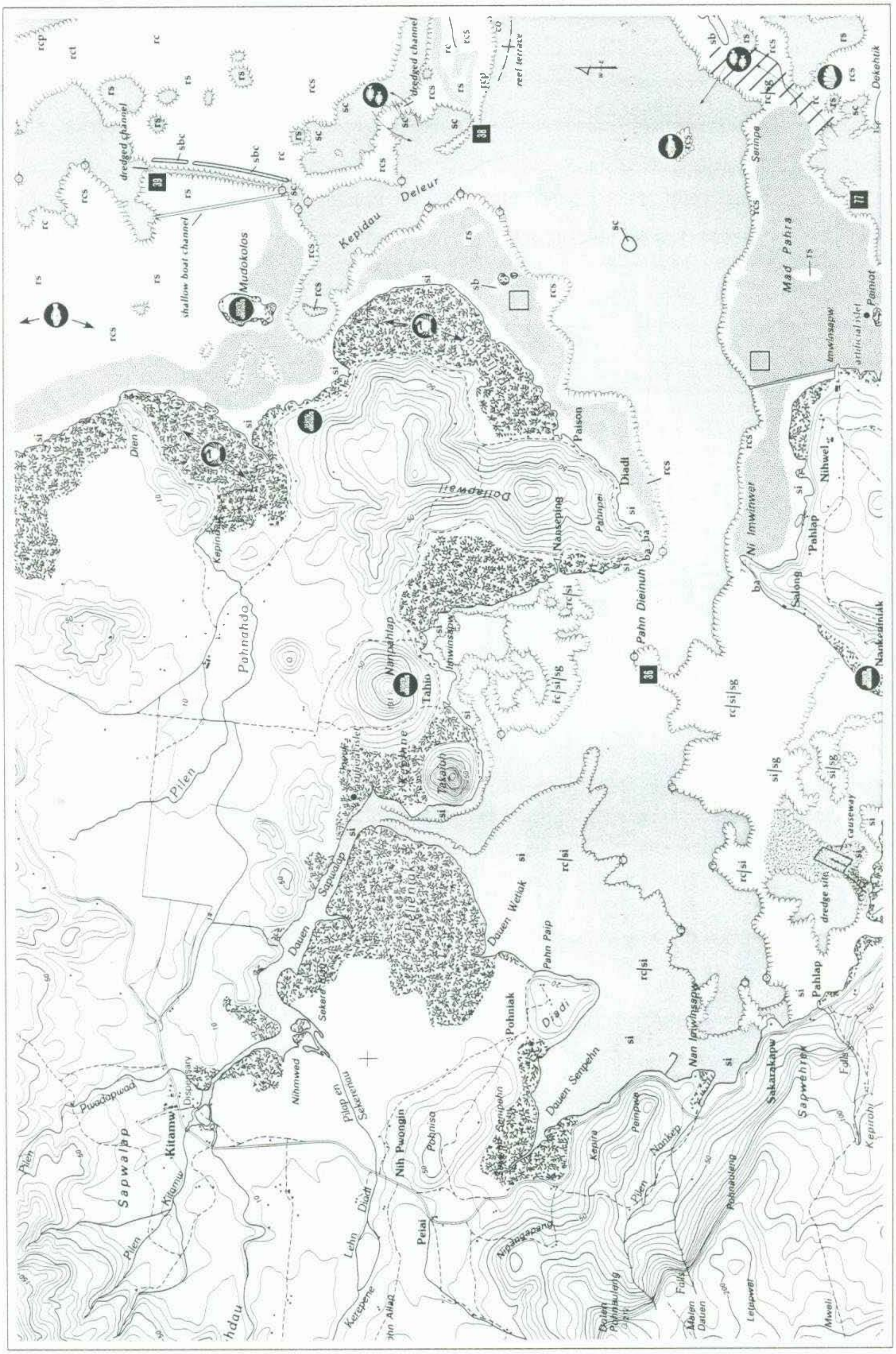
Map 8


Sapwalap
Pilen
Kitamw
Dispensary
Pohnahdo
Kepindau
Dien
Mudokolos
dredged channel
shallow boat channel
sbc
Nihmwed
Dauen Sapwalap
Sekere
Lehn Diadi
Pilap en Sekerenau
Nih Pwongin
Peiai
Pohnisa
Takaiuh
Tahio
Nanpahlap
artificial islet
Imwinsapw
Kepidau
Deleur
reef terrace
Pohniak
Dauen Weliak
Pahn Paip
Diadi
Dauen Senipehn
Nanseping
Paison
Pahnpei
Kepira
Peinpwe
Falls
Malen Dauen
Pohnauleng
Letepwet
Nan Imwinsapw
Pahn Dieinuh
Sakarakapw
Sapwehrek
Pahlap
dredge site
causeway
Mweli
Kepirohi
Ni Imwinwer
Salong
Nihwel
Mad Pahra
Serinpe
Dekehtik
Nankepinlak
Pahlap
imwinsapw
artificial islet
Pamiot
rc/si
rc/si/sg
si/sg
si
rcs
rs
rc
sc
sb
36
38
39
77

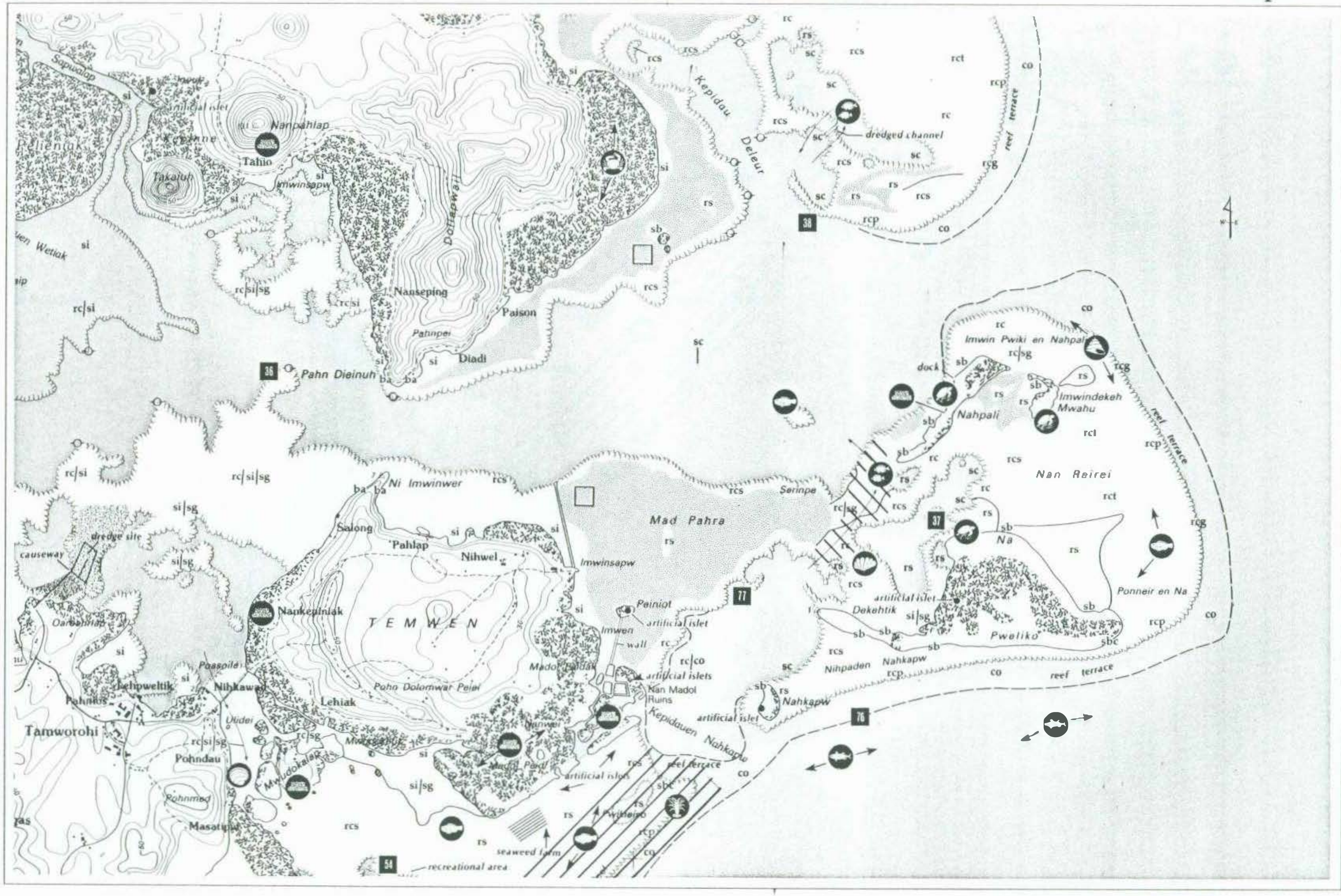
Map 7


trolling
reef terrace
Coral
Reef
dredged channel
shallow boat channel
dredge site
Mudokolos
Lukop
Pahnahdo
Metipw
Pilen
Pohn Tehnmei
Mesihsou
Ohwa
Paho Kalang
Ipwitek
Edisoleng

