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MARINE ENVIRONMENTAL ASSESSMENT REPORT ON UNITED STATES ARMY LEASED LANDS AT KWAJALEIN ATOLL

PREPARED FOR:

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EXECUTIVE SUMMARY

This narrative report presents the results of an environmental assessment of shallow marine waters adjacent to U.S. Army leased islands on Kwajalein Atoll, Republic of the Marshall Islands, as requested by the Environmental Section of the U.S. Army Corps of Engineers, Pacific Ocean Division. The assessment was performed to (1) inventory the coral, fish, algae, and macroinvertebrate populations; (2) document the impacts of previous and existing activities within the survey area; (3) assess the potential impacts of future activities within the survey area; and (4) identify options to minimize economic, social, and cultural impacts to the marine environment. This information will be incorporated into an Environmental Impact Statement currently under preparation by the U.S. Army Corps of Engineers.

The overall status and quality of the marine environment surrounding the U.S. Army Kwajalein Atoll (USAKA) facilities are good. Although initial construction activities caused severe environmental effects on Kwajalein, Meck, and Roi-Namur islands, the more recent level of activity has allowed significant recovery in most localities.

A diverse assemblage of marine life populates the nearshore coral reef system (Appendix 1). This assemblage supports both subsistence resource use by the Marshallese and recreational use by USAKA Contract personnel. Interviews with these resource users indicate that resources are abundant around the atoll, although there is a "perception" that they are not as plentiful as a decade ago. All users agree that the existing policy of closure of the Mid-Atoll Corridor during missions is only a minor inconvenience and does not greatly impact fisheries activities.

Gellinam and Gagan have the best developed lagoon coral reef assemblages adjacent to the USAKA leased islands. These should be protected against severe ecological impact. Gellinam is noteworthy because it has the only reproductively viable population of giant clams (Tridacna gigas) found during the survey.

The immediate projects planned for the USAKA leased islands in Kwajalein Atoll should not have lasting negative environmental impacts. The majority of these projects deal with maintenance dredging and pier repair, which will have short term effects on the already disturbed soft substratum of the harbors. The major environmental impact will be from the sediment burden placed on the biota adjacent to the harbors. This will be most critical at Gagan and Gellinam where there are well developed lagoon coral reef systems. Fill sites should first be surrounded by revetment and filter cloth, before the actual fill operation begins, to reduce the suspension of sediments.

It is possible, however, that the planned 1500 ft. (457 m) runway extension at Roi-Namur will have a greater and longer impact on the marine environment. Not only will a large, relatively productive and diverse reef area be covered, but the current patterns in the area will be significantly modified. This change in current patterns could have a significant impact on the surrounding biological assemblages. If feasible, extending the runway in the opposite direction would avoid these impacts.

The runway extension will also cause the loss of important fisheries habitat. The Marshallese interviewed on Ennubirr (Third Island) reported that this locality has the best fishing around Roi-Namur. Though it is known that part of this habitat will be lost because of the fill operation, it is not known what, if any, impacts will result from the altered current patterns.

If feasible, any future operations or activities that require extensive impact to the marine environment should be conducted at Meck or Kwajalein islands. Both islands have good facilities and the lagoon terraces and slopes have already been extensively modified and heavily impacted. The other islands investigated were not as extensively modified and appear to be recovering from past impacts. They should not, therefore, be subjected to major environmental disturbances if Meck or Kwajalein can be used.

Reef flat quarries are an important source of building materials and rock for shoreline protection. After dredging, the resulting holes provide new habitat for the development of coral reef biota. These quarry holes are used for a variety of recreational activities from fishing to collecting marine animals for aquariums. Our field survey revealed that the best reef development occurs in quarries that flush well and remove fine sediments. Specific quarry design recommendations are offered that will allow good coral reef development.

The following is a summary of specific recommendations addressing conclusions derived from the environmental assessment.

RECOMMENDATIONS

Quarries

1) Quarry Design: The best quarry design supplies the most armor stone and much of the construction aggregate while promoting diverse coral reef development. Maximum use of reef flat surface area supplies the most armor stone. Diverse coral reef development is accomplished by designing a system that flushes well and transports the fine sediments out of the quarry. Features that promote fine sediment removal include:

   a) Large size with complex shape and varying bathymetry (L-shaped, S-shaped, etc.) favors sediment removal.

b) Habitat complexity: leave islands, ridges, complex bottom, etc.

c) Maximum depth of quarry holes should be about 13 ft. (4 m).

d) Shoaling of the "downstream" end and portions of the shoreward side of quarries so sand can transport out.

e) Sloping of quarry margins on the "downstream" end and portions of the shoreward side so sand can be moved upslope and be transported out (don't have only vertical walls).

f) Location close to the ocean margin helps flush sediment.

g) Location near the interisland reef flat promotes flushing of sediment because of stronger currents at the ends of the islands.

h) When there are several adjacent cells, they should be interconnected so sediment can move "downstream" through the cells.

i) Start quarrying a series of cells "upstream" to decrease sedimentation in newly dredged quarries.

2) Designate USAKA quarries as reserves for coral and tridacnid clams. (see #6)

Water Quality

3) Water quality testing should be conducted, emphasizing the sanitary landfill on Kwajalein Island and the open dump on Roi-Namur, both of which previously measured water column levels of copper and mercury higher than allowable under Trust Territory ambient water quality standards (USAEHA, 1977; BMDSCOM, 1980).

4) Investigate the two Roi-Namur thermal discharge sites for elevated coliform and nutrient levels:

   a) The Roi-Namur Power Plant's discharge pipe into the lagoon.

   b) The discharge site east of Yokohama Pier by the sunken pontoon bridge.

5) The petroleum burn pit near the Kwajalein Island sanitary landfill should be monitored for leaching onto the adjacent ocean reef flat.

Tridacnid Clams

6) Prohibit the taking of all tridacnid clam species by USAKA personnel throughout Kwajalein Atoll. The IUCN Red Book (Wells et al., 1983) lists *Tridacna gigas* as "vulnerable," *T. maxima* as "insufficiently known," and *T. squamosa* as "indeterminate."

6.1) Because the lagoon reef adjacent to Gellinam Island has the only reproductively viable giant clam (Tridacna gigas) population of all the USAKA leased islands, it should be designated a marine conservation area, with no exploitation except for fishing.

6.2) Relocate clams from areas to be dredged/filled, possibly to quarry holes.

Roi-Namur Dryess Airfield Runway Extension

7) Consider option to partially extend the Roi-Namur Dryess Airfield runway in the opposite direction to the proposed plans. See alternatives and mitigating actions in the Discussion Section.

Landfill/Dredging Operations

8) Recommended procedure for landfill operations:

   a) Close off the intended fill area with rip rap and filter cloth, starting at the "downstream" side.

   b) Once rip rap is in place, the fill material should be transported to the site by the least environmentally destructive method. If there are adjacent coral reefs, do not barge the fill directly to the site through or over the reef.

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LIST OF ACRONYMS

BMDSCOM = U.S. Army Ballistic Missile Defense Systems Command

BTL = Bell Telephone Laboratories

COE = U.S. Army Corps of Engineers

ECI = Environmental Consultants, Inc.

EIS = Environmental Impact Statement

FSM = Federated States of Micronesia

gpd = gallons per day

IUCN = International Union for Conservation of Nature and Natural Resources

MIMRA = Marshall Islands Marine Resources Authority

NPDES = National Pollution Discharge Elimination System

RMI = Republic of the Marshall Islands

STP = Sewage Treatment Plant

USAED = U.S. Army Engineer Division (= COE)

USAEHA = U.S. Army Environmental Hygiene Agency

USAKA = U.S. Army Kwajalein Atoll

USASSCOM = U.S. Army SAFEGUARD System Command

I. INTRODUCTION

A. STUDY PURPOSE AND OBJECTIVES

Planned changes and improvements to the U.S. Army Kwajalein Atoll (USAKA) facilities and leased islands at Kwajalein Atoll, Marshall Islands, require an environmental evaluation. The U.S. Army Corps of Engineers, Pacific Ocean Division, provided a grant to the National Oceanic and Atmospheric Administration for the University of Hawaii Sea Grant Extension Service to assess the marine and coastal environment of Kwajalein and Roi-Namur islands and U.S. Army leased islands in the Mid-Atoll Corridor (Fig. 1; Table 1). This information will be incorporated into an Environmental Impact Statement (EIS) to be produced by the Corps of Engineers.

The study objectives include:

(1) taking an inventory of the coral, fish, algae, and macroinvertebrate populations;

(2) documenting the impacts of previous and existing activities conducted within the survey area;

(3) assessing the potential impacts of future activities within the survey area; and

(4) identifying options to minimize economic, social, and cultural impacts to the marine environment.

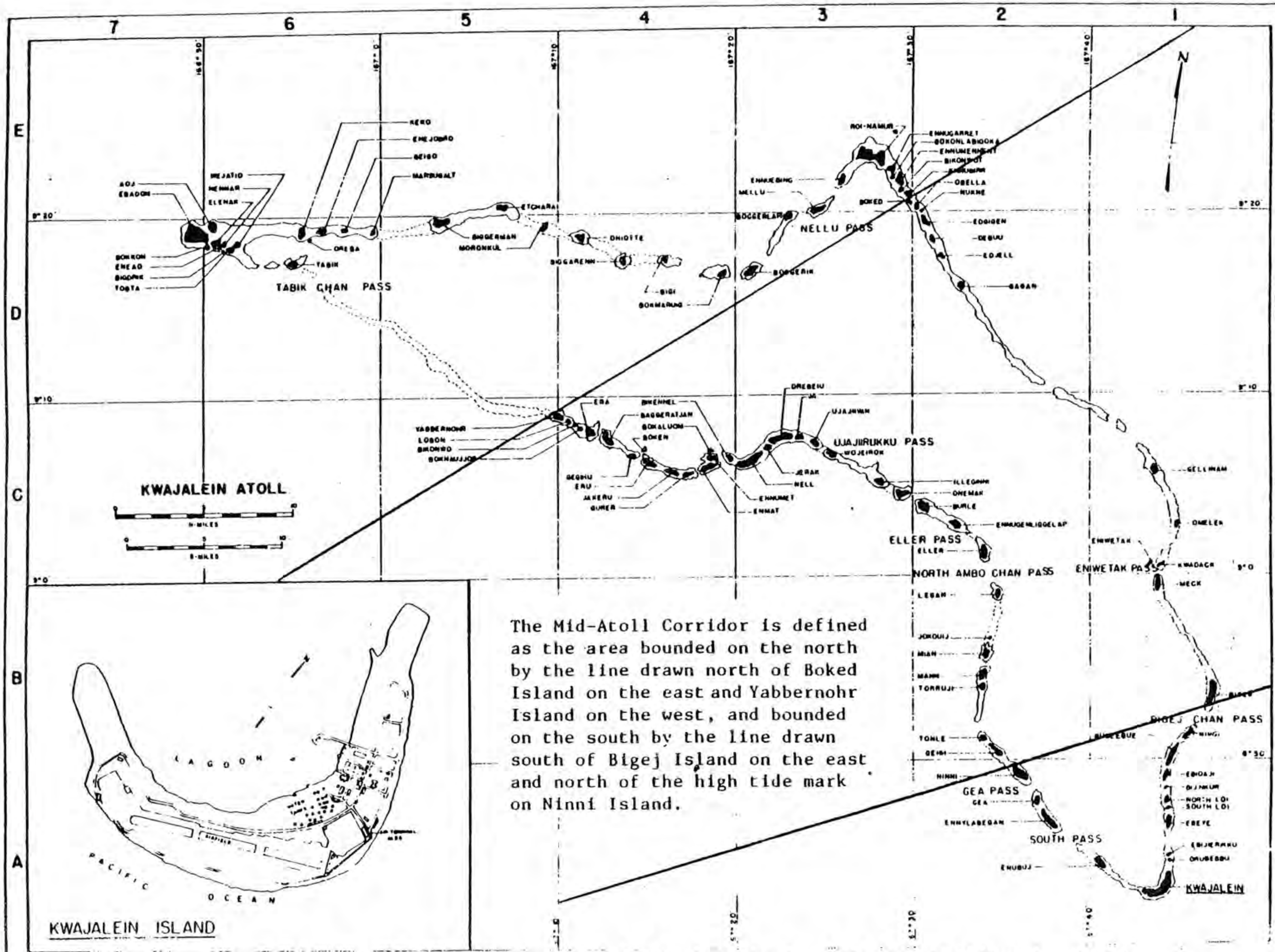

Figure 1. A map of Kwajalein Atoll, Republic of the Marshall Islands and the Mid-Atoll Corridor which is

TABLE 1. Surveyed USAKA Islands with Proposed Modifications (Belt Collins & Associates, 1987).

	No. Days Fieldwork	No. of Existing Quarries	Transect Site	Proposed Modifications Quarrying	Harbor Maintain/ Dredging	Land Fill
KWAJALEIN	8	10	X	X	X	X?
MECK	3	6	X		X	
ENIWETAK	2	0			X	
OMELEK	1	1				
GELLINAM	1	1			X	
GAGAN	2	1	X			
ROI-NAMUR	5	0	X	X	X	X
ENNYLABEGAN	1	0			X	
LEGAN	2	1			X	
ILLEGINNI	1	2				
GUGEEGUE	1	5	X			

B. SCOPE OF WORK

The study consisted of four phases: a literature search, a resource user survey, a field survey, and preparation of this report. The literature search revealed that the bulk of marine science information specific to Kwajalein Atoll is contained in government contracted and/or prepared documents. A history of marine environmental impacts can also be culled from these documents.

A resource user survey was conducted because there are no available Republic of the Marshall Islands (RMI) fisheries data.

Key Kwajalein Atoll coastal users were interviewed from Ebeye, Ennubirr, and Ebadon islands. In addition, a group of Rongelapese living on Mejatto and a group of USAKA contractors were also interviewed. The primary information solicited dealt with fishing methods, target species, fisheries problems and history.

The one month marine investigation (16 January to 16 February, 1988) was limited to the shallow coastal areas adjacent to USAKA leased islands. These are the areas that can potentially be impacted by modifications and changes to facilities and marine habitats. The planned changes and modifications addressed during the investigation were taken from the most recent USAKA facilities requirement evaluation (Belt Collins & Associates, 1987). In addition, previously impacted areas were surveyed to determine to what degree they had recovered.

The information from the field investigation and the literature search are contained herein. This report is organized in standard fashion and addresses past, present and planned future impacts known to date, to the shallow marine environment around USAKA leased islands. Recommendations are made to help minimize future impacts, including suggestions about alternative sites for activities, facility or structural design modifications, and enhancement techniques. Some recommendations are also made to speed the recovery of previously impacted areas. The recommendations are divided into two types: those which are the responsibility of USAKA and should be implemented, and those which are optional actions but beneficial and could be implemented by any interested party (including RMI, USAKA, or others). Of immediate importance, however, are the recommendations made to USAKA that affect the planned changes and modifications to facilities and leased marine habitats.

II. METHODS

The Kwajalein marine environmental assessment survey covered a total of eleven islands (Table 1: p. 20) and was completed in two phases. Phase 1 was conducted in December, 1987, and consisted of an initial site inspection by the project leader to determine logistical support and scheduling for the following field study. Interviews of coastal resource users around the atoll, particularly with fishermen and scuba divers, were also conducted during this Phase. Site visits to several of the islands to be surveyed assisted in determining the number of field days per island based on each island's size, the planned modifications, and adjacent marine habitat complexity.

A. FIELD STUDY

Phase II was the field study. Scientists from the University of Hawaii and the University of Guam (Appendix 2) conducted an comprehensive one month marine environmental survey (January 16- February 16, 1988) of the USAKA leased islands located within Kwajalein Atoll. The base of operations was on Kwajalein Island except for four days spent on Roi-Namur Island. Transportation to outer USAKA islands involved short helicopter flights. Consequently, helicopter flight schedules determined, in part, the amount of time available to work on each of the other islands. Furthermore, during USAKA mission activities (Jan. 27-28; Feb. 7-8), field work was restricted to the islands of Roi-Namur and Kwajalein. Since time was limited and there were a large number of islands to study, the field work was extensive in nature rather than intensive. Therefore, the data collected were qualitative and/or semiquantitative.

The study area consisted of eight U.S. leased islands located within the central part of Kwajalein Atoll, known as the Mid-Atoll Corridor, and the islands of Kwajalein and Roi-Namur. Additionally, the previously leased island of Gugeegue was surveyed. The survey area was generally restricted to marine areas landward to the highest storm berm (or, in many cases, the rip rap protecting the coastline) and seaward out to a depth that could be studied by snorkeling (usually the dropoff to the lagoon terrace). The study area extended only to the outer edge of the ocean reef flat on windward islands because winter sea conditions would not allow safe access to the fore reef.

The marine habitat was surveyed by walking, wading, and snorkeling. With the aid of aerial photographs, the field team walked the perimeter of each island (and drove along Kwajalein, Roi-Namur, and Ennylabegan) noting shoreline substratum, habitat, biota, currents, etc. During low tides, the structure and zonation of the reef flat was documented. Additionally, the team snorkeled the lagoon side of each island, paying most attention to harbor areas with planned construction or modification, and areas with good reef development. Those islands with dredged quarries on the ocean reef flat were snorkeled during low tide (Table 1: p. 20). The sequence of these activities varied depending upon the tidal stage since accessibility to some reef flat sites is restricted at high tide due to wave action.

Quantitative data were selectively collected from sites scheduled for future activity that might cause marine environmental impacts (such as quarrying, filling, and/or dredging). Transect markers made from 3/4 inch rebar stakes were driven into the reef on the islands of Roi-Namur, Kwajalein, Meck, Gagan, and Gellinam. As time and water conditions permitted, replicate transects were preformed. A total of three replicate transects, approximately 10 meters apart, were completed for proposed reef flat areas to be quarried/filled.

For all transects, a 10 meter brass chain, marked at one meter increments, was laid along the bottom. Percent coverage of benthic organisms was calculated by counting the number of links covering the various species and substratum (approx. 62 links per meter). A modified method after Brock (1982) was utilized in estimating fish density and abundance along the transect zone. The modification consisted of not taking standardized 50 m transects, but rather varying the length according to conditions and available time.

Qualitative assessments were made at all study sites. Species and relative abundance were noted, along with distributional, ecological, and habitat information.

The field team noted any localities with potential water quality problems. No effort was made to take samples because the Corps of Engineers notified us that another contract would be given expressly to investigate water quality around USAKA leased islands.

The terminology and framework for the reef descriptions used in this report are based on those used by Ristvet (1987). Figure 2 is a generalized cross section of a windward atoll reef.

B. RESOURCE USER INTERVIEWS

Interviews were conducted as a means of obtaining accurate, non-quantitative information on marine resource uses. This method has proven to be successful in extensive fishery interviews conducted by Johannes (1981) in Palau. An abbreviated interview method was subsequently utilized by Holthus (1987) in Pohnpei. The technique has since been incorporated into other coastal resource inventory projects in Micronesia.

During a nine day period (December 8-16, 1987), five groups of fishermen/divers were interviewed. Marshallese fishermen from Ebeye, Ennubirr, and Ebadon islands were interviewed, as well as a group of Rongelapese who are temporarily residing on Mejatto

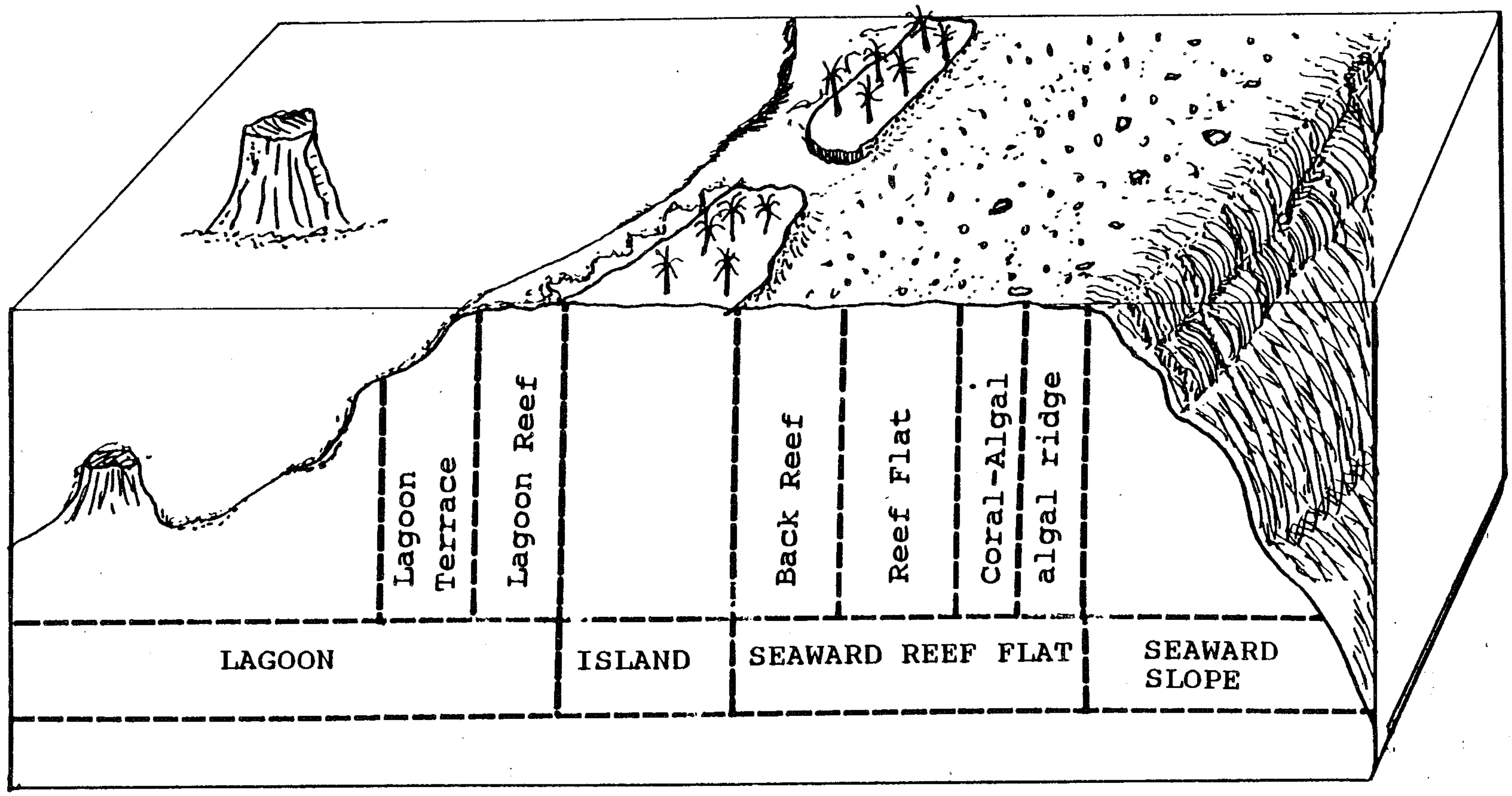

Figure 2. Typical zonation pattern of a windward atoll reef flat [after Wiens (1962) and Ristvet (1987)].

Island. Additionally, a group of contract USAKA workers from Kwajalein and Roi-Namur islands were interviewed.

Most fishing in the Marshall Islands is done by men and boys. As a consequence, all interviewees were male with the exception of several women who participated on Ebadon Island. There are two probable explanations for this deviance. One is that women are traditionally "reef gleaners" and, thus, consider themselves as resource harvesters rather than fishermen. The other probable explanation was the lack of presence of a female interviewer at most interview sessions.

All interviews, except for the Kwajalein Island session, were arranged through the RMI Liaison Office on Kwajalein and with the assistance of the Marshall Islands Marine Resources Authority (MIMRA). The Kwajalein Island interview session was arranged by Mr. Hideo Milne, Manager of the Kwajalein Special Services Department. Times, dates and people involved in the interviews are summarized in Appendix 4.

Prior to the interview sessions, a species list of popularly harvested fish and other marine organisms was generated from photographs in books in consultation with Mr. R. Virgil Alfred, a MIMRA Fisheries Officer (Appendix 3). Included in this list were the Marshallese and common names for each species, and the Latin names as verified in the field. For simpler demarcation on the maps during the interview sessions, numbers were assigned to each species. This list then served as a working template, with subsequent additions and deletions of fish species as the interview sessions progressed.

Four of the five interviews were conducted in the Marshallese language with Mr. Alfred acting as interpreter. The interviews on Kwajalein Island, conducted in English, were the only exception. After a brief introduction describing the scope and goals of the project, the fishermen marked the species ranges on maps noting particularly desirable fishing area. The fishermen were also queried about the gear and methods utilized for fishing, and the best seasons or months to harvest each species. Each interview lasted approximately four hours.

To acquire a more holistic perspective of the fishing practices in Kwajalein Atoll, the following questions were also posed to the fishermen:

1. Do they feel the fish catch has declined during the past decade?
2. Does the periodic closure of the Mid-Atoll Corridor affect fishing practices?
3. Are certain reef areas closed to particular fishermen because of custom or tradition?

III. RESULTS

A. PHYSIOGRAPHY

Kwajalein Atoll lies in the Ralik Chain of the Marshall Islands. It is located less than 700 miles (1126 km) north of the equator (9 degrees N Latitude, 167 degrees E Longitude) and, as such, has a humid, warm to hot tropical marine climate. The temperature is usually in the high 80's to low 90's and the humidity remains relatively high. The daily temperature range is less than 10 degrees F and the average difference between the warmest and coldest month is about 2 degrees F.

Kwajalein encompasses the world's largest atoll lagoon and covers a surface area of approximate 1100 sq. miles (2849 sq. km). It stretches 75 miles (121 km) from Ebadon Island to Kwajalein Island and averages about 15 miles (24 km) in width. There are approximately 100 islands on the atoll perimeter forming a land area of just 5.6 sq. miles (14.5 sq. km). Kwajalein, Roi-Namur, and Ebadon are the largest islands and comprise almost half of this area. Few natural elevations on the atoll exceed 15 ft. (4.6 m).

The largest component of the atoll is the lagoon, which ranges in depth from 120-180 ft. (37-55 m). The bottom consists primarily of soft substratum, although coral pinnacles and patch reefs are randomly scattered throughout the atoll. Coral pinnacles are generally distinguished from patch reefs by water depth. Patch reefs usually originate from a substratum visible from the surface and form flattened reef flats near the sea surface while the tops of coral pinnacles are in deeper lagoon waters and do not reach the sea surface to form flattened tops.

There are several major passes and channels that cut through the reef flat of Kwajalein Atoll (Table 2). These not only allow ships to safely enter the lagoon, but also transport large volumes of water. The passes are commonly areas of rough water because they allow oceanic swells to enter the lagoon.

TABLE 2. PASSAGES AND CHANNELS INTO KWAJALEIN ATOLL.
(As noted on the Kwajalein Atoll chart [DMA #81715])

Ambo Channel
Bigej Channel
Boggerik Passage
Ellep Passage
Eniwetak Passage
Gea Pass
Mann Passage
Milu Pass
Nell Passage
North Pass
Onemak East Passage
Onemak West Passage
South Ambo Channel
South Pass
Tabik Channel
Wojejairok Pass

The atoll rim consists of a number of distinct geological features and biotic habitats. These vary somewhat around the atoll depending on location, but can generally be separated into windward and leeward reefs, and the transition zones between them. The zonation and structure of a typical windward reef is shown in Fig. 2 (p. 27).

Kwajalein lies within the northeast tradewinds. These winds are more developed from December to June and average 16 mph (26 km/hr) from an east-north-east direction. From June to December, when the tradewinds move further north, the winds are weaker and generally come from a more easterly direction, although sometimes they shift to the southeast. Calms are rare and the sky is usually cloudy.

Precipitation is moderately high, averaging just over 100 inches (254 cm) per year. Most rainfall (75%) occurs from mid-May to mid-December. Moderate to heavy rain showers are common, especially in the wettest months from September to November. Light, short duration rain showers frequently occur from January through May. There are no orographic effects due to the absence of any significant land elevations. However, rainfall levels in different parts of large atolls such as Kwajalein may vary somewhat.

Although the Marshall Islands seldom are hit by typhoons, they are a spawning ground for tropical storms and typhoons during the wet season. Weak depressions can form near the atolls, causing locally heavy rain. Some of these eventually develop into typhoons after moving to the west.

The most recent occurrences of severe weather at Kwajalein Atoll were from the weak typhoons or tropical storms Mary, Rita, Alice, Freda, and Pamela which occurred in 1977, 1978, 1979, 1981, and 1982, respectively. These occurred within 150 nautical miles of Kwajalein Atoll, but their winds did not reach typhoon force at Kwajalein. However, Alice passed north of the atoll and her westerly winds caused considerable damage to USAKA facilities on Kwajalein Island due to waves generated inside the lagoon. Kwajalein Island is in the southeast corner of the atoll and has little natural protection on the lagoon side from waves approaching from the north. On the other hand, the facilities suffered no significant damage from Pamela's easterly onshore winds and waves due to the natural storm wave protection afforded by the shallow fringing reef on the ocean side.

Tropical Storm Roy hit Kwajalein Atoll on January 9, 1988, just prior to the sampling effort documented in this report. The storm was located to the south and was moving in a westerly direction when it struck Kwajalein and the winds and seas were from the ocean side. This was fortunate because the fringing reef on the ocean side of the atoll was able to absorb most of the storm's wave energy. The majority of the recorded damage was reported from the island of Ebeye, which is located just to the north of Kwajalein Island. Kwajalein Island suffered comparatively little damage in relation to Ebeye, probably because much of the ocean side of the island is protected by rip rap revetment. Ebeye suffered structural damage to many buildings and had portions of the island washed away.

Kwajalein's tidal range varies from 3-5 ft. (1-1.5 m) (Table 3). A large volume of water passes over the interisland reef flats during tidal changes, especially on the windward side, and create strong currents. At low tide, many sections of reef flat are emergent, some of which have well developed beach rock.

TABLE 3. Kwajalein Atoll Tidal Levels (COE, 1985).

	National Ocean Survey	1983 Measured
Highest Tide Observed	3.71 (ft.)	-
Mean Higher High Water	-	2.04 (ft.)
Mean High Water	1.74 (ft.)	1.68 (ft.)
Mean Sea Level	0.00 (ft.)	-
Mean Tide Level	-0.01 (ft.)	-0.05 (ft.)
Mean Low Water	-1.75 (ft.)	-1.80 (ft.)
Mean Lower Low Water	-	-1.91 (ft.)

NOAA reports a mean and spring tide range of 3.5 and 5.0 ft., respectively

B. SCOPE OF PREVIOUS ACTIVITIES

1. History of Environmental Impacts at Kwajalein Atoll

Man's activities have had a significant impact on the environment of Kwajalein Atoll. Micronesians introduced agricultural vegetation and domesticated animals, and accidental introductions probably included rodents and insects. Land clearing for coconut plantations was begun by the Germans for copra production, and coconut trees can still be found on several of the islands. However, the period of most rapid change started when Japan began developing Kwajalein Atoll into its largest military fortification within the Marshall Islands, in preparation for World War II.

Japanese military construction centered on the islands of Kwajalein and Roi-Namur, with support installations on other islands. Evidence of the resulting modifications to the atoll are still visible. The installations received heavy damage during the United States military takeover in 1944. Many of the Japanese structures were razed by U.S. forces in preparation for their own construction, but debris is still quite common because much of it was simply pushed into the lagoon. Additionally, quarries dredged prior to and during the war for construction materials are located on the outer reef flat of several of the islands.

The United States has continued occupation of parts of Kwajalein Atoll since 1944 under a lease agreement first with the landowners and later with the Republic of the Marshall Islands (RMI). Soon after occupation, the U.S. began construction of air and naval installations, along with their associated infrastructure. Activity and construction increased from 1951 to 1956 because Kwajalein became an important staging area for operations in Asia, and especially because of its close proximity to Bikini and Enewetak atolls where nuclear weapons were being tested. However, activity at Kwajalein diminished with the cessation of nuclear testing on these other atolls in 1958.

Many of the existing support facilities were built during the first half of the 1950's. It wasn't until 1959 that, on the brink of being abandoned by the Navy, Kwajalein Atoll was selected as a missile testing site. This initiated a program of facilities development that is still continuing and has resulted in some major modifications to terrestrial and marine habitats in parts of Kwajalein Atoll.

The greatest amount of habitat change has occurred on the islands of Kwajalein, Roi-Namur, and Meck. Kwajalein has served as the main headquarters for both the Japanese and U.S. forces. Likewise, Roi-Namur served as a major air field for both countries. As a direct result the terrestrial, and to a lesser extent the marine, habitats of both islands have been drastically changed. The development of support facilities on other islands has likewise altered their habitats to a great extent.

The major marine ecological impacts to Kwajalein Atoll are landfilling, dredging, quarrying, scrap and waste disposal, and wastewater discharge.

2. Landfill, Dredging, and Quarrying

The small islands of Kwajalein Atoll have often proved to be inadequate with respect to available space for the required USAKA facilities. Consequently, limestone materials have frequently been dredged from the atoll reef flats and lagoon as fill for expanding the land area. Obvious impacts of these actions include the loss of reef and marine habitats that are covered by the landfill operations and the destruction of habitat during dredging. Siltation and sediment plumes from dredging and filling operations cause a range of impacts from temporary silt suspension to the destruction of adjacent reef areas. Quarrying, on the other hand, causes an initial destruction of relatively barren reef flat habitat but results in new, more complex habitats that allow coral and fish colonization of the quarry hole once excavation is completed.

USAKA land expansion projects have occurred on four islands thus far, irreversibly covering a total of 264 acres (1 sq. km) of marine habitat. On Kwajalein Island, approximately 205 acres (0.8 sq. km) have been added to it's original 543 acres (2.2 sq. km) (BMDSCOM, 1980). Around 1961, 55 acres (0.2 sq. km) were added to the southwestern end of the island, while roughly 38 acres (0.15 sq. km) were added to the northeastern end (Losey, 1973; COE 1973b). Concurrently, the lagoon side was expanded in width, adding another 112 acres (0.45 sq. km) to the island's total area (Fig. 3).

At the northern point of Kwajalein Atoll, the two separate islands of Roi and Namur were combined and enlarged through a series of landfill projects conducted by the Japanese and Americans. Aerial photographs taken at the onset of the American drive to capture Roi and Namur islands from the Japanese reveal that both were naturally and artificially joined in 1944 (Fig. 4; BTL, 1981). On the lagoon side, a natural sand beach and an interisland beach rock spit linked the two islands together. On the seaward side, the Japanese had built a causeway that connected the islands across the interisland channel and the spit. By 1945, the Americans had permanently joined Roi and Namur islands by filling in the area from the causeway to the lagoon beach. Hence, the island is now known as Roi-Namur. Additionally, new land was created in the lagoon between the islands. Roi and Namur's original combined area of 358 acres (1.5 sq. km) had been enlarged to 398 acres (1.6 sq. km) during this landfill operation.

Between the years 1964-1974, Meck Island was enlarged by 14 acres (0.06 sq. km) with the fill extending onto the lagoon terrace (Fig. 5) (USASSCOM, 1973). Loss of marine habitat was

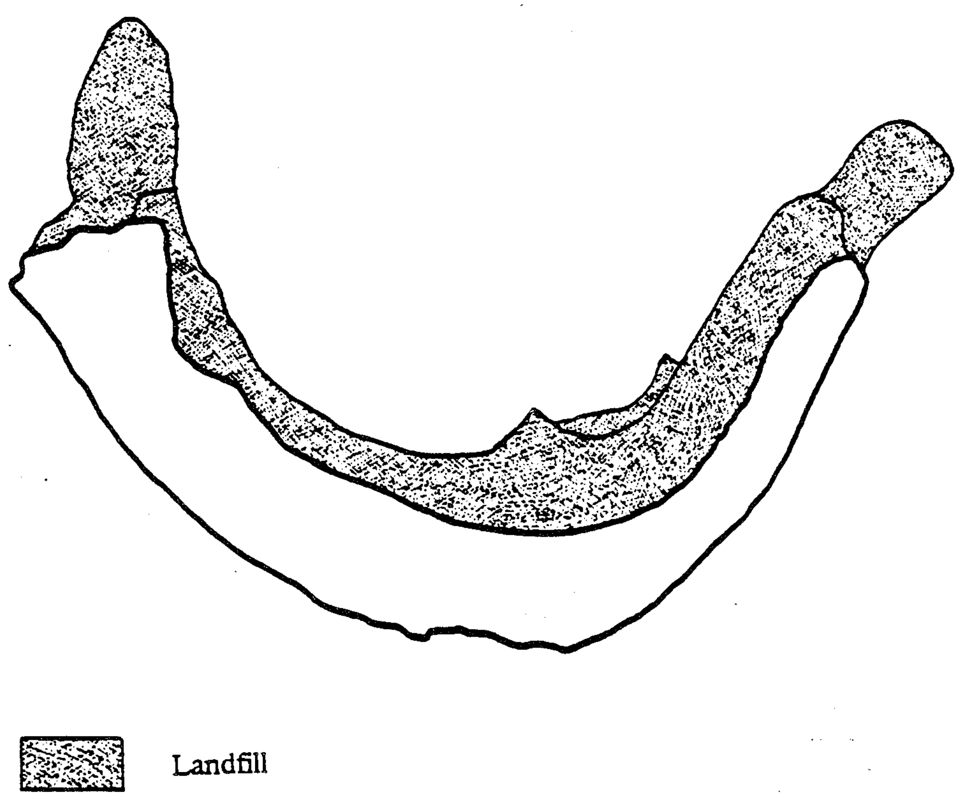

Figure 3. Location of landfill sites on Kwajalein Island, Kwajalein Atoll, RMI (BMDSCOM, 1980).

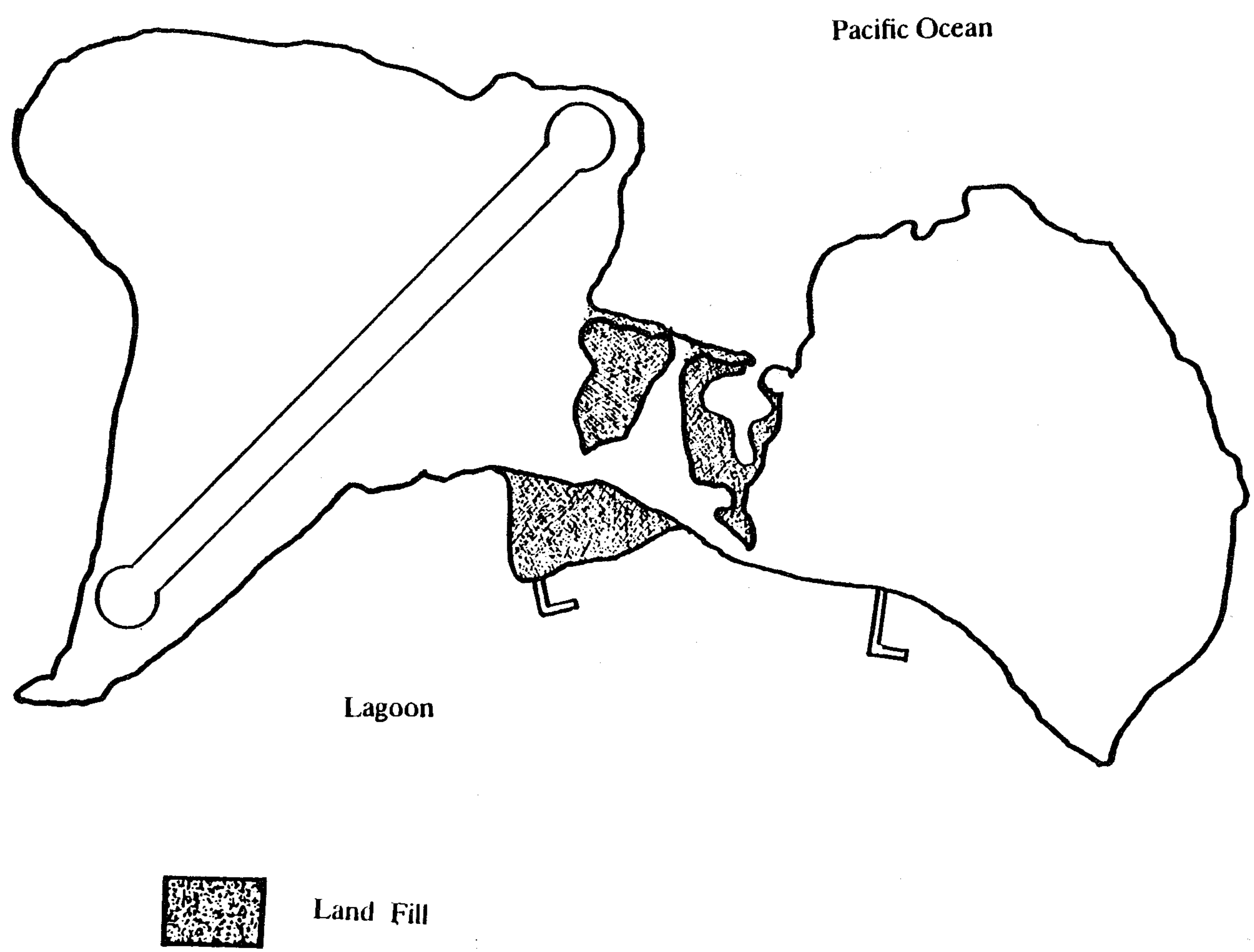

Figure 4. Landfill areas on Roi-Namur Island, Kwajalein Atoll, RMI. (BTL, 1981).

substantial due to the combined activities of both dredging and filling the lagoon terrace. Losey (1973) reported that nearly complete destruction of the lagoon slope and terrace reefs occurred due to utilization of simpler, alternate, and less expensive suction dredging and dragline dredging methods. Although some recent recruits of living corals were observed, Losey (1973) estimated that it would take longer than 25 years for Meck's reef terrace to recover.

Losey's (1973) 25 year recovery rate estimate is fairly accurate for some substrates. Some relatively large, undisturbed blocks of the original reef platform (about 10% of the lagoon terrace) have coral coverage up to 80%. Approximately 40% of the area is composed of small blocks and pieces of old reef rubble that were broken up during the dredging operations. These have newly exposed surfaces that are being recolonized by coral. They currently have about 60% coral coverage and will probably develop to their maximum potential by Losey's (1973) time estimate. The remaining area (about 50%), however, has been irreversibly modified by dredging activities. Large expanses of reef platform have been crushed into fine sediments that will allow only extremely limited coral development.

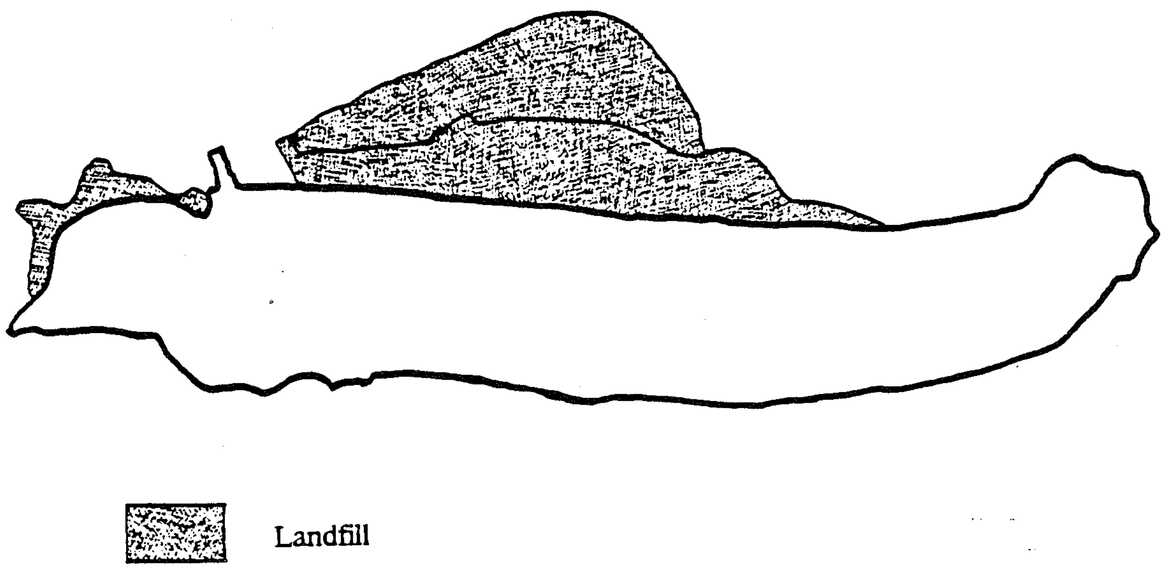

Figure 5. Location of the landfill sites on Meck Island, Kwajalein Atoll, RMI. (BMDSCOM, 1980).

Reports indicate that one acre of landfill was added to the seaward side of Illeginni Island (ECI, 1977). The precise location of the landfill, however, could not be discerned from previously published reports.

For over forty years, periodic dredging activities have occurred on all islands leased by USAKA, causing localized impacts to the marine water quality and environment. Most dredging activities reflect a need to maintain or improve harbor areas and facilities. Furthermore, aggregate materials are excavated from various lagoon sites for fill and construction materials vital to facilities development.

