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COASTAL RESOURCE INVENTORY OF MAJRO ATOLL, REPUBLIC OF THE MARSHALL ISLANDS

Prepared by

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and the

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EXECUTIVE SUMMARY

by
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INTRODUCTION

The Mājro Coastal Resource Inventory was prepared by the University of Hawaii Sea Grant Extension Service and the Environmental Resources Section of the U.S. Army Corps of Engineers, both located in Honolulu, Hawaii. This inventory was conducted at the request of the Government of the Republic of the Marshall Islands to help them develop coastal resource management plans that will foster rational, sustainable development and conservation of Majro's natural and cultural resources.

Aelōn̄-in Mājro (Mājro Atoll), lying in the southern part of the Republic of the Marshall Islands (RMI) at 171^{0} 12' E and 7^{0} 09' N, is one of the 28 atolls and five table reefs that make up a nation of 1,225 islands spread across the tropical northern Pacific. Mājro is the nation's capital and has a population of 20,000 on 3.5 square miles of land. Some parts of Mājro elicit an atmosphere of paradise with traditional villages, healthy coral reefs and clean beaches, while other parts of the atoll are degraded and polluted due to high population densities, littering, and intense development of the atoll's land, beaches, fisheries, and agricultural resources. The people are experiencing a loss of traditional culture and identity while the marine and land environments are suffering from widespread habitat degradation and potential species extinction.

Despite Mājro's history of urbanization and development, Mājro Atoll still supports many valuable reef and coastal areas that should be protected and managed for multiple uses including education, recreation, research, and tourism. These resource needs create a climate of both opportunity and pressure to further develop Mājro as the nation's business and transportation center, yet careful choices must be made on population control, coastal planning, and economic development. The leaders of the RMI recognize Mājro's potential and the critical need for wise stewardship of their nation's valuable and fragile resources. It is in this spirit that they requested U.S. assistance in mapping and inventorying their nation's coastal resources.

This narrative report serves as a companion document to the Coastal Resource Atlas on Mājro Atoll (Manoa Mapworks, 1989). Inventory reports have also been prepared for Arņo and (Kuwajleen) Kwajalein Atolls in the RMI. The report is designed to be used with the atlas in providing detailed information on the distribution of Mājro's coastal resources. This information is intended to help the people of Mājro and the RMI accomplish the following resource management goals and actions:

- Promote mariculture and commercial fishing;
- Protect subsistence fishing and gathering grounds;
- Conserve native forests and rare vegetation;
- Promote subsistence and commercial coastal agriculture;
- Develop island and marine tourism opportunities and destination areas;
- Establish island and marine parks and reserves;
- Prepare coastal and marine education curriculum;
- Conserve traditional, cultural and religious resources;
- Preserve significant historic and archaeological sites;
- Restore or protect beaches and eroding shorelines;
- Acquire coastal construction materials in a responsible manner;
- Design and site harbors, docks, and channels;
- Choose sites and develop procedures for solid waste disposal;
- Identify sites for cleanup of hazardous/toxic waste;
- Train government officials responsible for natural resources;
- Improve environmental assessment and coastal resource management; and
- Prepare long-range economic development and master plans.

The first part of this inventory summarizes the methodology, results, discussion, and conclusions sections that are presented in the individual appendix reports in light of the goals listed above. The appendices include reports by individual team members who were involved in collecting data for both the atlas and the inventory on the following subjects: a) archaeological and historic sites, b) terrestrial ecology and shoreline biota, c) marine invertebrates, d) reefs and stony corals, e) marine algae, f) reef fishes, g) fishery resource uses and interviews, h) coastal tourism, education, parks and reserves, j) engineering geology, and k) circulation and shoreline dynamics.

METHODOLOGY

Dr. James Maragos and staff from the Army Corps met with agency representatives from the RMI in Mājro during April and May of 1988 to gather initial impressions of islanders' coastal resource concerns and to make preliminary arrangements for the May and July field trips for the project. Donald Capelle, RMI Secretary for Resources and Development, Stephen Muller, Director of Marshall Islands Marine Resources Authority (MIMRA), and Peter Oliver, Special Assistant to the Chief Secretary for Compact Implementation served as the principal government contacts for the project.

During each meeting or interview, the purpose of the project was explained in Marshallese and English, and the Pohnpei Coastal Resource Atlas and Inventory was shown as an example of the product that would come out of the interview contributions and site-specific field surveys. Participants were asked to locate on maps specific areas, types, and status of coastal resources that were utilized. They were also asked about potential opportunities and problems regarding shoreline erosion, navigation projects, tourism and park sites, historic and cultural areas, aquaculture, and subsistence and commercial fisheries.

Approximately 40 combined field surveys were conducted during two and eight day visits in May and July, 1988, respectively by a "land" team which concentrated on interviews and walking site surveys, and "marine" teams, concentrating on snorkeling observations of selected lagoon and reef environments. The surveys commenced with orientation meetings held with officials and leaders of Mājro. Most of the surveys were conducted near historic locations, yet others were chosen to acquire a representative sample of different lagoon habitats, or to investigate specific shoreline construction options. Most of the sites were located on the inside of the lagoon due to the rough conditions of the ocean side of the atoll and the overall development orientation of the project.

The marine field surveys were qualitative in nature. Twenty-eight sites were surveyed during the eight day period in July. Some of these sites and others were also surveyed in May by Dr. Maragos, Stan Boc and Eric Bjorken of the U.S. Army Corps of Engineers. Each team member was responsible for recording or sketching specific coastal resources using clipboards, waterproof paper, species checklists and maps to record observations, as they snorkeled each site for one-half hour. Information on the relative abundance of corals, reef fish, algae, other invertebrates, along with identifying tourism and park sites were also recorded. Photographs were taken and some specimens were collected for the purposes of species confirmation, identification and obtaining more information. The Marshall Islands Marine Resources Authority (MIMRA), provided skiffs and support equipment during the May and July 1988 surveys. Mr. Stephen Muller and Ronald Virgil Alfred were invaluable in their assistance with arranging or participating in field visits.

Studies of lagoon circulation and shoreline dynamics in Mājro lagoon were made over a twenty day period by taking direct flow measurements with drogues (a float with weighted cloth hanging in the water) which were augmented by visual observations and interviews with residents. Current information was derived by deploying a drogue from a boat, recording its position, and allowing it to drift with the water for a period of time. It was then picked up and the new position was recorded. The starting and ending positions were mapped, and the speed and flow directions were calculated.

Team members and their areas of concentration were: R. Virgil Alfred (interpreter, fishes and shellfish); Jeben Barton (cultural and historic resources); Eric Bjorken (engineering geology); Stanley Boc (coastal engineering); Alfred Capelle (cultural and historic resources); Dr. Larry Harris (non-coral invertebrates); Kim Des Rochers (oceanography field assistant); Peter Galloway (shoreline and terrestrial biological resources); Robert Kelen (interpreter, environmental impacts); Nena Kilma (interpreter, fishes, shellfish); Dr. Austin Lamberts (reef corals and reef geomorphology); Dr. James Maragos (oceanography, reef geomorphology, and reef corals); Tabal Maun (cultural and fishery resources); Michael Molina (reef fishes); Peter Rappa (fishery resource use interviews); Peter Rosti (oceanography); Chuck Streck (cultural and archaeological resources); and Meriwether Wilson (tourism, marine parks, reserves and collection of algae for Dr. Karla McDermid).

RESULTS

The appendix reports provide detailed information on specific topic areas. Each report includes descriptions and assessments of individual sites, species lists, discussions of resources focusing on sustainable development, and summary recommendations. These reports are based upon collaborative work by the different team members listed above. The authors and topic areas included in the appendices are as follows: Archaeological and Historic Site Survey by C. Streck; Terrestrial Ecology and Shoreline Biota by P. Galloway; Non-Coral Marine Invertebrates by L. Harris; Reefs and Stony Corals by A. Lamberts and J. Maragos; Fishery Resource Uses and Interviews by P. Rappa; Reef Fishes by M. Molina; Engineering Geology by E. Bjorken; Circulation and Shoreline Survey by P. Rosti; Tourism, Education, Park and Reserve Opportunities by A.M. Wilson; Marine Algae by K. McDermid; and excerpts from the RMI-Plan of Action for Water Resources (OEA, 1989). Together these works comprise the full results of the inventory project.

A literature review relevant to each topic area is included in the bibliography section at each individual appendix report. Based on the literature reviews in the appendices, these reports are the first comprehensive evaluations of commercial and subsistence reef-based fisheries, mariculture, tourism, protected areas, non-coral invertebrates, seaweeds, and coastal engineering for Mājro Atoll. There has been very little scientific information published pertaining to Mājro. The Office of Economic Adjustment's (1989) Plan of Action for for water resources for the RMI offers priorities for many of the conservation and development challenges for Mājro as well as other areas in the RMI.

The interviews and meetings with the government officials and the traditional leaders were a vital part of the data collection process for this project, and strongly influenced the direction of site selection and issues to explore. These individuals provided information on: 1) the location of fisheries and botanical resources; 2) the status of the reef fisheries, i.e. whether it is declining, increasing or remaining the same; 3) the type of fishing gear used and the location of fishing spots; and 4) the location of cultural and archaeological sites. Suggestions and questions on the following were also provided: 1) potential shoreline erosion problems; 2) proposed navigation projects; 3) balancing economic, ecological and cultural goals with tourism development; 4) the preservation cultural artifacts; 5) adverse impacts of natural and human-induced stresses on the reefs and fisheries; 6) potential danger of overharvesting; 7) the need for development of commercial fisheries while maintaining subsistence needs and lifestyles; and 8) oil spills and emergency plans. These issues are outlined in more detail at the beginning of the DISCUSSION section of this summary report. The most valuable result of the interviews and meetings was that they provided a forum for the local people to express their ideas and concerns to the project team, and to know that their opinions were taken into account throughout all stages of the project.

The field surveys provided detailed, site-specific data and first-hand observations with which to evaluate the different resource options in a comprehensive fashion. This was further emphasized by the multi-disciplinary nature of the project's team members. While each member had a specific area of expertise, their responsibility included evaluating their resource speciality in light of the broader picture of development issues. For both the land and the marine flora and fauna, only the larger, more conspicuous species or genera were recorded, while small, cryptic or nocturnal species were only incidentally observed. In nearly all cases the categories of dominant, abundant, occasional, or rare were used to indicate the species abundance. The diversity of species was also described for each site, but these numbers may be underestimated due to the short survey time period and the limited number of sites sampled.

The results of the field work have led to the following major findings. The plant and animal species for both land and marine habitats in the densely human populated parts of Mājro were severely degraded while less populated areas exhibited a higher diversity and healthier conditions. This was especially true for the fish and invertebrate organisms found in the coral reef environments. Food fish resources in even the richest and healthiest parts of the lagoon may not be sufficient to meet local subsistence needs, especially if commercial fishing efforts increase. The nearly complete closure of about 60% of the rim of the lagoon from road and airport construction has considerably changed water and sediment flow dynamics and may be affecting the marine biota in the lagoon. Selected areas of the atoll are still suitable for ecologically oriented tourism, yet need to be immediately established as protected areas or otherwise protected. The following sections provide brief overviews of the results found for specific topic areas investigated during this project.

THE PHYSICAL ENVIRONMENT OF MAJRO

Geography and Reef Geomorphology

Māj̄ro is located at the southern end of the eastern chain of the Marshall Islands. At 7 degrees north latitude, Māj̄ro lies near the southern limit of the northeast tradewind belt and the northern limit of the doldrums, both of which are near the intertropical convergence zone of high rainfall. Māj̄ro receives over 180 inches of rain per year. The equatorial countercurrent runs south of the atoll in an west to east direction. Prevailing winds and waves usually approach from the northeast. Māj̄ro has a total of 3.5 square miles of dry land area, which comprises a ring of approximately 57 separate islets, that together encircle a lagoon of area of 114 square miles. In terms of lagoon area Māj̄ro ranks thirteenth out of 28 atolls in the Marshalls, and ranks seventh among the other atolls for dry land area.

Māj̄ro Atoll consists of a coral reef cap overlying a subsiding volcanic base. Māj̄ro, like other atolls, includes low islands which are composed of carbonate reef sands and rock. The islands are formed when storms and large waves throw reef materials up on the reef flats.

Māj̄ro is elliptical in shape and encloses a single large lagoon, with major passes along a six to seven mile stretch on the northeast side of the atoll. Māj̄ro has a 100 foot deep reef hole in the perimeter reef south of Ro̧nro̧n̄ island near the northern end of the lagoon with high live coral coverage on its slopes. (See Site 5 descriptions in the appendix reports). The maximum lagoon depth for Māj̄ro is 220 feet compared to 180 feet on Arno. Yet overall, much of Māj̄ro's lagoon is shallower, averaging less than 120 feet. All of Māj̄ro's major passes are on the northeast side the atoll, with Ko̧ļaļ-eņ Passage being the largest.

There are three primary features of the perimeter reefs: the ocean or seaward facing slope, the reef top or flat, and the lagoon facing slope. Islands cover over half of the surface area on these reef flats. The entire southwest perimeter of the atoll is connected for 30 miles. Tropical storms usually hit the southern side, which is where most of the land and people are located. On the ocean reef flats between the old and new airports, there are a number of quarries dating from pre-WWII days to the 1980's.

On the upper parts of the windward ocean reef slopes, there is often a system of buttresses, called spur-and grooves, which are dominated by crustose coralline algae and a high diversity and coverage of robust coral species. The upper part of the leeward ocean reef slopes exhibit a series of canyons which bisect the upper and outer reef margin. These slopes are covered with mixed coral and benthic algal assemblages. Lagoon reef slopes on the southwestern side of the atoll are subject to higher wave action and build up as the tradewinds traverse the lagoon from the windward (NE) direction. The lagoon side of Eoonmaaj and Telap Islands have been active dredge sites and are dominated by sand deposits and tali. The lagoon slopes near the passes, especially at Irooj Island, support flourishing coral reef communities at shallow depths and sand deposits in deeper water.

The seaward reefs are more continuous than the lagoon reefs throughout the atoll, with the most extensive and complex lagoon reef development occurring along the west, south and north sides of the atoll. The distribution of lagoon reefs (pinnacle and patch reefs) in the southeast area near urban Mājro have been altered from dredging operations for the navigation channel. Pinnacle and patch reefs are concentrated near the passes, the northwest corner of the lagoon and on both sides of Irooj Island.

Physical Oceanography

During a 20 day time period 24 drogues were deployed to measure water circulation and current patterns in the lagoon (see Rosti, 1989, this volume). There were 22 successful recoveries. These studies were made in the areas of: 1) the east end of the lagoon; 2) the bridge over the small boat channel; 3) the airport; and 4) Mājro Island (Laura) and the west end of the lagoon and the north side of the lagoon.

Within the lagoon there is excellent circulation in the central and western parts, while the circulation in the eastern end is poor. Degraded water quality, due to a lack of flushing, is now occurring in this eastern area. An average current of 0.2 knots runs westward along the airport and is forced to exit the lagoon over the reef north of Laura. The greatest mass of water exchange between the interior and the exterior of the lagoon occurs on the north side of the lagoon through Kolal-en Passage. The water exchange in the southeast corner of the lagoon at the small boat channel is narrow but significant.

Land-based shoreline surveys were made to examine the following conditions within the lagoon: 1) erosion and siltation; 2) shoreline modifications; 3) small boat channel; 4) beach conditions; 5) waste disposal and landfill; 6) sewage treatment and disposal; and 6) control of runoff.

The only part of Mājro that revealed serious erosion was at the lagoon side on the northern tip of Mājro Island, Laura. There is some siltation along the southern rim of the atoll in the lagoon. Corals in areas that have been affected by dredging and quarrying are dying and show little regrowth. The small boat channel is dangerous as it is too narrow and poorly marked. Litter, primarily disposable diapers and plastic, accumulates on all the beaches even in the most remote areas. On the beaches in urban parts of Mājro the litter may be over a foot deep. Solid waste at the dump is being dispersed throughout the lagoon by wind. Effluent discharge into the lagoon from the urban areas in Mājro is destroying the marine life and making the water unsafe for humans. The outfall pipe discharging to the ocean reefs off Telap from the waste treatment plant, is possibly too shallow and may be a pollution hazard. "Dips" or swales have been constructed across the main road to drain excess rainwater into the lagoon and are too shallow and not functioning draining properly. During heavy rains the dips fill with water, impeding vehicular traffic.

Marine Biota and Ecology

Recent visual records and collections in 1988 revealed stony corals at Majro belonging to 129 species and 47 genera and subgenera. The only previous coral lists were made in 1977 (Scanland, 1977) as part of the Dames and Moore dock proposal (see Lamberts and Maragos, this volume). The 1977 and 1988 lists together account for 146 species belonging to 50 genera and subgenera. The stony coral fauna of Mājro is representative of those described elsewhere in the Marshalls. Due to higher sampling intensity and a variety of methods, more species and genera of corals have been reported at Arņo, Bikini, and Āne-wetak (Enewetak) Atolls in the Marshalls. It is likely that more intensive surveys of patch, pinnacle, and pass reefs would have yielded additional species for Mājro.

A total of 158 species of non-coral invertebrates were recorded during the July surveys with most of the observations made within reef flat, lagoon reef, or patch reef habitats. Several observed molluscan species that have mariculture potential include: trochus (top shell), turban shells, giant clams, and pearl oysters. In addition, gastropods, holothurians, urchins, hermit crabs, zooanthids, sponges, gorgonians, soft corals, octopus, and echinoderms, were frequently observed. Many of these animals are cryptic or nocturnal, hiding under rocks or waiting to come out at night. Hence, the observations may undervalue the number and variety of organisms actually present on Mājro.

Observations of conspicuous, daytime, shallow-water reef fishes were conducted on Mājro during an eight-day period in July at 28 sites throughout the lagoon, while snorkeling at a depth no greater than 30 feet. Many cryptic, nocturnal, or rare species may have been overlooked due to the limited depths and time at each site. The average number of families and species of reef fishes seen at an individual site were 17 and 64, respectively. The range at the sites for the families was 5 to 22, and 9 to 89 for the species. A total of 246 reef-fish species representing 46 families were recorded throughout the lagoon. Approximately 39% of these reef-fishes are important as food sources for the islanders, including various species of mullet, squirrelfish, grouper, jack, snapper, emperor, goatfish, rudderfish, wrasse, parrotfish, mullet, barracuda, surgeonfish, rabbitfish and others.

Twenty-four taxa of marine algae were collected during the July surveys from littoral and shallow subtidal areas on Mājro and Arņo Atolls (McDermid, 1989). Two species had not been previously reported from the Marshalls. While the Marshalls have received much scientific attention, current information on marine algae is lacking and up-to-date collections, identifications, and assessments of algal abundances are needed. Since the 1950's a total of approximately 250 species of green, brown and red algae have been reported from the Marshall Islands.

Mineral Resources

The reefs between Teļap Island and the new airfield have been dredged and quarried in the past few decades for armor rock and construction materials. There are presently several active sand mining and coral rock dredging sites between the airfield and Eoonmaaj Islands. The high cost and rate of exploitation of these materials and adverse environmental impacts associated with excavation support the need for a comprehensive evaluation and management of coastal excavation, filling and other related construction activities.

Fisheries and Mariculture

It appears that the shallow-water reef-fish resources throughout M$\bar{a}$jro Atoll have been severly degraded. This is especially true in the southeastern region due to overfishing, poor circulation, pollution, sedimentation and habitat loss. The fact that there were few large-sized food fish at most of the sites indicates these resources are being overfished. Traditionally, the reef fish were utilized for subsistence needs but as M$\bar{a}$jro's population rises and the people become more affluent, the reef fish are increasingly targeted for commercial exploitation to satisfy expanding markets in the U.S. and Japan. The development of a commercial reef fishery will negatively impact the fisheries sector if it is not regulated. Modern fishing methods are replacing traditional methods and are resulting in increased catch efficiency and the potential danger of overfishing. Although data on stock sizes and yields do not currently exist, it would be best to target the open-ocean pelagics outside the reef for commercial harvesting rather than harvesting the inshore reef fish species.

While the food fish resources are declining and can no longer meet local needs, other shallow-water reef-fish resources could be utilized for education, research, recreational snorkeling, and diving. These include tangs, wrasses, butterflyfishes, angelfishes, damselfishes, moorish idols, and triggerfishes. These same non-food fish resources may also be substantial enough to support a small-scale commercial fishery for aquarium fish, but only if there is strict management, and accurate and mandatory recording and reporting of catch. Fishermen need to be licensed and directed to spread out their efforts.

The entire lagoon area has suitable environments for mariculture of different molluscan species such as trochus, giant clams, pearl oysters, algae, sponges, green snails and fish. The quarries have potential as mariculture sites. There is currently adequate power, water and communication infrastructure to support a shoreside facility. However, detailed information on the ecological requirements of different species and, associated infrastructure needs will need to be obtained before any projects are started to minimize short- and long-term negative impacts.

Tourism, Education, Parks and Reserves

The beauty of Mājro's natural environments and people offer a wealth of opportunities to develop a nature-oriented tourism industry based on natural attractions. Such an industry can be economically profitable, culturally sensitive, and ecologically sustainable, even on a populous atoll like Mājro, if conservation measures are taken through the establishment of parks and reserves. These protected areas enhance recreational and educational options for tourism. Tourism facilities, parks, and reserves can also support other industries such as fisheries and agriculture. Today the natural resources of Mājro are in jeopardy if the atoll continues to become more polluted and populated. Therefore, careful planning, strict environmental guidelines, and the establishment of parks and reserves play even more critical roles in the process of developing a tourism industry on Mājro.

Of the twenty-eight reef and lagoon sites that were surveyed, 16 were recommended as tourism and/or protected areas. Since many sites were recommended for more than one resource use (such as Enigu, which was recommended as a tourism area, education site, marine park/reserve, and island park/reserve), a combined total of 42 sites were actually suggested for tourism, education or protected area status. Of these, five were suggested as tourism sites. As discussed below, tourism destination areas and protected areas are intimately linked. The five sites listed under the tourism category were the most suitable for constructing a range of accommodation facilities from thatched huts to small resorts. Fifteen sites were mentioned specifically for having high education potential. A total of 37 sites were listed as protected areas including: six marine parks, four marine reserves, four coastal parks, two coastal reserves, three island parks and two island reserves. These categories are suggestions only; therefore, many sites were listed under more than one category. This was to initiate flexible thinking in resource planning for these areas, and to encourage the residents of Mājro themselves to become involved in choosing the most appropriate use for each site.

DISCUSSION

The fragile ecology, limited land area, unique oceanography and cultural systems on Mājro Atoll create an infinite mosaic of opportunities and problems that require a great deal of cooperation, research, planning and patience. Island environments necessitate integrative and holistic approaches to develop natural resources in a way that are economically viable and ecologically sustainable. Some of the major issues that resulted from the interviews and meetings are listed below, but they are not prioritized and do not necessarily reflect all of the concerns or hopes of the people of Mājro.

- Impact of natural stresses, such as storms, typhoons and starfish predation on the coral and shoreline areas of Mājro;

- Increasing shoreline erosion problems from both natural events and human-induced activities;

- Impacts of coastal transportation, dredging, filling and quarrying activities on shoreline, reefs, island and shoreline stabilization;

- Protection of fragile and unique natural habitats, such as coral reefs;

- Loss of traditional village lifestyle and cultural values with increasing exposure to advanced western technology and products;

- Threats of depleting reef-fish stocks from commercial overharvesting and potential decline of subsistence based fisheries economy;

- Ability to handle transportation and communication needs and evacuations in times of natural disasters or emergencies;

- Desire to develop parks and reserves to preserve species and habitats while providing opportunities for recreation and education;

- Need for docks, harbors and other types of transportation infrastructure to support tourism and fisheries opportunities; and

- Impacts of pollution from solid waste on the marine and coastal environments, the health of the residents and future tourism industry.

Artisanal/Subsistence Fisheries Economy

In the past, reef fish were harvested from Mājro's lagoon for locally oriented subsistence food needs rather than commercial export. Today the stocks no longer meet subsistence needs or current demands for food-fish and even commercial efforts are increasingly vulnerable to overfishing with advanced technologies and commercial interests that are targeted to shallow lagoon and reef species. It has been estimated that Micronesians depend on marine resources for 90% of their food protein, and in Mājro 27% of this fish is canned imports.

The food-fish resources are depleted mostly in the southeastern part of the lagoon, due to increasing amounts of habitat degradation, pollution, fishing pressure which in turn, result from increased urbanization. Only the northwestern part of the atoll has populations of shallow, reef-fish in concentrations that may still support subsistence needs for residents of this area, but not enough for commercial purposes.

Collection data is badly needed before any changes from subsistence to commercial uses of Mājro's fishery resources are explored. Without reliable data on stock sizes and potential yields of targeted species it is difficult to estimate maximum sustainable harvest levels. The species diversity that was revealed from the surveys may be higher than the annual sustainable yield and is not a reliable indicator alone. Reliable time-series, catch-rate data are needed on different species and fishing methods to understand variablilites of fishing success and to predict estimated harvest levels.

Since there is little written documentation of the subsistence catch on Mājro (although it was the primary mode of fishing here), information on subsistence or artisanal fisheries was obtained from Mājro's fishermen during a series of interview sessions, with groups of fishermen from the urban areas of Mājro Atoll and Mājro Island (Laura). These sessions, which were conducted in both Marshallese and

English, took place over a six day period in July of 1988. Each interview session lasted approximately four hours. The men were given a list of fishes developed from earlier inventories on Yap and Kwajalein to comment on regarding catch numbers, species, locations and gear type. Non-fin fish resources such as giant clams, trochus, conches, octopus, squid, turtles, lobster and land crabs were discussed with the fishermen. They were also asked about fisheries development projects and acceptable locations.

Fishermen reported that they receive most of their income from the sale of fish with an increasing number going to restaurants. They said there is also an increasing market for fresh and frozen fish in M̄ajro because fewer people have time to fish today. Fishing is only a part-time occupation for most fishermen. Reef fishermen from urban M̄ajro and Laura felt that the fishery has declined in the last 10 years; this appears especially true for molluscs such as turban, trochus and giant clams. Lobsters and octopus are becoming increasingly rare. They attribute the declines to overfishing and water pollution, especially in the urban areas. Boat fishermen on the other hand feel the resource has not declined, that they are catching as many now as ever, and that the resource will remain plentiful in the future.

Depending on the characteristics and quality of a quarry, these areas can be refuges for reef-fish and other marine resources to recover. Those which show high rates of stony coral recolonization may also be the best for fishes. Many of the prized subsistence reef fish such as goatfish, emperors, and snappers may do particularly well in holes located on seaward reef flats.

Different gear types and fishing techniques are used depending on species and quantity sought, weather, and season. The ten types of gear or techniques most commonly used for artisanal fishing included: 1) Pole and line, 2) Handline, 3) Trolling, 4) Cast net, 5) Gillnet, 6) Alwelwe (coconut frond net), 7) Spearfishing, 8)

Vertical longline, 9) Scoop/hoop net, and 10) Bottomfishing. Fishermen from Laura reported using stone fish traps in the past, but none were visible during the surveys. Spearfishing, gillnetting, and bottomfishing are the most widely used fishing techniques. Trolling is the preferred method for catching pelagic species on the ocean sides of the atoll, although the Marshallese exhibited a preference for reef fish for food. The alwelwe net, made of palm fronds, was used for feasts and special occasions. Yet today canned fish and canned meats have high status value and are used for special occasions.

Commercial Fishing

Today the fishermen are involved with various small-scale commercial fishery operations. The development of all commercial fisheries operation must be approached with great caution to protect both the subsistence sector interests and to secure the long-term viability of commercial operations. It would be best to target open-ocean pelagics (tuna, wahoo, etc.) and deep-dwelling bottomfish (snappers, jacks, groupers, etc.) while preserving the reef fish for subsistence needs, and recreational and educational opportunities.

Data on stock sizes and yields for commercially-targeted species is needed, as well as investigations on the biology and ecology of food species. Overfishing could result in the loss of certain species. Time series data with catch rates per species is needed to project harvests.

There is urgent need to institute a management program incorporating fisheries data findings that can help the government make sound management decisions regarding commercial exploitation.

The Japan International Cooperation Agency (JICA) has proposed a range of fisheries infrastructure projects to promote harvesting of fish from Arņo which will then be transferred to M̄ajro for local consumption there. The project could be beneficial to the people of Arṇo and Mājro through enhancing job opportunities, developing processing and storage facilities, improving the diet of the people of Arṇo and Mājro, and reducing the increasing tendency to import canned fish. Yet, this project as proposed is based on developing fish base facilities in parts of Arṇo that may be ecologically, culturally and technically unwise. The Arno Coastal Resource Inventory discusses this subject in more detail.

The high diversity of beautiful fish offer potential to establish a small-scale commercial aquarium fishery on Mājro Atoll. But the numbers and types of fish caught would need to be strictly regulated with accurate recording and reporting to ensure that one area or species is not jeopardized. The process of collecting small aquarium fish can be also physically damaging to the reef community. Short stakes and piles of rubble could be established in protected reef areas for a time so that they will attract young damselfish and other species. These isolated fish gathering areas can be enclosed to collect the fish without damaging the reefs.

The construction of docks, channels, causeways associated with commercial fishery facilities are just some of many examples of development projects that can have potential adverse impacts from unwise shoreline construction and alterations. These projects could have negative impacts on fish populations due to changes in circulation patterns and sediment flow dynamics. Shoreline development is discussed in more detail in subsequent sections.

Mariculture

There are a number of different types of mariculture activities which are suitable for Mājro Atoll, as on-shore facilities, and which could be successfully operated on many of the atoll islands. The current power, water and transportation infrastructure would still need to be refined and expanded for even simple operations. The Sites 5, 7, 12, 17 and throughout the northwest parts of the lagoon may be the most suitable environments for mariculture. The quarry holes have potential as mariculture sites; however, all holes may not be suitable depending upon shape, orientation, depth, bottom and exposure. The economics and biology of any type of mariculture should be thoroughly investigated before starting with any project.

The most appropriate organisms to culture in the wild include: giant clams, trochus, pearl shells, algae, sponges and green snails. Certain species of fish, such as mullet, lend themselves to cage culture. Generally, aquaculture would not have deleterious impacts on fisheries resources, yet foraging for invertebrates as spat in mariculture can be disruptive to the reef. Sticks and other substrata can be placed to provide settling surfaces for spat.

The Turbo spp. and Trocus niloticus snails are found in shallow reef habitats on the lagoon and ocean side slopes. Their only predator is the spiny lobster and since they too are desirable food species there is a built in economic incentive to control lobster predation on the snails. Shallow reef flats can be used to culture the giant clams, Tridacna maxima and Hippopus hippopus, but there needs to be cooperation with fishermen to prevent poaching. The lagoon reef flats in the northwestern part of the main lagoon are excellent sites for raising these animals since there is adequate water flow during all tides to protect the clams from rain or desiccation.

Currently there is a small mariculture facility on Āne-dik Island in Arno for giant clams and pearl oysters but it is underdeveloped and underutilized. Efforts to coordinate education and research projects with activities in Mājro should be made.

Natural and Cultural Parks and Reserves

The establishment of parks and reserves near tourism areas can help promote nature awareness and conservation which can in turn help sustain tourism, fisheries, and agriculture industries. Parks are areas which have unique features worthy of preserving such as coral reefs, a forest of trees, nesting areas for birds or a site with cultural artifacts. Parks are designed to be an area that can sustain a balance between nature protection and public use, and can be established as any combination of marine, coastal or island parks.

Reserves are areas designated primarily to emphasize species, habitat or ecosystem protection and allow only limited public use except for education, research, or traditional subsistence uses. These areas are established to maintain natural processes in an undisturbed state so there will always be representative examples of the species or habitat. Like parks, the size of a reserve is dependent on many factors such as, ownership, ecology, species characteristics, and access.

Many sites that have high numbers and rich species diversity of reef organisms, especially reef fish and corals, have recreation and education potential which can enhance tourism opportunities. These same sites may also may warrant protected status as a park or reserve to ensure the longevity of the reef inhabitants. Sites 1-7, 9-11 and 25-27, have high reef fish species diversity.

Protected areas can not only support and sustain nature-based tourism, but also ensure that habitats are kept intact which in turn provides fish for subsistence and commercial food needs. While it is suggested that commercial fishing be prohibited from parks and reserves, subsistence fishing that is small-scale and uses traditional capture methods should be allowed in the park and reserve areas. Marine parks and reserves should be considered as part of an island-wide resource management strategy as it has been proven that protected areas and fish stocks can enhance fisheries recruitment and recovery. While 37 sites have been recommended to be considered as a park or reserve, this section highlights the most suitable parts of the atoll.

Kōļaļ-eņ Island and surrounding waters and islets has areas that exhibit some of the highest percent cover and number of species of coral anywhere surveyed in Mājro. There is one patch reef in particular just off the island on the lagoon side that could be established as a marine park since it offers wonderful snorkeling. Underwater signs and a trail should be made around the patch reef. Landside exhibits could share more information on coastal plants and atoll ecology, as well as safety and cleanup concerns. Selected areas on the island were formerly cleared and are now ideal for picnicking and other land-based recreation.

The hole in the northwestern side of Wūlka Island is unique from a geological and oceanographic perspective. It is ideal for educational field trips since a high school is nearby. It should be established as a reserve for fish and corals. Irooj Island should also be established as an island reserve protecting the rich marine life, natural vegetation, and the sea birds on this isolated place between the atoll's two largest passes. Mājro Island (Laura) is currently used as a swimming and recreation area as it is unpolluted and fairly accessible from urban Mājro. This area and the surrounding reef flats should be established as a coastal park.

The quarries near the airport make wonderful natural labs for studying fish and coral recolonization which can be used by local school groups or visiting scientists. These quarries should be protected from development or alteration and established as a marine reserve or park. Near Moss store in urban Mājro is a land and reef flat area that would make an excellent coastal park. The land area was a former large residence and is already cleared and currently used as a recreation site.

The Enigu Islands are a series of small islets that have healthy reefs and coastal habitats. Since they are easily accessible from urban Mājro they are ideal for recreational and educational purposes, but need to be protected from intense fishing pressure or large-scale tourism development. They should be developed as parks which can also incorporate nature-based tourism options.

Tourism Destination Areas and Resorts

Tourism facilities, including food, lodging, recreation and other service businesses can have extremely negative impacts on the environment, destroying the natural worlds that attracted the visitors in the first place, if they are not developed in an ecologically sensitive manner. Environmentally sensitive construction will also help sustain habitats which are essential industries such as fishing and copra. Such considerations are extremely critical for places like M̄ajro which has beautiful but fragile ecosystems that are quickly being destroyed.

It is especially important in remote areas such as M̄ajro that tourism be beneficial to all sectors of the resident population through both direct benefits such as jobs or markets for local goods such as food fish and handicrafts, and indirect benefits such as cultural and ecological preservation for future generations. Island tourism requires the cooperation of the public and private sectors, including residents, visitors and outside investors. Having a nature-based tourism industry that offers a wide spectrum of accommodations is the easiest way to spread the wealth to more of M̄ajro's people, while at the same time being ecologically sustainable.

Small-scale village oriented tourism with modest construction (e.g. simple thatched huts) would have minimal impacts on the environment and could be locally owned, built, and managed. Camping areas with or without small shelters could be established in coastal or island parks. Increasing numbers of people that live in crowded parts of the world are willing to spend the high cost of travel to find unspoiled paradises such as those found in parts of M̄ajro. These tourists however may prefer more luxurious accommodations. Small resorts can still be nature-oriented and accentuate traditional buildings and lifestyles, while providing excellent food, attractive surroundings, and reliable water and power.

This emerging up-scale "eco-tourism" market usually incorporates people who find relaxation in outdoor pursuits such as diving, windsurfing, sailing and hiking and M̄ajro is well suited to provide such sporting opportunities. Tourism efforts should not be designed for or targeted to large-scale, mass tourism, as it usually attracts visitors that are less sensitive to their environment and who wish to be accommodated in large, modern hotels such as beach high-rises. M̄ajro cannot support such development without extreme loss of ecosytems, habitats and culture. Nonetheless, all scales of tourism development on M̄ajro are going to require increased infrastructure capacity regarding transportation, communication, food, water, sewage disposal, and power.

Educating both residents and visitors about the surrounding natural and cultural environments can help people understand each other and their habitats. This makes accepting conservation guidelines, whether it be for a building, a reef habitat or a culturally acceptable form of dress, easier for everyone involved. For example, it is suggested that visitors to M̄ajro Atoll be prohibited from removing marine life throughout the entire lagoon in order to mitigate any possible conflict between visitors and fishermen. As discussed above the establishment of parks and reserves for marine, coastal and island habitats or for sites of historical significance can be directly linked with and enhance educational, recreation, and economic tourism opportunities.

Many of the reef fishes, while not edible, have aesthetic value. These include scorpionfishes, butterflyfishes, angelfishes, wrasses, tangs and morrish idols to name a few. These fishes are an important component for nature-based tourism, which targets snorkelers and divers. Sites 5-7, 9-11 and 25-27 exhibit high species diversity and are good candidates for tourism and parks. Since high numbers of these colorful fish are associated with healthy reef environments these sites offer exceptional opportunities for diving and snorkeling.

While there are a variety of sites in Mājro that could provide excellent tourism opportunities, the following paragraphs highlight some of the best areas.

The islets in the Enigu area have offer the greatest potential for establishing a range of tourism accommodations as they are still in a healthy natural state and close to urban Mājro. All of these areas have been recommended for recreation oriented parks and a few reserves. Individual camping sites or thatched huts could be set up on the different islets with a main inn, restaurant or store on one of the larger islets. Transportation between the islets could be by water taxi with skiffs or canoes. The patch reefs in the area are suitable for snorkeling, while the lagoon can be enjoyed by windsurfers. Different marine and coastal sites in this area could be established as recreation oriented parks.

Kōļaļ-eņ Island has wide beaches on the southern side, well-developed ocean reef flats on the north side, and coastal forests. It is an an ideal place to mix small-scale tourism with marine and island parks. The lagoon is perfect for windsurfing and divers can enjoy the lagoon patch reefs as well as the ocean side reefs. Camping areas and family owned thatched huts should be established here.

The Marshall Island Sun Hotel was one of the few hotels near urban Mājro that had attractive beach and swimming areas for visitors. Yet the beach is still needed continual clearing of disposable diapers and plastic. Hotels should add ecologically oriented exhibits and brochures to their public areas to attract divers and other nature-oriented visitors.

Dredging and Dredge Sites

While the continued modification of Mājro's shoreline from dredging is unavoidable, some techniques are more hazardous than others. Suction dredging has the most deleterious impacts on the marine biota, especially corals, as it liquefies bottom material to an extent that the discharge does not settle out if dumped back into the lagoon. This rapidly kills the in situ marine life and adjacent coral reef communities from siltation. Bucket dredging for sand is the preferred alternative, and it could be accomplished at deeper offshore sites. If suction dredging must be used, siltation curtains at the dredge site and land-based settling ponds are advised.

Dredging should be confined to the urban (southeast) areas of the lagoon which have already been degraded by previous sewage pollution and causeway construction. Special dredging zones could be established. Attention should be made to avoid large coral heads in the area to maintain them as habitat refuges and centers of recolonization for fish displaced from dredge sites.

Fill Land Expansion

Any further filling or extension of island land on reef flats should be deferred until a long range land use plan is developed for the atoll, especially the urban sector, and until the adverse environmental consequences are addressed and mitigated. The preferred approach is to prohibit any further land fill expansion. (See also Peter Rosti's report, this volume)

Quarrying and Quarry Sites

As discussed earlier, the existing quarries have potential as recreation, education, scientific, coral and fish colonization, and mariculture sites, yet this should not encourage the unwise development of new quarries. Although quarries alter the reef structure, the impacts can be minimized and coral regrowth can occur if they are properly sited and designed. They should be located on the outer half of seaward facing reef flats, with depths ranging from 2-4 m (6-13 feet). Quarry holes that are too deep accumulate sand and inhibit coral colonization; those placed too far inshore promote shoreline erosion and the immediate need for protective structures increases. In order to promote safe access and use of existing quarry holes and to prevent onshore erosion, it is suggested that buffer zones between the inner shoreline and the outer edge of the reef flats be established.

Quarry rock is not a renewable resource, and the increasing demand for stone and aggregate argue that a management plan be developed for the planning, coordination and implementation of quarries. The plan can help conserve these finite resources, maximize yield of aggregate, protect environmental values, and minimize shoreline erosion and expense. The Water Resources Plan of Action (OEA, 1989) provides a cost estimate and proposal to develop such a plan.

Shoreline Erosion and Navigation

The combination of predominant NE winds and nearly complete closure of the leeward side of the atoll is forcing water to move in a westerly direction, causing erosion at the western end of Mājro Island (Laura). Erosion may also be occurring along other lagoon shoreline sites. Plans to improve the old dock as part of a new fisheries complex seem appropriate. The existing medium draft dock also appears adequate for cargo and commercial fishing. Small ramps or open pile docks may be needed off the lagoon side of islands designated for park and visitor attractions. The existing small boat channel at Eoonmaaj needs to be widened, including the approaches, and may need protecting to minimize hazardous crossing waves and surges (see JICA, 1989).

Water Quality

In order to provide improved circulation and flushing of lagoon water in the urban Mājro area, several of the pre-existing passages through the lagoon should be reopened. Such openings would allow wind and current driven water to flow southwestward into the sea and inhibit the movement of water further west and northwest in the lagoon along the shore to Mājro Island (Laura). Improved circulation would reduce the bacterial count and improve the water quality at the southeastern end of the lagoon. The ocean outfall should be inspected to determine whether serious impacts to coral reefs are occurring and whether corrective action is needed.