Map 8

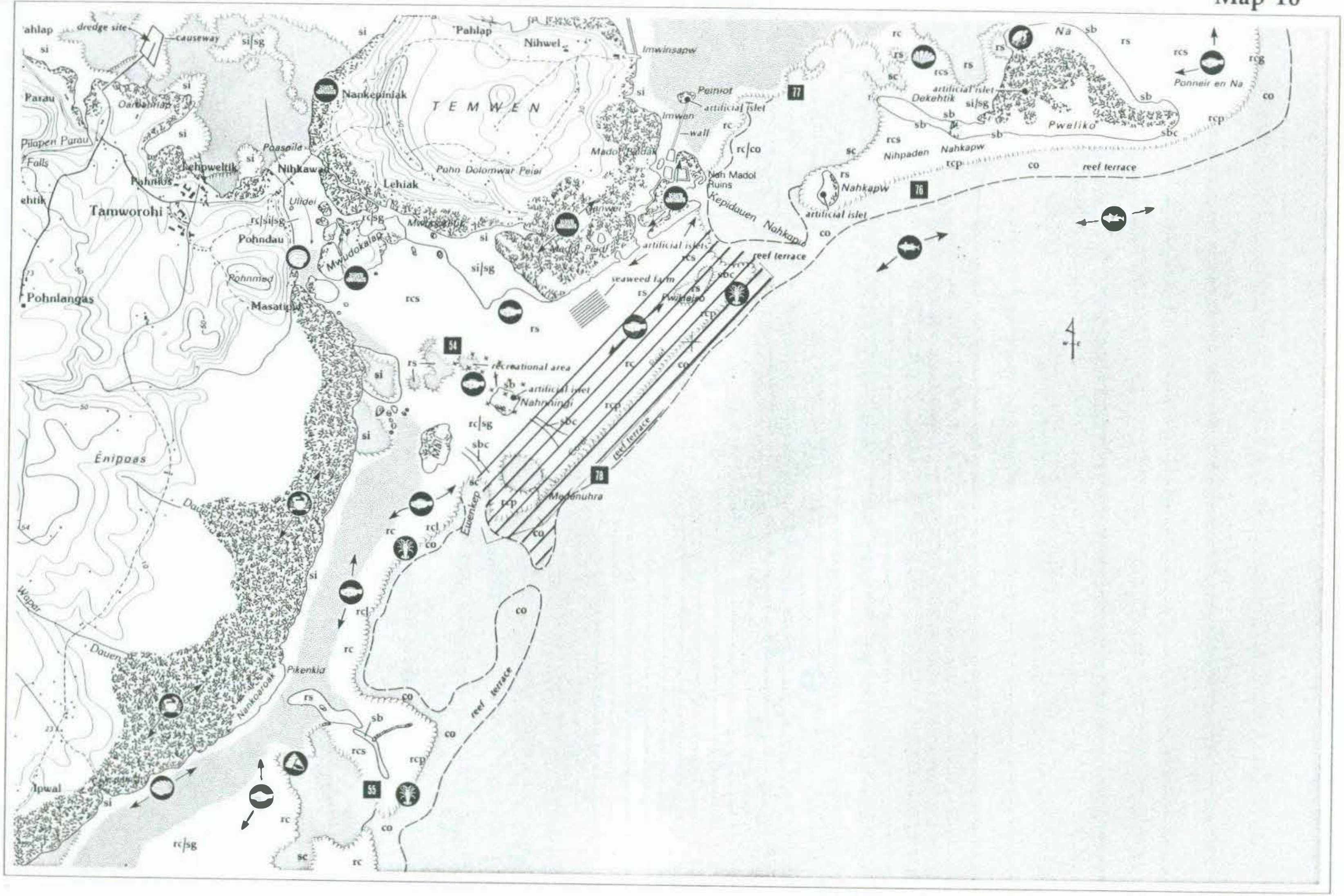

Kepidau
Deleur
Mudokolos
dredged channel
shallow boat channel
reef terrace
Mad Pahra
Serinpe
Dekehtik
Peiniot
artificial islet
Imwinsapw
Dien
Kepinahk
Paison
Dollapwail
Diadi
Nanseping
Pahn Dieinuh
Ni Imwinwei
Nihwel
Pahlap
Salong
Pahnaho
Pilen
Nanpohnlap
Tahio
Takaiou
Kepinne
Dauen Sapwalap
Dauen Wetak
Pahn Paip
Pohnlak
Nan Imwinsapw
Dauen Sempehn
Pohnisa
Nih Pwongin
Pelai
Lehn Diadi
Kerepene
Sapwalap
Kitamw
Dispensary
Pwadopwad
Nihmwad
dredge site
causeway
Sakarakapw
Sapwehrek
Falls
Kepiroht
Letipwel
Mwoli
Pohnaulong
Dauen Pohnaulong
Maien Dauen
Kenara
Pempehe
Nankep
Nanpadapang

Map 9



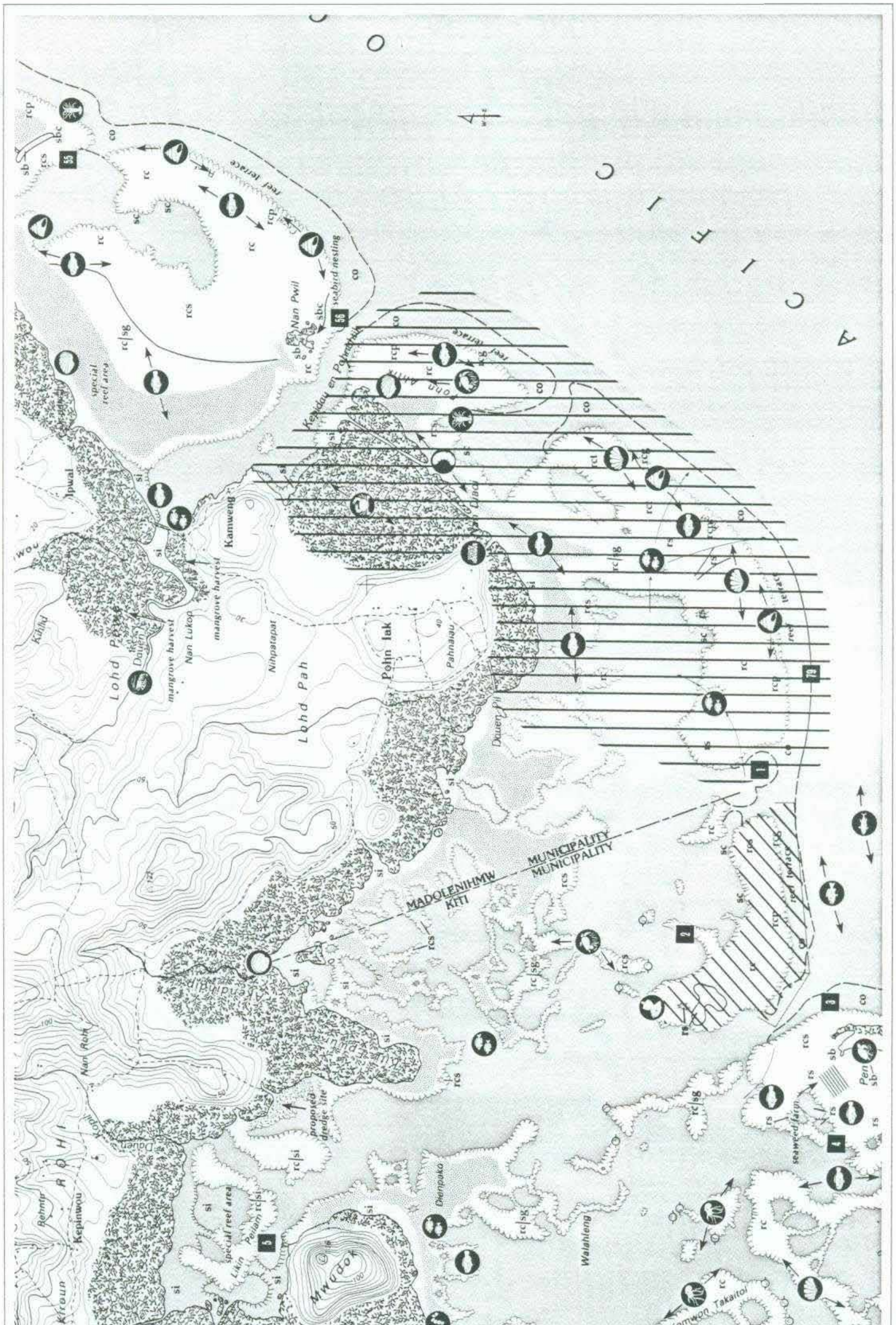
Kepidau Deleur
dredged channel
reef terrace
Nanpahlap
Tahio
Takaiuh
Dollapwail
Nanseping
Paison
Diadi
Pahn Dieinuh
Ni Imwinwer
Salong
Pahlap
Nihwel
T E M W E N
Nankepiniak
Poho Dolomwar Peiei
Lehiak
Mad Pahra
Imwinsapw
Peiniot
artificial islet
wall
artificial islets
Nan Madol Ruins
Kepidauen Nahkapw
Serinpe
Nahpali
Imwin Pwiki en Nahpali
Imwindekeh Mwahu
Nan Reirei
Na
Ponneir en Na
Pweliko
Dekehtik
Nihpaden
Nahkapw
dock
seaweed farm
recreational area
causeway
dredge site
Tamworohi
Pohndau
Masatum
Lehpweltik
Nihkawet
Pohnmed