Quarries have been dredged near or adjacent to twelve of the islands in Kwajalein Atoll (Table 1 (p. 20) plus South Loi; BMDSCOM, 1980), and there are plans to dredge more. The extracted materials serve vital functions in both the construction and protection of facilities. Fortunately, the dredging of quarries causes only very short term impacts on the biota and the resulting holes have not been shown to have adverse affects on the surrounding marine habitats or the islands. In fact, the consensus is that they improve the area by increasing biotic diversity, and some are frequently used for various recreational activities.

3. Scrap and Waste Disposal

After the U.S. forces razed the Japanese structures in 1944, the problem of scrap and waste disposal became very pronounced. In preparation for their own construction projects, unusable material was either burned or, more commonly, simply bulldozed into the lagoon. Remnants of these disposed materials are still visible throughout the USAKA controlled islands. Pieces of trucks, tanks, artillery, and buildings are strewn about the nearshore areas. In several instances walls of discarded materials, some as high as 20 ft. (6 m), have been formed into sea walls and revetments to help curtail shoreline erosion. Notable examples of this occur on Roi-Namur by the Speed-ball rocket launching site, at the southern end of Meck, and at the Kwajalein dump site. Both ferrous and non-ferrous metals (copper and copper alloys: toxic to many marine organisms) are abundant in these areas.

In accordance with previous ocean dumping permits, metal wastes such as vehicles, construction materials, and heavy equipment were barged to an authorized ocean dumping site off Kwajalein Atoll's South Pass (COE, 1976). Presently, the Kwajalein ocean dumping permit has expired and metal materials suitable for ocean dumping are being stored on the islands.

4. Water Quality

Marine water quality around USAKA controlled islands has generally been satisfactory except in the immediate vicinity of a few point-source discharges (BMDSCOM, 1980). These discharges include primarily sewage, heated water, and storm drain runoff. Water quality generally remains satisfactory because tradewind-generated offshore currents dilute and carry away discharges. However, USAKA is still required to monitor outfalls according to their NPDES permit.

USAKA power plants and some special air conditioning equipment utilize sea water as a heat exchange medium resulting in the discharge of heated effluents. A 1975 survey identified 11 thermal outfalls on Meck, Roi-Namur, and Kwajalein islands (McCain and Maragos, 1975). Survey conclusions revealed that these outfalls do not appear to be causing substantial stress to the marine environment.

The western end of Kwajalein Island has traditionally been used as a dump and landfill site. The landfill site has been sealed by constructing an "impermeable" revetment to contain the seaward margin of the landfill (COE, 1977). This has prevented further wave erosion of the landfill and littering of the emerged reef flat and ocean downwind from the landfill (COE, 1977). However, leachates have been observed seeping into adjacent reef flat waters (BMDSCOM, 1980).

A 1976 study (USAEHA, 1977) lists concentrations of various metals in the biota and water column around several Kwajalein Atoll locations. Though not mentioned in the report, copper and mercury levels in the water column exceeded Trust Territory ambient water quality standards in some localities, especially the sanitary land fill on Kwajalein Island and the open dump on Roi-Namur.

C. RESULTS OF FIELD WORK

An island by island description of faunal assemblages, habitats, and previous and current environmental impacts is incorporated into the next section along with the interview results.

1. Resource User Interviews

Fisheries currently represent the most important subsistence and economically viable resource in Micronesia. Johannes (1978) reported that Pacific Islander's lack of land based food supplies is more than compensated by harvesting marine resources. Micronesian fishermen continue to catch a variety of nearshore and pelagic species and, where a market exists, fish are being sold. Hence, the movement of fisheries from a means of subsistence to a means of reaping economic benefits has commenced.

Throughout the island nations, daily fish consumption remains high. For instance, in Yap State, Federated States of Micronesia (FSM), fish accounts for 80% of the annual dietary provision (Uwate, 1987). Fish consumption is thought to be equally high in the RMI, although currently there are no data to support this statement. Many Marshallese are involved in artisanal or subsistence fisheries to some extent, with fish identified as a major food source (Milone et al., 1985).

The Kwajalein Atoll interviews were designed to document marine resource use. The paramount group targeted for the interviews were local fishermen and divers.

a. General

All Kwajalein Atoll fishermen agreed that fish are plentiful and that they have no difficulty locating or catching fish for any occasion. However, with the exception of sport fishermen from Kwajalein Island, all further claimed that fishing was better five to ten years ago. Since there are no catch records, though, it is difficult to determine whether this perceived decline is real or not.

Very few Marshallese are engaged in subsistence fishing, except for those residing on Ebadon Island in the northwestern extreme of the atoll. There, the younger men's fishing catch provides the primary food source for Ebadon's 60-90 inhabitants. For the Rongelapese living on nearby Mejatto Island, fishing is an important supplemental protein source to the canned food supplied by the U.S. Department of Agriculture. When these supplies run low, sometimes as frequently as once a month, the Rongelapese depend even more heavily on fish, coconut crabs, *Trochus*, and other forms of seafood for subsistence.

Only a few people residing on Ennubirr (Third Island), located near Roi-Namur, fish on a full-time basis. Today, most residents of Ennubirr work at the USAKA facilities on Roi-Namur and fish only to supplement their diet of food purchased from the Roi-Namur store. Many young unemployed men (late teens and early twenties) however, fish occasionally, but do not consider themselves full-time fishermen.

In general, the same is true on Ebeye and Kwajalein. Most people derive their livelihood from USAKA employment or the cash economy derived by USAKA employment and fish only occasionally. Fishing is a recreational activity for the majority of Kwajalein Island fishermen. Most own and operate their own boats and fish for pelagic species such as mahimahi or tuna. The fish caught supplements personal needs, with a portion frequently sold to other USAKA personnel or to restaurants and/or local retailers on Ebeye. On Kwajalein Island there are no recognized, full-time, commercial fishermen nor are there fish catch records for either island.

b. Mid-Atoll Corridor

The existing policy of closure of the Mid-Atoll Corridor during missions seems to be the only limitation placed on all Kwajalein Atoll fishermen by USAKA. Most fishermen agreed that the short closure periods are only a minor inconvenience and do not greatly impact their activities.

c. Gear/Method

A variety of fishing methods are used by both Marshallese and USAKA fishermen. The method and gear type employed depends primarily on the targeted species and on the fisherman's financial capability to purchase equipment. The most popular fishing equipment and techniques utilized are: hand lines for bottom fishing, gill nets with various mesh sizes for nearshore fisheries, pole and lines for trolling, spear guns and underwater flashlights for night diving, and cast nets, scoop nets, and various types of surround nets for nearshore reef fishing.

Pelagic species such as tuna, wahoo, and dolphins (mahimahi) are caught by trolling. Reef species such as snappers and groupers are also caught from a power boat or canoe, but with a hand line. Spear guns and various nets are used to harvest shallow water reef fish including parrot fish, wrasses, surgeon fish, and rabbit fish. A list of fish species caught and fishing techniques utilized by Kwajalein Atoll fishermen is included in Appendix 4.

d. Fishing in U.S. Leased Islands

Of the ten USAKA leased islands, the fishermen interviewed reported catching fish in the vicinity of eight islands plus Gugeegue (a previously USAKA leased island), with only Omelek and Gellinam islands being unmentioned. The geographical isolation of these two islands from major population centers probably accounts for their apparent lack of exploitation; however, Ebeye fishermen are known to fish as far north as Gagan Island on occasion. The other eight USAKA islands and Gugeegue, however, were reported as fishing grounds for at least one type of seafood as detailed in the following island by island discussion. Fish species caught by each island are included at the end of each island description. Fish are listed by their common name with the Marshallese names appearing in parentheses. Appendices 3 and 4 list the marine species targeted by Kwajalein Atoll fishermen with information on methods used and seasonality.

2. Island Descriptions

a. Kwajalein Island

Kwajalein (Fig. 6) is a crescent shaped island located at the southeast corner of the atoll. It is the largest island on the atoll and has historically been the site of the most extensive and intensive human activity. These activities have resulted in a virtually complete modification of the terrestrial environment and substantial modification to the marine environment.

The major changes to the marine environment are a result of terrestrial activities and modifications, primarily dredging and filling. Landfill operations have occurred at both ends of the island and along the lagoon (Fig. 3: p. 39). Approximately 205 acres were added to Kwajalein Island (BMDSCOM, 1980), with most of the landfill material taken from the lagoon. Lagoon localities were also dredged to support shipping, Kwajalein harbor being the major harbor for the atoll. Maintenance dredging of the harbor continues on a periodic basis.

A need for shoreline revetment materials has caused further modifications to Kwajalein Island's marine environment. Beginning with the Japanese in the 1930's, the ocean reef flat of Kwajalein Island has been quarried for armor stone and fill

KWAJALEIN ATOLL COASTAL RESOURCE INVENTORY

BOTTOM TYPE AND SHORELINE CLASSIFICATION

(Based on field observations and aerial photograghic interpretation)

BOTTOM TYPE

Offshore
sc- sand bottom in water less than 10m.
sd- sand bottom in water depths greater than 10m.

Reef Complex
rcp- consolidated limestone with a smooth pavement-like surface.
rc- mixed bottom types consisting of reef rock (limestone) associated with shallow water formations.
co- areas of greater than 50% live coral cover.
rcg- consolidated reef with well defined spur-and-groove system.

SHORELINE

rr- rip rap shoreline.
sb- white sand beach of predominately calcareous material.
bc- concrete/cement masonry seawall and shoreline.
sbc- calcareous rubble and/or shingle beach.
br- beach rock, usually exposed along the shoreline.

VEGETATION

Halimeda/ seagrass beds

FIELD STATION

[K] KMRI Station

OTHER SYMBOLS

dredge site

observed range

quarry area

island area

[H] helicopter pad

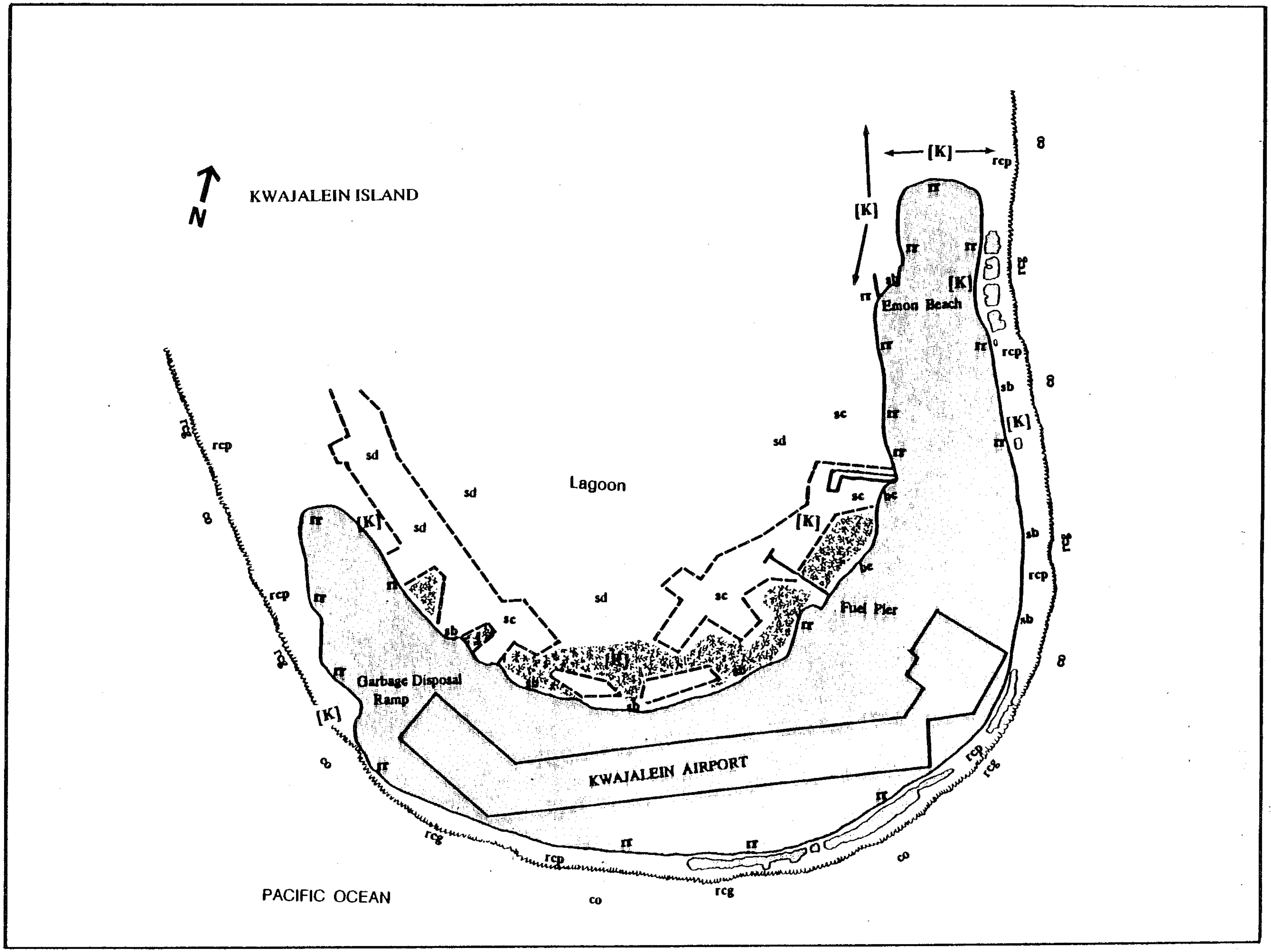

Figure 6. Thematic map showing the shoreline features and marine environment of Kwajalein Island, Kwajalein Atoll, RMI.

material. The most recent quarrying operation on Kwajalein began in December, 1987, with plans to quarry the entire eastern ocean reef flat to supply materials for various construction projects. The marine environment of Kwajalein Island surveyed in this investigation can be roughly divided into seven habitats consisting of the ocean reef flat, the northern interisland reef flat, lagoon reefs, the western reef flat, the lagoon (with dredged and undredged areas), the harbor, and quarries (Fig. 6).

Ocean Reef Flat

The ocean reef flat is the least modified of the marine habitats, despite the quarrying activities that have occurred. Because the reef flat is a relatively homogeneous, harsh environment, its biological assemblage is composed of a small, hardy group of plants and animals. This assemblage appears to be resilient to localized, non-chronic impacts and can rapidly recolonize disturbed areas.

The biota of the reef flat occurs in zones paralleling the reef margin. These zones generally correspond to Ristvet's (1987) geological scheme of zonation of a windward reef flat: algal ridge, coral-algal zone, reef flat, and back reef. Because winter sea conditions prevented the team from getting too close to the algal ridge, our transects only went as far as the coral-algal zone.

The coral-algal zone is covered by water at all times and has good circulation even at low tide due to wash over from waves breaking on the reef front. The substratum consists of crustose coralline algae and reef corals cemented into a very hard and wave resistant framework. A flat pavement extends landward from this zone. The seaward margin has large patches of the zooanthid Palythoa tuberculosa and the substratum has pits and holes. These pits and holes have better coral development than the surrounding shallower bench. Corals not growing in these holes are subjected to higher wave energy and are thus encrusting or dome shaped. Overall coral coverage is low and consists of branching Acropora humilis, encrusting Leptastrea purpurea, and other species of the genera Acropora, Favia, Platygyra, and Millepora. Some microatolls of Porites lutea occur.

There is good coverage by fleshy algae in the coral-algal zone, including Halimeda sp. and Padina sp. The coralline algae Porolithon onkodes is present, but there is no actively growing pink algal ridge. Echinoderms are also quite conspicuous. The seaward 33 ft. (10 m) has numerous sea urchins (Echinothrix diadema), reaching 21.5/$ft.^2$ ($2/m^2$) in some areas. The holothurians Actinopyga mauritiana and Holothuria atra are also present. Further landward the Echinothrix diadema population grades into the more wave and exposure resistant sea urchin Echinometra mathaei, with a few E. oblonga being present. The top shell Trochus niloticus occurs at densities of up to 10.7/ft.^{2} (1/m^2) and the vermetid snail Dendropoma maxima is abundant.

Echinometra mathaei is very abundant on the reef flat and occasional holothurians are found. Gobies, gastropods and hermit crabs occur in pot holes and pits. The dominant organisms, however, are blue-green algae and the brown alga Ralfsia occidentalis.

The back reef is primarily a blue-green algal mat with scattered hermit crabs and snails. The hermit crabs Calcinus laevimanus, C. elegans, Clibanarius sp., and Coenobita sp. are common, and Nerita spp., especially N. plicata, occur along the rip rap. Numerous small eels (Echidna nebulosa) take refuge in small pools under rocks. Grapsid crabs are very abundant on the rip rap, Grapsus tenuicrustatus being the most common.

The reef flat supports both resident and migrating fish populations depending on the tidal stage. During high tides, solitary predator species such as sharks and jacks migrate onto the reef flat from the ocean terrace. Mullets (mugilids) and flagtails (kuhliids), however, school along the reef flat margin and crest. Territorial damsel fish (pomacentrids) and a few wrasses (labrids) reside close to the scattered coral heads. Cryptic gobies live throughout the reef flat in empty vermetid tubes.

Northern Interisland Reef Flat

The interisland reef flat at the northern end of Kwajalein Island has a similar ocean reef flat. In addition, there are some large boulders near the reef crest that had been thrown up by storms. Smaller boulders and a lot of coral rubble had been recently deposited by Tropical Storm Roy (January 9, 1988). This coral and rock lay over and around older material that has been cemented together. Living Porites lutea coraliths (oval, unattached coral nodules) are abundant near the reef crest. There are cryptic organisms such as the crabs Cymo andreossyi and Paraxanthias sp. in and among the rocks and coraliths.

The lagoon side of the interisland reef flat has a large, solid thicket of the branching coral Montipora digitata that continues toward the lagoon. This thicket offers protection to a large assemblage of small reef fish. Pomacentrids are particularly abundant, including an aggressively territorial Stegastes sp. and Chrysiptera sp. Wrasses (labrids), butterfly fishes (chaetodontids), and angel fishes (pomacanthids) represent a major component of the fish fauna, and surgeon fishes (acanthurids) are fairly common in comparison to other areas.

Lagoon Reefs

Present lagoon coral reef development indicates that the previous fill operation at the northern end of the island did not have a permanent or devastating effect on the marine habitat or biota. The 1967 aerial photographs (Global Associates, 1967), taken a few years after the fill operation, do not give adequate shallow subsurface information to determine how much damage was originally done to the reef. However, this area appears to have recovered from this one-time impact. Moreover, our survey revealed this to be the only well developed coral reef habitat along Kwajalein Island's lagoon.

This reasonably lush lagoon coral reef extends from north of Emon beach out onto the interisland reef flat. It is interrupted only at the end of the island where currents have deposited sand and rubble. The coral reef shows previous impact from dredging, but has recovered well. The branching coral Montipora digitata is the dominant coral in shallow water, but other species become important as the water deepens. Conspicuous coral species include several Acropora spp., Pavona cactus, and Pocillopora damicornis. Near the dropoff, there are several large coral knolls with relatively high coral density and diversity. The topshell Trochus niloticus is abundant in this area.

Fish are moderately abundant along the shallow coral reef complex. Labrids (wrasses) forage around coral heads, but will actively follow snorkelers who disturb the bottom exposing prey items for them. Trigger fish are common.

The interisland lagoon reef flat and slope north of Kwajalein Island are undisturbed and have a lush coral reef development. The large coral knolls at the dropoff to the terrace approach the water surface and are extremely diverse and rich in coral and fish, and the large spiny holothurian Thelenota ananas occurs on the surrounding sand bottom. The dominant corals are Acropora humilis, table Acropora spp., and arborescent Acropora spp. These Acropora spp. account for about 50% of the total coral coverage and have a very high coverage on the top of the knolls. The highest coral diversity occurs on the vertical ledges and overhangs. These corals include species in the genera Acropora, Alveopora, Astreopora, Montipora, Pavona, Favia, Hydnophora, Fungia, Pocillopora, Herpolitha, Heliopora, and Millepora.

The coral knolls have an abundant non-coral invertebrate fauna and algae flora. The top shell Trochus niloticus and the vermetid snail Dendropoma maxima are the commonly seen macroinvertebrates, but there is also a large biota of cryptic organisms in the heterogeneous coral and rock substratum. These include sponges, tunicates, crabs, hydroids, algae, etc.

Fish diversity increases tremendously at the lagoon reef terrace and slope. Coral knolls provide overhangs and small cave habitats for squirrel fishes (holocentrids) and large pomacanthids (angel fishes). Wrasses (labrids), parrot fishes (scarids), butterfly fishes (chaetodontids), groupers (serranids), snappers (lutjanids), and jacks (carangids) are abundant. Schools of emperor fish (Gnathodentex aureolineatus) and goat fish or mullids (Parupeneus barberinus) frequent the area as do caesionids (fusiliers).

This assemblage of organisms continues up to the solid field of the coral Montipora digitata on the reef flat. Although the species composition is similar in the shallower water, the strong vertical aspect of the reef is reduced and then lost. Montipora digitata and the branching corals Acropora spp. dominate the coral fauna, and the blue coral Heliopora is more abundant. Macroinvertebrates, such as Trochus niloticus, are less abundant in the shallow water, and Thelenota ananas was not found.

Western Reef Flat

The western end of Kwajalein Island was also extended by a large fill operation. This area has a very wide reef flat because the fill was not made as wide as the natural island. Unlike the reef flat at the northern end of the island which is currently undisturbed, this wide ocean reef flat may be affected from the Garbage Disposal Ramp, the sanitary landfill site, and the pit used to burn hydrocarbon wastes. Extensive dumping of heavy machinery and scrap metal, including a lot of copper and alloys, has also been utilized to build revetments and to dispose of unwanted material. Some of this has been dumped onto the reef flat. Additionally, seepage from the sanitary landfill and wastes from the Garbage Disposal Ramp have washed onto the reef flat.

Nutrient enrichment appears to be caused by the landfill and garbage disposal. There is very high coverage by leafy algae, primarily Padina spp. and Caulerpa spp. Beds of partially exposed Halimeda cylindracea were observed in the central portion of the reef flat. Acetabularia moebii grows on shoreline rocks near the Garbage Disposal Ramp and some Ectocarpus breviarticulatus was found growing directly on exposed copper.

Holothurians such as Stichopus chloronotus and others are common on the reef flat, as are small eels (Echidna nebulosa). Toward the reef margin corals include Porites lutea microatolls, Pocillopora spp., and Acropora spp., suggesting better water circulation and less effect from the shoreline impacts. A well developed spur and groove system occurs along the reef margin. It has good coral coverage on the spurs (10%) and consists primarily of high water motion species in the genera Pocillopora, Porites, Millepora, and Acropora. The fish assemblage along this margin resembles that found on the previously discussed northern interisland reef flat.

The shoreline near the Garbage Disposal Ramp is a revetment composed of rock, metal, dumped materials and heavy equipment being fused together by penecontemporaneous cementation (Ristvet, 1987). This includes substantial amounts of copper and alloys that are toxic to many marine organisms.

The resident fish population adjacent to the Garbage Disposal Ramp exhibits significantly modified behavior patterns resulting from living off of disposed human garbage. There are parrot fishes (scarids), rabbit fishes (siganids), surgeon fishes (acanthurids), and Kyphosus spp. (rudder fishes) that immediately and aggressively approach anything that enters the water, including divers. This area is noted for attracting marine turtles (Chelonia mydas) and sharks. It is also a popular fishing spot for Kwajalein residents.

The purpose of the Garbage Disposal Ramp is to dispose of "wet" garbage from the Pacific Dining Room and Snack Bar. However, the survey team observed cans and other metal and glass objects being dumped with the wet garbage from a garbage truck. Furthermore, kitchen utensils were observed underwater beneath the ramp.

Lagoon Floor and Sand Flats

The majority of the lagoon bottom fronting Kwajalein Island is sand and algae with scattered small coral outcrops. Large portions of the bottom have been dredged, the resulting scars being obvious from aerial photographs (Global Associates, 1987). Though the harbor area receives periodic maintenance dredging, the other areas represent previous localities mined for fill material.

The dominant algae of the sand flats are Halimeda spp., primarily H. cylindracea. Also present are Caulerpa sertularioides, C. serrulata, Hormothamnion enteromorphoides, Codium arabicum, Boodlea composita, and Schizothrix calcicola. Dictyota bartayresii, Halimeda discoidea, H. opuntia, and Neomeris annulata are found on rocks. The vertical sides and tops of the dredge scars also have Halimeda gigas, Porolithon, and Schizothrix mexicana. There are a few areas with the sea grass Halophila minor, although it is more abundant at Roi-Namur.

Corals are a minor component of this sand flat assemblage. Scattered outcrops of species such as Montipora digitata, Pocillopora damicornis, Pocillopora spp., Porites spp., and Fungia occur, but they only become abundant on the hard substratum near and on the vertical dredge scars. These areas have corals such as Pocillopora eydouxi, Porites lutea, Lobophyllia sp., Symphyllia sp., Fungia fungites, Acropora hebes, Acropora horrida, Acropora sp. 1, Acropora sp. 2, Goniopora retiformis, Gardineroseris planulata, and Pavona varians. Acropora cytherea and A. humilis occur at the edge of dredge scars, as does branching Porites cylindrica, which is rare in shallow habitats around the USAKA islands. The corals Plerogyra sinuosa and Mycedium sp. occur on the vertical walls of the dredge scars. These walls also have large encrusting sponges (black, red, and gray), and vase sponges. Thickets of the staghorn corals Acropora formosa and Acropora aspera are found on some of the deeper sand flats.

Many of the macroinvertebrates of the sand flats and algae beds are cryptic. Some large anemones with commensal clown fish (Amphiprion melanopus) occur in the open on sand and/or rubble, and vermetid gastropods (Dendropoma maxima) occur on rocks. However, invertebrates such as portunid crabs (Thalamita sp.) and shrimp (Saron neglectus) occur under rocks, and the Halimeda beds support (and hide) a large population of cryptically colored and shaped spider crabs. There are two types of cryptic callianassids: mound building species occur in sand and the algae collecting species build burrows in rubble. The sand also supports gastropods and bivalve mollusks. The sea urchin Echinothrix diadema and species of soft coral (Sarcophyton and Sinularia) occur on the exposed hard substratum near the dredge scars, as do Octopus sp. Holothurians, however, are noticeably absent from the sand and Halimeda beds.

Fish are numerous on the sand flats and in the algae. Schools of rabbit fish (Siganus spinus) continually traverse the area and goat fish (Mulloides vanicolensis) are abundant. Small groupers (Epinephelus hexagonatus) occur on the deeper areas of the sand flat, as do job fish (Lethrinus sp.). The vertical walls of the dredged areas harbor a diverse and abundant fish assemblage, including unicorn fish, surgeon fish, box fish, emperor fish, rudder fish, puffer fish, tangs, dragon wrasses, trigger fish, squirrel fish, snappers, and groupers (Epinephelus hexagonatus). The rip rap at the southwestern end of the island is a good fishing spot.

Kwajalein Harbor and Echo Pier

Kwajalein harbor supports a somewhat different fauna than the rest of the lagoon because of periodic maintenance dredging, abundant artificial hard substratum, and the introduction of fouling organisms from shipping traffic. A substantial amount of filling has also occurred on the reef flat along the harbor area to widen the island for support facilities. Consequently, isolated segments of a very narrow shallow bench are the only remains of the original reef flat. The water deepens rapidly at the edge of this bench. Throughout the harbor, debris, including anchors and anchor chains, has accumulated on the bottom.

Just north of Echo Pier, outside the harbor, narrow remnants of the original reef flat support a coral assemblage that approaches 80% coverage on the deeper portion. The coral fauna is dominated by Acropora sp. 1, A. sp. 2, A. vaughani, A. humilis, and Montipora digitata, with a few isolated colonies of Porites cylindrica, A. horrida, and Fungia spp. There are also some large sponges on this platform.

The harbor bottom supports a different assemblage than the hard substratum of the pier. These soft sediments do not have a conspicuous macrofauna, although Halimeda is common except for the inner most reaches of the harbor. The walls of Echo Pier, however, support a diverse fouling assemblage consisting primarily of filter feeding organisms. There are also isolated coral colonies, but the abundance and diversity are low. The northern, outer wall of the pier has the most coral, ranging in coverage from 1-5%, and consisting of species in the genera Favia, Favites, Goniastrea, and Pavona. Tubastraea coccinea is found in shaded areas at the end of the pier. The coral species on the harbor side of the pier consist of Pocillopora damicornis, Montipora digitata, Porites lutea, Lobophyllia sp., and Symphyllia sp., with small amounts of Plerogyra sp. and Porites cylindrica. The base of the pier has the green whip coral Cirrhipathes sp.

The fish assemblage is most developed along the northern side of Echo Pier where remnants of the original reef flat exists. Although abundance is low (probably due to recreational fishing pressure from the pier), the diversity is high. The more abundant fish groups represented include wrasses (labrids), angel fishes (pomacanthids), surgeon fishes (acanthurids), and butterfly fishes (chaetodontids). Also present are groupers (serranids), jacks (carangids), emperors (lethrinids), and goat fishes (mullids). Large schools of the surgeon fish Acanthurus xanthopterus and juvenile and adult parrot fishes (Scarus sp.) forage along the lagoon reef flat terrace and interface.

Much of the harbor wall of Echo Pier could not be surveyed due to the presence of moored vessels. The outside wall and the end of the pier, however, have a rich assortment of fouling organisms. At the highest zone above the water line are two barnacle species: Tesseropora pacifica and a smaller unidentified species. There is also a large flat rock oyster that was being fed upon by the predatory snail Chicoreus brunneus, as were the barnacles. The sea stars Linckia multifora and Fromia milleporella are also present.

The pier's interlocking metal walls (sheet piling) and concrete fill extend three fourths of the length of the pier.

Steel pilings support the work platform at the distal end. The field team was able to survey beneath the end of the pier and the pilings because the platform is about one meter above the water line. This area has a diverse assemblage of suspension feeding invertebrates consisting of several spiny oysters (Spondylus spp., including Spondylus varians), snails (Siphonaria normalis), bivalves (Malleus regula, Chama sp., Hyotissa hyotis, and Lopha cristagalli), octocorals (Dendronephthya mirabilis and Telesto sp.), and unidentified hydroids.

The fish population declined considerably inside the harbor due to the lack of appropriate substratum and habitat. Juvenile fish such as angel fishes (pomacanthids), goat fishes (mullids), and file fishes (monacanthids) inhabit the encrusting coral colonies along the pier walls. Occasionally, solitary jacks (carangids) were sighted.

Algae encrusts most of the pier, except for a large portion on the harbor side that is relatively barren. Unlike the fauna, this flora consists of species commonly found in other habitats around the island. These include Dictyota bartayresii, Ralfsia occidentalis, Schizothrix calcicola, Bryopsis pennata, Halymenia sp., Halimeda spp., Caulerpa racemosa, Padina tenuis, and Neomeris annulata. Halimeda is relatively thick on the bottom around the pier and throughout the harbor except, as mentioned, for the most inner parts of the harbor.

Quarries

Kwajalein Island has a series of quarries on its southern and northeastern ocean reef flats. Sometime during the 1930's and early 1940's the Japanese dredged four quarries on the southern shore and one small quarry at what was then the northern tip of the island. The United States dredged four additional quarries adjacent to the fill area at the northern end of the island between 1959 and 1970 (COE, 1973a). A new phase of quarry dredging began in December, 1987, with the opening of a new quarry (Clement's Pool) on the eastern ocean reef flat. Further excavation of this quarry was conducted during our study and there are plans to quarry the remaining eastern ocean reef flat of the island.

The habitat and biota of the quarries vary somewhat from pool to pool. Although the biota does not vary much in overall diversity, the abundance and distribution are different. The consensus among informants who are familiar with Kwajalein Island's quarries is that the Japanese pools have a more developed biota because they are older than the U.S. dredged pools and, therefore, have had more time for colonization by marine life. However, field investigations of other islands that have quarries that were dredged at about the same time or more recently than the U.S. pools on Kwajalein, revealed that some of these quarries support a more abundant and diverse biota than the Japanese pools on Kwajalein Island. It was determined that ecological development in quarries depends on how well they flush, which in turn depends on design, depth, and placement on the reef.

The quarries on Kwajalein Island have a substantial amount of fine sediment on the bottom, especially those dredged by the U.S. This indicates that they do not flush well. During times of higher wave energy the sediments can be resuspended and become abrasive to sedentary organisms, which can also be smothered. Because sediments make the environment harsher, diversity and abundance of coral reef organisms are generally lower. Indicator organisms typically found in these fine sediment habitats are deposit feeding holothurians, especially synaptid holothurians. These are very abundant in Kwajalein Island quarries, especially the U.S. dredged pools.

The Japanese pools on the southern coast of the island are, with the exception of one tiny pool, long and irregular in shape. The two western pools are 3-7 ft. (1-2 m) in depth, and the eastern pool, which has a better coral reef biota, is shallow (1.5 ft. or 1/2 m) and has a more complex topography. Of the more than 17 species of coral that occur in the Japanese pools, the dominant species are *Acropora* spp., *Pocillopora* spp., *Montipora* spp., *Millepora* spp, and *Porites lobata* (Appendix 5).

Holothurians are the most noticeable of the macroinvertebrates because they are large and abundant. Bohadschia argus, Holothuria atra, Stichopus chloronotus, and Synapta maculata are in the open and dispersed throughout the pools, while a small holothurian (Afrocucumis africana) is found clustered under rocks. The sea urchin Echinothrix diadema is also common, as is the vermetid Dendropoma maxima. Soft corals (Sinularia spp.) have a patchy distribution in all of the pools.

The fish assemblages within all the Kwajalein quarries are fairly uniform in both diversity and abundance. Roughly 30 species occurred commonly in all quarries on Kwajalein and throughout the atoll. Surgeon fishes (acanthurids) and some damsel fishes (pomacentrids) typically migrate along the seaward wall while Kuhlia mugil (flag tails) and mullet run along the seaward reef flat margin. Throughout the quarries fish congregate near coral outcrops along the walls and remnant quarry stones. A variety of fish are seen including, angel fishes (pomacanthids), butterfly fishes (chaetodontids), wrasses (labrids), damsel fishes (pomacentrids), trigger fishes (balistids), file fishes (monacanthids), and goat fishes (mullids).

Interviews

The waters around Kwajalein Island are described as good fishing grounds for many reef fish including unicorn fish (mone), squirrel fish (mon and jera), goat fish (jome), lobster (wor), mullet (iiol), and grouper (momo). Rainbow runners (ikaidik) frequent the ocean reef terrace off the Kwajalein airport runway while the ocean reef off the northwestern tip of the island is exploited for gray job fish (laum) and flying fish (jojo). A net fisherman reports catching flag-tails (Kuhlia mugil) on the ocean reef flat along the airport runway.

Kwajalein fishermen reported catching pompano in the lagoon near Kwajalein and several adjacent islands. Both Ebeye and Kwajalein fishermen catch pelagic species such as skipjack tuna (lejabil), mahimahi (koko), wahoo (al), and blue marlin nearly year round off the southern end of the atoll. According to these fishermen, many of whom have fished off Kwajalein Island for 10 - 15 years, there has been no noticeable decline in the amount of fish caught around Kwajalein Island during the past decade.

b. Meck Island

Meck (Fig. 7) is the windward Mid-Atoll island that forms the southern border of the Eniwetak Passage. It is perhaps the most severely modified of the U.S. leased islands in the atoll, having been almost completely graded and filled between 1964 and 1969 for the construction of an airfield and facilities (Losey, 1973). The marine environment surrounding Meck has been severely altered by extensive dredging in the lagoon. A large area of the lagoon reef flat was covered with fill, and most of the ocean reef flat has been quarried.

The original 37 acre (0.15 sq. km) island was expanded by 14 acres (0.06 sq. km), primarily mid-island on the lagoon side where many of the facilities are now located (Fig. 5: p. 42). This was done by extensively dredging the lagoon terrace and slope for fill materials. Thus, not only was the lagoon dredged, but the shallow habitat near the island was buried.

Activity is currently low on Meck so ongoing impacts appear minor and/or periodic in nature (occasional maintenance dredging of the harbor). However, Meck is slated to be reactivated soon and the cargo/personnel pier will be replaced (Belt Collins & Associates, 1987).

Shoreline

Almost the entire island has been surrounded by a rip rap revetment for shoreline protection. This rip rap supports a large population of grapsid crabs (primarily *Grapsus tenuicrustatus*), neritid snails, and terrestrial hermit crabs (*Coenobita* sp.). The armor stone used for the revetment came from a series of six quarries that line most of the ocean reef flat.

A natural cobble beach extends along Meck's ocean side in front of the revetment. The gently sloping back reef supports a

KWAJALEIN ATOLL COASTAL RESOURCE INVENTORY

BOTTOM TYPE AND SHORELINE CLASSIFICATION

(Based on field observations and aerial photograghic interpretation)

BOTTOM TYPE

Offshore

sc- sand bottom in water less than 10m.
sd- sand bottom in water depths greater than 10m.

Reef Complex

rcp- consolidated limestone with a smooth pavement-like surface.
rc- mixed bottom types consisting of reef rock (limestone) associated with shallow water formations.
co- areas of greater than 50% live coral cover.
rcg- consolidated reef with well defined spur-and-groove system.

SHORELINE

rr- rip rap shoreline.
sb- white sand beach of predominately calcareous material.
bc- concrete/cement masonry seawall and shoreline.
sbc- calcareous rubble and/or shingle beach.
br- beach rock, usually exposed along the shoreline.

VEGETATION

Halimeda/ seagrass beds

FIELD STATION

[K] KMRI Station

OTHER SYMBOLS

dredge site

observed range

quarry area

island area

[H] helicopter pad

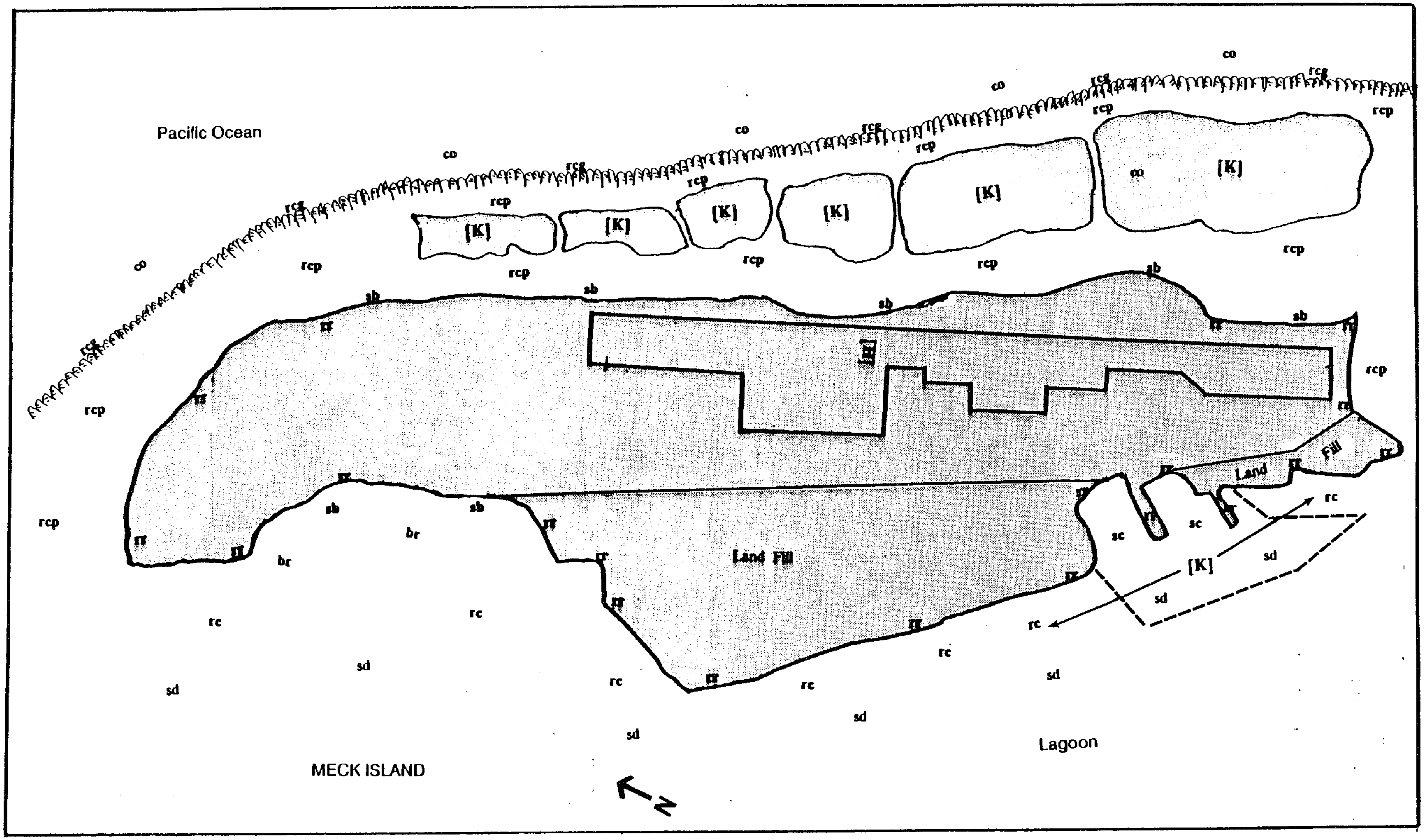

Figure 7. Thematic map showing the shoreline features and marine environment of Meck Island, Kwajalein Atoll, RMI.

typical simple reef flat biota consisting primarily of blue-green algae, hermit crabs (Calcinus spp. and Clibanarius sp.), and some snails. The reef flat is pitted with solution holes that collect rocks and sediment. These holes support the above mentioned animals and, in addition, it is not unusual to find eels (Echidna nebulosa) under the rocks.

Shallow Reefs

The only shallow marine areas around Meck that have not been extensively altered, or have at least recovered to a great extent, are at the north and south ends of the island. Both areas are shallow intertidal reef flat, but differ in exposure and wave energy. The northern tip of Meck fronts the Eniwetak Passage and is exposed to ocean swells and strong tidal currents. These prevented the field team from investigating the region to any extent. However, the water is shallow enough to determine that it has not been visibly altered.

There is typical interisland reef flat south of the island. Protected from high energy water by the reef front, the currents are less developed and are largely controlled by tidal fluctuations. The shape of the end of the island conforms to the runway resulting in some sheltered nearshore areas. These have fine sediments and cobble, and support a more diverse and abundant biota than is typical of exposed windward reef flats.

Lagoon

Meck's lagoon side is composed of a harbor near the southern end, a large landfill that has many of the facilities, and a man-made sand beach near the northern end. The harbor consists of a dredged area with a cargo/personnel pier and a marine ramp. The southern end of the harbor is bounded by a large dilapidated floating fuel pier. Except for the manmade sand beach and harbor, the entire lagoon shoreline is rip rap.

The marine biota of the lagoon appears to be slowly recovering, but due to the extensive dredging and filling there is very little hard substratum left for coral reef development. Meck's lagoon is basically sand habitat. However, there is low coverage by Acropora sp. 1, A. sp. 2, A. humilis, Pocillopora meandrina, P. eydouxi, Favia spp., and encrusting Montipora spp. where small sections of shallow bench remain. This bench also supports a few Trochus niloticus, some didemnid tunicates, and sponges but, in general, there are very few macroinvertebrates.

The nearshore reef close to the harbor supports a moderately diverse fish assemblage. Wrasses (labrids) and damsel fishes (pomacentrids), the dominant species, hide among the isolated coral heads along the shelf bordering the dredge scars. Overhanging shelves on the vertical dredged wall provide a cryptic habitat for squirrel fishes or holocentrids (Myripristis kuntee) while larger species (such as emperors [Lethrinus sp.]) migrate along the wall. The only observation of a sweeplip fish (Plectorhynchus sp.) occurred on the reef flat by several remnant dredged rocks near the floating pipe pier. Inside the floating pier, a school of bronze sweepers (Pempheris oualensis) was observed while just below, at a depth of about 40 ft. (12 m), two eagle rays (Aetobatus narinari) forged along the sand bottom. Several large groups of jacks (Caranx melampygus) migrated through the area.

Quarries

Only the northern end of the ocean reef flat has not been quarried for armor stone. It is relatively narrow and has a superficial development of surge channels that approach the beach. This is probably the result of higher intensity wave action due to the islands position facing the Eniwetak Passage.

A series of six quarries are on Meck's outer ocean reef flat. These were dredged from 1964-1965 (COE, 1973a). The quarries were designed as a series of cells parallel to the shoreline rather than just one large quarry as is found on some of the islands. They decrease in size toward the north and their shape is generally rectangular. The edges were intentionally left jagged and irregular to create a more complicated, heterogeneous habitat. The relief is also varied because armor stone blocks remain in some of the quarries. The overall effect is a diverse habitat and biota that is quite unlike that on the surrounding reef flat.