CONCLUSION and RECOMMENDATIONS

Artisanal/Subsistence Economies

1. Establish ongoing fisheries data collection on the existing subsistence fishery, including information on fisherman participation, fishing effort, catch rates and catch composition.

2. Develop fishery management regulations to protect reef stocks, based on modern and traditional methods.

3. Take measures to enhance small-scale recreational and subsistence fisheries in the urban Mājro area including: widening the bridge channel and instituting better sanitation practices.

4. Encourage charter boat fishing for game fish that are not harvested for subsistence purposes.

5. Develop a national fisheries management program and master plan incorporating subsistence opportunities to meet local needs.

6. Develop the management skills of fisheries personnel in interviewing and recording techniques of artisanal fisheries.

7. Develop fishery management regulations focusing on common property exploitation.

8. Establish fishery protected areas for subsistence use only.

9. Integrate artisanal fishing goals into a coastal resource management plan.

10. Implement ongoing fisheries data collection on the existing subsistence fishery based on the recommendations in a 1988 United Nations consultancy report (Molina, 1988, this volume).

Commercial Fishing

1. Restrict commercial fishing activities at Mājro to pelagic and deep bottom species, reserving the harvest of shallow-water, reef-fish for subsistence uses.

2. Conduct stock assessments on commercially targeted reef fish; estimate annual maximum sustainable yield and calculate allowable commercial catch.

3. Institute mandatory recording and submission to the government on fisheries data for all established commercial fishery operations.

4. Train Peace Corps workers in the basics of fisheries data collection and have them train the villagers and fishermen.

5. Have the MIMRA staff trained in data collection analysis methods at the University of the South Pacific and have them train fishermen.

6.Develop a national fisheries managment program and master plan incorporating commercial fishing goals and activities and integrate this with a coastal resource management plan.

7. Develop new fishery management regulations dealing with common property fishery resources.

8. Update local existing fishing regulations and expand local enforcement capability and activities.

Mariculture

1. Promote mariculture, beginning with low-technology operations such as giant clam or trochus grow-out.

2. Evaluate the potential of pearl shells, algae, sponges, green snails, green mussels and cage-culture of fishes.

3. Investigate the feasibility of using shoreside facilities, abandoned quarry holes and suitable lagoon areas.

Parks and Reserves

1. Have public meetings to involve the residents in making recommendations for appropriate sites to be parks and reserves, taking into account that most land in M̄ajro is privately owned.

2. Establish marine parks and reserves where reef-fish diversity is high, such as near Sites 5-7, 9-11 and 25-27, emphasizing the Enigu islets.

3. Allow subsistence fishing and compatible non-destructive activities throughout the lagoon, but prohibit the harvesting of organisms from protected areas for any other purpose.

4. Integrate parks and reserves areas with tourism in the Enigu and Kōļaļ-eņ islands areas.

5. Draft new or enact existing legislation to enforce preservation of selected species and habitats.

6. Prohibit the removal of marine life by non-residents from the atoll.

Tourism and Resorts

1. Have public meetings to begin the process of establishing tourism destination areas and resort capabilities.

2. Encourage the development of a multi-faceted tourism industry that involves both the private and public sector, and local and foreign investors.

3. Encourage a wide range of tourism and recreation accommodation options including camping areas, thatched huts, guesthouses, and small, up-scale resorts.

4. Integrate tourism development with parks and protected areas.

5. Integrate tourism with subsistence fishery activities for recreation, education and restaurant market supply purposes.

6. Explore tourism opportunities for Kōļaļ-eņ and Enigu areas.

7. Integrate environmental education activities with tourism related recreational opportunities.

8. Develop tourism oriented public awareness activities for visitors and residents that focus on both conservation awareness and skill development for the Marshallese people.

9. Develop a Tourism Master Plan for the entire RMI with specific recommendations for Mājro that are based on natural and cultural attractions.

10. Develop immediate and long-term activities that connect cleaning up the beaches, and overall support of non-polluting activities with tourism potential, especially for the urban parts of Mājro.

11. Encourage hotels, libraries or businesses to incorporate nature and conservation oriented exhibits, displays, brochures and videos in their lobbies or public areas.

Dredging and Dredge Sites

- Compile improved guidelines for dredging and quarrying activities that take into account potential direct and indirect negative impacts on shallow reef-fish resources. Incorporate these guidelines into a comprehensive lagoon resources recovery plan.

- Confine dredging operations to the southeast lagoon where most construction materials are needed.

- Confine nearshore dredging to a "zone" between Eoonmaaj and Jarōj Islands, which have already by degraded by urbanization.

- Prohibit dredging in areas where there are large prominent coral heads.

- Conduct sand dredging operations further offshore in the lagoon utilizing floating equipment.

- Avoid open water discharges from suction dredging since it can kill coral reef communities by siltation and has other negative long-term impacts on the marine life.

- Minimize siltation destruction from dredging by confining discharges using silt curtains or settling out the discharge in land-based settling ponds before the discharge water is returned to the lagoon.

- Double the width of the existing small boat channel to improve passage safety and reduce inflow velocities.

- The leeward entrance of the boat channel should be widened into a bell-shaped configuration to facilitate greater latitude for boats entering the channel.

Fill Land Expansion

- Discourage any further land fill expansion on Mājro Atoll.

Quarrying and Quarry Sites

- Base future quarry hole development on long-range plans to conserve quarry rock, maximize efficiency, and minimize adverse environmental impacts.

- Design quarries which are suitable for marine life settlement and growth and locate them on the seaward side of the reef, away from islands.

- Investigate the feasibility of using abandoned quarry holes for mariculture.

- Design quarry holes that are 6-13 feet deep and devoid of small loose rocks and sediment.

- Establish non-excavation (buffer) zones on the inner and outer ends of reef flats subject to quarrying to prevent shoreline erosion.

Shoreline Protection

- Protection of valuable coral reefs should be given high priority when establishing procedures for shoreline development projects.

- Investigate the feasibility of shore protection structures and measures for the northern eroding end of Mājro Island (Laura).

- Restoration of pre-existing openings is crucial in the urban area to provide improved circulation water quality, flushing to reduce the bacterial count from sewage pollution, and possibly shoreline erosion.

Causeways, Culverts and Bridges

- Design any potential causeway between Jarōj and Pikeel-ean̄ to minimize the disruption of natural water flow and sediment transport patterns and to reduce the negative impacts on fisheries and reef communities.

- Install culverts and bridges along the islands of the southeast lagoon to restore water quality and favorable conditions for coral reef recovery, especially between the islands of Jarōj, Wūlka, Pikōdāt, and Teļap.

- Use pre-existing leeward openings between islands for bridge siting to reestablish the exchange of wind and current driven water between the lagoon and ocean in order to improve water quality and reduce erosion along southwest lagoon shorelines to Mājro Island (Laura).

- Investigate the establishment of new culverts and bridges which may reduce shoreline erosion.

Solid Waste and Sewage Disposal

- Improve solid waste collection and disposal procedures to minimize negative long-term impacts.

- Investigate the privatization of waste collection and the establishment of regular garbage pickup schedules.

- Educate residents on the negative effects of solid waste disposal into the lagoon and surrounding waters.

- Focus immediate public cleanup efforts on the beach and roadside areas.

- Complete the wall around the existing solid waste dump site for both wind protection and cosmetic purposes.

- Compact and cover the existing landfill with sand on a more frequent basis.

- Inspect the outfall site. If warranted, extend the sewage discharge pipe out an additional 80 feet at a minimum; the deeper the outfall, the less deleterious effects it will have as it is subjected less to wind and tidal motions.

Other Recommendations

1. Develop a coastal resource management plan focusing on waste management, fisheries, tourism, agriculture, village settlement and transportation needs.

2. Eliminate the "dips" in the roadways in urban Mājro by clearing them, redigging the channels, and building culverts over them to allow water exchange amd safer passage of vehicles.

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APPENDICES

APPENDIX A

CIRCULATION AND SHORELINE SURVEY OF MĀJRO ATOLL, REPUBLIC OF THE MARSHALL ISLANDS

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ABSTRACT

Mājro Atoll is the seat of government of the Republic of the Marshall Islands, a small, rapidly growing country. With a present population exceeding 20,000 (1988 census), Mājro has been the site of numerous development and engineering efforts which have had extensive environmental effects.

Quarrying, landfill, and other shoreline modifications have contributed to changes in the geophysical processes of the atoll. Road and airport construction has resulted in nearly 60% closure of the lagoon, altering the flow dynamics.

This study was designed to gain a better understanding of the water flows in the lagoon, and to gain insight into the effects of human intervention on the physical processes of the atoll as a whole.

Direct flow measurements were taken using drogues. These were augmented by visual observations and interviews with local residents.

Beneficial conditions include excellent circulation in the central and western parts of the lagoon. Problems include poor circulation in the eastern end of the lagoon and a resultant partial fouling in the urban Mājro area. Nearly complete closure of the leeward side of the atoll (with a single small bridge), forces water westward, causing visible erosion at the tip of Mājro Island (Laura).

Recommendations include the construction of several additional bridges to enhance circulation, as well as improved procedures for dredging, sewage discharge and waste disposal.

OBJECTIVES

1) Evaluation of the water flows through the lagoon and an estimation of the impact of these flows on the shoreline.

2) Investigation of shoreline erosion observed and reported by the Marshallese government.

3) Observational survey of the shoreline conditions.

4) Recommendations regarding erosion control, shoreline project management, and improvements or changes in on-going procedures which may impact the atoll environment at Mājro.

METHODOLOGY

Water-based Methods

Accurate evaluation of water flows through an atoll the size of Mājro, (114 sq. mi.) in twenty days, is quite difficult. In order to get the most useful survey results, a mixture of methods was used. Flows were measured directly using floating drogues.

Visual observations were also recorded, and additional data was taken from interviews with local fishermen and other sources. Estimates of some flows were also made, based on source data from all these methods.

Drogue Study

Water flows may typically be measured by using direct-measuring flowmeters, or by other direct or indirect methods. The use of so-called drogues is an inexpensive, simple, and relatively crude survey method. A drogue is essentially an object of large surface area which is put into the water and is allowed to drift with the water mass for some period of time. Figure 1 illustrates the drogue design used for this study.

The drogue itself is merely a curtain of sail-cloth hung on a rigid rod, weighted at the bottom, and suspended from a float at the water surface. The drogue may be suspended just below the surface, or may be deployed at variable depths. In this study all of the deployments were essentially at the surface, (top of curtain at 3 ft depth), except for two deployments, which were at a depth of 85 ft.

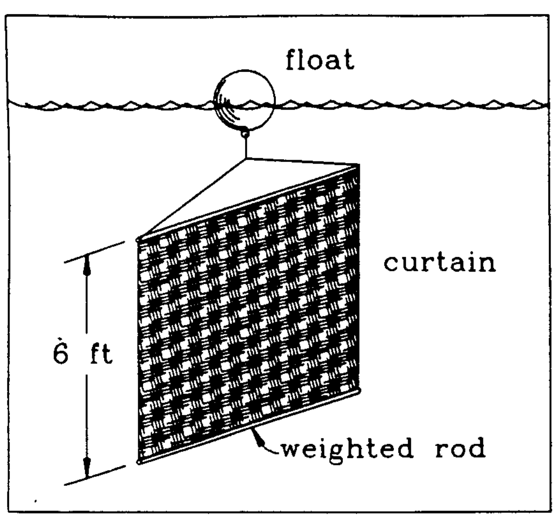

Figure 1 Typical drogue deployment

A drogue succeeds in accurately following water movement rather than wind movement so long as the drag of the water on the drogue far exceeds the drag of the wind on the float above it. Therefore, in principle, the drogue needs to be as large as is practical, and the float serving as its marker needs to be as small as possible and still be locatable by some means. In this study, no radio locator was available, so visual methods were used. The drogues used were 6 ft x 6 ft single-curtain type, with 14 inch diameter orange floats used as markers.

Current information is derived by deploying a drogue from a boat, recording its position, allowing it to drift with the water mass for some period of time, and then picking it up and recording its new position. By mapping the starting and ending positions, and dividing out the drift time, an average speed and straight-line flow direction may be calculated. Although such methods do not resolve velocity fluctuations occurring during the period of deployment, they do allow fairly accurate measurement of very low averaged flow velocities. As it turns out, flow velocities at Mājro are generally under 0.5 kt, so this method was quite successful.

Locating the points of deployment and recovery may be accomplished by more or less accurate methods. In this case, radio-rangefinder equipment was not available, so manual methods were used. A number of shore fix positions were established and their geographical locations mapped. In particular, three very tall water tanks in the urban Mājro area were used, as well as selected additional buildings and island features. The boat position was established before each deployment and after each pickup by sighting the shore fixes with a hand-bearing compass. The estimated accuracy of this method depends on the linear distance from the object sighted, but an angular accuracy of +/-2.5 degrees was estimated in this study.

A total of 24 deployments were made, with 22 successful recoveries. Two drogues were lost in rough conditions, due to fading daylight, and excessive deployment time.

Land-based Methods

Water flows were observed directly from shore in some places. Although these observations were short in duration, in some cases the flow rates observed were quite high, with useful results obtained in only a few minutes. Timed observation of small floats was used to measure flows under the small boat channel bridge.

Surveys of some shoreline areas were conducted on foot, and provided valuable qualitative information pertaining to flow directions, erosion, deposition, and other processes. In many instances such shoreline areas were accessible only during periods of low tide and/or very calm conditions.

Repeated observation of some easily accessible shoreline areas under widely varying conditions of tide, nearshore flow, wind, and wave conditions provided additional insight into the prevailing shoreline processes.

Interviews

Interviews with local people having long-term experience with the conditions in Mājro lagoon provided additional information of great value. Comments on seasonal effects, long-period processes, and the effects of storms and waves were recorded. Particular comments were solicited regarding erosion of the shoreline in some places, as well as the apparent long-term effects of man-made structures and shoreline modifications.

RESULTS

Current Study

The flow study reveals relatively slows flows in most places inside the lagoon. Table I (provided at the end of this report) summarizes current data obtained using the drogues. This data is shown schematically in Figure 2.

It must be noted that these data were taken over a very short time-period, during fairly stable weather conditions. Thus it may or may not reflect flows considered in the longer term, or under more severe weather regimes.

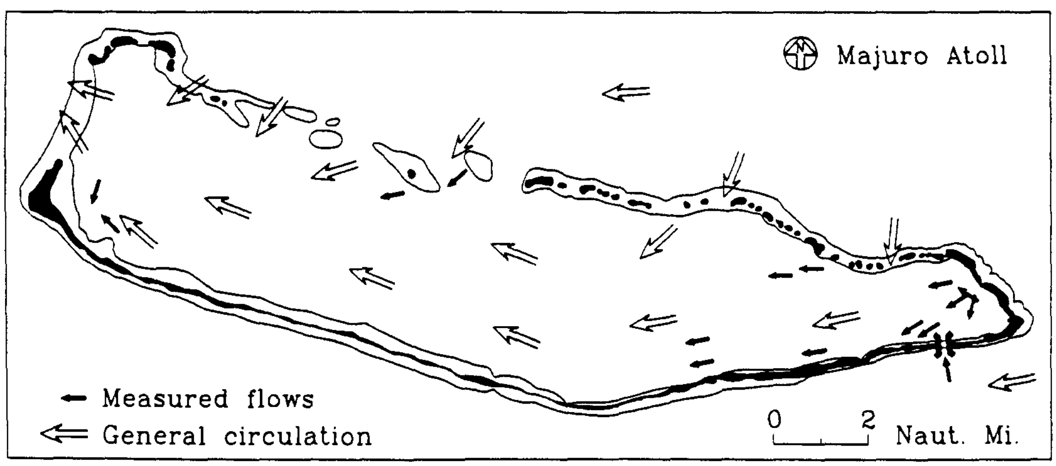

Figure 2 Circulation in Mājro Lagoon

East End of Mājro Lagoon

The prevailing wind at Mājro in July is from the northeast, typically 075 degrees (true). Surface flows measured near the east end of the lagoon, in the urban Mājro area, are almost all directly down-wind, or nearly so. The water appears to move downwind under wind stress, with the flow speed averaging around 0.2 kt. The water moving southwestward is deflected by the shore into more nearly westward motion.

The westward flow along the shore finds virtually no outlet for nearly 30 miles, with the water finally spilling seaward beyond the far end of the last island, Mājro islet (Laura).

There is no opening at the extreme northeast end of the island (at Jarōj), and the water there appears to be nearly motionless, even under moderate wind conditions. The water in this area is discolored (slightly green), probably having a long residence time, and subject to urban pollution influences.

Information from local sources suggests that nearshore flows do occur toward the southeast (alongshore), depositing sand. No such flows were actually measured in this study.

Two miles southwest of Jarōj, off Wūlka, the water does appear to be moving slowly southwest. Since it has no surface source, it must be supposed that some upwelling is occurring. The lagoon has a fairly flat bottom in this area, with an average depth of 145 ft. Drogues cast and followed at 85 ft depth show water moving to the northwest, rotated nearly 90 degrees from the direction of the surface water. This may be evidence of the source supplying water for the surface flow observed.

Further west, along the shores of Teļap and Long Island, the flow appears to be fairly steady, averaging about 0.2 kt westward.

Bridge Over Small Boat Channel

Approximately 2.5 miles west of the south-eastern corner of the lagoon (at Teļap), a small-boat channel was cut through the reef and a bridge was constructed, in the early 1980's. This channel provides the only opening in the present shoreline of Mājro along its entire south side. The opening is about 100 feet wide, and the water depth averages 15 feet.

Water flows were observed to be predominantly into the lagoon, with strong flows at high tide, and weak flows at low tide. Only two observations in 30 showed water flowing out of the lagoon, with very weak flows in those cases. Typical measured inflow speeds at high tide were 4 - 6 kt. At low tide, typical flows are estimated to be on the order of 1/2 to 1 kt.

Water emerging inside the lagoon from these flows turns westward, joining wind-driven surface water already moving westward.

Observation of these flows during conditions of a strongly rising tide reveals that the change in water level inside the lagoon at the east end may substantially lag behind the change in water level outside the lagoon. Although not measured directly, the difference in water levels appeared to be as much as one to two feet, with high water outside the lagoon rushing in under the bridge at speeds exceeding 5 kt.

Flows along the shore in the vicinity of the bridge outside of the lagoon seemed to be predominantly westward, regardless of tidal condition. This may be attributable to wave setup.

Airport Area

Measurements in the vicinity of the airport and elsewhere along the southern shore of the lagoon show a current averaging 0.2 kt westward. It is inferred that this westward-moving water is forced to turn northwestward following the shore, and eventually exits north of Mājro islet.

Mājro Island (Laura) and West End of Lagoon

Drogue-based flow measurement provided ambiguous results. These measurements were taken during conditions of falling tide. Of two cases, one showed a northwestward flow, and a nearly adjacent deployment showed a southward flow. It may be supposed that during conditions of falling tide, very little water motion actually takes place. The measured flows in these cases are very slow, averaging only 0.1 kt.

Information obtained from local sources suggests that during conditions of rising tide and high tide, the flow is strongly northwestward, with large volumes of water exiting the lagoon over the coral sill between Mājro and the Enigu Islands to the north. Indeed, shore-based flow observations indicate strong northwesterly flows even within 10 ft of the high-water mark along the shore at the northern tip of Mājro. Such strong flows were observed on both the lagoon side and the outside of the tip of Mājro Island (Laura). Photo interpretation by J. Eckelman of Manoa

Mapworks, comparing aerial photos taken in 1983, with 1955 AMS maps based on World War II-era aerial photos, shows evidence of long-term shoreline erosion on both sides of the tip of M̄ajro in the same places where these strong currents were observed.

North Side of Lagoon and K̄olal-en Passage

Flows were measured just south of Anemwanot Island, in the northeast quadrant of the lagoon. The islands along the north side of the lagoon are strung together with coral reef flats serving as sills between them. These sills are exposed at low tide, and reveal snaking riverine channels in some cases. Water enters from the north between these islands at high tide. The measured flows in the lagoon in this vicinity showed westward flow, consistent with measurements elsewhere.

The K̄oļaļ-eņ Passage area is the deepest channel into M̄ajro Lagoon. It exposes the interior of the lagoon to direct effects of large ocean swells, and exhibits strong current effects. This area is accessible safely by small craft only under the calmest of conditions. Flow measurements taken there showed flows into the lagoon in a generally southwesterly direction on a rising tide. No measurements were obtained there on a falling tide. These flows were clearly in excess of 0.5 kt, suggesting that the greatest mass of water exchanged between the interior of the lagoon and the outside occurs here.

It is not clear how much water exits the lagoon to the north on a falling tide, through the K̄oļaļ-eņ Passage. Some evidence suggests that at least some of the water moves westward, eventually exiting over the sill north of M̄ajro. It is clear, however, that this large opening allows by far the largest inflow into the lagoon.

DISCUSSION

Pre-20th Century Conditions

Currents, and shoreline conditions at M̄ajro were clearly quite different before the intervention of various modification projects of this century. Reports of older local residents, as well as observations taken at low tide, allow the development of a picture of earlier conditions, and serve to put the present situation into perspective. Figure 3 summarizes what pre-20th century conditions may have been like, especially in the eastern part of the atoll.

M̄ajro previously had many more openings between its various islands than it does today. In the urban M̄ajro area at the east end of the atoll, there were at least and must have served as entry points for wind- and wave-driven currents into the lagoon, especially at high tide. It may be inferred that the eastern end of the lagoon had good circulation, with tidally driven current pulses.

Along the southern side of the lagoon, there were openings between many of the islands until fairly recently. These openings are estimated to have totalled two and one half miles. They must have allowed substantial flows. Because of their location, these openings may have experienced flows primarily out of the lagoon.

The prevailing Equatorial Current outside the lagoon is flows primarily westward. Occasional seasonal shifts to eastward are reported to occur. Under such conditions, with openings all around the atoll, currents in the lagoon may have been primarily west or southwestward, and occasionally eastward, following these external currents and subject to wind conditions.

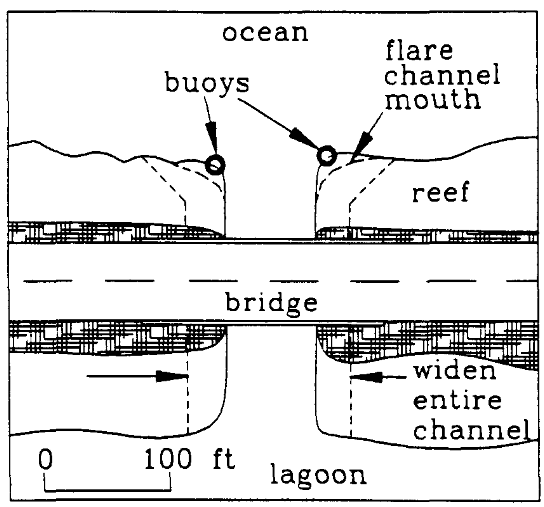

Figure 3 Proposed Bridges

Influence of Modern Shoreline Modifications

The openings between Jarōj, Wūlka, and Teļap were the first ones to be filled, and served to cut off the circulation in the easternmost end of the lagoon, especially just south of Jarōj.

Further filling at the new airport on the south side of the lagoon, and construction of a solid-filled causeway reaching from urban Mājro all the way to Mājro island, substantially altered the water flows. The causeway prevents any water exchange of water along the entire south side of the lagoon. Most of the water exchange of water along the entire south side of the lagoon. Most of the water entering from the north or northeast is forced along westward and eventually northwestward, before finally exiting north of M̄ajro island.

The small boat channel, located in the southeast rim of the lagoon, is so small that very little water can actually come through it, compared to the several miles of openings that once existed.

Present Conditions

The nearly complete closure of about 60% of the rim of the lagoon has resulted in considerably changed flow dynamics. Since the closure is along the leeward side of the lagoon, wind setup of the water level may be intensified under the normal northeasterly trade wind regime. This raised water-level effect was not actually measured, but its effects are apparent. Scouring of the reef and increasingly severe erosion are observed along the southwestern shore, especially at the tip of M̄ajro Island. (More specific notes on the shoreline erosion are provided in a section below.)

The closure of the passages through the urban M̄ajro area has resulted in a nearly stagnant area, especially just south of Jarōj. This area is characterized by greenish coloration of the water from algal buildup. Greatly increased bacterial counts have also been reported by other workers. Very slow currents are reported along-shore moving southward, but these were not measured. Wind-driven upwelling is inferred from the measured data, with gradually increasing southwesterly surface currents with increasing distance from Jarōj.

It appears that most of the flow into the lagoon occurs in pulses. When the tide is sufficiently high outside the lagoon, water enters primarily through the openings along the north edge of the lagoon, aided by the wind. Additional water enters through the small boat channel at relatively high velocity. When the tide has fallen sufficiently on the outside, the water flows out primarily at the western end. As noted earlier, the small boat channel almost always sees an inflow, even at low tide. Only an extremely low tide results in any outflow through this small opening.

Casual observations suggest that the inside of the lagoon may have tidal water levels substantially out of phase with the outside water levels. Visible water level differences between inside and outside apparently exceeding one foot were observed at the small boat channel. Measured flow speeds exceeded five kt in this narrow channel as already mentioned.

Summary of Beneficial Conditions

* Good flushing and clean water in the central and western parts of the lagoon.

* Small but significant water exchange in southeast corner of lagoon at small boat channel.

Summary of Problems

* Partial closure of the lagoon by causeway construction and other filling.

* Lack of flushing in the urban Mājro area.

* Shoreline erosion especially at Mājro island.

Shoreline Survey: Results and Discussion

Erosion and Siltation

Ground-level examination of the shoreline at Mājro has revealed serious erosion and redeposition processes only in one location, at the lagoon side of the northern tip of Mājro. Water flowing northwest along the lagoon side and exiting over the coral sill to the west is rapidly eroding the raised shoreline.

The shore rests on a dead coral reef base, which is barely awash at low tide. The shore itself rises abruptly four to six feet on the lagoon side and is composed of soil with embedded plants and plant roots. Large palm trees grow right to the edge.

Interviews with local residents revealed that the erosion has proceeded quite rapidly. One resident reported the shore has been set back as much as fifty feet in the last four months. Large palm trees have been torn from the edge and lie on the reef flat, some so recently toppled that they are still green. One local resident reported that in his lifetime as much as several hundred feet of shoreline has been lost, though most of it at a much slower rate than that observed recently.

Redeposition of sand and dirt eroded from the shore is occurring at the very tip of Mājro. A spit several hundred yards long has formed, tapering northwestward. The original shore is still visible, but the newly deposited material has been there at least several years and now supports grasses and some small bushes.

Another local resident however, reported that this spit has been there with seasonal variation "for a long time". He reported that the shape changes seasonally, with its tip sometimes bending in an arc to the north, into the lagoon, and at other times bending westward toward the open sea. Its present configuration (July 1988) is directly northwest with no bend.

Casual observation by wading and snorkel diving very near shore on both sides of the tip of Mājro revealed fairly strong currents even five feet off shore. No actual speed measurements were taken, but the direction was noted on several occasions to be to the northwest, on both sides of the island.

Erosion on this scale was not observed at any other location at Mājro. In fact, the lagoon side of Mājro island further east, and all locations examined eastward right to urban Mājro showed no signs of erosion at all. The one local exception observed is the area immediately around the lagoon side of the small boat channel, where scouring appears to occur continuously.

Some siltation is evident all along the southern lagoon side of the atoll. Coral formations appear to have experienced considerable stress and are dead or dying in some places. This effect appears to be concentrated toward the eastern end of the lagoon and not the western end. Some silt and sand burden was directly observed by snorkel diving in some nearshore reef areas along the lagoon side of Long Island, and may be representative of similar conditions elsewhere on the same shore.

Very slight sand transport effects were reported in the area south of Jar̄oj. A sand mining operation takes advantage of this transport. No objectional loss of sand appears to be occurring at Jar̄oj, and this process is probably very slow.

Shoreline Modifications

Numerous shoreline modification projects have been undertaken in modern times at Mājro. They include the dredge and fill operations for the construction of the causeway linking the islands of the southern side of the atoll, the construction of the new airport, dock construction in the urban Mājro area, sand mining operations, and others.

Taken as a whole, these activities have had considerable impact on the once-pristine condition of the shoreline. Two effects are especially important.

Direct destruction of the reef structure and nearshore habitat is the most visible result in many areas. At least 15 to 20 percent of the total shoreline appears to be permanently altered in this way, especially by coral mining and dredging for construction of the causeway.

The indirect consequence of these activities appears to have been siltation of some reef areas, with losses of live coral and other features of the reef habitat. Siltation appears to have affected primarily those modified areas which are inside the lagoon. Those areas outside the lagoon where mixing has occurred, appear to have good or excellent flushing, and siltation does not appear to be very significant.

Some quarry areas were examined for evidence of regrowth and natural restoration processes after their initial excavation. Such regrowth appears to proceed extremely slowly, and may be expected to take many tens of years.

Small Boat Channel

This channel and the "Mājro Bridge" were constructed ostensibly to provide leeward access to outside waters for fishermen and boaters using small craft. The channel construction is quite narrow, and is fairly hazardous to small craft some of the time. The designers of the channel and bridge clearly did not take into account the water flow conditions which now exist.

The channel itself is a fairly straight cut through the reef. Neither end is flared. Thus water entering the channel in either direction becomes immediately turbulent, with eddies large enough to affect boats.

The seaward side of the channel sometimes has breaking waves across its mouth. When these waves exceed three feet or so, boats are additionally influenced and the passage becomes even more hazardous. It appears that usually there is a current flowing westward outside the channel, along the shoreline. (This was not measured, but could be directly observed from shore). The combination of this current and any waves of any significant size make it particularly difficult for boats to accurately position themselves for entry into the channel.

The channel is also unmarked, neither by buoys of any kind, or by lights or markers of any kind. Thus the channel is particularly hazardous at night. Interviews with local boaters indicates that most do not consider the channel navigable at night except under the calmest of conditions.

It is significant that each of the several boaters interviewed considered the improvement of this channel of primary importance, and each had specific suggestions. These suggestions are discussed in a section below.

Beach Conditions

The shoreline at Mājro Atoll varies from rocky, to coral reef flats, to sandy beaches. Taken as a whole, most of the sandy beaches appear to be in good condition. However, as is well known to the RMI government, beach litter has become a serious problem, especially in the urban Mājro area, and along the southern lagoon side all the way to Mājro island. Non-biodegradable plastic litter is particularly evident. Some places in Jarōj appear to have beaches covered more than a foot deep in plastics, metal objects, and tires, etc. Floating plastic objects appear to drift downwind, ending up on beaches along the southern lagoon side. Mājro island appears to be particularly heavily deposited. Floating plastic objects were seen on nearly every boat outing in the lagoon. Even islands to the north, such as Irooj, which are otherwise fairly untouched, have moderate litter loads, both on the beaches and piled up on the shore, evidently having been left there by picnickers. It is expected that without significant policy changes, this problem can be expected to worsen.

Waste Disposal and Landfill

The conditions described above are intimately tied to waste disposal practices and related landfill practices at Mājro. To date Mājro has no comprehensive waste collection plan. Solid waste appears to be discarded onto the shoreline in some areas, and collected in other areas. Collected solids are trucked to a dump site located on a lagoon-side shoreline site several miles west of urban Mājro.

The dump site is managed with bulldozers, and solids are compacted periodically. The regular strong winds serve to scatter the lighter solids, and containment of these materials appears to be difficult. Any serious storm conditions serve to scatter these wastes back into the lagoon and over-land downwind toward the sea to leeward. An incomplete wall has been constructed between the dump site and the road to its leeward. This wall does inhibit some dispersal of lighter solids by the wind, but does not extend along the entire downwind margin of the site.

Sewage Treatment and Disposal

Mājro has until recently had no means to treat or dispose of sewage. With no appropriate facilities, the lagoon in the urban Mājro area has taken the brunt of the effluent. As a consequence, bacterial conditions in the lagoon in that area have been reported to make swimming in the lagoon not recommended, or unsafe.

In recognition of the problem, the RMI has built a new sewage treatment facility, and an outfall pipe has been constructed to the sea to leeward. While it is unclear when this facility will come to serve the majority of people at Mājro, it is a step in the right direction.

Of significance, however, is the nature of the outfall pipe. Plans appear to have called for an exit depth of forty feet for the end of the pipe. One knowledgeable local diver reported that inspection of the end of the pipe after its installation revealed that it is in roughly twenty five feet of water. Dispersal of the effluent in water that shallow, could have long-term deleterious effects on the nearshore leeward coral reef habitat.

Control of Runoff

Freshwater runoff is hardly a problem in most places at Mājro. In those places where roads are heavily used, and rainwater can collect rapidly, so-called "dips" or swales have been constructed across the main road to allow rapid runoff into the lagoon. These slanted channels appear to fill rapidly with rainwater whenever it rains. They do not appear to drain well at all. Examination of the drainage passages from the road to the lagoon revealed in most cases that the channels are clogged or have insufficient slope to be effective.

Objection to these dips has been voiced in the local newspaper. Even when dry they appear to be bothersome to drivers.

Summary of Beneficial Conditions

* Most exterior shoreline in excellent condition.

* North and west sides of atoll relatively undisturbed.

Summary of Problems

* Shoreline erosion at Mājro island.

* Siltation along some southern shores inside lagoon.

* Very slow regrowth of areas disturbed by quarrying and dredging.

* Dangerous conditions at small boat channel, including channel too narrow and lack of navigation markers.

* Litter on beaches, especially plastics and disposable diapers.

* Solid waste at dump site subject to dispersal by wind.

* Effluent discharge into lagoon in the urban Mājro area.

* Waste treatment plant discharge pipe may be insufficiently deep.

* Drainage of runoff "dips" inadequate, impeding vehicular traffic during rainstorms.

RECOMMENDATIONS

Lagoon Circulation and Erosion at Mājro

In view of the circulation problems presently observed at Mājro, the single most important thing which should be done is to reopen several previously existing passages through the lagoon. This can be done using channels and bridges, or large culverts, depending upon location. Openings should be provided in two areas, addressing two slightly different but interlocking problems.

Leeward openings should be provided in at least two and preferably three locations. These openings should be as large as possible. Although it would be impossible to build openings large enough to allow the flow volumes of earlier times, several reasonably sized bridges would probably help considerably. Three bridge sites suggested for the leeward side are marked on the map in Figure 3. Exact siting is not critical, but the further west they are the more effective they will be in alleviating erosion at Laura. Pre-existing openings between islands should be used for bridge siting. Such leeward openings would allow wind- and current-driven water to spill southwestward into the sea and inhibit the movement of water further west and northwest in the lagoon along the shore to Mājro island.

The second area where the restoration of pre-existing openings would be very useful is in the urban Mājro area. As many of the three largest original openings as possible should be reopened. Figure 3 also shows the suggested locations in detail. These openings were originally fairly narrow. Bridges with channels under them are suggested. Such channels must be deep enough to allow significant water exchange with the ocean.

These openings would serve to provide improved circulation and flushing of the water in the lagoon in the urban M̄ajro area. Improved circulation would reduce the bacterial count in the easternmost end of the lagoon. Perhaps water quality could be restored to a level appropriate for swimming and other tourist-related water activities. An additional and equally important consequence of these openings may be a significant impact on the water level balance between the east end of the lagoon and the open sea. If additional water can enter the lagoon on a rising tide through these openings, it may reduce the inflow rate at the small boat channel, improving boating safety substantially. These reopened passages do not need to be sufficiently large to accommodate small boat traffic themselves, since openings to windward are never preferred for boating.

Erosion at M̄ajro Island: An Additional Remedy

Since the shoreline erosion at M̄ajro appears to be developing very rapidly, an additional short-term remedy is suggested, which is very inexpensive and easy to implement. A stone wall can be constructed from the very tip of the lagoon side of M̄ajro, back at least several hundred yards. Such a wall, if sufficiently well constructed, could prevent further landward erosion. It should be stone and concrete, well anchored into the coral reef flat, and relatively heavy and watertight. A rip-rap wall of large rocks would not suffice, since the soil is completely exposed and would continue to erode behind it.

This sort of remedy would not alleviate the source of the problem but would certainly reduce or eliminate the effects until such time as more comprehensive solutions can be implemented.

Effects of Dredging and Quarrying

The continued modification of M̄ajro's shoreline by dredging, quarrying, sand mining, and other activities is clearly unavoidable. Some of these activities are more hazardous than others.

Suction dredging in particular, is one of the more hazardous activities in its long-term effects on marine life, if not conducted with the utmost caution. Suction dredging liquefies bottom material to such an extent that its discharge does not settle out if dumped back into the lagoon. Such discharge rapidly stresses the marine life subjected to it, and tends to kill off coral reef communities by siltation. Suction dredging should be avoided whenever possible at M̄ajro unless discharges into open water are prevented. Bucket dredging methods could be substituted instead since this method generally results in less impacts to coral reefs from sediment resuspension. If suction dredging must be used, then siltation should be inhibited by careful use of siltation curtains. Discharge should be settled out as much as possible in land-based settling ponds before discharge water is returned to the lagoon.

The effects of quarrying activities which directly affect the coral reef structure cannot be avoided in the short term. However, marine life regrowth at quarry sites may be promoted if the quarries are properly shaped. Quarries should be preferentially located on the seaward side of any island.

Small Boat Channel

Modifications to the small boat channel should be treated on two levels. Recommended major modifications which take a relatively long time to implement should not stand in the way of recommended minor modifications.

The suggested major modification is to double the width of the channel. This requires at least partial reconstruction of the bridge. Doubling the channel width would provide much improved passage safety for small boats. It may also reduce inflow current velocities to some extent, possibly by as much as half.

Recommended minor modifications are shown in Figure 4. The leeward (seaward) entrance should be widened into a bell-shaped configuration. This would allow boats greater latitude in their approach positioning upon entry into the channel. Lighted channel markers should be placed on both sides of the channel, exactly pinpointing the edges for navigation.

Solid Waste Disposal

Improvements in solid waste collection and disposal procedures will be necessary before the long-term impact of waste disposal into the lagoon can be abated. Discussion of comprehensive alternatives in this area are outside the scope of this report. It should be noted that one alternative which has been under discussion at M̄ajro is the privatization of waste collection and the establishment of regular periodic garbage pickup. Educating residents of M̄ajro regarding the deleterious effects of solid waste disposal into the lagoon and surrounding waters is probably also one of the most important priorities in this regard. Such plans would do much to improve conditions. Their implementation, even under the best of circumstances would take a long time. In the meantime, several lesser efforts could also help.

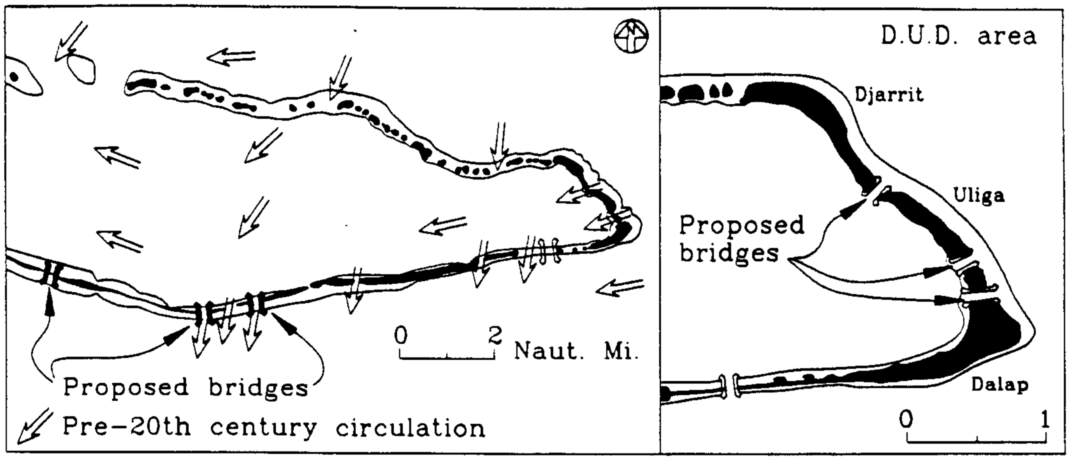

Figure 4 Proposed changes at small boat channel

During U.S. Secretary of State George Schultz's visit in July 1988, Mājro underwent its first-ever major public clean-up. This served to heighten public awareness of the litter problem. Instituting such cleanups on a periodic basis, say annually, would probably help considerably. A public cleanup effort specifically targetted toward beach cleanup would help improve public awareness of the specific effects of solid waste on Mājro's waters.

The solid waste disposal site presently in use should be improved in two respects. The wall which was begun as a cosmetic effort to isolate the view of the dump from the road should be completed to the west. This wall acts as a wind barrier and is effective in reducing the scatter of the lighter solid waste components such as plastics and paper. Additionally, more frequent compaction of this landfill and covering it periodically with sand would also help reduce scatter.

Sewage Discharge

The sewage discharge pipe which is believed to terminate in twenty five feet of water should be inspected. If the outfall discharges are causing impacts to shallow reef environments, it should be extended substantially. In principal, the deeper the outfall, the less deleterious effect it will have. If the pipe were extended to a depth of say 80-100 ft, the discharge would get scattered much more substantially than it is near the surface. Tidal motions at such depths are somewhat greater than near the surface and may be more effective in dispersing an outfall.