Map 10

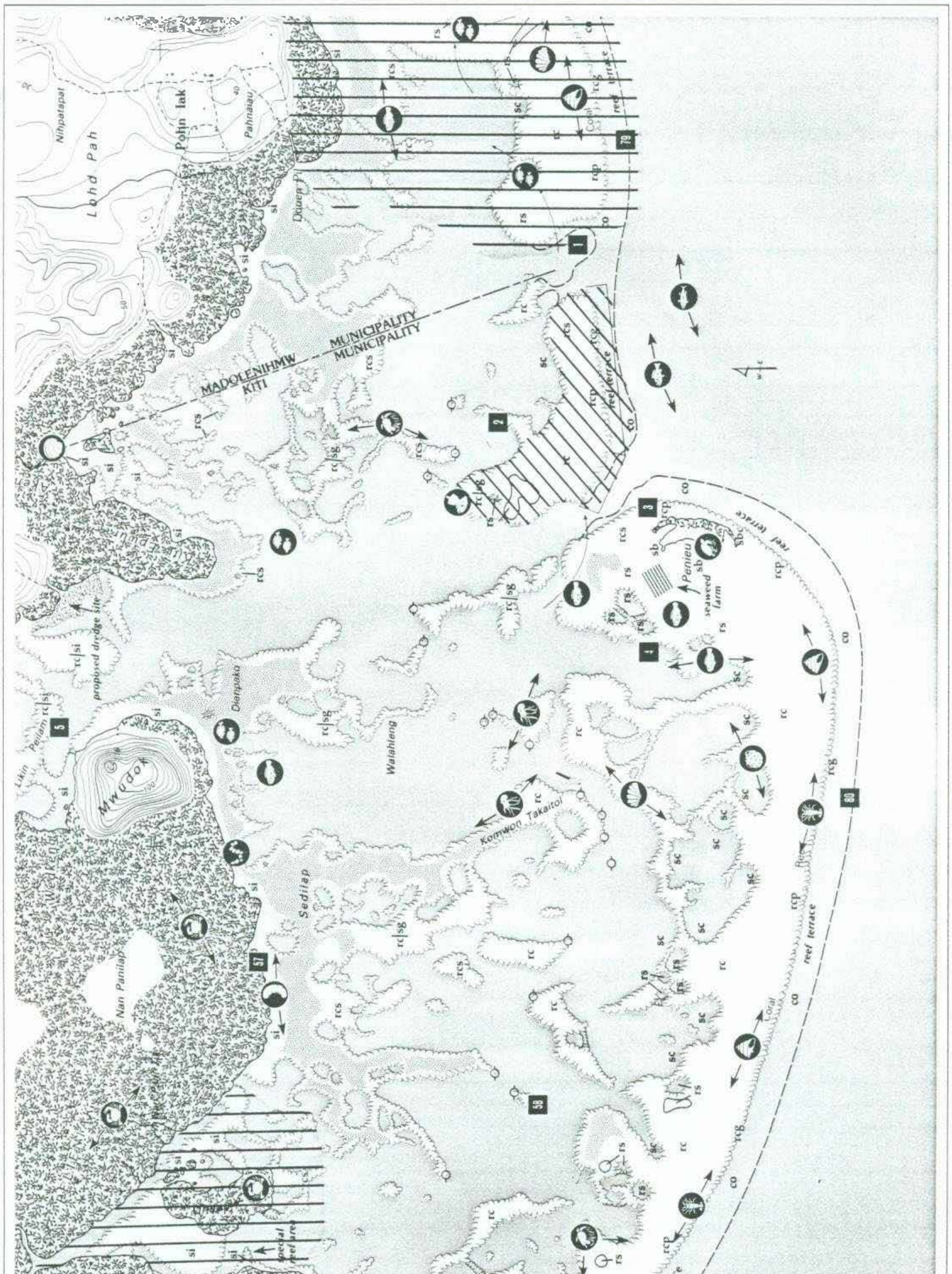


dredge site
causeway
Parau
Pilapen Parau
Falls
Pohnlus
Lehpweltik
Nihkawad
Tamworohi
Pohndau
Pohnlangas
Masatiak
Nankepiniak
TEMWEN
Pohn Dolomwar Peiei
Lehiak
'Pahlap
Nihwel
Imwinsapw
Peimot
artificial islet
Imwan
wall
Nan Madol Ruins
Kepidauen
Nahkapw
artificial islets
seaweed farm
reef terrace
recreational area
artificial islet
Nahnningi
Enipoas
Dauen
Waper
Pikenkid
Nankoaroak
Ipwal
Euwenkep
Medenuhra
Dekehtik
Nihpaden
Pweliko
Na
Ponneir en Na

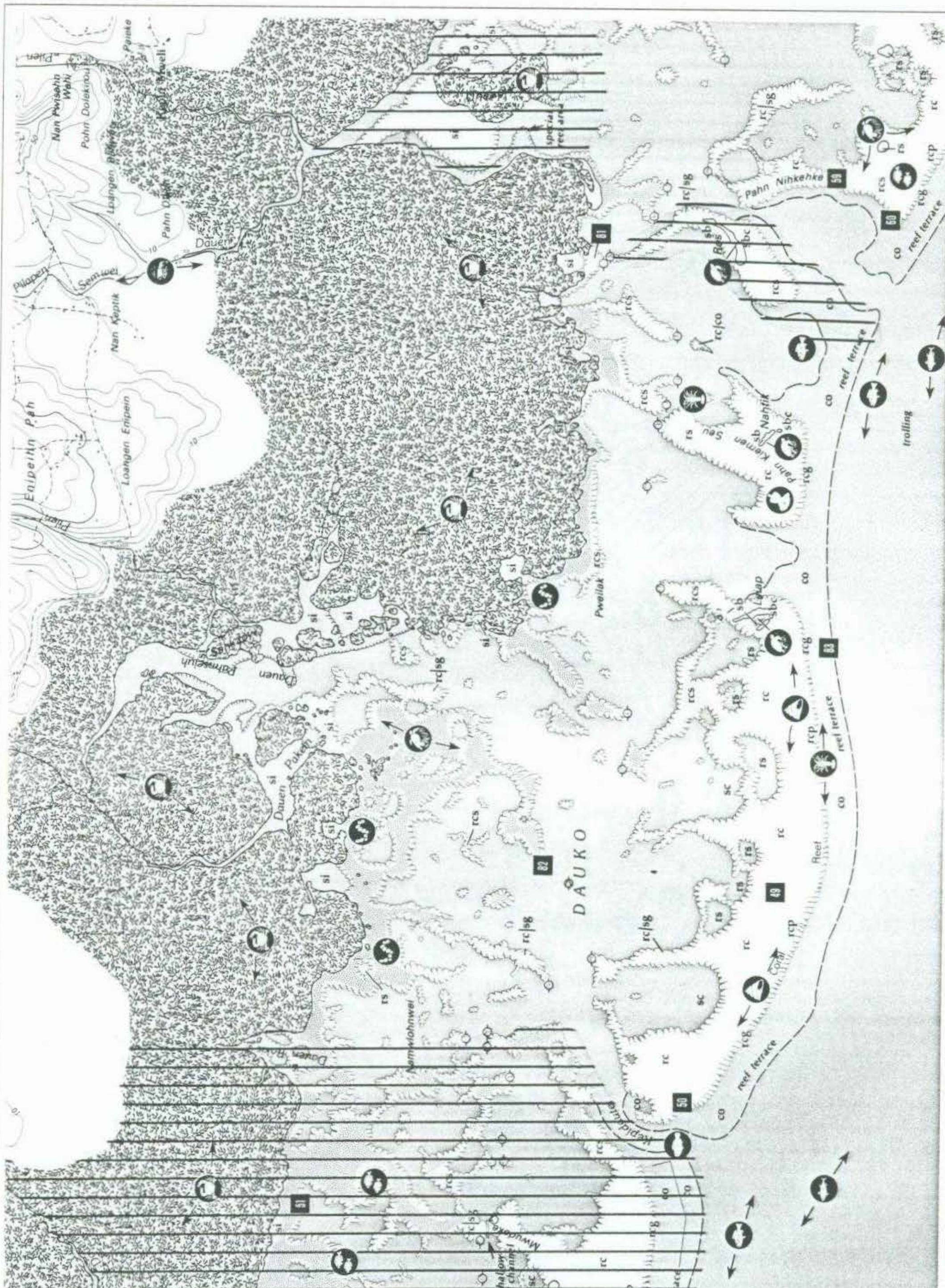
Map 11


MADOLENIHMW
MUNICIPALITY
KITI
MUNICIPALITY
Lohd Pah
Pohn Iak
Kamweng
Mwudok
Walahleng
Nan Pwil
seabird nesting
reef terrace
special reef area
mangrove harvest
proposed dredge site
seaweed farm
Nan Lukop
Pahnaiau
Dienpako
Kepinwou
Ipwal
Nan Roh

Map 12

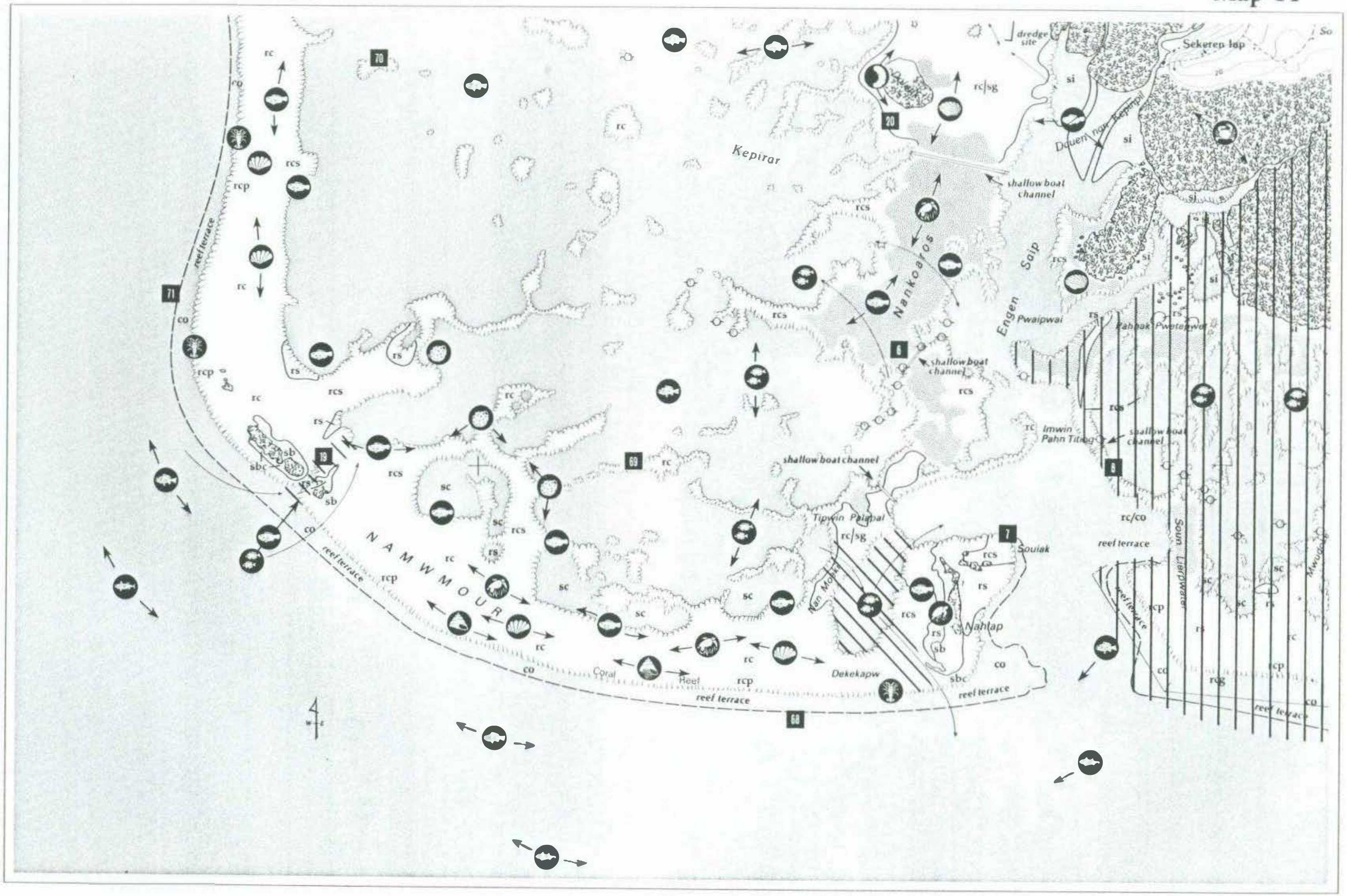

MADOLENIHMW MUNICIPALITY
KITI MUNICIPALITY
Lohd Pah
Pohn Iak
Mwudok
Walahleng
Sedilap
Komwon Takaitol
Nan Panilap
Pahn Nihkehke
Penieu
seaweed farm
proposed dredge site
reef terrace
special features