The distribution of biota in the quarries is patchy due to the varied and changing topography and habitat. Abundance also varies from pool to pool, generally decreasing toward the north. The diverse coral assemblage has an overall coverage of about 5%, but it approaches 50-60% on the knolls, and there are patches of Montipora digitata that have almost total coverage. A diverse group of Acropora spp. dominate the coral species present and include various branched and, toward the center of the quarries, table Acropora spp. Several other genera of corals are represented including Montipora, Porites, Coscinaraea, Platygyra, Hydnophora, Leptastrea, Pavona, Astreopora, Alveopora, Fungia, Pocillopora, Favia, Lobophyllia, and encrusting Millepora. Other cnidarians present are soft corals (Sinularia spp.), large anemones with associated clown fish (Amphiprion melanopus), and a corallimorph.

The quarries also have a diverse non-cnidarian macroinvertebrate fauna, the most conspicuous being the echinoderms. The sea urchin Echinothrix diadema occurs in clusters along ledges and in cracks, especially toward the center and ocean side of the quarries. The holothurian Holothuria atra is ubiquitous but not abundant. A few other species of holothurians are present but relatively rare, although Holothuria hilla and H. pervicax are frequently found under rocks. Several large mollusks are present including Trochus niloticus, three species of Lambis, the vermetid Dendropoma maxima, and a few species of tridacnid clams (Tridacna maxima, T. squamosa, and Hippopus hippopus).

Fish are abundant and diverse in the quarries. As with the other biota, they decrease in abundance in the smaller, northern quarries. Typical of Kwajalein Atoll quarries, wrasses (labrids) and damsel fishes (pomacentrids) are ubiquitous and abundant. The seaward quarry wall is inhabited by surgeon fishes, with Acanthurus triostegus being the most abundant. Elsewhere, the fish abundance conforms to the habitat complexity with a greater number of species present where there's increasing coral relief. Butterfly fishes (chaetodontids), squirrel fishes (holocentrids), and hawk fishes (cirrhitids) occupy the knolls along with wrasses (labrids) and damsel fishes (pomacentrids). Large schools of half beaks (Hemiramphus sp.) hover close to the water's surface while schools of goat fish (Mulloides vanicolensis and Parupeneus barberinus) and emperor breams (Gnathodentex aureolineatus) circle the quarry boundaries. The largest resident blacktip shark (4.5 ft. or 1.4 m) was also observed in Meck's most southern quarry.

Similar algal assemblages occur in all of the quarries, but abundance decreases toward the north. Unlike many areas, the algal mat is not well developed. Entophysalis sp., Ralfsia occidentalis, Dictyota friabilis, and D. divaricata grow on rocks while Neomeris annulata, Lobophora variegata, and Schizothrix calcicola form relatively large patches on the bottom. There are small amounts of several other algae including Asparagopsis taxiformis, which is eaten in Hawaii.

Interviews

Meck Island is located adjacent to the Eniwetak Passage. Meck, particularly on the southern lagoon side, has good fishing grounds for emperor (metjebjeb) and snapper (riuing). Fishermen also reported that parrot fish are highly targeted species between Meck Island and Bigej Island to the south. As with other channels, Eniwetak Passage affords access to the ocean with considerable trolling opportunities for pelagic species including mahimahi (koko), barracuda (ni, tua, jujukop), skipjack tuna (lejabil), and blue marlin.

c. Gagan Island

Gagan (Fig. 8) is located on the northern windward atoll rim on a long continuous section of reef flat with no passes. It has not been affected by human activity as greatly as Meck or

KWAJALEIN ATOLL COASTAL RESOURCE INVENTORY

BOTTOM TYPE AND SHORELINE CLASSIFICATION

(Based on field observations and aerial photograghic interpretation)

BOTTOM TYPE

Offshore
sc- sand bottom in water less than 10m.
sd- sand bottom in water depths greater than 10m.

Reef Complex
rcp- consolidated limestone with a smooth pavement-like surface.
rc- mixed bottom types consisting of reef rock (limestone) associated with shallow water formations.
co- areas of greater than 50% live coral cover.
rcg- consolidated reef with well defined spur-and-groove system.

SHORELINE

rr- rip rap shoreline.
sb- white sand beach of predominately calcareous material.
bc- concrete/cement masonry seawall and shoreline.
sbc- calcareous rubble and/or shingle beach.
br- beach rock, usually exposed along the shoreline.

VEGETATION

Halimeda/ seagrass beds

FIELD STATION

[K] KMRI Station

OTHER SYMBOLS

dredge site

observed range

quarry area

island area

[H] helicopter pad

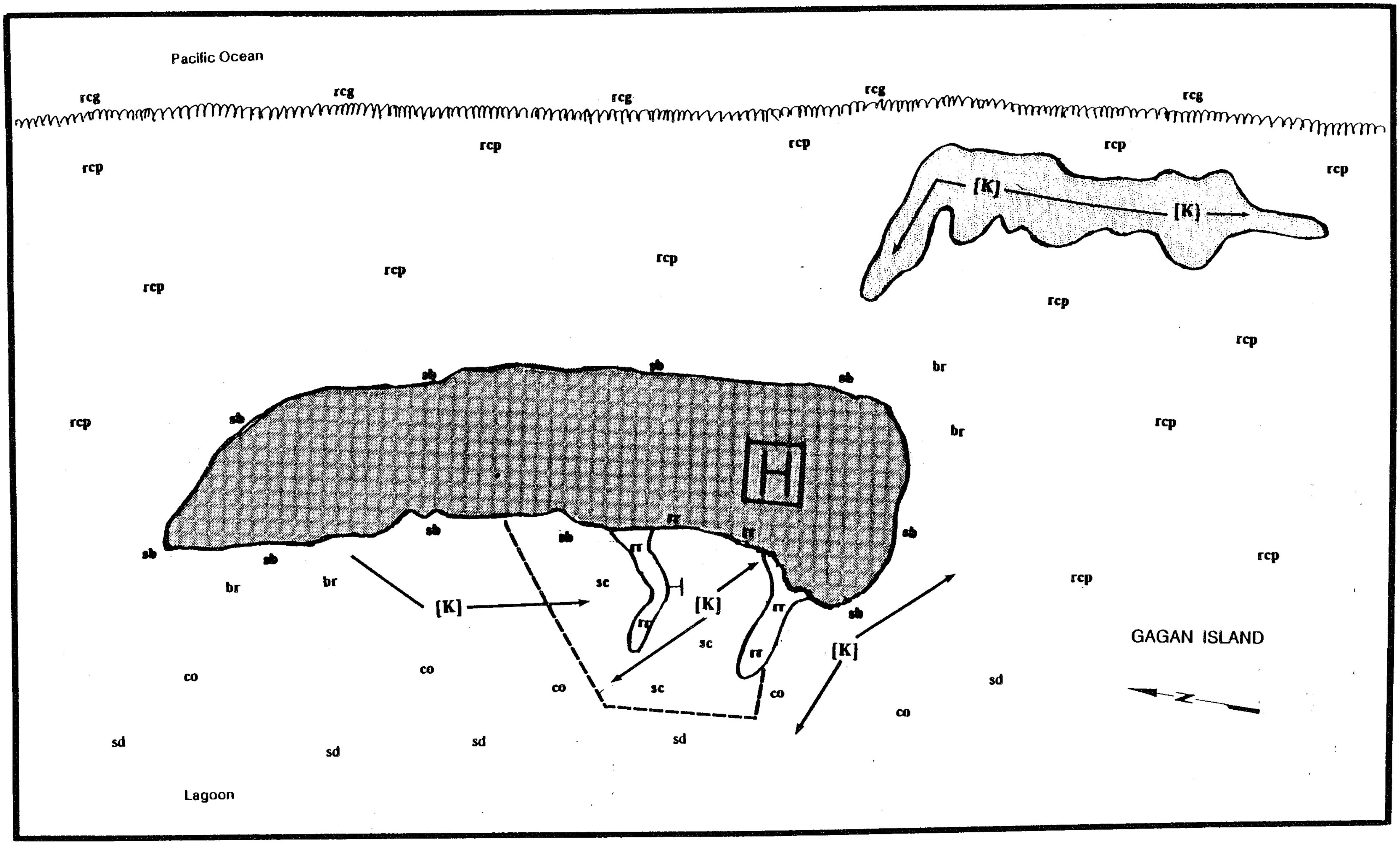

Figure 8. Thematic map showing the shoreline features and marine environment of Gagan Island, Kwajalein Atoll, RMI.

Kwajalein and still has areas with native vegetation. The lagoon has only been dredged in the harbor region, which is protected by two rock jetties. The harbor facilities include a marine ramp and a personnel pier.

Shoreline

Except for the harbor area, there is no rip rap around the island for shoreline protection. The sand beach adjacent to the northern jetty grades into rubble toward the northern end of the island. A storm berm has developed on the ocean side but decreases in size towards the southern end of the island where it appears to have been bulldozed. However, the southern tip has a well developed boulder berm. Currents have deposited sand at both ends of the island, especially at the southern end.

Lagoon Reefs

Gagan has one of the best developed lagoon coral reef systems observed adjacent to a USAKA island. Offshore from the southern sandbar, the lagoon reef extends north to the southern harbor jetty, which also has extensive coral coverage. Several branching coral *Acropora* spp. are dominant and coral coverage approaches 80% on the knolls. Coral diversity is high and includes species in the genera *Stylophora*, *Lobophyllia*, *Symphyllia*, *Heliopora*, *Alveopora*, *Hydnophora*, *Fungia*, *Cyphastrea*, *Echinopora*, *Favia*, and *Millepora*.

The area is also rich in other macroinvertebrate species, including the large holothurian *Thelenota ananas*. Also present are the soft corals *Sarcophyton* and *Sinularia*, and the sea urchin *Echinometra mathaei* occurs in shallow water . Anemone fish (*Amphiprion melanopus*) are associated with the large anemones *Heteractis ritteri* and *Stichodactyla mertensii*, and the top shell *Trochus niloticus* and the sea star *Linckia multifora* are among the corals. The alga *Neogoniolithon frutescens* is common and a fine filamentous mat occurs on dead corals. The algae *Hormothamnion enteromorphoides*, *Halimeda opuntia*, *Jania capillacea*, *Microcoleus lyngbyaceus*, *Bryopsis pennata*, and *Caulerpa* spp. are also present.

The fish assemblage is exceptionally diverse and abundant. Coral knolls and complex relief provide good habitat for a variety of fish, particularly cryptic species such as holocentrids (squirrel fish). Damsel fishes (pomacentrids), butterfly fishes (chaetodontids), and wrasses (labrids) represent the most ubiquitous species on the reef. Large scarids (parrot fish), lethrinids (emperors), carangids (jacks), lutjanids (snappers), and serranids (groupers) are equally apparent although not as abundant. A green sea turtle (*Chelonia mydas*) cruised through the area in addition to a blacktip and whitetip shark.

Spectacular coral coverage on the jetty rip rap approached 80% in places. Acropora thickets have recolonized the dredged outer harbor bottom with coverage as high as 20-30%. The large holothurian Thelenota ananas is abundant on the harbor bottom at a depth of about 16-20 ft. (5-6 m), where schools of goat fish (Mulloides vanicolensis) were sighted.

There is a barren, dredged area with poor circulation and warm water adjacent to the northern jetty. An unused pipe, originating from the beach, crosses this zone. A fine layer of Copper Blast and paint chips on the sand and beach in this area indicated that sand blasting had recently occurred on the island. The lack of biota in this area probably results from the poor circulation and warm water due to a shadowing effect by the jetty.

The well developed lagoon coral reef begins again north of the dredged area and extends beyond the north end of the island. The biota and structure are similar to that found at the southern end of the island, although the reef is larger. Coral, fish, invertebrate and algal assemblages are very similar to the southern reef, with additional sightings of a few large Tridacna gigas, a green sea turtle (Chelonia mydas), two blacktip sharks

(Carcharhinus melanopterus) and a whitetip shark (Triaenodon obesus).

Quarry

The ocean reef flat is relatively wide and has a typical windward reef flat structure and biota. One large L-shaped quarry was dredged at the island's southern end and continues out onto the interisland reef flat (Fig. 8: p. 83). The short side of the L-shape is roughly perpendicular to shore and about 164 ft. (50 m) in length while the long side is about 328 ft. (100 m) and parallel to the reef margin. The width of the quarry varies from 16-66 ft. (5-20 m), with depths shoaling and deepening between 3-13 ft. (1-4 m). The shape, therefore, is relatively irregular and appears to promote good flushing (based on bottom sediment composition which varies in size from gravel to cobble).

The quarry biota is quite rich and diverse. Approximately ten species of Acropora dominate the coral fauna, but there are also good numbers of the brain coral Favia sp., the fire corals Millepora tenera, Millepora platyphylla, and encrusting Millepora spp. Also present are members of the coral genera Astreopora, Pavona, and Cyphastrea, with small amounts of Pocillopora, Lobophyllia, Porites, Heliopora, Hydnophora, and Platygyra. There are a substantial number of the mushroom corals Fungia spp. but, surprisingly, no branching Montipora digitata, which commonly occurs in the quarries and the lagoon reefs of Kwajalein Atoll. The quarry bottom, with several stands of Acropora spp., is not as barren as the quarries on Kwajalein Island probably due to better flushing and coarser sediments.

Non-coral invertebrates are also common and diverse in Gagan quarry, with the notable exception of holothurians. Again, this was probably due to the absence of fine sediments. There are at least three species of soft corals, including Sinularia polydactyla and Sarcophyton glaucum. Anemone-anemone fish associations were noted, and the common unidentified corallimorph is present. The vermetid gastropod Dendropoma maxima is abundant and there are many Trochus niloticus. Tridacnid clams are also more abundant than in the other quarries studied. Of the echinoderms, Echinothrix diadema is the most common, but Echinostrephus aciculatus, Echinometra mathaei, Acanthaster planci, Leiaster sp., and the sea cucumber Actinopyga mauritiana also occur. Homotrema rubra, the encrusting red foraminiferan, and the ophiuroid Ophioplocus sp. are common under rocks. Several other invertebrates were noted and are listed in Appendix 5.

There is a rich algal flora, especially on the island side of the quarry. Halimeda opuntia and H. discoidea are abundant, and Microdictyon okamurai is common on rocks. Also present are Neomeris annulata, Udotea indica, Porolithon onkodes, Jania capillacea, Schizothrix calcicola, Lobophora varians, and Valonia ventricosa. A mat of red filamentous algae occurs on dead coral and on the base of corals.

Gagan quarry has the most diverse fish fauna noted in any of the quarries, including adults and juveniles of many species. Mullet schooled along the seaward reef flat quarry edge while schools of the surgeon fish Acanthurus olivaceus and parrot fish Calotomus carolinus swam across the quarry's sand bottom. Representative species of damsel fishes (pomacentrids), wrasses (labrids), and surgeon fishes (acanthurids) congregated along both quarry walls. Additionally, butterfly fishes (chaetodontids), small parrot fishes (scarids), goat fishes (mullids), snappers (lutjanids), and groupers (serranids) are present. A large school of pompano (Trachinotus bailloni) continuously dashed across the quarry's length as did a small blacktip shark (Carcharhinus melanopterus). Several pairs of dragon wrasses (Novaculichthys taeniourus) dived in and out of the quarry's sand bottom.

Interviews

Located south of Roi-Namur, Gagan's nearshore lagoon waters are exploited by fishermen from both Ennubirr in the north and Ebeye in the south. Lobster (wor) is found on the reefs, and snappers (jetar) and emperors (metjebjeb) occur in the vicinity of Gagan's waters.

d. <u>Gellinam Island</u>

Gellinam (Fig. 9) is a windward mid-atoll island located north of Eniwetak Passage. Most of it has been cleared of natural forest except at the northern end. Facilities include a helipad and harbor.

The lagoon adjacent to Gellinam appears unaffected by development except for the harbor area. The harbor is located near the southern end of the island and consists of two rip rap jetties protecting a pier and marine ramp. The harbor bottom and areas immediately adjacent to the jetties have been dredged. A rip rap revetment extends both north and south of the jetties to protect the helipad and other facilities, and supports a large population of <u>Grapsus tenuicrustatus</u>. A sand beach stretches along the lagoon shoreline and grades into a steep cobble berm (30 degree slope), indicating relatively high wave energy.

The northern end of the island has strong currents and is protected against erosion by a rip rap revetment. A small section of natural forest occurs in this area, which supports terrestrial hermit crabs (<u>Coenobita</u> sp.) along its margins. The beach on the ocean side of the island is primarily cobble except for rip rap revetment protecting the helipad and facilities at the southern end of the island. This revetment supports populations of grapsid crabs, especially Grapsus tenuicrustatus.

There is trash and debris, including copper and alloys, scattered about the island. This includes a dump that is encroaching on the only remaining patch of forest. Additionally, Copper Blast was scattered about the island.

Lagoon and Shallow Reefs

There is good coral reef development on either side of the harbor. The margin of the island has a narrow lagoon reef flat that descends to a sand bottom at a depth of at 13-16 ft. (4-5 m). Coral knolls and mounds are abundant with coral coverage approaching 80% on hard substratum. Nine or more Acropora spp. dominate the coral fauna, with Acropora valida being the most abundant. Montipora spp. are also common, but at least twenty other coral species are represented. There is also a large patch of Alveopora sp., and the staghorn corals Acropora formosa and A. virgata occur in deeper sandy areas.

The good coral reef development also supports an abundant and diverse macroinvertebrate fauna and algal flora. Tridacnid clams are fairly abundant, with Tridacna maxima dominating, but including T. gigas, T. squamosa, and Hippopus hippopus. Most of these clams are relatively small. However, a coral mound in deeper water north of the harbor has eight T. gigas ranging in

KWAJALEIN ATOLL COASTAL RESOURCE INVENTORY

BOTTOM TYPE AND SHORELINE CLASSIFICATION

(Based on field observations and aerial photograghic interpretation)

BOTTOM TYPE

<u>Offshore</u>
sc- sand bottom in water less than 10m.
sd- sand bottom in water depths greater than 10m.

<u>Reef Complex</u>
rcp- consolidated limestone with a smooth pavement-like surface.
rc- mixed bottom types consisting of reef rock (limestone) associated with shallow water formations.
co- areas of greater than 50% live coral cover.
rcg- consolidated reef with well defined spur-and-groove system.

SHORELINE

rr- rip rap shoreline.
sb- white sand beach of predominately calcareous material.
bc- concrete/cement masonry seawall and shoreline.
sbc- calcareous rubble and/or shingle beach.
br- beach rock, usually exposed along the shoreline.

VEGETATION

<u>Halimeda/</u> seagrass beds

FIELD STATION

[K] KMRI Station

OTHER SYMBOLS

dredge site

observed range

quarry area

island area

[H] helicopter pad

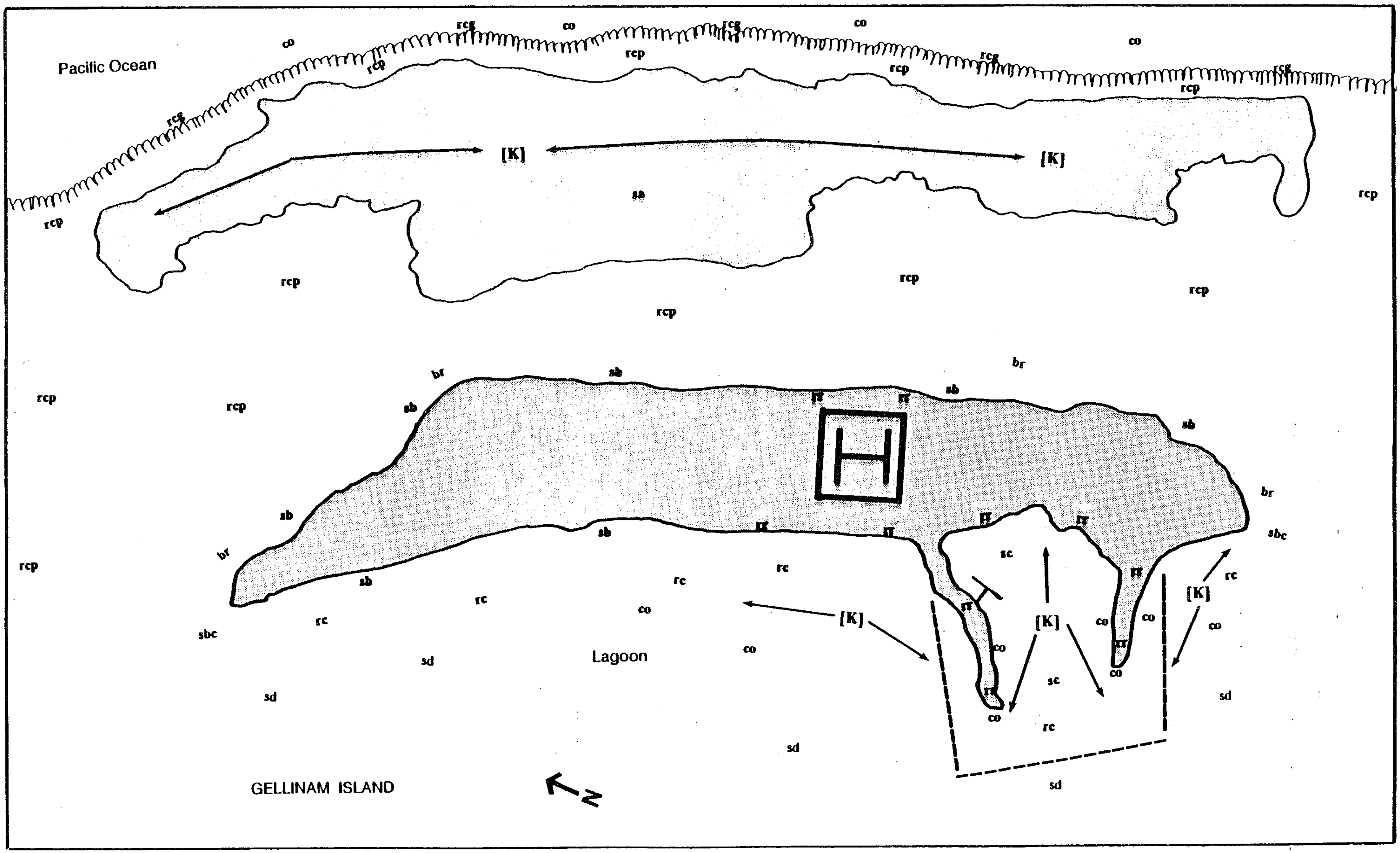

Figure 9. Thematic map showing the shoreline features and marine environment of Gellinam Island, Kwajalein Atoll, RMI.

size from 6-31 inches (16-79 cm). This is the largest, most dense population of T. gigas found during the survey. Several non-coral coelenterates are common in the lagoon reef area, including corallimorphs, Sinularia spp, and anemones in the genera Heteractis and Stichodactyla. Large gastropods are well represented by numerous Trochus niloticus, Dendropoma maxima, Strombus spp., and Lambis spp.

Algal development is good on the reef. Neogoniolithon frutescens occupies the spaces between corals, and Neomeris sp. and Schizothrix calcicola form patches on rocks. Microcoleus lyngbyaceus and Hormothamnion enteromorphoides are common, and several other species are present. There are several stands of Halimeda opuntia.

The fish assemblage is moderately abundant adjacent to both sides of the harbor. Wrasses, butterfly fish, and damsel fish represent the dominant species throughout the reef. Larger species, however, become more abundant with depth and include snappers (lutjanids), emperors (lethrinids), parrot fishes (scarids), and groupers (serranids). Schools of Siganus argenteus (rabbit fish), fusiliers, and Naso hexacanthus (unicorn fish) patrolled the survey area as did several blacktip and whitetip sharks.

Harbor Area

Fauna and flora decrease in the harbor area and on the jetties. Corals have less than 1% coverage on the south jetty and about 5% on the north jetty, and consist of the species Acropora valida, A. cytherea, Pocillopora meandrina, encrusting Millepora spp., and a few other species. The dredged harbor bottom is devoid of all but a few coral fragments. The rocks of the jetties support Lithophaga zittelliana, Echinometra mathaei, some strombid snails, and the clam Tridacna maxima is relatively abundant. The topshell Trochus niloticus is common on the jetty rocks, as is Vasum turbinellum. There are a few large anemones (Heteractis sp.) and a large Acanthaster planci was feeding on Acropora. Algal cover is reduced and consists primarily of patches of Hormothamnion and Schizothrix, with some Dictyota on the rocks and Sphacelaria near the boat ramp. The area immediately adjacent to the northern jetty (outside the harbor) has poor biotal development resulting from poor circulation. This area may also have been dredged.

Fish diversity dwindles to roughly a dozen common species within the harbor. Hidden among the rip rap walls are squirrel fishes (Neoniphon sammara, Sargocentron sp.). Surgeon fishes (acanthurids) and parrot fishes (scarids) actively scrape algae off the rip rap walls. Also present, but not as abundant are wrasses (labrids) and some butterfly fishes (chaetodontids).

Reef Flats and Quarries

The ocean reef flat is dominated by a large, irregularly shaped quarry that extends the length of the island (Fig. 9: p. 93). There are several large boulders remaining on the reef flat and areas that have been dynamited but not dredged. This indicates that the irregular shape of the quarry may partially be due to the cessation of quarrying before completion of the planned operation.

The back reef has the usual low diversity assemblage of *Grapsus tenuicrustatus*, *Littorina* spp. (*L. coccinea* and *L. undulata*), *Nerita plicata*, and *Coenobita* sp. on the rip rap and supratidal rocks. The reef flat has small crabs, hermit crabs, snails, and blue-green algae.

The quarry, which dominates the reef flat, has a complex shape and varying topography. Depth ranges from 1.5-13 ft. (0.5-4 m), and it has an irregular bottom and an "island" in the middle. The coarse sediment ranges from pea sized through gravel, cobble, and boulder. As a result, although there are few deposit feeding organisms such as holothurians, there is a rich epibenthic biota. The diverse coral assemblage approaches 100% coverage in some areas and averages about 5% throughout the quarry. Coral coverage and fish diversity are highest on the island side of the quarry, but there is good development throughout, including a lot of young coral recruits. *Acropora* spp. corals dominate in numbers and diversity with about eight species, but the coral fauna also includes several *Montipora* spp., four or five *Pocillopora* spp., *Millepora* spp, *Astreopora* sp., *Porites* spp., *Favia stelligera*, and about nine other species.

The macroinvertebrate assemblage of the quarry is well represented by echinoderms, including *Diadema savignyi*, *Echinothrix diadema*, *Echinostrephus aciculatus*, three *Ophionereis* spp., the irregular urchin *Brissopsis luzonica*, and the crinoid *Oligometra serripinna*. Mollusks include *Tridacna maxima*, *Hippopus hippopus*, *Dendropoma maxima*, *Cypraea moneta*, *Tectus pyramis*, *Trochus niloticus*, *Lambis truncata*, *Lithophaga zittelliana*, *Vasum turbinellum*, and *Astraea rhodostoma*. Decapods, though usually small and cryptic, are represented by some obvious species, notably a large *Dardanus* sp. in *Trochus* shells, *Trapezia* spp. and alpheid shrimp living commensally in *Pocillopora* spp., and *Alpheus* sp. living commensally with gobiid fish.

Algal development is good, but not quite as diverse as in the Gagan quarry. The highest diversity is at the southern end. Species present are *Dictyosphaeria versluysii*, *D. cavernosa*, *Halimeda discoidea*, *H. opuntia*, *Microdictyon okamurai*, and about eight or more other macroalgal species in lower abundance.

The fish assemblage is diverse and abundant in the quarry with the landward side having the greatest diversity. Acanthurids and some pomacentrids swim closely along the seaward wall. Elsewhere, fish diversity increases to over three dozen genera, particularly along the landward wall. Schools of the parrot fish (Calotomus carolinus) and flagtail (Kuhlia mugil) migrated throughout the quarry. Squirrel fish (holocentrids) are abundant underneath coral overhangs and near rock piles.

Interviews

During the fishermen interviews, no species were reported to be caught off Gellinam.

e. Omelek Island

Omelek (Fig. 10) is south of Gellinam Island and is the second island north of the Eniwetak Passage. Unlike the usually long, narrow configuration of most of the other USAKA islands surveyed, Omelek is almost triangular. Much of the island has been cleared, but three patches of forest remain. As with Gellinam Island to the north, Omelek's lagoon is modified primarily in the dredged harbor area, which also consists of two jetties that protect a marine ramp and a pier.

Beaches and Shoreline

Omelek receives higher lagoon wave energy than other windward study localities. However, rip rap has been used for shoreline protection only in the harbor area because Omelek's steeply sloped cobble beaches provide natural wave protection. A depositional beach and sandbar have formed at the northern end of the island where waves from the lagoon and ocean collide. A 3-4 knot (5.6-7.4 km/hr) current flows across the reef flat into the lagoon which required an armor stone revetment to be constructed to protect the weather satellite launch pad and to control storm erosion. The rip rap on Omelek differs from the other islands in that it is "dumped" stone rather than being stacked and lined up to form a revetment "wall." The northeastern coast of the island is a sand and cobble beach, while rip rap fronts the shoreline from the northeastern point to the southern end of the island. The rip rap is dumped directly on the reef flat and there is no beach.

The rip rap and rocks around the island support a population of *Grapsus tenuicrustatus*, *Nerita plicata*, and *Coenobita* sp. There are low numbers of littorinids along the ocean side and the dry blue-green algae *Nostoc* sp. occurs on the island.

KWAJALEIN ATOLL COASTAL RESOURCE INVENTORY

BOTTOM TYPE AND SHORELINE CLASSIFICATION

(Based on field observations and aerial photograghic interpretation)

BOTTOM TYPE

Offshore

sc- sand bottom in water less than 10m.
sd- sand bottom in water depths greater than 10m.

Reef Complex

rcp- consolidated limestone with a smooth pavement-like surface.
rc- mixed bottom types consisting of reef rock (limestone) associated with shallow water formations.
co- areas of greater than 50% live coral cover.
rcg- consolidated reef with well defined spur-and-groove system.

SHORELINE

rr- rip rap shoreline.
sb- white sand beach of predominately calcareous material.
bc- concrete/cement masonry seawall and shoreline.
sbc- calcareous rubble and/or shingle beach.
br- beach rock, usually exposed along the shoreline.

VEGETATION

Halimeda/ seagrass beds

FIELD STATION

[K] KMRI Station

OTHER SYMBOLS

dredge site

observed range

quarry area

island area

[H] helicopter pad

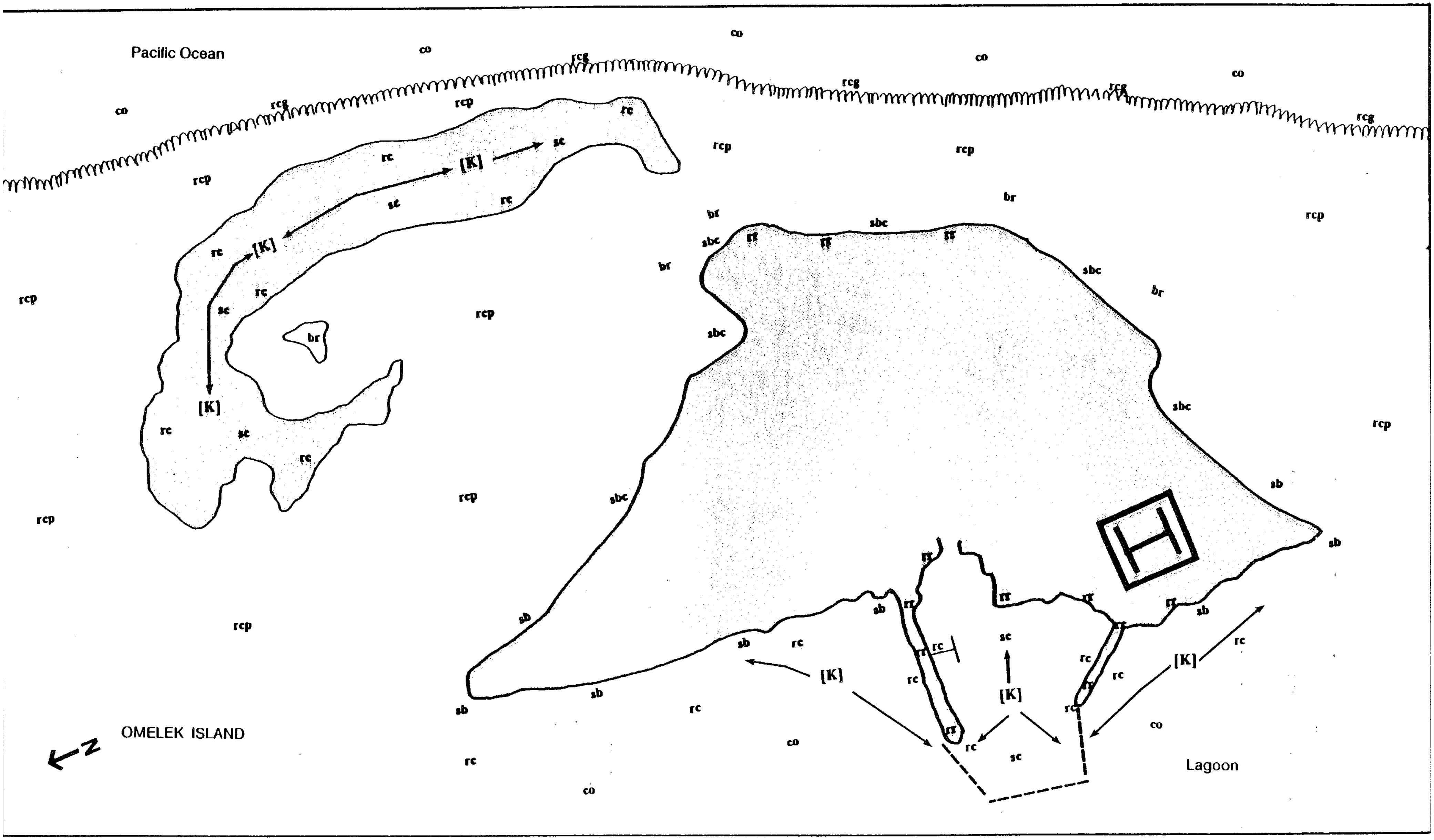

Figure 10. Thematic map showing the shoreline features and marine environment of Omelek Island, Kwajalein Atoll, RMI.

Shallow Lagoon Reefs

The high wave energy in the lagoon results in considerable scouring of the intertidal and shallow coastline, with the harbor offering only partial protection from surge. There are some high energy encrusting organisms and fish (particularly acanthurids) in shallow water, but little else. Corals and other organisms start appearing in low abundance at a depth of 3-5 ft. (1-1.5 m), but abundance was low and the habitat is more two dimensional than three. *Acropora* spp. dominate the coral fauna, particularly A. *verrucosa*. Robust species such as *Pocillopora meandrina*, *Pavona varians* and *P. clavus* occur. Unlike other areas in the study, there are large hemispherical heads of *Goniastrea* sp. and *Lobophyllia* sp. that grow to 3 ft. (1 m) in diameter and occur at a depth of about 6-7 ft. (2 m). Small numbers of several other coral species were also found. Non-coral invertebrates include *Dendropoma maxima*, *Sinularia polydactyla*, *Trochus niloticus* and a few tridacnid clams. Holothurians are represented by *Holothuria nobilis*, *Echinothrix diadema* and, because of the high wave energy, *Echinometra mathaei*. A few representatives of the large snail *Lambis truncata* and the cushion star *Culcita novaeguineae* were found near the southern jetty.

The shallow scoured areas have very little algae cover, consisting primarily of *Neomeris* sp., *Schizothrix* sp., and

Lobophora variegata. Coverage increases near the harbor, where patches of Dictyota spp. are so thick in places that they were sloughing off the southern jetty wall. Inside the harbor, the high energy Bryopsis pennata occurs.

Fish diversity and abundance are moderate at depths of 13 ft. (4 m) near the harbor jetties. Several fish schools swam through the area including rabbit fish (Siganus argenteus), acanthurids (Acanthurus guttatus), scarids (Calotomus carolinus) and fusiliers. A 4.5 ft. (1.4 m) nurse shark (Nebrius concolor) was observed resting in a small reef flat cave.

Harbor and Jetties

The southern jetty was built on an undredged section of lagoon reef flat. Colonial organisms such as ascidians and bryozoans occur on the inner jetty walls. Coral coverage approaches 50% on the shallow portion of the southern jetty, as opposed to 5% coverage on the dredged northern wall. However, this difference in coral coverage is probably due to the positioning of the jetty rather than the dredging. The northern jetty is oriented perpendicular to the wave direction and is subject to high wave energy and scouring. The southern jetty, however, is at a 45 degree angle to the wave direction, therefore protecting the fauna on the inside of the jetty from high wave energy and scouring.

The areas north and south of the harbor are similar in fauna and flora, indicating that the impact of the harbor and dredging is localized.

Quarry

Omelek has a single, relatively large quarry on its outer ocean reef flat. It has an irregular, hook shaped design with variable bottom topography and depth. Due to the triangular shape of the island, a major portion of the quarry is effectively on the interisland reef flat which promotes flushing and good circulation at all times. Strong currents were encountered moving in different directions within the hook.

Continuous water circulation promotes good flushing and a lack of fine sediments in the quarry. There are no real sand deposits, the smallest sediment size being "pea" sized. The margins of the pool are generally sloped, but there are some vertical sides. The high biotic abundance and diversity are probably due to the complex design, habitat diversity, and good water circulation. The proximity of the quarry to the reef flat edge results in waves splashing into the pool even during low tide.

The coral fauna is very diverse in the quarry with 100% coverage in some localities, and an overall coverage of about 50% on the walls. The species are typical of high wave energy environments and include several Acropora spp., lobate Porites spp., thick branched Pocillopora spp, and Millepora spp. Pocillopora damicornis is abundant along the island side and at the end of the hook, and some finely branched Acropora occur in the deeper portions. Several other species of coral were found throughout the quarry.

Additional invertebrate fauna consists of typical coral reef species. Echinoderms are represented by Holothuria atra, Actinopyga mauritiana, Echinostrephus, Echinothrix diadema, Brissus latecarinatus, and Brissopsis luzonica. There are a few tridacnid clams, and also Trochus niloticus, Tectus pyramis, Dendropoma maxima, and an Octopus sp.

Algal abundance and diversity vary in the quarry. At the southern end of the hook shaft the common algae are Halimeda opuntia, Dictyosphaeria cavernosa, D. versluysii, and a few other species. Productivity decreases toward the hook, with Caulerpa spp. dominating at the midpoint of the quarry and only some algal film occurring at the end of the hook.

Fish are abundant and diverse in the quarry, ranging from juveniles through adults. Schools of the goat fish Mulloides vanicolensis and surgeon fish Acanthurus olivaceus were seen, as well as halfbeaks (Hemiramphus sp.) which hovered just below the water surface. As in other quarries, the diversity and abundance of fish is greater along the landward side of the quarry hole.

Surgeon fish (acanthurids) abound along the seaward quarry wall where the wave wash surge is most apparent. Mullet were observed running along the seaward reef flat adjacent to the quarry hole. Damsel fishes (pomacentrids) and wrasses (labrids) commonly inhabited isolated coral heads along the sand bottom. On the landward side, however, small fish are particularly abundant, especially spotted groupers (Cephalopholis urodelus), parrot fish, and butterfly fishes.

Interviews

No fishing was reported being conducted off this island during the interview sessions.

f. Eniwetak Island

Eniwetak Island (Fig. 11) is unusual in that it is not on the reef flat. It has developed inside the lagoon adjacent to the Eniwetak Passage. As a result, it does not have a reef flat to protect it from storm waves and currents. Therefore, Eniwetak Island shows several areas of intensive erosion and deposition. Unlike most other USAKA controlled islands, it also has a well developed forest and associated biota. Particularly noticeable are the number of birds.

Shoreline

Beach sediments vary considerably around Eniwetak Island due to the strong currents through Eniwetak Passage. The eastern end of the island, which faces the passage, has a steeply sloped cobble beach and is bordered by an eroded embankment. Some rip rap has been placed in this area to reduce erosion. Exposed beach rock is common around the island and piles of coral rubble consisting of the remains of the finely branched coral *Acropora* spp., the organ pipe coral *Tubipora*, and the blue coral *Heliopora*, blanket the southern shoreline. A 10-13 ft. (3-4 m) high embankment fronts the southern shore, which is further evidence of a combination of strong wave action and storm damage on this side of the island. Eniwetak's northern shoreline is a well sorted fine grain white sand beach.

Harbor Area

The harbor area on the western end of the island has breaking waves and a scoured bottom. There are only a few small encrusting corals in shallow water. About 100 ft. (30 m) offshore there is higher relief, but coral coverage is still less than 5%. The coral fauna consists of high energy species, especially *Acropora monticulosa* and *A. palifera*. In addition to these massive species, there are *Pocillopora* spp, *Acropora* sp. 1, *A.* sp. 2, encrusting *Montipora* spp., and several other species.

KWAJALEIN ATOLL COASTAL RESOURCE INVENTORY

BOTTOM TYPE AND SHORELINE CLASSIFICATION

(Based on field observations and aerial photograghic interpretation)

BOTTOM TYPE

Offshore
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Reef Complex
rcp- consolidated limestone with a smooth pavement-like surface.
rc- mixed bottom types consisting of reef rock (limestone) associated with shallow water formations.
co- areas of greater than 50% live coral cover.
rcg- consolidated reef with well defined spur-and-groove system.

SHORELINE

rr- rip rap shoreline.
sb- white sand beach of predominately calcareous material.
bc- concrete/cement masonry seawall and shoreline.
sbc- calcareous rubble and/or shingle beach.
br- beach rock, usually exposed along the shoreline.

VEGETATION

Halimeda/ seagrass beds

FIELD STATION

[K] KMRI Station

OTHER SYMBOLS

dredge site

observed range

quarry area

island area

[H] helicopter pad

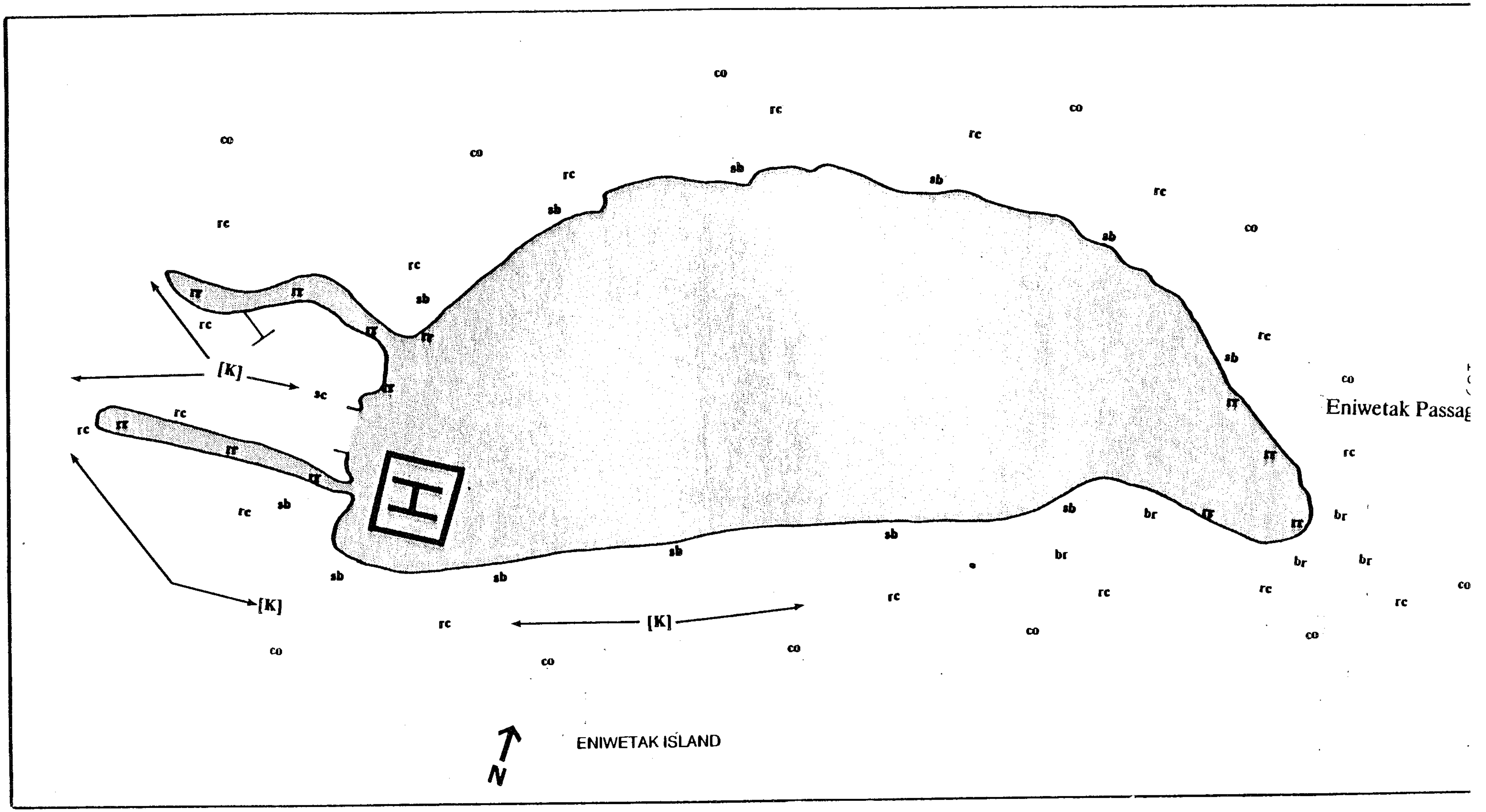

Figure 11. Thematic map showing the shoreline features and marine environment of Eniwetak Island, Kwajalein Atoll, RMI.