Rainfall Runoff

The "dips" across the roadway should be improved in one of two ways. In some instances, the drainage channels from the roadside to the lagoon simply needs to be cleared. Apparently such simple maintenance has not been undertaken in quite a while. In some cases, the slope of the drainage channel is not sufficiently steep to allow proper drainage even if the channel were cleared. In those cases, the channels should be re-dug and steepened to a slope of at least 1/4" per linear foot.

The dips which are right in the urban Mājro area could be covered over and made into culverts with drains running into them. This would allow traffic to pass without the disturbance of driving down and then back up out of each dip. During rainstorms, the dips fill with water, stalling cars and traffic along the road.

Summary of Recommendations

Lagoon Circulation & Erosion:

* 2 - 3 leeward openings with bridges.

* 3 channels and bridges in urban Mājro area.

* Rock wall, lagoon side of tip of Mājro island.

Dredging & Quarrying:

* Use siltation curtains when suction dredging.

* Avoid suction dredging whenever possible.

* Quarry on ocean sides of islands.

* Channels to open water for each quarry hole site.

Small Boat Channel:

* Marker buoys for navigation.

* Flared shape for outer end of channel.

* Widen channel.

Solid Waste Disposal:
* Privatization of waste collection.

* Regular waste pickups.

* Periodic public cleanups.

* Beach cleanup.

* Complete wall at dump site.

* Cover solid waste frequently with heavy material.

Sewage Discharge:
* Extend outfall pipe to 80-100 ft depth.

Rainwater Runoff:
* Clean out "dips".

* Cover "dips" in urban Mājro area rebuilding as culverts.

Table 1 Ma̅jro Lagoon current data

#	LOCAL DATE (July '88)	PLACE (3 ft deep, or as noted)	LOCAL START TIME	TIDAL PHASE	TIME PAST HIGH TIDE	TRUE DIRECTION	SPEED KT
1	7/14	D.U.D./SE	9:58	↓↓	5:37	225°	0.17
2	"	"	10:06	↑↑	5:47	244°	0.25
3	"	D.U.D./SW	12:20	↑↑	8:01	255°	0.20
4	"	"	12:30	↑↑	8:11	230°	0.20
5	15	"	10:30	↓↓	5:36	272°	0.12
6	"	"	10:35	↓↓	5:39	232°	0.14
7	18	"	9:28	↓↓	3:01	242°	0.15
8	"	Sun Hotel	10:20	↓↓	3:53	243°	0.17
9	"	D.U.D./SE	11:35	↓↓	5:08	250°	0.36
10	"	"	11:40	↓↓	5:13	244°	0.50
11	"	"	14:02	↑↑	7:35	240°	0.30
12	"	D.U.D./NW	14:04	↑↑	7:37	254°	0.24
13	19	Airport	9:15	↓↓	2:21	256°	0.23
14	"	"	9:25	↓↓	2:31	256°	0.25
15	"	Anemwanot	12:10	↓↓	5:14	272°	0.08
16	"	"	12:15	↓↓	5:19	285°	0.22
17	21	Laura	10:55	↓↓	2:55	173°	0.06
18	"	"	11:00	↓↓	3:00	284°	0.16
19	23	D.U.D./SE (85 ft deep)	11:05	↓↓	1:22	330°	0.09
20	23	"	11:10	↓↓	1:30	316°	0.11
21	26	Calalin	~12:00	↑↑	10:05	235°	~1/2
22	"	SW of Iroj	~12:15	↑↑	10:20	245°	<1/2

APPENDIX B

EVALUATION OF CONSTRUCTION MATERIALS AND ENGINEERING GEOLOGY OF MĀJRO ATOLL, REPUBLIC OF THE MARSHALL ISLANDS

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INTRODUCTION

The purpose of this report is to point out the critical need for the Government of the Republic of the Marshall Islands (RMI) to acquire and/or assist the construction industry to develop sources of construction materials. Construction materials are not in abundant supply throughout the atolls because of the limited amount of land available. Good material is in short supply, hard to locate, and getting more costly to acquire and develop every day.

The future development of the island and even the repair and maintenance of present facilities require construction materials from sand to armor rock. The government at this time purchases these construction materials from one private source on Mājro which is in very limited supply and non-replenishable. The Capital Improvements Program and Department of Public Works has been entirely dependent upon the acquisition of small amounts of material from this sole source. Because of this problem, the government is faced with paying a high cost for producing the various materials as well as the problem of not having a uniform product and getting inferior material.

It would be impossible to predict exactly what the future needs of construction materials could be, but without question there will be definite future requirements for all kinds of materials in all parts of the Republic of the Marshall Islands. Development in certain parts of the atoll will require different kinds of material than will development in other parts of the atoll and this can only be foreseen by long range planning.

The government of the RMI must realize they can no longer continue with haphazard sources of supply and must exercise some long range planning to acquire, control, and conserve sources to supply all kinds of construction materials.

General geology of Majro Atoll

The Marshall Islands are a group of low coral atolls scattered in two irregular and roughly parallel chains extending in a north and south direction from about 14^{0} 43' N to 4^{0} 34' N., and between 160^{0} 48' E. and 172^{0} 10' E. The Mājro Atoll is located at the southeast end of the Ratak Group in the Marshall Islands. The atoll encloses a lagoon which is 30 miles long (east to west) by three to four miles wide north to south and includes a string of small islands (islets) arranged in a discontinuous, ring-shape. Estimates as to the total dry-land area in the atoll range from 0.3 to 3.5 square miles, based probably on whether the measurements were made at high or low tide.

Mājro Atoll is a large mass of calcareous sediments and coral limestone that extends above the ocean floor and caps a seamount. The seamount is assumed to be volcanic in origin as evidenced from dredging on the outer slopes at great depths. Although no deep borings have been made in Mājro Atoll, two borings drilled to bedrock on Āne-wetak (Enewetok) Atoll (approximately 400 miles NW of Kuwajleen (Kwajalein) Atoll) reach volcanic bedrock at 4,222 and 4,160 feet below sea level. Above the bedrock, magnesium limestone cores were obtained. In still shallow depths up to the surface, principally calcareous materials were recovered. Surprisingly, about 70 percent of the material encountered was unconsolidated. This suggests that the limestone cap on the top of most atolls are essentially a cone of hard limestone filled with loose limestone sediments and occasionally consolidated layers or masses containing cavities. At Enewetok, a cavity as large as 55 feet vertically was encountered during drilling. Atoll limestone deposits are created by the combined action of marine animals and plants; principally corals, foraminifera, and calcareous algae, each secreting calcium carbonate and growing upon the skeletons of their predecessors.

At Mājro, the surface of this limestone is irregular and generally submerged below sea level. However, around the top of the atoll is a higher, near level ridge of hard coral limestone that varies in width and frequently extends above the water surface forming islands and reefs. The surrounding ocean depth plunges to as much as 1,000 fathoms (6,000 feet) within two miles of the atoll, and 2,200 fathoms within 10 miles.

The land surface at Mājro Atoll consists of low, flat islands (maximum natural elevation is about 10 feet). The topography may be considered to be micro-relief. The islets are essentially an accumulation of unconsolidated calcareous sands and gravels on the reef surface or hard erosional remnants of higher biogenetic to clastic limestone reef surfaces, or, more often, a combination of these. The surface of these islets is generally flat, but around the edges there is commonly a low ridge. Along the lagoon side, this ridge is not commonly composed of sand or fine gravel. Along the seaward side, it is more often a hard coral limestone reef surface with cobbles. Substantial portions of the heavily inhabited islands such as Telap Island consist of sandy fills dredged from the lagoon.

METHODOLOGY

This study was accomplished using an interview process supported by mine and dredge site visits. Mājro Atoll was visited between 23 March and 25 March

1989 to gather general information and data concerning the mining and dredging of reefs (for rock, sand, aggregates, and common/select fill) for construction purposes. Information included material sources, types, uses, production rates and techniques, availability, ownership, costs, problems and constraints, etc. Government offices (such as the Department of Public Works and Capital Improvements Program Office), construction contractors and material producers were visited to obtain much of the required information. Previously mined areas for construction materials and dredged sites were visited to observe environmental and geotechnical effects imposed.

RESULTS

From the visits to government agencies, it was learned that the RMI's primary concern as expressed by the RMI Environmental Protection Authority is with the environmental impacts of quarrying and dredging on the marine resources. No environmental constraints have been established in the past nor present to preclude indiscriminate quarrying and dredging. This was verified by field visits to the dredge sites used to construct intra-island causeway project from Teļap to M̄ajro Island (Laura) and the airport shore protection project. Although the physical effects of dredging are highly visible, it's long-range environmental impact could not be predicted. The Department of Public Works expressed concern for the high cost ($7.00 to $9.00 per cubic yard) for sand, gravel and rock which could be severely inflated in the future as demand increases and supply decreases. Presently, all earth construction materials are produced from one commercial quarry operated by Pacific International, Inc. (PII). Mr. Jerry Kramer, Vice President of Operations of PII estimated current reserves at about 1,000,000 cubic yards of sand and gravel and 200,000 cubic yards of coralline rock. At the current consumption rate, these reserves could be depleted in about 4 to 5 years. Pacific International is studying potential sites for it's future operations and expressed concern over possible government restrictions which could preclude the use of favorable sites. Coral atolls typically have hard coral limestone rock on shallow reef flats on the oceansides of islands and unconsolidated sediments on the lagoon-side of islands and on the lagoon floor. Thus, more than one site must be designated for excavation because sufficient amounts of all types of materials may not co-exist at one location.

DISCUSSION

The Republic of the Marshall Islands has maintained a "hands off" policy in the conservation and development of their natural resources, more specifically in the area of construction materials. In the past, the demand for these materials has been met by a sole source industry and by allowing contractors to use whatever is locally available in order to reduce construction costs. Environmental conservation efforts and increasing construction demands by foreign investment is resulting in decreasing an already limited material supply. A double standard in materials acquisition is unknowingly being developed since the government would rather stimulate the materials industry rather than obtain their own construction materials sources and yet, regulate the industry by imposing environmental constraints. Presently, there is no sole regulatory authority (other than the president) and the materials industry operates in a somewhat chaotic or uncertain atmosphere. One would expect material prices to be highly inflated as a result, but the material prices are not much greater than costs on other Pacific Islands. Nonetheless, as available land space becomes developed, less land is available for resource production and prices will become greatly inflated if new material sources are not identified.

CONCLUSIONS AND RECOMMENDATIONS

With the present policies, we can conclude that construction material cost will only increase at a disproportionately higher rate than inflation. In the worst case, present supplies will be depleted in the near future and new sources will remain undeveloped and possibly unobtainable. The only alternative will be to import materials from neighboring atolls or nations.

It is not the intent of this report to provide solutions to this complex material acquisition dilemma. It is only prudent to suggest the RMI government follow a course of action to provide data from which decisions can be made. For this purpose, the following actions are recommended:

- Initiate detailed construction materials supply study (inventory). Fill and aggregate quantities have only been approximated; this information needs refinement.

- Inventory future construction material demand.

- Conduct study to centralize authority or create permit board with sole responsibility for issuing land use decisions. Set up dredging and fill requirements and restrictions.

- Analyze cost effectiveness of developing RMI government-owned material source (for comparative studies-basis of comparison).

- Analyze cost effectiveness of developing offshore material source. This study should also include economic analyses for alternative or substitute materials such as concrete armor units and coral cobble gabions as substitutes for armor rocks.

The plan of action for water resources for the RMI provides additional details and the cost of sponsoring a study to develop a management plan for construction materials for Mājro Atoll (OEA, 1989)

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APPENDIX C

OBSERVATIONS ON THE CORALS AND REEFS OF MĀJRO ATOLL, REPUBLIC OF THE MARSHALL ISLANDS

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ABSTRACT

Aelon-in Mājro (Mājro Atoll) [7°N, 169°E] is located near the southern end of the Ratak (eastern) chain of the Republic of the Marshall Islands. Compared to other atolls in the Republic, it is of average size with respect to lagoon surface area (114 square miles), is above average in terms of dry land area (3.5 square miles), and receives abundant rainfall (in excess of 180 inches per year). Mājro Atoll's closest neighbor is Arņo Atoll, some 10 miles to the east. Mājro Atoll is the capitol of the Republic and supports the largest population (over 15,000) of any other atoll in the Marshalls.

Despite its air and sea accessibility and large population, Mājro has never been the subject of detailed or extensive coral reef or marine biological surveys until 1988. A draft environmental impact statement for the new commercial dock involved biological surveys including coral reefs in the dock area and several other sites in 1977 (Dames & Moore, 1977). Brief notes on previous crown-of-thorns starfish infestations on Mājro's reefs were reported by Branham (1972). Other recent reviews of coastal and related environmental concerns in Mājro and the rest of the Marshall Islands is found in Maragos (1986) and the Office of Economic Adjustment (1989).

Observations on the reefs and corals of Mājro were accomplished over a three day period in May 1988 by Maragos and an 8-day period in July 1988 by Lamberts. A variety of habitats were visited including previously used quarry and dredge sites, candidate marine park and protected areas, and a number of other reef sites. A combined total of 40 sites were visited in 1988.

Despite a long history of environmental problems in Mājro lagoon, many lagoon and pass reefs in the north and eastern sides of the atoll support healthy flourishing coral communities with several serving as viable candidates for park and protected status. Furthermore, rock quarries along the ocean facing sides of reef flats appear to encourage rapid coral recolonization. Other reefs are recovering from past outbreaks of crown-of-thorns starfish which feed on reef corals. Leeward ocean reef slope communities visited in 1971 by Maragos and the marine biological team in 1988 contain luxuriant and diverse coral and fish assemblages worthy of scientific study, recreation, tourism use, and education (see Wilson, 1989). Heavy demand for construction aggregate and armor rock to support a variety of ongoing and proposed coastal development projects mandates preparation and coordination of a management plan for dredging and quarrying operations. The restoration of

pre-urbanization levels of water exchange and circulation in Mājro lagoon by installing culverts and bridges (see Rosti, 1989) might reduce water pollution, improve conditions for lagoon coral communities as well as discouraging shoreline erosion.

A total of 146 species of stony corals belonging to 50 genera and subgenera have now been reported from Mājro Atoll. The higher numbers reported at nearby Arņo (180 species, 60 genera and subgenera) can be explained as the result of much greater sampling and collecting efforts at Arno.

INTRODUCTION

Mājro Atoll was surveyed by a multidisciplinary team of coastal and marine scientists and engineers in May and July, 1988 as part of the Mājro Atoll component of the Marshall Islands Coastal Resource Atlas and Inventory Program. Despite its position as the principal population center and capitol of the Republic of the Marshall Islands, Mājro Atoll has never been the subject of a comprehensive scientific survey until the 1988 studies. Reef biologists and geologists have passed through Mājro to study other atolls in the southern Marshalls (most notably Arno and Jaluit) and northern Marshalls (Āne-wetak, Bikini and Ronlap). Some of these investigators spent a day or two recording observations on the reefs and marine life of Mājro Atoll.

Previous unpublished reports on the reefs and corals of Mājro include Branham (1972) (Appendix 1), who monitored infestations of the crown-of-thorns starfish, Acanthaster in 1969 and 1971 on reefs near the pass region and Irooj (Eroj island), and Dames and Moore (1977) which involved coral reef surveys by Thomas Scanland (Appendix 5) at seven sites in 1977 to assess the impacts of the then proposed commercial dock at Teļap (Dalap Island). Maragos conducted surveys of several Mājro reefs in 1971 and monitored the dock project in 1976. These and other observations were summarized in a review paper on coastal resource management needs for the atoll and other Pacific islands (Maragos, 1986). Paul Jokiel visited Mājro Atoll for one day in 1988 recording observations at several quarries and pinnacle reefs (Appendix 6).

Since the end of World War II, Mājro has become the population and political center for the Republic of the Marshall Islands. Previously Japan had established Jaluit Atoll as the government center for the Marshalls, but U.S. forces decided to move the center to Mājro by the end of the decade. During the subsequent four decades, Mājro Atoll has experienced many physical and social changes. As the capitol and urban center of the Marshalls, many residents have been attracted to Mājro in search of jobs, better education, and other opportunities. To support an ever growing population and facilitate efficient utility and transportation services, road fill causeways were constructed on reef flats to connect the three largest southern islands, Teļap, Wūlka, and Jarōj (previously Dalap, Uliga, and Djarrit or "D-U-D"). Additional causeways were later constructed to connect remaining islands along the south and western side of the atoll (in a clockwise direction) to Mājro (Laura). Later the small airfield on Teļap was abandoned and a new jet airfield and water catchment system was constructed on the reefs and islands along the SW side of the atoll. Eventually the entire roadway between Jarōj and Mājro was paved, additional housing constructed, water supply reservoirs installed, shore protection structures built, a new sewage treatment plant, and completed many other capital improvements completed on the atoll. Collectively these actions modified the reef environments at Mājro Atoll in several ways:

- a number of quarry holes have been opened on the reef flats to obtain armor stone and other aggregate,

- southern lagoon reef areas are frequently dredged to obtain general purpose fill and aggregate,

- the closing of openings on the reef flats between islands for road causeways reduced water circulation and water quality in the southern lagoon,

- urban encroachment towards the shoreline and strong currents resulting from causeway construction has aggravated shoreline erosion and coastal property damage,

- until the new ocean outfall was constructed and placed in operation, municipal sewage was discharged into the southern lagoon possibly degrading water quality and,

- refuse and trash disposal may have affected some reef areas.

In light of the above trends, the 1988 series of scientific studies at the atoll attempted to address potential problems and solutions associated with the above issues and to characterize the health, diversity, development potential, and conservation needs of the atoll. The present study focuses on corals and reefs with emphasis in the following areas:

a. assess impacts and patterns of coral reef recovery at dredge sites in the lagoon,

b. assess patterns, rates and optimal conditions for coral colonization in the many quarry holes,

c. evaluate candidate marine park and protected areas (since M̄ajro has few if any designated recreational areas),

d. speculate on possible water quality and pollution effects on coral reefs in the south lagoon and,

e. accomplish a general biological survey of various reef habitats of the atoll, since it had never been the subject of any comprehensive survey.

MATERIALS AND METHODS

The 1988 coral reef surveys were qualitative, consisting of the recording of observations on waterproof paper during snorkeling dives. The only SCUBA assisted dives correspond to NE lagoon reef sites off Irooj and Ro̧n̄ro̧n̄ islands. Cross sectional profiles of reef and substrate features were sketched at each site. Underwater photographs were taken by Maragos at the reef flat quarry, lagoon dredge, and candidate park and protected area sites which he visited. Maragos also measured using a ruler, the maximum diameters of corals which had colonized the walls and floors of reef flat quarry sites. Lamberts assembled a small coral collection to assist in some species identifications. Most species were identified from visual records in the field. Taxonomic assignments relied upon the recent published literature by Veron and coworkers (Veron, 1986; Veron and Wallace, 1984; Veron and Pichon, 1976; 1979; 1982; and Veron et al 1977). Additional notes on corals and reef features are also found in Harris (1989, this volume) and Wilson

(1989, this volume). The locations for the 1988 surveys are shown on the companion volume, the Mājro Atoll Coastal Resource Atlas. Letter symbols in blocks refer to the May 1988 stations of Maragos, while the numerical symbols in blocks refer to the July 1988 stations of Lamberts.

The Marshall Islands Marine Resources Authority kindly provided skiff and diving equipment support during the May and July 1988 surveys. Mr. Stephen Muller and Ronald Virgil Alfred were especially helpful in arranging or participating in field visits.

Relative abundance of corals was estimated in the field using a semi-quantitative hierarchy of terms as follows:

D = dominant
A = abundant
C = common
O = occasional or uncommon
R = rare

Definitions for the above terms is provided as Appendix 2 to the report. Best professional judgment and previous experience aided in the abundance evaluations. Time did not permit transect, quadrat or other quantitative procedures.

During 1969-71, the U.S. government-sponsored Pacific-wide surveys to document the effect and extent of predation on corals from infestations of the crown-of-thorns starfish, Acanthaster. Mājro was chosen as one of the many Micronesian survey sites and an infestation site off Irooj island was the focus of the survey (Branham, 1972). The report from that study is reproduced as Appendix 1.

RESULTS

Brief descriptions of the reef environment and corals at each station are provided in Appendix 3. Some cross-sectional profiles of the reef, listing substrate types and major coral genera are reproduced for typical reef flat rock quarry sites, dredged sites, candidate marine park and protected sites, and other reef sites in Appendix 4.

Major reef habitats which occur at Mājro Atoll and which were visited during the 1988 surveys are listed in Table 1, and corals reported from the atoll are listed in Table 2. Due to potential hazards from adverse winds, waves, water currents, and aggressive sharks, the windward ocean reef slopes including the buttress (spur-and-groove) systems and terraces were not surveyed.

Reef geomorphology and oceanography of Mājro Atoll

The report by Rosti (1989, this volume) provides detailed observations on the current patterns and oceanography of lagoon and perimeter reefs of the atoll. Only some very general observations of oceanographic patterns are covered in this report.

Mājro, at 7 degrees north latitude, is considered a "wet" atoll near the southern end of the eastern (Ratak) chain of the Marshalls and near the intertropical convergence zone of high rainfall. It lies near the boundary between the northeast tradewind belt and the doldrums further to the south. The nearest large current system, the Equatorial Countercurrent, runs from west to east well south of the atoll. The prevailing winds and waves are from the NE except during times of tropical storms which generally approach the atoll from the south.

In terms of its lagoon surface area (approximately 114 square miles), Mājro ranks thirteenth out of 28 atolls in the Marshalls and is slightly smaller in size than its nearest neighbor Arņo Atoll (130 square miles of lagoon) to the east. In terms of land area, Mājro (at 3.54 square miles) ranks seventh among the atolls of the republic, with Kuwajleen (Kwajalein), Ailinglapalap, Mili, Arņo, Likiep, and Maloelap atolls having larger land areas.

The distribution of reefs and lands at Mājro show some similarities and differences compared to those of nearby Arņo Atoll. First the major deep passes occur along a seven mile stretch of the NE side for Mājro compared to six mile long stretch of passes along the NE side of Arņo. Also, most of the atoll land is distributed along the south and western sides of Mājro Atoll, as with Arņo. Although the total lagoon areas are similar for the two atolls, and both show rectangular outlines with the long axis facing NE, their types differ markedly. Mājro lacks the reef extensions and sublagoon arms or "horns" which characterize Arņo. Mājro on the other hand, has a well developed deep residual reef hole south of Ro̧n̄ro̧n̄ island near the northern end of the lagoon along the perimeter reef. The total length and area of perimeter reefs for Mājro are much less than that for Arņo Atoll due to the lack of reef extensions, horns or "meanders."

Maximum lagoon depth for the two atolls is similar with Mājro reporting depths of 220 ft compared to Arņo's maximum depth of 180 ft. The deepest portion of Mājro lagoon is centrally located away from perimeter reefs opposite the pass region. Much of the lagoon is shallower, between depths 20-30 fathoms (120-180 ft). The NW end of the lagoon is shallowest averaging less than 20 fathoms (120 ft).

PASSES

All naturally deep passes through the reef between the lagoon and the ocean are clustered along a seven-mile stretch of the NE side of the atoll. By far the largest pass, To-ļap (Calalin or Kōļaļ-eņ channel) spans a distance of 3 miles between Irooj and Kōļaļ-eņ islands and shows a maximum depth of about 20 fathoms (120 ft), although much of the pass shows depths of less than 6 fathoms (36 feet). Another deep and large passage occurs to the other (NW) side of Irooj island and is called To-en-an-Etao. It shows a maximum depth of about 10 fathoms. There are two other smaller passages or breaks through the shallow reef between Pata-en-lap, a coral head on the NW side and Būrukulik, a coral head on the SE side of the stretch. These show reported soundings of 2 fathoms or less (12 ft or less). In addition a man-made channel was cut through the perimeter reef near the SE end of the atoll near the former islet of Eoonmaaj. This channel appears to be about 15 ft deep and 50 ft wide at its narrowest point.

The great widths and depths of the NE pass region of Mājro subject adjacent lagoon, reef and island areas to greater wave and current exposure. Oftentimes small skiff passage across the lagoon will include semicircular lagoonward detours to avoid the treacherous currents and steep waves in the vicinity of the passes. The tidal exchange through the deep passes must be considerable based upon their depth and observed velocities for water currents. The principal exchange of water between the lagoon and ocean probably occurs through the deep passes. Elsewhere along the NE facing side of the atoll, water pours into the lagoon from the ocean side due to wave setup which drives water across the shallow reefs between the islets into the lagoon, especially during moderate to high tide conditions. These wave driven water currents contribute substantially to the net exchange of lagoon waters with fresh sources of ocean water since the currents generally move lagoonward during all stages of the tide. Major outflow of lagoon waters probably occurs in the deep passes during ebb tide. Rosti (1989) also reports considerable outflow of lagoon waters over the wide reef flat at the northwest end of the atoll, north of the island of Mājro (Laura). During normal tradewind conditions, winds tend to move down the elongated lagoon from east to west causing the building up of wind chop and lagoon water turbulence in a direction from Jarōj-Teļap to Mājro-Ro̧n̄ro̧n̄.

The entire SW half of the atoll's perimeter reefs between Mājro and Jarōj are covered with islands, preventing water exchange between the lagoon and ocean except through the man-made channel at Eoonmaaj. However, before recent road causeway construction, water exchange over the reef flat occurred between the successive islands of Jarōj, Wūlka, Āne-likōre, Pikōdāt, Teļap, Utwe, Āne-dik, Lo̧-kōjbar, Ļōjemwā, Ļo̧morokeil, Limejokden, and Mājro.

Perimeter Reefs

Perimeter reefs surrounding the lagoon at Mājro Atoll include three major habitats or faces: the ocean facing reef slope, the reef flat, and the lagoon facing reef slope. Of these, the reef flats have been the most often studied and the atoll islands constitute the dominant feature on the reef flats at Mājro Atoll. Islands cover at least half of the total available surface area on reef flats, and the entire SW perimeter from Mājro to Jarōj is now connected as one continuous island over a distance of 30 miles. The ocean and lagoon facing reef flats opposite the islands is generally not very wide except off the islands at the NW end of the atoll between Mājro and Ron̄ron̄. Hence land areas are exposed to damage and erosion from large waves, surge, and strong currents during tropical storms which tend to approach the atoll from the south where most of the atoll's vulnerable land is situated.

A unique perimeter reef feature discussed later is the large deep residual reef hole south of Ro̧n̄ro̧n̄ island. The depth of the hole appeared to approach 100 ft with the steep walls of the hole covered with flourishing reef coral communities.

Much of the previous shallow open reef flats around the perimeter of the atoll have been filled especially along the SW side. Inspection of the atlas maps suggest that at least half or more of Mājro's perimeter reef flats are now covered with the original islands and fill land extensions to them for roadways, airfields, residential, commercial, and government facilities.

Reef flat quarries

A number of existing rock quarry holes on the reef flat from Teļap to Limejokden islands were surveyed to determine characteristics and patterns of recolonization by marine life. Tables 2 and 3 summarizes information collected during the 1988 surveys in the quarries. Appendix 5 provides additional information on corals in the airport quarries reported by Scanland in 1977 (Dames and Moore, 1977). Quarry holes are features created during construction activity including blasting and rock removal to obtain armor stone to protect the shorelines of erosion-prone islands, runway embankments, harbor facilities and other structures. The other rock in the quarry holes serves as a source of larger sized aggregate for concrete, paving, and bedding layers for fill land, road, causeway and shoreline revetment projects.

The quarries fall into three groups: the oldest Japanese quarries, the circa 1970 airport quarries, and the youngest bridge and channel quarries. The first group are small inshore, and shallow holes less than four feet deep concentrated along the ocean shoreline of Telap island that were excavated before 1944 by the Japanese. The second group consists of a large interconnected series of quarry cells occurring along the ocean side of the jet runway and water reservoir complex on Āneņ-eļip, Ļo̧-kōjbar, Ļo̧morokeil, and Limejokden Islands. For the most part, these quarries are separated by narrow sills only a few feet wide along a mile long sketch of the reef. They tend to be large, moderately deep (averaging 10 feet) and extend out to the outer reef margin near the surf zone. These quarries were opened about 1970 to support ongoing runway and road paving projects and are perhaps the largest single set of quarry holes in the Marshall Islands. The third set of quarry holes occur on opposite sides of the bridge and channel along the ocean facing reef flats. These holes are young (excavated in the early 1980s) and vary in size from small to moderate and in depth from moderate to great (6 to 26 ft).

Tables 3 and 4 summarize information on the features of the quarry holes surveyed. The following generalizations can be made with regard to the quarry observations:

a. The older Japanese-era quarries (A-D) were too shallow and too close to shore to promote coral development although benthic algal populations were high.

b. The airfield and water reservoir quarries (H-L) showed heavy coral colonization if located on outer ocean facing reef flats and if large stable hard surfaces were available for successful settlement.

c. The bridge and channel quarries (E-G) are young and show active but incomplete coral colonization. Deeper quarry holes (>15 ft) tended to have sand covered floors.

Ocean facing reef slopes

Lamberts made observations in 1988 along the ocean facing margins and reef slopes. Refer to Harris (1989) for some recent coral observations. In 1971 Maragos made a series of ocean reef slope dives between M̄ājro and Teļap islands. In all cases live reef corals exhibited heavy coverage and diversity. Many stretches would be fairly accessible to sport divers and marine biologists during conditions of offshore winds and low wave action. The diversity and composition of reef corals along the leeward slopes was comparable to observations by Maragos in similar environments at Āne-wetak (Enewetak), Namdik (Namorik), Bok-ak (Taongi), Pikaar (Bikar), Kuwajleen (Kwajalein), Arņo and other atolls in the Marshalls.

Lagoon facing reef slopes

Lagoon reef slope environments at M̄ājro Atoll appear often covered with mixed coral and benthic algae assemblages on sand dominated substrates. Observations in 1971 by Maragos along lagoon facing reef slopes between Eoonmaaj and Limejokden islands revealed highly diverse and abundant coral communities on the slopes. However, 1988 observations along some of these same areas revealed a decline in live coral coverage and much greater sediment coverage. Lagoon reef slopes between Eoonmaaj and Teļap islands have been the sites of active dredging to obtain coral aggregate and fill material for various construction projects during the past 2 decades. Actively dredged slopes are almost totally dominated by sand deposits and sand tali. Isolated coral heads and associated reef fish communities still survive in some actively dredged areas.

Lagoon reef slopes near passes

Surveys in 1971 and 1988 reveal that the reef slopes off the back side of Irooj Island continue to support flourishing communities of reef corals and associated reef fishes. Many species of coral were present with many in high abundance to depths of 80 ft or more. The slope eventually gives way to a sand dominated talus. Proximity of the site to vigorous circulation from the deep passes on both sides of

Irooj may be responsible for maintaining the luxuriance of the reef site. Furthermore, there appears to be little residual effect from previous crown-of-thorns infestations at the site in 1969-1971 (see Branham, 1972).

Deep reef hole at Ro̧n̄ro̧n̄

A unique reef feature, a deep residual reef hole on the perimeter reef south of Ro̧n̄ro̧n̄ island was surveyed in May and July 1988 at the suggestion of the RMI fisheries office as a candidate marine protected area or park site. During the May 1988 survey, water visibility was extremely good allowing the bottom of the reef hole at a depth of 80-100 ft to be seen from the sea surface. Since the entire perimeter of the hole is protected from wave action by reef flats, the site is especially safe and easy to visit, especially at low tide. Extremely high coral coverage and diversity were reported along all observed walls and upper margins of the reef hole. The deep floor of the hole was covered with sand with scattered mounds and coral heads. The hole is a residual portion of the deep lagoon closed off from the rest of the lagoon by reef growth.

Lagoon pinnacle and patch reefs

Several pinnacles and patch reefs in Mājro lagoon were surveyed by the July 1988 team with one also surveyed by the May 1988 team. Jokiel also recorded observations on pinnacles during his one day visit to Mājro in 1988 (see Appendix 6). The tops of the pinnacles show higher proportion of sediments with the reef slopes dominated with live coral. The floor of the lagoon at the base of observed patch reefs and pinnacles were covered with sand deposits.

The distribution of pinnacle and patch reefs in Mājro lagoon has been modified by previous dredging operations to clear a safe navigation channel through the main pass and SE lagoon to the urban area of the atoll (Teļap-Āne-likōre-Pikōdāt-Wūlka-Jarōj). It appears that pinnacles and patch reefs, if any, were cleared from the southeast lagoon based upon inspection of available navigation charts. Pinnacle and patch reefs are concentrated in several other areas of the lagoon including the nearshore areas off Mājro Island, the entire NW end of the lagoon, and lagoon of both deep passes (To-lap and To-en-an-Etao) to either side of Irooj. A few isolated patch reefs occur in the central SE lagoon, and one was previously used for anchoring a navigation buoy.

Reef Corals

A total of 129 species belonging to 47 genera and subgenera of stony corals were reported during the 1988 surveys. The only previous coral lists were compiled by Scanland in 1977 as part of the environmental survey for then proposed commercial dock off the lagoon side of Tel̦ap (Dames and Moore, 1977). Scanland reported 52 species of reef corals at seven sites (Appendix 5). Of interest was the fact that the most species (33) were reported from the airport quarry sites. When the 1977 Scanland list is combined with the 1988 survey lists, a total of 146 species belonging to 50 genera and subgenera have now been reported from M̧ājro Atoll.

This is a sizable number of coral species and genera given the limited sampling and collections at the atoll by coral scientists. It is likely that more intensive surveys of pass reefs, patch and pinnacle reefs, and ocean reef slopes would yield additional species. Hence the greater number of coral species, genera, and subgenera reported at neighboring Arņo Atoll can be simply explained on the basis of much greater sampling intensity and variability at Arņo.

DISCUSSION

Quarries

Results of field surveys of reef flat quarry holes at M̧ājro atoll suggest that coral development is maximized in the holes under the following conditions:

1) quarry holes are located on the outer half of seaward facing reef flats,

2) quarry hole depths range from 2-4 meters (6 to 13 feet), and

3) loose material is absent from the holes except for large slabs and rocks that are not moved about by wave surge.

The above can serve as guidelines for the opening of newer quarry holes. Deeper quarry holes tended to accumulate sand, inhibiting coral colonization. Quarry holes extending too far inshore tended to promote shoreline erosion and prompt the need for protective structures as noted off the quarry holes for the new airfield. Environmental conditions, although favorable for algae are not favorable for corals in shallow inshore quarry holes. The great deal of coral development in the airport and bridge quarry holes may also have been facilitated by the close proximity of adjacent holes, separated by only narrow walls or sills. Water was seen spilling from one to another in a chain which tended to enhance circulation. On the other hand, quarry holes extended clear out to the outer reef edge, perhaps increasing shoreline exposure to wave action. In fact, it was very difficult to accomplish coral surveys in the airport quarries at high tide due to heavy surge, wave action, and bubbles which inhibited observations. Some quarry holes may serve as excellent sites for educational, scientific, tourism and possibly aquaculture use. To promote safe access and use of future quarry holes, it is recommended that a buffer zone be established at both the inner (shoreline) and outer edge of the reef flats perhaps with a minimum width of 50-100 feet for each. The offshore buffer zone might reduce heavy wave action and reef damage during storms while the inner zone might prevent shoreline erosion and promote safer access and exit by swimming and snorkeling residents and visitors.

Quarry rock exists as a finite resource at M̄ajro (see Bjorken and Maragos, 1989) and heavy future demand for armor stone and aggregate argues that a management plan for quarrying be developed, coordinated, and implemented. This plan could help to conserve quarry rock resources by promoting phased development and optimal designs for quarry holes to maximize yield and environmental values, while minimizing shoreline erosion, other adverse impacts and expense.

Dredge sites

Observations of active and previously used dredged sites between Eoonmaaj and Tel̦ap suggest that:

1) dredging does not promote recovery of corals and

2) adjacent undredged coral heads may be able to survive turbidity and sedimentation from clamshell based dredging operations.

These observations suggest that dredging activities be confined to the urban (SE) end of M̄ajro's lagoon which has already been degraded by previous sewage pollution and road causeway construction. Perhaps an authorized dredging zone could be demarcated. It makes the most sense to confine dredging to this region to avoid adverse impacts to other reefs and associated fisheries. Large living coral heads within the zone could also be spared dredging to serve as "relief" habitat and centers of recolonization for fish displaced from dredged sites and for coral larval settlement. Large heads of *Porites cylindrica*, *Porites lutea*, and *Porites* (*S*.) *rus* all seem well adapted to moderate sedimentation.

Sand dredging could be accomplished at deeper offshore lagoon sites away from living reefs by using clamshell dredges mounted on floating barges or using small suction dredges to pipe sediment slurry onshore into confined disposal basins for de-watering. Careful plans and procedures for such dredging can avoid impacts to reefs and corals.

Rosti (1989) recommends installation of culverts and bridges to reestablish more tidal exchange of lagoon and ocean waters between the islets of the SE lagoon (Jarōj to Mājro) and to reduce possible shoreline erosion. Road causeway fills previously blocked water flow over the reef flats between the islands, rendering circulation in the lagoon more sluggish. Increased levels of sewage discharges into the same area of the lagoon from an ever growing population may have contributed to water pollution and observed decline of lagoon reef slope communities. Now sewage discharges have been moved to the ocean side of the reef off Telap where flushing is optimal. Reef coral recovery may now be possible in the SE lagoon and may be further accelerated by installing culverts or bridges between the successive islands of Jarōj, Wūlka, Āne-likōre, Pikōdāt, Teļap, Utwe, Āne-dik, Būkielōbo, Mājpin, Eoonmaaj, Rairōk, Ānen-elip, Lo̧-kōjbar, L̦ōjemwā, L̦o̧morokeil, Limejokden, and Mājro. These structures would need to be properly designed to avoid shoreline erosion, but collectively should improve water quality and conditions for coral reef recovery.

Several reef sites are worthy of designation and status as marine parks and protected areas. These are discussed in more detail by Wilson (1989).

In particular we believe selected sites off the leeward ocean reef slope, the reef hole south of Ro̧n̄ro̧n̄, the backreef off Irooj, the inshore reefs off Ko̧ļaļ-eņ, perhaps an undisturbed pinnacle/patch reef in the SE lagoon, and the reef complex off the NW end of the atoll (including perimeter reefs, patch reefs, and pinnacles) be included. In addition, some quarries off the airport may be safe as potential snorkeling sites for visitors and residents. All of the above areas display well developed and diverse coral assemblages of recreation and educational value to residents and tourists.

The diversity of reef habitats varying from degraded to near pristine conditions at Mājro Atoll also support development of a marine laboratory at

M̄ajro to promote reef, aquaculture, fisheries, environmental and marine park studies. The presence of the community college instructors, scientists, students, and a large residential population are additional reasons for establishing a marine laboratory on M̄ajro. Proximity to Arņo Atoll, the reefs of which has been unaffected by urbanization and development, would serve as a close and accessible site for additional reef studies out of a main laboratory at M̄ajro Atoll.

CONCLUSIONS AND RECOMMENDATIONS

Future quarry holes development should be based upon a long range plan to conserve quarry rock and maximize efficiency and environmental values. Quarry holes should be located on the outer half of seaward reef flats, with depths between 6-12 feet and devoid of small loose rock and sediment. Non-excavation (buffer) zones should be established on the inner and outer ends of reef flats subject to quarrying to prevent shoreline erosion.

Dredging operations should be confined to the SE lagoon where most construction materials are needed. Nearshore dredging should be confined to a "zone" between Eoonmaaj and Jarōj islands which have been previously degraded by urbanization. Prominent live coral heads in the zone should be spared. Sand dredging should occur further offshore in the lagoon using floating equipment.

Culverts and bridges should be installed along the islands of the SE lagoon to restore water quality and favorable conditions for reef coral recovery. Shoreline erosion may also be reduced as a result of the new culverts or bridges (see Rosti).

M̄ajro Atoll, despite a long history of urbanization, construction and development, supports many valuable reef areas that should be protected and managed for multiple uses including education, recreation, research, and tourism.

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Table 1. Classification scheme for shallow reef features used for Mājro Atoll. List of 1988 survey stations corresponding to each category is provided in the right column.

Reef feature	1988 field station
Lagoon reef slopes and margins on the windward (N,E) side of the atoll	1, 3, 6, 7, 21, 25, 26, 27, 28
Lagoon reef slopes and margins on the leeward (S,W) side of the atoll	12, 13, 14, 20, 22
Shallow reef flats	5, 9, 10, 23
Lagoon patch reefs	2, 4, 8, 11
Lagoon pinnacle or mound reefs	M
Lagoon residual reef hole	N, 5
Reefs facing channels or passes	K,O
Dredged lagoon reefs	L, 15, 16, 18, 19
Quarried reef flats	A, B, C, D, E, F, G, H, I, J
Ocean facing reef slopes on leeward side of atoll	24
Ocean facing reef slopes and terraces on windward side of atoll	none surveyed

Table 2. Preliminary combined checklist of corals reported from Mājro Atoll by James Maragos in May 1988 and Austin Lamberts in July 1988. Species not reported at nearby Arno atoll are marked with an asterisk (*). Species reported only by T.B. Scanland (Dames and Moore) in 1977 are indicated with a cross (+).