Map 13

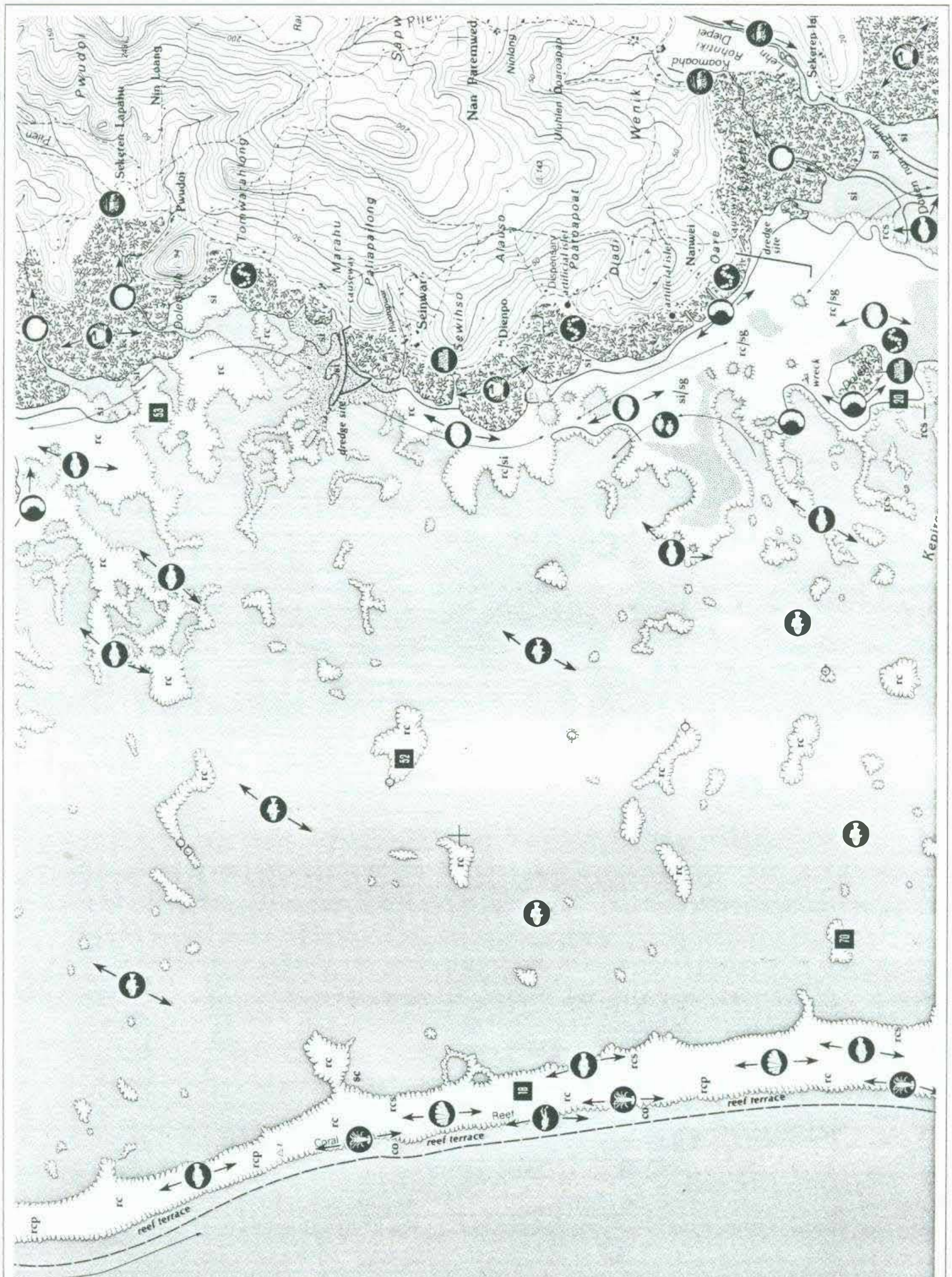


Enipeinn Pah
Loangen Enipein
Nan Kepik
Dauen
DAUKO
Pweilak
Pahn Nihkehke
Pahn Kiemen
Reef
reef terrace
trolling
Soun Liepwater

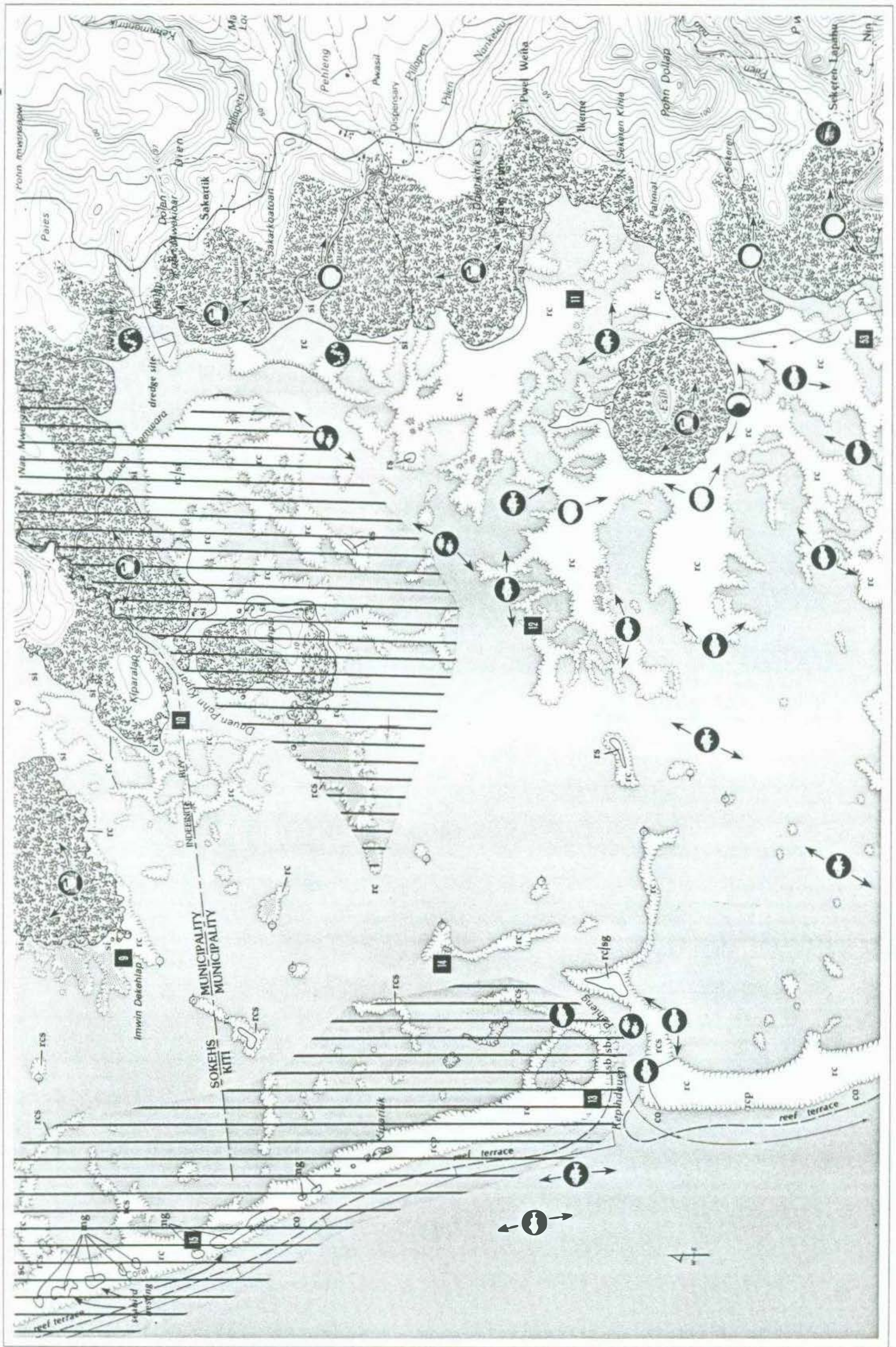
Map 14


Sekeren Iap
dredge site
Douen
si
rc/sg
shallow boat channel
Kepirar
Nankoaros
Engen Saip
Pwaipwai
Pahpak Pwetepwe
shallow boat channel
Imwin Pahn Titiog
rc/co
reef terrace
Soun Lierpwater
Mwudok
shallow boat channel
Tipwin Palpal
Nan Moluk
Souiak
Nahlap
Dekekapw
Coral Reef
N A M W M O U R
reef terrace
rc
rcs
rcp
rs
sc
sb
sbc
co