Scrape marks are abundant on the substratum, including the corals, which are the result of large scarids feeding.

Three species of soft coral dominate the non-coral macroinvertebrates: Sinularia polydactyla, Cladiella sp., and one other species. The density of vermetid gastropods (Dendropoma maxima) is higher than other study sites. The invertebrate fauna also includes Tridacna maxima, Actinopyga mauritiana, Lithophaga zittelliana, Zoanthus sp., and Echinostrephus aciculatus.

Algal coverage in the harbor is relatively high, possibly due to nutrient input from the forest and birds. The algae include Hormothamnion enteromorphoides, Schizothrix calcicola, Halimeda spp., Caulerpa verticillata, Neomeris vanbosseae, and Ralfsia occidentalis. Near the jetty the rocks have a veneer of Dictyota friabilis and the bottom of the harbor has a lot of silted Caulerpa cupressoides. The abundance of algae has resulted in a large population of algivorous fish. The dominant species are scarids and surgeon fish, particularly Acanthurus guttatus and A. olivaceus.

The species of coral on the harbor jetties are similar to surrounding areas, but the coverage is significantly lower. At the time of the survey, the water was turbid with suspended silt particles. The vermetids, which are quite abundant, were producing a lot a mucus. Other invertebrates found include Actinopyga mauritiana, Lithophaga zittelliana, Trochus niloticus,

Tridacna sp., and Zoanthus sp. The harbor bottom is devoid of obvious macroinvertebrates except for callianassids and enteropneusts. As with areas outside the harbor, scarids are abundant and causing considerable bioerosion.

Pass Reef

Because of the number of coral fragments found along the southern shore, the team snorkeled out through the breakers to investigate the area. A shallow, 65 ft. (20 m) wide terrace descends to a depth of 16 ft. (5 m), and then drops into the channel along a 60 degree incline. The shoreward side of the terrace had been Acropora thickets, including Heliopora, Millepora, Tubipora, and Alveopora. However, these had been sheared off, probably by Tropical Storm Roy. This was undoubtedly the source of the coral rubble on the shore.

Below 6-7 ft. (2 m) in depth, coral coverage reaches 50% or greater, with strikingly large heads of Hydnophora, which are up to 6-7 ft. (2 m) in diameter. There are also large colonies of lobate Porites, Millepora platyphylla, and Astreopora, plus at least 18 other species. Millepora tenera occurs in deep water.

The macroinvertebrates and algae of the southern shore are similar to the harbor area. The three species of soft coral are again abundant, as is Dendropoma maxima. There are several Tridacna maxima, and Lithophaga zittelliana density is high on the shallow terrace, reaching densities of 35-60/yd^2 (30-50/m^2). Because wave action is high, there is a lot of Echinometra mathaei boring into the carbonate along the shore.

The ichthyofaunal assemblage found offshore of Eniwetak Island along the inner Eniwetak channel wall resembles an ocean reef fish population despite its lagoonal location. Due to increased habitat diversity and complexity, the variety, size, and abundance of fish increased substantially compared to other lagoonal environments. Conspicuous representatives include acanthurids (surgeon fish), serranids (groupers), lethrinids (emperors), carangids (jacks), lutjanids (snappers), and balistids (trigger fish). Less conspicuous, although probably more abundant, are damsel fishes (pomacentrids), wrasses (labrids), parrot fishes (scarids), and butterfly fishes (chaetodontids).

Interviews

Eniwetak Island is also located adjacent to the Eniwetak Passage. Because of Eniwetak's location inside the lagoon and fronting the passage, it is buffeted by strong currents and, subsequently, is not a favored fishing site. As with other channels, Eniwetak Passage affords access to the ocean with considerable trolling opportunities for pelagic species including mahimahi (koko), barracuda (ni, tua, jujukop), skipjack tuna (lejabil), and blue marlin.

g. Ennylabegan Island

Ennylabegan (Fig. 12), commonly referred to as Carlos, is a leeward island, located between Gea Pass and South Pass. The windward side of the island faces the lagoon which, during the study, had higher energy waves than the ocean side. Marshallese live on the northern and southern ends of the island, and USAKA facilities are mid-island. Offshore survey work was conducted only adjacent to the USAKA leased portion of the island. However, shoreline descriptions are supplemented by notes taken while driving around the entire island.

The island has been extensively cleared of native vegetation, although some areas were replanted with coconut trees. The coastline is unmodified except for some portions of the USAKA controlled areas at mid island. There is a Japanese-built pier on the lagoon side and rip rap was placed along the ocean coastline to protect USAKA equipment and facilities. An access channel was also dredged to the pier.

KWAJALEIN ATOLL COASTAL RESOURCE INVENTORY

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SHORELINE

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VEGETATION

Halimeda/ seagrass beds

FIELD STATION

[K] KMRI Station

OTHER SYMBOLS

dredge site
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quarry area
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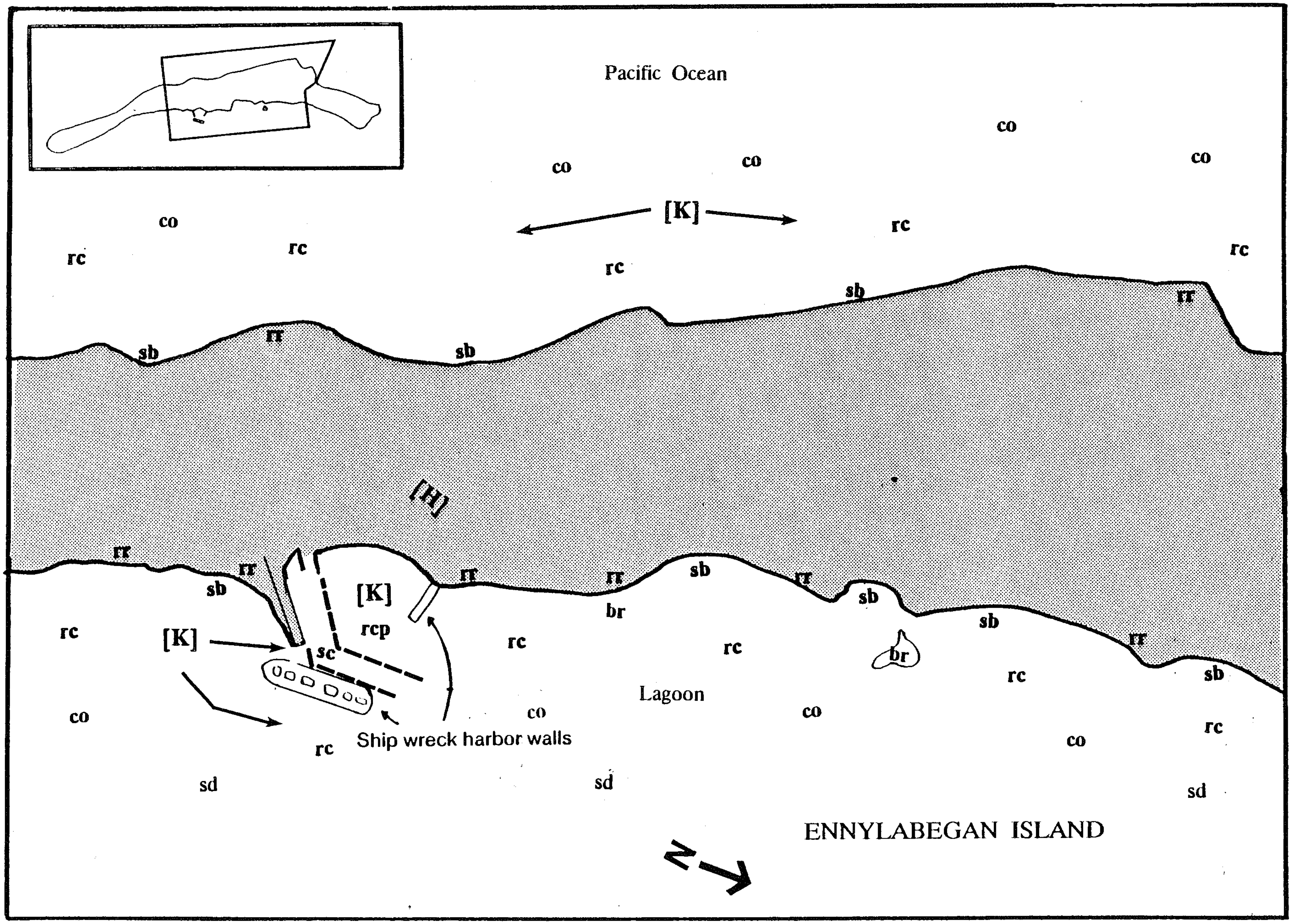


Figure 12. Thematic map showing the shoreline features and marine environment of Ennylabegan Island, Kwajalein Atoll, RMI.

Shoreline

Most of the shoreline is beach composed of sediments that range from sand to cobble. Pitted beach rock and, in isolated spots, beach rock berms are emergent on the ocean reef flat. This reef flat is about 230-246 ft. (70-75 m) wide and slopes into a ridge and valley system with high coral coverage on the ridges. Trash is abundant on the beaches and heavy equipment has been abandoned/dumped onto the beach and reef flat.

Lagoon Reefs

The lagoon reef is well developed but shows signs of recent impact, probably from Tropical Storm Roy. Just south of the harbor the shallow reef within the breaker zone shows signs of scouring from lagoon swells. Beyond this area is a zone 100-130 ft. (30-40 m) wide with broken Acropora sp. 1 and A. sp. 2, and small amounts of broken Pocillopora eydouxi, Millepora platyphylla, and several other coral species. The dominant, non-coral macroinvertebrates are three species of soft coral: Sarcophyton, Cladiella sp., and Sinularia polydactyla. There are also some top shells (Trochus niloticus), Tridacna maxima, and boring sea urchins (Echinostrephus aciculatus).

Beyond this zone, at a depth of 6-7 ft. (2 m) or more, the amount of broken and damaged coral decreases, but is still apparent. This 33-66 ft. (10-20 m) wide zone has the same coral species, including *Acropora vaughani*. In addition, there are some strikingly large *Hydnophora* heads (6-7 ft. or 2 m in diameter) and large *Pocillopora eydouxi*. *Acropora cytherea* and *Montipora verrilli* occur at a depth of 13 ft. (4 m). There is a large field of *Alveopora* at this deeper level, including some large lobate *Porites* and large *Lobophyllia* (3 ft. or 1 m in diameter).

The entire reef area is covered by an algal mat of various thicknesses. *Halimeda opuntia* grows between the corals and there are numerous brown spots of *Schizothrix calcicola*. Several other species of algae occur in this area, including *Codium arabicum*, *Halimeda discoidea*, *Dictyota bartayresii*, *Microcoleus lyngbyaceus*, and *Asparagopsis taxiformis*. Algal abundance decreases near and in the harbor.

The fish assemblage increases rapidly in abundance from the shallow reef flat to deeper coral reef terraces. The convict tang *Acanthurus triostegus* and damsel fish *Plectroglyphidodon dickii* are the most abundant fish along the scoured reef flat, although several wrasses (labrids) and other damsel fishes (pomacentrids) are common. The fish assemblage diversifies and enlarges considerably at a depth of 13 ft. (4 m). Larger, solitary species including *Naso unicornis* (unicorn fish), *Variola louti* (coral trout), *Cephalopholis argus* (grouper), and *Balistoides conspicillum* (clown trigger fish) occur. Schools of rabbit fish (*Siganus argenteus*), rudder fish (*Kyphosus* sp.), and surgeon fish (*Acanthurus xanthopterus*) cruised through the area regularly.

Harbor and Jetties

The harbor is formed and protected by the Japanese pier and two barges that were sunk to serve as jetties. The larger of the two barges was placed at the end of the pier. Its lagoon side is covered by extensive crustose colonies and the bottom has large numbers of the solitary coral *Tubastraea coccinea*. The more protected harbor side of the hull has branching colonies of *Acropora* sp. 1, *Montipora* spp., *Leptastrea purpurea*, *Favia* sp., and a few other coral species. There are also barnacles and pearl oysters (*Pinctada margaritifera*) on the hull.

The dredged harbor bottom is sandy and appears to have a shallow anoxic layer. There are some callianassid burrows but few other indications of macroinvertebrates. Beyond the dredged portion of the harbor, the bottom grades into a lagoon reef flat assemblage similar to that south of the harbor.

Within the harbor boundaries, the fish biomass decreased significantly. As with other nearshore reef flat areas, small labrids and pomacentrids are dominant. A large school of *Acanthurus xanthopterus* foraged along the harbor channel wall and sunken barges.

Ocean Reefs

The survey team made an ocean survey at mid island across from the harbor. The shallow scoured reef flat in the breaker zone has relatively few species and low abundance, with Acropora sp. 1 being the dominant coral, but including Pocillopora meandrina and species in the genera Porites, Leptastrea, Millepora, and Hydnophora. Outside the breaker zone coral coverage increase to 10-20%. The vermetid Dendropoma maxima is the only obvious non-coral macroinvertebrate present in the shallow scoured area. Actinopyga mauritiana, Sinularia polydactyla, colonial ascidians, Echinometra mathaei, Echinothrix diadema, Echinostrephus aciculatus, and Trochus niloticus occur in deeper water.

About 165 ft. (50 m) from shore, where water depth reaches 6-7 ft. (2 m), the environment becomes richer. In addition to the above coral species, there are Acropora monticulosa, A. humilis, encrusting Montipora spp., Favia sp., and Pavona spp. A developed canyon system begins at a depth of about 10 ft. (3 m), with a relatively diverse coral assemblage on the ridges and cobbles in the canyons.

There is algal mat on most of the reef rocks. The algae included Schizothrix calcicola, S. mexicana, Sphacelaria tribuloides, and Hormothamnion enteromorphoides. There is an unusually small amount of Halimeda opuntia.

The fish population increased tremendously with both distance from shore and depth. The surgeon fishes Acanthurus triostegus, A. lineatus, and the damsel fish Stethojulis bandanensis are abundant along the shallow wave swept platform while other wrasses (labrids), damsel fishes (pomacentrids), and butterfly fishes (chaetodontids) are common. Seaward, the diversity increases substantially. Representatives include several groupers (Variola louti, Cephalopholis argus, C. urodelus), parrot fishes (Scarus frenatus, S. sordidus), snappers (Lutjanus bohar, L. fulvus, L. gibbus), and goat fish (Mulloides flavolineatus). Solitary predator species are also common including sharks and jacks.

Interviews

Ennylabegan Island, the only Kwajalein Atoll island partially leased by USAKA, has a small resident population of Marshallese. Although no interviews were conducted on Ennylabegan, Mr. Hideo Milne of Kwajalein Island stated that there are several subsistence and part-time commercial fishermen residing on the island. Fishermen from Ebeye and Kwajalein reported that rabbit fish (muramor) and striped surgeon fish (kwi) are the targeted reef fish in this area. A species of edible crab (baru or aton) is abundant on the nearby island of Gea, but may also be found less frequently on Ennylabegan. South Pass, located just south of Ennylabegan, is described by Kwajalein fishermen as being particularly abundant with blacktip shark (boko); it was also identified as a good recreational dive site. Blue marlin and mahimahi (koko) can be caught off the oceanside of Ennylabegan throughout the year.

h. Roi-Namur Island

Roi-Namur is the northernmost island on the atoll (Fig. 13). Originally separate, the islands of Roi and Namur were joined together naturally and by dredging and filling. Now the second largest island on Kwajalein Atoll, the combined island of Roi-Namur has had 40 acres (0.16 sq. km) added to it since 1948 (BMDSCOM, 1980).

Joining the islands and the subsequent dredging and filling operations have substantially modified the marine habitat around Roi-Namur. Additionally, periodic maintenance dredging is still required to provide boat access to the fuel pier and Yokohama Pier. However, there is no information to determine how greatly the original joining of the islands changed the lagoon habitat. Evidence on the ocean side suggests that strong currents once passed between the islands. There are remnants of deep, steep sided channels with massive skeletons of the robust branching

KWAJALEIN ATOLL COASTAL RESOURCE INVENTORY

BOTTOM TYPE AND SHORELINE CLASSIFICATION

(Based on field observations and aerial photograghic interpretation)

BOTTOM TYPE

<u>Offshore</u>

sc- sand bottom in water less than 10m.
sd- sand bottom in water depths greater than 10m.

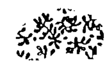
<u>Reef Complex</u>

rcp- consolidated limestone with a smooth pavement-like surface.
rc- mixed bottom types consisting of reef rock (limestone) associated with shallow water formations.
co- areas of greater than 50% live coral cover.
rcg- consolidated reef with well defined spur-and-groove system.

SHORELINE

rr- rip rap shoreline.
sb- white sand beach of predominately calcareous material.
bc- concrete/cement masonry seawall and shoreline.
sbc- calcareous rubble and/or shingle beach.
br- beach rock, usually exposed along the shoreline.

VEGETATION

 <u>Halimeda/</u> seagrass beds

FIELD STATION

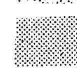
[K] KMRI Station

OTHER SYMBOLS

dredge site

 observed range

 quarry area

 island area

[H] helicopter pad

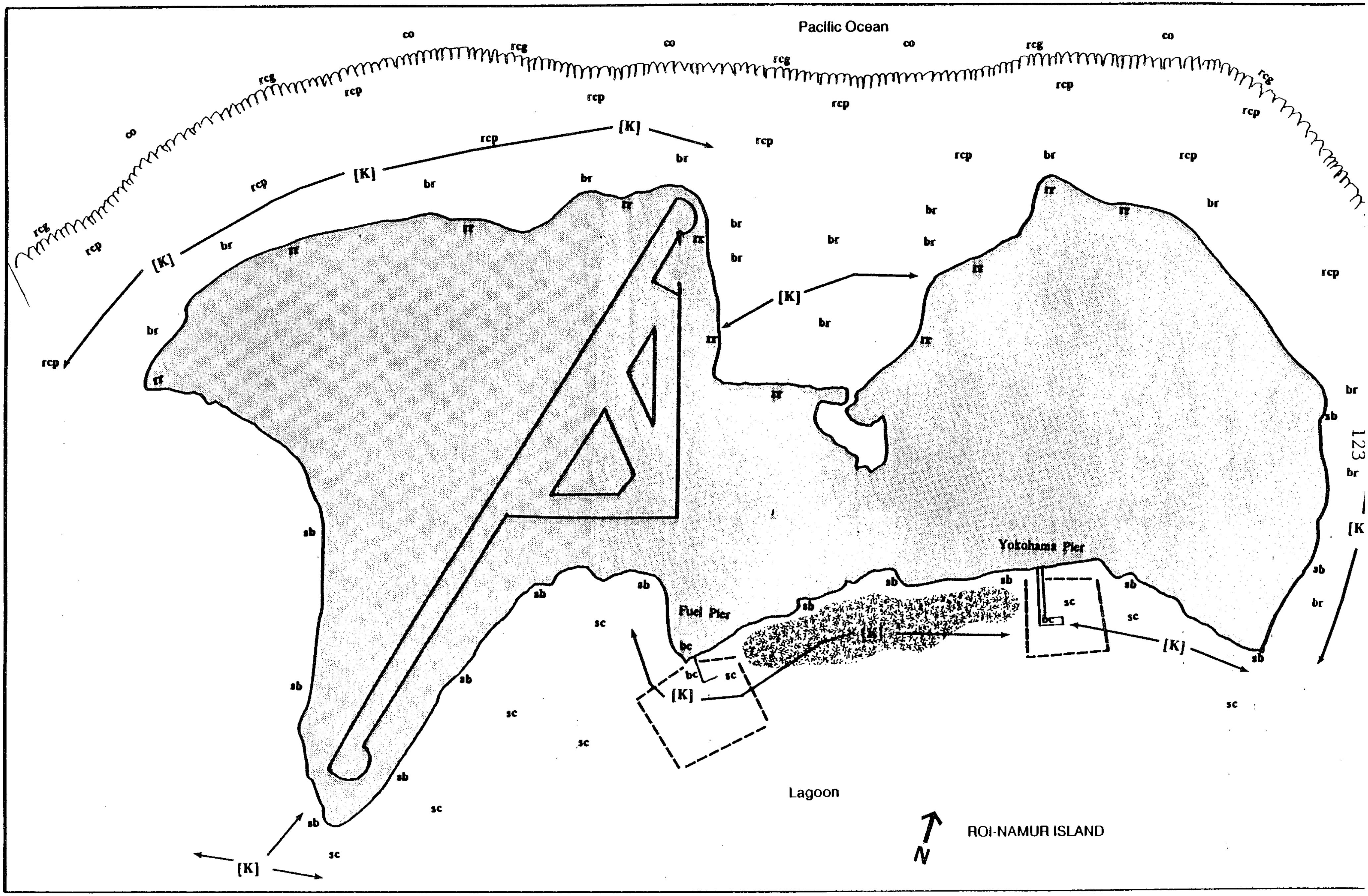


Figure 13. Thematic map showing the shoreline features and marine environment of Roi-Namur Island, Kwajalein Atoll, RMI.

coral *Acropora palifera* buried in the sand. Currently, with the channel sealed off, the poor water circulation supports only minimal coral development and no living *Acropora palifera*. This change in water flow between the islands would also have affected the lagoon.

Roi-Namur, which has extensive facilities development, does not have as much rip rap or shoreline protection as Kwajalein or Meck islands. Revetments have only been built to protect areas such as the rocket launching facility, the northern end of the runway, the housing facilities, the harbor area, and the radar facilities. Other parts of the island, especially on Namur, have natural shorelines.

Northern (Ocean) Reef Flat

The ocean reef flat is quite wide, averaging about 656-820 ft. (200-250 m), and has relatively strong currents during tidal changes. Four 33 ft. (10 m) transects were taken on the ocean reef flat of Roi where future quarry dredging is planned. These transects covered the area from the northern end of the runway to near the western end of the island.

Though the ocean reef flat is wider than most other areas studied, the assemblage of organisms and zonation are quite similar. The coral algal zone has microatolls of *Porites lutea* and a few other coral species including *Leptastrea purpurea*. The typical echinoderms _Echinothrix diadema_ and _Echinometra mathaei_ occur, as well as _Echinostrephus aciculatus_ and _Bohadschia argus_. Algae are abundant, especially _Caulerpa racemosa_, _C. serrulata_, _Padina_ sp., and _Dictyosphaeria_ sp., and the algal mat is well developed. The gobie _Istigobius rigilius_ and the wrasse _Thalassoma quinquevittatum_ are the most abundant fishes sighted, but acanthurids and pomacentrids are also present.

Roi's reef flat and back reef are also similar to other areas, but are more pitted and have more beach rock development than some. Therefore, in addition to the dominant algae and blue-green algae, there is more protected habitat for small cryptic invertebrates, especially snails.

Remnants of the interisland reef between Roi and Namur are evident on the northern coast of the island. These generally consist of emergent beach rock, sand channels, and steep sided ridges that have deeply eroded undercuts. These channels and ridges are oriented perpendicular to the reef front which implies that strong currents once flowed between the islands. The beach rock and ridges are extensively pitted and commonly exposed at low tides. Coral development is very poor, generally consisting of small amounts of _Pocillopora damicornis_ on the sides of the ridges. This semienclosed embayment has poor circulation and the water moving across the reef flat has deposited a fine coating of sediment on all surfaces. However, some of the scattered dark areas appearing in aerial photographs (Global Associates, 1987) are thriving patches of Montipora digitata, with a few colonies of Porites lutea.

The mollusk Strombus luhuanus occurs in the sand channels, sometimes in dense aggregations, as do callianassids. Cypraea tigris, large yellow tunicates, and a small vermetid species occur along the ridges. However, the most obvious animals are the holothurians, which are indicative of a depositional environment. The species present are Bohadschia argus, B. vitiensis, Holothuria atra, H. edulis, H. hilla, and H. leucospilota. The vermetid gastropod Dendropoma maxima is common in the Porites lutea heads, porcelain crabs (Petrolisthes sp.) are common on the reef flat under stones, and a few large polychaete fire worms were found under rocks next to the Namur shoreline.

A dense algal mat covers the rocks. Schizothrix calcicola is also common on rocks and there is some Halimeda in the large sand flat near the Roi side. Bryopsis pennata, Valonia ventricosa, and Martensia fragilis grow under the overhangs eroded into the sides of the ridges. Porolithon onkodes and Gelidiopsis intricata were also found.

About eight species of fish are common, and there are a lot of juveniles in the branching Montipora digitata beds. Especially noticeable are the territorial damsel fishes Stegastes nigricans and Plectroglyphidodon dickii. Small schools of neon-blue damsel fish (Chromis viridis) are scattered throughout the area. Frequently hovering just at the edge of the coral mounds are several small emperor fishes or lethrinids (Gnathodentex aureolineatus).

Eastern and Western Shallow Reefs

The east and west ends of Roi-Namur have shallow reef flats and very strong currents. The eastern end of Namur has a smooth, consolidated limestone bench with some exposed beach rock between Namur and Ennugarret islands. At low tide the water is about 8 inches (20 cm) deep with a few pockets to 20 inches (50 cm). Coral coverage is very low due to the strong currents and shallow depths, consisting of a few microatolls of Porites lutea with the alga Microdictyon okamurai growing on top. Holothuria atra is the dominant macroinvertebrate. The reef flat deepens to 1-2 ft. (0.5 m) on the lagoon side where it supports some extensive beds of the branching coral Montipora digitata. The staghorn coral Acropora aspera is dominant, but the corals Porites lutea, Pocillopora damicornis, Fungia fungites, and Millepora exaesa are also present. These corals extend into the lagoon.

In addition to Holothuria atra, H. leucospilota is present on the reef flat, as are a few Tridacna maxima and Lithophaga zittelliana. The red-eyed crab, Eriphia sebana, occurs along the shoreline. The algae Microdictyon okamurai, Codium arabicum, Dictyota friabilis, and Halimeda opuntia occur on the reef flat and Boodlea composita and Schizothrix are among the scattered corals. Although diversity is relatively low, algal productivity is high because of the algal mat covering most of the rocks.

Few fish species were observed along the ocean reef flat, although small eels (Echidna nebulosa), which hide in the reef rock cracks, actively forage throughout the area. Colonies of the coral Montipora digitata serve as a sanctuary for small fish. Wrasses are dominant (Macropharyngodon meleagris, Halichoeres trimaculatus, and Stethojulis bandanensis) with damsel fishes or pomacentrids also being abundant. Schools of juvenile parrot fish (Scarus spp.) appeared frequently in this location.

The western end of Roi is also shallow and has high current velocities. Rip rap protects the western point near the launch site and the area around the dump. Much of this rip rap is composed of metal debris and dumped heavy equipment. Near the runway the open dump appears to be encroaching on the reef flat. A large sand bar has formed at the end of the runway where currents and waves flowing over the reef flat meet lagoon waves and longshore currents.

The shoreline consists of sand except at the western point where currents scour the shoreline. Subtidally, there is sand

and rubble with occasional coral outcrops. In the area of the planned airport runway extension, coral coverage is low, less than 1% overall and less than 5% on hard substratum. The most common coral is _Millepora tenera_, with _Porites_ heads relatively common and up to 3 ft. (1 m) in diameter. The corals _Millepora exaesa_, _Leptastrea purpurea_, _Heliopora coerulea_, _Porites_ spp., _Pocillopora_ spp., _Acropora_ spp., plus representatives of several other genera are present. Although overall coral coverage is quite low, diversity is high. The amount of overturned material suggests that this area is disturbed regularly.

Some _Tridacna maxima_ are present but, in general, macroinvertebrates are not abundant. The echinoderms _Culcita novaeguineae_, _Echinothrix diadema_, and _Echinometra mathaei_ are present, and vermetid _Dendropoma maxima_ occurs on hard substratum. There are also scattered gastropods. However, the scattered coral outcrops do not offer enough protection from the strong currents and predatory fish for macroinvertebrates to be abundant. Algal mat dominates the area followed by an assortment of other algae including blue green algae and species in the genera _Hormothamnion_, _Lobophora_, _Neomeris_, _Peyssonelia_ and _Schizothrix_. A large patch of _Asparagopsis taxiformis_ lies on the reef flat northeast of the runway extension site.

Fish diversity is moderate throughout the runway extension area. Solitary predator species such as jacks and small sharks frequented the area during our investigation. Likewise, wrasses (labrids), damsel fishes (pomacentrids), and butterfly fishes (chaetodontids) darted between the isolated coral heads. Several favored food species of the Third Islanders were also observed, including groupers (Epinephelus hexagonatus) and surgeon fishes (Acanthurus olivaceus, Ctenochaetus strigosus).

Lagoon Reefs

The lagoon habitat on the eastern side of the planned runway extension area is a substantially different from the reef flat and the usual lagoon habitat. A depositional environment, the bottom is composed mostly of sand and gravel. However, there are large beds of Pocillopora eydouxi, some of which measure 33 ft. (10 m) across (3 were marked with rebar stakes). There are also small amounts of Pocillopora damicornis, Montipora digitata, Montipora verrilli, and Acropora sp. 1. Around the Pocillopora eydouxi heads there is Dendropoma maxima, two species of tunicates, large clusters of small sabellid polychaetes, Echinothrix diadema, and anemones (Heteractis gelam) with commensal clown fish (Amphiprion melanopus). A few individuals of Tridacna maxima are also present.

Algae are concentrated around the coral and do not occur on the sand. The species occurring between coral branches are: Microcoleus lyngbyaceus, Hormothamnion enteromorphoides, Codium arabicum, Dictyota friabilis, and Dictyota divaricata. Also present in scattered clumps are Schizothrix mexicana, Galaxaura, Gelidiopsis intricata, Hypnea esperi, and Boodlea composita.

The most outstanding component of the Pocillopora eydouxi beds is a huge anemone colony (Heteractis gelam) that clings to the branches of one colony. Associated with this are hundreds of commensal clown fish (Amphiprion melanopus) representing an assortment of growth stages. Also abundant along the perimeter of the stand are groupers (Epinephelus hexagonatus), several wrasses, and damsel fishes. A small green sea turtle (Chelonia mydas) was observed just outside of the survey area.

Piers and Seagrass Beds

The lagoon side of the island has been dredged for shipping access to the two piers. It is a depositional environment and, although there are cobbles in some area, consists mostly of sand and fine sediment. Typically, Halimeda is common in shallow water, but some sizable beds of the sea grass Halophila minor are also present. This is an interesting discovery because Thalassia hemprichii was the only sea grass previously known from the Marshall Islands (Tsuda et al., 1977). Halophila minor was also found in the lagoon at Kwajalein Island.

The cargo/fuel pier, located on a small peninsula, is currently being modified. Interlocking steel plates, similar to the ones on Yokohama Pier, were being emplaced to form external walls. The western side of this peninsula has rock and cobble that grades into sand in deeper water. Coral coverage is low and consists primarily of Montipora digitata patches. There are also tube forming callianassids, a few large anemones (Heteractis gelam), and Cypraea moneta. Crabs (Thalamita sp.) and shrimp occur under the rocks.

As water depth approaches 6-7 ft. (2 m), there are a few other coral species, including Pocillopora damicornis, Fungia fungites and Acropora horrida. The diversity and number of juvenile fish suggest that this area might be a nursery ground for chaetodontids, pomacentrids, labrids, and acanthurids. Symbiotic alpheid shrimp/goby burrows are common in the sand, and a few Lambis crocata were found. There are also some rock oysters near the pier. Several empty 55 gallon barrels are scattered throughout the area.

The substratum around the pier is sand and rubble and has no corals. There are infaunal enteropneusts, mollusks, and callianassids in the sand, with Halophila minor growing on the surface. A fouling assemblage of hydroids, sponges, limpets, and barnacles covers the I-beam legs and supports of the pier, but coverage is not thick or heavy. The sacrificial anodes on the legs appear to be protecting the metal from galvanic corrosion.

Juveniles dominate the fish assemblage in the fuel pier region. The only siting of *Heniochus chrysostomus* (banner-fish) on Roi-Namur occurred here. The blue-dot file fish (*Oxymonacanthus longirostris*) is associated closely with the piling coral heads, as are damsel fishes (pomacentrids) and butterfly fishes (chaetodontids). A lion fish (*Pterois volitans*) hovered closely to the pier pilings also.

The central area of the island between the two piers is largely sand and rubble. There are alternating large patches of *Halimeda* and *Halophila minor*, plus a few other algal species such as *Caulerpa serrulata*, *Microcoleus lyngbyaceus*, and *Padina tenuis*. The sand has a shallow anoxic layer. Coral coverage is low and consists of a few patches of *Montipora digitata*, *Acropora* sp. 1, small amounts of encrusting *Millepora* sp., and *Pocillopora damicornis*. *Holothuria atra* is abundant on the sand, many being smaller asexually produced fission products. Sediments become coarser near Yokohama Pier and the sea grass gets thicker. There are also larger numbers of *Holothuria atra*, with some yellow tunicates, enteropneusts, *Mitra* sp., and *Trochus niloticus* also occurring. A floating raft just west of Yokohama Pier is heavily fouled with anemones (*Aiptasia pulchella*), bryozoans, ascidians and hydroids. A noticeable temperature increase identifies the area around the power plant discharge.

The coral, sand, seagrass, and algae provide an assortment of fish habitats. Damsel fishes (*Dascyllus aruanus*, *Chromis viridis*, *Chrysiptera glauca*), goat fishes (mullids), and wrasses (labrids) are abundant throughout the coral zones. Isolated schools of rudder fish (kyphosids), jacks (carangids), and rabbit fishes (siganids) passed through the area while flat fish (*Bothus* sp.) appeared commonly on the sand flats. Coral heads interspersed amongst the seagrass beds served as a haven for juvenile damsel fishes (pomacentrids) and wrasses (labrids). Surgeon fishes (*Acanthurus triostegus*, *A. sordidus*) and rudder fish (*Kyphosus* sp.) congregated around the thermal outfall from the Roi-Namur Power Plant.

Yokohama Pier has interlocking steel plates (sheet piling) on top of a concrete base, forming a solid wall. Some corals have colonized the walls, but coverage is less than 1%. These consist primarily of *Pocillopora damicornis*, *Symphyllia* sp., *Lobophyllia* sp., *Montipora verrilli*, *Favia* sp., and *Fungia* spp. The non-coral macroinvertebrates consist of *Trochus niloticus*, two species of large tunicates (yellow and brown), hermit crabs (*Calcinus laevimanus*), limpets, boring bivalves (*Lithophaga*), barnacles and grapsid crabs (*Plagusia* sp.). Unidentified bait fish schools and juvenile fish were abundant around the pier. Holothurians are common around the pier and include the species *Bohadschia argus*, *B. vitiensis*, *Holothuria edulis*, *H. atra*, and one Thelenota ananas. There are also a few boring sea urchins (Echinostrephus aciculatus).

The Yokohama Pier fish assemblage is similar to that found at the fuel pier, with juveniles being abundant and diverse. Damsel fishes (pomacentrids) and wrasses (labrids) are dominant, with surgeon fishes (acanthurids) being slightly less abundant. Several species, including Lactoria cornuta (cow fish) and Stegastes sp. (damsel fish), were observed residing inside discarded metal containers and cans.

Juvenile fish are abundant around a sunken pontoon bridge that is located east of Yokohama Pier. There is also a warm water discharge upstream (East) from the bridge. The rocks in the vicinity of the discharge are covered by white fuzz that might represent bacterial production (there is a very large Holothuria atra population just downstream).

Interviews

Interviews with fishermen from Ennubirr Island (near Roi-Namur) revealed that one of the best fishing grounds is located on the reef flat southwest of the Roi-Namur runway. The fish assemblage is both abundant and diverse, with ten species harvested regularly, including the yellowtail parrot fish (kilkil), wrasses (mera), rabbit fish (muramor), goat fish (motal), and surgeon fish (bulak). A planned USAKA runway expansion project could have significant negative impact on this fishing ground.

Snapper (jato) and grouper (jawe) are frequently caught by Ennubirr fishermen along the lagoon reef terrace, while the northern tip of Roi-Namur provides a good stock of convict tang (kuban). Fishermen, however, also report that ciguatoxic fish occur off the northern tip of Roi-Namur.

The North Pass, located southwest of Roi-Namur Island, provides the closest ocean outlet for fishermen from both Roi-Namur and Ennubirr islands. Migratory pelagic species such as mahimahi (koko) and skipjack tuna (lejabil) are caught in this region. Wahoo (al) and barracuda (ni, tua or jujukop) are caught in great quantities along the ocean reef terrace.

i. Legan Island

Legan is a leeward island situated between the Ambo Channel and the South Ambo Channel (Fig. 14). It is L- or boot-shaped with most of the island covered by vegetation. The lagoon side of the island has been modified by dredging and filling. The "foot" or short arm of the island has been widened and lengthened to accommodate the USAKA facilities. A finger jetty has been built at the end to protect the marine ramp and pier, and the area has been dredged to accommodate boating traffic.

The ocean side of the island has been extensively modified by natural means. A 1967 aerial photograph (Global Associates, 1967) shows that Legan used to be dumb-bell shaped, with the ocean reef flat extending into the center of the island and leaving just a narrow band of land connecting the two rounded ends. The island currently has an almost perfectly straight ocean beach, with vegetation all along the shoreline. The straight ocean "berm" most likely formed during a storm and sealed off the center of the island. The center of the island now consists of a salt pond that supports a number of birds. Terrestrial hermit crabs (Coenobita sp.) are all around the pond's edges, as are blue-green algal mats, which also float on the water surface. The pond is roughly 33 X 190 ft. (30 X 175 m) in size.

Shoreline

The only rip rap on Legan protects the facilities at the end of the "foot." The rest of the island has natural cobble or sand beaches and berms. All sides of the island receive periodic high energy waves, as indicated by the sediment size and steepness of the beaches. However, the lagoon has some sandy beach, indicating a depositional environment. This is because there is a rather large offshore limestone bench that partially protects the island.

KWAJALEIN ATOLL COASTAL RESOURCE INVENTORY

BOTTOM TYPE AND SHORELINE CLASSIFICATION

(Based on field observations and aerial photograghic interpretation)

BOTTOM TYPE

Offshore

sc- sand bottom in water less than 10m.

sd- sand bottom in water depths greater than 10m.

Reef Complex

rcp- consolidated limestone with a smooth pavement-like surface.

rc- mixed bottom types consisting of reef rock (limestone) associated with shallow water formations.

co- areas of greater than 50% live coral cover.

rcg- consolidated reef with well defined spur-and-groove system.

SHORELINE

rr- rip rap shoreline.

sb- white sand beach of predominately calcareous material.

bc- concrete/cement masonry seawall and shoreline.

sbc- calcareous rubble and/or shingle beach.

br- beach rock, usually exposed along the shoreline.

VEGETATION

Halimeda/ seagrass beds

FIELD STATION

[K] KMRI Station

OTHER SYMBOLS

dredge site

observed range

quarry area

island area

[H] helicopter pad

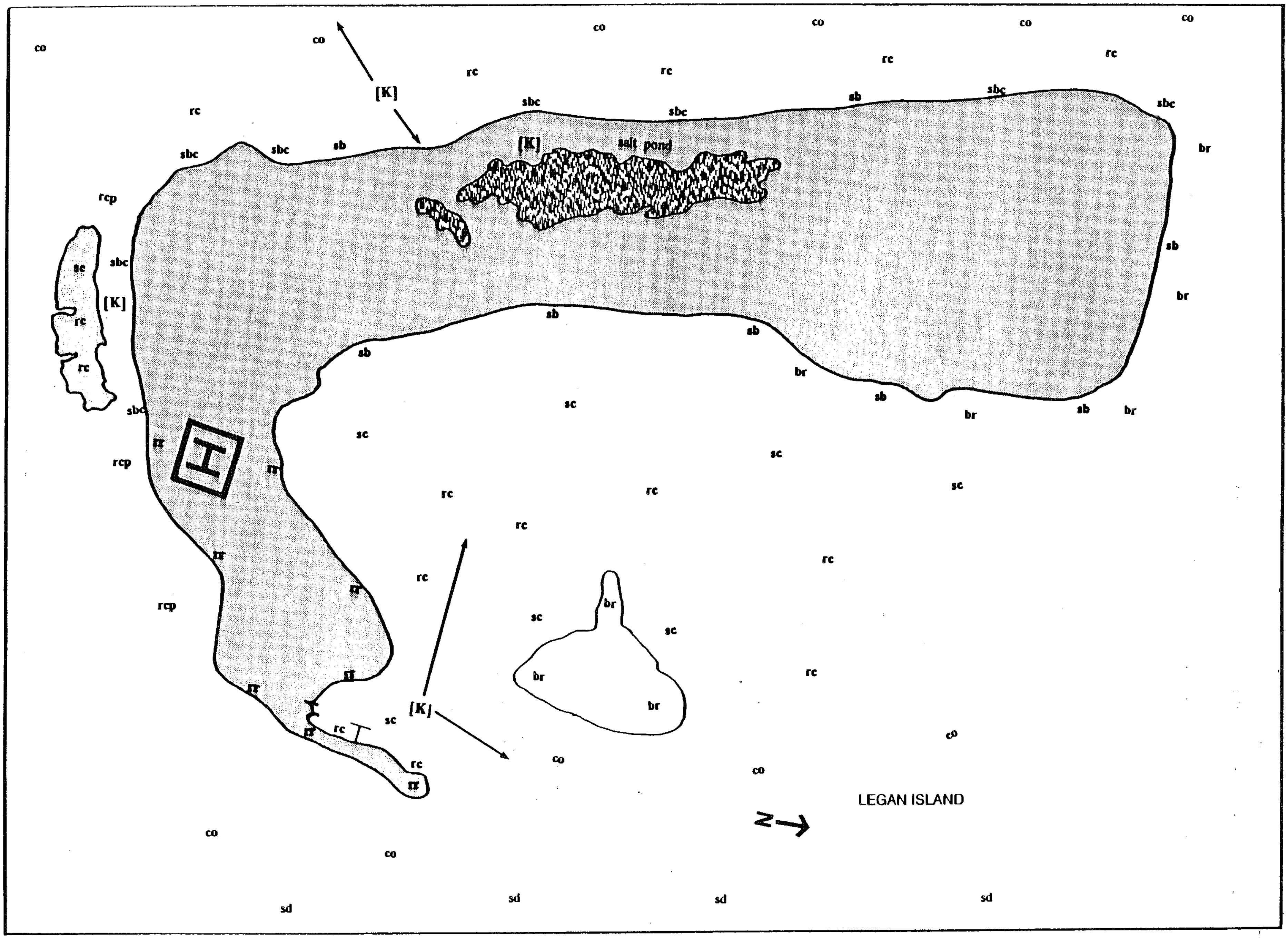


Figure 14. Thematic map showing the shoreline features and marine environment of Legan Island, Kwajalein Atoll, RMI

The south and west (ocean) sides of the island have steep cobble beaches. The south end has a 100 ft. (30 m) sloping platform that goes to a depth of 15 ft. (4.5 m). The bottom then drops more rapidly onto sand flats. The ocean side of the island has a sloping platform that extends 295-328 ft. (90-100 m) and has a depth of 7-10 ft. (2-3 m). The substratum is primarily boulders and large cobbles with pockets of sand. Although scoured, it has a coating of fine algal mat and some Galaxaura sp. The vermetid Dendropoma maxima is abundant on larger cobbles, as is a black colonial ascidian. Micromollusks are common under rocks, and crabs are abundant under rocks within 65 ft. (20 m) of shore. One holothurian (Actinopyga mauritiana) was found under a rock. Fish are quite abundant, especially grazers such as acanthurids. Corals are sparse and consist mostly of Acropora spp. and Montipora spp.

Grapsus tenuicrustatus is common along the ocean shoreline, and porcellanid and xanthid crabs are abundant under cobbles and boulders found along the limestone bench at the base of the cobble beach. A shallow moat in the bench, about 33-50 ft. (10-15 m) long and 10 ft. (3 m) wide, parallels the coastline at the southern end. It contains the corals Montipora digitata, Acropora sp. 1, and Porites lutea. The limestone bench and cobble beach extend around the northern end of the island and about 1/3 of the distance down the lagoon side until it grades into a sand beach. The sand beach results from being in the wave shadow of the offshore raised limestone bench, and extends to the "foot" of the island.

Harbor and Jetties

Despite the protection afforded by the finger jetty, a large swell was entering the harbor during the study. Waves come from two directions: the open lagoon and the channel between the island and the raised limestone bench. As a result, water motion was confused in the harbor.