FAMILY THAMNASTERIIDAE

- <u>Psammocora</u> <u>contigua</u> (Esper)
- <u>P.</u> <u>haimeana</u> (Edwards and Haime)
- <u>P.</u> <u>nierstraszi</u> van der Horst
- <u>P.</u> <u>profundacella</u> (Gardiner)
- <u>P.</u> <u>superficialis</u> (Gardiner)

FAMILY POCILLOPORIDAE

- <u>Pocillopora</u> <u>brevicornis</u> Lamarck
- <u>P.</u> <u>danae</u> Verrill
- <u>P.</u> <u>damicornis</u> (Linnaeus)
- <u>P.</u> <u>eydouxi</u> Edwards and Haime
- <u>P.</u> <u>meandrina</u> Dana
- <u>P.</u> <u>setchelli</u> Hoffmeister
- <u>P.</u> <u>verrucosa</u> (Ellis and Solander)
- * <u>P.</u> <u>woodjonesi</u> Vaughan
- <u>Seriatopora</u> <u>hystrix</u> Dana
- <u>S.</u> <u>caliendrum</u> Ehrenberg
- <u>Stylophora</u> <u>pistillata</u> (Esper)

FAMILY ACROPORIDAE

- \+ <u>Acropora</u> <u>acuminata</u>
- <u>A.</u> <u>austera</u> (Dana)
- <u>A.</u> <u>aspera</u> (Dana)
- <u>A.</u> <u>cerealis</u> (Dana)
- <u>A.</u> <u>clathrata</u> (Brook)
- <u>A.</u> (<u>Isopora</u>) <u>cuneata</u> (Dana)
- <u>A.</u> <u>cytherea</u> (Dana)
- <u>A.</u> <u>danai</u> (Edwards and Haime)

+ A. delicatula

A. digitifera (Dana)

+ A. echinata/paniculata

A. echinata (Dana)

A. florida (Dana)

A. formosa (Dana)

* A. grandis (Brook)

A. humilis (Dana)

A. hyacinthus (Dana)

A. kirstyae Vernon and Wallace

* A. latistella (Brook)

A. listeri (Brook)

A. nana (Studer)

A. nasuta (Dana)

+ A. nasuta/cymbicyathus

A. nobilis (Dana)

A. (Isopora) palifera (Lamarck)

A. palmerae Wells

+ A. cf rosaria

A. robusta (Dana)

+ A. syringodes

A. teres

A. tubicinaria

A. valenciennesi (Edwards and Haime)

A. valida (Dana)

A. vaughani Wells

Astreopora gracilis Bernard

A. listeri Bernard

A. myriophthalma (Lamarck)

A. ocellata Bernard

+ Montipora sp (berryi?)

M. caliculata (Dana)

M. danae (Edwards and Haime)

* M. digitata (Dana)

* M. foliosa (Pallas)

M. foveolata (Dana)
+ M. granulosa
M. informis Bernard
M. marshallensis Wells
M. tuberculosa (Lamarck)
M. venosa (Ehrenberg)
M. verrucosa (Lamarck)
+ M. verrilli

FAMILY AGARICIIDAE

Gardineroseris planulata (Dana)
Pavona clavus (Dana)
+ Pavona sp/Leptoseris sp
P. cactus (Forskol)
P. varians Verrill
* P. decussata (Dana)
P. frondifera Lamarck
+ P. frondifera/praetorta
P. (Polyastra) venosa Ehrenberg
Pachyseris speciosa (Dana)
Leptoseris sp

FAMILY FUNGIIDAE

Fungia (Verrillofungia) concinna Verrill
Fungia (Danafungia) horrida Dana
Fungia fungites (Linnaeus)
F. (Pleuractis) paumotensis Stutchbury
F. (P.) scutaria (Lamarck)
F. (Ctenactis) echinata (Pallas)
Halomitra pileus (Linnaeus)
Herpolitha limax (Esper)

FAMILY PORITIDAE

+ Alveopora cf. verilliana
Goniopora sp 1
G. sp 2
G. sp 3
Porites spp
P. cylindrica Dana
P. lobata Dana
P. lutea Edwards & Haime
P. nigrescens Dana
P. (Synaraea) rus (Forskol)

FAMILY FAVIIDAE

Barabattoia mirabilis Yabe and Sugiyama
Cyphastrea chalcidicum (Forskol)
Favia favus (Forskol)
F. laxa Klunzinger
F. pallida (Dana)
+ F. pallida/speciosa
F. rotundata (Veron, Pichon and Best)
F. stelligera (Dana)
Favites flexuosa Dana
F. halicora (Ehrenberg)
Leptastrea purpurea (Dana)
Oulophyllia crispa (Lamarck)
Goniastrea pectinata (Ehrenberg)
Echinopora lamellosa (Esper)
Platygyra lamellina (Ehrenberg)
P. daedalea (Ellis and Solander)
P. pini Chevalier
Leptoria phrygia (Ellis and Solander)

FAMILY MERULINIDAE

- Merulina ampliata (Ellis and Solander)
- Scapophyllia cylindrica Edwards & Haime
- Hydnophora microconos (Lamarck)
- H. exesa (Pallas)
- H. rigida Dana
- * Paraclavarina triangularis (Veron, Pichon and Best)

FAMILY MUSSIDAE

- Blastomussa wellsi Wijsman - Best
- Acanthastrea echinata (Dana)
- + Echinophyllia aspera
- Lobophyllia corymbosa (Forskol)
- L. hemprichii (Ehrenberg)
- Symphyllia recta (Dana)

FAMILY OCULINIDAE

- * Galaxea sp
- * G. astreata (Lamarck)

FAMILY PECTINIIDAE

- Mycedium elephantotus (Pallas)
- * Oxypora lacera (Verrill)

CARYOPHYLLIIDAE

- Plerogyra simplex Rehberg

FAMILY SIDERASTREIIDAE

- + Coscinaraea sp. (ostreaformis?) +

FAMILY MILLEPORIDAE

Millepora dichotoma (Forskol)
M. exaesa (Forskol)
M. platyphylla Hemprich and Ehrenberg

FAMILY HELIOPORIDAE

Heliopora coerulea (Pallas)

ALCYONARIA

Sarcophyton sp
Sinularia sp.

Table 3. Reef flat Quarry hole characteristics, at Majro Atoll as recorded by J.E. Maragos in May 1988

Site no.	Age	Quarry type	Size	Depth(ft)	Location	Characteristics
A	old (pre 1944)	inshore rectangle	small	2-3	north ocean side of Telap	mostly fleshy algae with a few corals (<1% cover)
B	old (pre 1944)	inshore rectangle	smallest	1-2	north Telap ocean side	no corals, mostly fleshy algae
C	old (pre 1944)	mid reef flat, rectangle	small	2-3	mid Telap ocean side	no corals but algae, sea cucumbers and eel observed
D	old (pre 1944)	mid reef rectangle	moderate	3-4	south Telap ocean side	corals (7 species, 1% cover) noticeable rusted machinery nearby. Live coral fragments carried into hole by waves and currents
E	young (post 1981)	mid reef to offshore elongated interconnected cells	moderate	10-13	east side of bridge and channel on ocean reef	heavy coral colonization and schools of fish. Drifts of detached algae (Padina) litter (metal cans) in holes, sea cucumbers abundant
F	young (post 1981)	elongated quarry adjacent to channel on mid reef	moderate	3-5	east side of man-made channel and ocean	heavy scour and suspended sediments inhibit coral
G	young (post 1981)	elongated quarry mid reef	moderate to large	6-27	west side of man-made channel	Hard pavement. Sand covered bottom for holes greater than 13 ft deep. Higher coral coverage on outer walls and heavy coral colonization
H	moderate (circa 1970)	elongate outer outer reef flat	large	6-12	near runway opposite reservoirs	heavy coral coverage (10%-25%) and diversity (22 spp). Trochus fish and other invertebrates common.
I	moderate (circa 1970)	elongate inner island	large	10-30	NW end of runway on lagoon side of island	murky quarry, poor visibility and no live coral. A few algae over fine sand deposits.

Table 3. Reef flat Quarry hole characteristics, at Mājro Atoll as recorded by J.E. Maragos in May 1988

Site no.	Age	Quarry type	Size	Depth(ft)	Location	Characteristics
J	moderate (circa 1970)	elongate inner reef flat	large	4-13	ocean side of reef flat adjacent to site I	murky, lacked corals, dominated by sand growths of the algae _Caulerpa_, _Dictyota_ some bivalves
K	moderate (circa 1970)	elongate outer reef flat	large	3-12	ocean side outer edge of reef	exposed to heavy waves and strong currents. Heavy coral development (10% coverage, 9 spp) approaching 30% on outer walls.

Table 4. Species of reef corals reported from Mājro reef flat rock quarries with estimates of their abundance and maximum colony diameters. Data from May 1988 survey of Maragos.

species	overall abundance	max. colony diameter (cm) in quarries E&H	quarry sites
Acropora palifera	C		D,E,G,H
Acropora digitifera	A	(E)25-30	D,E,G,H,K
Acropora vaughani	C		D,G
Acropora cytherea	O	(E)40-45 (H)300	E,H
Acropora humilis	O	(E)30	E,H,K
Acropora hyacinthus	C	(H)40-60	H
Acropora formosa	A		H
Acropora virgata	C		H
Porites lobata	C		A,H
Porites (S) rus	O		H
Porites cylindrica	C	D	
Pocillopora meandrina	O	(E)25 (H)30-40	E,G,H,K
Pocillopora verrucosa	A	(E)10-25	D,E,G,H
Pocillopora eydouxi	A	(E)10-20	D,E,H,K
Pocillopora damicornis	A	(E)25 (G)25	D,E,G,K
Psammocora sp.	R		E
Millepora dichotoma	O		H
Millepora platyphylla	A	(F)90-100	F,G,H,K
Montipora sp.	O	(G)30-50	K
Montipora foliosa	C		H
Montipora digitata	O		H
Pavona varians	C		H,K
Hydnophora microconos	C		H
Sinularia sp	C		H
Astreopora sp	C		H
Platygyra daedalea	O		H
Favia pallida	O		H

APPENDIX 1

CROWN-OF-THORNS, Acanthaster planci IN THE MARSHALL ISLANDS

In the summers of 1969 and 1971 (June), investigators from the University of Hawaii visited Mājro and Arņo Atolls in the Republic of the Marshall Islands. Kwajalein Atoll was visited on both trips and in 1971 Namorik Atoll was also examined. The object of the first trip was to gain some understanding of the distribution of the crown-of-thorns on selected atolls while the second trip, two years later, was primarily concerned with evaluating the rate of change associated with the coral-eating sea stars.

The starfish distribution on Mājro has been carefully plotted by Ben Sablan, Chief, Starfish Control, Marshall Islands, with the aid of the local divers that he has trained. The distribution in general had not changed in the two years since the last survey. The densest aggregation remained on the patch reef just west of North West Passage near Irooj Island (see previous report). The greatest population density, estimated by the transect method, on the lee side of the reef, was approximately one starfish for each 45 square meters of reef in the affected area. The total population in the area was probably about 300 animals, slightly less than the 1969 estimate. The total diameter of the starfish averaged 34cm. No measurements were made in 1969 but comparisons with photographs made during that trip indicate that the animals were perhaps 5cm larger in 1971. In 1969 they were feeding predominantly on table Acropora on the steep lee slope of the reef. In 1971 this slope consisted predominantly of dead coral (all species) and the starfish were most abundant on top of the reef in about 2m of water on table Acorpora. None of the animals collected in the daytime were actively feeding. All were sexually mature and the gonads contained an abundance of gametes (i.e. they were ripe).

Previously infested areas of Arņo Atoll were re-examined. One area east of the pass region where Acanthaster were abundant in 1969 showed little effect of the starfish. Most of the corals were alive. Two small (32 and 20cm total diameter) starfish were found long several hundred meters of normal reef. No starfish were found on the patch reef of predominantly dead coral near TuTu Passage (see previous report).

Coral recovery was examined on the "dead" patch reef. This reef was reported by Leonard de Brum to have been infested by Acanthaster in July 1968. In 1969, it appeared mostly dead and had a small population of large starfish. In 1971 the reef still looked dead and no starfish were found. Close examination was made by placing a meter square frame on the reef in various places and determining in detail the species and size of living coral colonies. In most of the squares examined, ten to twenty colonies, ranging in size from 3cm to about 20cm in longest dimension, were found. Approximately 24 species were represented. The most abundant species were those expected on a "normal" living reef but other species were also represented so the species diversity was somewhat greater than "normal". The prospects seemed good for the recovery of corals on the patch reef examined.

Most of the reefs in the vicinity of Tutu and Taklep passages on Arno consisted of dead coral probably killed by Acanthaster. All of the patch reefs and pinnacles examined between the pass region and Arno Anchorage on the leeward side of the atoll were similarly "dead", as was a large area of leeward ocean reef at the Anchorage. Adjacent areas of reef were "healthy". These observations suggest that Arno has had excessive grazing of coral by Acanthaster in the last decade. It would be a good place to make observations on reefs recovery patterns and rates.

Kwajalein Atoll was not re-examined in 1971 but divers from the local SCUBA Club reported that the situation has not changed since out last discussion with them in 1969. At that time they were aware of the starfish aggregation that we observed and have been examining them periodically since.

Namorik Atoll was chosen for observation because of its small size and enclosed lagoon with no deep passes. Much of the lagoon reef was surveyed and some of the ocean reef, particularly on the leeward side. Isolated Acanthaster were found on the various patch reefs and pinnacles examined and on the main reef, but no aggretions were seen. The patch reefs in the lagoon were particularly interesting. They were characteristically flat with lush coral growth on top, but undercut, with little coral and many pelecopods, on the sides. From one to three Acanthaster were found on each patch reef examined. The starfish were conspicuous and actively feeding during the day. There was little freshly killed coral evident around the feeding sites but the general impression was that the starfish might be important contributors to the ecological state of these reefs.

RECOMMENDATIONS

Our observations, particularly on Arno, suggest that large aggregations of Acanthaster have occurred occasionally on atoll reefs in the Marshalls. The aggregations can alter the nature of the reefs drastically. Smaller numbers of starfish probably also influence coral growth and consequently the reef ecology. The Marshalls consist almost exclusively of atolls. Atolls are more dependent on living coral reefs than are high islands. We therefore, recommend that the Acanthaster situation in the Marshalls be given particular attention. All atolls should be extensively surveyed, particularly the "outer islands", where the people are both aware of the problems and considerably dependent on their reefs. Starfish eradication should be undertaken, particularly in areas of concentration equivalent to those on Mājro, but also isolated starfish should be eliminated when found. A census should be taken and a representative sample of starfish measured before or during eradicaton efforts. The data thus collected can be analyzed by scientists at the University of Hawaii.

A starfish census can quickly be taken by using a marked transect line. Inexpensive light cotton twine can be used without bothering to reclaim the line. A length of line, approximately 100 or 250 yards, is marked off in convenient segments of 25 yards. The end of each segment can be marked with a series of knots or other convenient markers to help in keeping track of which areas have been examined. The transect lines should be kept on spools for easy laying by a swimmer.

The census is taken by laying out the transect line straight through the area to be examined and anchoring each end firmly. It can also be "tacked down" to bits of coral periodically along its length to keep it from moving around. Two observers and a recorder with a pad suitable for underwater are to swim along the line counting each starfish and recording the number in each segment, within 10 yards on either side of the line. The observers, one on each side, point out each starfish within 10 yards of the line and the recorder keeps track of the finds, making sure that each starfish is counted only once. Thus, a number of starfish in a band of known area can be determined and expressed as the number of starfish per unit area. In this way, the extent of the aggregation can readily be plotted on a map.

Starfish have been measured routinely as follows. The total diameter, in centimeters, is measured across the center of the disc from the tip of one arm to the tip of the opposite arm. The diameter of the disc is measured across the animal from the base of the same arms. The weight in grams can be determined with a spring balance. The number of arms is determined by inverting the animal and estimating the number of rows of tube feet (i.e. ambulacral groves). The sex of each animal can readily be determined by slitting open the dorsal side of several arms and the adjacent disc and exposing the whitish gonads. Males can be distinguished from females directly after a little practice or by crushing a bit of the gonad on a smooth black surface. Crushed male gonads exude a smooth white milky fluid while the female gonad gives off a slightly granular appearing mass of tiny eggs. If the gonad is easily found and appears large and whitish, the animal is ripe. If the gonad is small and hard to find but white or totally absent, the animal is immature. If the gonads are small and hard to find and orange or yellow in color, the animal is spent. This data should be recorded along with the date and location of collection.

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Appendix 2

Definitions for relative abundance terms used in the field for corals.

SYMBOL	TERM	DEFINITION (WITHIN A ZONE OR HABITAT TYPE ON THE REEF	DEFINITION (FOR THE REEF SITE A WHOLE)
D	dominant	the coral constitutes a majority in abundance or coverage (50% or more of total)	the coral contributes substantial abundance or coverage (25% or more of total) or is conspicuous in all zones
A	abundant	the coral contributes substantial abundance or coverage, or is very numerous	coral is conspicuous in most zones or is dominant within a single zone
C	common	coral present as several or more individuals or as a few larger colonies	coral conspicuous in only one or a few zones or locally substantial in a single zone
O	occasional	uncommon, present only as a few individuals, or present as a single conspicuous individual	present more than once but not substantially within a single zone
R	rare	reported only once as a single inconspicuous individual	reported only once from the reef

Appendix 3

Reef surveys of Mājro, July 19-26, 1988, by A.E. Lamberts.

Site 1 7-19-88 Low tide 12:25 Survey Time 10:45-11:20

Long, sloping reef flat first of sand then beach rock and 30% coral, mostly Porites lutea heads changing to 100% cover at the reef edge, virtually all digitate Acropora. A ten foot drop to flat Acropora and a 30 degree sand slope with large heads of Porites. Common general were Astreopora, Montipora, Platygyra. Various other genera but no Fungids, Millepora or Stylophora. An interesting and diverse reef.

Site 2 7-19-88 Survey Time 11:40-12:00pm

Patch reef 1/4 mile off middle of Irooj Island. It was about 100 yards across with almost 100% cover with pedestal type plate Acropora, many overturned. Some branched Acropora between, as well as 3 species of Pocillopora. Middle area out of water at low tide. Sides sloped at 45 degrees with a few heads of Porites lutea visible.

Site 3 7-19-88 Survey Time 13:00-13:40

Off the middle of the sandy beach at the island of Kōļaļ-eņ is a sandy moat and then a patch reef about 60 yards in diameter covered with 3' of water at low tide. Dominant coral was digitate Acropora of various species, about 80% coverage. Windward side huge mounds of Porites cylindrica, several species of Pocillopora common on lee side. Astreopora and Pavona also common. An excellent reef for snorkelers.

Site 4 7-19-88 Survey Time 15:00-15:30

Patch reef 150 yards out from E. end of Kōļaļ-eņ Island. 100 yards across. Under about 10' of water at low tide. East side a precipitous 70 degree drop to deep water. Coral cover near 50% with digitate and pedestal Acropora dominant. Several large boulders of P. lutea. Pocillopora verrucosa common as were soft corals.

Site 5 7-20-88 Low tide 12:54 Survey Time 12:00pm-12:45

The immense reef flat south of Wūlka of the Enygain Island group is barely covered with water at low tide. There is some sand, about 50% reef rock and interspersed are variety of small coral heads of some 15 genera. Cyphastrea, Pocillopora, Montipora, Porites, Psammocora, Platygyra, and Acropora were all well represented. In the center of the reef was a dark blue hole about 100 x 50 yards and 10 yards to sand. The sides consisted of huge heads of Porites cylindrica. also some large mounds of Acropora cuneata as well as Porites (Synaraea) rus all interspersed with clumps of Seriatopora hystrix.

Site 6 7-20-88 Survey Time 13:00-13:30

This survey was on the reef edge directly south of the High School on Wūlka Island. As the edge was approached from the previous described flat, digitate Acropora became dominant although in number of heads Astreopora could also be called dominant. At the edge there was an abrupt drop of 30' to sand. About 20 genera of coral noted, among them Scapophyllia, Platygyra daedalea and Fungia fungites were abundant. An interesting reef face with coral cover as near 100% as one can find on a mixed reef.

Site 7 8-20-88 Survey Time 13:50-14:35

Reef edge of East end Jelte Island. An abrupt drop as described for site 6 with virtually 100% coral cover with the same generic mix. Two of our team used SCUBA and brought voucher specimen of Galaxea, Pachyseris, Halomitra and Goniopora not previously noted in our current studies.

Site 8 8-20-99 Survey Time 15:00-15:20

Patch reef 1/4 mile south of Site 7. Water 10' at low tide. Water murky. Coral cover about 25%, much rubble. Small digitate Acropora, heads of Porites, Goniastrea and much soft coral.

Site 9 **8-21-88** **Survey Time 11:30-12:30**

Reef flat 1000' wide from tip of Mājro (Laura) west. Water 3-4' deep, low tide. Rocks and coral 50%, snad 50%. Wheels of Porites lutea and P. cylindrica near shore being replaced by digitate Acropora of several species at 100 yards out. Pavona sp., Pocillopora damicornis and Oulophyllia crispa also common. Genera expected, Stylophora, Psammocora, Seriatopora, Heliopora not observed.

Site 10 **8-21-88** **Survey Time 13:00-13:30**

Site was S.E.E. from the tip of Mājro (Laura). There was a sand flat of about 1000' with some seagrass and Holothuria atra covered with 6" of water. Then scattered heads of P. lutea which grew larger as the water deepened some 200' from a 30 degree drop to deep water. Here coral cover approached 80%, digitate Acropora dominant with few other corals. Near the drop there were spherical heads of P. lutea some 6' across, fewer as water deepened.

Site 11 **8-21-88** **Survey Time 14:00-14:40**

A mile N.E. of Mājro (Laura) harbor were three patch reefs. We surveyed the largest and farthest out. It was about 100 x 60 yards covered with 12" water and had 45 degree slopes to deep water. Coral cover 30 - 40% with soft coral Sarcophyton sp. dominant. Several 4' heads of P. lutea and a few pedestal pinkish reticulate Acropora. Dr. Larry Harris using SCUBA brought Mycedium elephantotus, Echinopora sp. and a specimen of Paraclaverina triangularis a newly described genera from Australia, not previously reported from Majro. This was from 50'.

Site 12 **8-21-88** **Survey Time 15:10-15:40**

Site was a reef projection below Mājro (Laura) and about 1/4 mile out. Center area awash with huge chunks of coral rock. Out from this some 50-60' coral cover was near 100% with digitate Acropora dominant. These included digitate species A. nana, A. cerealis, A. latisstella. Pocillopora damicornis was common, all other genera rare. As the water deepened there were the characteristic huge boulders of Porites lutea.

Site 13 8-21-88 Survey Time 16:00-16:20

Near shore toward Ma̅jro (Laura) Island the water deepened. The bottom was mostly rubble with less than 5% coral cover. There was some digitate Acropora, an occasional favid and some heads of Porites lutea.

Site 14 8-22-88 Survey Time 11:00-11:30

Lagoon reef just N.E. of Airport runway. Profile ran from shore to deep water in 50 yards, mostly rubble with less than 25% coral coverage, 8 genera counted, digitate Acropora most common but also branched A. grandis. P. lutea in deeper waters. Many coral heads smashed. Water was murky, visibility poor.

Site 15 8-22-88 Survey Time 11:40-11:50

Near large rocks thrown up during airport construction. A mile East of Site 14, same contour. 99% rubble, 1% coral mostly digitate Acropora.

Site 16 8-22-88 Survey Time 12:40-13:00

South end of Airport runway, lagoon side, out from Riprap. Profile same as site 14. Out some 30 yards was 10 yard band of almost 100% coral cover mostly digitate Acropora. Fungia fungites was abundant. An additional 7 genera, 12 species of coral noted, all rare but Pocillopora damicornis and verrucosa, were common.

Site 17 8-22-88 Survey Time 15:15-16:15

Seaward reef quarry, east end of airport runway. this borrow pit was about 200 by 50 yards in size, with water 5-6' at low tide. Many large boulders caused swirling but no real current. Much algae, coral cover about 5%. Pocillopora damicornis dominant in some areas. Isolated large stands of Acropora formosa five yards across and a similar one of A. aspera with a smaller one of A. nobilis. Twenty seven species from 13 genera counted, mostly rare. Not an easy access even at low tide.

Additional information on Quarry sites distilled from notes made by Dr. James Maragos who examined all of them on May 13, 1988. These quarries extend for almost a mile east of the Airport runway, on the outer reef flat and some are very close to the outer edge of the reef rim.

Those at the east end were very old and too shallow tosupport much coral. The quarries near the airfield reservoir are long, almost continuous, close to the outer edge and 2-3 M deep. Here there is good coral growth with almost 100% cover in places. Wave currents and turbulence strong at high tide. Dr. Maragos list of coral observed complements mine. He also noted the many Holothurians in the shallow, sandy pits.

He also surveyed two "inner" quarries on the lagoon side but found both to be shallow and devoid of coral. Finally he surveyed a quarry N.W. of the Airport. This was on the reef flat and had openings through the reef rim. He noted heavy wave action and strong currents. Coral cover was up to 35% at the front and about 10$ on the back wall but poorly developed. He noted the genera Pocillopora, Pavona, Montipora and Acropora digitifera. He also noted Millepora sp.

Site 19 8-23-88 Low Tide 15:09 Survey Time 11:45-12:15

Across the channel and 100 yards W of Site 18. I did not participate. Dr. Harris noted the same general topography and coral cover as Site 18.

Site 20 8-25-88 Low Tide 16:40 Survey Time 16:00-16:30

This site was the beach in front the Marshall Sun Hotel. There was a sand beach with several tiers of beachrock running NWW followed by sand, rubble, trash, dead coral and trash to 30 yards out. In the next 30 yards Porites lutea wheels some 5-6 ft. dominant. Much soft coral. At 100 yards in 6' of water Porites lutea again common. Coral cover about 50%. A dirty reef but one of the best in S.E. Majro.

Site 21 8-25-88 High Tide 12:31 Survey Time 12M-12:45

From the Yacht club north there is a long reef platform and to the west is a channel of about 100 yards separating it from the next island. The half of the channel nearest the club had a sandy dirty bottom with rubble, junk, garbage and Padina sp. The other half had a curious coral growth. To the left of the island and out 100 yards coral coverage was almost 100%. First Porites lutea, then banks of P. cylindrica with some P. nigrescens. One area of several yards across was all Psammocora contigua. Further north were many large heads of P. (Synaraea) rus. In the narrows were a few small areas of digitate Acropora but for the most part, Porites was dominant.

Site 22 July 25, 1988 Survey Time 13:30-14:00

The area S.W. from the High school had a gentle slope so that at 100 yards the water was 8'. For the first 100' sand and rubble with much Padina sp., beer cans and plastic diaper liners. In the second 100' coral cover was about 2% with three genera of coral recorded. In deeper water a few heads of Porites lutea.

Site 23 July 25,1988 Survey Time 14:30-15:15

A shallow bay on the seaward side behind a watertower and Stacey's restaurant. It was about 100 yards across and 200 yards from the road to the reef crest. Bottom was sand, beach rock and rubble with many Ophiuroids sp. A few heads of P. lutea covered less than 1% of the bottom. A few fragments of Acropora which had apparently washed in. Water warm and murky.

Site 24 July 24, 1988

A dive on the outer reef face across from the Marshall Sun Hotel. This was by Dr. Larry Harris and Mike Molina using SCUBA. I did not participate.

Site 25 7/26/88 High Tide 13:37 Survey 10:45-11:25

The following four surveys were made in the lagoon off islands midway between Kōj̦al̦-eņ and Jaraj. This area was a sand flat stretching 200 yards from between the first two islands until it fell sharply to deep water. Scattered rocks with coral growth constituting less than 2% of the area. Porites sp. was most conspicuous, Acropora was noted as well as a few other genera, all represented by only one or two heads each.

Site 26 July 26, 1988 Survey 11:35-12:15

A short platform reef opposite the W tip of the second island (Pikōn-jip). It was dominated by Zooanthids of three species. The first third, about 20 yards, of the platform was sand and rubble. The second third had rocks with Zooanthids and intermingled coral with coverage of about 25%. Porites dominant, P. lutea, cylindrica, nigrescens and rus. Goniopora abundant as were Acropora digitate species, Pocillopora damicornis, Astreopora myriophthalma, and Seriatopora hystrix. Thirteen genera with 27 species recorded. There was again a sharp dropoff wit large heads of P. lutea in deeper waters.

Site 27 July 26, 1988 Survey Time 12:50-13:30

This was a relatively small coral patch toward the lagoon edge of a shallow sandy bar. In the midst there was an area of rubble changing to live coral in deeper water. Porites (Synaraea) rus was dominant and formed huge mounds. On the seaward side there were similar mounds of P. lutea. Several species of Acropora were present, Seriatopora sp. common, as was Fungia fungites. Zooanthids, 3 species were again common. Nine genera of coral, 15 species recorded.

Site 28 July 26, 1988 Survey Time 14:00-14:45

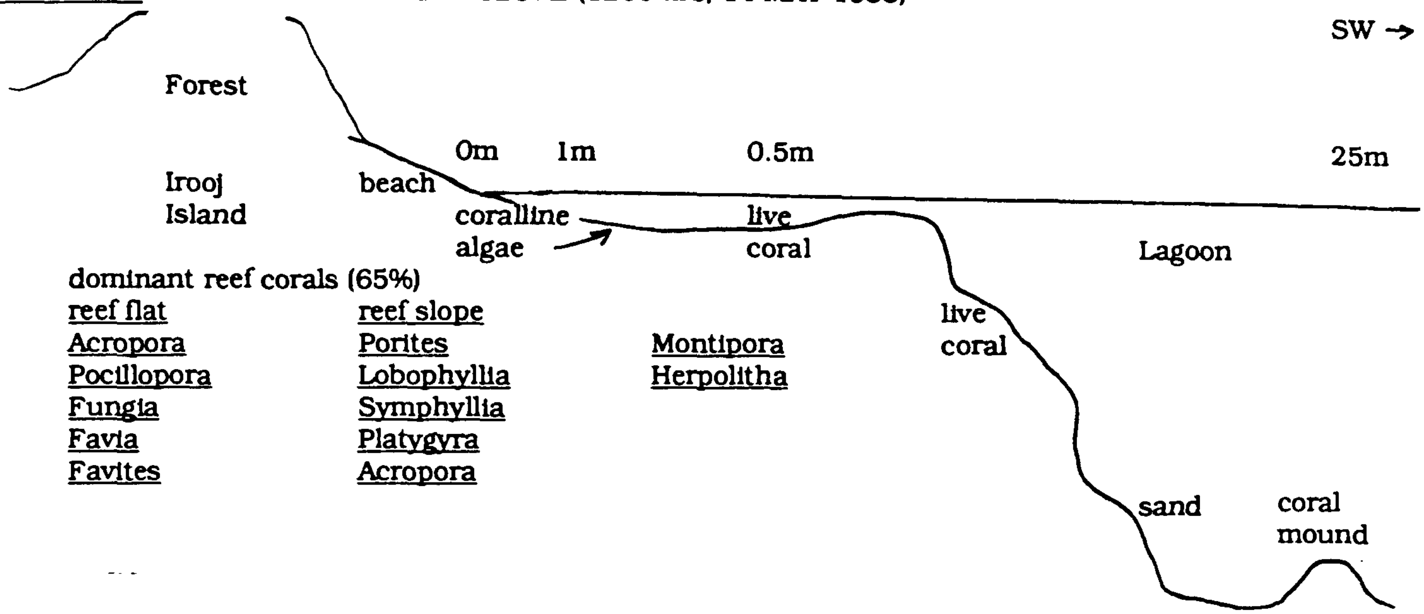
This was a platform reef similar in contour to Site 26. In the coral area there was about 50% reef rock, 5% sand and 45% live coral. It was a Porites reef with distribution like that on Site 27. Pocillopora damicornis was abundant. Nine genera, 14 species of coral recorded. Interestingly, we saw no Heliopora, Stylophora, Seriatopora, Goniopora, Lobophyllia or Symphyllia. It seemed to be a place where we might find Alveopora but found none. We again began seeing Padina sp. so prominent on the sand banks opposite the city areas where pollution was fairly heavy.

Austin E. Lamberts
August 10, 1988

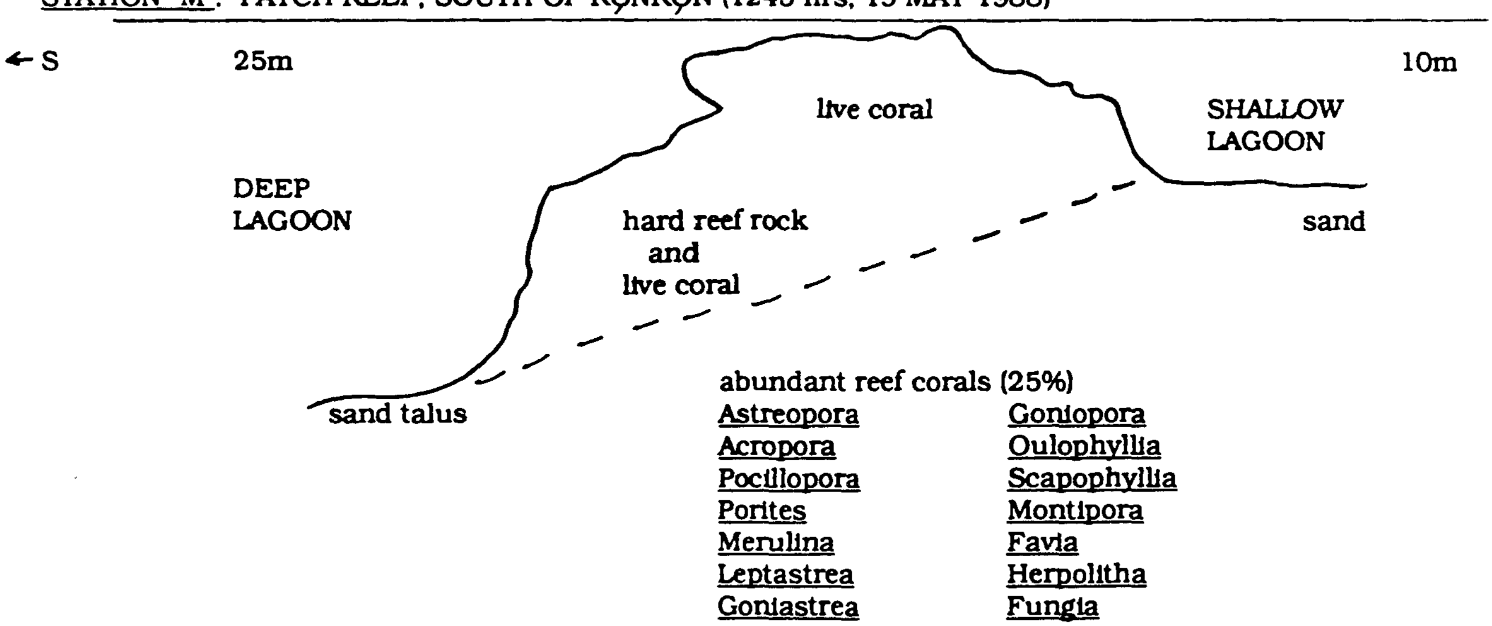
APPENDIX 4

1988 Reef cross section profiles, Maj̄ro Atoll (from field notes and sketches of J.E. Maragos)

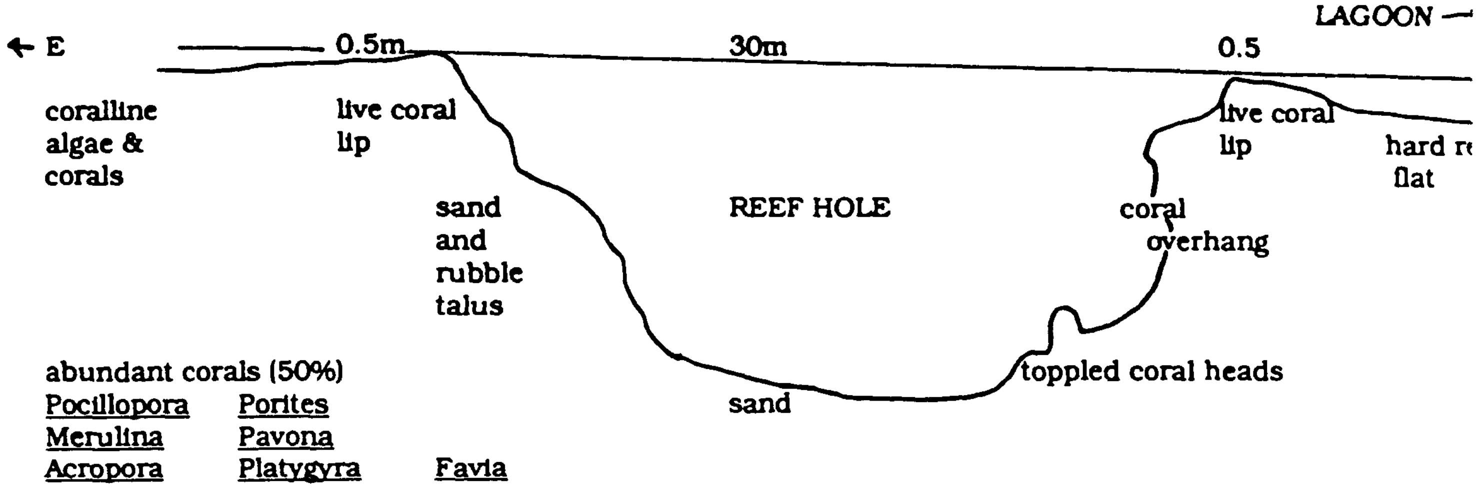
STATION "O": IROOJ LAGOON REEF SLOPE (1200 hrs, 14 MAY 1988)



STATION "M": PATCH REEF, SOUTH OF RO̧N̄RO̧N̄ (1245 hrs, 19 MAY 1988)

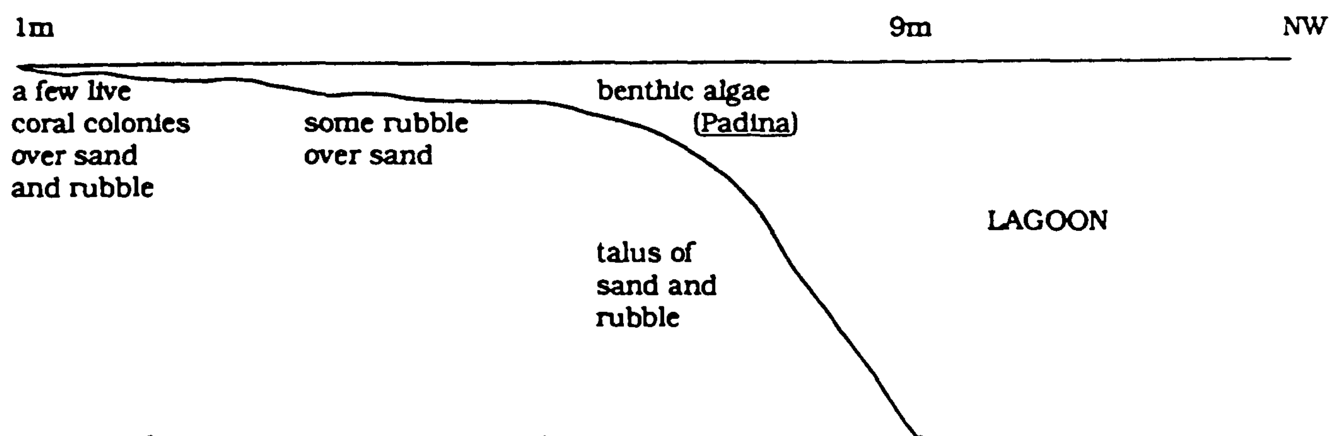


STATION N: RǪÑ RǪÑ DEEP REEF HOLE (1400 hrs. 19 MAY 1988)

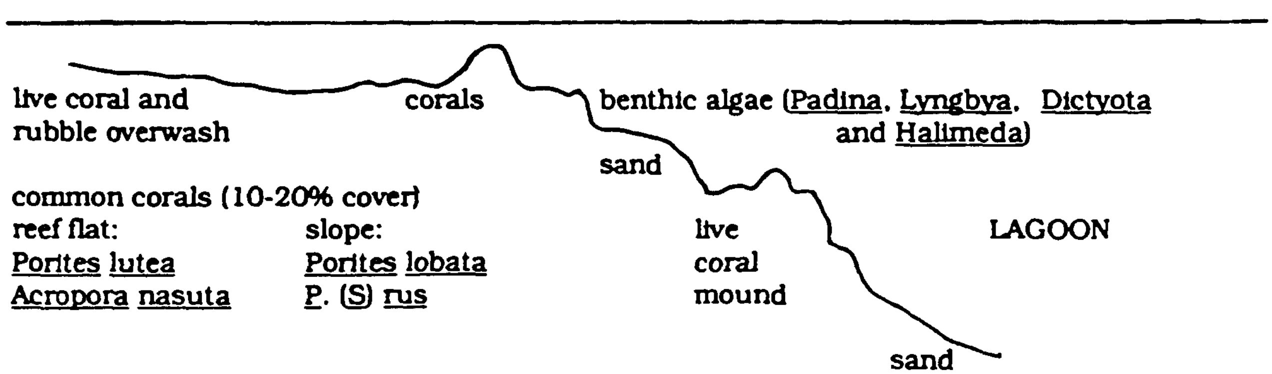


STATION "L": SE LAGOON DREDGE SITES (1000 hrs. 14 MAY 1988)