Map 15

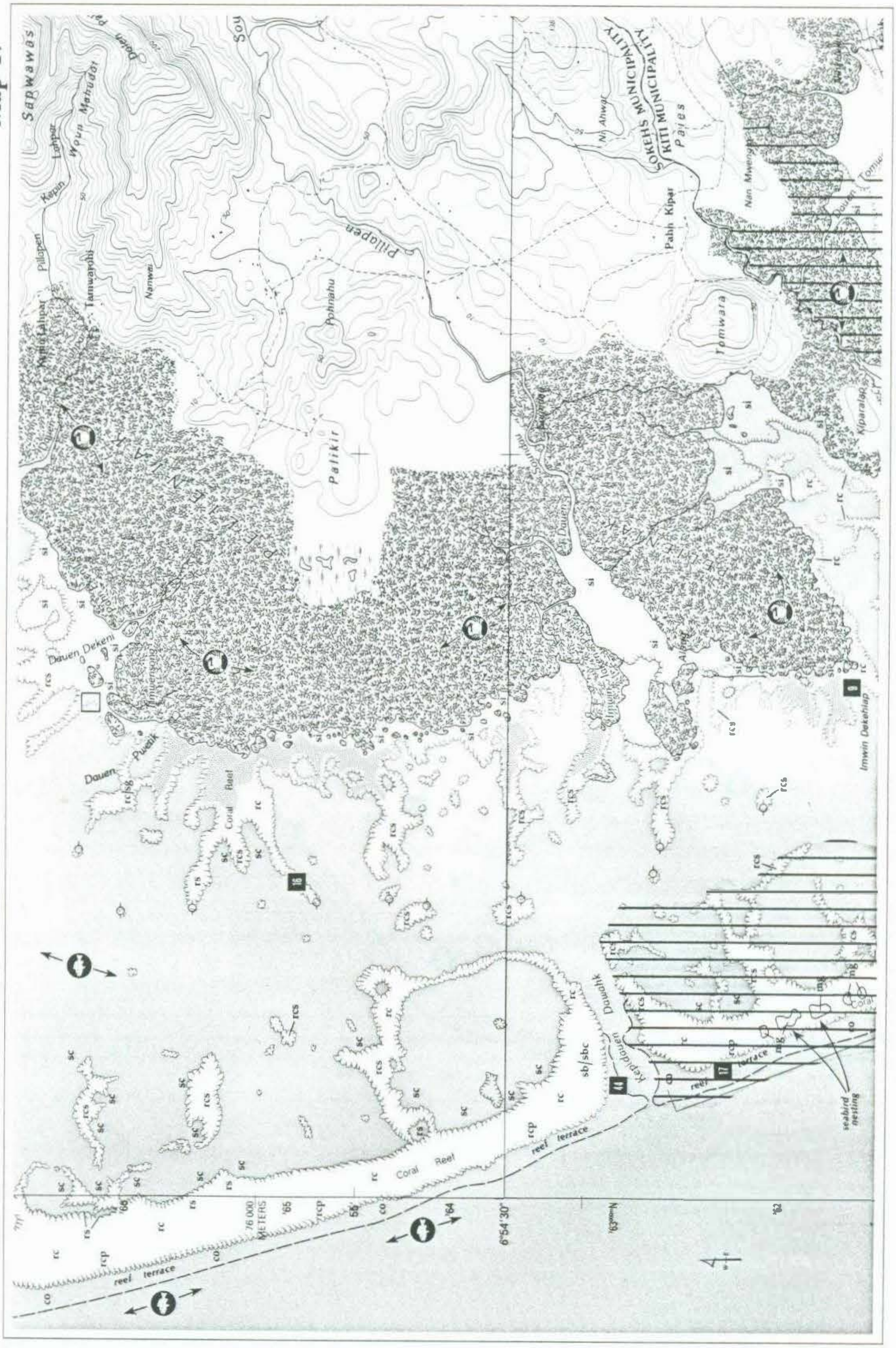

Sekeren Lapahu
Pwudoi
Nin Loang
Tomwarahlong
Marahu
causeway
Pallapailong
Seinwar
Sewihso
Alauso
Dienpo
Paaroapoat
Wenik
Nanwei
Oare
dredge site
wreck
rc
rcp
rcs
si
rc/si
rc/sg
si/sg
sc
reef terrace
Coral
Reef
53
52
18
70
20

Map 16



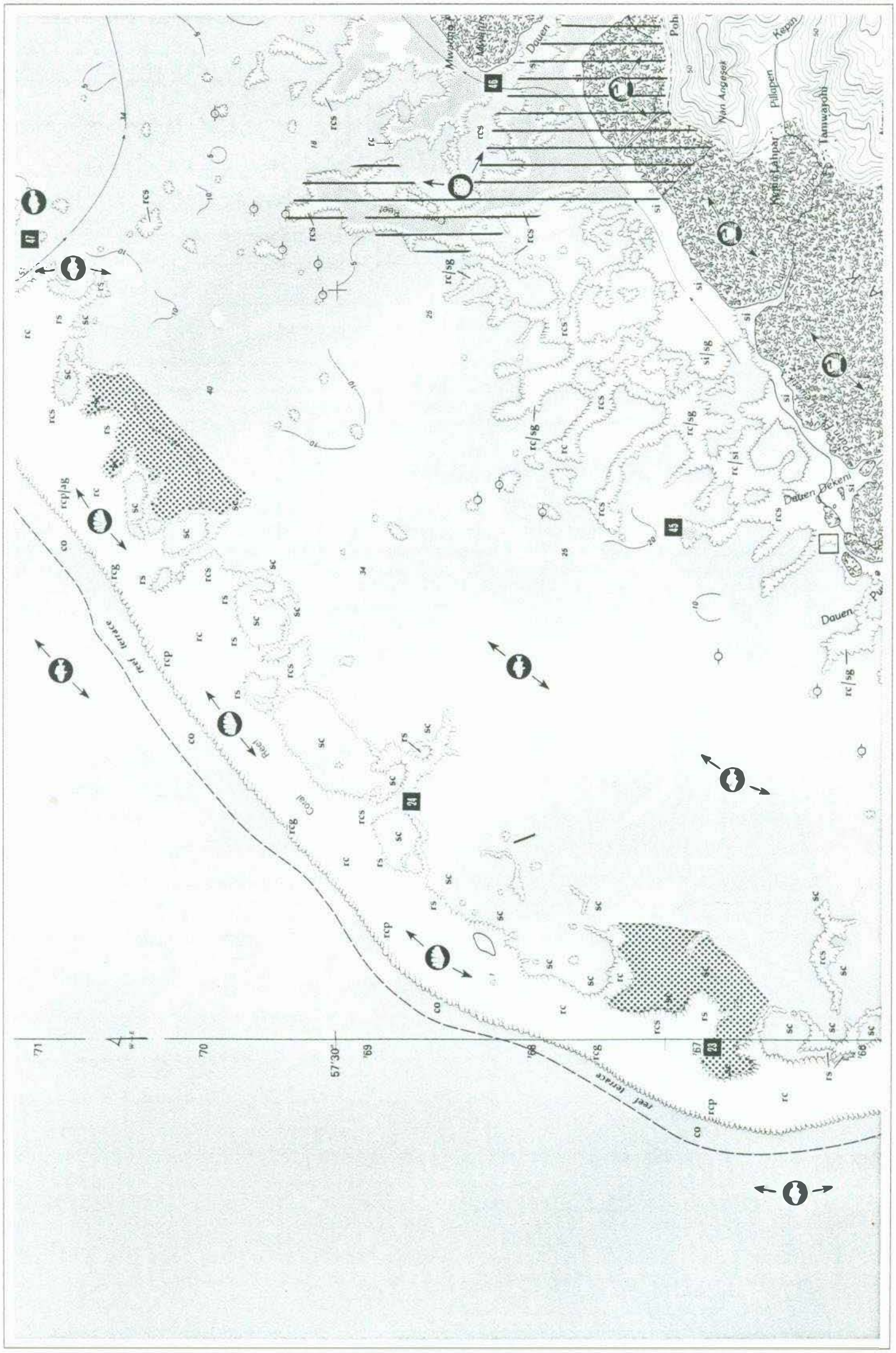
SOKEHS
KITI
MUNICIPALITY
MUNICIPALITY
INDEFINITE
reef terrace
dredge site
Pohn Dollap
Sekeren Lapahu
Ikerne
Pehleng
Dispensary
Esiil
Kiparalap
Imwin Dekehlap