Biota varied in the harbor according to locality and exposure. At the base of the finger jetty, coral coverage is low (1%) and consists of Acropora sp. 1, A. sp. 2, Pocillopora damicornis, and P. meandrina. The I-beam supports of the pier do not have zinc anodes and support colonies of Pocillopora spp., Favia sp., and Pavona varians. Diversity and abundance of coral increase to about 10% coverage further out on the finger, with the highest coverage being at the base. The additional species found were Acropora humilis, Pocillopora verrucosa, A. vaughani, A. irregularis, A. palifera, encrusting Acropora, Fungia spp., Montipora spp., Millepora exaesa, and Euphyllia glabrescens. The dredged harbor bottom is almost barren of macrobiota.

The harbor walls have colonies of the didemnid ascidian Eudistoma sp. and a predatory nudibranch feeding on it (Nembrotha sp.). Vermetids (Dendropoma maxima) are common and barnacles encrust the pier supports and the splash zone of the rip rap. Sinularia polydactyla, Lithophaga, and Trochus niloticus occur in deeper water on carbonate, and one Heteractis ritteri was found on the sand at the harbor mouth.

Algae are abundant in the harbor. The rocks and boat ramp are covered by Entophysalis sp. and some Ralfsia occidentalis. Halimeda opuntia is common on the jetty wall, as are a few other algae such as Hormothamnion enteromorphoides, Dictyota divaricata, and Schizothrix calcicola.

Fish diversity is moderate to high within the harbor. Small wrasses (Thalassoma quinquevittatum, Halichoeres hortulanus), territorial damsel fishes (Stegastes nigricans), butterfly fishes (Chaetodon citrinellus), and pipe fish (Corythoichthys intestinalis) compose the major ichthyofauna colonizing the harbor walls. Several jacks cruised through the region (Caranx melampygus, Trachinotus blochii).

The bench outside the harbor has a well developed coral reef assemblage and is aesthetically pleasing. Although coral coverage is only 20-30%, it is quite diverse. There are table corals (Acropora cytherea) as well as several high energy species such as Pocillopora eydouxi, P. meandrina, P. verrucosa, A. humilis, lobate Porites, Montipora sp., Platygyra sp., and others. Macroinvertebrate abundance and diversity is also higher on the outside bench. Along with more Sinularia polydactyla, there is _Sarcophyton_ sp., _Tridacna_ sp., _Actinopyga mauritiana_, _Echinothrix diadema_, and _Acanthaster planci_. An unidentified black sponge encrusts the bench substratum.

Indications are that algal production is high on the bench outside the harbor. All hard substrata is heavily grazed by algivorous fish, resulting in very little visible algae. _Codium arabicum_, _Dictyota friabilis_, and an algal mat were found under or between corals. There are also small amounts of _Boodlea composita_, _Caulerpa serrulata_, _Gelidiopsis intricata_, and _Microcoleus lyngbyaceus_. _Padina_ is abundant in the harbor entrance.

Along the outside bench the fish diversity is low, but increases tremendously along the benches perimeter and onto the lagoon terrace. Small pinnacles become prominent features and suitable habitats for squirrel fishes (holocentrids) and some groupers (_Cephalopholis argus_, _Variola louti_). Elsewhere, surgeon fish are abundant (_Acanthurus nigroris_, _A. lineatus_, _A. pyroferus_) as well as butterfly fishes (chaetodontids), damsel fishes (pomacentrids), wrasses (labrids) and rabbit fishes (siganids).

The survey team had only a brief look at a very interesting coral assemblage near the harbor between the raised limestone bench and the island. The substratum is primarily sand, but it supports staghorn and table corals (_Acropora_ spp.) and foliaceous plate corals. The algae _Turbinaria ornata_ is also abundant. The fish assemblage of this protected environment is similar to the harbor region. The only sitting of the black polka dot yellow box fish (_Ostracion cubicus_) occurred here.

Quarry

The Legan quarry is located by the "heel" of the island at the southwest end. There appears to be a lot of wave energy at all times. The quarry is irregular in shape with approximate dimensions of 66 X 165 ft. (20 X 50 m). Some of the quarried rock was left on the bench, and cobble and boulders cover the quarry's bottom.

There is generally low faunal coverage in the quarry, but relatively high diversity. Much of the biota are high energy species. The overall coral coverage is less than 1%, but localized areas have 5-10% coverage. There are several _Acropora_ spp., _Pocillopora eydouxi_, _P_. _meandrina_, _Pavona varians_, _Porites_ spp., _Montipora_, _Millepora exaesa_, _Leptastrea purpurea_, _Astreopora_, and a few other species. The diversity is quite high for a small quarry with low coral coverage.

The quarry is unusual because it has high densities of a black didemnid ascidian (_Eudistoma_ sp.) that is also found in other localities around the island. As in the other localities, it was being grazed on by the nudibranch _Nembrotha_ sp. Other invertebrates found include the mollusks Dendropoma maxima (abundant), Tectus pyramis, Turbo argyrostomus, Cerithium nodulosum, Trochus ochroleucus, and Trochus niloticus. The tridacnid clams Hippopus hippopus, Tridacna squamosa, and T. maxima were each represented by one specimen. Sinularia spp., Lobophytum sp., Echinothrix sp., Dardanus sp., Echinaster sp., Echinostrephus, hydroids, and Physalia physalis also occur.

Algal production is relatively high in the quarry. There is an algal mat on the rocks, along with Chaetomorpha sp., Acetabularia moebii, and Neomeris annulata. Lobophora variegata occurs in rubble and Codium arabicum and C. edule were present but had been overgrown by the didemnid ascidian. Other algae found include Porolithon onkodes, Caulerpa spp., Dictyota spp., Schizothrix calcicola, Hormothamnion enteromorphoides, and Asparagopsis taxiformis.

The fish assemblage is diverse and fairly abundant despite the quarry's small size. Surgeon fishes (Acanthurus guttatus, A. olivaceus, A. triostegus) commonly occur along the quarry's ocean walls. Butterfly fish (Chaetodon citrinellus, C. reticulatus) frequently associate themselves with small coral patches. Furthermore, the only occurrence of C. meyeri documented in this survey occurred here. Several dragon wrasses (Novaculichthys taeniourus) dove in and out of the sand bottom, with other wrasses (Thalassoma quinquevittatum, Stethojulis bandanensis, Halichoeres hortulanus, and H. margaritaceus) also being abundant. A small blacktip shark (Carcharhinus melanopterus) patrolled the quarry.

Interviews

Legan is also located on the leeward atoll rim. While no fishing was reported, coconut crabs (baruleb) are harvested on the island.

j. Illeginni Island

Illeginni (Fig. 15) is a mid-atoll leeward island and, like Legan, it is L- or boot-shaped. It lies on a section of reef flat that stretches approximately 6 miles (9.5 km) between Onemak West Passage and Wojejairok Pass. The "foot" of the island is adjacent to the Onemak West Passage.

Illeginni lies closer to the ocean and, therefore, the lagoon reef flat is approximately twice the width of the ocean reef flat. During low tide, beach rock is commonly exposed along the ocean side and the eastern end fronting the channel.

Marine impacts on Illeginni consist primarily of a one acre landfill site on the seaward reef flat, and a rather large lagoon boat harbor and channel that were dredged in 1970. Mission-related activities are currently at a very low level and much of the facility appears "deserted;" therefore, current impacts are very slight. However, there is litter and abandoned debris everywhere, including the reef flat. This will eventually end up in the ocean if it is not cleaned up.

Shoreline and Shallow Reefs

The coastline of Illeginni consists primarily of a 33 ft. (10 m) wide beach composed of gravel and cobble, with scattered areas of exposed beach rock. Few areas have what is considered a sand beach. Rip rap occurs at two localities: at the harbor and at the "heel" of the island.

The ocean reef flat is a shallow bench with accumulated rock and a lot of discarded debris that varies in size from copper wire to parts of buildings. The bench has a few shallow tide pools, some of which have corals and Holothuria atra. The reef flat gradually slopes seaward to an area of ridges and sand filled canyons, at which point water depth increases rapidly.

Except for the shallow tide pools, corals are not present in the shallow breaker zone. The corals Acropora sp. 1 and A. sp. 2 begin about 65-100 ft. (20-30 m) from shore, as do Pocillopora verrucosa and encrusting Montipora. At a depth of 13 ft. (4 m) the coral diversity increases greatly, including the species Millepora tenera, Acropora humilis, Favia spp., Pavona clavus, Millepora platyphylla, Alveopora. Water clarity was very good about 328 ft. (100 m) from shore in the area of the ridges and

KWAJALEIN ATOLL COASTAL RESOURCE INVENTORY

BOTTOM TYPE AND SHORELINE CLASSIFICATION

(Based on field observations and aerial photograghic interpretation)

BOTTOM TYPE

Offshore
sc- sand bottom in water less than 10m.
sd- sand bottom in water depths greater than 10m.

Reef Complex
rcp- consolidated limestone with a smooth pavement-like surface.
rc- mixed bottom types consisting of reef rock (limestone) associated with shallow water formations.
co- areas of greater than 50% live coral cover.
rcg- consolidated reef with well defined spur-and-groove system.

SHORELINE

rr- rip rap shoreline.
sb- white sand beach of predominately calcareous material.
bc- concrete/cement masonry seawall and shoreline.
sbc- calcareous rubble and/or shingle beach.
br- beach rock, usually exposed along the shoreline.

VEGETATION

Halimeda/seagrass beds

FIELD STATION

[K] KMRI Station

OTHER SYMBOLS

dredge site
observed range
quarry area
island area
[H] helicopter pad

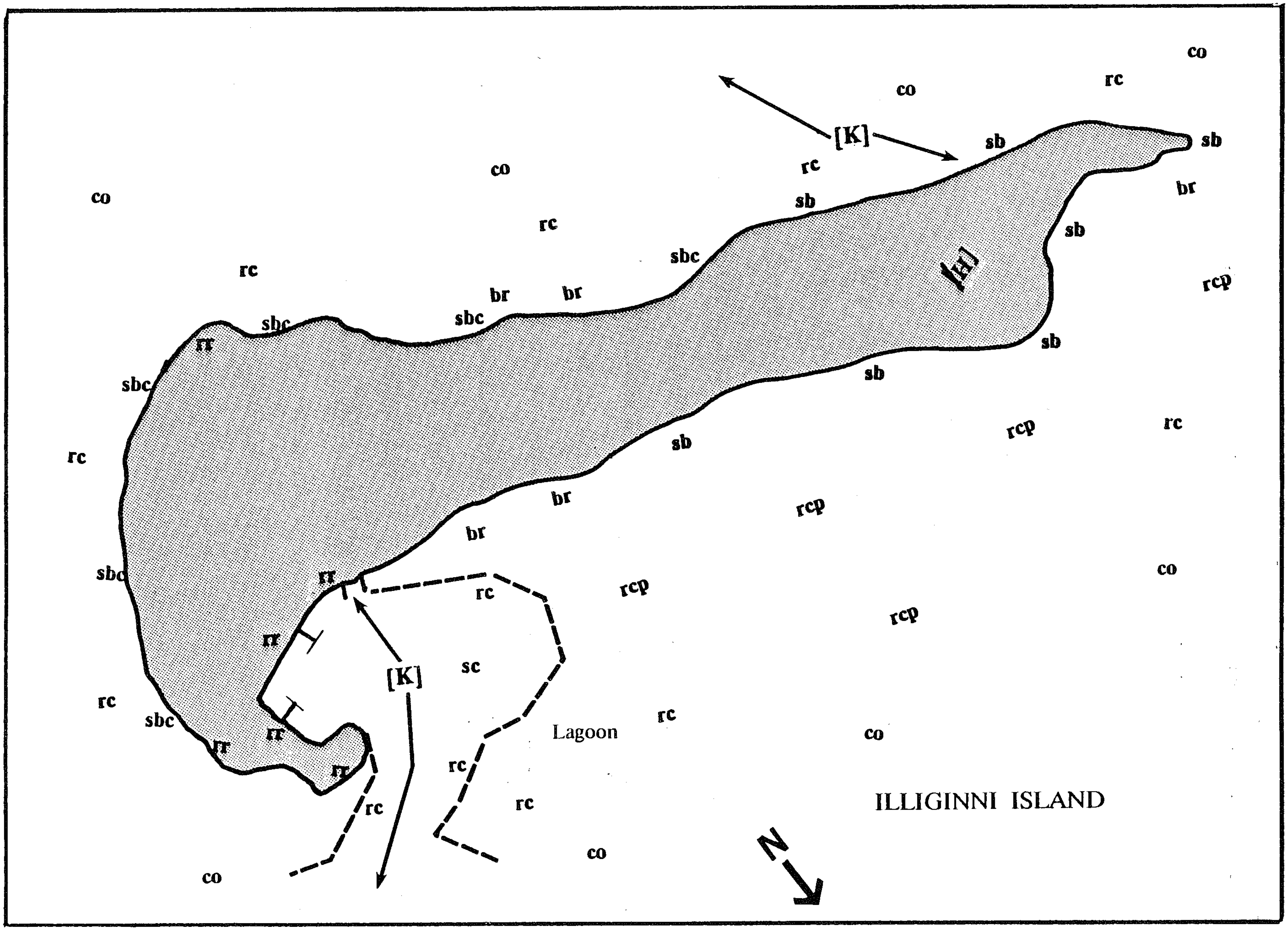


Figure 15. Thematic map showing the shoreline features and marine environment of Illeginni Island, Kwajalein Atoll, RMI.

canyons. Water depth is about 100 ft. (30 m) and coral coverage (50-80%) is high on the ridges. This area has a very striking appearance because about half of the coral coverage is by Alveopora sp., which is quite an unusual phenomenon. Also sighted were Pocillopora eydouxi, lobate Porites, several species of table corals (Acropora spp.), Fungia fungites, and Acropora vaughani.

Macroinvertebrates are also more abundant as water deepens and consist of the cnidarians Palythoa tuberculosa, Sinularia polydactyla, Sarcophyton glaucum, Macrorhynchus sp., and Aglaophenia sp. There are also a few Tridacna maxima, and some Dendropoma maxima, barnacles, Lithophaga zittelliana, and colonial didemnids. The algae are heavily grazed by the abundant and diverse fish assemblage and are therefore more common in holes and between corals. These algae species include Codium arabicum, Sphacelaria sp., Schizothrix mexicana, Jania capillacea, Caulerpa serrulata, Halimeda opuntia, Ralfsia occidentalis, and Asparagopsis taxiformis.

Different fish assemblages occur on the two distinct habitats. Species on the nearshore shallow wave-sweep platform include Acanthurus nigricans (surgeon fish), Rhinecanthus aculeatus (trigger fish), and small Stegastes spp. (damsel fishes). Further seaward, where lush ridges and canyons occur, fish diversity and abundance increase tremendously. Small species including wrasses (labrids), damsel fishes (pomacentrids), angel fishes (pomacanthids), butterfly fishes (chaetodontids), and goat fishes (mullids) are abundant, although inconspicuous in the lush coral. Larger, solitary species frequently hover in the water column (emperors, groupers, parrot fishes, snappers, and jacks). Also observed in this lush environment were four species of sharks including a whitetip, blacktip, gray (Carcharhinus albimarginatus) and silver (C. amblyrhynchos).

Harbor and Channel

Illeginni has a large dredged harbor that contains fuel and personnel piers, and a marine ramp. Because of its size and shape, species abundance and diversity vary according to water circulation and exposure to waves and swell. The fuel pier is at the base of the harbor and has the least biotal development. Small amounts of the corals Acropora spp., Pocillopora meandrina, and a few other species occur on the revetment and pier, but abundance and diversity are comparatively low. These increase in abundance toward the personnel pier where there is more water motion. There are coral thickets of Acropora and Montipora digitata on the harbor bottom (about 2% coverage). Several additional species occur on the personnel pier and adjacent revetment, including Fungia fungites, Astreopora sp., Goniastrea retiformis, Millepora exaesa, Pocillopora verrucosa, P. damicornis, P. elegans, Stylophora sp., Favia spp., and small amounts of lobate Porites. Pocillopora eydouxi and Alveopora sp. occur near the harbor mouth where water motion is highest.

Across the harbor channel there is a rich assemblage of coral along the dredged reef face. This is a high wave energy assemblage with 20-30% coral coverage that includes many of the same species that occur on the other side of the harbor. There is a rich section along the curve in the harbor that has 50-60% coral coverage.

The harbor has a typical epifauna growing on the hard substratum, consisting of Dendropoma maxima, Lithophaga zittelliana, Trochus niloticus, and a few other species. Additional fouling organisms occur on the piers, including sponges, hydroids, ascidians, and pearl oysters (Pinctada margaritifera). In addition to the coral thickets on the harbor bottom, there are callianassids and goby/alpheid shrimp burrows but, surprisingly, no holothurians.

Algae are not abundant in the harbor due to grazing by fish. The species present are common around the island and include representatives from the genera Schizothrix, Neomeris, Microcoleus, Caulerpa, Hormothamnion, and Halimeda. Some places have a fairly thick mat of Dictyota divaricata on the rocks.

The fish assemblage populating the harbor area typifies the nearshore Kwajalein atoll environment. Surgeon fishes (Acanthurus guttatus, A. mata) are numerous along the rip rap surge zone, while damsel fish (Plectroglyphidodon dickii and Stegastes sp.) dart among the coral thickets. Large parrot fishes and small groupers (Cephalopholis urodelus) inhabit the harbor wall area. The juvenile orange color phase of Acanthurus mata is especially abundant.

Interviews

Illeginni Island, located on the leeward atoll rim, is bordered by Onemak West Passage at its southern end. Ebeye fishermen frequently fish the passage area and report catching white lined cob (letjebjeb) and groupers (olalo, joanuron or jowame). Blue marlin is occasionally caught outside the Passage by Kwajalein fishermen. Mullet (iiol) occur along the lagoon reef flat margin and terrace at Illeginni and nearby Onemak Island.

k. Gugeegue Island

Gugeegue (Fig. 16) is a windward island to the north of Ebeye and is close to the Bigej Channel. Previously a USAKA leased island, it is now inhabited by a small group of Marshallese fishermen. Gugeegue will be part of the proposed RMI

KWAJALEIN ATOLL COASTAL RESOURCE INVENTORY

BOTTOM TYPE AND SHORELINE CLASSIFICATION

(Based on field observations and aerial photograghic interpretation)

BOTTOM TYPE

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sc- sand bottom in water less than 10m.
sd- sand bottom in water depths greater than 10m.

<u>Reef Complex</u>

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rc- mixed bottom types consisting of reef rock (limestone) associated with shallow water formations.
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SHORELINE

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sb- white sand beach of predominately calcareous material.
bc- concrete/cement masonry seawall and shoreline.
sbc- calcareous rubble and/or shingle beach.
br- beach rock, usually exposed along the shoreline.

VEGETATION

Halimeda/ seagrass beds

FIELD STATION

[K] KMRI Station

OTHER SYMBOLS

dredge site
observed range
quarry area
island area
[H] helicopter pad

Kwajalein Atoll Causeway Project that will go from Ebeye in the south to Ninge (COE, 1985).

Although Gugeegue is no longer leased by USAKA, the field team made a short visit to investigate the quarries and to assess reported storm damage from waves generated by Tropical Storm Roy. RMI officials told us that two large buildings had been moved from their foundations by the storm.

Storm Damage

Two long, single story apartment buildings had been built on Gugeegue by RMI with the intention of relocating some Marshallese from the extremely crowded conditions on Ebeye. These structures were mounted on cement foundations located parallel to the reef flat and about 165-200 ft. (50-60 m) from the beach. Storm waves generated by Tropical Storm Roy had lifted them from their foundations, moving one building about 100 ft. (30 m) and the other about 200 ft. (60 m) toward the center of the island. Remarkably, the buildings showed little external damage.

Trees had been uprooted by the storm and some relatively large rocks had been washed onto the island (at least 1/3 the width of the island from the beach). The northern quarter of the island had drift deposits of pumice in the middle of the island

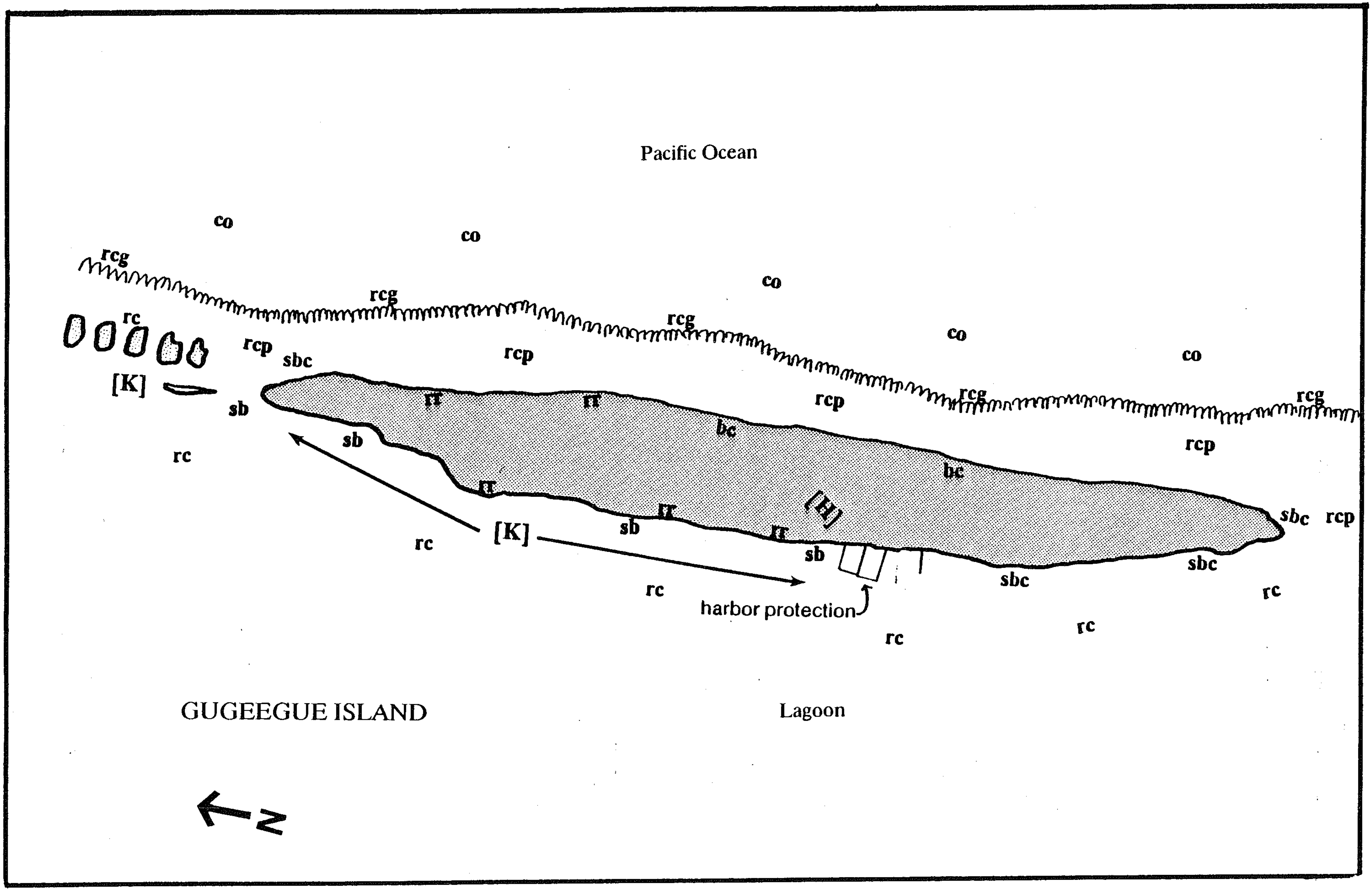

Figure 16. Thematic map showing the shoreline features and marine environment of Gugeegue Island, Kwajalein Atoll, RMI.

and erosional channels indicating that waves had crossed the island in several places.

The island had obviously been struck by relatively large storm generated waves. However, with the exception of a few uprooted trees and some rock, the island and biota showed few effects. The most striking impact was to the RMI housing project. However, the older USAKA facilities, which had been protected by rip rap and retaining walls, showed no adverse effects.

Quarries

Gugeegue has a series of five small, shallow quarries. They are 65-100 ft. (20-30 m) wide, about 130 ft. (40 m) long, and have a maximum depth of 3-5 ft. (1-1.5 m). The most northern quarry is smaller, with a length of about 80 ft. (25 m). We had hoped that the quarries' location on the interisland reef flat would allow us to make a comparison of biota between quarries dredged on interisland reef flats to those dredged in front of islands (the majority of quarries studied). Unfortunately, the low biotic development in Gugeegue's quarries is a result of their small size and large distance from the reef edge rather than their location on the interisland reef flat. Therefore, an accurate comparison between other quarries located on Kwajalein atoll's fringing reef flat could not be made.

The quarries are filled with fine sediments and have poor coral reef development. The dominant coral in the quarries is Montipora digitata and forms thickets along the edges and the back (lagoonward) side of the pools. With the exception of the thickets, coral coverage is extremely low. There are small amounts of the corals Porites lutea, Acropora sp. 1, A. humilis, Pocillopora eydouxi, Millepora exaesa, Pavona clavus, P. varians, and Hydnophora microconos.

Most of the macroinvertebrates are along the edges of the quarries. Holothurians are the most abundant group, and are indicator species of the abundant fine sediments. Nine species were found with Holothuria atra being the most abundant. However, several other species were common including H. leucospilota, H. nobilis, H. hilla, H. pervicax, Synapta maculata, Actinopyga mauritiana, and A. echinites. One specimen of Bohadschia argus was sighted.

The sea urchin Echinothrix diadema is common along the edges of the quarries and a few Diadema savignyi were sighted. Hermit crabs (Calcinus spp.) are common under and around rocks. Snails include Conus spp, Dendropoma maxima, Turbo argyrostomus, Cypraea spp, and Cymatium muricinum. Live bivalves include Isognomon perna and Modiolus vagina, but some empty shells (Modiolus auriculatus, Periglypta reticulata, and Pinna muricata) were also found.

All of the quarries have a similar algal assemblage. Diatom films, *Boodlea composita*, and *Dictyota bartayresii* are common, with some *Dictyota friabilis*, *Schizothrix calcicola*, *S. mexicana*, and *Padina tenuis* also being present. The shallow end of quarry four (counting toward the north) has some *Caulerpa sertularioides*.

Similar fish assemblages reside in all of the quarries due to their uniform size, shape, depth, and coral assemblages. Most of the fish congregate amongst the fingers of the *Montipora digitata* and near small rock outcrops along each quarry's perimeter. Despite a low species diversity, several wrasses (labrids), damsel fishes (pomacentrids), and butterfly fishes (chaetodontids) were commonly observed. Unlike other quarries surveyed, *Acanthurus triostegus* (convict tang) was the only surgeon fish present. Additionally, a pair of *Chaetodon rafflesi* butterfly fish marked the only sighting of this species during the survey.

Interviews

Gugeegue lies just north of Ebeye and Kwajalein islands on the atoll's windward side just south of Bigej Channel. Its proximity to two major population centers and a major channel make the surrounding waters a targeted fishing area. A variety of fish are caught along the lagoon terrace including squirrel fish (mon), snapper (jetar), pompano (ettiu-tou), jacks (manol) and grouper (joanuron). In addition to facilitating access to the rich pelagic fishing grounds, the channel has a plentiful fauna and is fished regularly for snapper (riuing), mahimahi (koko), barracuda (ni), and skipjack tuna (lejabil). Blue marlin is caught in the area outside Bigej Channel and Gugeegue.

Gugeegue is slated to be the northernmost island linked by a causeway to alleviate Ebeye's existing crowded conditions. Consequently, the adjacent reef areas will be subjected to increasing fishing pressure. Furthermore, the causeway will require substantial reef flat filling and dredging, which could have a significant negative environmental impact on the area unless numerous bridges and culverts are incorporated into the project. Another result of the causeway will be to allow Marshallese fishermen to exploit underutilized areas to the north.

IV. DISCUSSION

Among the objectives for this environmental study are the assessment of potential impacts of future activities within the survey area and the identification of options to minimize impacts to the marine environment. These objectives are addressed through an island by island discussion of proposed USAKA projects, and by discussion of specific topics of importance.

A. ISLAND BY ISLAND ANALYSIS

The following reflects an analysis of the proposed USAKA projects that will directly or indirectly effect coastal and nearshore marine environments. The proposed projects are from the most recent USAKA facilities planning document (Belt Collins & Associates, 1987). Though not mentioned in this document, there are also plans for extensive quarrying operations at Kwajalein and Roi-Namur islands.

Individual coastal projects that will cause marine impacts are reviewed separately by island. Each project's scope is briefly outlined followed by a description of potential impacts and recommendations for mitigating alternatives. Understandably, some of these alternatives may not be feasible because they impair USAKA mission requirements and/or are uneconomical. Their inclusion, however, represents the full range of alternatives available for consideration.

1. Roi-Namur Island

Project: Extension of the Dryess Army Airfield Runway

The paramount coastal impact occurring on Roi-Namur is the proposed lengthening of the Dryess Army Airfield runway from 4500 ft. (1372 m) to a minimum of 6000 ft. (1828 m), to allow use by large aircraft such as C-5s or C-141s. The proposed 1500 ft. (457 m) extension would be oriented in a southwesterly direction requiring landfill on the interisland reef flat between Roi-Namur and Ennuebing islands (Fig. 17).

Potential Marine Environmental Impacts

The proposed reef runway extension will have significant impacts on the marine environment and the lifestyle of nearby residents. Survey data indicate that this area has the highest diversity of coral and fish species observed in shallow water adjacent to Roi-Namur Island. Although overall coral coverage is less than 1%, it's as high as 5% on hard substratum. Tridacnid clams also occur and there is a large patch of the red alga *Asparagopsis taxiformis*, which is eaten by some non-Marshallese Pacific islanders, located just northwest of the proposed runway extension. The required fill operation will, therefore, impact

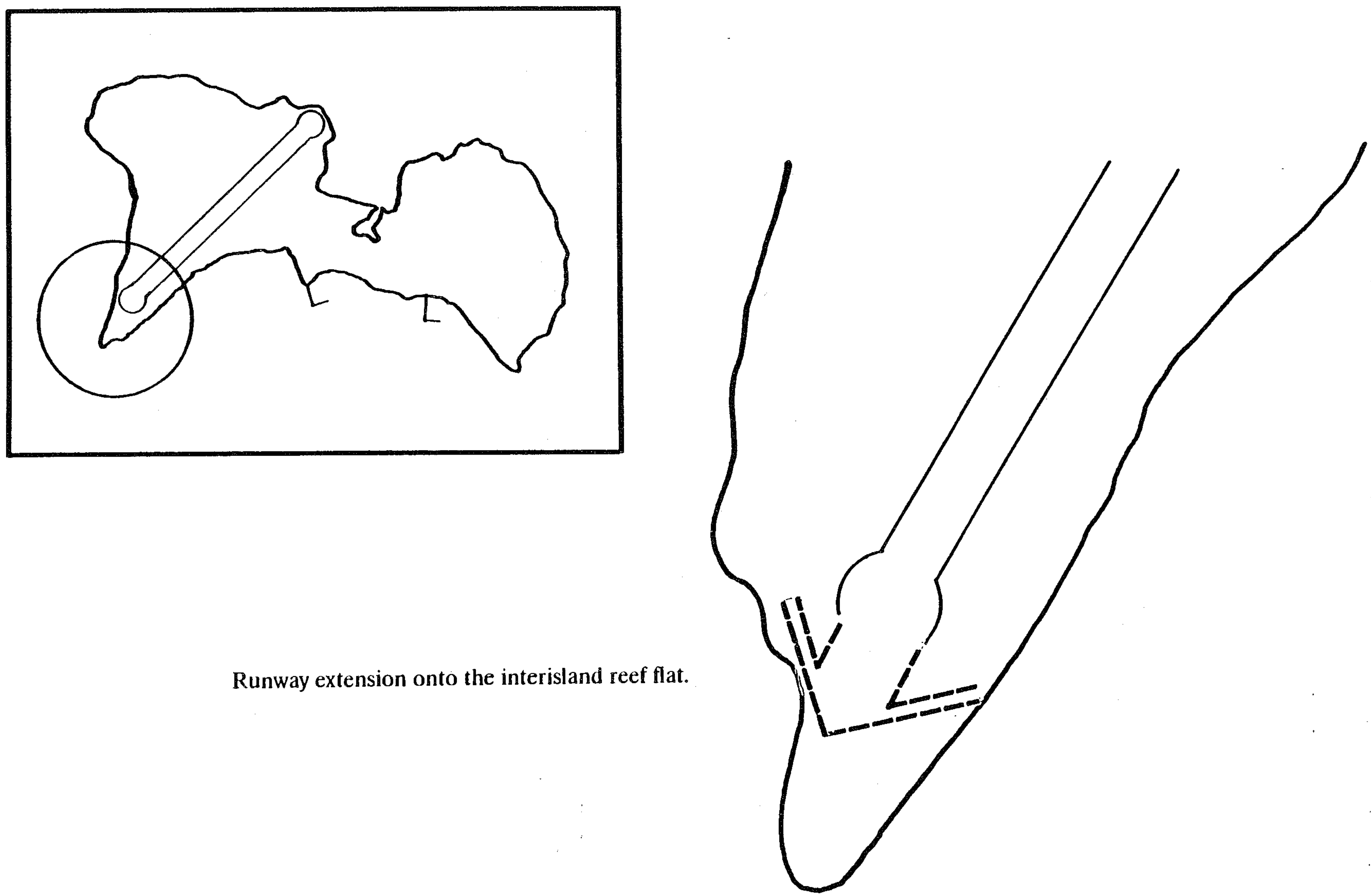

Figure 17. Locational map of the proposed Dryess Airfield runway extension project scheduled for Roi-Namur Island, Kwajalein Atoll, RMI (Belt Collins & Associates, 1987).

parts of the only developed shallow reef surrounding Roi-Namur Island.

The runway extension will also cause the loss of valuable fisheries habitat. The Marshallese interviewed on Ennubirr (Third Island) reported that this locality has the best fishing in the area. Fish are both abundant and diverse, and the population consists of ten target species rather than the approximately five species found in most locations.

Options

(1) One option is to not build the runway extension. This would preserve the only shallow high diversity coral reef community surrounding Roi-Namur Island and the most productive fishing habitat available to Third Islanders. This option could, however, impair the mission requirements of USAKA.

(2) As a second option, the runway extension could be partially built in the opposite direction so that it extends out onto the ocean reef flat to the northeast. This would cause less of an environmental impact because the reef flat is a simpler habitat that is more resilient to disturbance. Roughly 650 ft. (200 m) of ocean reef flat is available for a part of the runway extension and the balance could be built at the

currently proposed site. This has the advantage of part of the extension being built adjacent to the armor stone quarries. A possible disadvantage, however, is that the portion of the runway on the ocean reef flat would be more exposed to ocean and storm swells. The additional cost of building at both ends of the runway would also have to be weighed against the reduction in habitat disturbance and loss.

(3) The final option is to complete the runway extension as proposed. However, the following mitigative actions should be implemented.

a. Tridacnid clams should be relocated to alternate sites such as a quarries or areas with similar environmental conditions.

b. Before the filling operation begins, the intended fill area should be closed off with rip-rap and filter cloth starting at the lagoon side. The fill will then be contained within an essentially enclosed basin so relatively small amounts of sediment will escape and impact the adjacent coral reef areas.

c. Fill material should be supplied from other noncritical atoll habitats and be transported to the fill locations by boat and truck. The adjacent lagoon and reef slope must not be dredged for this purpose, nor should fill material be barged directly to this locality. Both of these activities would have severe environmental impacts.

d. During dredging and filling operations, the impact of the sediment plume on adjacent reef areas should be monitored. However, strong currents through this area should facilitate the flushing action by transporting the suspended sediment into the lagoon.

Project: Cargo/Fuel Pier

Pending the outcome of structural testing of the cargo/fuel pier, either strengthening or replacement of the pier will be recommended and implemented. During the field investigations, the shoreline adjacent to the pier already was being strengthened with interlocking metal plates (sheet piling), followed by back filling with concrete.

Potential Marine Environmental Impacts

The lagoon habitat adjacent to the pier is primarily sand and algae, and should only be temporarily affected by sediment laden waters during construction. The strengthening or replacement of the pier should, therefore, only affect the immediate area.

There is a considerable amount of discarded debris around and under the pier. The area should be cleaned up when work is completed for safety and to improve aesthetics.

Project: Secondary Sewage Treatment Plant

A secondary sewage treatment plant was requested to stop the current practice of discharging untreated wastewater into the Roi-Namur lagoon (Belt Collins & Associates, 1987). The proposed new sewage treatment plant (STP) would accommodate increased domestic sewage load which is expected to increase to 70,000 gpd (gallons per day) by FY90 from the current 30,000-35,000 gpd. However, the existing sewage facility was judged to be adequate (Belt Collins & Associates, 1987). Currently USAKA is exploring the option of reducing treatment levels from secondary to primary or advanced primary. A decision has not been made to delete the STP and it will be built with some level of treatment based upon the results of further analysis and the nature of approvals from the US Environmental Protection Agency (EPA) and the RMI EPA.

Potential Marine Environmental Impacts

Periodic water quality testing should be conducted to monitor this lagoon discharge of untreated wastewater for elevated fecal-coliform counts. This could assist in the analysis of the appropriate level of treatment needed. Although no negative environmental impacts were noted during the field study, the anticipated increase in wastewater discharge make this necessary to be sure that wastewater discharges into the lagoon do not result in significant ecological or public health impacts. USAKA is required to monitor outfalls according to their permit.

2. Omelek Island

Project : Omelek Island Pier

An engineering study has been recommended to develop alternative designs for the Omelek pier. This is intended to facilitate safer boat access and to prevent vessels from swinging on the pilings during mooring, which has caused damage to the pier.

Potential Marine Environmental Impacts

Omelek's lagoon reef flat is subjected to high wave energy resulting in a scoured bench with a reduced biota. Design modifications to the pier should, therefore, have minimal effect on the surrounding marine environment. Our present understanding is that only the pier is to be modified. However, should it be determined that the southern jetty will have to be modified to provide more protection to the pier, there could be significant impact to the lush coral reef biota that has developed on the protected side of the jetty. In this case, a further environmental assessment should be carried out and appropriate mitigation measures developed.

3. Gellinam Island

Project: Maintenance dredging near the Gellinam pier

Maintenance dredging near the Gellinam pier has been recommended to take place during the FY88 to improve access and berthing in the harbor area.

Potential Marine Environmental Impacts

As with other dredging projects, there will be a short term effect on the already disturbed soft substratum of the harbor floor. Likewise, the sediment laden water will have only a temporary impact on the adjacent lagoon habitat. The primary impact will be to the lush and diverse coral assemblage blanketing the rip rap of both sides of the inner harbor walls and the fields of staghorn coral located on sand flats at the harbor mouth. Care should be exercised during dredging to impact these areas as little as possible. Silt curtains would offer some protection by separating the coral assemblages from the dredged areas. Gagan Island has the only other USAKA harbor with similar marine flora and fauna development. Any future dredging in either Gellinam or Gagan harbor should be conducted in a manner that will minimize degradation of these unique assemblages.

4. Legan Island

Project: Maintenance dredging at Legan harbor

As with Gellinam Island, maintenance dredging is scheduled for the Legan harbor/pier area to improve access and berthing.

Potential Marine Environmental Impacts

The proposed dredging will cause short term effects on the already disturbed soft substratum of the harbor floor. The sediment suspended in the water column during dredging should have only a temporary impact on most of the surrounding lagoon habitat. However, a unique channel environment, protected by an emerged beach rock platform, lies adjacent to the harbor. Patch reefs of staghorn, table, and lobe corals are scattered throughout this sandy area, with the highest concentration located next to the harbor. Since Legan is the only USAKA island with this type of environment, care should be taken to prevent excessive transport of sediment laden waters into these shallow sand flats. Sediment curtains could be used to redirect sediment laden waters during dredging, if necessary. However, Legan has natural flushing capabilities due to its location between two major channels (Ambo and South Ambo Channels) that should facilitate the transportation of suspended sediments from this locality.

5. Ennylabegan Island

Project: Maintenance Dredging of the Ennylabegan harbor area

Extensive maintenance dredging is scheduled during FY88 to insure safe access to the pier facility on Ennylabegan.

Potential Marine Environmental Impacts

Field investigations revealed that continued maintenance dredging will have short term effects on the already disturbed soft substratum of the harbor floor. Furthermore, any plans to enlarge the harbor area in the future would not greatly impact the existing coral bench in the harbor.

6. Meck Island

Project: Replacement of the cargo/personnel pier

The cargo/personnel pier is scheduled to be replaced in the same location to accommodate vessels ferrying passengers to Meck during reactivation of the island facilities. Additionally, small craft berthing facilities are required to accommodate docking of several small boats at the same time. It has been recommended that this development occur concurrently with the replacement of the Meck Cargo pier.

Potential Marine Environmental Impacts

Meck's lagoon has been completely modified and heavily degraded due to landfill and dredging. Dredging or pier construction would cause minimal additional environmental disturbance. The adjacent area will only be temporarily impacted by sediment laden waters. However, an attempt could be made to improve aesthetics by cleaning-up existing and any new debris when work is completed. If possible, any future operations or activities that require extensive impact to the marine environment should be conducted at Meck Island.

7. Kwajalein Island

Project: Housing Landfill Project

A 15 acre (0.06 sq. km) landfill project for housing expansion was previously proposed for the northeastern tip of the island but is currently not being recommended. If this project is implemented at some later time, it will occur adjacent to Kwajalein Island's only section of good lagoon reef. This reef should be maintained and protected from ecological degradation, especially dredging.

Potential Marine Environmental Impact

The primary danger will be from the sediment load that will occur during the filling operation. Therefore, the strong currents at the end of Kwajalein Island must be prevented from carrying sediment along the lagoon shore. Consequently, the following recommendations are made to mitigate this problem.

<u>Options</u>

(1) Before the filling operation commences, the intended fill area should be closed off with rip rap and filter cloth, starting at the lagoon side. As a result, the fill will be contained within an essentially enclosed basin with relatively small amounts of sediment escaping and impacting the adjacent coral reef. Despite these precautions, however, the impact of sediment plumes on adjacent coral areas should be monitored during all phases. If significant environmental impacts occur, alternative methods should be pursued.

(2) Fill material should be supplied from non-critical habitats and be transported to the fill location by truck. The adjacent reef and slope should not be dredged for this purpose, nor should fill material be barged directly to this locality. Both of these activities would have strong environmental impacts on the last remaining Kwajalein Island lagoon coral reef system.

(3) The adjacent reef should be protected and reserved for marine recreation and associated activities.

(4) Any future activities planned for adjacent areas must be designed, implemented, and monitored with the intention of preventing serious marine environmental impacts to this region.

Project: Kwajalein Harbor Piers

Three piers are located within the boundaries of Kwajalein Harbor: the cargo, fuel, and recreational piers. The cargo pier, commonly referred to as Echo Pier, serves as the primary cargo handling facility for USAKA. Recently, the structural integrity of the pier has been questioned because of its age, vulnerable location relative to storm waves, and susceptibility to corrosion. Furthermore, its cargo handling capabilities are limited by the lift and reach capacity of the stationary pedestal crane, and by the lack of storage space. The existing fuel pier is also limited by its design, and further dredging will be required to accommodate deeper draft vessels.

Consequently, a feasibility study was recommended to assess available alternatives to fortify, replace, and/or relocate these structures. The feasibility study will include a cost/benefit analysis for the options to replace the piers, combine the cargo and fuel capabilities into a new multipurpose pier at a new site, or combine the cargo and fuel capabilities into a new multipurpose pier at the existing fuel pier site.

Potential Marine Environmental Impacts

The lagoon habitat adjacent to Echo Pier is primarily sand and algae, although there is a fouling assemblage on the pier and a small coral population on the narrow reef flat adjacent to the north side of Echo Pier. This area had previously been heavily degraded by dredging and filling, and currently by occasional maintenance dredging. Replacement of Echo Pier at its existing site would, therefore, only cause only minimal damage to the already impacted area. During construction, the sediment laden waters would temporarily impact the area.

Constructing a combined fuel and cargo pier at a new site or the existing fuel pier site, however, would entail substantial construction. Because there is potential for a much greater environmental impact, an additional environmental assessment should be made if either of these options are chosen.

Project: Barge Slip Ramp

Recommendations to enlarge and improve the safety of the barge slip ramp at the same location was requested in the facilities request report.

Potential Marine Environmental Impacts

These activities would cause minimal impact to the dredged area adjacent to the existing slip ramp. Sediment laden waters would only temporarily impact the area. Additional dredging further into the lagoon may be required to accommodate larger vessels; however, the environmental impacts would be minimal to the sand and algae beds found in adjacent areas.

B. SPECIFIC TOPICS OF IMPORTANCE

1. Quarries

The average land elevation is about 6 ft. (1.8 m) on Kwajalein Atoll, with few natural points exceeding 15 ft. (4.6 m) above sea level. As dynamic entities, atoll islands are subjected to cycles of erosion and deposition due to a combination of tidal forces, wave movements, and storms. Random tropical storms and typhoons cause the most rapid changes to island morphology, although the results are often catastrophic, destroying life and property. Hence the dynamic nature of these islands is often unacceptable for development and the economy. As a consequence, shoreline protection systems are often necessary, as in the case of several of the USAKA leased islands.