1. near dredged site off Ecoonmqqj

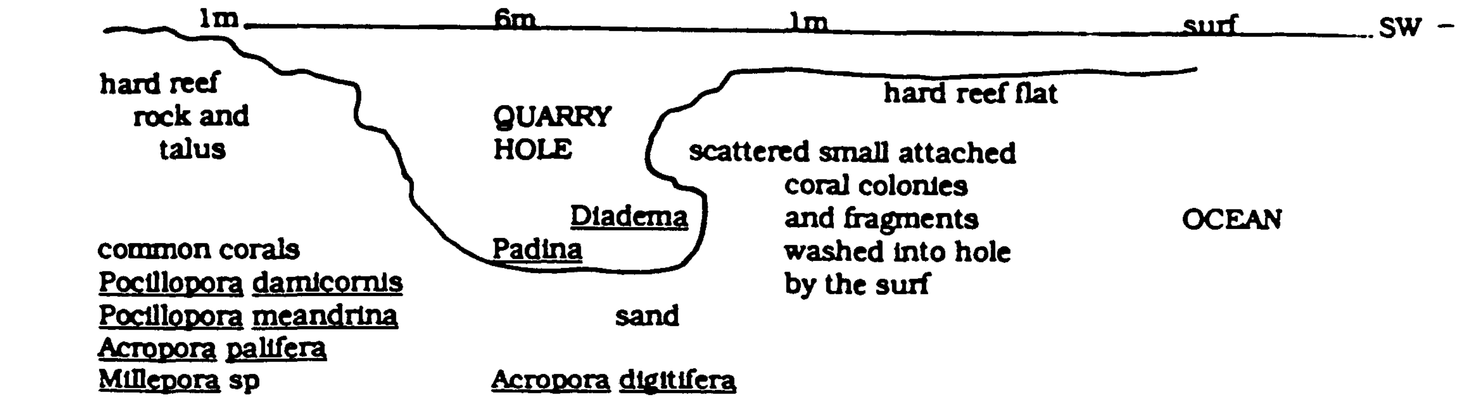


2. undredged reef adjacent to a dredged site off Telap

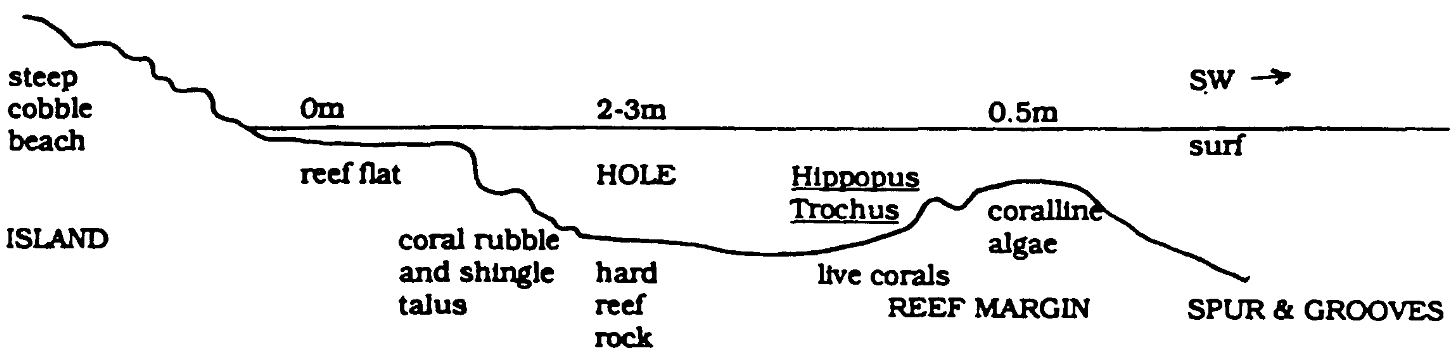


QUARRY HOLES

STATION G: NW SIDE OF EOONMAAJ BRIDGE AND CHANNEL
(1300 hrs. 13 MAY 1988): HOLE 13



STATION H: RAIRŌK QUARRY OPOOSITE WATER SUPPLY RESERVOIRS
(1400 hrs, 13 MAY 1988)



predominant corals (10-25%)

Acropora (corymbose)	Acropora (tables)	Astreopora
Pocillopora spp	Montipora (foliaceous)	Platygyra
Millepora spp	Acropora (staghorns)	Favia
Sinularia	Hydnophora	Porites

Appendix 5. Reef Building Coral Recorded on Field Reconnaisance, Majro Atoll, Marshall Islands, March 4-8, 1977

Taxa[1]	Locations[2] (Subtidal): Majuro Dock Site	(Subtidal): West of Dock Site	(Subtidal): Control (Rairok)	(Subtidal): Uliga Fill Borrow Area	(Subtidal): Airport Armor Borrow Area	(Intertidal): Airport Outer Reef Flat	(Intertidal): Dock Site Outer Reef Flat
Acropora cf. acuminata	-[3]	-	-	-	+[4]	-	-
A. sp. (delicatula)	-	-	-	-	+	-	-
A. cf. digitifera	-	-	-	-	-	+	+
A. echinata/paniculata[5]	-	-	+	-	+	-	-
A. cf. formosa	-	+	+	+	-	-	-
A. humilis	-	+	+	+	+	-	-
A. nasuta/cymbicyathus[5]	-	+	+	+	+	-	-
A. cf. rosaria	-	+	+	+	+	-	-
A. cf. syringodes	-	-	-	?[6]	+	-	-
A. cf. teres	-	-	-	-	+	-	-
A. tubicinaria	-	+	+	-	+	-	-
A. sp. 1[7]	-	-	-	-	+	-	-
A. sp. 2[7]	-	+	+	+	-	-	-
A. sp. 3[7]	-	+	+	-	-	-	-
Alveopora cf. verrilliana	-	-	-	-	+	-	-
Astreopora sp.	-	-	+	+	-	-	+
Coscinaraea sp. (ostreaeformis?)	-	-	-	+	-	-	-
Cyphastrea sp.	-	-	-	-	+	-	-
Echinophyllia aspera	-	-	+[8]	-	-	-	-
Favia pallida/speciosa[5]	-	-	-	-	+	-	+
Fungia (Pleuractis) scutaria	-	-	-	+	+[9]	-	-
Halomitra philippinensis	-	-	-	+	-	-	-
Heliopora coerulea	-	-	-	-	+	-	-
Herpolitha limax	-	-	-	+	-	-	-
Hydnophora microconos	-	-	-	-	+	-	-

Appendix 5. Reef Building Coral Recorded on Field Reconnaisance, Majro Atoll, Marshall Islands, March 4-8, 1977

Taxa[1]	Locations[2] (Subtidal) Majuro Dock Site	West of Dock Site	Control (Rairok)	Uliga Fill Borrow Area	Airport Armor Borrow Area	(Intertidal) Airport Outer Reef Flat	Dock Site Outer Reef Flat
H. rigida	-	+	-	+	-	-	-
Leptastrea purpurea	-	+	+	+	+	-	+
Lobophyllia sp. 1[10]	-	+	+	+	+	-	-
L. sp. 2[10]	-	+	+	+	-	-	-
Millepora platyphylla	-	-	+	+	+	-	-
Montipora sp. (berryi?)	-	-	-	-	+	-	-
M. sp. 1	-	-	-	-	+	-	-
M. sp. aff. granulosa	-	-	+	-	+	-	-
M. sp. aff. ramosa	-	+	+	+	+	-	-
M. verrilli	-	-	+	-	-	-	-
Mussidae[11]	-	-	-	+	-	-	-
Pavona cf. decussata	-	+	+	-	-	-	-
P. frondifera/praetorta[5]	-	+	+	+	-	-	-
P. varians	-	+	+	+	+	-	-
Pavona sp./Leptoseris sp.[12]	-	-	-	+	-	-	-
Platygyra daedalea	-	+	-	-	+	-	-
Pocillopora damicornis	-	+	+	+	?[6]	-	-
P. cf. danae/verrucosa[5]	-	-	-	-	+	+	+
P. eydouxi	-	-	-	-	+	-	+
P. cf. meandrina	-	+	+	+	+	-	-
Porites andrewsi	-	+	+	+	+	-	-
P. lutea	+	+	+	+	+	+	+
P. (Synaraea) iwayamaensis	-	+	+	+	-	-	-
Psammocora cf. contigua	-	+	+	+	-	-	-
P. (Plesioseris) profundicella	-	+	+	+	-	-	-

Appendix 5. Reef Building Coral Recorded on Field Reconnaisance, Majro Atoll, Marshall Islands, March 4-8, 1977

Taxa[1]	Locations[2] (Subtidal)					Locations[2] (Intertidal)	
	Majuro Dock Site	West of Dock Site	Control (Rairok)	Uliga Fill Borrow Area	Airport Armor Borrow Area	Airport Outer Reef Flat	Dock Site Outer Reef Flat
Seriatopora hystrix	-	-	+	-	+	-	-
Stylophera mordax/pistillata[5]	-	+	+	+	+	-	-
Number of Taxa Observed Total 52	1	24	29	29	33	3	7

FOOTNOTES:

1. ALL IDENTIFICATIONS ARE PROVISIONAL, BASED ON FIELD NOTES AND LIMITED VERIFICATION SPECIMENS.

2. LOCATIONS ARE DESCRIBED IN THE TEXT (PAGES - AND IN PLATE).

3. (-) INDICATES THAT THE TAXON WAS NOT OBSERVED, BUT DOES NOT DEMONSTRATE ABSENCE.

4. (+) INDICATES THAT THE TAXON WAS IDENTIFIED FROM FIELD NOTES AND/OR SPECIMENS FOR THIS LOCATION.

5. SP./SP. INDICATES THAT THESE TWO SIMILAR SPECIES WERE NOT SEPARATED IN THE FIELD.

6. ? INDICATES A QUESTIONABLE SITE IDENTIFICATION FOR THIS TAXON.

7. IDENTIFICATION MATERIAL SUFFICIENT TO DETERMINE THAT THESE TAXA WERE DIFFERENT FROM THE NAMED TAXA, BUT INSUFFICIENT TO PLACE PROVISIONAL SPECIES IDENTIFICATIONS.

8. ONLY OBSERVED ON A REEF AT A DEPTH OF 90'.

9. THIS SPECIMEN WAS PROBABLY A "TOSS-IN" FROM THE OUTER REEF SUBTIDAL.

10. THESE TWO SPECIES ARE COLUMNAR (SP. 1) AND MEANDROID (SP. 2) FORMS OF *LOBOPHYLLIA*; BOTH MAY BE A *L. COSTATA*.

11. A SINGLE VERY SMALL COLONY (C. 4 POLYPS) ONLY, WAS NOT SUFFICIENT TO ALLOW A PROVISIONAL GENERIC IDENTIFICATION.

12. A SINGLE COLONY WHICH SHOWS CHARACTERISTICS INTERMEDIATE BETWEEN THESE TWO GENERA.

APPENDIX 6

Field Report, Mājro Atoll, Republic of the Marshall Islands, 14 October 1988.

Paul I. Jokiel

I spent one day accompanied by Mr. Virgil Alfred, Fisheries Officer, Republic of the Marshall Islands. As requested, we did a quick survey of the pass islands and several of the lagoon patch reefs.

Enematet Island

Walked the length of the island. Typical copra plantation, lagoon side sandy, little coral development, ocean reefs typical of Marshall Islands.

Kōļaļ-eņ Island

Kōļaļ-eņ Island is located near the ocean pass. Must have permission of chief to visit. It is occupied by several families and is used to grow copra. Pigs are kept in pens, chickens are allowed to forage. Mr. Alfred reports that turtles have been known to nest on beaches near pass, but this is rare (perhaps one nest every few years). A giant clam farm has been established in the lagoon, and several thousand clams are positioned here in trays. Clams were in the 10cm to 20cm size range. Two large patches of live coral, each about 50m by 50m, occur on the lagoon side in shallow (1-2m) water. Very diverse corals with high coverage of all common species in protected waters. Excellent dive site for tourists due to lack of currents. Relatively few sites to dive on lagoon side of islands, mostly sand bottom, so these areas should be protected. Very rich coral cover (especially table corals) on pass slopes of island, but this is a dangerous dive area because of strong currents at incoming and outgoing tide. Can only dive at slack water.

Pass Area

This area inhabiteed by porpoises which met our boat. These mammals are taken for "chief's food" by the natives. Outside pass is excellent fishing (trolling) for oceanic gamefish such as tuna, mahi, jacks, etc.

Irooj Island

This island is uninhabited, but visitors must have permission of chief of Kol̄aļ-eņ Island who claims ownership. The island is still in a very natural state with well developed forests and understory. Very diverse botanical area with a wide variety of atoll plants including very large birds-nest ferns which are very striking. This island is a bird nesting area and is heavily populated with terns. On lagoon side of the island the sandy beach grades into an area of Porites "coral wheels" in the low intertidal. This grades into a zone of Montipora digitata in the subtidal. The upper lagoon slope is very rich and dominated by branched Acropora. Deeper lagoon reef slopes are dominated by tabulate Acropora. Marine resources are very rich here. The ocean reefs to the north and south produce lobster, which are taken at spring low tides during the night. Turtle nesting (rarely) occurs on this island. There is a very extensive shallow reef system extending from the lagoon side of Irooj to the channel entrance. There is excellent fishing in this area, probably because of high bottom relief and good water circulation. Trolling, spearfishing, and net fishing all produce good results. Scarids and acanthurids are supported by extensive hard carbonate substrata, planktivores are abundant due to good cover under coral tables and plenty of food supplied by currents. Large predators are also abundant. Difficulty of reaching the island has prevented overexploitation of the resource. This is the only rich lagoon area along most of the coastline towards Ro̧n̄ro̧n̄ Island. Mr. Alfred reported that a few pinnacles with fairly good coral coverage and relatively good fish populations occur near Ro̧n̄ro̧n̄ Island.

Lagoon Pinnacles

These pinnacles are now marked by permanent navigation buoys that were installed just prior to my visit, but were not there during the original survey. Consult notice to mariners for locations.

Channel Marker No. 8 (red)

This is a concrete structure resting on top of a pinnacle that is at a depth of 25m. The pinnacle is a large dome-shaped structure with little relief. Mostly rubble with patches of coral. Not an attractive dive site or a productive fishing area.

Channel Marker No. 9 (green)

A concrete structure resting on top of a pinnacle in 5m of water at shallowest point. Pinnacle is approximately a few hundred meters across, sloping gently toward urban Mājro. Most of the area appears to be highly disturbed sand/rubble with a few good patches of coral. Dominant species are Porites, Synaraea, and table Acropora. Reportedly not good for spearfishing but trolling can yield rainbow runners.

Channel Marker No. 11 (old buoy reef)

A concrete structure located on top of a pinnacle in 20m of water. Very poor reef area top is mostly rubble, some live coral on sides of pinnacle. Not an attractive dive site.

Patch Reef off of Ajej (Ejit) Island

The reef is marked with a permanent checker panel located in 3m of water. Reef ranges in depth from 3m to 10m with high relief and extremely high coverage by the coral Synaraea. Large sponges are present. Water appeared to have a high organic content, probably due to restricted circulation and nearby land discharge of nutrients. Reported to be very productive site for octopus fishing.

APPENDIX D

OBSERVATIONS ON THE REEF-ASSOCIATED INVERTEBRATE FAUNA OF MĀJRO ATOLL, REPUBLIC OF THE MARSHALL ISLANDS

prepared by

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INTRODUCTION

This report is based on a survey of a series of reef sites on Mājro Atoll conducted during the period 19 to 26 July 1988. The animal diversity of tropical coral reefs represent one of the highest levels known (Levinton, 1982). The organization of coral reef ecosystems has been studied by numerous authors (Odum and Odum, 1955; Wells, 1957; Colin, 1987) and reviewed in a number of treatises (Wells,1957; Wiens, 1962; Jones and Endean, 1973a, b; Barnes, 1983, Devaney, et al, 1987). The most conspicuous group of invertebrates, the scleractinian corals, are covered in separate reports in this volume (Lamberts and Maragos, 1989). However, this represents only one class of animals out of the 33 known invertebrate phyla, most of which are found on Indo-Pacific coral reefs.

Our knowledge of the majority of the invertebrate phyla represented on coral reefs is poor, with the greatest information available for four groups, the Cnidaria, Mollusca, Arthropoda and Echinodermata. A majority of invertebrates are small and/or cryptic in distribution. To adequately sample most groups requires intensive sampling and often complex extraction techniques, which were beyond the scope of this study. The purpose of this survey was to describe the dominant and conspicuous invertebrate species which might also serve as sources of food or as indicators of reef health.

MATERIALS AND METHODS

Twenty-eight sites were visited during the course of the survey. The sites had been selected in consultation with members of the Marshallese government and represented locations that were of special interest, such as possible locations for development or preservation. The sampling procedure at each station was similar. The sites were occupied for 30 to 60 minutes. Team members swam over the same general area and made notes on sheets of underwater paper. Photographs of interesting features and sketches of reef structure were made. Most identifications were made in the field, but unknown specimens were returned to our base of operations at the Sun Motel for identification. The team members used breath-hold diving for most observations. SCUBA dives were made at sites on the ocean side of reefs and also on some of the pinnacles to gather information on assemblages of animals at deeper depths.

At each site, observations were made of the conspicuous invertebrate species, particularly those that had some potential as food, for export or as important members of the community, such as the coral-eating seastars Acanthaster planci and Culcita novaeguineae. Efforts were made to check as many subhabitats as possible, such as undercut ledges and the undersides of dead coral heads. Skeletons of large crustaceans and the shells of bivalves and gastropods that are normally hidden during the day were recorded and collected if indentification was necessary. Also, soft sediment areas were checked for indications of biological activity such as trails and mounds. The species observed were identified using suitable references and categorized as to abundance, habitat and any noticable natural history notes such as spawning aggregations. Valuable information on historical abundances, fisheries importance and habitat preferences for several species were provided by our boatmen and by members of the Fisheries Group.

RESULTS AND OBSERVATIONS

There was much variation in the reef geomorphology and the species composition of each site. While there were a number of corals and some large invertebrates that were consistently present at many of the sites, the variation in form and relative abundance of species was dramatic. Table 1 summarizes the major reef types as adapted from Lamberts and Maragos (1989, this report) and lists the stations visited by reef and habitat type.

Table 1. Summary of reef type for the 28 stations visited. The numbers listed with each reef type correspond to the stations described in the following section.

Reef Type	Station Number
Lagoon reef slopes and margins on the windward (N, E) side of the atoll.	1, 3, 26, 27, 28
Lagoon reef slopes and margins on the leeward (S, W) side of the atoll.	6, 10, 12, 13, 14, 16, 18, 19, 20, 22
Shallow reef flats	9, 21, 23, 24, 25

Lagoon patch reefs	2, 4, 7, 8
Lagoon pinnacle or mound reefs	11
Sublagoons and residual lagoon reef holes	5

There were several conspicuous differences between the atoll systems on Arņo and Mājro. The most obvious one concerns the overall morphology of the atolls. Arņo is cresent shaped and actually has three lagoons, while Mājro is an elongate atoll with one lagoon. There are less than 2000 people living on Arno while there are over 15,000 on Mājro. Arņo Atoll is unaltered in that no reef flats have been filled in yet to connect islands, while about half of the islands have been connected by a road on Mājro and there is only one passage left for water exchange along half the atoll. The closing off of water exchange on Mājro is probably the most critical difference between the two systems in terms of health of the reef system.

There were two differences in the atolls that would probably remain, even if the road had not been built on Mājro. There was significantly more Heliopora, the blue coral, on Arņo reefs than on any part of Mājro. Maragos and Lamberts (1989) have reported on this as well. This is probably due mostly to recruitment and other ecological processes independent of man, but it was obvious nonetheless. The second difference primarily related to fish numbers and fishing pressure. There were almost always more fish on the reefs in Arņo; this is no doubt due to the fewer numbers of people fishing there as compared to Mājro. It was obvious that fish numbers increased at the far end of Mājro Atoll (near Laura Island) where there were fewer people. I have seen this same contrast in a number of other locations, such as Hawaii, Singapore, Tahiti, St. Croix, and New England. The discrepancey between the two atolls might not be so big, if part of the lagoon on Mājro was not so degarded by reduced water exchange.

There is one other pattern that was consistent on both atolls. The crown-of-thorns sea star Acanthaster planci has received a great deal of publicity as a coral predator and much of its reputation is well-deserved. However, there is another coral-eating sea star that seems to play a much more important role in the lagoons of Arņo and Mājro. Culcita novaeguineae eats a greater diversity of coral than does

Acanthaster and were common on the reefs of both atolls. In fact, the first indication of the presence of Culcita was large numbers of fleshy soft corals which replace stony corals in areas where there is predation. Soft corals do not provide the food or the hiding places that stony corals do and they inhibit the recolonization of reef building corals. Culcita occurred in low numbers at many stations and seemed to be more common where there was obvious foraging by humans. Triton shells and fish probably feed on small Culcita. This sea star does not explode in numbers and devastate whole reef systems as does Acanthaster, but they may reduce the productivity of a reef by consuming hard corals and providing for a shift to high densities of soft corals. It might be beneficial to encourage harvesting of this sea star just to inhibit the loss of hard coral populations.

SITE DESCRIPTIONS

The survey began near Irooj Island and progressed around to Mājro Island and down past the airport to the causeway and town and then over to the reefs near Denmeo. The reef structure and species composition of every site was different, due to exposure to currents and topography of the bottom. What follows is a general summary by site. Many of the species listed were hiding and were seen only by turning dead coral plates and looking into undercut ledges and caves, but that is typical of many invertebrates on coral reefs due to the importance of fish as predators.

Site 1. Reef flat at Irooj. This is a small isolated island by the main channel and it is heavily populated with several species of seabirds. There was much evidence of fishing pressure in the form of broken corals. The survey began at a edge of a fringing reef. The reef flat gave way to a rich growth of branching Acropora, that also had large colonies of Goniopora which was not common on Arņo. There were crinoids in the undercuts along the reef edge. The slope became more gentle behind the island and there was more staghorn coral. Several individuals of the large holothurian Bohadschia argus were seen on the sand at the drop-off into the lagoon. The asteroids Culcita and Acanthaster were present with Culcita at the reef edge and the crown-of-thorns sea star on an isolated coral mound. Trochus spp. were the only obvious gastropods. A few Tridacna maxima were seen on the reef.

Site 2. A SCUBA dive was made on the protected side of a patch reef on the inside of Irooj. The slope was relatively steep with much dead coral skeleton serving as the bases for a limited amount of live coral. There was much sand and silt on the slope and a few soft corals and numerous sponges. The most conspicuous sponges were the black tubular sponge and a red lobate form. The third common one was a yellow-brown encrusting form. There were a few *Tridacna maxima* on the upper part of the slope and the asteroids *Culcita* and *Acanthaster* were seen. There were very few conspicuous invertebrates other than corals and sponges.

Site 3. A fringing reef off the inside of Kōļaļ-eņ. The island went from sand beach to a shallow rubble area to a rich coral reef. There were a few *Tridacna maxima* on top and very rich coral growth with undercuts along the edge. An *Acanthaster* was seen along the edge and the large spiny holothurian *Thelenota ananas* was seen on the sand. A very large specimen of the auger shell *Terebra maculata* was also seen burrowing through the sand, but few other mollusks were visible. This area would make for a great snorkeling trail, especially combined with Site 4.

Site 4. Patch reef off the south end of Kōļaļ-eņ. This reef could be reached from the island by snorkeling. Rubble on the island side of the reef gave way to a top rich in coral, but there were many freshly broken pieces indicating recent human activity. No *Tridacna maxima* were seen. One *Acanthaster* was present on the edge. Large mounding coral heads grew out from the edge. On one side there was a small cave with a large brown gorgonian. *Trochus niloticus* was present and a molt of a spiny lobster *Panulirus* sp. was seen. A large specimen of the holothuroid *Thelenota ananas* was seen on the sand. On the outside of the reef, there is a steep drop-off to 40 or more feet where there was a large concentration of fish, many of which were good-sized (up to a meter in length). This was one of the most striking fish groupings observed on the trip. This reef would make an excellent preserve along with Site 3.

Site 5. Reef flat at the northwest end of the atoll. The survey began in a small residual sublagoon isolated from the main lagoon south of the island of Rǫn̄rǫn̄. There was a heavy development of *Porites cylindrica* around the edge and then sand to about 40 feet. Specimens of Stichopus variegatus were observed on the sand in the lagoon. The reef flat was only about 1 foot deep at low tide, but it was one of the richest seen on the trip. The flat was full of fish and a multitude of sessile and motile invertebrates. An Octopus sp. was seen as were many Tridacna maxima, both alive and as shells (piles of shells indicating harvesting). Only one old Hippopus hippopus shell was seen. Snails of all sorts were common and there were many small crabs, shrimp and ophiuroids under coral pieces. Among the gastropods seen were Trochus niloticus, Conus marmoreus, Murex sp., Cypraea tigris, C. talpa, C. hysterix and Lambis chiraga. An Acanthaster was seen at the edge of the reef flat. This end of the lagoon should be considered for pearl oyster mariculture, especially the small sublagoon.

Site 6. Continuation of the reef flat south of Site 5 in slightly deeper water. The edge of the reef drops off into the lagoon and is undercut with many caves and permeated with passages. The coral diversity is extremely high. Tridacna maxima was common and there were black coral strands growing out of the undercuts and crinoids were present in the depressions. Conus marmoreus and C. miles were present as was Cypraea erosa and C. mappa. The only holothuroid seen was Holothuria edulis, but there were several. This site should be considered as a potential location for a nature preserve for snorkeling.

Site 7. Dived off lagoon patch reef south of Anen-Bubu-En east of Ro̧n̄ro̧n̄. There was a gentle slope and the reef was mostly dead, but the coral diversity was high. Stichopus variegatus was relatively common on the slope. Several oysters Pinctada margaritifera and a large Pinna sp. were seen. This may suggest that pearl oysters would grow better deeper in the lagoon than in the surface waters. Lambis lambis was present and a Culcita was seen. A few Tridacna maxima were present on top of the reef. Also seen on the slope was a large anemone with branching tentacles - very different and, a new soft coral that was yellow with drooping cylindrical ends.

Site 8. Patch reef into lagoon on way to Mājro (Laura Island). The reef was large in area with a pavement base and scattered coral heads and rubble. There was a heavy growth of algae on the pavement. A species of Murex was aggregated for spawning under a number of different coral plates. Strombus luhuanus was common. There was more live coral farther up the reef, but there was no time to explore there.

Site 9. Reef flat on the ocean side of Mājro (Laura Island) at the northern tip. The flat began with a sand beach that dropped to a shallow mini-lagoon with mini-atolls of Porites that often fused to complex structures. The sand between them contained specimens of Holothuria atra, Conus leopardis, Cerithium sp. and Strombus luhuanus. A few Hippopus hippopus were seen and Lambis lambis was found on the more ocean side. The reef then grades to shallow pavement and rubble before emerging at low tide at the ocean edge. The rubble is mostly dead, but with many small invertebrates under it. There was a very large population of S. luhuanus in this area (I later saw at least six islanders harvesting something - presumed it to be Strombus for food). Also seen in this rubble zone were Lambis chiraga, Conus epicapalis, C. miles, Cypraea tigris, C. mappa, and C. arabica. Also seen was a Cyerce type saccoglossan with clear cerata under a piece of coral rubble; this observer had not seen anything like it, but could not collect it.

Site 10. Lagoon side of Mājro out to the edge of the reef. At the shore there was a sand flat grading into a shallow grass flat and then into rubble and on into Acropora thickets and then into mixed corals and finely into large scattered mounds. The grass bed was full of small Holothuria atra which indicated it is a nursery area; there should have been lots of bivalves in among the roots. Algae was abundant in the rubble zone and damselfish gardens were present in the Acropora thickets. Culcita was common along with fleshy soft corals in the mounding coral zone. There were also a few Tridacna maxima. There were a number of Cypraea tigris in the mounding corals which indicated that this area has not been heavily fished by snorkelers. Spondylus spp. were seen in some of the caves in the coral mounds as were heavy aggregations of sponges. This is one of the few grass flat areas seen and preserving it should be a priority as sea grass beds are nursery areas for a number of species in addition to the observed H. atra.

Site 11. Patch reef out in lagoon east of Mājro. The top was about 10 feet at low tide with different corals than at most reefs visited previously (see Lamberts and Maragos, 1989 this report). Much of the reef was dead with corals growing off the aggregations of coral skeletons. There were some aggregations of staghorn

Acropora and a form that looked like Acropora, but was quite different when touched (Paraclavarina triangularis). Most of the coral was a large-polyped form of Lobophyllia. A few pearl oysters Pinctada margaritifera were seen and there were new sponges, especially a large grey vase shaped form. No holothuroids or Tridacna were seen. One Conus marmoreus was observed.

Site 12. Fringing reef off Mājro (Laura Island) at town end. This was an extension of the shore reef, but outside of the anchorage. The shallow flat consisted of rubble and large dead coral skeleton boulders. This graded into pavement with scattered coral heads and then large mounding aggregations. Soft corals were very common as were the cause - more than 10 specimens of Culcita were seen in a small area. Quite a number of dead Acropora plates were lying on the bottom and they harbored a variety of life on the undersides. Turbo sp., Trochus sp. as well as Holothuria atra and a Cypraea tigris were seen. There were also a few Tridacna maxima.

Site 13. Reef outside of a small passage into Mājro sublagoon. The reef flat was dead rubble that dropped off to mounding Porites and smaller corals on the pavement. Again there was much dead table Acropora. Holothuria atra was common on the pavement and Bohadschia argus was present out deeper among the isolated coral heads. There were a few Culcita and a couple of Trochus niloticus were seen. There was a lot of coral damage, either from anchors or divers.

Site 14. Fringing reef inside lagoon by Japanese Memorial west of airport at Limejokden. Shallow rubble covered with algae graded into live Acropora and Porites and then into sand and small mounding Porites at the drop-off. Cypraea arabica was common in the rubble zone and species of Turbo and Trochus were present (the boatman said both were harvested to eat). Large encrusting colonies of the zoanthid Polythoa sp. was common in the Acropora/Porites zone - this was the first seen on the trip. There was much damage to small Acropora heads from divers and anchors.

Site 15. West end of airport to investigate a quarry and then to dive on the drop-off into the lagoon. The quarry was a thin trench about 20 feet deep. It was filling in with rubble and would do so naturally - it was already narrower than in photographs taken a few years previously. The only live coral were small pieces that had been blown in by storm surge and none was growing attached. There was much algae growing on the rubble and Padina sp. was most conspicuous. The slope next to the quarry dropped off steeply and had some live coral though diversity was low and there were few associated forms to be seen. There were a couple of species of gorgonian and soft corals that were common at the lower end of the slope. Very few shells were seen and no holothurians were observed. One Acanthaster was present on the slope.

Site 16. Lagoon reef by airport terminal. The breakwater itself was barren with some fish hiding in the cracks. The rubble zone was algal covered and there were spawning aggregations of Aplysia sp. under rocks as well as Cypraea arabica. The coral zone below the rubble seemed quite healthy and Trochus niloticus was seen as were a couple of specimens of Echinothrix in depressions in the coral. There were no Tridacna or Hippopus present.

Site 17. Quarry on ocean reef flat at terminal end of airport. This area has much wave wash and is very rich in coralline algae, including an arborescent form that is like a coral head with much empty space inside for small invertebrates. The depth is only about 8 feet at high tide and large slabs of coral rock have been left. Holothuria leucospilota and a long synaptid were common as was a small cephalospidean and there were quite a number of small Trochus niloticus and other trochids. The first specimens of the cleaning shrimp Stenopus hispidis were seen in a crack. The echinoid Echinothrix diadema was common in cracks. This would be an excellent habitat to culture trochid snails.

Site 18. Rubble flat on the lagoon side and immediately east of the causeway. It was a shallow flat of rubble, probably dredge spoil. There were some small heads of live corals, but most of the substrate consisted of algal covered rubble. There were quite a few invertebrates hiding under the rubble including xanthid crabs, a small Octopus sp., several small Diadema and a young Stichopus variegatus. There were also a number of gastropods including Strombus luhuanus, Trochus niloticus, Murex spp. Cypraea arabica, C. lynx, and C. isabella. There were also a pair of anaspideans Dolabella sp. On the outer edge, there were a couple of Bohadschia argus. It is always easier to find animals in rubble, since it is not necessary to kill corals to expose them.

Site 19. This site was on the west side of the causeway at Eoonmaaj along the breakwater. There was a small flat out beyond the dredge pit and there were some corals growing on the sand. A *B. argus* was on the flat and there were also a couple of hermit crabs and *Murex* spp. A *Trochus niloticus* was seen at the end of the rubble ridge. Considering the amount of water flow through the causeway, this area was not very healthy looking; this is probably a result of the dredging operation being conducted adjacent to the site.

Site 20. This was the reef behind the Marshall Island Sun Hotel. This is a fairly extensive fringing reef that begins in rubble and then grades into live coral, beginning with *Porites*, which becomes more extensive before breaking up into a large number of isolated coral mounds. Many people fish and hunt this area so there are no obvious edible invertebrates like *Tridacna maxima*. The branching coral was heavily covered in *Zoanthus* sp. and contained clones of the anemone *Entacmaea quadricolor* and its associated damselfish *Amphiprion melanopus*. *Culcita* was common in deeper water as were soft corals. A few crinoids were seen when turning rubble. The holothuroids included *Holothuria atra*, *H. leucospilota*, *Stichopus variegatus* and *Bohadschia argus*. There were a few ophiuroids under rubble and heart urchins in the sand. The echinoid *Echinometra* was also seen in some of the piles of rubble. The gastropods included *Cypraea arabica*, *C. lynx*, *C. erosa* and *Murex* spp. There were also small xanthid crabs and hermit crabs seen. The amount of zoanthids overgrowing the corals suggests that this reef is not as healthy as it first appears.

Site 21. Passage at end of Jarōj (Djarrit Island) and site of proposed continuation of the road by filling in the passage. The reef flat on the ocean side is covered by a thin turf and very high densities of ophiuroids. As the channel goes between the islands, it deepens and there are ridges with undercuts and much rubble. *Diadema* is aggregated in the ledges and there are several large yellow, solitary tunicates. There were numerous individuals of a large sabellid or feather duster worm. Also present was *Echinothrix diadema* and a long thin synaptid holothurian. *Holothuria atra* was common, and there were young of *Stichopus* sp., *Bohadschia argus* and *Holothuria leucospilota*. The rubble also contained numerous polychaetes and crabs and several young *Trochus* sp. This is a rich area and important to the circulation of the lagoon. It would be better to deepen the channel and put in a bridge so there would be more water entering the lagoon. One might consider altering the passage to form a small boat channel as well.

Site 22. Reef next to high school in town. The reef is dominated by one or two species of massive finger coral Lobophyllia sp. It grades into sand in front of the school and there are worm castings and heart urchin tests in the sand. The coral has extensive clones of the anemone Entacmaea quadricolor and its associated fish Amphiprion melanopus. Echinometra occurred under some of the rubble and there were a few sponges. Holothuria leucospilota was under rubble in the shallows and Bohadschia argus was seen in a little deeper water. The low diversity indicates a stressed system.

Site 23. Shallow flat on the ocean side between Wūlka (Uliga) and Teļap (Dalap). This is the site of a former pass between islands. The reef flat is a pavement with low turf and numerous ophiuroids, small gastropods, crabs and hermit crabs. There are also some sponges - the small brown one and a grey-green form. Echinometra was seen in depressions out near the edge.

Site 24. The ocean reef flat by the Marshall Island Sun Hotel. This is a typical ocean-side reef flat. Next to the island there is pavement with turf and small gastropods. As one proceeds toward the ocean, the pavement becomes pitted and some pieces of rubble are present. In the depressions are Echinometra which is the primary excavator of the pits and Trochus niloticus when the urchins are gone. Small coral heads begin to appear and it becomes more three dimensional with bigger undercuts. There are also clumps of arborescent coralline algae. A slate pencil urchin was seen under on big piece of rubble and Echinothrix occupied a number of depressions. The holothuroid Actinopyga mauritiana was seen flattened to the pavement in this outer zone.

Site 25. Reef flat between small islands up towards Kōļaļ-eņ and west of Āne-ko. This is a shallow flat with rubble right up to the drop off into the lagoon. The flat drops off slightly so there are a few small coral mounds that are cut through. There was much open sand on the pavement and much algae. The nudibranch Phestilla lugubris which feeds on Porites corals was found. Conus marmoreus, C. episcopus, Strombus luhuanus, Cypraea arabica, C. moneta and Lambis lambis were the major gastropods seen. Linckia sp. was the only asteroid seen, while both Echinometra and Echinothrix were present and four holothuroid spp. were seen. Holothuria atra was most common in the shallow, then H. leucospilota was found under rubble along with Stichopus variegatus and a long synaptid.

Site 26. A fringing reef between Āne-ko and Pikōn-lip. The corals were healthy and diversity was good. There were large heads of Goniopora and three species of zoanthids seen and all were common. There were also soft corals. In the sand and rubble, there were a few Lambis lambis and Strombus luhuanus and the large spiny holothuroid Thelanotus ananas. In some of the Porites cylindrica heads, there were clones of anemone Entacmaea quadricolor and the anemone fish Amphiprion melanopus. This was a well developed live reef with little rubble under which to look for motile invertebrates. No Tridacna seen.

Site 27. End of reef off Denmeo. Shallow reef dropping off slowly to about 40 feet of sand with scattered large coral aggregates. The aggregates had a big grey tubular sponge Cribochalina olemda, a large sabellid and a zoanthid with large polyps. Stichopus variegatus was common on the sand and several Thelanota ananas were also seen. There were a couple of the large blue Linckia laevigata. In the sand were many trails and holes and a very common heart urchin, approximately 1 inch in length, with long spines. Shells of the pearl oyster Pinctada margaritifera were observed, but none were seen alive. One Tridacna maxima was seen as was one Lambis chiraga. Some of the coral heads had Entacmaea quadricolor and Amphiprion melanopus.

Site 28. Cove on the lagoon side of Anel. Shallow lagoon reef with small coral heads and some rubble and sand. Zoanthids were common and some coral heads had the association of Entacmaea quadricolor and Amphiprion melanopus. There were small Stichopus variegatus under rubble as well as Holothuria leucospilota. There were a couple of Lambis lambis on the sand and a Cypraea isabella and fireworms under coral heads.

The survey covered a wide diversity of reef habitats and the number of invertebrates seen was high. Table 2 gives a list of the invertebrates, other than corals, seen during the survey. This is but a small representation of what could be listed if intensive sampling and collecting had been done, however, it does attempt to focus on the more conspicuous and better known groups and those species that have potential food value and/or of potential commercial importance.

Table 2. Invertebrates identified on reefs of Mājro and Arņo Atolls. The table is set up with the species given first and then a series of codes for atoll, habitat and relative abundance. The list also includes species found on Mājro Atoll, since the habitats are so similar that species seen on one atoll are almost certainly present on the other. The classification was based on that presented in Devanney, et al, 1987b).