Map 17

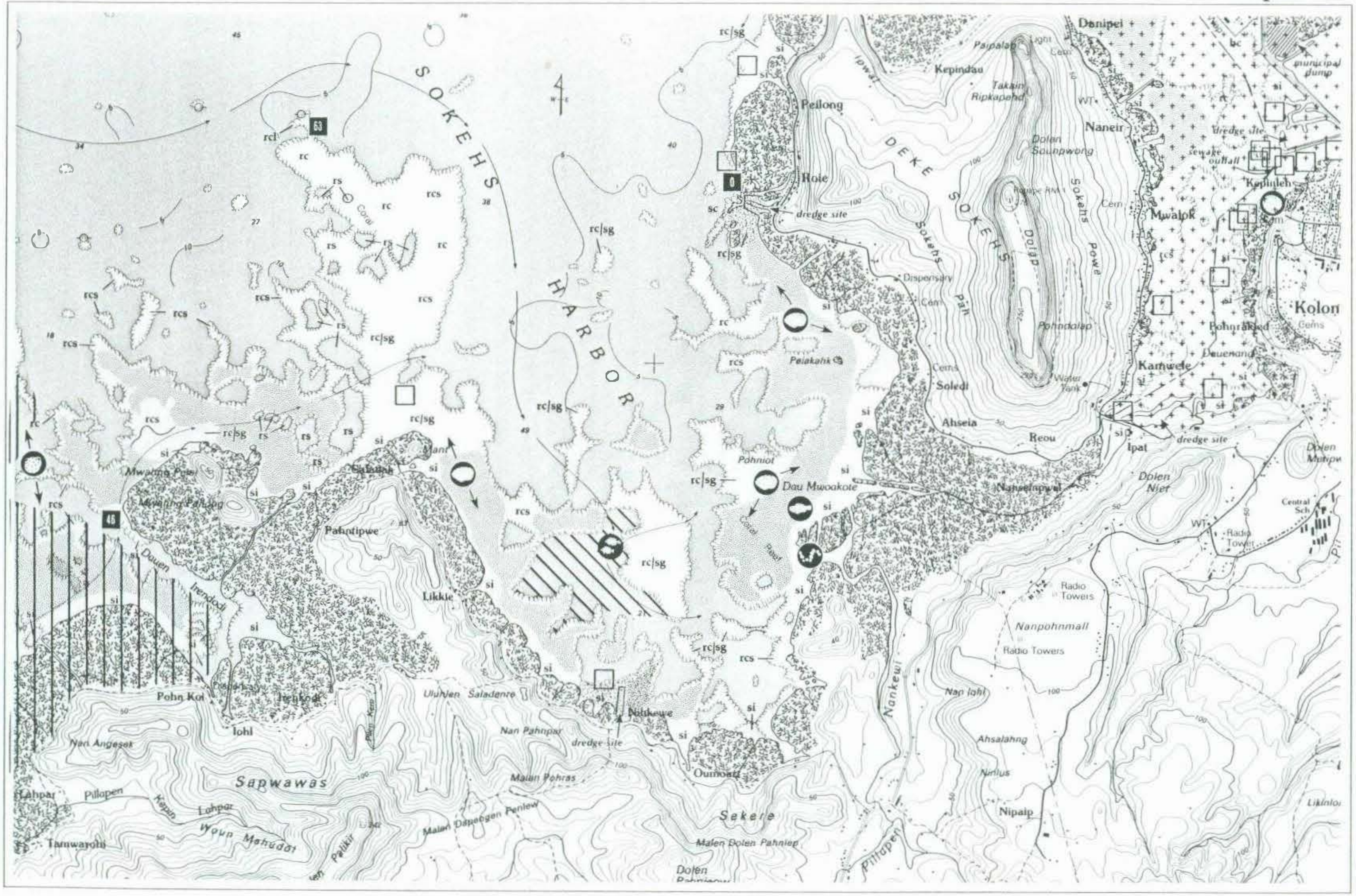


Sapwawas
Pillapen
Tamworohi
Palikir
Pohnahu
Pahn Kipar
Paies
SOKEHS MUNICIPALITY
KITI MUNICIPALITY
Tomwara
Kiparalap
Dauen Dekeni
Dauen Pueik
Imwin Dekehlap
Kepidauen
Dawahk
Coral Reef
reef terrace
seabird nesting
76 000 METERS
6°54'30"

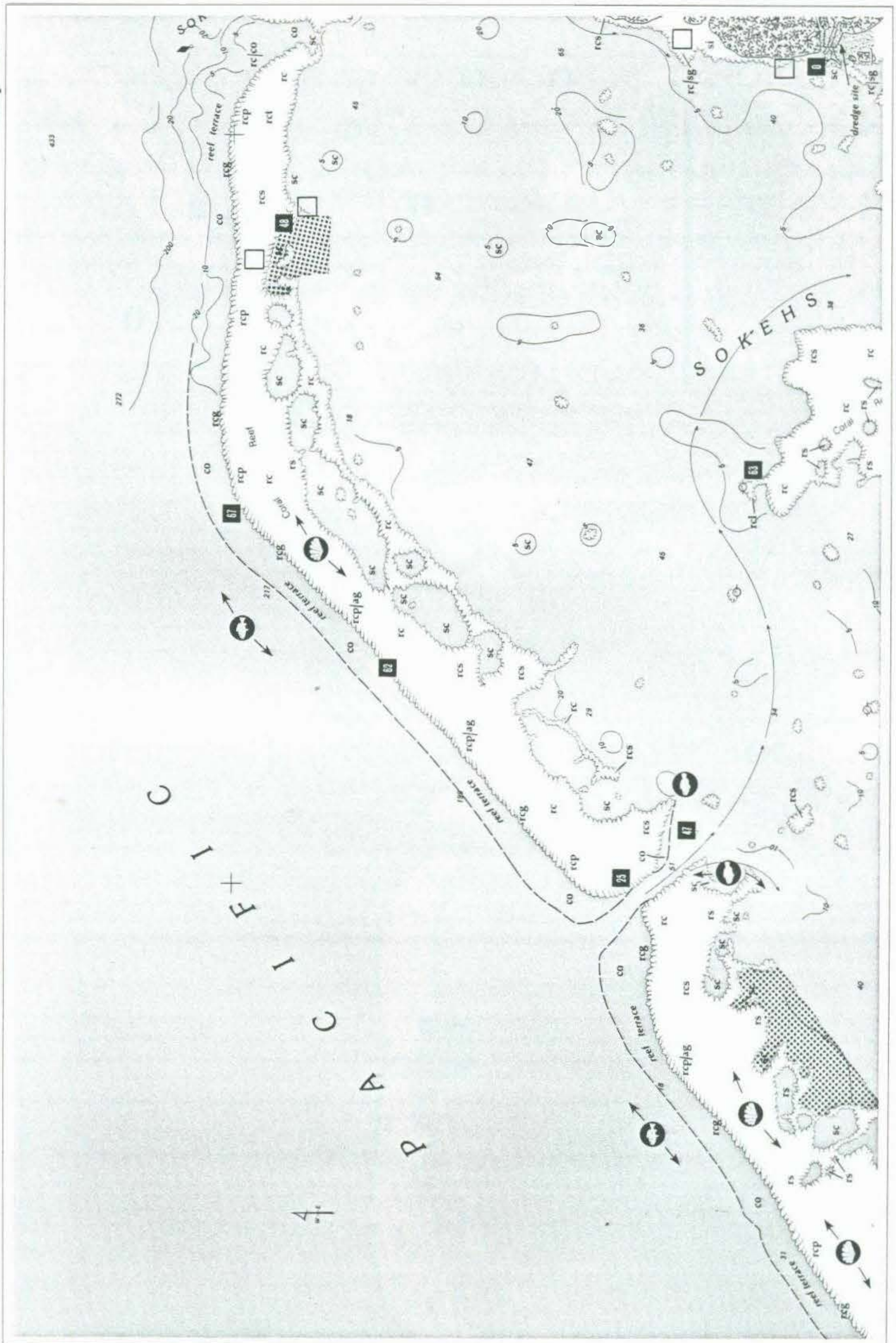
Map 18


reef terrace
Coral
Dauen Pekeni
Nan Angesek
Pillapen
Kepan
57°30'
rcs
rc
rs
sc
co
rcg
rcp
rc/sg
si
si/sg

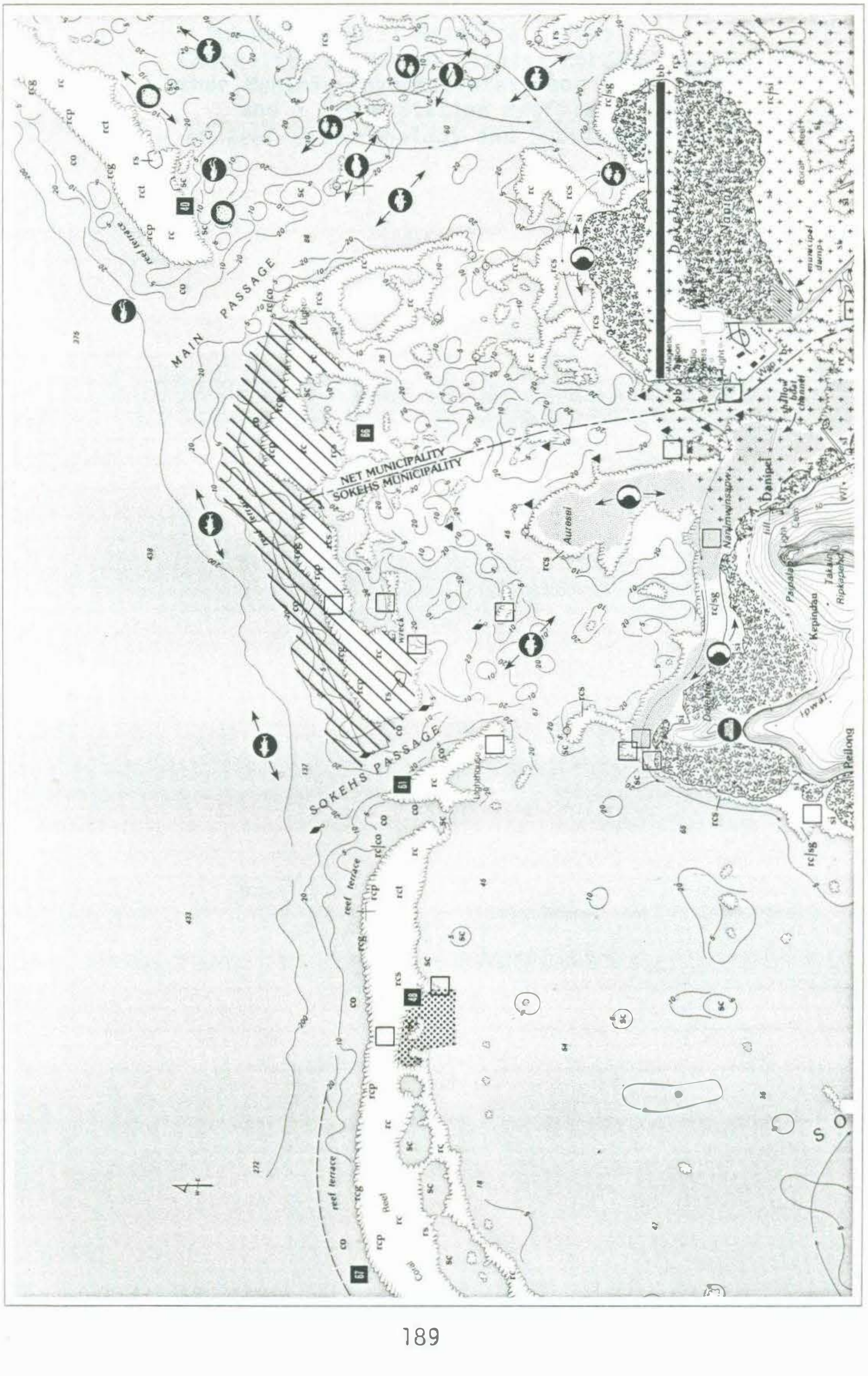
Map 19


SOKEHS HARBOR
DEKE SOKEHS
Sokehs Powe
Sokehs Pah
Dolap
Danipei
Kepindau
Paipalap
Takain Ripkapehd
Naneir
Dolen Sounpwong
Peilong
Roie
dredge site
Mwalok
Kepinleh
Kolon
Pohnrakied
Kamwele
Dauenand
municipal dump
sewage outfall
Pohndolap
Water Tank
Soledi
Ahseia
Reou
Ipat
Dolen Niet
Central Sch.
Radio Tower
Radio Towers
Nanpohnmall
Nan Iohl
Ahsalahng
Nipaip
Nankewi
Pillapen
Dau Mwoakote
Pohniot
Nahseinpwel
Peiakahs
Coral Reef
Likkie
Pahntipwe
Mwahng Pahlong
Douen Irendodi
Irenkodi
Pohn Kol
Iohl
Nan Angesek
Sapwawas
Lohpar
Pillapen
Tamwaroti
Woun Mahudai
Malen Pohras
Nan Pahnpar
Uluhlen Saladenre
Nikewe
Ounoatr
Sekere
Malen Dolen Pahniep
Dolen