For these U.S. leased islands, rip rap or design stone is used for shoreline protection and consists of an assortment of materials emplaced along the island perimeters. Ideally, the outermost layer of the rubblemound revetments, as they are called, consists of hard cap reef rock. However, the debris resulting from World War II was some of the first material to be used. Damaged and/or unusable equipment and material was bulldozed to the edge of the islands where it offered limited protection against erosion and high seas. This practice was continued until more effective shoreline protection and environmental regulations required alternative means to be used.

Currently, material used to build rip rap revetments consists of armor stone, which is cap rock excavated from the ocean reef flats. This rock is loosened by blasting the reef with explosives. After removal, the finer, subsurface material is dredged to a depth of 3-10 ft. (1-3 m) or more and is used as landfill or concrete aggregate.

The resulting quarry holes are an anomaly on the homogeneous and monotonous windward reef flats. Typically, the Kwajalein Atoll reef flats are nearly flat, shallow platforms. Although they vary in width and the algal ridge may or may not be developed, they all tend to be quite similar in structure and support a small, low diversity biota. Therefore, by quarrying large holes, the habitat and biota are being drastically changed, inviting the recruitment of species previously unable to survive in this zone due to exposure to temperature extremes, desiccation, harsh wave action, and scour.

The consequences of altering a habitat depend on several factors. From a management perspective, an analysis of the percentage of habitat proposed to be changed in relationship to the total amount of similar existing habitat in the area is crucial. And special consideration must be given to managing critical habitats. With reference to quarrying on Kwajalein

Atoll, the amount of ocean reef flat that has been and is proposed to be quarried is very small, if not insignificant, compared to the total reef flat area.

Evidence suggests that quarries can be dredged on the exposed windward reef flats without adversely affecting the surrounding biological assemblages. Just prior to our field study, one new quarry had been dredged on Kwajalein Island. Additionally, the cap rock had been blasted for the future dredging of a quarry on either side. Although this blasting and dredging undoubtedly had a severe localized impact on the area, little or no biological damage could be discerned 6 weeks later. Tidal fluctuations and waves over the reef flat (and Tropical Storm Roy) undoubtedly erased most of the evidence of previous environmental impact, but also facilitated rapid recruitment of a new yet similar assemblage of marine flora and fauna. This relatively simple reef flat assemblage, therefore, appears very resilient to localized, non-chronic impacts.

Unlike the reef flat, quarries can develop a very diverse and complicated biota. Typically, this biota consists of 20-30 species of coral, 30-70 species of fish, and several species of large echinoderms, mollusks, crustaceans, and algae (Appendix 5). The overall development of the quarry biota, as in other tropical habitats, is directly related to habitat heterogeneity and the abundance and diversity of the corals.

A comparison of twenty five quarries throughout the atoll revealed dramatic differences in design and biotal development. Therefore, various characteristics were analyzed to determine which quarry configurations promote the most aesthetically pleasing and luxuriant biota (Tables 4 & 5). The characteristics considered included age, size, depth, geometry, location, and the strength of water movement. Results indicate that the most diverse coral reef development occurs in quarries that flush well and are able to transport out fine sediments.

From our observations, the best coral development occurs in large, relatively shallow quarries that have complex shapes and bathymetry (L-shape, S-shape, islands, etc.) (Figs. 8, 9, 10, 18). Size and heterogeneity promote good coral development, but should be coupled with means to remove fine sediments such as keeping them shallow or establishing exit ramps. The ends of the quarry should be shallower (Fig. 18, 19), especially the "downstream" end. It is also good to have portions on the lagoon side of the quarry shallower (not having all vertical sides). It is easier to transport fine sediment up a gradient than over a wall (Fig. 20, 21). Evidence from quarries at Majuro Atoll suggests that quarries with depths greater than 13 ft. (4 m) tend to trap and accumulate sediment regardless of shape (J. Maragos, personal communication).

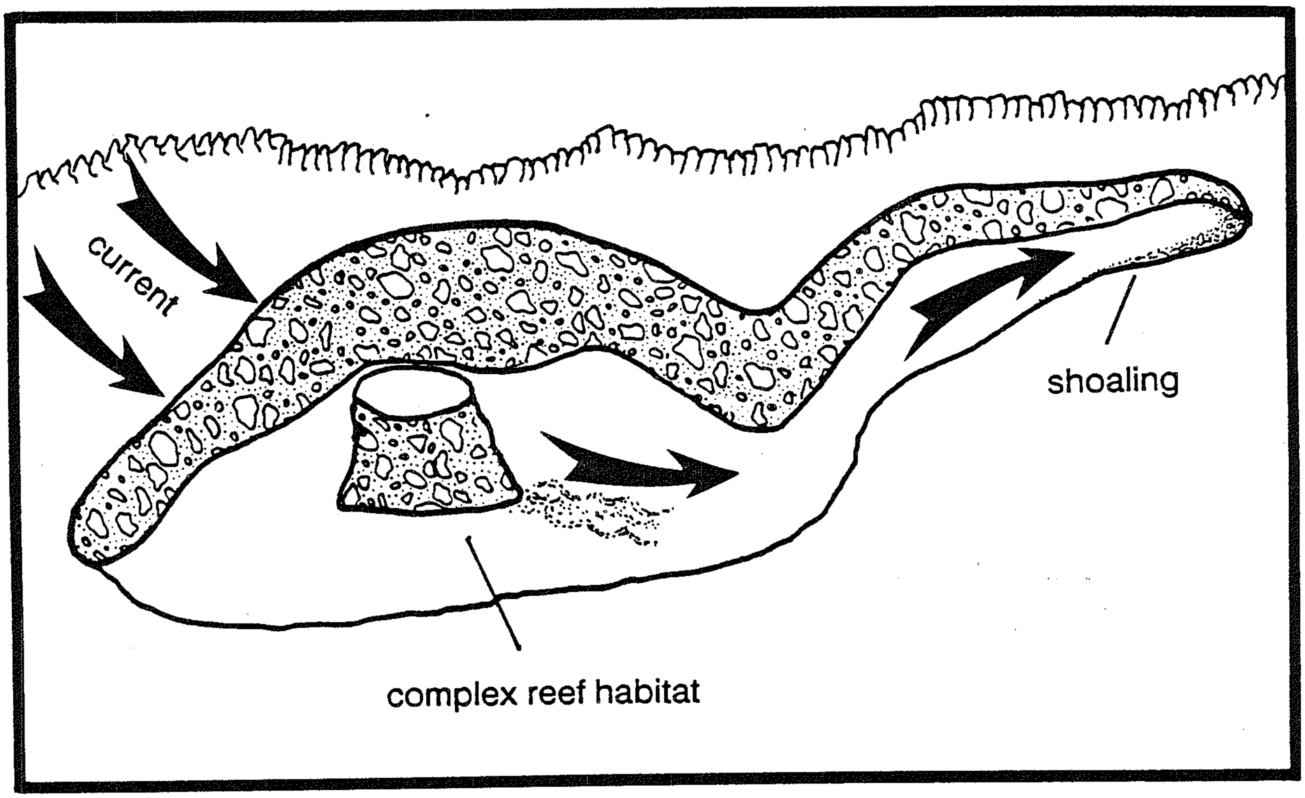

Figure 18. An example of a proposed quarry with good flushing abilities and complex topography.

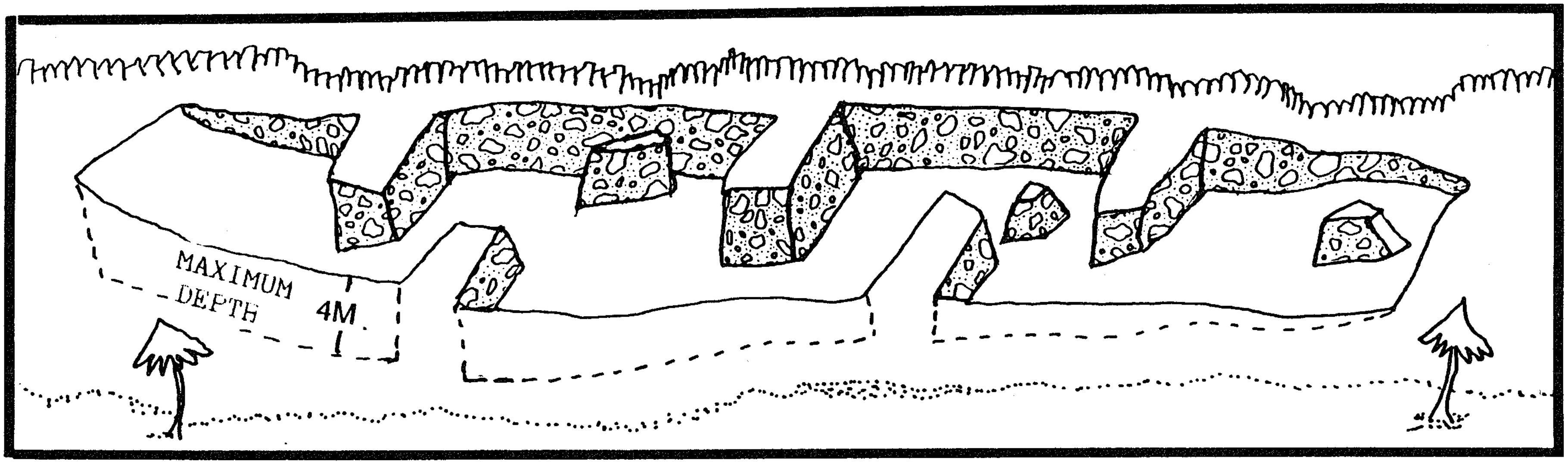

Figure 19. An example of modifications to the proposed quarry cells displaying complex topography and flushing abilities.

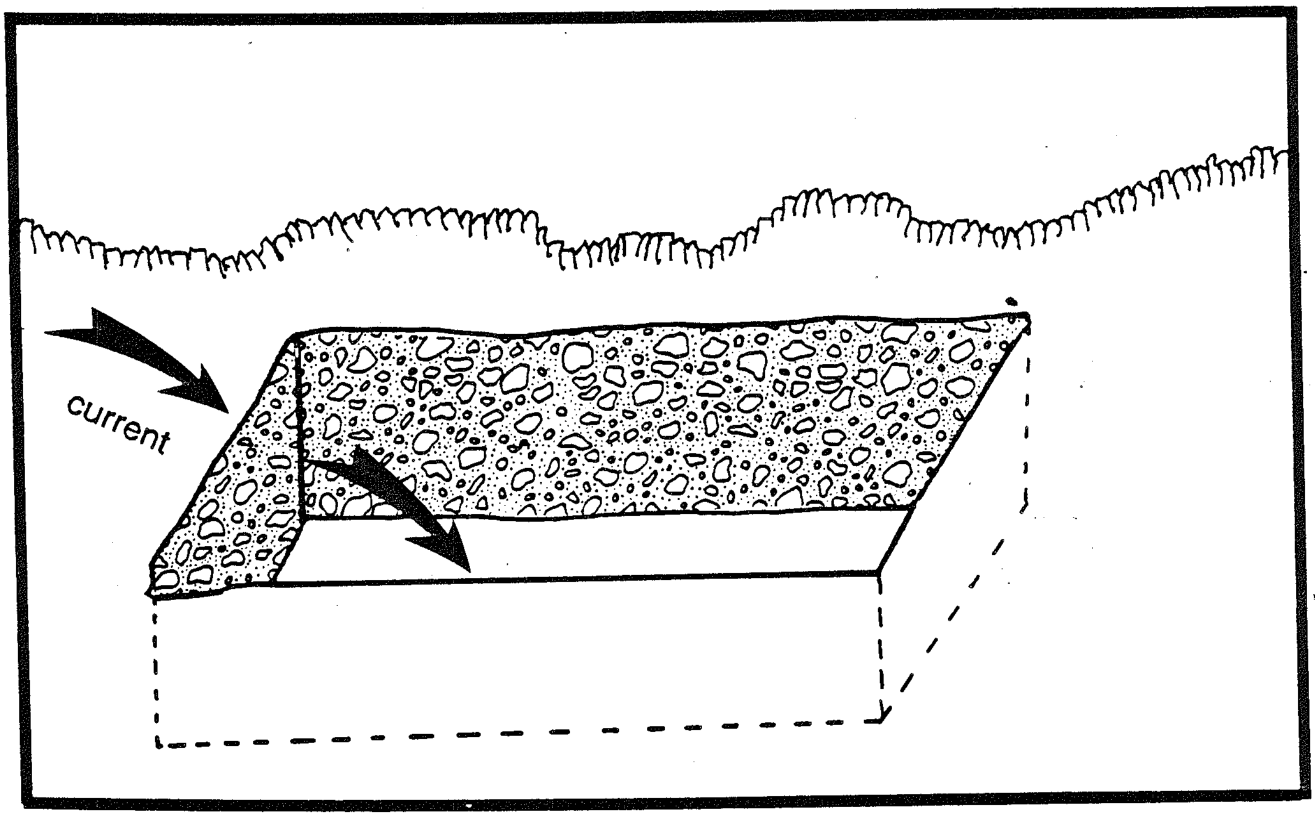

Figure 20. Current quarry design with poor sediment flushing abilities found on Kwajalein Island, Kwajalein Atoll, RMI.

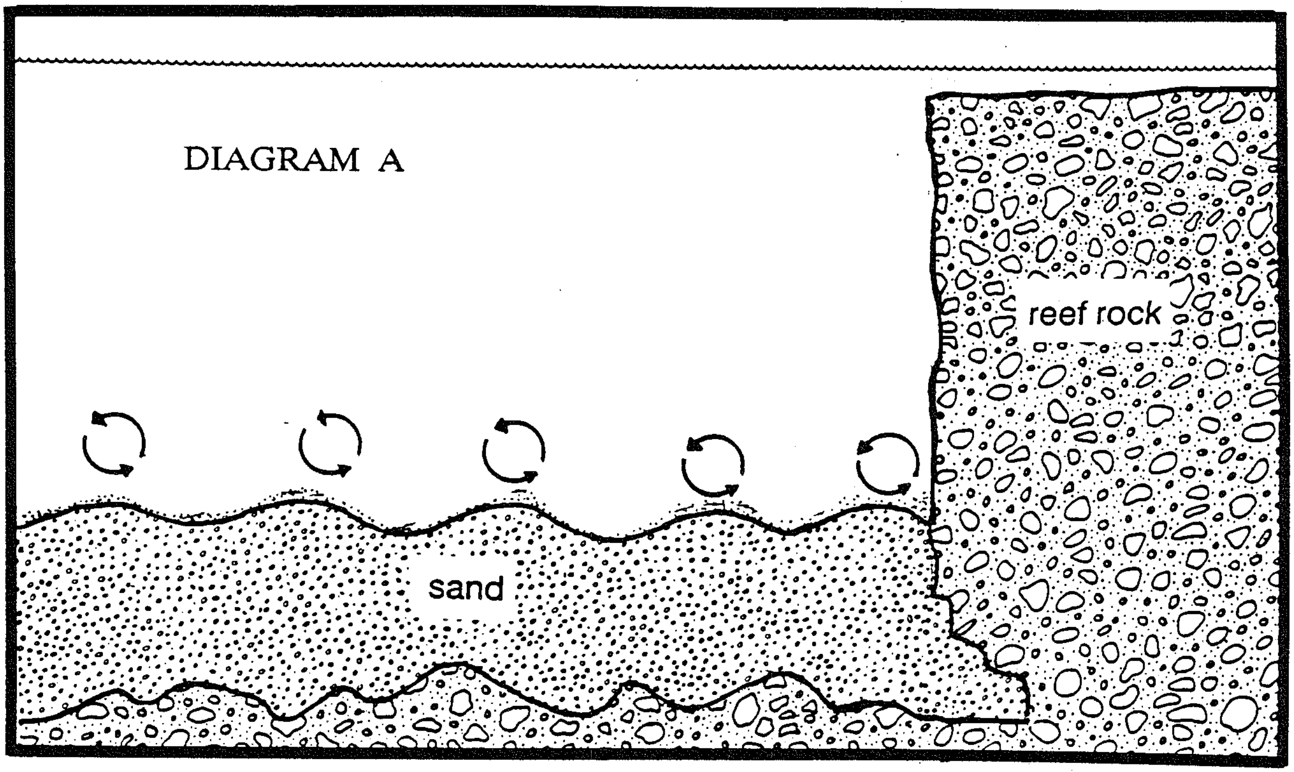

Figure 21. Diagram A represents the current quarry design on Kwajalein Island which has vertical walls preventing the transport of fine sediments out of the quarry. Diagram B represents modifications to the quarry design by shoaling several walls to enhance the transport of fine sediments out of the quarry.

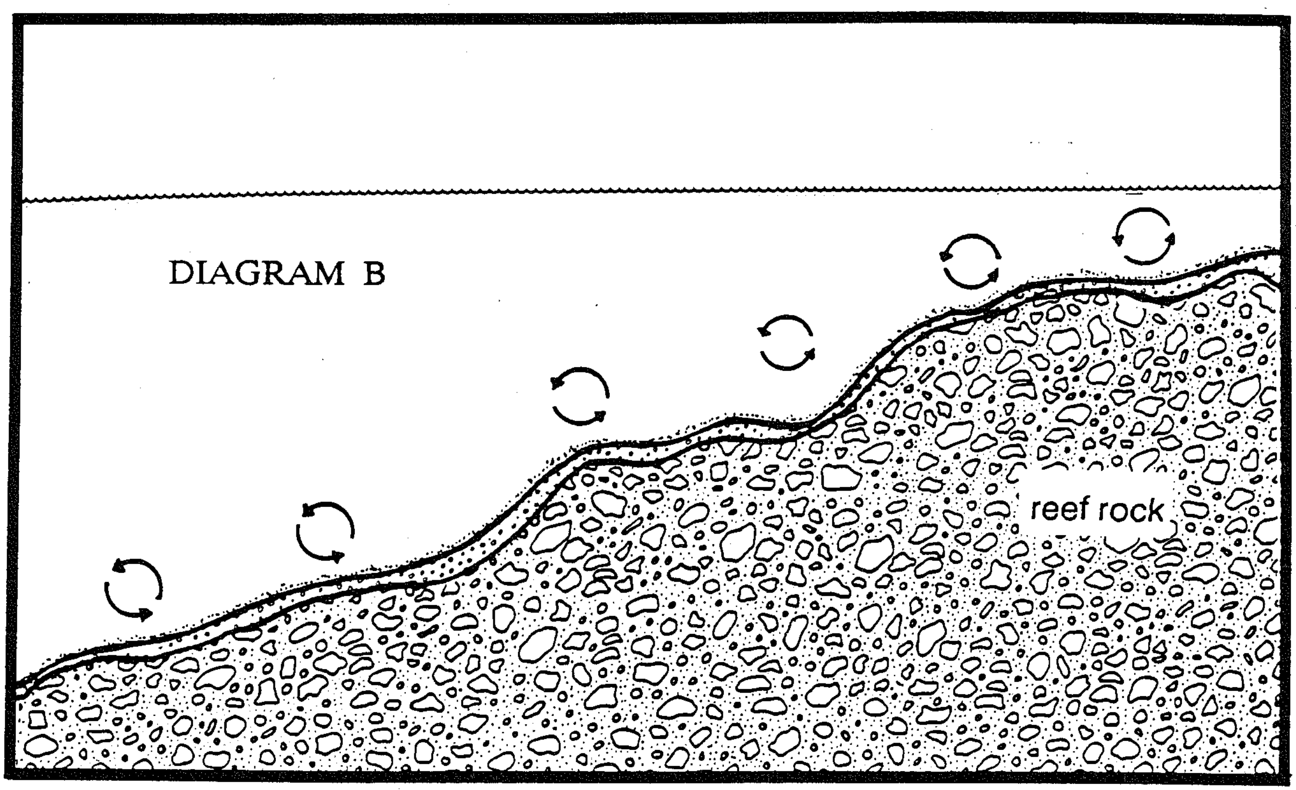

TABLE 4. KWAJALEIN ATOLL QUARRY DATA.

	Depth (m)	Distance from Ocean (m)	Distance from Shore (m)	Interisland (Y/N)	Upstream/+ Downstream/ Centered	Island Position++ U/M/D	Remarks
Kwaj 1	1-2	18-42	18	N	D	M	LONG, NARROW
2	1-2	55	18	N	M	M	VERY SMALL
3	1-2	18	18	N	M	M	LONG, NARROW
4	0.5	60	10	N	U	M	LONG, NARROW
5	2-3	50*	40*	N	ALONE	M	NEW POOL
6	0.2-0.5	120	10	N	D	U	VERY SMALL
7	2-3	50	42	N	D	U	SM. SQUARISH CELL
8	2-3	50	42	N	M	U	SM. SQUARISH CELL
9	2-3	50	42	N	M	U	SM. SQUARISH CELL
10	1-2	50	42	N	U	U	SM. SQUARISH CELL
Meck 1	0.5-3	4-5	27-75	PARTLY	D	D	LG. RECTANGULAR CELL
2	0.5-3	4-5	28	N	M	M	LG. RECTANGULAR CELL
3	0.5-3	12	28	N	M	M	SQUARISH CELL
4	0.5-3	10	48	N	M	M	SM. RECTANGULAR CELL
5	0.5-3	10	48	N	M	M	SM. RECTANGULAR CELL
6	0.5-3	10	48	N	U	M	SM. RECTANGULAR CELL
Gagan	1-4	5-10*	24-**	Y		D	LG."L"-SHAPED, "L" NEAR DOWNSTREAM END OF ISLAND; REST INTERISLAND
Gellinam	0.5-4	5-11	17-88	N		M	LG., LONG, IRREGULAR
Omelek	0.5-3	10	65-150	ALMOST		U	LG., IRREG., HOOK SHAPED
Legan***	0.5-2	5	12	N		U	SM., IRREGULAR
Gugeegue 1	1	50		Y	D	U	SM. RECTANGULAR CELL
2	1-1.5	50		Y	M	U	SM. RECTANGULAR CELL
3	1.5	50		Y	M	U	SM. RECTANGULAR CELL
4	1	50		Y	M	U	SM. RECTANGULAR CELL
5	0.5	50		Y	U	U	SM. RECTANGULAR CELL

Measurements are from aerial photographs. The reef flat edge and the ocean edge of the quarries were often difficult to determine because of breaking waves. Because the photographs are at different scales, some will have more measurement error; the distances should, therefore, be compared for "scale" rather than for exact measurement.

* Estimated distance because locality not in aerial photograph.

** The major portion is on the interisland reef flat.

*** Legan is the only leeward island studied with a quarry.

\+ Upstream/Downstream/Centered refers to the quarries position in relation to the longshore current direction when there is a series of quarries.

++ Refers to the quarries position in relation to the upper, lower, or mid section of the island.

TABLE 5. Quarries dredged on Kwajalein Atoll (COE, 1973a).

Location	Date	Quantity of Material Removed (cubic yds)
Kwajalein	1959-1965	35,000
	1964-1965	27,805
	1970	125,000
	1987	Not available
	1988	Not available
South Loi	1959-1965	2,070
	1964-1965	35,010
Meck	1964-1965	5,520
	1974	Not available
Gellinam	1971	8,000
Legan	1971	4,100
Omelek	1971	3,000
Gugeegue	Not available	Not available
Ninji	Not available	Not available
Roi-Namur	Not available	Not available
Gagan	Not available	Not available
Ennylabegan	Not available	Not available
Illeginni	Not available	Not available

"Data is not available for quarry work done prior to and during World War II by the Japanese and American forces although their quarry sites still exist."

Location is also important in flushing sediment from quarries. Better flushing occurs when the quarry is located closer to the outer reef margin. Likewise, there are stronger currents and better flushing at the ends of islands. However, it is not known if there is any inherent difference in coral reef development between quarries dredged in front of islands and quarries dredged on the interisland reef flat. The only interisland reef flat quarries that were studied are at Gugeegue. These are very small, far from the ocean margin, have poor coral development, and are filled with fine sediments. Their size and distance from the ocean margin, therefore, prevent them from being accurately compared to the "good" quarries that occur in front of and at the ends of the other islands.

Quarry design is important because current plans call for extensive quarrying on Kwajalein and Roi-Namur islands. On Kwajalein, the entire northeastern ocean reef flat, extending from Kwaj Lodge to the northern end of the residential housing area, has been slated for quarrying activities. Plans call for the excavation of a single row of sixteen rectangular shaped cells. The dimensions of the proposed quarries range from 200-300 ft. (60-90 m) in width to 100-400 ft. (30-120 m) in length, with a maximum depth of 15 ft. (4.5 m) (Fig. 22). The excavated rock will be utilized in the production of concrete aggregate and as revetment stones for shoreline stabilization.

On Roi-Namur, the entire north-west side of the ocean reef flat has been designated as a quarry site. As designed, these quarries will form two parallel rows of sixteen rectangular shaped cells (32 total), which are roughly 350 ft. (107 m) wide by 200 ft. (60 m) long, having a maximum depth of 15 ft. (4.6 m). As at Kwajalein Island, the excavated rock will be utilized in the production of concrete aggregate and as revetment stones for

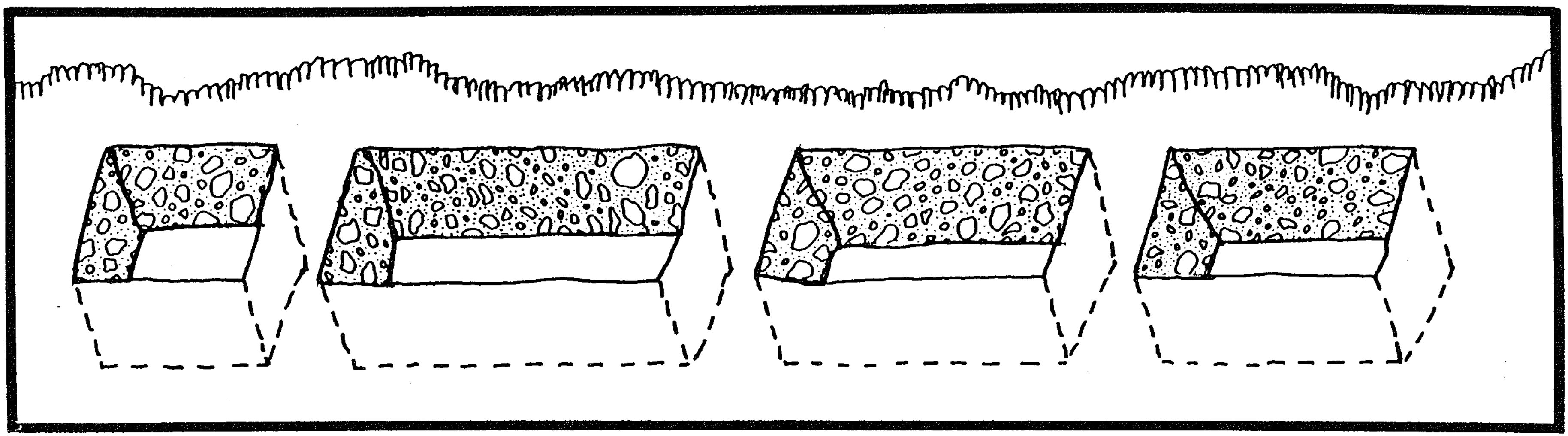

Figure 22. Current design for multiple quarry cells with inherent poor flushing abilities.

shoreline stabilization projects, including the proposed Dryess Airfield Runway extension project. Based on the design and coral reef development of existing quarries, the proposed Kwajalein and Roi-Namur quarries will have poor reef development and will collect fine sediments. This will be do to their steep walls, depth, and smooth rectangular shape. Figure 19 shows a possible modification to the proposed design that will supply more armor stone and promote better coral reef development.
The promotion of coral reef development is important because quarries can be used for activities such as recreation, fishing, and collecting. The varied biota and habitats are aesthetically pleasing and interesting. During low tide, several of the quarries are quite calm and protected, thus offering safe snorkeling and diving for those individuals uncomfortable in open water.

Shell collecting and aquarium fish collecting are two activities that are frequently undertaken in the quarries. The limited pressure of these activities probably has little ecological impact. However, slow growing organisms such as tridacnid clams and corals will recover very slowly with even limited collecting pressure.

Collecting of corals and tridacnid clams should be prohibited in all quarries. Quarries with good water circulation and other characteristics favorable to clams could also serve as repositories for transplanted tridacnid clams. If they prove to be adequate sites for larger clam populations, it might be feasible to culture sufficient numbers to restock depleted areas.

In summary, it is felt that dredging quarries on the windward ocean reef flats of Kwajalein Atoll currently does not pose a negative environmental impact on surrounding habitat or biota. In fact, they enhance the immediate area by increasing habitat and biota diversity. Existing data suggest that the quarries will reach their fullest ecological development if they are large, shallow (7-10 ft. in depth below the reef flat), irregular, close to the reef margin, partially extend out onto the interisland reef flat, and shoal on the back side and "downstream." Well developed quarries are popular for a variety of marine related activities. However, it must be stressed that, as with all ocean related activities, judgment must be used concerning when it is safe to utilize the quarries. The safest time is when the tide is lowest and, even then, some quarries have very strong currents and surge.

2. Dredging and Filling Operations

Landfill projects should be sited and designed to protect important reef areas from serious ecological impact. The primary danger will be from the sediment load that will occur during the filling operation. Because currents are very strong throughout the Atoll, the best way to control damage from sedimentation is to isolate the fill from currents. Therefore, before a filling operation is begun, the intended area should be closed off with rip rap and filter cloth, starting at the down current end. As a result, the fill will be completed in an essentially enclosed basin and relatively small amounts of sediment will escape and impact adjacent areas. Fill material should be supplied from non-critical atoll habitats; coral reef habitat should not be dredged.

3. Giant Clams

Five tridacnid clam species are known from Kwajalein Atoll: *Tridacna gigas*, *T. maxima*, *T. squamosa*, *T. crocea*, and *Hippopus hippopus*. Of these, *Tridacna gigas* attains the largest size. The Marshall Island population of *T. gigas* is also isolated due to extirpation of the species in the Mariana and Caroline islands (excluding Belau).

Fishing pressure is the primary reason *Tridacna gigas* is extirpated in many areas and threatened throughout its range. It is a favored food resource throughout the Pacific Ocean, including the Marshall Islands, and is easy to find and collect because it only occurs in shallow water. Currently, the size of this resource and the fishing pressure are unknown for the Marshall Islands.

Four of the tridacnid species were found during the survey, but Tridacna gigas was the least common. The only population found that has a density that might be sufficient for reproductive success is in the lagoon behind Gellinam Island. Though we were unable to survey the ocean reefs or the RMI islands in the Atoll, evidence was not encouraging that this species has a sufficient population size for any kind of commercial or sport fishery.

A prohibition should be instituted on harvesting any tridacnid clams by USAKA personnel within the areas controlled by USAKA, including the Mid-Atoll Corridor. The population observed during this investigation could be exhausted with only a minimal harvesting effort, and cannot withstand much pressure from sport divers or collectors. Evidence of harvesting is obvious by the number of shells displayed around the USAKA islands, and the fact that one specimen of Tridacna maxima was taken just prior to the survey team's arrival at Gellinam. This ban on commercial and sport collecting should remain in effect indefinitely or until a resource assessment study can be conducted to determine the status and potential of the resource.

If the resource assessment is accomplished and populations are adequate in some localities, clams can be seeded in depleted areas. If the entire atoll is depleted, then an aquaculture or fisheries restoration program for Kwajalein Atoll could be sponsored by the RMI. For this venture, USAKA could provide some logistical support and access to the Mid-Atoll Corridor for scientific experts from the United States to assist the Marshallese with launching such a program. If the resource size is increased, or shown to be sufficiently large, a program could be initiated by the RMI to export Marshallese tridacnid clams throughout the Caroline Islands as seed stock for aquaculture programs. This could be especially important with Tridacna gigas, which no longer occurs in most localities of the Caroline Islands.

Tridacnid clams should be transplanted from any area that is intended for dredging or filling. For instance, there are some clams in the area off Roi-Namur that is slated for the runway extension. These should be moved to a safe locality, possibly to a quarry hole, by employing the assistance of the SCUBA clubs active on Kwajalein and Roi-Namur islands.

4. Shoreline Cleanup

One of the more noticeable aspects of the USAKA leased islands is the tremendous amount of discarded materials that have been placed along the shoreline (Table 6). This material consists of everything from heavy equipment and gantry cranes to scrap wire and beer cans. The greatest amount of dumped material was utilized as shoreline revetments and in some instances, for landfill. Some areas, however, have become small garbage or dump sites for old equipment on several of the more remote USAKA islands. It's difficult to determine how long ago this material was dumped; much of it probably was deposited prior to the establishment of current environmental regulations.

TABLE 6. Surveyed USAKA islands with dumped materials along the shoreline, intertidal, and subtidal areas.

	SHORELINE				INTERTIDAL				SUBTIDAL			
	1	2	3	4	1	2	3	4	1	2	3	4
KWAJALEIN		X		X	X			X		X	X	X
MECK	X	X		X				X	X	X		
ENIWETAK												
OMELEK	X											
GELLINAM	X	X	X									
GAGAN		X	X	X			X				X	
ROI-NAMUR	X	X	X	X	X	X		X		X		X
ENNYLABEGAN	X	X		X	X	X		X	X		X	
LEGAN			X									
ILLEGINNI	X	X		X	X	X		X		X		
GUGEEGUE	X	X		X	X	X		X		X		

1. Disposable garbage = materials that could be easily cleaned-up and removed from the area. Examples include cans, bottles, etc.
2. Dumped materials = large pieces of discarded equipment including copper, wire and steel and various motors, gears, and sheet metal pieces.
3. "Copper Blast" piles.
4. Heavy equipment = trucks, dredges, graders, and cranes

In addition to the scrap piles and non-quarry stone revetments being unsightly and dangerous, they can also have a impact on the marine biota. A significant portion of the deposited materials are made from copper or copper alloys, which are toxic to many marine organisms at even low concentrations. A 1976 study (USAEHA, 1977) lists concentrations of various metals in the biota and water column around several Kwajalein Atoll locations. Though not mentioned in the report, copper and mercury levels in the water column exceeded Trust Territory ambient water quality standards in some localities, especially the sanitary land fill on Kwajalein Island and the open dump on Roi-Namur.

Several localities have a substantial amount of these emplaced or "dumped" materials. The western end of Kwajalein Island, near the Garbage Disposal Ramp and the incinerator pit, has rip rap made from an assortment of heavy equipment and metal trash. There is also assorted debris such as large anchors and anchor chains around Echo Pier. At both ends of Meck Island, there are dumped materials including parts of a gantry crane. The dump at the northern end of Gagan Island consists of computer components, parts of buildings and construction materials, while Gellinam Island has copper and alloy scraps scattered around. Heavy equipment, trucks and other trash are dumped along Ennylabegan's beaches and the intertidal zone. Furthermore, the entire berm bordering the USAKA leased portion on the leeward ocean side is composed of trash which is now overgrown by Scaevola. Roi-Namur has an assortment of dumped materials along the lagoon shorelines ranging from an artillery piece at the southern end of the runway and an assortment of trash around Yokohama Pier, to a sunken pontoon bridge or pier east of Yokohama Pier. The trash dump at the end of.the runway is encroaching on the intertidal zone. Illeginni, previously used as a missile target area, has junk, garbage, unused dilapidated buildings, etc., strewn all around the island.

The materials that have been dumped and/or abandoned on the various islands should be cleaned up for ecological, safety, and aesthetic reasons. Until USAKA's ocean dumping permit is renewed, an alternative means of disposal or storage will have to be found. One possibility is to utilize the barges that bring supplies to Kwajalein and sometimes return empty. Instead of returning to their home ports empty, these barges could transport scrap/discarded materials to the mainland U.S. or to an approved ocean dumping site near Kwajalein where it can be properly disposed of, some of which might be reused or recycled. Another option is to establish a local recycling center for soda and beer cans on Kwajalein and Roi-Namur. A small surcharge could be collected from each beverage purchase, which could fund a community service organization on Kwajalein, such as the boy scouts, to collect and sort the materials for shipping. In any case, copper and copper alloys should not be disposed of in the nearshore marine environment.

Litter and disposable trash are problems only in a few localities. Ignoring Illeginni, which needs a thorough clean up at all levels, most of the islands are relatively free of trash. Ennylabegan and Gellinam need some attention, although it might be difficult to keep the Ennylabegan beaches clean because they are downstream from the Ebeye dump and therefore receive an assortment of rafted in materials. The one island with a very noticeable shoreline litter problem is Roi-Namur. Most of this will eventually end up in the ocean if nothing is done. Fortunately, there is an active campaign to keep Kwajalein Atoll clean and it seems to be working relatively well in most areas. This program should be emphasized more strongly for the Roi-Namur beaches and intertidal zones.

5. Copper Blast

The tropical climate of Kwajalein Atoll makes control of rust and oxidation of equipment and facilities a significant, chronic and expensive problem. Rusting of larger structures is controlled by sand blasting and repainting. The product currently used for sand blasting is "Copper Blast." It is made from granulated copper slag and is composed primarily of the following elements: iron oxides (50%), silicon dioxide (37%), aluminum oxide (4%), magnesium oxide (2%), arsenic (.03%), lead (.08%), Beryllium (.0005%), and Cadmium (.001%). The concentrations of arsenic, lead, beryllium, and cadmium are apparently within EPA standards and should not be toxic in the marine environment (Data supplied by Pattie at Mr. Sandman, Inc., Honolulu, Hi.).

No obvious biological impact to the marine environment was observed. However, "Copper Blast" accumulates to a depth of several inches under and downwind from areas where work is being conducted. As a result, some intertidal and subtidal areas have the appearance of a black sand (volcanic) beach. These areas were limited in size and should not be a serious problem because of the reported low concentrations of toxic elements in "Copper Blast."

Because Kwajalein Atoll commonly has strong winds, at least seasonally, it is recommended that some kind of downwind skirting be used to keep the expended "Copper Blast" near the work area and out of the marine environment. This will protect the marine system from a largely unnecessary impact and will also facilitate the subsequent cleanup.

V. CONCLUSIONS & RECOMMENDATIONS

The immediate projects planned for USAKA leased islands in Kwajalein Atoll should not have lasting negative environmental impacts. The majority of these projects deal with maintenance dredging and pier repair, which will have short term effects on the already disturbed and previously dredged soft substratum of the harbors. The major environmental impact will be from the sediment burden placed on the biota adjacent to the harbors. This will be most critical at Gagan and Gellinam where there are well developed lagoon coral reef systems. However, the lagoon habitat adjacent to Kwajalein and Roi-Namur, where most of the work is planned, is primarily sand and algae, and will only temporarily be impacted by sediment laden water. Likewise, the construction and modifications planned for the docking facilities at these two locations will have only temporary impacts.

It is possible, however, that the planned 1500 ft. (457 m) runway extension at Roi-Namur will have a greater and longer effect on the marine environment. Not only will a large, relatively productive and diverse reef area be covered, but the current patterns in the area will be significantly modified. This change in current patterns could have a significant impact on the surrounding biological assemblages.

The runway extension will also cause the loss of important fisheries habitat. The Marshallese interviewed on Ennubirr (Third Island) reported that this locality has the best fishing around Roi-Namur. Though it is known that part of this habitat will be lost because of the fill operation, it is not known what, if any, impacts will result from the altered current patterns. Therefore, serious consideration should be given to alternatives such as partially extending the runway in the opposite direction. This would reduce the amount of lost habitat, and also reduce the amount of change to the current patterns.

If feasible, any future operations or activities that require extensive impact to the marine environment should be conducted at Meck Island. This recommendation is proposed because Meck's lagoon terrace and slope have already been completely modified and heavily impacted. Meck is also relatively large and has good facilities, including a runway and docking facilities which would facilitate the implementation of new activities. The other islands investigated were not as extensively modified as Meck and appear to be recovering from past impacts. They should not, therefore, be subjected to any unnecessary major environmental disturbances if Meck can be used.

Environmental monitoring should be required for all future projects. This monitoring should occur at intervals before, during, and after the projects, with their scopes determined on a case by case basis (some small, inconsequential projects may not need monitoring). This is the only mechanism to assess the true impact of a project and accumulate enough data and information to make wise management decisions. There should be regular, perhaps biannual, inspections to monitor the longer term environmental impacts of projects.

Based on our observations, we believe that a full time ecologist position is warranted due to the large scope and requirements of USAKA's mission. This person should be based on Kwajalein Island and report directly to the USAKA Commander. The ecologist should be a person with a general background in the terrestrial and marine ecology of atolls, but also have a knowledge of environmental regulations and management. This person should compliment the Corps of Engineers environmental staff, assist environmental contractors working on Kwajalein Atoll, and help plan future projects on the atoll. The ecologist's duties should include providing technical and logistical support for specialized environmental surveys accomplished by off-atoll scientists (e.g. sponsored by the Corps), reviewing proposes project plans for environmental implications, keeping USAKA current on environmental requirements, enforcement of environmental base regulations and insuring that the projects are monitored and carried out according to design. In addition to USAKA responsibilities, this office could provide support to the RMI for environmental and resource concerns.

Two major conclusions can be drawn from the resource user surveys. The first is that the existing policy of closure of the Mid-Atoll Corridor during missions is only a minor inconvenience and does not greatly impact fisheries activities. Therefore, no modification of current USAKA policy is deemed necessary.

The second conclusion drawn from the resource user surveys is that, although fishery resources are still abundant at Kwajalein Atoll, there is a perception that the resources are not as plentiful as they were a decade ago. Unfortunately, this "perception" cannot be verified because there are no fisheries data for the area, and there is no established mechanism or procedure for collecting the necessary data.

It seems doubtful that the present level of subsistence and recreational fishing activity on Kwajalein Atoll will significantly deplete pelagic species resources. However, inshore fisheries are more vulnerable to over exploitation. The introduction of gill nets may be having a negative impact on inshore fish populations as in Hawaii, where fisheries managers have regulated the minimum allowable mesh size as a measure to protect reef fish stocks. Similar regulation should be considered for Kwajalein Atoll by RMI/MIMRA and USAKA.

Without a fisheries data collecting program, however, it is impossible to measure resource depletion rates. Such a program should be initiated by RMI/MIMRA, but could be greatly enhanced by USAKA cooperation and participation. If resource depletion is occurring, this information will be necessary to determine the cause and to initiate a recovery program.

A. USAKA RECOMMENDATIONS

Quarries

1) Quarry Design: The best quarry design supplies the most armor stone while promoting diverse coral reef development. Maximum use of reef flat surface area supplies the most armor stone. Diverse coral reef development is accomplished by designing a system that flushes well and transports the fine sediments out of the quarry. Features that promote fine sediment removal include:

   a) Large size with complex shape and varying bathymetry (L-shaped, S-shaped, etc.) favors sediment removal.

   b) Habitat complexity: leave islands, ridges, complex bottom, etc.

c) Maximum depth of quarry holes should be about 13 ft. (4 m).

d) Shoaling of the "downstream" end and portions of the shoreward side of quarries so sand can transport out.

e) Varying slope of quarry margins on the "downstream" end and portions of the lagoon side so sand can transport out (don't have only vertical walls).

f) Location close to the ocean margin helps flush sediment.

g) Location near the interisland reef flat promotes flushing of sediment because of stronger currents at the ends of the islands.

h) When there are several adjacent cells, they should be interconnected so sediment can move "downstream."

i) Start quarrying a series of cells "upstream" to decrease sedimentation in newly dredged quarries.

2) Designate USAKA quarries as reserves for coral and tridacnid clams. (see #7)

Water Quality

3) Water quality testing should be conducted emphasizing the sanitary landfill on Kwajalein Island and the open dump on Roi-Namur, both of which previously measured water column levels of copper and mercury higher than allowable under

Trust Territory ambient water quality standards (USAEHA, 1977; BMDSCOM, 1980).

4) Investigate the two Roi-Namur thermal discharge sites for elevated coliform and nutrient levels:

   a) The Roi-Namur Power Plant's discharge pipe into the lagoon.

   b) The discharge site east of Yokohama Pier by the sunken pontoon bridge.

5) The petroleum burn pit near the Kwajalein Island sanitary landfill should be monitored for leaching onto the adjacent ocean reef flat.

<u>Ocean Dumping</u>

6) There is need for a means of disposal of large, unusable materials. Therefore, suitable environmental studies should be conducted to determine the viability of ocean dumping and other disposal alternatives.

<u>Tridacnid Clams</u>

7) Prohibit the taking of all tridacnid clam species by USAKA personnel throughout Kwajalein Atoll. The International Union for Conservation of Nature and Natural Resources (IUCN) Red Book (Wells et al., 1983) lists *Tridacna gigas* as

"vulnerable," _T. maxima_ as "insufficiently known," and _T. squamosa_ as "indeterminate."

7.1) Because the lagoon reef adjacent to Gellinam Island has the only reproductively viable giant clam (_Tridacna gigas_) population of all the USAKA leased islands, it should be designated a marine conservation area, with no exploitation except for fishing (see #17).