KEY

ATOLL	– A = ARNO ATOLL, M = MĀJRO ATOLL
HABITAT	– O = OCEAN, RF = REEF FLAT, L = LAGOON REEFS, PR = PATCH REEFS
DENSITY	– R = RARE (1 SEEN) U = UNCOMMON (2 - 5) C = COMMON (6 - 10) N = NUMEROUS (11+)

TAXON	ATOLL	HABITAT	DENSITY
PHYLUM SARCODINA			
CLASS RETICULAREA			
ORDER FORAMINFERIDA			
Family Homotremidae,	A, M	L, RF, PR	C
PHYLUM PORIFERA			
CLASS DEMOSPONGIAE			
ORDER HADROMERIDA			
Family Clionidae	A, M	L, RF, PR	C
Family Tethyidae			
Tethya sp.	A, M	L, RF, PR	C

ORDER HAPLOSCLERIDA			
Family Niphatidae			
Cribrochalina olemda	M	L	U
Family Callyspongiidae			
Callyspongia sp.	M	L, PR	U - C
ORDER DICTYOCERATIDA			
Family Dysideidae			
Dysidea sp.	A, M	L, RF, PR	C
Family Unknown			
Plakellia sp.	M	L, PR	C
Phyllospongia sp.	A, M	L, RF, PR	C
Black columns	A, M	L, RF, PR	N
Small brown volcanos	A, M	L, RF, PR	N
PHYLUM CNIDARIA			
CLASS HYDROZOA			
ORDER HYDROIDA			
SUBORDER ANTHOMEDUSAE			
Pennaria sp.	M	L, RF	C
SUBORDER LEPTOMEDUSAE			
Aglaophenia sp.	A, M	L, PR	C
Lytocarpus spp.	A, M	L, RF, PR	C
ORDER MILLEPORINA			
Millepora spp.	A, M	L, PR	C
ORDER STYLASTERINA			
Distichopora sp.	A	O, L, RF, PR	C-N
Stylaster spp.	A, M	O, L, RF, PR	C

CLASS ANTHOZOA			
SUBCLASS ALCYONARIA			
ORDER STOLONIFERA			
Family Tubiporidae			
Tubipora musica	A, M	O	U
ORDER GORGONACEA			
Paramuricea sp.	M	L, RF	C
ORDER ALCYONACEA			
Family Alcyoniidae			
Numerous genera and species - need better references in the field to make identifications.			
ORDER COENOTHECALIA			
Family Helioporidae			
Heliopora coerulea	A, M	L	C(A),U(M)
SUBCLASS ZOANTHARIA			
ORDER ZOANTHIDEA			
Family Zoanthidae			
Palythoa tuberculosa	M	L, RF, O, RF	U
Palythoa sp.	M	L, RF	U
Zoanthus sp.	M	L, RF	N
ORDER ACTINIARIA			
Family Aiptasiidae			
Aiptasia pulchella	M	L, RF	C
Family Actinodendronidae			
Actinodendron sp.	A	RF	R
Family Stichodactylidae			
Entacmaea quadricolor	A, M	L	N
Radianthus simplex (on sand)	A	L, RF	R
Calliactis polypus	A, M	L, RF	U

ORDER CORALLIMORPHIA			
Ricardoa sp.	M	L, RF, PR	N
ORDER ANTIPATHARIA			
Cirrhipathes sp.	A, M	O, L, RF, PR	U - C
PHYLUM BRYOZOA			
CLASS UNKNOWN			
ORDER UNKNOWN			
Family Unknown			
bryozoans	A, M	O, RF, PR	U - C
PHYLUM PLATYHELMINTHES			
CLASS TURBELLARIA			
ORDER POLYCADIDA			
Family Unknown			
Pseudoceros bedfordi	A	O, RF	R
PHYLUM NEMERTEA			
Lineus sp.	A, M	O , RF	U
PHYLUM MOLLUSCA			
CLASS GASTROPODA			
SUBCLASS PROSOBRANCHIA			
ORDER ARCHAEOGASTROPODA			
Family Neritidae			
Nerita maxima	A, M	RF	C - N
Nerita plicata	A, M	RF	C
Nerita polita	A, M	RF	C
Family Trochidae			
Tectus pyramis	A, M	L, RF, PR	U
Trochus sp.	A, M	L, RF, PR	U
Trochus niloticus	A, M	O, L, RF, PR	U - C
Trochus sp. (small, red)	A, M	RF	U
Family Turbinidae			

Turbo petholatus	A, M	O, RF	U
Turbo argyrostomus	A, M	L, O, RF	U
ORDER MESOGASTROPODA			
Family Bursidae			
Bursa bufonia	A	O, RF	R
Bursa granularis	M	O, RF	R
Family Cassididae			
Phalium glaucum (shell)	M	L, RF	R
Phalium whitworthi (shell)	M	L, RF	R
Casmaria ponderosa	A, M	L, RF, PR	U
Cassis cornuta	A,M	L, RF	R
Family Cerithiidae			
Cerithium spp.	A, M	L, RF, PR	C
Family Cymatiidae			
Charonia tritonis (shell)	A	O, RF	R
Cymatium pileare	A, M	L, RF, PR	R
Family Cypraeidae			
Cypraea annulus	M	O, RF	U
Cypraea arabica	A, M	L, RF, PR	C
Cypraea argus (shell only)	A, M	O, L, RF	R
Cypraea caputserpentis	A	O, RF	R
Cypraea carneola	A	L, RF	R
Cypraea erosa	A, M	L, RF, PR	C
Cypraea helvola	A, M	L, RF, RF	R
Cypraea isabella	A, M	L, RF	R
Cypraea lynx	A, M	L,RF	U
Cypraea maculata	M	O,RF	U
Cypraea mappa	A, M	L, RF, PR	U
Cypraea monerta	A, M	O, RF	N
Cypraea poraria	A	O,RF(slope)	R
Cypraea scurra	A	L, PR	R
Cypraea talpa	A, M	L, RF, PR	U
Cypraea tigris	A, M	L, RF, PR	U
Cypraea vitellus	A, M	L	U

Family Littorinidae			
Littorina spp.	A, M	RF	N
Family Strombidae			
Lambis chiragra	A, M	L, RF	U
Lambis crocata (lambis)	A, M	L, RF, PR	U - C
Lambis truncata (shell)	A	O,	R
Strombus luhuanus	A, M	L, RF, PR	N
Strombus gibborulus	A, M	L, RF	R
Strombus spp.	A, M	L, RF	R
Family Naticidae			
Polinices spp.	A, M	L, RF, PR	U
Family Tonnidae			
Tonna perdix (shell only)	A, M	L, RF	R
Family Vermetidae			
Dendropoma maxima	A, M	O, L, RF, PR	N
Serpulorbis sp.	A, M	L, RF	U - N
ORDER NEOGASTROPODA			
Family Vasidae			
Vasum ceramicum	A, M	L, RF	U
Vasum turbinellum	A, M	RF	U
Family Harpidae			
Harpa spp.	A	L	U
Family Mitridae			
Mitra sp.	A, M	L, PR	U
Family Conidae			
Conus aulicus (shell only)	A	L, RF	R
Conus ebraeus	A, M	O, RF	N
Conus episcapalis	M	L, RF	U
Conus leopardus	M	L, RF	U
Conus marmareus	A, M	L, RF, PR	U
Conus miles	A, M	O, L, RF, PR	C
Conus sponsalis	A, M	O, RF	C
Conus striatus	A	L, RF	R
Conus tulipa	A	L, RF	R

Conus virgus	A	L, RF	R
Family Terebridae			
Terebra maculata	A, M	L, RF	U
SUBCLASS OPISTOBRANCHIA			
ORDER ANASPIDEA			
Family Aplysidae			
Aplysia sp.	M	L, RF	C
Dolabella sp.	M	L, RF	U
ORDER CEPHALOSPIDEA			
Family Aglajidae			
Chelidonura sp. 1 (black, blue lines)	A	L, PR	R
Chelidonura inornata	M	O, RF, L, PR	C - N
ORDER SARCOGLOSSA			
Family Cyercidae			
Cyerce sp.	M	L, RF	R
ORDER NUDIBRANCHIA			
Family Chromodoridae			
Chromodoris sp.	M	L, RF	R
Family Platydoridae			
Platydoris formosa	M	L, RF	R
Family Phylliidiidae			
Phyllidia pustulosa	A, M	O	R
Phyllidia varicosa	A	O, L, RF	R
Family Cuthonidae			
Phestilla lugubris	M	L, RF	R
Family Aeolidiae			
Pteraeolidia ianthina	A	L, PR	R

SUBCLASS PULMONATA			
ORDER BASOMMATOPHORA			
Family Siphonariidae			
Siphonaria normalis	A	O, RF	R
CLASS BIVALVIA			
Family Arcidae			
Anadara antiquata	A, M	L, PR	U
Arca spp.	A, M	O, RF, L, PR	C
Family Chamidae			
Chama sp.	A, M	L, PR	U
Family Malleidae			
Promantellum parafragile	A, M	L, RF, PR	U
Family Lucinidae			
Codakia sp.	A, M	L, PR	C
Family Pectinidae			
Pecten sp.	A, M	L	R
Family Pinnidae			
Pinna muricata	M	L, PR (40ft.)	R
Family Pteriidae			
Pinctada margaritifera	A, M	L, PR, RF	R - U
Family Spondylidae			
Spondylus varians	A	L, FR, PR	U
Spondylus sp.	A, M	L FR	R
Family Tellinidae			
Tellina elizabethae	A, M	L	U
Macoma sp.	A, M	L	U
Family Tridacnidae			
Hippopus hippopus	A, M	L, RF	U
Tridacna maxima	A, M	O, L, RF, PR	U - N
(probably combined with Tridacna squamosa)			
Family Cardiidae			
Trachycardium robustum	A, M	L, RF, PR	C
Trachycardium sp.	A, M	L, PR	C

Family Veneridae			
Lioconcha Hieroglyphica	A, M	L	U
Periglypta reticulata	A, M	L, RF, PR	U
Venus isocardia	A, M	RF, L, PR	U
CLASS CEPHALOPODA			
ORDER OCTOPODA			
Family Octopodidae			
Octopus sp.	A, M	L, RF, PR	R
PHYLUM ANNELIDA			
CLASS POLYCHAETA			
Family Amphinomidae			
Hermodice sp.	A, M	L, RF, PR	C
Eurythoe complanata	A, M	L, RF, PR	C
Family Sabellidae			
Sabellastarte sanctijosephi	M	L, RF, PF	C
Family Serpulidae			
Spirobranchus giganteus	A, M	O, L, RF, PR	R - C
Family Eunicidae			
Eunice sp.	A, M	L, RF, PR	U
Family Terebellidae			
Terebellid sp.	A, M	L, RF, PR	U
PHYLUM SIPUNCULA			
Phascolosoma spp.	A, M	L, RF, PR	U - C
PHYLUM ARTHROPODA			
SUBPHYLUM CRUSTACEA			
CLASS MAXILLOPODA			
SUBCLASS CIRRIPEDIA			
PRDER THORACICA			
SUBORDER BALANOMORPHA			
SUPERFAMILY CORONULOIDEA			
Family Tetraclitidae			

Tesseropora pacifica	A, M	RF	C
CLASS MALACOSTRACA			
ORDER STOMATOPODA			
Family Unknown			
stomatopods	A, M	RF, PR	U
ORDER DECAPODA			
SUBORDER PLEOCYEMATA			
INFRAORDER STENOPODIDEA			
Family Stenopodidae			
Stenopus hispidus	M	O, L, RF	R
INFRAORDER CARIDEA			
SUPERFAMILY ALPHEOIDEA			
Family Alpheidae			
Alpheid spp.	A, M	RF, L, PR	C
Alpheus sp. (commensal with goby)	A, M	L, RF, PR	C
Family Hippolytidae			
Saron marmoratus	A	L, RF	R
INFRAORDER PALINURA			
SUPERFAMILY PALINUROIDEA			
Family Palinuridae			
Panulirus penicillatus (molts only)	A, M	L, RF	R
INFRAORDER ANOMURA			
SUPERFAMILY THALASSINOIDEA			
Family Callianassidae			
Callianassid sp. (burrows in rubble)	A, M		L, RF, PR C
SUPERFAMILY PAGUROIDEA			
Family Coenobitidae			
Coenobita spp.	A, M	on islands	C
Family Diogenidae			
Dardanus guttatus	A, M	RF	R

Dardanus megistos	A, M	L, RF, PR	U
hermit with anemone in shell	A, M	L, RF	U
SUPERFAMILY GALATHEOIDEA			
Family Porcellanidae			
Petrolisthes spp.	A, M	L, O, RF, PR	C
INFRAORDER BRACHYURA			
SECTION BRACHYRHYNCHA			
SUPERFAMILY CALAPPOIDEA			
Calappa sp.	M	L, RF	R
SUPERFAMILY PORTUNOIDEA			
Family Portunidae			
portunid crabs	A, M	RF	C
SUPERFAMILY XANTHOIDEA			
Etisus splendidus	A	PR	R
small xanthid crabs	A, M	L, RF, PR	C
SUPERFAMILY GRAPSOIDEA			
Family Gecarcinidae			
Gecarcoidea lalandii	A, M	on islands	C
SUPERFAMILY OCYPODOIDEA			
Family Ocypodidae			
Ocypode sp.	A, M	islands	C
PHYLUM ECHINODERMATA			
CLASS CRINOIDEA			
Family Colobometridae			
Oligometra serripinna	A, M	O, L, RF, PR	U
(several other commatulids)	A, M	O, L, PR	U
CLASS HOLOTHUROIDEA			
ORDER ASPIDOCHIROTIDA			
Family Holothuriidae			
Actinopyga iecanora	A	L, PR	R
Actinopyga echinites	A	L, PR	R
Actinopyga mauritiana	M	O, RF	U

Bohadschia argus	A, M	L, RF, PR	C
Holothuria (Halodeima) atra	A, M	L, RF	N
Holothuria (Halodeima) edulis	A, M	L, RF, PR	U
Holothuria (Thymiosycia) hila	A, M	O, L RF, PR	N
Holothuria (Mertensiothuria) leucospilota	A, M	O, L, RF	N
Holothuria (Microthele) nobilis	M	L, RF	R
Neothyonidium magnum (in sand with tentacles showing)			
	A, M	L, RF	U - R
Family Stichopodidae			
Stichopus harrens (under rocks in shallow rubble)			
	ML, RF		U
Stichopus chloronotus	A	L, PR	R
Thelenota ananas	A	L, PR	U
ORDER APOPIDA			
Family Synaptidae			
Polyplectana kefesteini (shallow rubble)			
	A, M	L, RF	U
Synapta maculata	M	L, RF	U - C
CLASS ASTEROIDEA			
Family Acanthasteridae			
Acanthaster planci	A, M	O, L, RF PR	U
Family Echinasteridae			
Mithrodia clavigera	A, M	L, RF, PR	R
Echinaster callosus	A	L, RF	R
Family Oreasteridae			
Culcita novaeguineae	A, M	O, L, RF, PR	C
Choriaster granulatus	A	L, PR	U
Family Ophidiasteridae			
Fromia milleporella	A, M	L, RF, PR	U
Fromia monilis	A, M,	L, RF, PR	U
Leiaster sp.	A, M	L, RF, PR	U
Linckia laevigata	A, M	L, RF, PR	U
Linckia multifora	A, M	O, L, RF, PR	U

CLASS OPHIUROIDEA

Family Ophiocomidae

Ophiocoma erinaceus	A, M	L, RF, PR	C

Family Ophiuridae

Ophiamyxa australis	A	L, RF, PR	R
Ophiomastix asperula	A, M	O, RF	N
Ophioachnella gorgonia	M	L, RF	R

CLASS ECHINOIDEA

Family Brissidae

Brissopsis luzonica (tests on sand and reefs - no live found)

	A, M	RF, L, PR	U

Family Diadematidae

Diadema savignyi	M	L, RF	C
Echinothrix calamaris	A, M	L, RF	U
Echinothrix diadema	A, M	O, L, RF	U

Family Echinometridae

Echinometra mathaei	M	O, L, RF	C - N
Echinometra oblonga	M	L, RF, PR	U
Echinostrephus aciculatus	A, M	O, RF	C - N
Heterocentrotus trigonarius	M	O, RF	R

Family Toxopneustidae

Tripneustes gratilla	M	L, RF	U

PHYLUM HEMICHORDATA

CLASS ENTEROPNEUSTA

Family Ptychoderidae

Ptychodera flava	A, M	L, RF	U

PHYLUM CHORDATA

SUBPHYLUM TUNICATA

CLASS ASCIDIACEA

ORDER APLOUSOBRANCHIATA

Family Didemnidae

Didemnum molle	A, M	L, PR	C
ORDER UNKNOWN			
Family Unknown			
tunicate (large, yellow)	M	L, RF	U - C

CONCLUSIONS AND RECOMENDATIONS

The coral reef ecosystems on Mājro Atoll were diverse in form and also in their richness and health. The invertebrates listed in Table 2 represent only a small subsample of the rich diversity of plant and animal life present in Mājro's coastal waters. Although the reefs varied from location to location, the pattern observed showed a decreasing health and diversity as one moved from the Mājro Island (Laura) end of the lagoon towards the urban area. The healthy reefs showed an impact of human harvesting which should be considered a natural component of reef ecology. These reefs supported large populations of associated animals. The stressed reefs, however, showed reduced live coral diversity and a limited variety of associated animals, particularly those that might be used for food such as giant clams. The healthy reefs were comparable to those on Arņo, but the stressed reefs were impoverished in comparison to the healthy reefs on either atoll.

The Marshall Islands have been inhabited for over 3,000 years, so the reefs we were surveying have been exposed to human exploitation for an extremely long period of time. At almost every site, there was evidence of human harvesting in the form of piles of dead shells or fishtraps or pieces of broken coral. It is therefore important to view man as a component of the atoll reef ecosystem. The richness of the reefs on Arņo is evidence that man can use the reefs in a positive way and not destroy them. It appears that as long as the reefs are healthy, they will support varied fisheries and there is the possibility that their productivity could be enhanced through various forms of mariculture.

The one conspicuous alteration of the reef system, that might be attributed to human fishing pressure, is the presence of the coral-eating sea star <u>Culcita novaeguineae</u>. Continued predation on corals by this sea star appears to allow a buildup of soft corals which then inhibit the recruitment of hard corals. Few species either eat soft corals or use them as a refuge, therefore the reefs support fewer numbers of associated fish and invertebrates than if the reef was dominated by hard corals. Since <u>Culcita</u> does not form large, reef-threatening aggregations, they have received little attention. It would be interesting to see if systematic removal of <u>Culcita</u> on selected reefs would result in enhanced coral growth.

There were obvious differences in the health, diversity and numbers of animals on some of the lagoon reefs of Mājro compared to those of Arņo. This appears to be a clear example of the negative impact of cutting off water flow to a lagoon. The reefs of Arņo are rich in life, and while they may be overfished for certain species in some areas, they have the ability to recover quickly because the corals, algae and invertebrate fauna are present and healthy.

The reefs of an inhabited atoll are bound to be heavily exploited for a variety of species since man is one of the major predators in the reef ecosystem. Evidence of harvesting was common in the form of piles of empty shell and freshly broken branches of coral on reefs. Those reefs closest to the greatest population areas will be most heavily fished. Historically, fishing seems to be generalized with a variety of species being taken, but without eliminating any given species. This is no different than the feeding strategy of most top carnivores in most ecosystems. As long as the reefs themselves are healthy, there will be recruitment of new individuals to sustain the system. It probably has been important that reefs are controlled by family groups, since this limits the level of harvesting on any given reef system.

Coral reef systems are fragile and susceptible to irreversible damage if pollution, dredging, decreased water exchange or new harvesting techniques occur. The decrease in fisheries on some of the reefs in M̄ajro lagoon seem to be due mostly to the decreased water flow from the causeway than to overfishing because the corals are dead or dying in addition to reduced fish and invertebrate populations. New harvesting techniques such as nighttime spear fishing and/or extensive use of gill nets may severely reduce some fish species. It is unlikely that overfishing alone will have long term impacts on most invertebrate species as long as the reefs are healthy, since most have pelagic larvae and refuges where harvesting is minimal. A natural consequence of sustained reduction of some species in an ecosystem is that other species will increase to take their place and these may alter the reef community. The relatively high numbers of Culcita and soft corals on numerous reefs may be an example of a species increasing due to lowered competition and/or predation and altering the reef community structure. Some invertebrate species appear to have potential for mariculture and export for the aquarium trade.

Aquarium Trade.

The marine aquarium trade is expanding both in general demand and in the variety of species being sold. Invertebrates are now commonly seen in pet stores and seem to sell well. One can try almost any species, but most are neither hardy nor common enough to make for a sustained fishery. Below are listed some species that might be investigated:

1. Strombus luhuanas is a small, commonly found conch harvested for food. It is active, colorful and hardy and feeds on algal scum. It and several other small strombids may be good candidates.

2. Cypraea arabica is quite common under rubble on lagoon reefs and is a nice size for a marine aquarium. Other cowries might also work, especially those that can be harvested without destroying living corals. There are a number of cowries that are found in the shallow rubble zone, above where active coral growth occurs.

3. Holothuria atra is very common in sea grass beds as 3 to 5cm juveniles. This is a hardy species that should live well in marine aquaria.

4. Tridacna maxima is hardy and small specimens are very colorful and should be popular with aquarists.

5. Entacmaea quadricolor is an aggregating anemone that is common in Porites cylindrica colonies. The anemone is of moderate size and should be a good aquarium anemone. Entacmaea forms a species-specific association with the anemone fish Amphiprion melanopus. The fish and the anemone will probably do best if kept together. There are large populations of this association on Majro and it could be marketed as a package.

There are undoubtedly many other species that could be tried, but these are obvious species of invertebrates that would seem to be appropriate for this trade, based on limited observations. There would also appear to be opportunities for several types of mariculture operations.

Mariculture.

1. Juvenile Fish Attractors for the Aquarium Trade: Many species of reef invertebrates and fish have pelagic planktonic larvae that settle out in specific habitats. Collecting small fish and invertebrates for the aquarium trade and/or juveniles for mariculture efforts can be highly disruptive to coral reefs. It should be possible to establish coral colonies on short stakes and to set up rubble piles on open reef flat areas isolated from reefs that will attract the young of damselfish and other species. These isolated heads can be enclosed in nets, cleared of fish and replaced without impacting reefs. Dead blocks or plates of coral can be set out in different arrays and the fish and invertebrates that accumulate on their undersides can be harvested in the same way. These isolated aggregations of substrates will serve to increase the structure available to a variety of plants and animals of no

direct use to collectors, but their presence will help to increase the productivity of the reef system as a whole. There may also be particular substrates that are particularly attractive to the young of species, such as *Tridacna maxima*, that have mariculture potential and it would be worthwhile investigating the potential of such spat collectors.

2. Mariculture of Mollusks. Several molluscan species such as the turban shells, giant clams and pearl oysters are of interest as both food and for sale. There are specific areas of the atoll that might be used for growing out each of these groups.

a. *Trochus niloticus* and *Turbo* spp. These snails can be found in several shallow reef habitats, but they are commonly harvested on the oceanside reef flat. Young *Trochus* are found in the depressions of the urchin *Echinometra mathei*. It would appear that quarries on the oceanside reef flat would be ideal areas for raising species of *Turbo niloticus* and some *Turbo* spp. The only serious predator to be found in this habitat are species of the spiny lobster *Panulirus* spp. and they are in high demand as food, so there is an economic incentive to control them by harvesting.

Lamberts and Maragos (1989, this volume) describe the status of the quarries on Mājro. There is a wide variation in the development of corals in the different quarries. Such quarries do not appear to damage the integrity of the reef flat and they may have a possible benefit for mariculture of snails. There were no quarries on the reef flats identified for Arņo, but future demands for construction material may lead to requests to mine some oceanside reef flats. Studies of the mariculture potential of quarries on Mājro is recommended as well as closer investigation of any possible negative impacts, before any altering of the flats on Arņo is permitted.

b. *Tridacna maxima* and *Hippopus hippopus*. Shallow reef flats that are always submerged could be used for culturing these species if there is cooperation with local fishermen to prevent poaching. The reef flats need to be wide, submerged and with good flow of water during mid to high tide. On Arņo, the reef flat between Namwi and Āne-kā-ej and possibly down to Ūl-en should be excellent for raising both *Tridacna* and *Hippopus*; there is an extensive area with water flow at mid to high tide and sufficient water depth at low tide to protect the clams from rain or dessication at even the lowest minus tides. On Mājro Atoll, the reef flat between Mājro Island (Laura) and Ro̧nro̧n̄ would appear to be a good site for giant clam culture, if poaching can be dealt with.

No specimens of *Tridacna gigas* were seen during the survey, though some very old shells were seen on a couple of islands. This animal does occur in the Marshall Islands and is easily cultured. It should be considered for mariculture, since the reef flats suggested are adequate habitat and there is high demand for the meat of this species.

c. *Pinctada margaritifera*. The pearl oyster *Pinctada margaritifera* was regularly seen on Arņo reefs and only occasionally observed on Mājro, though a very small specimen was collected on the reef near Roguron on Mājro. We were not able to visit the pearl oyster farm on Arņo due to an early return to Mājro. The farm seems to be having problems, but the reasons are not known. It would appear the pearl oyster culture is feasible on both Arņo and Mājro, however, a different area of the lagoon might possibly be more suitable for clam culture.

The present farm is on the windward side of the atoll near Tutu Island and passage. There is good water flow in this area, but the water is oceanic and has had little residence time in the lagoon. The longer water remains in the lagoon, the more enriched with organic particulates and plankton it becomes. Therefore, it would seem likely that pearl oysters would do best on the leeward side of atolls and may do best in deeper water, maybe below 10m than above. It would be interesting to conduct growth studies with oysters by suspending young oysters at different locations around the lagoon and over a range of depths at each site. It is predicted that oysters might do best near Matol-eņ and Arņo on Arņo and near Laura and Āneen-bubu on Mājro.

Resorts, Preserves, and Road Extensions.

Resorts

The islands about and including Rọn̄rọn̄ would appear to be suited to resort development and the reefs are good in this region.

Preserves

Some of the reefs and islands about Irooj would appear to be good candidates for preservation. The seabird colony on Irooj should be protected and the well developed reefs in this section of the lagoon would seem to be worth developing as marine parks.

In many other reef areas where snorkeling and diving have become the big attraction, spearfishing as well as bottom fishing is banned - e.g. Heron and Lizard

Islands on the Great Barrier Reef, The Cayman Islands in the Caribbean. Coral reefs are interesting, but it is large numbers of fish, especially large ones, that excite divers. Fishing pressure is bound to grow as the population grows and reef fish are easily overfished. The same would be true for harvesting of invertebrates, such as giant clams, for food or sale. It will require cooperation of fishermen to protect some areas. The tradeoff is more money in tourism, but the fishermen will have to see the benefits or they will resent being kept from their reefs and the system will not work.

Causeway extension

The lagoon on Mājro is presently suffering from reduced water flow. The closing of more reef flats will be disastrous to the future health of the lagoon. It would be more effective to open more passages and use bridges on Mājro. This is a model that should be considered for most atolls. The system of bridges connecting the Florida Keys is a much better way to handle connecting islands. To make space, the preferred way would be to fill onto the reef flat on the ocean side and out into the lagoon side of the islands. Reef flats between islands are the source of water, nutrients and larvae for the exploitable fish and invertebrates of the lagoon reef system.

The difference in the health, diversity and numbers of animals on the lagoon reefs of Arņo and the southwest section of the Mājro lagoon are a clear example of the negative impact of cutting off water flow to a lagoon. The reefs of Arņo are rich in life and while they may be overfished at times, they have the ability to recover quickly, because the corals, algae and invertebrate fauna are present and healthy. The causeway on Mājro has cut off water flow to the most heavily used part of the lagoon which has become stressed and impoverished. Silt from dredging and pollution in the form of organic wastes that consume oxygen during bacterial degredation are choking the remaining reefs. Increasing the water flow in the southwest portion of the lagoon would flush the silt and pollutants and help the reefs to rebound from short term abuses.

Another problem relating to the causeway is the change in water flow patterns in the lagoon which is having a negative impact on Mājro Island (Laura) in the form of erosion. Water appears to pile up on the Mājro side of the lagoon, and can only leave the lagoon around the end of the island which is causing shoreline erosion. A solution would be to open channels for water flow at strategic points along the causeway. The size and number of such openings should be determined by more complete current analyses, but several passages spanned by bridges would improve the health of the lagoon and could offer better small boat access to the outside for fishing.

In summary, Mājro Atoll contains areas of rich and diverse reef system, but the causeway, dredging and dumping has severely impacted the southwest section of the lagoon. The invertebrate fauna is typical of that reported for other Marshall Island atolls (Devaney, et al, 1987). The reef ecosystem can sustain continued human exploitation where healthy reefs occur and can have the potential for increased use, if care is taken to protect the integrity of the coral reef community. It is possible to improve the status of the southwest section of the lagoon, if water flow can be improved. Living corals are the basis of reef ecosystems and maintaining and/or improving their continued health should be a primary consideration in any future development plans.

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APPENDIX E

AN ANNOTATED LIST OF MARINE ALGAE FROM MĀJRO AND ARŅO ATOLLS, REPUBLIC OF THE MARSHALL ISLANDS

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ABSTRACT

Twenty-four taxa of marine algae were collected in July 1988 from littoral and shallow subtidal areas on Mājro and Arņo Atolls. Two species collected, *Acanthophora spicifera* and *Udotea argentea*, have not previously been reported from the Marshall Islands.

Although the Marshall Islands have been the site of much scientific research, current information about marine algal resources is lacking. Comprehensive taxonomic treatments of Marshall Islands algae were published in the 1950's (Taylor 1950, Dawson 1956, Dawson 1957). Since then, algal studies have been sporadic and have added only a few species to the marine flora (see Tsuda 1987). Ecologists working on Āne-wetak, Bikini, and nearby atolls have also made brief algal species lists (Palumbo 1950, Odum and Odum 1955, Gilmartin 1960, Bakus 1967, Marsh 1970, Smith and Marsh 1973, Agegian et al. 1986). A recent compilation of all published records of marine algae from the Marshall Islands (Tsuda 1987) yielded a total of 238 species of green, brown, red and blue-green algae. However, up-to-date collections, identifications and assessments of algal abundances are severely needed.

This list of seaweed species is based on collections made during a marine resources survey project sponsored by the University of Hawaii Sea Grant Extension Service in July 1988. Despite time constraints and the "non-phycological" backgrounds of the collectors, 49 fine specimens were collected and pressed, representing 24 species of marine algae. Of these, fifteen are Chlorophyta, two Phaeophyta and eight Rhodophyta. On the next survey, I would suggest taking small vials filled with 4% formalin-seawater solution (or other liquid preservative). With this technique, more of the small, filamentous algae could be collected. These "fuzzy" algal turfs, although often overlooked in collections, are thought to be the most productive component of reef ecosystems, and probably the major food source for herbivorous reef fishes.

In this list, species are arranged in systematic order. Pertinent taxonomic literature is cited, especially previous reports in the Marshall Islands. Specimens numbered KM2051 through KM2062 were collected by Peter and Tahl Rosti on Mājro; numbers KM2063 through KM2099 were collected by Meriwether Wilson on Arņo Atoll. All specimens were deposited as vouchers in the Bernice P. Bishop Museum Herbarium in Honolulu.

CHLOROPHYTA--GREEN ALGAE

Dictyosphaeria cavernosa (Forskal) Borgesen Palumbo 1950, Taylor 1950, Dawson 1956, Dawson 1957. Specimens: KM2070, KM2086, KM2094

Microdictyon setchellianum Howe
Dawson 1956.
Specimens: KM2073, KM2079, KM2093

Bryopsis hypnoides Lamouroux
Taylor 1950, Dawson 1957.
Specimens: KM2060

Caulerpa bikinensis Taylor
Taylor 1950, Dawson 1957.
Specimens: KM2080

Caulerpa racemosa (Forskal) J. Agardh
Palumbo 1950, Taylor 1950, Dawson 1956, Dawson 1957, Gilmartin 1960. Specimens: KM2056, KM2081, KM2096. C. racemosa is well-known as a seaweed used for human consumption. It is eaten raw with coconut cream and grated coconut or other condiments in Fiji, Samoan, Tonga, Tokelau Islands and Tahiti (Abbott 1984). This seaweed is also eaten in the Philippines, Japan, Indonesia and China (Chapman and Chapman 1980).

Caulerpa serrulata (Forskal) J. Agardh
Taylor 1950, Dawson 1956, Dawson 1957, Gilmartin 1960.
Specimens: KM2054, KM2063, KM2089

Caulerpa sertularioides (Gmelin) Howe
Dawson 1956, Gilmartin 1960.
Specimens: KM2061

Caulerpa urvilliana Montagne
Palumbo 1950, Taylor 1950, Dawson 1956, Dawson 1957. Specimens: KM2054, KM2064, KM2085, KM2087, KM2088

Udotea argentea Zanardini NEW RECORD

Yamada 1934: p. 75 fig. 44; Pham-hoang 1969, p. 509, fig. 4.116.

Specimens: KM2099. This species is known from the Ryuku Islands and from South Vietnam. The specimen from Arno Atoll is 14 cm tall from base of holdfast to topmost frond. The sand-covered holdfast is 9 cm long and 1.4 cm diam. The upper portion is composed of many, branching, multi-lobed, silvery-green fronds which are lightly calcified.

Udotea palmetta Decaisne

Dawson 1956, Dawson 1957.

Specimens: KM2053, KM2075, KM2076

Tydemania expeditionis Weber van Bosse

Taylor 1950, Dawson 1956, Dawson 1957, Gilmartin 1960, Gilmartin 1966, Hillis-Colinvaux 1977.

Specimens: KM2052, KM2090, KM 2097

Halimeda discoidea Decaisne

Taylor 1950, Gilmartin 1960.

Specimens: KM2068, KM2084

In the Marshall Islands, Halimeda fragments are recognized as a major source of lagoon bottom deposits (Odum and Odum 1955, Gilmartin 1960).

Halimeda monile (Solander) Lamouroux

Taylor 1950, Dawson 1956, Dawson 1957, Gilmartin 1960, Gilmartin 1966, Hillis-Colinvaux 1977.

Specimens: KM2066

Halimeda opuntia (L.) Lamouroux

Taylor 1950, Dawson 1956, Dawson 1957, Gilmartin 1960, Hillis-Colinvaux 1977.

Specimens: KM2072, KM2077, KM2078, KM2082 (var. elongata), KM2095, KM2098

Halimeda stuposa Taylor

Taylor 1950, Dawson 1957, Hillis-Colinvaux 1977.

Specimens: KM2069, KM2071, KM2083, KM2092

PHAEOPHYTA--BROWN ALGAE

Lobophora variegata (Lamouroux) Womersley

as Pocockiella variegata Taylor 1950, Dawson 1956, Dawson 1957, Gilmartin 1960, Smith and Marsha 1973.

Specimens: KM2067

Dictyota dichotoma (Hudson) Lamouroux

Gilmartin 1960.

Specimens: KM2058

This specimen is composed of blade fragments and is identified with hesitation.

RHODOPHYTA--RED ALGAE

Liagora sp.

Specimens: KM2055

Several Liagora species are reported from the Marshall Islands. Identification to species is best made with fresh or liquid preserved material.

Champia sp.

Specimens: KM2098 epiphyte on Halimeda

Spyridia filamentosa (Wulfen) Harvey

Taylor 1950, Dawson 1957, Gilmartin 1960.

Specimens: KM2051, KM2057

This species was common in the shallow Mājro lagoon waters. Spyridia filamentosa, in others parts of the Pacific, is known to be a host alga for the epiphytic dinoflagellate Gabierdiscus toxicus which produces ciguatoxin, the cause of ciguatera poisoning in humans who ingest certain reef fish (Shimizu et al. 1982).

Dictyurus purpurascens Bory

Taylor 1950, Dawson 1956, Dawson 1957.

Specimens: KM2091

Dasya sp.

Specimens: KM2074

Acanthophora spicifera (Vahl) Borgesen NEW RECORD

Dawson 1954, p. 456, fig. 61a,b; Pham-hoang 1969, p. 272, fig. 2.202; Magruder and Hunt 1979, p. 57.

Specimens: KM2059

This species is considered a "weed" in Hawaii and thought to have been introduced from Guam (Doty 1961). Although the specimen from Mājro is small and fragmentary, it agrees well with previous descriptions and illustrations of this very distinct species.

Laurencia sp.

Specimens: KM2062, KM2065, KM2098 epiphtyte on Halimeda

APPENDIX F

OBSERVATIONS ON THE SHALLOW REEF-FISH RESOURCES OF MĀJRO ATOLL, REPUBLIC OF THE MARSHALL ISLANDS

prepared by

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INTRODUCTION

Since becoming the administrative center of the Marshall Islands approximately 40 years ago, Mājro Atoll has sustained a continuously escalating population, now estimated at over 15,000. Concurrently, the harvesting of Mājro's shallow reef-fish, primarily for food, has intensified. Marine environmental degradation, largely resulting from construction and waste disposal activities, has added to the pressure under which these resources must survive.

Expectations of a continuously increasing population, and it's associated urbanization, have created concern for the future of Mājro's reef-fish resources. This, coupled with deficiencies in the knowledge of Mājro's fish resources at a time when the government must make sound planning and management decisions, has made the acquisition of more detailed information on these resources critically important.

METHODS

Field observations on Mājro's shallow-water reef fishes were made from July 19 to 26, 1988. Twenty-eight survey sites were selected on the basis of their historical resource value, proximity to planned infrastructure improvement projects, or potential for tourism, recreation, research, education, or fisheries utilization (see companion atlas). The surveys were conducted for the purpose of compiling general descriptions of reef-fish resources as part of a comprehensive coastal resource inventory of Mājro Atoll.

During the surveys, conspicuous daytime reef-fish species at each site were identified and ranked in terms of their site-specific relative abundances. Visual observations were written on underwater paper, mostly while snorkeling at depths no greater than 30 feet. However, Sites 2, 7, 11, 15, and 27, were surveyed during SCUBA dives to depths less than 60 feet. Each survey dive lasted approximately 30 minutes and data were recorded while swimming through each area without "backtracking".

The relative abundances of the fish species observed at each site were ranked according to the following general scheme:

A = Abundant (15+ individuals)

C = Common (5-14 individuals)

O = Occassional (2-4 individuals)

R = Rare (1 individual)

RESULTS

The results of the reef-fish surveys are presented in the overall and site-specific species lists included at the end of this report. The average numbers of families and species of reef fishes seen at an individual site were 17 and 64, respectively. The range for the number of reef-fish families observed at the sites was 5 to 22. The range for the number of species recorded at the sites was 9 to 89. A total of 246 reef-fish species representing 46 families were recorded throughout the lagoon. Approximately 39% of these species may be considered to be food fishes which also have commercial potential. Many cryptic, nocturnal, "hidden" and very rare species were overlooked due to the short amount of time spent at each site.

Brief, general comments regarding each site are as follows:

Site 1: Lagoon fringing reef. Moderately-high diversity of reef-fish species, with many juveniles. Appeared to have been heavily fished. Mid-sized groupers, wrasses and parrotfishes were seen. The subsistence fishing potential here seemed fairly high. The potential for recreation and education appeared high.

Site 2: Shallow lagoon patch reef. Relatively high reef-fish diversity, with food fishes not very abundant. Periodically subjected to strong currents and wave assault through the main pass. Potential for subsistence fishing appeared to be moderately high, as did that for recreation and education.

Site 3: Lagoon fringing area. Relatively high fish species diversity was found here. Athough some surgeon fishes and emperors were abundant, the site's potential for subsistence fishing appeared moderate. Educational and recreational potentials appeared to be greater.

Site 4: Shallow lagoon patch reef (3 m to top). Reef fish diversity was moderately high. Large schools of fusiliers, snappers, emperors and surgeonfishes were noted. The potential for subsistence fishing appeared high, as did those for recreation and education.

Site 5: Deep hole in shallow lagoon fringing reef flat. Moderately high species diversity was recorded. Most abundant food fishes included squirrelfishes, emperors, rudderfishes, parrotfishes and surgeonfishes. Large-sized groupers were seen near the bottom of the hole. Potential for subsistence fishing appeared high. Good educational and mariculture potentials.

Site 6: Shallow lagoon fringing reef flat. Very high reef-fish species diversity was recorded here. Snappers, parrotfish and surgeonfish were seen in abundance. Large-sized individuals of many food species were noted. Subsistence fishing potential appeared to be fairly high, as did the potential for education. This end of the lagoon appeared to have potential for various mariculture activities.

Site 7: Shallow lagoon fringing reef. Diversity of reef-fish species was high. Many species of food fishes were seen, most notably snappers, rudderfishes, goatfishes, parrotfishes, emperors and surgeonfishes, all of which were also abundant. High potentials appeared to exist for both subsistence fishing and education.

Site 8: Shallow lagoon patch reef (3 m to top) reef-fish diversity was moderate. Abundant food species included snappers, parrotfishes and surgeonfishes. Subsistence fishing potential appeared to be fairly high.

Site 9: Shallow fringing reef flat. Moderately low reef-fish species diversity was observed. Many juveniles were present, especially very large aggregations of surgeonfishes. Mullet were very abundant. Over all, however, the potential for subsistence fishing appeared to be moderate. The sand beach at the site gives it recreation potential.

Site 10: Shallow lagoon fringing reef. Reef-fish diversity here was moderate. Few food-fish species were seen, and surgeonfishes were the most abundant.

Moderate potential for subsistence fishing, and higher potentials for recreation and education.

Site 11: Shallow lagoon patch reef (3 m to top). High fish species diversity was found. Large aggregations of surgeonfishes and parrotfishes were seen. Fusiliers were also abundant. Subsistence fishing potential looked fairly high.

Site 13: Shallow lagoon fringing reef. Reef-fish diversity was relatively low. Several species of food fishes were seen, but abundance was fairly low. Habitat looked pretty disturbed, and possibly overfished. Subsistence fishing potential appeared low.

Site 14: Shallow lagoon fringing reef. Moderate reef-fish species diversity. Several species of food fishes were present. Rabbitfishes, parrotfishes and surgeonfishes were most abundant. Habitat looked disturbed, and possibly overfished. Subsistence fishing potential did not appear to be more than moderate.

Site 15: Shallow lagoon fringing reef. The highest reef-fish species diversity among all Mājro sites was recorded here. Several species of food fishes, among which were snappers, goatfishes, and rudderfishes, were noted in abundance over the dropoff. The potential for subsistence fishing appeared to be relatively high, especially between the dropoff and the first terrace below.

Site 16: Shallow lagoon fringing reef. Moderately-low reef-fish diversity. Food-fish representation and abundance were both low. Subsistence fishing potential appeared to be rather poor.

Site 17: Quarry pit in seaward fringing reef flat. Moderately-low reef-fish diversity. Very few food-fish species were seen, and low relative abundances were recorded for those which were present. The potential for subsistence fishing appeared to be low, while the potential for utilizing this and similar pits for mariculture seemed much greater.

Site 18: Shallow lagoon fringing reef. Reef-fish species diversity was moderately low. Several food-fish species were observed, but in general abundances were low except for surgeonfishes. The site was disturbed and habitat was poor. Subsistence fishing potential appeared to be generally low, with possibilities of intermittant good catches due to the closeness of a channel to the open ocean.

Site 19: Shallow lagoon fringing reef. Moderately-low species diversity here also. Several food-fish species were seen, but mostly in small numbers. The most abundant were goatfishes, parrotfishes and surgeonfishes. Habitat here was also disturbed, and the subsistence fishing potential looked to be similar to the previous site.

Site 20: Shallow lagoon fringing reef. Diversity of reef fishes was found to be moderately-high. Food-fish representation was moderate, with the most abundant species having been recorded among parrotfishes and surgeonfishes. Subsistence fishing potential appeared to be fair. Potentials for recreation and tourism seemed better, particularly if waste disposal in the area was controlled.

Site 21: Shallow lagoon fringing reef. Potential causeway site. Reef-fish diversity at this site was moderate. Many juveniles seen. Several species of food fish were present, but mostly in low numbers. Potential for subsistence fishing appeared low to moderate. Waste disposal in the immediate area needs to be controlled.