Map 20



Map 21


MAIN PASSAGE
SOKEHS PASSAGE
NET MUNICIPALITY
SOKEHS MUNICIPALITY
reef terrace
reef terrace

APPENDIX 2

Pohnpei Coastal Resource Survey: Checklists of Marine Plants, Corals, Other Benthic Invertebrates, and Fish; and a Field Station Profile of Reef Geomorphology and Substrate

ACANTHOPHYLLIA
ACANTHASTREA
  ECHINATA
  HILLAE
ACRHELIA HORR.
ACROPORA
  ABROTANOIOES
  ACUMINATA
  ASPERA
  DELICATULA
  CYTHEREA
  ECHINATA
  FLORIDA
  FORMOSA
  GRANULOSA
  HEBES
  HUMILIS
  LONGICYATHUS
  NASUTA
  PALIFERA
  PROSTRATA
  PROCUMBENS
  ROBUSTA
  SQUARROSA
  SPLENDIDA
  SUBGLABRA
  SURCULOSA
  VALIDA
  VARIABILIS
  VAUGHANI
ALVEOPORA
  ALLINGI
  SUPERFICIALES
ASTREOPORA
  ELLIPTICA
  GRACILIS
  INCRUSTANS
  LISTERI
  MYRIOPHTHALMA
  OCELLATA
ANACROPORA SPIN.
ANOMASTREA
BLASTOMUSSA
CAULASTREA
CLADOCORA
CLAVARINA
COSCINARAEA
  COLUMNA
  MONILE
  WELLSI
CULICIA RUBEOLA
CYCLOSERIS
CYNARINA
CYPHASTREA
  CHALCIDICUM
  MICROPHTHALMA
  SERAILIA,
DIASERIS
DIPLOASTREA HELI.
ECHINOPHYLLIA AS.
ECHINOPORA LAMEL.
EUPHYLLIA
  CRISTATA
  FIMBRIATA
  GLABRESCENS
FAVIA
  AMICORUM
  FAVUS
  LAXA
  MATTAII
  PALLIDA
  ROTUMANA
  STELLIGERA
FAVITES
  ABDITA
  FLEXUOSA
  PENTAGONA
  RUSSELLI
FUNGIA
  (H) ACTINIFORMIS
  (V) CONCINNA
  (O) OAHAI
  (C) ECHINATA
  (F) FUNGITES
  (D) HORRIDA
  (P) PAUMOTENSIS
  (V) REPANDA
  (P) SCUTARIA
GALAXEA FASCICUL.
GARDINEROSERIS
GONIASTREA
  PALAUENSIS
  PECTINATA
  RETIFORMIS
GONIOPORA
  BERNARDI
  FRUCTICOSA
  LOBATA
HALOMITRA PILEU.
HELIOPORA COERU.
HERPOLITHA LIMA.
HETEROCYATHUS
HETEROPSAMMIA
HYDNOPHORA
  EXESA
  MICROCONOS
  RIGIDA
LEPTASTREA
  BOTTAE
  PURPUREA
  TRANSVERSA
LEPTOSERIS
  HAWAIIENSIS
  INCRUSTANS
  MYCETOSEROIDE
  SCABRA
  TUBULIFERA
LEPTORIA PHRYGI.
LITHOPHYLLON ED.
LOBOPHYLLIA
  CORYMBOSA
  HATAII
  HEMPRICHII
MADRACIS KIRBYI
MERULINA AMPLIA.
MILLEPORA
  DICHOTOMA
  EXESA
  LATIFOLIA
  PLATYPHYLLA
  TUBEROSA
MONTASTREA
  CURTA
  VALENCIENNESI
MONTIPORA
  BERRTI
  COLEI
  COMPOSITA
  DANAE
  DIGITATA
  EHRENBERGII
  FLOWERI
  FOLIOSA
  FOVEOLATA
  GRANULOSA
  HOFFMEISTERI
  LOBULATA
  MONASTERIATA
  RAMOSA
  SOCIALIS
  SPINOSA
  TUBERCULOSA
  VERRILLI
  VERRUCOSA
MYCEDIUM
  ELEPHANTOTUS
  TENUICOSTATUM
OULOPHYLLIA CRISP.
OXYPORA LACERA
PACHYSERIS
  RUGOSA
  SPECIOSA
PALAUASTREA RAMOS.
PARAHALOMITRA ROB.
PAVONA
  CACTUS
  CLAVUS
  DECUSSATA
  QUERDENI
  EXPLANULATA
  MALDIVENSIS
  MINUTA
  VARIANS
  VENOSA
PECTINIA LACTUCA
PHYSOGYRA LICHTEN.
PLATYGYRA
  DAEDALEA
  LAMELLINA
  PINI
  SINENSIS
PLEROGYRA SINUOSA
PLESIASTREA VERSI.
POCILLOPORA
  BREVICORNIS
  DAMICORNIS
  ELEGANS
  EYDOUXI
  MEANDRINA
  VERRUCOSA
  WOODJONESI
PORITES
  ANNAE
  AUSTRALIENSIS
  CYLINDRICA
  DENSA
  LICHEN
  LOBATA
  LUTEA
  MURRAYENSIS
  SOLIDA
  STEPHENSONI
  (S) RUS
PSAMMOCORA
  CONTIGUA
  DIGITATA
  EXPLANULATA
  HAIMEANA
  NIERSTRASZI
  STELLATA
  SUPERFICIALIS
SANDOLITHA ROBU.
SCAPOPHYLLIA CY.
SCOLYMIA
SERIATOPORA
  ACULEATA
  HYSTRIX
SIDERASTREA
STYLARAEA PUNCT.
STYLOCOENIELLA
  ARMATA
  GUENTHERI
STYLOPHORA
  MORDAX
  PISTILLATA
SYMPHYLLIA NOBI.
TRACHYPHYLLIA G.
TUBIPORA MUSICA
TURBINARIA
  BIFRONS
  FRONDENS
  PELTATA
ZOOPHILUS ECHINAT.

NONREEF CORALS

ACALYCIGORGIA
ANTIPATHES BIFARIA
BELLONELLA INDICA
CIRRHIPATHES SPIRALIS
DENDRONEPHTHYA
DENDROPHYLLIA
  GRACILIS
  MICRANTHUS
DESMOPHYLLUM
DISTICHOPORA VIOLACE.
JUNCEELA GEMMACEA
LOBOPHYTUM BATARUM
MELITHAEA ALBITINCTA
NIDALIA LAMPAS
PALYTHOA
SARCOPHYTON
  DIGITATUM
  TROCHELIOPHORUM
SINULARIA
  FLEXIBILIS
  POLYDACTYLA
SIPHONOGORGIA
  GODEFFROYI
SOLENOPODIUM STECHEI
STEPHANOGORGIA FAULK.
STYLASTER
  DUCHASSAINGI
  ELEGANS
SUBERGORGIA SUBERDSA
TUBASTRAEA COCCINEA

ZOANTHUS

aculeus
hyacinth.
irregul.
ten uis
ramose sp.

CHECKLIST OF BENTHIC INVERTEBRATES

ARTHROPODA
- CRUSTACEA
  - DECAPODA
    - ALPHEIDAE
      - ALPHEUS LOTTINI
    - OIOGENIOIDAE
      - CALCINUS LAEVIMANUS
      - C. MINUTUS BUITENDIJK
      - DARDANUS LAGOPODES
    - HAPALOCARCINIDAE
      - HAPALOCARCINUS MARSUPIALIS
    - CALAPPIDAE
      - CALAPPA HEPATICA
    - PORTUNIDAE
      - THALAMITA CRENATA
    - XANTHIDAE
      - ?EPIXANTHUS DENTATUS
      - TETRALIA GLABERRIMA
      - TRAPEZIA CYMODOCE
      - T. DIGITALIS
      - T. FERRUGINEA
      - T. INTERMEDIA
      - T. RETICULATA
    - GRAPSIDAE
      - METOPOGRAPSUS MESSOR