7.2) Relocate clams from areas to be dredged/filled, possibly to quarry holes.

Roi-Namur Dryess Airfield Runway Extension

8) Consider option to partially extend the Roi-Namur Dryess Airfield runway in the opposite direction to the maximum extent practicable instead of the proposed plans. See alternatives and mitigating actions in the Discussion Section.

Landfill/Dredging Operations

9) Recommended procedure for landfill operations:

   1) Close off the intended fill area with rip rap and filter cloth, starting at the "downstream" side.

   2) Once rip rap is in place, the fill material should be transported to the site by the least environmentally

destructive method. If there are adjacent coral reefs, do not barge the fill directly to the site through the reef.

10) Monitor the impact of sediment plumes from dredge/fill operations. This should be done before, during, and after the operation, and should include monitoring of currents.

11) If the recently suspended plans to extend the northern end of Kwajalein Island are implemented at a future time, care should be taken to protect the valuable adjacent lagoon coral reef habitat.

12) If possible, restrict expansion operations, or activities that require extensive impact to the marine environment, to Meck and Kwajalein islands.

13) Relocate clams from areas to be dredged/filled, possibly to quarry holes (see #7).

<u>Copper Blast</u>

14) Clean up "Copper Blast" after sand blasting.

14.1) Use skirting to keep "Copper Blast" near the work area and away from the marine environment.

B. OPTIONAL USAKA RECOMMENDATIONS

Staff Ecologist

15) There is need for an Ecologist in the USAKA organization. We, therefore, recommend that a full time Staff Ecologist position be created and staffed on Kwajalein Island. This person would have complimentary functions to environmental support provided by the Corps.

15.1) The Ecologist should work with the COE environmental staff to coordinate on-site monitoring of existing and future construction projects that affect the atoll environment. Duties should also include monitoring existing thermal and sewage discharges.

15.2) Recreational shell collecting is an important leisure activity for many USAKA contractors. Therefore, we recommend promoting selective shell collecting which will allow everyone to participate in this activity over time. Furthermore, a pamphlet describing safety procedures, natural history, collection techniques, and shell curation should be developed as an educational aide for USAKA residents

15.3) The Ecologist could be responsible for the periodic collection of fisheries statistical data if such a program is initiated by RMI/MIMRA (see #22)

15.4) The Ecologist could be the primary USAKA liaison for any RMI/MIMRA tridacnid clam assessment, restoration, or repopulation projects (see #23,26)

15.5) Enforce base environmental regulations.

Marine Reserve Areas

16) Protect the reef north of Emon Beach, which is the only well developed lagoon reef adjacent to Kwajalein Island.

17) Based on the paucity of tridacnid clams and the poor coral development observed during the field survey, the lagoon reefs adjacent to Gellinam and Gagan islands should be designated marine conservation areas, with no exploitation except for fishing.

18) Protection of the Kwajalein and Roi-Namur lagoon seagrass beds should be considered. These are the only documented localities for Halophila minor in the Marshall Islands.

Shoreline Debris

19) Remove accumulated shoreline debris that is not being used for shoreline protection or embedded in beach rock. This is especially important for copper and copper alloys, which are toxic to many marine organisms.

19.1) The Roi-Namur shoreline and intertidal zone should be cleaned.

20) Future relinquishment of USAKA islands to RMI control should involve removing unusable materials for safety and aesthetics.

21) It is recommended that additional care be taken during the separation of wet garbage food items from other non-biodegradable materials such as cans and bottles prior to dumping at the Kwajalein Garbage Disposal Ramp.

C. <u>OPTIONAL RECOMMENDATIONS FOR COOPERATIVE VENTURES</u>

22) Fisheries data, which are necessary for responsible resource management, are not available for the Marshall Islands. If RMI/MIMRA should initiate a data collection program, USAKA could cooperate through logistical support and help in data collection (see #15.3).

23) USAKA could work with and encourage the RMI government to implement a tridacnid clam resource assessment to determine the status of this resource (see #15.4). A restoration program should be started if deemed necessary.

24) Local USAKA dive clubs could possibly participate in some of the survey work.

25) USAKA could cooperate with RMI to use restored/cultured clams to restock Kwajalein Atoll.

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APPENDIX 1. Marine Species Identified at Kwajalein Atoll.

	KWAJ.	GUG.	MECK	ENIW.	OMELEK	GELL.	GAGAN	ROI.	ENNY.	LEGAN	ILLEG.
DIVISION CYANOPHYTA											
CLASS CYANOPHYCEAE											
ORDER CHROOCOCCALES											
Family Chamaesiphonaceae											
Entophysalis sp.				X							X
ORDER OSCILLATORIALES											
Family Nostocaceae											
Calothrix scopulorum											
Hormothamnion enteromorphoides	X		X	X	X	X	X	X	X	X	X
Nostoc sp. (terrestrial)		X	X	X							
Family Oscillatoriaceae											
Microcoleus lyngbyaceus	X		X		X	X	X	X	X	X	X
Schizothrix calcicola	X	X	X	X	X	X	X	X	X	X	X
Schizothrix mexicana	X	X	X					X	X		X
ORDER UNKNOWN											
Family Unknown											
blue-green algae	X		X		X		X	X		X	
DIVISION CHLOROPHYTA											
CLASS CHLOROPHYCEAE											
ORDER ULVALES											
Family Ulvaceae											
Enteromorpha clathrata											
ORDER CAULERPALES											
Family Bryopsidaceae											
Bryopsis pennata	X			X	X		X	X			
Family Caulerpaceae											
Caulerpa cupressoides				X	X	X		X		X	X
Caulerpa peltata							X				
Caulerpa racemosa	X			X				X			
Caulerpa serrulata	X		X					X		X	X
Caulerpa sertularioides	X	X	X								
Caulerpa urvilliana											
Caulerpa verticillata			X	X			X	X		X	X
Caulerpa sp.					X	X					
Family Codiaceae											
Chlorodesmis sp.											
Codium arabicum	X					X		X	X	X	X
Codium edule										X	
Halimeda cylindracea	X	X						X			
Halimeda discoidea	X	X	X	X	X	X	X		X		
Halimeda gigas	X		X					X			
Halimeda opuntia	X		X	X	X	X	X	X	X	X	X
Halimeda taenicola											
Halimeda sp. 1	X		X								
Rhipilia sp.											

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Tydemania expeditionis			X								
Udotea indica						X	X				
ORDER SIPHONOCLADALES											
Family Boodleaceae											
Boodlea composita	X	X	X			X		X	X	X	
Family Siphonocladaceae											
Cladophoropsis sp.											
Family Valoniaceae											
Dictyosphaeria cavernosa					X	X					
Dictyosphaeria versluysii					X	X					
Dictyosphaeria sp.							X	X			
Valonia aegagropila											
Valonia ventricosa							X	X	X		
ORDER DASYCLADALES											
Family Dasycladaceae											
Acetabularia moebii	X									X	
Neomeris annulata	X		X		X	X	X			X	X
Neomeris vanbosseae				X				X	X		
ORDER CLADOPHORALES											
Family Anadyomenaceae											
Microdictyon okamurai			X		X	X	X	X			
Family Cladophoraceae											
Chaetomorpha sp.										X	
DIVISION PHAEOPHYTA											
CLASS PHAEOPHYCEAE											
ORDER ECTOCARPALES											
Family Ectocarpaceae											
Ectocarpus breviarticulatus	X										
Feldmannia indica									X		
Family Ralfsiaceae											
Ralfsia occidentalis	X		X	X						X	X
ORDER SPHACELARIALES											
Family Sphacelariaceae											
Sphacelaria tribuloides									X		
Sphacelaria sp.	X			X		X					X
ORDER DICTYOTALES											
Family Dictyotaceae											
Dictyopteris repens											
Dictyota bartayresii	X	X	X					X	X		
Dictyota divaricata			X					X		X	X
Dictyota friabilis	X	X	X	X	X	X		X	X	X	
Dictyota sp.	X				X	X					
Lobophora variegata	X		X	X	X		X	X	X	X	
Padina japonica									X		
Padina tenuis	X	X						X			
Padina sp.	X		X							X	

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ORDER FUCALES											
Family Sargassaceae											
Turbinaria ornata										X	
ORDER UNKNOWN											
Family Unknown											
Diatom film	X	X	X		X	X				X	X
DIVISION RHODOPHYTA											
CLASS FLORIDEOPHYCEAE											
ORDER NEMALIALES											
Family Acrochaetiaceae											
Acrochaetium sp.											
Family Bonnemaisoniaceae											
Asparagopsis taxiformis			X					X	X	X	X
Family Chaetangiaceae											
Galaxaura filamentosa			X						X		X
Galaxaura oblongata											
Galaxaura sp.								X		X	
Family Gelidiaceae											
Gelidiella acerosa					X						
Gelidium pusillum					X						
ORDER CRYPTONEMIALES											
Family Corallinaceae											
Amphiroa sp.											
coralline algae	X										
Jania capillacea	X		X			X	X	X			X
Lithothamnion sp.											
Neogoniolithon frutescens					X	X	X				
Porolithon gardineri						X	X				
Porolithon onkodes	X		X	X	X	X	X	X	X	X	
Family Cryptonemiaceae											
Halymenia sp.	X		X								
Family Peyssoneliaceae											
Peyssonelia rubra	X		X		X			X	X		X
ORDER GIGARTINALES											
Family Gracilariaceae											
Gelidiopsis intricata			X			X		X		X	
Family Hypneaceae											
Hypnea esperi								X			
ORDER CERAMIALES											
Family Ceramiaceae											
Centroceras clavulatum											
Ceramium sp. 1											
Ceramium sp. 2											
Herposiphonia tenella											
Polysiphonia scopulorum											

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	KWAJ.	GUG.	MECK	ENIW.	OMELEK	GELL.	GAGAN	ROI.	ENNY.	LEGAN	ILLEG.
Spyridia filamentosa											
Tolypiocladia glomerulata											
Wrangelia sp.								X			
Family Delesseriaceae											
Martensia fragilis								X			
Family Rhodomelaceae											
Laurencia papillosa											
CLASS UNKNOWN											
ORDER UNKNOWN											
Family Unknown											
algal mat	X	X	X	X	X	X	X	X	X	X	X
DIVISION TRACHEOPHYTA											
CLASS ANGIOSPERMAE											
SUBCLASS MONOCOTYLEDONEAE											
Family Hydrocharitaceae											
Halophila minor	X							X			
PHYLUM SARCODINA											
CLASS RETICULAREA											
ORDER FORAMINIFERIDA											
Family Homotremidae											
Homotrema sp.	X				X	X	X				
PHYLUM PORIFERA											
CLASS DEMOSPONGIAE											
ORDER HADROMERIDA											
Family Clionidae											
clionid sponge			X		X		X	X	X		
CLASS UNKNOWN											
ORDER UNKNOWN											
Family Unknown											
sponge (encrusting; black/purple)	X									X	
sponge (black)	X										
sponge (gray)	X										
sponge (green							X				
sponge (orange)			X				X	X			
sponge (red)	X							X			
sponge (red, encrusting)	X		X								X
sponge (tan)	X										
sponge (vase-like)	X										
sponges	X	X		X				X			

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	KWAJ.	GUG.	MECK	ENIW.	OMELEK	GELL.	GAGAN	ROI.	ENNY.	LEGAN	ILLEG.
PHYLUM CNIDARIA											
CLASS HYDROZOA											
ORDER HYDROIDA											
SUBORDER LEPTOMEDUSAE											
Family Campanulariidae											
Obelia sp.											X
Family Plumulariidae											
Aglaophenia sp.			X				X			X	X
SUBORDER UNKNOWN											
Family Unknown											
hydroids	X		X			X		X			X
Macrorhynchia phoenicea										X	X
Lytocarpus sp.	X										
ORDER SIPHONARIA											
Physalia physalis	X					X			X	X	
ORDER MILLEPORINA											
Family Milleporidae											
Millepora exaesa	X	X	X		X	X	X	X	X	X	X
Millepora platyphylla			X	X	X	X	X		X		X
Millepora tenera	X		X	X	X	X	X	X			X
ORDER STYLASTERINA											
Family Stylasteridae											
Distichopora sp.					X	X	X				
Stylaster sp.	X						X				
CLASS ANTHOZOA											
SUBCLASS ALCYONARIA											
ORDER STOLONIFERA											
Family Tubiporidae											
Tubipora musica				X							
ORDER TELESTACEA											
Family Telestidae											
Telesto sp.	X										
ORDER ALCYONACEA											
Family Alcyoniidae											
Cladiella sp.				X					X		
Lobophytum sp.						X				X	
Sarcophyton glaucum							X				X
Sarcophyton sp.	X		X	X			X		X	X	
Sinularia polydactyla	X	X	X	X	X		X		X	X	X
Sinularia rigida			X								
Sinularia sp. 1			X								
Sinularia sp.	X		X				X			X	
Sinularia spp.				X		X				X	
Family Nephtheidae											
Dendronephthya (Roxasia) mirabilis	X										

APPENDIX 1. Marine Species Identified at Kwajalein Atoll.

	KWAJ.	GUG.	MECK	ENIW.	OMELEK	GELL.	GAGAN	ROI.	ENNY.	LEGAN	ILLEG.
ORDER COENOTHECALIA											
Family Helioporidae											
Heliopora coerulea	X			X	X	X	X	X	X		
SUBCLASS ZOANTHARIA											
ORDER ZOANTHIDEA											
Family Zoanthidae											
Palythoa tuberculosa	X							X			X
zoanthids with green center	X										
Zoanthus sp.	X			X							
ORDER ACTINIARIA											
Family Aiptasiidae											
Aiptasia pulchella						X		X			
Family Stichodactylidae											
anemones			X				X				
anemone sp. (large, sand dwelling)	X										
carpet anemone			X								
Heteractis aurora						X					
Heteractis magnifica						X	X			X	
Heteractis sp.											X
Macrodactyla doreensis					X			X			
Stichodactyla mertensii						X	X				
Family Unknown											
anemones	X	X						X			
SUBORDER ASTROCOENIINA											
Family Acroporidae											
Acropora acuminata							X				X
Acropora aspera	X							X			
Acropora cytherea	X	X		X		X	X		X	X	
Acropora formosa	X					X	X				X
Acropora horrida	X							X			X
Acropora humilis	X	X	X	X		X	X	X	X	X	X
Acropora hyacinthus				X		X					
Acropora irregularis						X				X	
Acropora monticulosa				X			X		X	X	
Acropora ocellata						X					
Acropora palifera				X		X			X	X	X
Acropora tenuis						X					
Acropora valida						X					
Acropora vaughani	X			X			X		X	X	X
Acropora virgata						X					
Acropora sp. 1	X	X	X	X			X	X	X	X	X
Acropora sp. 2	X		X	X			X		X	X	X
Acropora sp. (encrusting)	X									X	
Acropora spp. (arborescent)	X										

APPENDIX 1. Marine Species Identified at Kwajalein Atoll.

	KWAJ.	GUG.	MECK	ENIW.	OMELEK	GELL.	GAGAN	ROI.	ENNY.	LEGAN	ILLEG.
ORDER SCLERACTINIA											
Acropora spp. (tables)	X		X								X
Acropora spp. (bushy)	X										
Acropora spp.	X		X		X		X				
Astreopora sp.	X		X	X	X	X	X			X	X
Montipora digitata	X	X	X					X	X	X	X
Montipora foveolata			X	X							
Montipora studeri						X					
Montipora verrilli	X	X	X			X	X	X	X	X	X
Montipora verrucosa						X				X	
Montipora sp. (nobby)						X					
Montipora spp. (encrusting)	X		X	X					X	X	X
Montipora spp.	X	X			X	X	X		X		
Family Pocilloporidae											
Pocillopora damicornis	X	X	X		X	X		X		X	X
Pocillopora danae	X										
Pocillopora elegans	X			X							X
Pocillopora eydouxi	X	X	X	X	X	X		X	X	X	X
Pocillopora meandrina	X		X	X	X	X		X	X	X	X
Pocillopora verrucosa	X		X	X	X	X	X			X	X
Pocillopora spp.		X	X				X				
Seriatopora hystrix						X	X				
Stylophora mordax						X	X				
Stylophora pistillata					X	X					
Stylophora sp.			X								X
SUBORDER FUNGIINA											
Family Agariciidae											
Gardineroseris planulata	X		X				X				
Pavona cactus	X										
Pavona clavus		X		X	X	X	X		X	X	X
Pavona maldivensis								X			
Pavona varians	X	X	X		X	X	X	X	X	X	
Pavona spp.	X										X
Family Fungiidae											
Fungia (Verillofungia) concinna						X		X			
Fungia (Danafungia) danai	X										
Fungia (Fungia) fungites	X					X	X	X	X	X	X
Fungia (Pleuractis) scutaria	X		X		X	X	X	X		X	
Herpolitha sp.	X										
Polyphyllia talpina								X			
Family Poritidae											
Alveopora sp.	X		X	X	X	X	X		X		X
Porites cylindrica	X										
Porites lichen					X		X				
Porites lobata					X						
Porites lutea	X	X	X		X	X	X	X	X	X	X
Porites (lobate)				X	X				X	X	X

APPENDIX 1. Marine Species Identified at Kwajalein Atoll.

	KWAJ.	GUG.	MECK	ENIW.	OMELEK	GELL.	GAGAN	ROI.	ENNY.	LEGAN	ILLEG.
Porites spp.	X		X			X		X	X	X	
Family Siderastreidae											
Coscinaraea sp.			X								
SUBORDER FAVIINA											
Family Faviidae											
Cyphastrea sp.					X	X	X				
Echinopora sp.						X	X		X		
Favia pallida				X							
Favia speciosa				X		X					
Favia stelligera				X		X	X				
Favia spp.	X		X		X		X	X	X	X	X
Favites sp.	X										
Goniastrea pectinata								X			
Goniastrea retiformis	X						X	X			X
Goniastrea sp.			X		X						X
Hydnophora microconos	X	X	X		X	X	X	X	X	X	
Leptastrea purpurea	X		X	X	X			X	X	X	
Platygyra sp.	X	X	X	X	X	X	X			X	X
Family Merulinidae											
Merulina sp.									X		
Family Mussidae											
Lobophyllia sp.	X		X		X	X	X	X	X		
Symphyllia valenciennesii	X		X	X	X	X	X	X			
Family Pectiniidae											
Mycedium sp.	X										
SUBORDER CARYOPHYLLIINA											
Family Caryophylliidae											
Euphyllia glabrescens					X	X				X	X
Plerogyra sinuosa	X										
SUBORDER DENDROPHYLLIINA											
Family Dendrophylliidae											
Tubastraea coccinea	X		X						X		
Turbinaria sp.				X		X		X			
ORDER CORALLIMORPHARIA											
Family Actinodiscidae											
Rhodactis howesii											X
corallimorphs	X	X	X			X	X				
ORDER ANTIPATHARIA											
Cirrhipathes sp. (green)	X										
PHYLUM BRYOZOA											
CLASS UNKNOWN											
ORDER UNKNOWN											
Family Unknown											
bryozoans					X			X			

APPENDIX 1. Marine Species Identified at Kwajalein Atoll.

	KWAJ.	GUG.	MECK	ENIW.	OMELEK	GELL.	GAGAN	ROI.	ENNY.	LEGAN	ILLEG.
PHYLUM PLATYHELMINTHES											
CLASS TURBELLARIA											
ORDER POLYCLADIDA											
Family Unknown											
flat worm			X								
PHYLUM MOLLUSCA											
CLASS GASTROPODA											
SUBCLASS PROSOBRANCHIA											
ORDER ARCHAEOGASTROPODA											
Family Haliotidae											
Haliotis sp.	X										
Family Neritidae											
Nerita maxima		X									
Nerita plicata	X	X	X	X	X	X				X	X
Nerita polita			X								
Family Trochidae											
Tectus pyramis				X	X	X	X			X	
Trochus creniferus			X								
Trochus niloticus	X		X	X	X	X	X	X	X	X	X
Trochus ochroleucus										X	
Trochus sp. (small, red)			X								
Family Turbinidae											
Astraea rhodostoma						X					
Turbo argyrostomus		X								X	
Family Unknown											
limpets								X			
ORDER MESOGASTROPODA											
Family Bursidae											
Bursa bufonia	X										
Bursa granularis			X								
Family Capulidae											
Cheilea equestris (shell only)								X			
Family Cassididae											
Cassis cornuta (shell only)	X										
Family Cerithiidae											
Cerithium nodulosum	X									X	
Family Cymatiidae											
Cymatium muricinum		X									
Cymatium pileare						X					
Family Cypraeidae											
Cypraea annulus	X										
Cypraea argus (shell only)						X					
Cypraea depressa			X								
Cypraea moneta	X		X			X		X			
Cypraea scurra (shell only)		X									
Cypraea teres		X									

APPENDIX 1. Marine Species Identified at Kwajalein Atoll.

	KWAJ.	GUG.	MECK	ENIW.	OMELEK	GELL.	GAGAN	ROI.	ENNY.	LEGAN	ILLEG.
Cypraea tigris								X			
Cypraea spp.			X								
Family Littorinidae											
Littorina coccinea		X				X					
Littorina undulata		X				X					
Littorina sp.				X	X						
Family Ovulidae											
Ovula ovum			X								
Family Strombidae											
Lambis chiragra			X								
Lambis crocata			X	X				X			
Lambis truncata			X		X	X					
Strombus dentatus			X								
Strombus lentiginosus	X										
Strombus luhuanus	X		X					X			
Strombus sp.			X								
Strombus spp.						X					
Family Tonnidae											
Tonna perdix (shell only)		X									
Family Vermetidae											
Dendropoma maxima	X	X	X	X	X	X	X	X	X	X	X
Serpulorbis sp.	X										
vermetids (small species)								X			
ORDER NEOGASTROPODA											
Family Buccinidae											
Engina mendicaria			X								
Family Conidae											
Conus chaldaeus	X	X	X								
Conus distans		X	X								
Conus ebraeus	X	X									
Conus flavidus		X									
Conus sanguinolentus		X									
Conus sponsalis	X			X							
Conus sp. (very large)								X			
Family Harpidae											
Harpa amouretta						X					
Family Mitridae											
Mitra paupercula			X								
Mitra sp.								X			
Mitra spp.	X										
Family Muricidae											
Chicoreus brunneus	X										
Family Terebridae											
Terebra sp.	X		X								

APPENDIX 1. Marine Species Identified at Kwajalein Atoll.

	KWAJ.	GUG.	MECK	ENIW.	OMELEK	GELL.	GAGAN	ROI.	ENNY.	LEGAN	ILLEG.
Family Thaididae											
Drupa grossularia				X							
Drupa morum	X		X								
Drupella elata	X		X								
Morula granulata	X		X								
Morula uva			X								
Muricodrupa fenestrata		X									
Thais aculeata		X									
Family Vasidae											
Vasum ceramicum			X								
Vasum turbinellum	X		X			X		X			
SUBCLASS OPISTOBRANCHIA											
ORDER SARCOGLOSSA											
Family Plakobranchidae											
Plakobranchus ocellatus	X	X	X								
ORDER NUDIBRANCHIA											
Family Gymnodorididae											
Nembrotha sp.										X	
Family Phyllidiidae											
Phyllidia pustulosa							X				
Phyllidia varicosa							X				
Phyllidia sp.								X			
Family Unknown											
nudibranch								X			
SUBCLASS PULMONATA											
ORDER BASOMMATOPHORA											
Family Siphonariidae											
Siphonaria normalis	X	X									
CLASS BIVALVIA											
Family Arcidae											
Anadara antiquata (shell only)	X										
Family Chamidae											
Chama sp.	X					X					
Family Isognomonidae											
Isognomon perna		X									
Family Malleidae											
Malleus regula	X										
Family Mytilidae											
Lithophaga zittelliana				X		X	X	X	X	X	X
Modiolus auriculatus (shell only)		X									
Modiolus vagina		X									
Family Ostreidae											
Hyotissa hyotis	X										
Lopha cristagalli	X										
rock oyster (large, flat)	X							X			

APPENDIX 1. Marine Species Identified at Kwajalein Atoll.

	KWAJ.	GUG.	MECK	ENIW.	OMELEK	GELL.	GAGAN	ROI.	ENNY.	LEGAN	ILLEG.
Family Pectinidae											
scallop	X										
Family Pinnidae											
Pinna muricata (shell only)		X						X			
Family Pteriidae											
Pinctada margaritifera									X		X
Family Spondylidae											
Spondylus varians	X										
Spondylus sp.			X								
Spondylus spp.	X										
Family Tellinidae											
Scutarcopagia linguafelis (shell only)				X							
Family Tridacnidae											
Hippopus hippopus			X		X	X				X	
Tridacna gigas						X	X				
Tridacna maxima			X	X	X	X		X	X	X	X
Tridacna squamosa			X			X				X	X
Tridacna sp.	X						X				
Family Veneridae											
Periglypta reticulata		X	X			X					
CLASS CEPHALOPODA											
ORDER OCTOPODA											
Family Octopodidae											
Octopus sp.	X		X		X					X	
SUBCLASS NAUTILOIDEA											
Family Nautilidae											
Nautilus sp. (shell only)											
PHYLUM ANNELIDA											
CLASS POLYCHAETA											
Family Amphinomidae											
Eurythoe complanata								X			
Family Sabellidae											
Sabellastarte sanctijosephi								X			
Family Serpulidae											
Spirobranchus giganteus			X								
Family Spirorbidae											
spirorbid sp.						X					
Family Terebellidae											
spaghetti worm	X					X					
PHYLUM ARTHROPODA											
SUBPHYLUM CRUSTACEA											
CLASS MAXILLOPODA											
SUBCLASS CIRRIPEDIA											

APPENDIX 1. Marine Species Identified at Kwajalein Atoll.

	KWAJ.	GUG.	MECK	ENIW.	OMELEK	GELL.	GAGAN	ROI.	ENNY.	LEGAN	ILLEG.	
ORDER THORACICA												
SUBORDER BALANOMORPHA												
SUPERFAMILY CORONULOIDEA												
Family Tetraclitidae												
Tesseropora pacifica	X		X		X			X	X	X	X	
ORDER UNKNOWN												
Family Unknown												
barnacle (small)		X										
barnacle sp. (in Millepora)					X		X					
barnacle sp. (in Astreopora)					X							
CLASS MALACOSTRACA												
ORDER STOMATOPODA												
Family Unknown												
stomatopods	X							X				
ORDER DECAPODA												
SUBORDER PLEOCYEMATA												
INFRAORDER STENOPODIDEA												
Family Stenopodidae												
Stenopus hispidus	X											
INFRAORDER CARIDEA												
SUPERFAMILY ALPHEOIDEA												
Family Alpheidae												
alpheids (in Lobophyllia)								X				
alpheids (in Pocillopora)					X	X						
alpheid sp.								X				
Alpheus sp. (commensal with goby)						X		X		X	X	
Alpheus sp. (in Porites lutea)					X	X		X	X			
Family Hippolytidae												
Saron marmoratus	X											
INFRAORDER PALINURA												
SUPERFAMILY PALINUROIDEA												
Family Palinuridae												
Panulirus longipes femoristriga	X											
Panulirus penicillatus			X									
Panulirus sp. (unidentified)	X											
Family Scyllaridae												
Parribacus sp. (probably P. antarcticus)		X										
Family Synaxidae												
Palinurellus wieneckii	X											
INFRAORDER ANOMURA												
SUPERFAMILY THALASSINOIDEA												
Family Callianassidae												
callianassid sp. 1 (burrows in rubble)		X							X			X
callianassid sp. 2 (sand mounds)	X			X		X		X	X		X	

APPENDIX 1. Marine Species Identified at Kwajalein Atoll.

	KWAJ.	GUG.	MECK	ENIW.	OMELEK	GELL.	GAGAN	ROI.	ENNY.	LEGAN	ILLEG.	
INFRAORDER CARIDEA												
SUPERFAMILY ALPHEOIDEA												
Family Alpheidae												
alpheids (in Lobophyllia)								X				
alpheids (in Pocillopora)					X	X						
alpheid sp.								X				
Alpheus sp. (commensal with goby)						X		X		X	X	
Alpheus sp. (in Porites lutea)					X	X		X	X			
Family Hippolytidae												
Saron marmoratus	X											
INFRAORDER PALINURA												
SUPERFAMILY PALINUROIDEA												
Family Palinuridae												
Panulirus longipes femoristriga	X											
Panulirus penicillatus			X									
Panulirus sp. (unidentified)	X											
Family Scyllaridae												
Parribacus sp. (probably P. antarcticus)		X										
Family Synaxidae												
Palinurellus wieneckii	X											
INFRAORDER ANOMURA												
SUPERFAMILY THALASSINOIDEA												
Family Callianassidae												
callianassid sp. 1 (burrows in rubble)		X							X			X
callianassid sp. 2 (sand mounds)	X			X		X		X	X		X	
SUPERFAMILY PAGUROIDEA												
Family Coenobitidae												
Coenobita spp.			X		X	X						
Family Diogenidae												
Calcinus elegans	X	X										
Calcinus imperialis			X									
Calcinus laevimanus	X	X	X					X				
Calcinus latens	X		X									
Calcinus seurati			X									
Clibanarius sp.	X		X			X						
Dardanus guttatus	X											
Dardanus megistos			X									
Dardanus sp. (large)	X		X			X				X		
hermit with anemone on shell		X										
hermit crabs	X		X					X		X		
SUPERFAMILY GALATHEOIDEA												
Family Porcellanidae												
Neopetrolisthes sp.							X					
Petrolisthes spp.			X				X	X				

APPENDIX 1. Marine Species Identified at Kwajalein Atoll.

	KWAJ.	GUG.	MECK	ENIW.	OMELEK	GELL.	GAGAN	ROI.	ENNY.	LEGAN	ILLEG.
INFRAORDER BRACHYURA											
SECTION OXYRHYNCHA											
SUPERFAMILY MAJOIDEA											
Family Majidae											
spider crab	X						X				
SECTION BRACHYRHYNCHA											
SUPERFAMILY PORTUNOIDEA											
Family Portunidae											
portunid crab								X			
Thalamita sp. 1	X							X			
Thalamita sp. 2										X	
SUPERFAMILY XANTHOIDEA											
Family Xanthidae											
Carpilius convexus											
Carpilius maculatus											X
Cymo andreossyi	X										
Cymo deplanatus	X										
Eriphia sebana			X				X	X			
Etisus sp. (carapace only)	X										
Lybia sp.											
Lydia? sp.							X				
Paraxanthias sp.	X										
Pilodius areolatus			X								
Pseudozius caystrus						X					
Trapezia guttata	X										
Trapezia rufopunctata			X								
Trapezia sp. (orange)			X								
Trapezia sp. (red with white stripes)							X				
Trapezia sp. (white with red spots)		X									
Trapezia? sp. (white)						X					
Trapezia sp.	X					X					
SUPERFAMILY GRAPSOIDEA											
Family Gecarcinidae											
Gecarcoidea lalandii											
Family Grapsidae											
Cyclograpsus? sp.							X				
Geograpsus sp.							X				
grapsid sp.						X	X				
Grapsus tenuicrustatus	X	X	X	X	X	X	X		X	X	
Percnon planissimum	X		X								
Plagusia sp.	X							X			
SUPERFAMILY OCYPODOIDEA											
Family Ocypodidae											
Ocypode ceratophthalma									X		
Ocypode sp.	X		X								
Family Cryptochiridae											
cryptochirid sp. (in P. damicornis)						X	X				

APPENDIX 1. Marine Species Identified at Kwajalein Atoll.

	KWAJ.	GUG.	MECK	ENIW.	OMELEK	GELL.	GAGAN	ROI.	ENNY.	LEGAN	ILLEG.
PHYLUM ECHINODERMATA											
CLASS CRINOIDEA											
Family Colobometridae											
Oligometra serripinna						X					
CLASS HOLOTHUROIDEA											
ORDER DENDROCHIROTIDA											
Family Cucumariidae											
Afrocucumis africana	X		X				X				
ORDER ASPIDOCHIROTIDA											
Family Holothuriidae											
Actinopyga echinites		X									
Actinopyga mauritiana	X	X	X	X	X	X	X		X	X	
Bohadschia argus	X	X	X					X			
Bohadschia vitiensis								X			
Holothuria (Halodeima) atra	X	X	X		X			X			X
Holothuria (Halodeima) edulis								X			
Holothuria (Thymiosycia) hilla		X	X					X			
Holothuria (Mertensiothuria) leucospilota			X						X		X
Holothuria (Microthele) nobilis		X			X						
Holothuria (Mertensiothuria) pervicax			X	X							
Labidodemas sp.	X										
Family Stichopodidae											
Stichopus chloronotus	X										
Thelenota ananas	X						X	X			
ORDER APOPIDA											
Family Synaptidae											
Euapta godeffroyi			X								
Synapta maculata	X	X									
CLASS ASTEROIDEA											
Family Acanthasteridae											
Acanthaster planci	X					X	X			X	
Family Echinasteridae											
Echinaster luzonicus	X										
Echinaster sp.										X	X
Family Oreasteridae											
Culcita novaeguineae	X				X			X			
Family Ophidiasteridae											
Fromia milleporella	X			X		X					
Leiaster sp.							X				
Linckia laevigata	X										
Linckia multifora	X			X			X				
CLASS OPHIUROIDEA											
Family Ophiocomidae											
Ophiocoma erinaceus		X									
Family Ophionereididae											
Ophionereis spp.				X		X					
Family Ophiuridae											
Ophioplocus sp.							X				

APPENDIX 1. Marine Species Identified at Kwajalein Atoll.

	KWAJ.	GUG.	MECK	ENIW.	OMELEK	GELL.	GAGAN	ROI.	ENNY.	LEGAN	ILLEG.
Family Unknown											
ophiuroids	X							X		X	
CLASS ECHINOIDEA											
Family Brissidae											
Brissopsis luzonica					X	X					
Brissus latecarinatus					X						
Family Diadematidae											
Diadema savignyi		X	X								
Echinothrix calamaris	X										
Echinothrix diadema	X	X	X	X	X	X	X	X	X	X	
Family Echinometridae											
Echinometra mathaei	X			X	X	X	X	X	X		
Echinometra oblonga	X										
Echinostrephus aciculatus			X	X	X	X	X	X	X	X	
Heterocentrotus mammillatus	X						X				
Heterocentrotus trigonarius (spines)								X			
Family Toxopneustidae											
Toxopneustes pileolus	X										
Tripneustes gratilla	X										
PHYLUM HEMICHORDATA											
CLASS ENTEROPNEUSTA											
Family Ptychoderidae											
?Ptychodera flava				X				X			X
PHYLUM CHORDATA											
SUBPHYLUM TUNICATA											
CLASS ASCIDIACEA											
ORDER APLOUSOBRANCHIATA											
Family Didemnidae											
Eudistoma sp.			X						X	X	X
tunicate (colonial)	X		X		X	X		X	X		X
ORDER UNKNOWN											
Family Unknown											
tunicate (large, brownish)								X			
tunicate (large, yellow)				X				X			X
tunicates	X							X		X	
PHYLUM CHORDATA											
CLASS CHONDRICHTHYS											
ORDER LAMNIFORMES											
Family Carcharhinidae											
Carcharhinus albimarginatus											X
Carcharhinus amblyrhynchos											X
Carcharhinus melanopterus			X	X		X	X			X	X
Triaenodon obesus				X			X			X	X
Family Ginglymostomatidae											
Nebrius concolor					X						X

APPENDIX 1. Marine Species Identified at Kwajalein Atoll.

	KWAJ.	GUG.	MECK	ENIW.	OMELEK	GELL.	GAGAN	ROI.	ENNY.	LEGAN	ILLEG.
ORDER RAJIFORMES											
Family Dasyatididae											
Dasyatis kuhlii				X				X			
stingray			X								
Family Mobulidae											
Manta alfredi						X					
Family Myliobatidae											
Aetobatus narinari			X							X	
CLASS OSTEICHTHYES											
ORDER ANGUILLIFORMES											
Family Muraenidae											
Echidna nebulosa	X		X								
Gymnothorax flavimarginatus	X		X								
Gymnothorax meleagris						X					
ORDER SALMONIFORMES											
Family Synodontidae											
Saurida gracilis	X										
Synodus variegatus	X	X	X				X	X			
Synodus sp.	X		X		X		X				
ORDER GONORHYNCHIFORMES											
Family Chanidae											
Chanos chanos						X		X			
ORDER ATHERINIFORMES											
Family Atherinidae											
bait fish	X		X					X			
Family Belonidae											
Platybelone argalus	X										
Strongylura incisa			X								
Family Hemiramphidae											
Hemiramphus sp.	X	X	X		X	X		X			
ORDER BERYCIFORMES											
Family Holocentridae											
Myripristis berndti					X	X					
Myripristis kuntee	X		X		X			X		X	
Neoniphon opercularis			X			X					
Neoniphon sammara	X	X	X		X	X	X				
Neoniphon sp.	X										
Sargocentron caudimaculatus	X										
Sargocentron diadema	X							X			
Sargocentron punctatissimum	X		X								
Sargocentron spiniferum	X		X				X				
ORDER GASTEROSTEIFORMES											
Family Aulostomidae											
Aulostomus chinensis	X				X		X				
Family Fistulariidae											
Fistularia commersonii	X		X			X	X				
Family Syngnathidae											
Corythoichthys intestinalis	X	X	X					X		X	X

APPENDIX 1. Marine Species Identified at Kwajalein Atoll.

	KWAJ.	GUG.	MECK	ENIW.	OMELEK	GELL.	GAGAN	ROI.	ENNY.	LEGAN	ILLEG.
ORDER SCORPAENIFORMES											
Family Scorpaenidae											
Pterois antennata	X										
Pterois volitans								X			
ORDER PERCIFORMES											
Family Acanthuridae											
Acanthurus achilles	X					X	X				
Acanthurus guttatus	X		X	X	X	X			X	X	X
Acanthurus lineatus	X		X	X	X	X	X	X	X	X	X
Acanthurus mata	X		X	X	X	X	X	X	X	X	X
Acanthurus nigricans	X			X		X			X		
Acanthurus nigrofuscus	X										
Acanthurus nigroris					X			X		X	
Acanthurus olivaceus	X		X	X	X	X	X			X	X
Acanthurus pyroferus	X		X	X	X	X	X		X	X	
Acanthurus thompsoni										X	
Acanthurus triostegus	X	X	X	X	X	X	X	X			
Acanthurus xanthopterus				X			X		X	X	
Ctenochaetus striatus	X		X	X		X	X	X		X	X
Ctenochaetus strigosus	X	X					X		X		X
Naso brevirostris	X										
Naso hexacanthus	X					X					X
Naso lituratus	X		X	X	X	X	X	X		X	X
Naso unicornis	X		X		X		X		X		
Zebrasoma scopas	X	X			X	X	X	X		X	X
Zebrasoma veliferum	X					X		X			
Family Apogonidae											
Apogon cyanosoma	X							X			
Apogon novemfasciatus	X										
Apogon sp.	X		X		X						
Family Blenniidae											
Aspidontus taeniatus	X				X	X	X				
Exallias brevis						X	X				
Istiblennius lineatus								X			
Istiblennius sp. (green)	X										
Family Bothidae											
Bothus sp.			X	X	X			X			
Family Caesionidae											
Caesio teres					X					X	
Pterocaesio marri						X					
Family Carangidae											
Caranx melampygus	X		X			X	X	X		X	X
Decapterus sp.				X							
Gnathanodon speciosus							X				
Trachinotus bailloni							X			X	
Trachinotus blochii							X				

APPENDIX 1. Marine Species Identified at Kwajalein Atoll.

	KWAJ.	GUG.	MECK	ENIW.	OMELEK	GELL.	GAGAN	ROI.	ENNY.	LEGAN	ILLEG.
Family Centrarchidae											
Lepomis macrochirus	X			X	X	X	X				
Family Chaetodontidae											
Chaetodon auriga	X		X	X		X	X	X	X	X	X
Chaetodon bennetti	X										
Chaetodon citrinellus	X	X	X	X	X	X	X	X	X	X	X
Chaetodon ephippium	X	X	X		X	X		X	X	X	X
Chaetodon lineolatus	X		X					X			X
Chaetodon lunula	X	X	X		X	X	X	X	X	X	X
Chaetodon meyeri										X	
Chaetodon ornatissimus	X	X	X		X		X	X	X	X	X
Chaetodon rafflesi		X									
Chaetodon reticulatus	X		X		X	X	X	X	X	X	X
Chaetodon trifascialis	X	X			X	X	X				
Chaetodon trifasciatus									X	X	
Chaetodon unimaculatus					X						X
Chaetodon vagabundus	X				X	X	X	X	X		X
Forcipiger flavissimus										X	
Heniochus acuminatus								X			
Heniochus chrysostomus								X			
Family Cirrhitidae											
Paracirrhites arcatus	X		X	X	X	X	X		X	X	X
Paracirrhites forsteri	X						X			X	
Family Ephippididae											
Platax orbicularis	X										
Family Gobiidae											
Istigobius rigilius								X			
Valenciennea strigatus	X		X		X	X		X		X	
Family Grammistidae											
Grammistes sexlineatus	X										
Family Haemulidae											
Plectorhinchus sp.			X								
Family Kuhliidae											
Kuhlia mugil	X		X			X		X			
Family Kyphosidae											
Kyphosus cinerascens	X	X	X	X	X	X	X	X	X	X	X
Kyphosus vaigiensis			X								
Kyphosus sp.	X		X		X						
Family Labridae											
Anampses caeruleopunctatus	X						X				
Anampses cuvier						X					
Anampses melanurus					X	X					
Anampses meleagrides					X						
Anampses twistii							X				
Bodianus axillaris	X			X			X			X	
Bodianus bilunulatus					X						
Bodianus bimaculatus					X						

APPENDIX 1. Marine Species Identified at Kwajalein Atóll.

	KWAJ.	GUG.	MECK	ENIW.	OMELEK	GELL.	GAGAN	ROI.	ENNY.	LEGAN	ILLEG.
Cheilinus chlorurus		X	X								
Cheilinus fasciatus				X				X		X	X
Cheilinus unifasciatus	X										
Cheilio inermis	X							X			
Coris aygula	X		X								
Coris gaimard	X		X	X	X	X	X			X	X
Coris picta							X				
Epibulus insidiator	X			X						X	X
Gomphosus varius	X		X		X	X	X	X	X	X	X
Halichoeres chrysus	X	X	X		X	X	X	X	X	X	X
Halichoeres hortulanus	X	X	X	X	X	X	X	X		X	X
Halichoeres margaritaceus	X	X	X	X	X	X	X	X		X	
Halichoeres marginatus	X		X			X		X	X		
Halichoeres miniatus			X								
Halichoeres nebulosus			X								
Halichoeres trimaculatus	X	X	X	X	X	X	X	X	X	X	
Hemigymnus fasciatus			X	X	X						
Hemigymnus melapterus	X		X				X				
Labroides bicolor	X		X		X	X				X	X
Labroides dimidiatus	X	X	X	X	X	X	X	X		X	X
Macropharyngodon meleagris	X		X	X	X	X	X	X		X	
Macropharyngodon moyeri			X								
Macropharyngodon negrosensis			X								
Macropharyngodon sp.								X			
Novaculichthys taeniourus	X		X		X	X	X	X		X	X
Pseudocheilinus hexataenia	X							X			
Stethojulis bandanensis	X	X	X		X	X	X	X	X	X	X
Thalassoma amblycephalum	X							X			
Thalassoma hardwicke			X				X	X			
Thalassoma lunare			X					X			
Thalassoma lutescens			X								X
Thalassoma purpureum			X				X				
Thalassoma quinquevittatum	X	X	X	X	X	X	X	X	X	X	X
Thalassoma trilobatum			X								
wrasse (lemon color)				X							
Family Lethrinidae											
Gnathodentex aureolineatus	X		X		X	X		X			X
Lethrinus amboinensis	X							X			
Lethrinus sp.			X		X	X					
Monotaxis grandoculis	X		X			X	X	X			
Family Lutjanidae											
Aphareus furcatus	X										
Lutjanus bohar										X	
Lutjanus ehrenbergii	X										
Lutjanus fulvus	X	X	X		X	X	X	X		X	
Lutjanus gibbus	X		X				X	X			
Macolor niger					X						X

APPENDIX 1. Marine Species Identified at Kwajalein Atoll.