Site 22: Shallow lagoon fringing reef. Relatively low fish species diversity was noted. Food-fish representation was also low, parrotfishes having been seen in greatest numbers. The habitat here looked disturbed and was polluted. The potential for subsistence fishing appeared to be low. Due to the presence of a nearby high school, the site may have some educational potential.

Site 23: Shallow seaward fringing reef flat. Very low reef-fish diversity was seen. No important food-fish species were seen. Subsistence fishing potential appeared to be very low. Habitat was poor, disturbed and polluted.

Site 24: Shallow seaward fringing reef flat. Not surveyed.

Site 25: Shallow lagoon fringing reef. Reef-fish diversity observed to be relatively low, with many juveniles. However, fair food-fish representation was seen, of which the most notable were jacks and mullets. The potential for subsistence fishing appeared to be moderate, while those for recreation and education seemed only slightly better.

Site 26: Shallow lagoon fringing reef. Moderately-high fish diversity recorded here. A few food-fish species were seen in fair abundance. Most abundant were surgeonfishes, goatfishes and parrotfishes. Potential for subsistence fishing appeared fair, especially beyond dropoff. Recreation and education potentials seemed higher.

Site 27: Shallow lagoon fringing reef. Slightly above-average species diversity was found. Many types of food fishes were present, but not in great abundance. In general, the subsistence fishing potential at this site seemed to be moderate, while the potentials for education and recreation appeared to be higher.

Site 28: Shallow lagoon fringing reef. Reef-fish diversity was moderately-high. Only a few species of food fishes observed, however, and surgeonfishes and parrotfishes were most abundant. The potentials for subsistence fishing, recreation and education all appeared to be relatively low.

DISCUSSION

The survey results suggest that the reef-fish resources of Mājro lagoon have been adversely impacted, apparently by the loss of habitat and intensification of fishing effort. Yet, the lagoon still supports a fairly diverse array of species which includes many common food fishes. The fact, however, that food fishes were represented in high abundance, or by large-sized individuals, at relatively few survey sites indicates that the lagoon has been subjected to a high degree of fishing pressure.

Most notable among the food fishes observed in Mājro lagoon were mullets, rudderfishes, goatfishes, surgeonfishes, wrasses, rabbitfishes, squirrelfishes, jacks, snappers, emperors, and groupers. Traditionally, these resources have been utilized to fulfill the subsistence needs of Mājro's population. As this population has grown, and become more affluent and convenience-oriented, these resources have been increasingly targeted for commercial exploitation to satisfy an expanding domestic market.

At the present time, the demand in Mājro for local reef fish is high, and may be reaching levels which cannot be supplied on a continuous basis by lagoon resources. In general, these resources appeared to be somewhat depleted in the southeastern region of the lagoon, which may be due to greater amounts of habitat degradation, pollution, and fishing pressure which have occured there as a result of increased urbanization.

Since the northwestern region of the atoll generally contains the greatest concentration of shallow, lagoon reef-fish resources, that area is very valuable for supporting subsistence fishing activities inside the lagoon. It is extremely important to Mājro's subsistence sector that the reproductive potential of these resources be protected from decline. Unfortunately, even in the richest parts of the lagoon, the shallow, reef-fish resources did not appear substantial enough to sustain even light commercial exploitation for very long.

In the absence of reliable data on the stock sizes and potential yields of targeted species, it is not possible to estimate maximum sustainable harvest levels for lagoon fishes. If such levels are exceeded, overfishing can result in a long-term reduction in the availability of certain species, and this appears to be occurring in Mājro lagoon. Furthermore, without a reliable time series of catch-rate data associated with different species and fishing methods, it is very difficult to understand variabilities of fishing success and to predict estimated harvest levels.

The urgent need for instituting a management program for reef-fish resources in Mājro lagoon is very evident. A program based on reliable biological, ecological, and fisheries data for important species would greatly assist the government in making sound management decisions, particularly with regard to commercial fisheries exploitation.

Many species of commercially-valuable aquarium fish were also seen at several sites in the lagoon. These included various types of tangs, wrasses, butterflyfishes, angelfishes, damselfishes, moorish idols, triggerfishes and others. It was not uncommon to see large concentrations of individual species at many of the sites.

These resources, however, appeared substantial enough to sustain only a small-scale commercial fishery for aquarium fish. Management of such a fishery is often strict, with the accurate recording and reporting of catch data being mandatory. The chances for long-term viability of the fishery might be improved by limiting the number of licensed participants and by spreading out the harvest as much as possible to prevent the overharvesting of any one area or species.

The relatively high reef-fish species diversity displayed at some of the sites could also make contributions to the development of tourism in M̄ajro. Many tourists in Micronesia are also SCUBA divers or snorkelers who find tropical reefs, including the fish which live there, to be very attractive. In particular, many sites in the northwestern region of the lagoon and along the northern barrier reef islets, such as Sites 5-7, 9-11, and 25-27, appeared to have recreational and tourism potentials worthy of further consideration. These locations, as well as Sites 1-4, were found to have additional potential values in the areas of education and research.

Of all the sites surveyed, those mentioned above were noted as being the best candidates for designation as marine protected areas within M̄ajro lagoon. Sites 1-7, 26 and 27 were among the richest in terms of reef-fish resources. An area encompassing the entire reef complex in the northwestern region of the lagoon and extending eastwardly to the Enigu group of islets is worthy of protection.

While reef-fish diversity and abundance are important aspects, areas selected for protection should be evaluated in terms of the broad range of qualities they display and the potentials they may have to offer various sectors. Although it is wise to ban commercial fishing from protected areas, subsistence fishing activities can often be allowed.

The reduced level of reef-fish resources evidenced in the southeastern region of the lagoon is probably attributable to a combination of reasons. Habitat loss and overfishing are likely to be the two most important factors involved.

Pollution, retarded water circulation due to causeway construction, and dredging and associated siltation have undoubtedly been major causes of habitat degradation in the southeastern lagoon. It is reasonable to speculate that this, in conjunction with an unregulated intensification of localized fishing effort near an expanding population center, has resulted in already fragile resources becoming overfished.

The combined actions of improving water circulation, reducing pollution and regulating dredging and fishing activities could positively influence the reestablishment of reef-fish resources in the southeastern region of the lagoon.

Proposed construction of a causeway at Site 21 appears feasible if done properly and in a manner which will not further retard water circulation in the lagoon. The enhancement of oceanic water transport into this part of the lagoon might promote the recovery of nearby degraded areas and have a positive effect on resources throughout the lagoon.

Opportunities exist for practicing various types of mariculture in Mājro lagoon. Given the current power, water, transportation, communication etc. situation in Mājro, there appears to be an adequate support base for accomodating a shoreside facility. Furthermore, several areas within the lagoon (eg., Sites 5, 7, 12 and 17) and within the northwestern region in general, appeared to have potentials for culturing different species in the wild. The suitability of culturing giant clams, trochus, pearl shells, algae, sponges, green snails, and various types of fish are worth investigation.

The possibility of utilizing some of the abandoned quarry holes for mariculture purposes also appears to be worth looking into. It was noted that not every hole may be suitable, depending on factors such as shape, orientation, depth, bottom characteristics, exposure etc. As in any potential mariculture venture, thoroughly evaluating the associated requirements and economics before implementation is attempted, usually reduces the amount of risk involved.

The natural recovery of reef-fish resources in abandoned quarry holes will vary with the overall characteristics associated with individuals holes. In general, reef-fish colonization, in terms of species diversity, is expected to be better in holes in which hard corals recover best. However, even in holes where coral growth is minimal certain fish species can often be found in high abundance. Many of these species are desirable food fishes, eg., goatfishes, emperors and snappers, and such holes, particularly those on seaward reef flats, are potentially important for subsistence fishing.

FISH SPECIES OBSERVED AT MAJURO ATOLL
JULY 19 - 26, 1988

FAMILY/Species

HEMIGALEIDAE (Reef White-tip Sharks)
- *Triaenodon obesus* (Ruppell)

CARCHARHINIDAE (Requiem Sharks)
- *C. melanopterus* (Quoy & Gaimard)

MURAENIDAE (Moray Eels)
- *Echidna nebulosa* (Ahl)
- *Gymnothorax javanicus* (Bleeker)
- *G. undulatus* (Lacepede)
- *Sideria picta* (Ahl)
- *S. prosopeion* (Bleeker)

CLUPEIDAE (Sprats, Herrings, Sardines)
- *Spratelloides delicatulus* (Bennett)
- *S. gracilis* (Schlegel)

SYNODONTIDAE (Lizardfishes)
- *Saurida gracilis* (Quoy & Gaimard)

ATHERINIDAE (Silversides)
- *Hypoatherina ovalaua* (Herre)

HEMIRAMPHIDAE (Halfbeaks)
- *Hyporhamphus acutus acutus* (Gunther)
- *H. dussumieri* (Valenciennes)

HOLOCENTRIDAE (Soldierfishes, Squirrelfishes)

Myripristis murdjan (Forsskal)
M. pralinia Cuvier
M. violacea Bleeker
Neoniphon opercularis (Valenciennes)
N. sammara (Forsskal)
Sargocentron caudimaculatum (Ruppell)
S. microstoma (Gunther)
S. spiniferum (Forsskal)

AULOSTOMIDAE (Trumpetfishes)

Aulostomus chinensis (Linnaeus)

FISTULARIIDAE (Coronetfishes)

Fistularia commersonii Ruppell

SYGNATHIDAE

Corythoichthys intestinalis (Ramsay)

SCORPAENIDAE (Scorpionfishes)

Synanceia verrucosa Bloch & Schneider

SERRANIDAE (Groupers, Fairy Basslets)

Anyperodon leucogrammicus (Valenciennia)
Cephalopholis argus (Schneider)
C. urodeta (Bloch & Schneider)
Epinephelus cyanopodus (Richardson)
E. fuscoguttatus (Forsskal)
E. merra Bloch
E. microdon (Bleeker)
Plectropomus areolatus (Ruppell)
P. laevis (Lacepede)
Variola louti (Forsskal)

GRAMMISTIDAE (Soapfishes)

Belonoperca chaubanaudi Fowler & Bean

CIRRHITIDAE (Hawkfishes)

Paracirrhitus arcatus (Cuvier)
P. forsteri (Schneider)

APOGONIDAE (Cardninalfishes)

Apogon cyanosoma Bleeker
A. leptacanthus Bleeker
A. nigrofasciatus Lachner
A. novemfasciatus Cuvier
Cheilodipterus quinquelineata (Cuvier)

MALACANTHIDAE (Sand Tilefishes)

Malacanthus latovittatus (Lacepede)

ECHENEIDAE (Remoras)

Echeneis naucrates Linnaeus

CARANGIDAE (Jacks, Trevallys)

Caranx melampygus (Cuvier)
C. sexfasciatus Quoy & Gaimard
Trachinotus blochii (Lacepede)

GERREIDAE (Mojarras)

Gerres argyreus (Schneider)

LUTJANIDAE (Snappers)

Aphareus furca (Lacepede)
Aprion virescens Valenciennes
Lutjanus bohar (Forsskal)
L. fulvus (Schneider)
L. gibbus (Forsskal)
L. monostigmus (Cuvier)
L. semicinctus Quoy & Gaimard
Macolor niger (Forsskal)

CAESIONIDAE (Fusiliers)

Caesio caerulaurea Lacepede
C. teres Seale
Pterocaesio marri Schultz

HAEMULIDAE (Sweetlips)

Pentapodus caninus (Bleeker)

NEMIPTERIDAE (Threadfin Breams)

Scolopsis lineatus Quoy & Gaimard

LETHRINIDAE (Emperors)

- _Gnathodentex aureolineatus_ (Lacepede)
- _Lethrinus ramak_ (Forsskal)
- _L. xanthochilus_ (Klunzinger)
- _Monotaxis grandoculus_ (Forsskal)

MULLIDAE (Goatfishes)

- _Mulloides flavolineatus_ (Lacepede)
- _M. vanicolensis_ (Valenciennes)
- _Parupeneus barberinus_ (Lacepede)
- _P. cyclostomus_ (Lacepede)
- _P. multifasciatus_ (Quoy & Gaimard)
- _P. pleurostigma_ (Bennett)

KYPHOSIDAE

- _Kyphosus vaigiensis_ (Quoy & Gaimard)

CHAETODONTIDAE (Butterflyfishes)

- _Chaetodon auriga_ Forsskal
- _C. bennetti_ Cuvier
- _C. citrinellus_ Cuvier
- _C. ephippium_ Cuvier
- _C. kleini_ (Bloch)
- _C. lineolatus_ Cuvier
- _C. lunula_ (Lacepede)
- _C. mertensii_ Cuvier
- _C. meyeri_ Schneider
- _C. punctatofasciatus_ Cuvier
- _C. rafflesii_ Bennett
- _C. reticulatus_ Cuvier
- _C. semeion_ Bleeker
- _C. trifascialis_ (Quoy & Gaimard)
- _C. trifasciatus_ Park
- _C. ulietensis_ Cuvier
- _C. unimaculatus_ Bloch
- _C. vagabundus_ Linnaeus
- _Forcipiger flavissimus_ Jordon & McGregor
- _F. longirostris_ (Broussonet)
- _Heniochus acuminatus_ (Linnaeus)
- _H. chrysostomus_ Cuvier
- _H. monoceros_ Cuvier
- _H. singularis_ Smith & Radcliffe
- _H. varius_ (Cuvier)

POMACANTHIDAE (Angelfishes)

Centropyge bicolor (Bloch)
C. bispinosus (Gunther)
C. flavissimus (Cuvier)
C. vrolicki (Bleeker)
Pygoplites diacanthus (Boddaert)

POMACENTRIDAE (Damselfishes)

Amphiprion melanopus Bleeker
A. peridaeraion Bleeker
A. tricinctus Schultz & Welander
Chromis agilis Smith
C. atripectoralis Welander & Schultz
C. lepidolepis Bleeker
C. margaritifer Fowler
C. ternatensis (Bleeker)
C. viridis (Cuvier)
Dascyllus aruanus (Linnaeus)
D. reticulatus (Richardson)
D. trimaculatus (Ruppell)
Abudefduf saxatilis (Linnaeus)
A. septemfasciatus (Cuvier)
A. sordidus (Forsskal)
Amblyglyphidodon aureus (Cuvier)
A. curacao (Bloch)
A. leucogaster (Bleeker)
A. ternatensis (Bleeker)
Chrysiptera glauca (Cuvier)
C. leucopoma (Lesson)
C. traceyi Woods & Schultz
Plectroglyphidodon dickii (Lienard)
P. johnstonianus Fowler & Ball
P. lacrymatus (Quoy & Gaimard)
P. leucozona (Bleeker)
Pomacentrus amboinensis Bleeker
P. coelestis Jordan & Starks
P. vaiuli Jordan & Seale
Stegastes albifasciatus (Schlegel & Muller)
S. fasciolatus (Ogilby)
S. nigricans (Lacepede)

LABRIDAE (Wrasses)

Cheilinus celebecus Bleeker
C. chlorourus (Bloch)
C. fasciatus (Bloch)
C. trilobatus Lacepede
C. undulatus Ruppell
C. unifasciatus Streets
Epibulus insidiator (Pallas)
Novaculichthys taeniourus (Lacepede)
Xyrichthys pavo Valenciennes
Cirrhilabrus sp.
Pseudocheilinus evanidus Jordan & Evermann
P. hexataenia (Bleeker)
Anampses meleagrides Valenciennes
Cheilio inermis (Forsskal)
Coris aygula Lacepede
C. gaimardi (Quoy & Gaimard)
C. variegata (Ruppell)
Gomphosus varius Lacepede
Halichoeres chrysus Randall
H. hortulanus (Lacepede)
H. margaritaceus (Valenciennes)
H. marginatus Ruppell
H. melanurus (Bleeker)
H. trimaculatus (Quoy & Gaimard)
H. melapterus (Bloch)
Macropharyngodon meleagris (Valenciennes)
M. negrosensis Herre
Stethojulis bandanensis (Bleeker)
S. strigiventer (Bennett)
Thalassoma amblycephalum (Bleeker)
T. hardwickii (Bennett)
T. lunare (Linnaeus)
T. lutescens (Lay & Bennett)
T. purpureum (Forsskal)
T. quinquevitattum (Lay & Bennett)
Labrichthys unilineatus (Guichenot)
Labroides bicolor Fowler & Bean
L. dimidiatus (Valenciennes)
L. pectoralis Randall & Springer
Labropsis micronesica Randall
L. xanthonota Randall

SCARIDAE (Parrotfishes)

Cetoscarus bicolor (Ruppell)
Hipposcarus longiceps (Valenciennes)
Scarus altipinnis (Steindachner)
S. bleekeri (deBeaufort)
S. dimidiatus Bleeker
S. forsteni (Bleeker)
S. frenatus Lacepede
S. ghobban Forsskal
S. gibbus Ruppell
S. globiceps Valenciennes
S. niger Forsskal
S. oviceps Valenciennes
S. psittacus Forsskal
S. rubroviolaceus (Bleeker)
S. schlegeli (Bleeker)
S. sordidus Forsskal
S. spinus Kner

MUGILIDAE (Mullets)

Crenimugil crenilabis (Forsskal)
Liza vaigiensis (Quoy & Gaimard)

PINGUIPEDIDAE (Sandperches)

Parapercis clathrata Ogilby
P. millipunctata (Gunther)

BLENNIIDAE (Blennies)

Aspidontus dussumieri (Valenciennes)
Meiacanthus atrodorsalis (Gunther)
Plagiotremus tapienosoma (Bleeker)

MICRODESMIDAE (Dartfishes, Wormfishes)

Gunnellichthys monostigma Smith
Ptereleotris evides (Jordan & Hubbs)
P. heteroptera (Bleeker)
P. microlepis Bleeker

GOBIIDAE (Gobies)

Amblygobius phalaena (Valenciennes)
Fusigobius neophytus (Gunther)
Valenciennea sexguttatus (Valenciennes)
V. strigatus (Brousonet)

ACANTHURIDAE (Surgeonfishes)

Acanthurus dussumieri Valenciennes
A. lineatus (Linnaeus)
A. mata Cuvier
A. nigricans (Linnaeus)
A. nigricauda Dunker & Moore
A. olivaceus Bloch & Schneider
A. pyroferus Kittlitz
A. thompsoni (Fowler)
A. triostegus (Linnaeus)
A. xanthopterus Valenciennes
Ctenochaetus binotatus Randall
C. striatus (Quoy & Gaimard)
Zebrasoma scopas (Cuvier)
Z. veliferum (Bloch)
Naso brevirostris (Valenciennes)
N. lituratus (Bloch & Schneider)
N. unicornis (Forsskal)
N. vlamingii (Valenciennes)

ZANCLIDAE (Moorish Idols)

Zanclus cornutus (Linnaeus)

SIGANIDAE (Rabbitfishes)

Siganus argenteus (Quoy & Gaimard)
S. corallinus Valenciennes
S. puellus (Schlegel)
S. spinus (Linnaeus)
S. vulpinus (Schlegel & Muller)

BOTHIDAE (Lefteye Flounders)

Bothus mancus (Brousonet)

BALISTIDAE (Triggerfishes)

Balistipus undulatus (Mungo Park)
Balistoides viridescens (Bloch & Schneider)
Odonus niger (Ruppell)
Pseudobalistes flavimarginatus (Ruppell)
Rhinecanthus aculeatus (Linnaeus)
R. rectangulus (Bloch & Schneider)
S. chrysoptera (Bloch & Schneider)

MONACANTHIDAE (Filefishes)

Oxymonacanthus longirostris (Bloch & Schneider)

TETRAODONTIDAE (Smooth Puffers)

Arothron hispidus (Linnaeus)

A. meleagris (Lacepede)

A. nigropunctatus (Bloch & Schneider)

A. stellatus (Bloch & Schneider)

Canthigaster solandri (Richardson)

Number of Families : 44
Number of Species : 246

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FAMILY/Species	Rank
SERRANIDAE	
Cephalopholis urodeta	O
Epinephelus fuscoguttatus	O
Variola louti	O
CIRRHITIDAE	
Paracirrhitus arcatus	O
P. forsteri	R
LUTJANIDAE	
Aphareus furca	R
Aprion virescens	R
LETHRINIDAE	
Monotaxis grandoculus	R
MULLIDAE	
Parupeneus barberinus	O
P. pleurostigma	O
CHAETODONTIDAE	
Chaetodon auriga	R
C. citrinellus	R
C. lineolatus	R
C. reticulatus	R
C. trifascialis	R
C. trifasciatus	R
C. ulietensis	O
C. vagabundus	R
POMACANTHIDAE	
Centropyge flavissimus	C
Pygoplites diacanthus	R
POMACENTRIDAE	
Amblyglyphidodon curacao	O
Chromis agilis	C
C. lepidolepis	O
C. margaritifer	A
Chrysiptera leucopoma	O
Dascyllus aruanus	C
Plectroglyphidodon dickii	C
P. johnstonianus	O
P. lacrymatus	O
Pomacentrus coelestis	A
P. vaiuli	C
Stegastes nigricans	O

LABRIDAE	
Cheilinus undulatus	R
Coris aygula	R
C. gaimardi	O
Epibulus insidiator	R
Gomphosus varius	O
Halichoeres chrysus	O
H. hortulanus	O
H. marginatus	O
H. trimaculatus	O
Hemigymnus melapterus	O
Labroides bicolor	R
L. dimidiatus	O
Macropharyngodon negrosensis	R
Novaculichthys taeniourus	R
Stethojulis bandanensis	O
Thalassoma amblycephalum	A
T. hardwickii	O
T. quinquevittatum	C
SCARIDAE	
Cetoscarus bicolor	O
Scarus altipinnis	C
S. bleekeri	R
S. gibbus	O
S. niger	R
S. rubroviolaceus	A
S. schlegeli	O
S. sordidus	C
PINGUIPEDIDAE	
Parapercis millipunctata	R
BLENNIIDAE	
Plagiotremus tapienosoma	O
MICRODESMIDAE	
Ptereleotris evides	O
GOBIIDAE	
Valenciennea strigatus	O
ACANTHURIDAE	
Acanthurus lineatus	R
A. nigricans	O
A. nigricauda	A
A. olivaceus	C
Ctenochaetus striatus	C
Zebrasoma scopas	O

BALISTIDAE

Sufflamen chrysoptera	O

MONACANTHIDAE

Oxymonacanthus longirostris	R

Number of Families : 17
Number of Species : 70

FAMILY/Species	Rank
HOLOCENTRIDAE	
Myripristis murdjan	O
M. pralinia	O
M. violacea	C
SERRANIDAE	
Cephalopholis urodeta	O
Epinephelus microdon	R
Variola louti	O
LUTJANIDAE	
Lutjanus gibbus	R
L. monostigmus	R
NEMIPTERIDAE	
Pentapodus caninus	O
LETHRINIDAE	
Gnathodentex aureolineatus	C
Monotaxis grandoculus	C
MULLIDAE	
Mulloides vanicolensis	O
Parupeneus cyclostomus	R
P. multifasciatus	O
P. pleurostigma	R
CHAETODONTIDAE	
Chaetodon auriga	O
C. ephippium	O
C. mertensii	R
C. trifascialis	O
C. trifasciatus	C
C. unimaculatus	O
Forcipiger longirostris	R
Heniochus chrysostomus	R
H. varius	R
POMACANTHIDAE	
Centropyge bicolor	C
C. bispinosus	R
C. flavissimus	R
Pygoplites diacanthus	O

POMACENTRIDAE	
Amblyglyphidodon curacao	A
A. leucogaster	R
Chromis agilis	C
C. ternatensis	A
Chrysiptera leucopoma	C
Dascyllus aruanus	A
Plectroglyphidodon dickii	O
P. lacrymatus	O
Pomacentrus vaiuli	C
LABRIDAE	
Cheilinus fasciatus	O
C. unifasciatus	O
Cirrhilabrus sp.	A
Epibulus insidiator	O
Gomphosus varius	O
Halichoeres chrysus	O
H. melanurus	O
Hemigymnus melapterus	O
Labroides bicolor	O
L. dimidiatus	O
Labropsis micronesica	R
Pseudocheilinus evanidus	O
Stethojulis bandanensis	O
Thalassoma lutescens	O
SCARIDAE	
Cetoscarus bicolor	R
Hipposcarus longiceps	R
S. ghobban	O
S. gibbus	R
S. niger	R
S. oviceps	R
S. rubroviolaceus	C
S. schlegeli	C
S. sordidus	C
PINGUIPEDIDAE	
Parapercis millipunctata	O
MICRODESMIDAE	
Ptereleotris evides	R
P. heteroptera	O
ACANTHURIDAE	
Acanthurus nigricans	C
A. nigricauda	O
A. olivaceus	R
A. pyroferus	O
Ctenochaetus binotatus	R
C. striatus	A
Naso lituratus	O
Zebrasoma scopas	O

ZANCLIDAE	
Zanclus cornutus	O
SIGANIDAE	
Siganus argenteus	O
S. puellus	C
BALISTIDAE	
Balistapus undulatus	R
Sufflamen chrysoptera	R
MONACANTHIDAE	
Oxymonacanthus longirostris	O

Number of Families : 18
Number of Species : 77

FAMILY/Species	Rank
ATHERINIDAE	
Hypoatherina ovalaua	A
HOLOCENTRIDAE	
Myripristis murdjan	R
M. violacea	O
Neoniphon opercularis	O
Sargocentron spiniferum	R
FISTULARIIDAE	
Fistularia commersoni	R
SERRANIDAE	
Cephalopholis urodeta	R
Epinephelus merra	O
CIRRHITIDAE	
Paracirrhitus arcatus	C
LUTJANIDAE	
Aphareus furca	R
Lutjanus bohar	O
L. fulvus	O
L. gibbus	O
LETHRINIDAE	
Monotaxis grandoculus	A
MULLIDAE	
Parupeneus barberinus	R
P. pleurostigma	O
CHAETODONTIDAE	
Chaetodon auriga	C
C. citrinellus	O
C. ephippium	O
C. lunula	O
C. trifascialis	R
C. trifasciatus	O
C. ulietensis	O
POMACANTHIDAE	
Centropyge flavissimus	C

POMACENTRIDAE	
Amblyglyphidodon curacao	C
A. leucogaster	O
Chromis agilis	C
C. atripectoralis	A
C. margaritifer	A
C. ternatensis	C
C. viridis	A
Chrysiptera leucopoma	C
Dascyllus aruanus	A
D. reticulatus	C
Plectroglyphidodon dickii	A
P. lacrymatus	O
P. leucozonus	O
Pomacentrus amboinensis	O
P. coelestis	A
P. vaiuli	C
LABRIDAE	
Cheilinus chlorourus	R
Gomphosus varius	C
Halichoeres chrysus	O
H. hortulanus	C
H. margaritaceus	R
H. marginatus	O
H. melanurus	O
H. trimaculatus	O
Hemigymnus melapterus	O
Labrichthys unilineatus	C
Labroides bicolor	O
L. dimidiatus	C
Macropharyngodon meleagris	R
Stethojulis bandanensis	R
Thalassoma amblycephelum	O
T. hardwickii	C
T.quinquevittatum	C
SCARIDAE	
Cetoscarus bicolor	C
Scarus rubroviolaceus	O
S. schlegeli	O
S. sordidus	C
S. spinus	O
PINGUIPEDIDAE	
Parapercis clathrata	R
BLENNIIDAE	
Plagiotremus tapienosoma	R

GOBIIDAE	
Valenciennea strigatus	R
ACANTHURIDAE	
Acanthurus lineatus	R
A. nigricauda	A
A. olivaceus	O
Ctenochaetus binotatus	O
C. striatus	A
Zebrasoma scopas	O
Z. veliferum	R
ZANCLIDAE	
Zanclus cornutus	C
BALISTIDAE	
Balistipus undulatus	O
Rhinecanthus aculeatus	R
Sufflamen chrysoptera	O
MONACANTHIDAE	
Oxymonacanthus longirostris	O
TETRAODONTIDAE	
Arothron nigropunctatus	R

Number of Families : 21
Number of Species : 78

FAMILY/Species	Rank
HOLOCENTRIDAE	
Myripristis murdjan	O
M. pralinia	O
M. violacea	C
SERRANIDAE	
Cephalopholis urodeta	O
Plectropomus areolatus	R
P. laevis	R
CIRRHITIDAE	
Paracirrhitus arcatus	R
P. forsteri	R
MALACANTHIDAE	
Malacanthus latovittatus	R
LUTJANIDAE	
Aphareus furca	R
Lutjanus bohar	C
L. gibbus	A
CAESIONIDAE	
Caesio caerulaurea	A
Pterocaesio marri	R
LETHRINIDAE	
Monotaxis grandoculus	A
MULLIDAE	
Parupeneus barberinus	O
P. multifasciatus	O
P. pleurostigma	O
CHAETODONTIDAE	
Chaetodon auriga	O
C. citrinellus	O
C. ephippium	R
C. reticulatus	R
C. trifascialis	O
C. trifasciatus	O
C. ulietensis	O
Forcipiger flavissimus	O
Heniochus chrysostomus	O
POMACANTHIDAE	
Centropyge flavissimus	C
C. vrolicki	O
Pygoplites diacanthus	R

POMACENTRIDAE	
Amblyglyphidodon curacao	A
Chromis agilis	A
C. atripectoralis	A
C. lepidolepis	A
C. margaritifer	C
C. ternatensis	A
C. viridis	A
Chrysiptera leucopoma	C
Dascyllus aruanus	O
D. reticulatus	O
Plectroglyphidodon dickii	C
Pomacentrus coelestis	A
P. vaiuli	O
LABRIDAE	
Anampses meleagrides	R
Cheilinus undulatus	R
Coris gaimardi	R
Epibulus insidiator	R
Gomphosus varius	C
Halichoeres chrysus	R
H. hortulanus	O
H. marginatus	R
H. trimaculatus	R
Hemigymnus melapterus	O
Labrichthys unilineatus	O
Labroides bicolor	O
L. dimidiatus	R
Thalassoma quinquevittatum	C
SCARIDAE	
Cetoscarus bicolor	C
Scarus bleekeri	O
S. frenatus	R
S. gibbus	C
S. niger	R
S. schlegeli	R
S. sordidus	C
ACANTHURIDAE	
Acanthurus mata	C
A. nigricans	O
A. nigricauda	A
Ctenochaetus striatus	C
Naso brevirostris	R
N. lituratus	O
Zebrasoma scopas	O
ZANCLIDAE	
Zanclus cornutus	O

SIGANIDAE	
Siganus argenteus	0
S. puellus	0
BALISTIDAE	
Balistipus undulatus	0

Number of Families : 17
Number of Species : 75

FAMILY/Species	Rank
HEMIGALEIDAE	
Triaenodon obesus	R
HOLOCENTRIDAE	
Myripristis murdjan	R
M. pralinia	O
M. violacea	O
Neoniphon sammara	A
AULOSTOMIDAE	
Aulostomus chinensis	R
SERRANIDAE	
Anyperodon leucogrammicus	R
Epinephelus fuscoguttatus	R
E. merra	R
Plectropomus areolatus	R
CIRRHITIDAE	
Paracirrhitus forsteri	R
LUTJANIDAE	
Lutjanus fulvus	O
L. gibbus	C
L. monostigmus	O
LETHRINIDAE	
Monotaxis grandoculus	A
MULLIDAE	
Parupeneus barberinus	O
P. multifasciatus	O
KYPHOSIDAE	
Kyphosus vaigiensis	A
CHAETODONTIDAE	
Chaetodon auriga	O
C. ephippium	O
C. lineolatus	R
C. meyeri	O
C. punctatofasciatus	R
C. semeion	O
C. trifascialis	R
C. trifasciatus	C
C. ulietensis	R
Heniochus chrysostomus	R

POMACANTHIDAE	
Centropyge flavissimus	C
Pygoplites diacanthus	R
POMACENTRIDAE	
Amblyglyphidodon curacao	A
Amphiprion melanopus	C
Chromis agilis	C
C. atripectoralis	A
C. margaritifer	A
C. viridis	A
Chrysiptera glauca	A
C. leucopoma	O
Dascyllus aruanus	A
Plectroglyphidodon leucozona	C
LABRIDAE	
Cheilinus celebecus	O
C. fasciatus	O
C. trilobatus	R
C. undulatus	O
Coris gaimardi	R
Gomphosus varius	O
Halichoeres chrysus	O
H. hortulanus	R
H. margaritaceus	A
H. trimaculatus	A
Hemigymnus melapterus	A
Labrichthys unilineatus	R
Labroides bicolor	O
L. dimidiatus	O
Macropharyngodon meleagris	C
Pseudocheilinus hexataenia	R
Stethojulis bandanensis	O
Thalassoma amblycephalum	A
T. hardwickii	O
SCARIDAE	
Hipposcarus longiceps	O
Scarus forsteni	C
S. oviceps	O
S. schlegeli	O
S. sordidus	A
BLENNIIDAE	
Meiacanthus atrodorsalis	R
Plagiotremus tapienosoma	R
ACANTHURIDAE	
Acanthurus nigricans	O
A. olivaceus	R
A. pyroferus	O
A. triostegus	A
Ctenochaetus striatus	C
Naso brevirostris	O
Zebrasoma scopas	R

ZANCLIDAE	
Zanclus cornutus	C
SIGANIDAE	
Siganus vulpinus	C
BALISTIDAE	
Balistipus undulatus	O

Number of Families : 19
Number of Species : 76

FAMILY/Species	Rank
CLUPEIDAE	
Spratelloides delicatulus	A
HOLOCENTRIDAE	
Myripristis pralinia	O
M. violacea	C
Neoniphon sammara	C
SERRANIDAE	
Epinephelus merra	O
Variola louti	O
CIRRHITIDAE	
Paracirrhitus arcatus	O
CARANGIDAE	
Caranx melampygus	C
LUTJANIDAE	
Lutjanus bohar	O
L. gibbus	A
L. monostigmus	O
L. semicinctus	R
CAESIONIDAE	
Caesio caerulaurea	C
LETHRINIDAE	
Gnathodentex aureolineatus	C
Monotaxis grandoculus	C
MULLIDAE	
Parupeneus barberinus	C
P. cyclostomus	O
P. multifasciatus	C
CHAETODONTIDAE	
Chaetodon auriga	O
C. citrinellus	O
C. ephippium	C
C. lunula	O
C. meyeri	R
C. reticulatus	O
C. trifascialis	O
C. trifasciatus	O
C. ulietensis	O
Forcipiger flavissimus	R
Heniochus varius	R
POMACANTHIDAE	
Centropyge flavissimus	C
Pygoplites diacanthus	O

POMACENTRIDAE	
Amblyglyphidodon curacao	A
Chromis agilis	A
C. atripectoralis	A
C. margaritifer	O
C. viridis	A
Chrysiptera leucopoma	C
Dascyllus aruanus	A
Plectroglyphidodon dickii	C
P. johnstonianus	R
P. lacrymatus	R
P. leucozona	C
Pomacentrus coelestis	A
P. vaiuli	C
Stegastes albifasciatus	O
S. nigricans	O
LABRIDAE	
Cheilinus fasciatus	R
C. undulatus	C
Epibulus insidiator	R
Gomphosus varius	O
Halichoeres chrysus	O
H. hortulanus	R
H. margaritaceus	O
H. marginatus	O
H. melanurus	R
H. trimaculatus	O
Hemigymnus melapterus	C
Labroides bicolor	O
Macropharyngodon meleagris	C
Novaculichthys taeniourus	R
Stethojulis bandanensis	R
Thalassoma amblycephalum	A
T. hardwickii	C
T. lutescens	R
T. quinquevittatum	C
SCARIDAE	
Cetoscarus bicolor	C
Hipposcarus longiceps	C
Scarus frenatus	O
S. ghobban	R
S. gibbus	A
S. oviceps	C
S. sordidus	A
BLENNIIDAE	
Plagiotremus tapienosoma	R
MICRODESMIDAE	
Ptereleotris evides	O

ACANTHURIDAE	
Acanthurus nigricans	O
A. nigricauda	C
A. pyroferus	C
Ctenochaetus binotatus	O
C. striatus	A
Naso lituratus	C
N. unicornis	C
Zebrasoma scopas	R
Z. veliferum	R
ZANCLIDAE	
Zanclus cornutus	O
SIGANIDAE	
Siganus argenteus	C
S. vulpinus	O
BALISTIDAE	
Balistipus undulatus	R

Number of Families : 20
Number of Species : 87

FAMILY/Species	Rank
CARCHARHINIDAE	
Carcharhinus melanopterus	R
SYNODONTIDAE	
Saurida gracilis	R
HOLOCENTRIDAE	
Myripristis pralinia	R
M. violacea	R
Sargocentron spiniferum	R
SERRANIDAE	
Epinephelus fuscoguttatus	R
Plectropomus areolatus	O
P. laevis	O
CARANGIDAE	
Caranx melampygus	R
LUTJANIDAE	
Aphareus furca	C
Aprion virescens	R
Lutjanus bohar	R
L. fulvus	A
L. monostigmus	A
CAESIONIDAE	
Caesio caerulaurea	A
HAEMULIDAE	
Pentapodus caninus	C
LETHRINIDAE	
Lethrinus xanthochilus	O
Monotaxis grandoculus	A
MULLIDAE	
Mulloides flavolineatus	A
Parupeneus barberinus	O
P. multifasciatus	C
P. pleurostigma	C
KYPHOSIDAE	
Kyphosus vaigiensis	A

CHAETODONTIDAE	
Chaetodon auriga	O
C. ephippium	O
C. kleini	R
C. mertensii	O
C. meyeri	R
C. punctatofasciatus	R
C. reticulatus	R
C. trifascialis	R
C. trifasciatus	O
C. vagabundus	R
Forcipiger flavissimus	O
F. longirostris	R
Heniochus chrysostomus	O
H. varius	R
POMACANTHIDAE	
Centropyge bicolor	R
C. flavissimus	R
Pygoplites diacanthus	C
POMACENTRIDAE	
Amblyglyphidodon curacao	R
Chromis agilis	A
C. atripectoralis	A
Chrysiptera leucopoma	A
C. traceyi	R
Dascyllus aruanus	A
D. trimaculatus	O
Pomacentrus coelestis	A
LABRIDAE	
Cheilinus celebecus	O
C. chlorourus	O
C. fasciatus	C
C. unifasciatus	O
Cirrhilabrus sp.	O
Epibulus insidiator	R
Gomphosus varius	O
Halichoeres chrysus	O
H. melanurus	O
Hemigymnus melapterus	O
Labroides bicolor	O
L. dimidiatus	O
Macropharyngodon meleagris	R
Thalassoma amblycephalum	A
T. hardwickii	O
SCARIDAE	
Cetoscarus bicolor	O
Hipposcarus longiceps	C
Scarus bleekeri	R
S. dimidiatus	R
S. forsteni	R
S. sordidus	A

BLENNIIDAE	
Meiacanthus atrodorsalis	R
MICRODESMIDAE	
Ptereleotris evides	A
GOBIIDAE	
Amblygobius phalaena	O
ACANTHURIDAE	
Acanthurus nigricans	R
A. nigricauda	C
A. pyroferus	O
Ctenochaetus striatus	A
Naso lituratus	O
N. unicornis	R
Zebrasoma scopas	O
Z. veliferum	O
ZANCLIDAE	
Zanclus cornutus	C
BALISTIDAE	
Balistipus undulatus	O

Number of Families : 22
Number of Species : 82

FAMILY/Species	Rank
HOLOCENTRIDAE	
Myripristis violacea	R
SERRANIDAE	
Epinephelus merra	O
Plectropomus areolatus	R
MALACANTHIDAE	
Malacanthus latovittatus	O
LUTJANIDAE	
Aphareus furca	R
Lutjanus bohar	O
L. gibbus	A
LETHRINIDAE	
Monotaxis grandoculus	C
MULLIDAE	
Parupeneus barberinus	C
P. multifasciatus	C
P. pleurostigma	O
CHAETODONTIDAE	
Chaetodon auriga	O
C. citrinellus	R
C. ephippium	O
C. trifasciatus	O
POMACANTHIDAE	
Centropyge flavissimus	O
POMACENTRIDAE	
Chromis agilis	C
C. atripectoralis	A
C. margaritifer	O
Dascyllus aruanus	C
D. reticulatus	O
Plectroglyphididon dickii	O
P. johnstonianus	R
P. lacrymatus	O
P. leucozona	C
Pomacentrus coelestis	A
P. vaiuli	O
Stegastes albifasciatus	A
S. fasciolatus	O
S. nigricans	O

LABRIDAE	
Cheilinus undulatus	O
Coris gaimard	O
Gomphosus varius	C
Halichoeres chrysus	O
H. hortulanus	O
H. margaritaceus	C
H. marginatus	O
H. melanurus	R
H. trimaculatus	C
Hemigymnus melapterus	O
Labroides dimidiatus	O
Stethojulis bandanensis	O
Thalassoma amblycephalum	A
T. hardwickii	O
T. quinquevittatum	O
SCARIDAE	
Cetoscarus bicolor	C
Hipposcarus longiceps	O
Scarus gibbus	C
S. schlegeli	O
S. sordidus	A
PINGUIPEDIDAE	
Parapercis millipunctata	O
MICRODESMIDAE	
Ptereleotris evides	O
GOBIIDAE	
Valenciennea strigatus	O
ACANTHURIDAE	
Acanthurus nigricans	O
A. nigricauda	C
A. olivaceus	A
Ctenochaetus striatus	A
Naso brevirostris	C
Zebrasoma veliferum	R
ZANCLIDAE	
Zanclus cornutus	O
SIGANIDAE	
Siganus argenteus	A