MOLLUSCA
- GASTROPODA
  - HALIOTIDAE
    - HALIOTIS SP.
  - TROCHIDAE
    - EUCHELUS ATRATUS
    - TROCHUS MACULATUS
    - T. NILOTICUS
  - TURBINIDAE
    - TURBO ARGYROSTOMUS
  - NERITIDAE
    - NERITA GRAYANA
    - N. PLICATA
    - N. RETICULATA
    - N. CF. SQUAMULATA
    - *N. UNDATA
  - LITTORINIDAE
    - LITTORINA UNDULATA
  - PLANAXIDAE
    - PLANAXIS SULCATUS
  - CERITHIIDAE
    - BITTIUM SP.
    - CERITHIUM COLUMNA
    - C. NODULOSUM
    - C. PLANUM
    - C. cf. RAVIDUM
    - CERITHIUM
    - RHINOCLAVIS ASPERA
    - R. FASCIATUS
    - R. STAERSIS
  - STROMBIDAE
    - LAMBIS LAMBIS
    - STROMBUS GIBBERULUS
    - S. LUHUANUS
    - S. MICROURCEUS
    - S. MUTABILIS
    - S. URCEUS
  - CYPRAEIDAE
    - CYPRAEA CARNEOLA
    - C. EROSA
    - C. HELVOLA
    - C. ISABELLA
    - C. LYNX
    - C. MONETA
    - C. TALPA
    - C. TIGRIS
    - C. VITELLUS
  - NATICIDAE
    - POLINICES TUMIDUS
  - CYMATIIDAE
    - *CYMATIUM NICOBARICUM
  - MURICIDAE
    - CHICOREUS BRUNNEUS
    - CHICOREUS
    - DRUPA RUBUSIDAEA
    - DRUPELLA CARIOSA
    - D. CORNUS
    - MORULA MARGARITICOLA
    - THAIS ARMIGERA
    - T. HIPPOCASTANUM
  - CORALLIOPHILIDAE
    - CORALLIOPHILA VIOLACEA
    - OVOVULA MADREPORARUM
  - COLUMBELLIDAE
    - MITRELLA LIGULA
    - PYRENE SP.
  - BUCCINIDAE
    - CANTHARUS FUMOSUS
  - NASSARIIDAE
    - NASSARIUS QUADRASI
  - FASCIOLARIIDAE
    - LATIRUS SP.
    - PERISTERNIA CF. INCARNATA
  - VASIDAE
    - VASUM TURBINELLUS
  - MITRIDAE
    - CANCILLA FILARIS
    - IMBRICARIA PUNCTATA
    - MITRA EMERITARUM
    - M. MITRA
    - M. NIGRICANS
    - NEOCANCILLA PAPILIO
  - COSTELLARIIDAE
    - VEXILLUM GRANOSUM
    - V. PLICARIUM
  - TURRIDAE
    - LOPHIOTOMA CF. ACUTA
  - CONIDAE
    - CONUS BALTEATUS
    - C. DISTANS?
    - C. EBERNEUS
    - C. FLAVIDUS
    - C. LITTERATUS
    - C. MAGUS
    - C. MARMOREUS
    - C. VIRGO
  - TEREBRIDAE
    - TEREBRA AFFINIS
    - *T. CINGULIFERA
    - T. FELINA
    - T. GUTTATA
    - T. MACULATA
    - T. SUBULATA
  - PYRAMIDELLIDA
    - PYRAMIDELLA SULCATA
- BIVALVIA
  - ARCIDAE
    - ANCDARA CF. NODIFERA
    - ARCA VENTRICOSA
    - BARBATIA TENELLA
  - PINNIDAE
    - ATRINA VEXILLUM
  - PTERIIDAE
    - PINCTADA MARGARITIFERA
    - PINCTADA SP.
    - PTERIA SP.
  - ISOGNOMONIDAE
    - ISOGNOMON PERNA
  - SPONDYLIDAE
    - SPONDYLUS TENEBROSUS
    - SPONDYLUS SP.
  - OSTREIDAE
    - LOPHA CRISTOGALLI
    - LOPHA SP.
  - CHAMIDAE
    - CHAMA CF. REFLEXA
    - CHAMA SP.
  - CARDIIDAE
    - ACROSTERIGMA cf. ELONGATUM
    - FRAGUM FRAGUM
  - TRIDACNIDAE
    - HIPPOPUS HIPPOPUS
    - TRIDACNA MAXIMA
  - TELLINIDAE
    - TELLINA CF. VIGATO
    - SCUTARCOPAGIA SCOBINATA

ECHINODERMATA
- ASTEROIDEA
  - ACANTHASTER PLANCI
  - CULCITA NOVAEGUINEAE
  - LINKIA LAEVIGATA
  - L. MULTIFORA
  - ECHINASTER LUZONICUS
- ECHINOIDEA
  - DIADEMA CF. SETOSUM
  - HETEROCENTROTUS MAMMILLATUS
- HOLOTHUROIDEA
  - STICHOPUS CHLORONOTUS
  - S. HERMANNI
  - ACTINOPYGA MAURITIANA
  - BOHADSCHIA GRAEFFEI
  - B. ARGUS
  - B. MARMORATA
  - HOLOTHURIA ATRA
  - H. EDULIS
  - H. NOBILIS
  - H. LEUCOSPILOTA
  - SYNAPTA SP.

CHECKLIST OF MARINE PLANTS

CYANOPHYTA (BLUE-GREENS)
- HORMOTHAMNION ENTEROMORPHOIDES
- MICROCOLEUS LYNGBYACEUS
- SCHIZOTHRIX CALCICOLA
- SCHIZOTHRIX MEXICANA

CHLOROPHYTA (GREENS)
- BOERGESENIA FORBESII
- BOODLEA COMPOSITA
- CAULERPA RACEMOSA
- CAULERPA SERRULATA
- CHLORODESMIS CF. FASTIGIATA
- DICTYOSPHAERIA SP.
- HALIMEDA cf. DISCOIDEA
- HALIMEDA cf. INCRASSATA
- HALIMEDA MACROLOBA
- HALIMEDA OPOUNTIA
- NEOMERIS VANBOSSEAE
- RHIPILIA ORIENTALIS
- TYDEMANNIA EXPEDITIONIS
- VALONIA FASTIGIATA
- VALONIA VENTRICOSA

PHAEOPHYTA (BROWNS)
- DICTYOTA CF. BARTAYRESII
- ECTOCARPUS CF. BREVIARTICULATUS
- HYDROCLATHRUS CLATHRATUS
- LOBOPHORA VARIEGATA
- PADINA SP.
- RALFSIA PANGOENSIS
- SARGASSUM POLYCYSTUM
- TURBINARIA ORNATA
- TURBINARIA DECURRENS

RHODOPHYTA (REDS)
- ACANTHOPHORA SPICIFERA
- ACTINOTRICHIA FRAGILIS
- AMANSIA CF. GLOMERATA
- AMPHIROA FOLIACEA
- AMPHIROA FRAGILLISSIMA
- CERAMIUM
- CORALLINE ALGAE
- GELIDIUM SP.
- GRACILARIA SALICORNIA
- GRACICARIA SP.
- HALYMENIA DURVILLAEI
- HYPNEA SP.
- JANIA SP.
- LAURENCIA SP.
- TOLYPIOCLADIA GLOMERATA

SEAGRASSES
- ENHALUS ACOROIDES
- THALASSIA HEMPRICHII
- CYMODOCEA SP.

REEF SURVEY

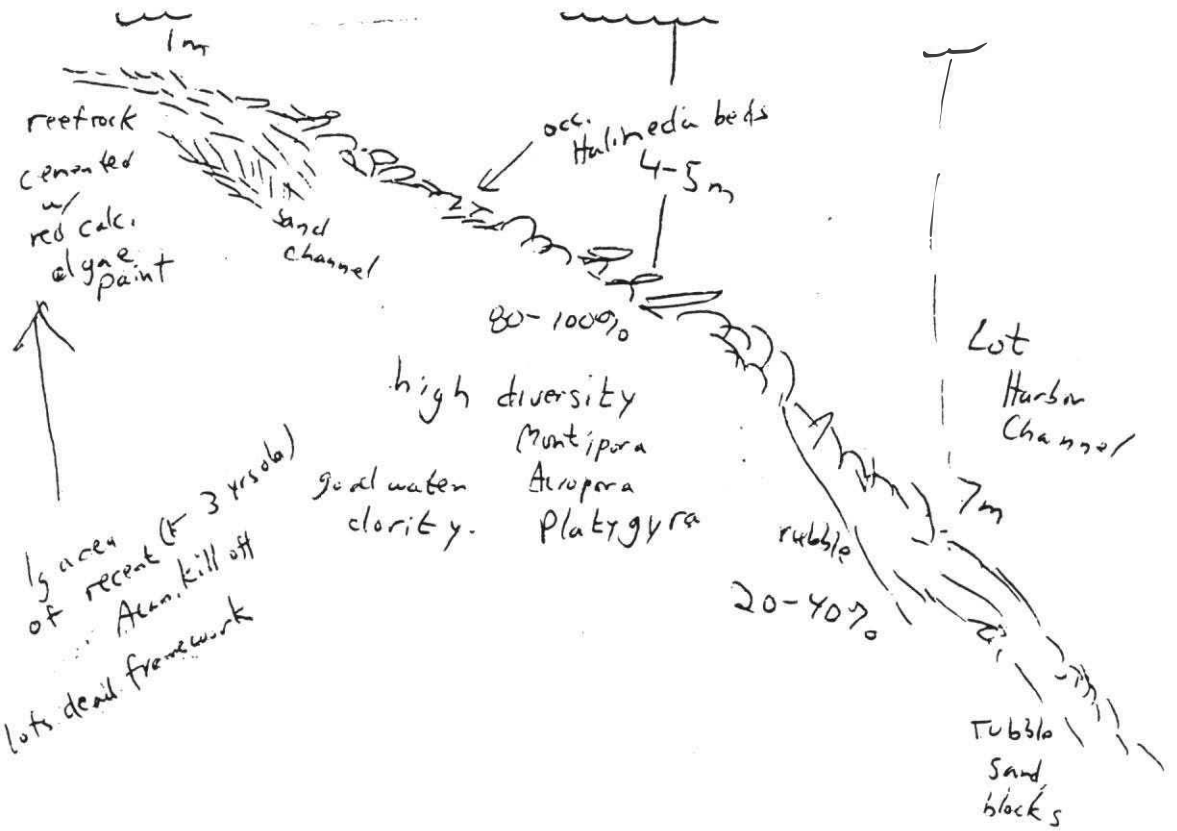
Site No.: 56
Date: 24 Apr
Name: PJ
Other Personnel:
Depth Range: snorkel

Winds: light
Seas: smooth
Currents: —
Weather: +
Water Quality: good

Location: Lot Harbor – in lee of Nth Pwil I Island

Description: outer edge of fringing reef – N side of Lohd Harbor pass

Code_____ Species/Subject | Rel. Abundance | Other



Remarks: (Pollution, Coastal Vegetation, Problems)
Lohd Harbor to k. Itti boundary – reef flat – dense, short seagrass esp near mangrove

A. Algae
B. Invert./Mollusc.
C. Geomorphology
D. Uses

one lg. basalt outcrop on reef flat just outside mangrove