	KWAJ.	GUG.	MECK	ENIW.	OMELEK	GELL.	GAGAN	ROI.	ENNY.	LEGAN	ILLEG.
Family Microdesmidae											
Ptereleotris evides						X		X			
Ptereleotris sp.								X			
Family Mugilidae											
mullet							X				
Valamugil ?engeli							X				
Family Mugiloididae											
Parapercis clathrata	X			X	X	X	X	X			
Family Mullidae											
Mulloides flavolineatus	X		X					X			
Mulloides vanicolensis	X		X		X	X	X			X	X
Parupeneus barberinus	X		X		X	X		X	X	X	X
Parupeneus bifasciatus	X		X		X	X	X	X			
Parupeneus cyclostomus	X		X	X	X	X				X	X
Parupeneus multifasciatus	X		X	X	X	X	X	X	X	X	X
Parupeneus pleurostigma			X								
Upeneus arge	X										
Upeneus subvittatus								X			
Family Nemipteridae											
Pentapodus macrurus						X					
Scolopsis lineatus	X				X	X		X			
Family Pempherididae											
Pempheris oualensis			X								
Family Pomacanthidae											
Centropyge bicolor						X					
Centropyge flavissimus	X	X	X	X	X	X	X	X	X	X	X
Centropyge heraldi										X	
Centropyge shepardi	X										
Pomacanthus imperator									X		
Pygoplites diacanthus	X			X						X	X
Family Pomacentridae											
Abudefduf sexfasciatus	X							X			X
Abudefduf sordidus	X	X	X	X		X		X		X	
Abudefduf sp.	X										
Amblyglyphidodon curacao	X		X		X	X	X	X			X
Amphiprion chrysopterus			X			X		X			X
Amphiprion melanopus					X	X	X	X		X	X
Chromis atripectoralis			X								
Chromis margaritifer	X	X	X			X	X		X	X	
Chromis viridis	X	X	X		X	X	X	X	X	X	X
Chrysiptera glauca	X	X					X	X			
Chrysiptera leucopoma	X	X	X		X	X	X	X		X	X
Chrysiptera traceyi	X		X		X	X		X		X	X
Dascyllus aruanus	X	X			X	X		X		X	X
Dascyllus reticulatus	X		X		X	X	X	X		X	X
Dascyllus trimaculatus	X										
Plectroglyphidodon dickii	X	X	X	X	X	X	X	X	X	X	X

APPENDIX 1. Marine Species Identified at Kwajalein Atoll.

	KWAJ.	GUG.	MECK	ENIW.	OMELEK	GELL.	GAGAN	ROI.	ENNY.	LEGAN	ILLEG.
Plectroglyphidodon lacrymatus	X		X		X	X	X	X		X	X
Plectroglyphidodon leucozona	X		X					X			
Pomacentridae sp.								X			
Pomacentrus pavo	X			X	X	X	X	X	X	X	X
Pomacentrus vaiuli	X				X	X	X	X		X	X
Pomacentrus sp.			X								
Stegastes albifasciatus			X					X			
Stegastes fasciolatus	X		X							X	
Stegastes lividus								X			
Stegastes nigricans	X	X	X	X	X	X	X	X	X	X	X
Family Scaridae											
Bolbometopon muricatum						X					
Calotomus carolinus	X			X	X	X	X			X	
Calotomus spinidens			X	X			X	X			
Calotomus sp.	X										
Scarus forsteni	X										
Scarus frenatus									X		
Scarus frontalis						X					
Scarus gibbus	X		X	X	X	X	X		X	X	X
Scarus oviceps			X	X	X	X	X	X			X
Scarus psittacus	X		X								
Scarus rubroviolaceus			X	X	X						
Scarus schlegeli				X							
Scarus sordidus	X		X	X	X	X	X	X	X	X	X
Scarus sp.								X	X	X	X
Scarus spp.	X	X	X	X	X	X	X				
Family Serranidae											
Cephalopholis argus	X	X	X	X		X	X				
Cephalopholis urodelus	X	X		X	X	X		X		X	X
Epinephelus fasciatus			X								
Epinephelus hexagonatus	X	X	X		X	X	X	X		X	
Epinephelus merra	X	X						X			
Epinephelus microdon	X										
Epinephelus sp.	X				X						
Plectropomus areolatus						X					
Variola louti	X		X	X		X				X	X
Family Siganidae											
Siganus argenteus	X		X				X				
Siganus spinus	X										
Siganus vulpinus	X		X			X					
Family Zanclidae											
Zanclus cornutus	X		X	X	X	X	X	X	X	X	X
ORDER TETRAODONTIFORMES											
Family Balistidae											
Balistapus undulatus	X				X	X				X	
Balistoides conspicillum									X	X	
Balistoides viridescens						X				X	X

APPENDIX 1. Marine Species Identified at Kwajalein Atoll.

	KWAJ.	GUG.	MECK	ENIW.	OMELEK	GELL.	GAGAN	ROI.	ENNY.	LEGAN	ILLEG.
Balistidae sp. 1 (brown)				X							
Melichthys niger						X					X
Melichthys vidua			X		X	X				X	X
Rhinecanthus aculeatus	X	X	X		X	X		X	X	X	X
Rhinecanthus rectangulus	X		X	X	X	X			X		
Sufflamen bursa											X
Sufflamen chrysopterus			X		X	X		X	X	X	X
Family Diodontidae											
Diodon hystrix	X		X				X	X			X
Diodon sp.	X										
Family Monacanthidae											
Oxymonacanthus longirostris	X		X		X	X	X	X		X	X
Paraluteres prionurus					X					X	
Family Ostraciidae											
Lactoria cornuta								X			
Ostracion cubicus	X									X	
Ostracion meleagris	X		X								
Family Tetraodontidae											
Arothron hispidus	X										
Arothron meleagris	X		X				X			X	X
Canthigaster solandri	X	X	X				X	X			
PHYLUM CHORDATA											
CLASS REPTILIA											
ORDER TESTUDINES											
Family Cheloniidae											
Chelonia mydas		X					X	X			

APPENDIX 2. FIELD STUDY PERSONNEL

Paul Jokiel, Ph.D
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Specialty: Reef Corals

Anne M. Orcutt, BA
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Honolulu, Hawaii 96822
Specialty: Ichthyology

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Sea Grant Extension Service
University of Hawaii
Honolulu, Hawaii 96822
Specialty: Resource User Interviewer

Robert H. Richmond, Ph.D
Assistant Professor of Marine Biology
Marine Laboratory
University of Guam
UOG Station
Mangilao, Guam 96923
Specialty: Coral Biology/Larval Ecology/Invertebrate Zoology

Barry D. Smith, MS
Marine Laboratory
University of Guam
UOG Station
Mangilao, Guam 96923
Specialty: Benthic Macroinvertebrate Biologist

Richard H. Titgen, Ph.D
Sea Grant Extension Service
University of Hawaii
Honolulu, Hawaii 96822
Specialty: Carcinology/Invertebrate Zoology

Susanne T. Wilkins, MS
Research Assistant
Marine Laboratory
University of Guam
UOG Station
Mangilao, Guam 96923
Specialty: Phycology

APPENDIX 3.COASTAL FISHES OF KWAJALEIN ATOLL.

This list represents the working master fish list used during the Kwajalein Atoll coastal resource user interview sessions conducted by Peter Rappa and R. Virgil Alfred. The list was compiled by Mr. Alfred and Anne Orcutt. As time permitted, an attempt was made to verify as many scientific names as possible.

	COMMON NAME	MARSHALLESE NAME	SCIENTIFIC NAME
1.	Parrot Fish	Mera	Scarus sp. Calotomus sp.
2.	Squirrel Fish	Mon, Jera	Myripristis sp. Sargocentron sp.
3.	Goat Fish	Jo, Jome, Jolokmor, Motal	Mulloides sp. Parupeneus sp.
4.	Surgeon Fish	Ael, Mok, Kobat, Kwi, Bwilak	Acanthurus sp
5.	Grouper	Kiro, Lejebjeb, Booklim, Olalo, Jawe, Jowame, Joanuron	Variola louti Epinephelus sp. Plectropomus spp.
6.	Unicorn Fish	Mone, Bataklaj, Ikonae, Narbok	Naso hexacanthus Naso unicornis
7.	Gray Jobfish	Laum	Aprion virescens
8.	Jack Fish	Lane, Ikibwuj, Dedeb, Manol, Deltokrok	Caranx spp. Carangoides sp.
9.	Snapper	Jato, Jetar, Jeblo Jalia, Dijin	Lutjanus spp.
10.	Rabbit Fish	Ellok, Muramor	Siganus spp.
11.	Emperor Fish	Mejakut, Mojani, Kie	Lethrinus spp.
12.	Mullet	Iiol, Aotak, Akor	Valamugil sp. Crenimugil sp.
13.	Rudder Fish	Bejrok	Kyphosus spp.
14.	Convict Tang	Kuban	Acanthurus triostegus
15.	Trigger Fish	Imim, Bub, Liele, Jonamre	Pseudobalistes sp. Melichthys sp. Rhinecanthus

		aculeatus
16. Scad	Molmol, Bati	
17. Silver Fish	Ilmok	_Plectropomus laevis_
18. Sweetlips Porgy	Kentol	_Plectorhynchus_ sp.
19. Wahoo	Al	_Acanthocybium solandri_
20. Dolphin Fish	Koko	_Coryphaena hippurus_
21. Tuna	Bwebwe, Lojabwil, Looj,	_Thunnus albacares_
	Jilo	_Katsuwonus pelamis_
		Gymnosarda unicolor
		Euthynnus affinis
22. Barracuda	Nitua, Jure, Jujukob	_Sphyraena barracuda_
23. Marlin	Lojkaan	
24. Flying Fish	Jojo	
25. Sharks (all types)	Bako	
26. Turtles (all types)	Won	
27. Lobster	Wor	
28. Trochus Shell	Likebbejdat, Likadboulul	_Trochus_ sp.
29. Turban Shell	Jidduul	
30. Clams	Mejenwod, Dimuj, Totwod,	_Tridacna maxima_
	Kabwor	_Tridacna gigas_

APPENDIX 4. RESOURCE INFORMATION FROM INTERVIEWS.

ISLAND: EBEYE
PLACE: KADA CONFERENCE ROOM
DAY & TIME: THURSDAY, 12/10/87

Participants: R. Virgil Alfred (MIMRA)
Peter J. Rappa (SGES)
Wilmer Bolkeim
Ned Namra
Mijiki Jacob
En Lik
Kadrik Lemar
Anjeion Jorling
Abin Jaedrik

Fish Number	Common Fish Name	Method of Fishing Commonly Used	Season To Fish
1	Yellowtail Parrot Fish	Handline	Dec-Jan
2	Squirrel Fish	Night spear fishing with torch	Winter All Year
3	Goat Fish	Cast or Gill Net	All Year
4	Surgeon Fish	Spear fishing	All Year
5	Striped Surgeon Fish	Spear fishing	All Year
6	Grouper	Handline	
7	Unicorn Fish	Spear fishing & gill netting	All Year
8	Grouper	Handline	Winter
9	Gray Job Fish	Handline	All Year
10	Jack Fish	Handline	All Year
12	Wrasses	Cast Net	All Year
14	Rabbit Fish	Night Spearfishing	
15	White-lined Cob	Handline	Dec-Jan
16	Emperor Fish	Handline & gill netting	All Year
18	Flower Carpetcod	Handline	Winter
19	Mullet	Gill netting & Cast net	All Year
20	Rudder Fish	Gill net/Diving net	
21	Jack Fish	Handline	All Year
24	Mahimahi	Trolling	Winter
25	Yellowfin Tuna	Trolling	All Year

Fish Number	Common Fish Name	Method of Fishing Commonly Used	Season To Fish
26	Trigger Fish	Traditional method	All Year
27	Grouper	Pole & Line	All Year
28	Skipjack Tuna	Gill net	Summer
29	Pompano	Cast net	All Year
30	Dogfish Tuna	Trolling	
31	Spotted Grouper	Handline	All Year
33	Surgeon Fish	Spearfishing & gill netting	
35	Snapper	Handline	All Year
38	Flying Fish	Torch & Scoop net	
39	Grouper	Handline	Winter
40	Solder Fish	Handline & Gill net	
42	Snapper	Handline & Rod and reel	
44	Jack Fish	Handline	All Year
45	Wahoo	Trolling	
46	Crabs	Hand	All Year
47	Coconut Crabs	Hand (night time)	All Year
48	Clams	Hand	All Year
49	Turtle	?	?
50	Spider Conch	Hand	?
51	Squid	Cast line	
52	Octopus	Diving	
53	Lobsters	Diving/Spearing	
55	Unicorn Fish	Spear fishing & gill netting	All Year
58	Convict Tang	Cast or gill net	
61	Spiny Puffer Fish	Spear fishing	All Year
62	Balloon Fish	Spear fishing	
63	Surgeon Fish	Coral hands	
64	Scad	Traditional method	All Year
67	Grouper	Handline	Winter
68	Slipper Lobster	Diving/Reef with torch	Winter
69	Blacktip shark	DO NOT FISH	

ISLAND: ENNUBIRR
PLACE: SCHOOL HOUSE
DAY & TIME: FRIDAY, DEC. 12, 1987

PARTICIPANTS: R. Virgil Alfred (MIMRA)
Peter J. Rappa (SGES)
Josa Joseph
Ridle Tatius
Jolly Anitak
Carlson James
Anderson Thomas
Gilbert Calep
Nakishi Mejbon
Stanley James
Johnsay Kobeney

Fish Number	Common Fish Name	Method of Fishing Commonly Used	Season To Fish
1	Yellowtail Parrot Fish	Handline	Dec-Jan
2	Squirrel Fish	Trolling	Night Time
5	Striped Surgeon Fish	Spear fishing	All Year
6	Grouper	Fly fishing	
7	Unicorn Fish	Spear fishing	
8	Grouper	Line fishing	
9	Gray job Fish	Line fishing	
11	Goat Fish	Reef fishing	
13	Snapper	Line fishing	
14	Rabbit Fish	Spear fishing	All Year
16	Emperor Fish	Handline	Winter
17	Snapper	Handline	
18	Flower Carpetcod	Handline	
19	Mullet	Net fishing, gill net	
24	Mahimahi	Trolling	Winter
25	Yellowfin Tuna	Trolling	Apr-May Dec-Jan
28	Skipjack Tuna	Trolling	Jun-Jul
29	Pompano	Cast net	
30	Dogfish Tuna	Trolling	Night time
32	Barracuda	Trolling	
33	Surgeon Fish	Spear fishing	All Year
37	Snapper	Handline & gill net	
38	Flying Fish	Scoop net	
41	Rainbow Runner	Trolling	

ISLAND: MAJETTO
PLACE: LOCAL HOME
DAY & TIME: MONDAY, DEC. 14, 1987

PARTICIPANTS:
R. Virgil Alfred (MIMRA)
Peter J. Rappa (SGES)
Annie Orcutt (SGES)
Kallin Edmond
Kelok Majednik
Corless F.
Kobang Anjain
Jorsu Anjain
Lelei Edmond
Atti Kun
Mark M.
Rocky J.
Isaac E.
Ratei Anitak

Fish Number	Common Fish Name	Method of Fishing Commonly Used	Season To Fish
3	Goat Fish	Cast net	
14	Rabbit Fish	Surround net	
20	Rudder Fish	Spear fishing; Pole & Line	
25	Yellowfin Tuna	Trolling	Winter
27	Grouper	Spear; Pole & Line	
30	Dogfish Tuna	Trolling/Handline	
33	Surgeon Fish	Spear fishing	
35	Snapper	Spear fishing	
47	Coconut Crab		
37	Snapper	Spear fishing	
48	Clams		
49	Turtles	Dive & Spear	
53	Lobsters	Diving	
65	Scad	Net fishing; Stone trap	
66	Silver Fish	Casting, net fishing	
69	Blacktip shark		
70	Surgeon Fish	Spear fishing	

ISLAND: EBADON
PLACE: LOCAL HOME
DAY & TIME: MONDAY, DEC. 14, 1987

PARTICIPANTS: R. Virgil Alfred (MIMRA)
Peter J. Rappa (SGES)
Annie M. Orcutt (SGES)
Edward Jaedrik
Swington Roadrik
Biamon Janilong
Jally Neamon
Helken Lee
Carlson Band
Alec Jaedrik
Isaac Edmond
Romen Kios
Jae Roadrik
Lee Namon
Kenja Tamlo
Tony Neamon
Bondrik Kalewa
Tar Ablo
Ainahaina Shima
Jebane Livai
Key Blamon
Alice Pound

Fish Number	Common Fish Name	Method of Fishing Commonly Used	Season To Fish
3	Goat Fish	Cast net	
12	Wrasses	Nets	All Year
14	Rabbit Fish	Nets	
19	Mullet	Nets	All Year
20	Rudder Fish	Nets	All Year
24	Mahimahi	Trolling	All Year
25	Yellowfin Tuna	Trolling	All Year
26	Trigger Fish	Fish Traps	
27	Grouper	Spear fishing	
30	Dogfish Tuna	Trolling	All Year
33	Surgeon Fish	Net	
46	Crabs		
47	Coconut Crab	Hand harvest	
48	Clams	Hand harvest	
49	Turtles		

Fish Number	Common Fish Name	Method of Fishing Commonly Used	Season To Fish
52	Octopus	Spear fishing	
53	Lobsters	Hand harvest	
65	Scad	Stone Trap	Winter
69	Blacktip Shark		
72	Squirrel Fish	Spear fishing	
73	Top Shell	Hand harvest	
74	Snapper	Handline	
75	Long Nose Emperor Fish	Spear fishing	
76	Turban Shell	Hand harvest	
79	Mackerel Tuna	Trolling	All Year
80	Flag tail Fish	Nets	All Year

ISLAND: KWAJALEIN
PLACE: BOAT YARD (ROUND HOUSE)
DAY & TIME: TUESDAY, DEC. 15, 1987

PARTICIPANTS: R. Virgil Alfred (MIMRA)
Peter J. Rappa (SGES)
Annie M. Orcutt (SGES)
Paul G. Thomas
Bob G. Gould
Jim Friel
Bob Shimamoto
Ed Borges

Fish Number	Common Fish Name	Method of Fishing Commonly Used	Season To Fish
2	Squirrel Fish	Spear	
7	Unicorn Fish		
14	Rabbit Fish		
20	Rudder Fish		
24	Mahimahi	Trolling or Baited hook	Winter
25	Yellowfin Tuna		
28	Skipjack Tuna		
29	Pompano	Net or Pole line	Jun-Oct
30	Dogfish Tuna	Diving	
31	Spotted Grouper		
32	Barracuda		
38	Flying Fish		
41	Rainbow Runner		
45	Wahoo		
49	Turtles		
53	Lobsters	Hand harvest	
58	Convict Tang		
72	Squirrel Fish	Spear fishing	All Year
81	Blue Marlin	Trolling or Baited	Winter
82	Parrot Fish	Night spear fishing	
84	Mullet		
85	Helmet Shells	Hand harvest	
86	Neritid Snails	Hand harvest	
87	Flag Tail Fish	Nets	

APPENDIX 5. Marine Species Identified in Kwajalein Atoll Quarries.

	KWAJ.	GUG.	MECK	OMELEK	GELL.	GAGAN	LEGAN	ILLEG.
Algae								
DIVISION CYANOPHYTA								
CLASS CYANOPHYCEAE								
ORDER CHROOCOCCALES								
Family Chamaesiphonaceae								
Entophysalis sp.			X					
ORDER OSCILLATORIALES								
Family Nostocaceae								
Hormothamnion enteromorphoides			X			X		
Family Oscillatoriaceae								
Microcoleus lyngbyaceus			X					
Schizothrix calcicola	X	X	X				X	X
Schizothrix mexicana		X	X					
ORDER UNKNOWN								
Family Unknown								
blue-green algae	X		X					
DIVISION CHLOROPHYTA								
CLASS CHLOROPHYCEAE								
ORDER CAULERPALES								
Family Caulerpaceae								
Caulerpa cupressoides					X	X		X
Caulerpa sertularioides		X						
Caulerpa verticillata								X
Caulerpa sp.					X	X		
Family Codiaceae								
Codium arabicum								X
Codium edule								X
Halimeda discoidea						X	X	
Halimeda opuntia			X		X	X	X	
Halimeda sp. 1	X		X					
Udotea indica						X	X	
ORDER SIPHONOCLADALES								
Family Boodleaceae								
Boodlea composita		X						
Family Valoniaceae								
Dictyosphaeria cavernosa					X	X		
Dictyosphaeria versluysii					X	X		
Dictyosphaeria sp.							X	
Valonia ventricosa							X	
ORDER DASYCLADALES								
Family Dasycladaceae								
Acetabularia moebii								X
Neomeris annulata	X		X			X	X	X

APPENDIX 5. Marine Species Identified in Kwajalein Atoll Quarries.

	KWAJ.	GUG.	MECK	OMELEK	GELL.	GAGAN	LEGAN	ILLEG.
ORDER CLADOPHORALES								
Family Anadyomenaceae								
Microdictyon okamurai					X	X	X	
Family Cladophoraceae								
Chaetomorpha sp.								X
DIVISION PHAEOPHYTA								
CLASS PHAEOPHYCEAE								
ORDER ECTOCARPALES								
Family Ralfsiaceae								
Ralfsia occidentalis	X		X					
ORDER DICTYOTALES								
Family Dictyotaceae								
Dictyota bartayresii	X	X						
Dictyota divaricata			X					X
Dictyota friabilis		X	X					X
Dictyota sp.	X							
Lobophora variegata	X		X				X	X
Padina tenuis		X						
Padina sp.	X		X					
ORDER UNKNOWN								
Family Unknown								
Diatom film	X	X	X					
DIVISION RHODOPHYTA								
CLASS FLORIDEOPHYCEAE								
ORDER NEMALIALES								
Family Bonnemaisoniaceae								
Asparagopsis taxiformis			X					X
ORDER CRYPTONEMIALES								
Family Corallinaceae								
coralline algae	X							
Jania capillacea			X			X	X	
Neogoniolithon frutescens					X			
Porolithon gardineri						X		
Porolithon onkodes	X				X	X	X	X
Family Cryptonemiaceae								
Halymenia sp.	X		X					
Family Peyssoneliaceae								
Peyssonelia rubra	X		X		X			
CLASS UNKNOWN								
ORDER UNKNOWN								
Family Unknown								
algal mat	X	X	X		X	X	X	X

APPENDIX 5. Marine Species Identified in Kwajalein Atoll Quarries.

	KWAJ.	GUG.	MECK	OMELEK	GELL.	GAGAN	LEGAN	ILLEG.
PHYLUM SARCODINA								
CLASS RETICULAREA								
ORDER FORAMINIFERIDA								
Family Homotremidae								
Homotrema sp.					X	X	X	
PHYLUM PORIFERA								
CLASS DEMOSPONGIAE								
ORDER HADROMERIDA								
Family Clionidae								
clionid sponge			X		X		X	
CLASS UNKNOWN								
ORDER UNKNOWN								
Family Unknown								
sponge (green)						X		
sponge (orange)						X		
sponges		X						
PHYLUM CNIDARIA								
CLASS HYDROZOA								
ORDER HYDROIDA								
SUBORDER LEPTOMEDUSAE								
Family Plumulariidae								
Aglaophenia sp.			X				X	X
SUBORDER UNKNOWN								
Family Unknown								
hydroids			X			X		
Macrorhynchia phoenicea								X
ORDER SIPHONARIA								
Physalia physalis	X							X
ORDER MILLEPORINA								
Family Milleporidae								
Millepora exaesa	X	X	X		X	X	X	X
Millepora platyphylla			X		X	X	X	
Millepora tenera	X		X		X	X	X	
ORDER STYLASTERINA								
Family Stylasteridae								
Distichopora sp.					X	X	X	
Stylaster sp.							X	
CLASS ANTHOZOA								
SUBCLASS ALCYONARIA								
ORDER ALCYONACEA								
Family Alcyoniidae								
Lobophytum sp.								X
Sarcophyton glaucum							X	
Sinularia polydactyla			X				X	X
Sinularia rigida			X					

APPENDIX 5. Marine Species Identified in Kwajalein Atoll Quarries.

	KWAJ.	GUG.	MECK	OMELEK	GELL.	GAGAN	LEGAN	ILLEG.	
Sinularia sp.	X		X				X	X	
ORDER COENOTHECALIA									
Family Helioporidae									
Heliopora coerulea					X		X		
SUBCLASS ZOANTHARIA									
ORDER ZOANTHIDEA									
Family Zoanthidae									
zoanthids with green center	X								
ORDER ACTINIARIA									
Family Stichodactylidae									
anemone			X				X		
Heteractis aurora						X			
Family Unknown									
anemones	X								
ORDER SCLERACTINIA									
SUBORDER ASTROCOENIINA									
Family Acroporidae									
Acropora cytherea						X			
Acropora formosa						X			
Acropora humilis		X	X			X	X	X	
Acropora hyacinthus						X			
Acropora irregularis						X			
Acropora monticulosa							X	X	
Acropora ocellata						X			
Acropora palifera						X		X	
Acropora valida						X			
Acropora vaughani							X		
Acropora sp. 1	X	X	X				X	X	
Acropora sp. 2	X		X				X	X	
Acropora sp. (encrusting)								X	
Acropora spp. (arborescent)	X								
Acropora spp. (bushy)	X								
Acropora spp. (tables)	X		X						
Acropora spp.	X		X		X		X		
Astreopora sp.			X		X	X	X	X	
Montipora digitata	X	X	X						
Montipora foveolata			X						
Montipora studeri						X			
Montipora verrilli			X						
Montipora verrucosa								X	
Montipora sp. (encrusting)	X								X
Montipora sp. (nobby)						X			
Montipora spp.					X	X	X		
Family Pocilloporidae									
Pocillopora damicornis	X	X	X		X	X			
Pocillopora danae	X								
Pocillopora elegans	X								

APPENDIX 5. Marine Species Identified in Kwajalein Atoll Quarries.

	KWAJ.	GUG.	MECK	OMELEK	GELL.	GAGAN	LEGAN	ILLEG.
Pocillopora eydouxi	X	X	X		X	X		X
Pocillopora meandrina	X		X		X	X		X
Pocillopora verrucosa	X		X		X	X	X	
Pocillopora spp.			X				X	
Stylophora mordax						X		
Stylophora sp.			X					
SUBORDER FUNGIINA								
Family Agariciidae								
Gardineroseris planulata	X		X				X	
Pavona clavus		X					X	X
Pavona varians		X	X			X	X	X
Family Fungiidae								
Fungia (Verillofungia) concinna						X		
Fungia (Fungia) fungites							X	
Fungia (Pleuractis) scutaria	X		X		X	X	X	
Family Poritidae								
Alveopora sp.	X		X		X			
Porites lichen					X		X	
Porites lobata					X			
Porites lutea	X	X	X		X	X	X	X
Porites spp.	X		X			X		
Family Siderastreidae								
Coscinaraea sp.			X					
SUBORDER FAVIINA								
Family Faviidae								
Cyphastrea sp.					X	X	X	
Echinopora sp.						X		
Favia stelligera						X	X	
Favia spp.	X		X				X	
Hydnophora microconos	X	X	X				X	X
Leptastrea purpurea	X		X		X			X
Platygyra sp.			X		X	X	X	
Family Mussidae								
Lobophyllia sp.			X				X	
ORDER CORALLIMORPHARIA								
Family Actinodiscidae								
corallimorphs	X	X	X				X	
PHYLUM PLATYHELMINTHES								
CLASS TURBELLARIA								
ORDER POLYCLADIDA								
Family Unknown								
flat worm			X					
PHYLUM MOLLUSCA								
CLASS GASTROPODA								
SUBCLASS PROSOBRANCHIA								

APPENDIX 5. Marine Species Identified in Kwajalein Atoll Quarries.

	KWAJ.	GUG.	MECK	OMELEK	GELL.	GAGAN	LEGAN	ILLEG.
ORDER ARCHAEOGASTROPODA								
Family Trochidae								
Tectus pyramis					X	X	X	X
Trochus niloticus			X		X	X	X	X
Trochus ochroleucus								X
Family Turbinidae								
Astraea rhodostoma						X		
Turbo argyrostomus		X						X
ORDER MESOGASTROPODA								
Family Bursidae								
Bursa granularis			X					
Family Cerithiidae								
Cerithium nodulosum	X							X
Family Cymatiidae								
Cymatium muricinum		X						
Family Cypraeidae								
Cypraea annulus	X							
Cypraea argus (shell only)						X		
Cypraea depressa			X					
Cypraea moneta	X					X		
Cypraea scurra (shell only)		X						
Cypraea teres		X						
Family Ovulidae								
Ovula ovum			X					
Family Strombidae								
Lambis chiragra			X					
Lambis crocata			X					
Lambis truncata			X			X		
Family Tonnidae								
Tonna perdix (shell only)		X						
Family Vermetidae								
Dendropoma maxima	X	X	X		X	X	X	X
ORDER NEOGASTROPODA								
Family Conidae								
Conus chaldaeus		X	X					
Conus distans		X						
Conus ebraeus		X						
Conus flavidus		X						
Conus sanguinolentus		X						
Family Vasidae								
Vasum turbinellum			X			X		
SUBCLASS OPISTOBRANCHIA								
ORDER SARCOGLOSSA								
Family Plakobranchidae								
Plakobranchus ocellatus	X	X	X					
ORDER NUDIBRANCHIA								
Family Gymnodorididae								
Nembrotha sp.								X

APPENDIX 5. Marine Species Identified in Kwajalein Atoll Quarries.

	KWAJ.	GUG.	MECK	OMELEK	GELL.	GAGAN	LEGAN	ILLEG.
Family Phyllidiidae								
Phyllidia pustulosa							X	
Phyllidia varicosa							X	
CLASS BIVALVIA								
Family Chamidae								
Chama sp.						X		
Family Isognomonidae								
Isognomon perna		X						
Family Mytilidae								
Lithophaga zittelliana						X	X	
Modiolus auriculatus (shell only)		X						
Modiolus vagina		X						
Family Pinnidae								
Pinna muricata (shell only)		X						
Family Tellinidae								
Scutarcopagia linguafelis (shell only)				X				
Family Tridacnidae								
Hippopus hippopus			X		X	X		X
Tridacna maxima			X		X	X		X
Tridacna squamosa			X					X
Tridacna sp.	X						X	
Family Veneridae								
Periglypta reticulata		X	X					
CLASS CEPHALOPODA								
ORDER OCTOPODA								
Family Octopodidae								
Octopus sp.			X		X			
PHYLUM ANNELIDA								
CLASS POLYCHAETA								
Family Terebellidae								
spaghetti worm	X							
PHYLUM ARTHROPODA								
SUBPHYLUM CRUSTACEA								
CLASS MAXILLOPODA								
SUBCLASS CIRRIPEDIA								
ORDER THORACICA								
SUBORDER BALANOMORPHA								
SUPERFAMILY CORONULOIDEA								
Family Tetraclitidae								
Tesseropora pacifica	X		X		X			
ORDER UNKNOWN								
Family Unknown								
barnacle sp. (in Millepora)					X		X	
barnacle sp. (in Astreopora)					X			

APPENDIX 5. Marine Species Identified in Kwajalein Atoll Quarries.

	KWAJ.	GUG.	MECK	OMELEK	GELL.	GAGAN	LEGAN	ILLEG.
CLASS MALACOSTRACA								
ORDER STOMATOPODA								
Family Unknown								
stomatopods	X							
ORDER DECAPODA								
SUBORDER PLEOCYEMATA								
INFRAORDER STENOPODIDEA								
Family Stenopodidae								
Stenopus hispidus	X							
INFRAORDER CARIDEA								
SUPERFAMILY ALPHEOIDEA								
Family Alpheidae								
alpheids (in Pocillopora)					X	X		
Alpheus sp. (commensal with goby)						X		X
Alpheus sp. (in Porites lutea)					X			
INFRAORDER PALINURA								
SUPERFAMILY PALINUROIDEA								
Family Palinuridae								
Panulirus penicillatus			X					
INFRAORDER ANOMURA								
SUPERFAMILY PAGUROIDEA								
Family Diogenidae								
Calcinus elegans		X						
Calcinus imperialis			X					
Calcinus laevimanus		X						
Calcinus latens	X							
Dardanus megistos			X					
Dardanus sp. (large)	X		X			X		X
hermit with anemone on shell		X						
hermit crabs	X		X					
INFRAORDER BRACHYURA								
SECTION OXYRHYNCHA								
SUPERFAMILY MAJOIDEA								
Family Majidae								
spider crab							X	
SECTION BRACHYRHYNCHA								
SUPERFAMILY XANTHOIDEA								
Family Xanthidae								
Trapezia rufopunctata			X					
Trapezia sp. (orange)			X					
Trapezia sp. (red with white stripes)							X	
Trapezia sp. (white with red spots)		X						
?Trapezia sp. (white)						X		
SUPERFAMILY GRAPSOIDEA								
Family Grapsidae								
Percnon planissimum	X							
Plagusia sp.	X							

APPENDIX 5. Marine Species Identified in Kwajalein Atoll Quarries.

	KWAJ.	GUG.	MECK	OMELEK	GELL.	GAGAN	LEGAN	ILLEG.
Family Cryptochiridae								
cryptochirid sp. (in P. damicornis)						X		
PHYLUM ECHINODERMATA								
CLASS CRINOIDEA								
Family Colobometridae								
Oligometra serripinna						X		
CLASS HOLOTHUROIDEA								
ORDER DENDROCHIROTIDA								
Family Cucumariidae								
Afrocucumis africana	X		X				X	
ORDER ASPIDOCHIROTIDA								
Family Holothuriidae								
Actinopyga echinites		X						
Actinopyga mauritiana	X	X	X		X	X	X	
Bohadschia argus	X	X	X					
Holothuria (Halodeima) atra	X	X	X		X			
Holothuria (Thymiosycia) hilla		X	X					
Holothuria (Mertensiothuria) leucospilota			X					
Holothuria (Microthele) nobilis		X						
Holothuria (Mertensiothuria) pervicax			X	X				
Labidodemas sp.	X							
Family Stichopodidae								
Stichopus chloronotus	X							
ORDER APOPIDA								
Family Synaptidae								
Euapta godeffroyi			X					
Synapta maculata	X	X						
CLASS ASTEROIDEA								
Family Acanthasteridae								
Acanthaster planci	X						X	
Family Echinasteridae								
Echinaster sp.								X
Family Ophidiasteridae								
Leiaster sp.							X	
Linckia laevigata	X							
CLASS OPHIUROIDEA								
Family Ophiocomidae								
Ophiocoma erinaceus		X						
Family Ophionereididae								
Ophionereis spp.						X		
Family Ophiuridae								
Ophioplocus sp.							X	
Family Unknown								
ophiuroids	X							

APPENDIX 5. Marine Species Identified in Kwajalein Atoll Quarries.

	KWAJ.	GUG.	MECK	OMELEK	GELL.	GAGAN	LEGAN	ILLEG.
CLASS ECHINOIDEA								
Family Brissidae								
Brissopsis luzonica					X	X		
Brissus latecarinatus					X			
Family Diadematidae								
Diadema savignyi		X	X					
Echinothrix calamaris	X							
Echinothrix diadema	X	X	X		X	X	X	X
Family Echinometridae								
Echinometra mathaei							X	
Echinostrephus aciculatus			X		X	X	X	X
Family Toxopneustidae								
Toxopneustes pileolus	X							
Tripneustes gratilla	X							
PHYLUM CHORDATA								
SUBPHYLUM TUNICATA								
CLASS ASCIDIACEA								
ORDER APLOUSOBRANCHIATA								
Family Didemnidae								
Eudistoma sp.			X					X
tunicate (colonial)						X		
ORDER UNKNOWN								
Family Unknown								
tunicates								X
PHYLUM CHORDATA								
CLASS CHONDRICHTHYS								
ORDER LAMNIFORMES								
Family Carcharhinidae								
Carcharhinus melanopterus			X			X		
CLASS OSTEICHTHYES								
ORDER ANGUILLIFORMES								
Family Muraenidae								
Echidna nebulosa	X							
Gymnothorax meleagris						X		
ORDER SALMONIFORMES								
Family Synodontidae								
Saurida gracilis	X							
Synodus variegatus	X	X					X	
Synodus sp.	X		X				X	
ORDER ATHERINIFORMES								
Family Atherinidae								
bait fish	X		X					
Family Belonidae								
Platybelone argalus	X							
Strongylura incisa			X					

APPENDIX 5. Marine Species Identified in Kwajalein Atoll Quarries.

	KWAJ.	GUG.	MECK	OMELEK	GELL.	GAGAN	LEGAN	ILLEG.
Family Hemiramphidae								
Hemiramphus sp.	X	X	X			X		
ORDER BERYCIFORMES								
Family Holocentridae								
Myripristis berndti					X			
Myripristis kuntee	X				X			
Neoniphon opercularis			X			X		
Neoniphon sammara	X	X	X		X	X		
Neoniphon sp.	X							
Sargocentron caudimaculatus	X							
Sargocentron diadema	X							
Sargocentron punctatissimum			X					
Sargocentron spiniferum	X		X					
ORDER GASTEROSTEIFORMES								
Family Aulostomidae								
Aulostomus chinensis	X				X		X	
Family Fistulariidae								
Fistularia commersonii	X		X				X	
Family Syngnathidae								
Corythoichthys intestinalis	X	X	X					
ORDER SCORPAENIFORMES								
Family Scorpaenidae								
Pterois antennata	X							
ORDER PERCIFORMES								
Family Acanthuridae								
Acanthurus achilles	X						X	
Acanthurus guttatus			X			X		
Acanthurus lineatus	X				X	X	X	
Acanthurus mata	X		X		X	X	X	
Acanthurus nigricans	X					X		
Acanthurus nigrofuscus	X							
Acanthurus nigroris					X			
Acanthurus olivaceus			X		X	X	X	
Acanthurus pyroferus	X		X		X	X	X	
Acanthurus triostegus	X	X	X		X	X	X	
Acanthurus xanthopterus							X	
Ctenochaetus striatus	X		X			X	X	
Ctenochaetus strigosus	X	X					X	
Naso hexacanthus						X		
Naso lituratus			X		X	X	X	
Naso unicornis	X		X				X	
Zebrasoma scopas		X				X		
Zebrasoma veliferum						X		
Family Apogonidae								
Apogon novemfasciatus	X							
Apogon sp.	X		X					

APPENDIX 5. Marine Species Identified in Kwajalein Atoll Quarries.

	KWAJ.	GUG.	MECK	OMELEK	GELL.	GAGAN	LEGAN	ILLEG.
Family Blenniidae								
Aspidontus taeniatus	X				X	X	X	
Exallias brevis						X		
Istiblennius sp. (green)	X							
Family Bothidae								
Bothus sp.					X			
Family Carangidae								
Caranx melampygus	X						X	
Trachinotus bailloni							X	
Trachinotus blochii							X	
Family Centrarchidae								
Lepomis macrochirus	X					X	X	
Family Chaetodontidae								
Chaetodon auriga	X		X			X	X	
Chaetodon citrinellus	X	X	X			X	X	
Chaetodon ephippium	X	X	X		X			
Chaetodon lineolatus	X		X					
Chaetodon lunula	X	X	X		X		X	
Chaetodon meyeri								X
Chaetodon ornatissimus	X	X	X		X			
Chaetodon rafflesi		X						
Chaetodon reticulatus			X		X	X	X	
Chaetodon trifascialis		X			X	X	X	
Chaetodon vagabundus						X	X	
Family Cirrhitidae								
Paracirrhites arcatus	X		X		X	X	X	
Paracirrhites forsteri	X						X	
Family Ephippididae								
Platax orbicularis	X							
Family Gobiidae								
Valenciennea strigatus	X					X		
Family Grammistidae								
Grammistes sexlineatus	X							
Family Kuhliidae								
Kuhlia mugil	X		X			X		
Family Kyphosidae								
Kyphosus cinerascens	X	X	X		X	X	X	
Kyphosus vaigiensis			X					
Kyphosus sp.	X		X					
Family Labridae								
Anampses caeruleopunctatus							X	
Anampses melanurus						X		
Anampses meleagrides					X			
Bodianus axillaris	X						X	
Bodianus bilunulatus					X			
Bodianus bimaculatus					X			
Cheilinus chlorurus		X	X					

APPENDIX 5. Marine Species Identified in Kwajalein Atoll Quarries.

	KWAJ.	GUG.	MECK	OMELEK	GELL.	GAGAN	LEGAN	ILLEG.
Cheilinus unifasciatus	X							
Cheilio inermis	X							
Coris aygula	X		X					
Coris gaimard	X		X		X	X	X	X
Coris picta							X	
Epibulus insidiator	X							
Gomphosus varius	X		X		X	X	X	
Halichoeres chrysus	X	X	X		X	X	X	
Halichoeres hortulanus	X	X	X		X	X	X	
Halichoeres margaritaceus	X	X	X		X	X	X	
Halichoeres marginatus	X		X			X		
Halichoeres miniatus			X					
Halichoeres nebulosus			X					
Halichoeres trimaculatus	X	X	X		X	X	X	
Hemigymnus fasciatus			X					
Hemigymnus melapterus	X		X				X	
Labroides bicolor	X		X		X			
Labroides dimidiatus	X	X	X		X	X	X	
Macropharyngodon meleagris	X		X		X	X	X	X
Macropharyngodon moyeri			X					
Macropharyngodon negrosensis			X					
Novaculichthys taeniourus	X		X		X	X	X	X
Stethojulis bandanensis	X	X	X		X	X	X	
Thalassoma amblycephalum	X							
Thalassoma hardwicke			X				X	
Thalassoma lunare			X					
Thalassoma lutescens			X					
Thalassoma purpureum			X				X	
Thalassoma quinquevittatum	X	X	X		X	X	X	
Thalassoma trilobatum			X					
Family Lethrinidae								
Gnathodentex aureolineatus	X		X		X	X		
Lethrinus sp.					X	X		
Monotaxis grandoculis	X							
Family Lutjanidae								
Lutjanus ehrenbergii	X							
Lutjanus fulvus	X	X	X		X	X	X	
Lutjanus gibbus			X					
Family Microdesmidae								
Ptereleotris evides						X		
Family Mugilidae								
Valamugil ?engeli							X	
Family Mugiloididae								
Parapercis clathrata	X				X	X	X	
Family Mullidae								
Mulloides flavolineatus	X		X					
Mulloides vanicolensis	X		X		X	X	X	

APPENDIX 5. Marine Species Identified in Kwajalein Atoll Quarries.

	KWAJ.	GUG.	MECK	OMELEK	GELL.	GAGAN	LEGAN	ILLEG.
Parupeneus barberinus	X		X		X	X		
Parupeneus bifasciatus			X		X	X	X	
Parupeneus cyclostomus	X				X	X		
Parupeneus multifasciatus	X		X		X	X	X	
Family Nemipteridae								
Scolopsis lineatus	X							
Family Pomacanthidae								
Centropyge bicolor						X		
Centropyge flavissimus	X	X	X		X	X	X	
Family Pomacentridae								
Abudefduf sexfasciatus	X							
Abudefduf sordidus	X	X	X					
Abudefduf sp.	X							
Amblyglyphidodon curacao	X				X		X	
Amphiprion chrysopterus						X		
Chromis atripectoralis			X					
Chromis margaritifer	X	X	X			X	X	
Chromis viridis	X	X			X	X	X	
Chrysiptera glauca	X	X					X	
Chrysiptera leucopoma	X	X	X		X		X	X
Chrysiptera traceyi	X		X		X	X		
Dascyllus aruanus		X			X			
Dascyllus reticulatus	X		X			X	X	
Dascyllus trimaculatus	X							
Plectroglyphidodon dickii	X	X	X		X	X	X	
Plectroglyphidodon lacrymatus			X		X	X	X	
Plectroglyphidodon leucozona			X					
Pomacentrus pavo	X				X	X	X	
Pomacentrus vaiuli						X	X	
Pomacentrus sp.			X					
Stegastes albifasciatus			X					
Stegastes fasciolatus	X		X					
Stegastes nigricans	X	X	X		X	X	X	
Family Scaridae								
Calotomus carolinus						X	X	
Calotomus spinidens			X				X	
Calotomus sp.	X							
Scarus forsteni	X							
Scarus gibbus			X				X	
Scarus oviceps			X				X	
Scarus psittacus	X		X					
Scarus rubroviolaceus			X					
Scarus sordidus	X		X		X	X	X	
Scarus sp.		X	X		X		X	
Scarus spp.	X							
Family Serranidae								
Cephalopholis argus	X	X	X			X		

APPENDIX 5. Marine Species Identified in Kwajalein Atoll Quarries.

	KWAJ.	GUG.	MECK	OMELEK	GELL.	GAGAN	LEGAN	ILLEG.
Cephalopholis urodelus		X			X	X		
Epinephelus hexagonatus	X	X	X		X	X	X	
Epinephelus merra	X	X						
Epinephelus sp.	X							
Family Siganidae								
Siganus argenteus	X		X					
Siganus vulpinus			X					
Family Zanclidae								
Zanclus cornutus			X		X	X	X	
ORDER TETRAODONTIFORMES								
Family Balistidae								
Balistapus undulatus								X
Balistoides viridescens						X		
Melichthys vidua			X			X		
Rhinecanthus aculeatus	X	X	X		X	X		
Rhinecanthus rectangulus	X		X		X			
Sufflamen chrysopterus					X			
Family Diodontidae								
Diodon hystrix	X						X	
Diodon sp.	X							
Family Monacanthidae								
Oxymonacanthus longirostris	X				X	X	X	
Paraluteres prionurus					X			
Family Ostraciidae								
Ostracion cubicus								X
Ostracion meleagris	X		X					
Family Tetraodontidae								
Arothron meleagris	X						X	
Canthigaster solandri	X	X					X	