BALISTIDAE	
Sufflamen chrysoptera	R
MONACANTHIDAE	
Oxymonacanthus longirostris	O

Number of Families : 19
Number of Species : 63

FAMILY/Species	Rank
SERRANIDAE	
Epinephelus merra	O
CIRRHITIDAE	
Paracirrhitus arcatus	R
APOGONIDAE	
Cheilodipterus quinquelineata	R
LUTJANIDAE	
Lutjanus fulvus	R
L. monostigmus	O
NEMIPTERIDAE	
Scolopsis lineatus	O
MULLIDAE	
Parupeneus barberinus	O
P. cyclostomus	R
P. multifasciatus	O
CHAETODONTIDAE	
Chaetodon auriga	O
C. citrinellus	C
C. lunula	R
C. trifasciatus	C
POMACANTHIDAE	
Centropyge flavissimus	O
POMACENTRIDAE	
Chromis atripectoralis	A
C. viridis	A
Chrysiptera glauca	A
C. leucopoma	C
Dascyllus aruanus	A
Plectroglyphidodon leucozona	C
Pomacentrus coelestis	O
P. vaiuli	O
Stegastes albifasciatus	R
S. nigricans	A

LABRIDAE	
Cheilinus undulatus	O
Cheilio inermis	R
Cirrhilabrus sp.	R
Coris gaimardi	R
C. variegata	R
Gomphosus varius	O
Halichoeres marginatus	R
H. melanurus	R
H. trimaculatus	O
Hemigymnus melapterus	O
Thalassoma hardwickii	C
T. lunare	O
T. lutescens	O
Stethojulis bandanensis	O
SCARIDAE	
Scarus altipinnis	C
S. frenatus	R
S. oviceps	O
S. schlegeli	A
S. sordidus	A
MUGILIDAE	
Liza vaigiensis	A
PINGUIPEDIDAE	
Parapercis millipunctata	R
GOBIIDAE	
Amblygobius phalaena	O
ACANTHURIDAE	
Acanthurus nigricans	R
A. nigricauda	R
A. olivaceus	O
A. triostegus	A
Ctenochaetus striatus	A
Naso brevirostris	R
N. lituratus	O
BALISTIDAE	
Balistipus undulatus	R
Rhinecanthus aculeatus	R
MONACANTHIDAE	
Oxymonacanthus longirostris	O

Number of Families : 17
Number of Species : 56

FAMILY/Species	Rank
CLUPEIDAE	
Spratelloides delicatulus	A
HOLOCENTRIDAE	
Myripristis violacea	R
SERRANIDAE	
Epinephelus merra	R
LUTJANIDAE	
Lutjanus gibbus	O
MULLIDAE	
Parupeneus barberinus	O
P. multifasciatus	C
CHAETODONTIDAE	
Chaetodon auriga	O
C. citrinellus	R
C. ephippium	O
C. trifascialis	R
C. trifasciatus	O
Heniochus chrysostomus	O
POMACENTRIDAE	
Abudefduf saxatilis	O
Amblyglyphidodon curacao	O
Chromis viridis	A
Dascyllus aruanus	C
Plectroglyphidodon dickii	C
P. johnstonianus	R
P. lacrymatus	O
P. leucozona	C
Pomacentrus coelestis	A
P. vaiuli	R
Stegastes albifasciatus	O
S. nigricans	A

LABRIDAE	
Cheilinus chlorourus	R
C. undulatus	O
C. unifasciatus	R
Gomphosus varius	C
Coris variegata	R
Epibulus insidiator	O
Halichoeres chrysus	O
H. hortulanus	C
H. margaritaceus	O
H. melanurus	C
H. trimaculatus	C
Hemigymnus melapterus	O
Labrichthys unilineatus	C
Labroides bicolor	O
L. dimidiatus	O
L. pectoralis	R
Pseudocheilinus hexataenia	R
Stethojulis bandanensis	C
Thalassoma amblycephalum	C
T. hardwickii	O
T. lunare	R
T. lutescens	O
T. quinquevittatum	C
SCARIDAE	
Hipposcarus longiceps	O
Scarus frenatus	O
S. ghobban	O
S. oviceps	O
S. schlegeli	O
S. sordidus	A
BLENNIIDAE	
Plagiotremus tapienosoma	R
ACANTHURIDAE	
Acanthurus nigricans	C
A. nigricauda	O
A. triostegus	A
Ctenochaetus striatus	A
Naso brevirostris	O
Zebrasoma scopas	O
ZANCLIDAE	
Zanclus cornutus	O
SIGANIDAE	
Siganus argenteus	C

Number of Families : 13
Number of Species : 62

FAMILY/Species	Rank
HEMIGALEIDAE	
Triaenodon obesus	R
SYNODONTIDAE	
Saurida gracilis	O
HOLOCENTRIDAE	
Myripristis murdjan	O
AULOSTOMIDAE	
Aulostomus chinensis	R
SERRANIDAE	
Anyperodon leucogrammicus	R
Epinephelus fuscoguttatus	R
E. microdon	O
Plectropomus areolatus	R
Variola louti	R
LUTJANIDAE	
Lutjanus bohar	R
L. gibbus	O
L. monostigmus	R
CAESIONIDAE	
Caesio caerulaurea	A
C. teres	A
HAEMULIDAE	
Pentapodus caninus	A
LETHRINIDAE	
Lethrinus ramak	O
Monotaxis grandoculus	C
MULLIDAE	
Parupeneus barberinus	O
P. cyclostomus	R
P. multifasciatus	C
P. pleurostigma	R
CHAETODONTIDAE	
Chaetodon auriga	C
C. ephippium	O
C. kleini	O
C. mertensii	O
C. trifascialis	O
C. trifasciatus	C
C. ulietensis	R
Heniochus chrysostomus	O
H. singularis	O
H. varius	R

POMACANTHIDAE	
Pygoplites diacanthus	O
POMACENTRIDAE	
Amblyglyphidodon aureus	O
A. curacao	A
A. leucogaster	R
Dascyllus aruanus	C
D. reticulatus	O
Plectroglyphidodon johnstonianus	R
Pomacentrus coelestis	A
P. vaiuli	C
LABRIDAE	
Cheilinus celebecus	R
C. chlorourus	O
C. fasciatus	C
C. unifasciatus	R
Cirrhilabrus sp.	A
Coris variegata	R
Epibulus insidiator	O
Gomphosus varius	O
Halichoeres chrysus	O
H. hortulanus	R
H. melanurus	R
Hemigymnus melapterus	O
Labroides dimidiatus	R
Labropsis xanthonota	O
Stethojulis bandanensis	O
Thalassoma amblycephalum	R
T. lutescens	C
SCARIDAE	
Cetoscarus bicolor	C
Hipposcarus longiceps	C
Scarus bleekeri	C
S. forsteni	R
S. frenatus	O
S. ghobban	O
S. gibbus	A
S. schlegeli	O
S. sordidus	O
MICRODESMIDAE	
Ptereleotris evides	C
ACANTHURIDAE	
Acanthurus nigricans	O
A. nigricauda	R
A. olivaceus	R
A. thompsoni	O
Ctenochaetus striatus	C
Naso brevirostris	A
N. lituratus	R
Zebrasoma scopas	O
Z. veliferum	O

ZANCLIDAE	
Zanclus cornutus	C
SIGANIDAE	
Siganus puellus	C
S. vulpinus	O
BALISTIDAE	
Pseudobalistes flavimarginatus	R
Balistoides viridescens	O
Sufflamen chrysoptera	R

Number of Families : 20
Number of Species : 82

FAMILY/ Species	Rank
CLUPEIDAE	
Spratelloides delicatulus	A
HEMIRAMPHIDAE	
Hyporhamphus dussumieri	C
CARANGIDAE	
Caranx melampygus	O
Trachinotus blochii	R
LUTJANIDAE	
Lutjanus bohar	A
L. fulvus	O
L. gibbus	A
L. monostigmus	O
L. semicinctus	C
LETHRINIDAE	
Monotaxis grandoculus	A
MULLIDAE	
Mulloides flavolineatus	R
Parupeneus barberinus	O
P. cyclostomus	O
P. multifasciatus	C
CHAETODONTIDAE	
Chaetodon auriga	O
C. ephippium	R
C. lineolatus	O
POMACENTRIDAE	
Amblyglyphidodon curacao	O
Chromis atripectoralis	A
C. viridis	A
Pomacentrus coelestis	A
P. vaiuli	R
LABRIDAE	
Cheilinus chlorourus	R
C. fasciatus	R
C. undulatus	R
Coris variegata	O
Gomphosus varius	O
Halichoeres melanurus	R
Labroides bicolor	R
L. dimidiatus	O
Thalassoma amblycephalum	A
T. lutescens	O
T. quinquevittatum	O

SCARIDAE	
Hipposcarus longiceps	O
Scarus bleekeri	O
S. forsteni	O
S. frenatus	O
S. ghobban	C
S. schlegeli	O
S. sordidus	C
ACANTHURIDAE	
Acanthurus nigricans	C
A. nigricauda	C
A. olivaceus	R
Ctenochaetus striatus	C
Naso lituratus	R
N. unicornis	R
Zebrasoma veliferum	R
ZANCLIDAE	
Zanclus cornutus	O
BALISTIDAE	
Balistoides viridescens	R
TETRAODONTIDAE	
Arothron stellatus	O

Number of Families : 14
Number of Species : 50

FAMILY/Species	Rank
CLUPEIDAE	
Spratelloides delicatulus	A
FISTULARIIDAE	
Fistularia commersonii	R
SYGNATHIDAE	
Corythoichthys intestinalis	R
LUTJANIDAE	
Lutjanus bohar	R
L. monostigmus	R
MULLIDAE	
Parupeneus barberinus	C
P. cyclostomus	R
KYPHOSIDAE	
Kyphosus vaigiensis	O
CHAETODONTIDAE	
Chaetodon auriga	O
C. bennetti	R
C. citrinellus	R
C. ephippium	C
C. lunula	O
C. trifasciatus	C
C. ulietensis	R
Heniochus chrysostomus	R
POMACENTRIDAE	
Amblyglyphidodon curacao	A
Amphiprion perideraion	O
Chromis agilis	O
C. atripectoralis	A
C. viridis	A
Dascyllus trimaculatus	C
Plectroglyphidodon dickii	C
Pomacentrus coelestis	A
P. vaiuli	C
LABRIDAE	
Cheilinus fasciatus	R
Coris variegata	R
Epibulus insidiator	C
Halichoeres hortulanus	R
Hemigymnus melapterus	C
Labroides dimidiatus	C
Thalassoma hardwickii	O
T. lutescens	O

SCARIDAE	
Cetoscarus bicolor	R
Hipposcarus longiceps	C
Scarus bleekeri	C
S. frenatus	O
S. ghobban	O
S. gibbus	R
S. globiceps	R
S. oviceps	R
S. schlegeli	R
S. sordidus	C
ACANTHURIDAE	
Acanthurus nigricans	C
A. nigricauda	O
A. triostegus	R
Ctenochaetus striatus	A
Naso brevirostris	O
Zebrasoma scopas	R
Z. veliferum	O
ZANCLIDAE	
Zanclus cornutus	C
SIGANIDAE	
Siganus argenteus	R
S. puellus	C
S. vulpinus	O

Number of Families : 13
Number of Species : 54

FAMILY/Species	Rank
SERRANIDAE	
Epinephelus merra	O
NEMIPTERIDAE	
Scolopsis lineatus	C
MULLIDAE	
Parupeneus multifasciatus	C
CHAETODONTIDAE	
Chaetodon auriga	O
C. citrinellus	O
C. ephippium	R
C. lunula	R
C. trifascialis	R
C. trifasciatus	O
C. vagabundus	R
POMACENTRIDAE	
Amblyglyphidodon curacao	R
Chromis viridis	A
Dascyllus aruanus	A
D. reticulatus	O
Plectroglyphidodon dickii	R
P. johnstonianus	R
P. leucozona	C
Pomacentrus coelestis	A
P. vaiuli	C
Stegastes albifasciatus	O
LABRIDAE	
Cheilinus chlorourus	O
C. trilobatus	R
C. undulatus	O
Coris variegata	R
Gomphosus varius	C
Halichoeres chrysus	O
H. margaritaceus	R
H. marginatus	O
H. melanurus	O
H. trimaculatus	O
Hemigymnus melapterus	C
Labrichthys unilineatus	O
Labroides dimidiatus	C
Macropharyngodon meleagris	R
Stethojulis bandanensis	C
Thalassoma amblycephalum	C
T. hardwickii	R
T. lutescens	O
T. quinquevittatum	C

SCARIDAE	
Cetoscarus bicolor	R
Scarus ghobban	C
S. schlegeli	A
S. sordidus	C
BLENNIIDAE	
Plagiotremus tapienosoma	O
MICRODESMIDAE	
Gunnellichthys monostigma	C
ACANTHURIDAE	
Acanthurus lineatus	C
A. nigricans	O
A. nigricauda	C
A. olivaceus	C
A. thompsoni	R
A. triostegus	O
A. xanthopterus	O
Ctenochaetus striatus	A
Naso lituratus	R
N. unicornis	R
Zebrasoma scopas	O
ZANCLIDAE	
Zanclus cornutus	O
SIGANIDAE	
Siganus argenteus	A
S. corallinus	R
S. spinus	O
BALISTIDAE	
Sufflamen chrysoptera	O

Number of Families : 13
Number of Species : 61

FAMILY/Species	Rank
HOLOCENTRIDAE	
Myripristis murdjan	R
M. pralinia	C
M. violacea	C
Neoniphon sammara	C
Sargocentron caudimaculatum	O
SERRANIDAE	
Cephalopholis urodeta	R
Epinephelus cyanopodus	C
E. merra	O
Plectropomus areolatus	O
ECHENEIDAE	
Echeneis naucrates	R
LUTJANIDAE	
Lutjanus bohar	O
L. fulvus	C
L. gibbus	A
L. monostigmus	A
Macolor niger	R
HAEMULIDAE	
Pentapodus caninus	R
LETHRINIDAE	
Monotaxis grandoculus	C
MULLIDAE	
Mulloides vanicolensis	A
Parupeneus barberinus	O
P. multifasciatus	C
KYPHOSIDAE	
Kyphosus vaigiensis	A
CHAETODONTIDAE	
Chaetodon auriga	O
C. citrinellus	R
C. ephippium	O
C. lunula	O
C. mertensii	R
C. trifasciatus	O
C. ulietensis	R
C. unimaculatus	R
Heniochus acuminatus	O
H. chrysostomus	O
H. monoceros	O
H. varius	O

POMACANTHIDAE	
Pygoplites diacanthus	R
POMACENTRIDAE	
Amblyglyphidodon curacao	O
A. leucogaster	O
Chromis agilis	C
C. atripectoralis	A
C. margaritifer	O
C. ternatensis	A
Chrysiptera leucopoma	O
Plectroglyphidodon leucozona	C
Pomacentrus coelestis	A
P. vaiuli	O
LABRIDAE	
Cheilinus chlorourus	C
C. fasciatus	R
C. trilobatus	O
C. unifasciatus	R
Cirrhilabrus sp.	A
Epibulus insidiator	O
Gomphosus varius	O
Halichoeres chrysus	O
H. margaritaceus	O
H. marginatus	O
H. melanurus	C
H. trimaculatus	O
Hemigymnus melapterus	O
Labrichthys unilineatus	O
Labroides dimidiatus	O
Pseudocheilinus evanidus	R
Stethojulis bandanensis	O
Thalassoma hardwickii	R
T. lunare	R
T. lutescens	O
T. quinquevittatum	O
SCARIDAE	
Cetoscarus bicolor	O
Scarus bleekeri	O
S. forsteni	O
S. frenatus	O
S. ghobban	C
S. niger	O
S. schlegeli	C
S. sordidus	A
BLENNIIDAE	
Plagiotremus tapienosoma	R
MICRODESMIDAE	
Ptereleotris evides	O

GOBIIDAE	
Valenciennea sexguttatus	O
ACANTHURIDAE	
Acanthurus lineatus	R
A. nigricans	O
A. nigricauda	C
A. triostegus	R
Ctenochaetus striatus	A
Naso lituratus	O
N. unicornis	C
N. vlamingi	O
Zebrasoma veliferum	R
ZANCLIDAE	
Zanclus cornutus	O
SIGANIDAE	
Siganus argenteus	O
S. corallinus	O
BALISTIDAE	
Balistoides viridescens	R

Number of Families : 20
Number of Species : 89

FAMILY/Species	Rank
HOLOCENTRIDAE	
Myripristis murdjan	O
SERRANIDAE	
Epinephelus merra	R
Variola louti	R
LUTJANIDAE	
Lutjanus bohar	R
L. fulvus	O
NEMIPTERIDAE	
Scolopsis lineatus	C
LETHRINIDAE	
Monotaxis grandoculus	O
MULLIDAE	
Parupeneus multifasciatus	O
CHAETODONTIDAE	
Chaetodon auriga	R
C. citrinellus	O
C. ephippium	R
C. punctatofasciatus	R
C. reticulatus	O
C. trifasciatus	O
Heniochus chrysostomus	R
POMACENTRIDAE	
Amblyglyphidodon curacao	C
Chromis atripectoralis	A
C. viridis	A
Chrysiptera leucopoma	R
Dascyllus aruanus	C
Plectroglyphidodon johnstonianus	O
P. leucozona	O
Pomacentrus vaiuli	O
Stegastes nigricans	O

LABRIDAE	
Cheilinus chlorourus	R
C. trilobatus	O
Epibulus insidiator	R
Gomphosus varius	C
Halichoeres chrysus	O
H. marginatus	O
H. melanurus	O
Hemigymnus melapterus	C
Labrichthys unilineatus	O
Labroides dimidiatus	O
Macropharyngodon meleagris	O
Stethojulis bandanensis	O
Thalassoma lunare	R
T. lutescens	O
T. quinquevittatum	O
SCARIDAE	
Scarus bleekeri	O
S. forsteni	R
S. frenatus	C
S. ghobban	R
S. niger	R
S. schlegeli	C
S. sordidus	C
ACANTHURIDAE	
Acanthurus mata	O
A. nigricans	O
A. nigricauda	C
A. olivaceus	C
A. pyroferus	R
Ctenochaetus striatus	A
Naso brevirostris	R
N. lituratus	O
N. unicornis	R
Zebrasoma scopas	O
ZANCLIDAE	
Zanclus cornutus	C

Number of Families : 12
Number of Species : 57

FAMILY/Species	Rank
HOLOCENTRIDAE	
Neoniphon sammara	O
Sargocentron microstoma	R
SERRANIDAE	
Epinephelus merra	C
CIRRHITIDAE	
Paracirrhitus arcatus	O
NEMIPTERIDAE	
Scolopsis lineatus	C
MULLIDAE	
Mulloides vanicolensis	O
Parupeneus multifasciatus	O
CHAETODONTIDAE	
Chaetodon auriga	O
C. citrinellus	C
C. reticulatus	O
C. trifascialis	C
C. trifasciatus	R
C. vagabundus	O
POMACENTRIDAE	
Abudefduf sordidus	C
Chromis atripectoralis	A
C. viridis	A
Chrysiptera leucopoma	A
C. glauca	C
Dascyllus aruanus	O
D. reticulatus	A
Plectroglyphidodon dickii	A
P. leucozona	R
Pomacentrus vaiuli	O
Stegastes albifasciatus	A
S. nigricans	A

LABRIDAE	
Cheilinus chlorourus	O
C. undulatus	O
Coris aygula	R
Gomphosus varius	O
Halichoeres hortulanus	C
H. margaritaceus	C
H. marginatus	C
H. trimaculatus	C
Hemigymnus melapterus	R
Labroides dimidiatus	C
Novaculichthys taeniourus	O
Stethojulis bandanensis	C
Thalassoma amblycephalum	O
T. hardwickii	C
T. lutescens	O
T. quinquevitattum	C
SCARIDAE	
Scarus frenatus	R
S. schlegeli	C
PINGUIPEDIDAE	
Parapercis millipunctata	C
BLENNIIDAE	
Plagiotremus tapienosoma	R
ACANTHURIDAE	
Acanthurus lineatus	C
A. nigrofuscus	A
A. olivaceus	O
A. triostegus	C
Ctenochaetus striatus	A
Naso lituratus	O
N. unicornis	R
Zebrasoma scopas	O
ZANCLIDAE	
Zanclus cornutus	C
BALISTIDAE	
Rhinecanthus rectangulus	R
MONACANTHIDAE	
Oxymonacanthus longirostris	O
TETRAODONTIDAE	
Canthigaster solandri	R

Number of Families : 16
Number of Species : 57

FAMILY/Species	Rank
HOLOCENTRIDAE	
Myripristis murdjan	R
Neoniphon sammara	C
Sargocentron spiniferum	O
SERRANIDAE	
Epinephelus cyanopodus	R
E. merra	O
E. microdon	R
Plectropomus laevis	O
LUTJANIDAE	
Lutjanus bohar	O
LETHRINIDAE	
Monotaxis grandoculus	R
MULLIDAE	
Parupeneus barberinus	C
P. multifasciatus	O
CHAETODONTIDAE	
Chaetodon auriga	O
C. citrinellus	R
C. ephippium	O
POMACENTRIDAE	
Abudefduf saxatilis	O
Amblyglyphidodon curacao	R
Chromis agilis	R
C. viridis	C
Dascyllus aruanus	A
Pomacentrus coelestis	A
P. vaiuli	C
Stegastes albifasciatus	A
LABRIDAE	
Cheilinus chlorourus	C
C. unifasciatus	R
Cheilio inermis	R
Gomphosus varius	O
Halichoeres chrysus	O
H. margaritaceus	O
H. marginatus	O
H. melanurus	O
H. trimaculatus	C
Hemigymnus melapterus	O
Labroides dimidiatus	R
Novaculichthys taeniourus	O
Stethojulis bandanensis	C
Thalassoma amblycephalum	A
T. lutescens	R

SCARIDAE	
Hipposcarus longiceps	O
Scarus frenatus	O
S. ghobban	C
S. gibbus	C
S. schlegeli	C
S. sordidus	C
BLENNIIDAE	
Plagiotremus tapienosoma	R
MICRODESMIDAE	
Gunnelichthys monostigma	A
GOBIIDAE	
Amblygobius phalaena	O
ACANTHURIDAE	
Acanthurus nigricauda	C
A. olivaceus	R
A. triostegus	O
Ctenochaetus striatus	A
Naso brevirostris	A
N. lituratus	R
Zebrasoma scopas	R
Z. veliferum	O
ZANCLIDAE	
Zanclus cornutus	R
SIGANIDAE	
Siganus spinus	C
BALISTIDAE	
Balistoides viridescens	C
Rhinecanthus aculeatus	R

Number of Families : 16
Number of Species : 58

FAMILY/Species	Rank
MURAENIDAE	
Gymnothorax javanicus	R
HEMIRAMPHIDAE	
Hyporhamphus acutus	O
HOLOCENTRIDAE	
Neoniphon sammara	O
SERRANIDAE	
Epinephelus fuscoguttatus	R
E. merra	O
CIRRHITIDAE	
Paracirrhitus arcatus	O
APOGONIDAE	
Cheilodipterus quinquelineata	R
LUTJANIDAE	
Lutjanus fulvus	O
NEMIPTERIDAE	
Scolopsis lineatus	C
MULLIDAE	
Mulloides vanicolensis	A
Parupeneus barberinus	O
P. multifasciatus	R
CHAETODONTIDAE	
Chaetodon auriga	O
C. citrinellus	R
C. lunula	O
C. trifasciatus	R
C. vagabundus	R
POMACENTRIDAE	
Abudefduf saxatilis	O
Amblyglyphidodon curacao	O
Chromis atripectoralis	A
C. viridis	A
Chrysiptera leucopoma	R
Dascyllus aruanus	C
D. reticulatus	O
Pomacentrus coelestis	A
P. vaiuli	C
Stegastes albifasciatus	C

LABRIDAE	
Cheilinus chlorourus	O
Gomphosus varius	O
Halichoeres hortulanus	C
H. margaritaceus	C
H. marginatus	O
H. melanurus	O
H. trimaculatus	C
Hemigymnus melapterus	R
Labroides dimidiatus	R
Novaculichthys taeniourus	R
Stethojulis bandanensis	C
Thalassoma hardwickii	O
T. lutescens	O
SCARIDAE	
Hipposcarus longiceps	O
Scarus frenatus	R
S. schlegeli	C
S. sordidus	A
PINGUIPEDIDAE	
Parapercis millipunctata	O
BLENNIIDAE	
Plagiotremus tapienosoma	R
ACANTHURIDAE	
Acanthurus mata	O
A. nigricans	R
A. nigricauda	C
A. triostegus	C
Ctenochaetus striatus	A
Zebrasoma veliferum	R
SIGANIDAE	
Siganus argenteus	R

Number of Families : 17
Number of Species : 53

FAMILY/Species	Rank
CLUPEIDAE	
Spratelloides delicatulus	A
ATHERINIDAE	
Hypoatherina ovalaua	A
GERREIDAE	
Gerres argyreus	R
LUTJANIDAE	
Lutjanus fulvus	C
L. monostigmus	O
NEMIPTERIDAE	
Scolopsis lineatus	C
MULLIDAE	
Mulloides flavolineatus	O
M. vanicolensis	O
Parupeneus barberinus	O
P. multifasciatus	O
CHAETODONTIDAE	
Chaetodon auriga	O
C. citrinellus	O
C. ephippium	O
C. lineolatus	R
C. lunula	O
C. trifascialis	O
C. trifasciatus	O
C. vagabundus	O
Heniochus acuminatus	R
H. chrysostomus	O
H. singularis	R
POMACENTRIDAE	
Abudefduf saxitilis	C
Amblyglyphidodon curacao	A
Chromis agilis	R
C. atripectoralis	A
C. ternatensis	R
C. viridis	A
Dascyllus aruanus	C
Plectroglyphidodon dickii	O
Pomacentrus coelestis	A
P. vaiuli	O
Stegastes albifasciatus	A
S. nigricans	A

LABRIDAE	
Cheilinus chlorourus	O
C. fasciatus	R
C. undulatus	O
Coris variegata	R
Gomphosus varius	C
Halichoeres hortulanus	R
H. marginatus	O
H. melanurus	C
H. trimaculatus	C
Hemigymnus melapterus	C
Labrichthys unilineatus	C
Labroides dimidiatus	C
Macropharyngodon meleagris	R
Pseudocheilinus evanidus	R
Stethojulis bandanensis	O
S. strigiventer	A
Thalassoma amblycephalum	R
T. hardwickii	C
T. lutescens	O
T. quinquevitttatum	O
Xyrichthys pavo	R
SCARIDAE	
Scarus frenatus	C
S. ghobban	C
S. oviceps	R
S. psittacus	R
S. schlegeli	A
S. sordidus	A
GOBIIDAE	
Amblygobius phalaena	R
ACANTHURIDAE	
Acanthurus dussumieri	C
A. nigricans	C
A. triostegus	R
Ctenochaetus striatus	A
Naso lituratus	R
N. unicornis	O
Zebrasoma scopas	R
Z. veliferum	O
ZANCLIDAE	
Zanclus cornutus	C

SIGANIDAE

Siganus argenteus	R

MONACANTHIDAE

Oxymonacanthus longirostris	R

Number of Families : 15
Number of Species : 72

FAMILY/Species	Rank
MURAENIDAE	
Echidna nebulosa	R
HOLOCENTRIDAE	
Myripristis murdjan	R
SERRANIDAE	
Epinephelus merra	O
GRAMMISTIDAE	
Belonoperca chaubanaudi	R
APOGONIDAE	
Cheilodipterus quinquelineata	R
LUTJANIDAE	
Lutjanus fulvus	R
NEMIPTERIDAE	
Scolopsis lineatus	O
MULLIDAE	
Parupeneus multifasciatus	O
CHAETODONTIDAE	
Chaetodon auriga	O
C. citrinellus	O
C. ephippium	R
C. trifasciatus	C
POMACENTRIDAE	
Amblyglyphidodon curacao	R
Amphiprion melanopus	A
Chromis atripectoralis	A
C. ternatensis	R
C. viridis	A
Chrysiptera leucopoma	A
Dascyllus aruanus	A
D. reticulatus	O
D. trimaculatus	R
Plectroglyphidodon dickii	R
P. johnstonianus	O
Pomacentrus coelestis	A
Stegastes albifasciatus	C
S. nigricans	A

LABRIDAE

Cheilinus celebecus	R
C. chlorourus	O
C. undulatus	R
Gomphosus varius	O
Halichoeres marginatus	R
H. melanurus	O
H. trimaculatus	A
Hemigymnus melapterus	O
Labrichthys unilineatus	O
Labroides dimidiatus	R
Novaculichthys taeniourus	R
Pseudocheilinus hexataenia	R
Stethojulis bandanensis	C
Thalassoma amblycephalum	C
T. hardwickii	C
T. lunare	C
T. lutescens	C
T. quinquevittatum	R

SCARIDAE

Scarus altipinnis	C
S. dimidiatus	R
S. frenatus	O
S. oviceps	O
S. schlegeli	R
S. sordidus	C

BLENNIIDAE

Plagiotremus tapienosoma	R

GOBIIDAE

Amblygobius phalaena	C
Fusigobius neophytus	R
Valenciennea sexguttatus	O

ACANTHURIDAE

Acanthurus triostegus	O
Ctenochaetus striatus	A
Naso unicornis	R
Zebrasoma scopas	O
Z. veliferum	R

BALISTIDAE

Balistoides viridescens	R
Rhinecanthus aculeatus	R

TETRAODONTIDAE

Canthigaster solandri	R

Number of Families : 17
Number of Species : 62

FAMILY/Species	Rank
SERRANIDAE	
Epinephelus cyanopodus	O
E. merra	O
LUTJANIDAE	
Lutjanus fulvus	O
NEMIPTERIDAE	
Scolopsis lineatus	O
MULLIDAE	
Parupeneus barberinus	O
P. multifasciatus	O
CHAETODONTIDAE	
Chaetodon auriga	C
C. ephippium	O
C. trifasciatus	O
Heniochus chrysostomus	R
POMACENTRIDAE	
Amphiprion melanopus	A
Amblyglyphidodon curacao	A
Chromis atripectoralis	O
C. viridis	A
Chrysiptera leucopoma	O
Dascyllus aruanus	A
Pomacentrus coelestis	A
Stegastes albifasciatus	C
LABRIDAE	
Cheilinus chlorourus	O
C. fasciatus	O
C. undulatus	O
Epibulus insidiator	O
Halichoeres melanurus	O
H. trimaculatus	O
Hemigymnus melapterus	O
Labroides dimidiatus	R
Pseudocheilinus evanidus	C
Stethojulis bandanensis	O
Thalassoma hardwickii	C
SCARIDAE	
Scarus bleekeri	O
S. frenatus	C
S. ghobban	O
S. niger	R
S. schlegeli	A
S. sordidus	C

BLENNIIDAE	
Aspidontus dussumieri	O
Plagiotremus tapienosoma	R
MICRODESMIDAE	
Gunnelichthys monostigma	C
GOBIIDAE	
Amblygobius phalaena	O
ACANTHURIDAE	
Acanthurus nigricans	R
A. nigricauda	O
Ctenochaetus striatus	C
Zebrasoma scopas	R
Z. veliferum	O
SIGANIDAE	
Siganus argenteus	O
S. corallinus	R

Number of Families : 13
Number of Species : 46

FAMILY/Species	Rank
MURAENIDAE	
Gymnothorax undulatus	R
Sideria picta	R
POMACENTRIDAE	
Chrysiptera glauca	C
C. leucopoma	C
Stegastes albifasciatus	C
LABRIDAE	
Cirrhilabrus sp.	R
ACANTHURIDAE	
Acanthurus triostegus	O
TETRAODONTIDAE	
Arothron hispidus	R
Canthigaster solandri	R

Number of Families : 5
Number of Species : 9

FAMILY/Species	Rank
MURAENIDAE	
Gymnothorax undulatus	R
CLUPEIDAE	
Spratelloides gracilis	A
HEMIRAMPHIDAE	
Hyporhamphus acutus	R
SERRANIDAE	
Cephalopholis urodeta	O
Epinephelus merra	C
CIRRHITIDAE	
Paracirrhitus arcatus	C
P. forsteri	R
APOGONIDAE	
Apogon novemfasciatus	O
CARANGIDAE	
Caranx sexfasciatus	A
LUTJANIDAE	
Lutjanus fulvus	C
LETHRINIDAE	
Lethrinus harak	R
Monotaxis grandoculus	R
MULLIDAE	
Parupeneus barberinus	R
P. multifasciatus	O
CHAETODONTIDAE	
Chaetodon auriga	O
C. citrinellus	O
POMACENTRIDAE	
Abudefduf saxatilis	C
Chromis ternatensis	R
Chrysiptera leucopoma	C
Dascyllus aruanus	A
Pomacentrus coelestis	A
Stegastes albifasciatus	A

LABRIDAE	
Cheilinus chlorourus	O
Coris gaimardi	C
Halichoeres margaritaceus	C
H. trimaculatus	A
Labroides dimidiatus	R
Macropharyngodon meleagris	O
Navaculichthys taeniourus	C
Stethojulis bandanensis	C
Thalassoma amblycephalum	C
T. lutescens	R
SCARIDAE	
Scarus gibbus	C
MUGILIDAE	
Crenimugil crenilabis	C
Liza vaigiensis	A
BLENNIIDAE	
Plagiotremus tapienosoma	O
GOBIIDAE	
Amblygobius phalaena	C
Valenciennea sexguttatus	C
ACANTHURIDAE	
Acanthurus olivaceus	C
A. triostegus	A
Ctenochaetus striatus	C
Naso lituratus	R
N. unicornis	O
BALISTIDAE	
Rhinecanthus aculeatus	O
R. rectangulus	R
Sufflamen chrysoptera	O
MONACANTHIDAE	
Oxymonacanthus longirostris	R

Number of Families : 20
Number of Species : 47

FAMILY/Species	Rank
SERRANIDAE	
Epinephelus merra	O
CIRRHITIDAE	
Paracirrhitus arcatus	R
P. forsteri	R
LUTJANIDAE	
Lutjanus monostigmus	R
NEMIPTERIDAE	
Scolopsis lineatus	O
LETHRINIDAE	
Monotaxis grandoculus	O
MULLIDAE	
Mulloides vanicolensis	R
Parupeneus cyclostomus	O
P. multifasciatus	C
CHAETODONTIDAE	
Chaetodon auriga	O
C. citrinellus	C
C. reticulatus	O
C. trifascialis	R
C. trifasciatus	C
C. vagabundus	O
POMACANTHIDAE	
Centropyge flavissimus	C
C. vrolicki	O
POMACENTRIDAE	
Abudefduf septemfasciatus	C
Amblyglyphidodon curacao	C
Amphiprion melanopus	A
Chromis atripectoralis	A
C. margaritifer	R
C. viridis	A
Chrysiptera leucopoma	A
Dascyllus aruanus	A
Plectroglyphidodon dickii	C
P. lacrymatus	O
Pomacentrus coelestis	A
P. vaiuli	O
Stegastes albifasciatus	C
S. nigricans	C

LABRIDAE	
Cheilinus chlorourus	O
C. undulatus	O
Coris aygula	O
C. gaimardi	O
Gomphosus varius	C
Halichoeres hortulanus	C
H. margaritaceus	R
H. marginatus	O
H. melanurus	R
H. trimaculatus	O
Hemigymnus melapterus	C
Labroides dimidiatus	C
Novaculichthys taeniourus	O
Pseudocheilinus hexataenia	R
Stethojulis bandanensis	C
Thalassoma amblycephalum	C
T. hardwickii	C
T. lutescens	O
SCARIDAE	
Scarus frenatus	R
S. oviceps	O
S. schlegeli	C
S. sordidus	A
PINGUIPEDIDAE	
Parapercis millipunctata	R
BLENNIIDAE	
Meiacanthus atrodorsalis	O
Plagiotremus tapienosoma	R
GOBIIDAE	
Amblygobius phalaena	O
ACANTHURIDAE	
Acanthurus lineatus	R
A. mata	O
A. nigricans	O
A. nigricauda	O
A. olivaceus	C
A. triostegus	A
Ctenochaetus striatus	A
Zebrasoma scopas	C
ZANCLIDAE	
Zanclus cornutus	R
BOTHIDAE	
Bothus mancus	O
BALISTIDAE	
Rhinecanthus aculeatus	O
Sufflamen chrysoptera	O

MONACANTHIDAE	
Oxymonacanthus longirostris	O
TETRAODONTIDAE	
Arothron meleagris	R
Canthigaster solandri	R

Number of Families : 20
Number of Species : 72

FAMILY/Species	Rank
HOLOCENTRIDAE	
Myripristis murdjan	O
SCORPAENIDAE	
Synanceia verrucosa	R
SERRANIDAE	
Cephalopholis argus	R
Epinephelus cyanopodus	C
E. merra	O
APOGONIDAE	
Apogon cyanosoma	A
A. leptacanthus	A
Cheilodipterus quinquelineata	O
LUTJANIDAE	
Lutjanus bohar	R
MULLIDAE	
Parupeneus barberinus	R
P. cyclostomus	O
P. pleurostigmus	O
CHAETODONTIDAE	
Chaetodon auriga	O
C. ephippium	R
C. lunula	R
C. trifasciatus	C
C. vagabundus	O
POMACANTHIDAE	
Centropyge flavissimus	O
C. vrolicki	R
POMACENTRIDAE	
Amblyglyphidodon curacao	A
Chromis agilis	C
C. margaritifer	O
C. ternatensis	C
C. viridis	A
Chrysiptera traceyi	R
Dascyllus aruanus	A
D. trimaculatus	C
Pomacentrus coelestis	A
P. vaiuli	O

LABRIDAE	
Cheilinus fasciatus	O
C. undulatus	R
C. unifasciatus	C
Cirrhilabrus sp.	O
Gomphosus varius	C
Halichoeres marginatus	R
H. melanurus	C
H. trimaculatus	C
Hemigymnus melapterus	R
Labrichthys unilineatus	R
Labroides bicolor	R
L. dimidiatus	C
L. pectoralis	O
Macropharyngodon meleagris	R
Novaculichthys taeniourus	R
Stethojulis bandanensis	C
Thalassoma amblycephalum	A
T. hardwickii	R
T. lunare	C
T. lutescens	C
SCARIDAE	
Scarus forsteni	O
S. frenatus	R
S. niger	R
S. oviceps	O
S. rubroviolaceus	O
S. schlegeli	O
S. sordidus	O
MICRODESMIDAE	
Ptereleotris microlepis	A
ACANTHURIDAE	
Acanthurus nigricauda	O
A. pyroferus	O
A. xanthopterus	R
Ctenochaetus striatus	A
Naso lituratus	R
BALISTIDAE	
Balistipus undulatus	O
Odonus niger	O

Number of Families : 14
Number of Species : 64

FAMILY/Species	Rank
MURAENIDAE	
Sideria prosopeion	R
HOLOCENTRIDAE	
Myripristis murdjan	R
SERRANIDAE	
Epinephelus merra	C
CIRRHITIDAE	
Paracirrhitus arcatus	R
APOGONIDAE	
Apogon nigrofasciatus	O
Cheilodipterus quinquelineata	O
LUTJANIDAE	
Lutjanus fulvus	O
NEMIPTERIDAE	
Scolopsis lineatus	C
LETHRINIDAE	
Gnathodentex aureolineatus	O
Monotaxis grandoculus	R
MULLIDAE	
Mulloides vanicolensis	R
Parupeneus barberinus	O
P. cyclostomus	O
P. multifasciatus	O
CHAETODONTIDAE	
Chaetodon auriga	O
C. citrinellus	R
C. ephippium	O
C. lunula	R
C. raflesi	O
C. trifascialis	O
C. trifasciatus	C
C. vagabundus	O
POMACANTHIDAE	
Centropyge flavissimus	R

POMACENTRIDAE	
Amphiprion melanopus	A
A. tricinctus	R
Amblyglyphidodon curacao	R
Chromis atripectoralis	A
C. margaritifer	R
C. viridis	A
Chrysiptera leucopoma	O
Dascyllus aruanus	A
Plectroglyphidodon dickii	C
P. johnstonianus	R
P. lacrymatus	O
Pomacentrus coelestis	A
P. vaiuli	O
Stegastes albifasciatus	A
S. nigricans	A
LABRIDAE	
Cheilinus chlorourus	O
C. undulatus	R
Gomphosus varius	C
Halichoeres hortulanus	O
H. margaritaceus	R
H. marginatus	O
H. melanurus	R
H. trimaculatus	C
Hemigymnus melapterus	O
Labrichthys unilineatus	R
Labroides dimidiatus	O
Pseudocheilinus hexataenia	R
Stethojulis bandanensis	O
Thalassoma amblycephalum	C
T. hardwickii	O
T. lunare	O
T. lutescens	C
T. purpureum	R
T. quinquevittatum	R
SCARIDAE	
Scarus oviceps	R
S. rubroviolaceus	C
S. schlegeli	C
S. sordidus	A
PINGUIPEDIDAE	
Parapercis clathrata	R
BLENNIIDAE	
Plagiotremus tapienosoma	O
GOBIIDAE	
Valenciennea sexguttatus	O

ACANTHURIDAE	
Acanthurus nigricans	R
A. nigricauda	R
A. triostegus	A
Ctenochaetus striatus	A
Naso lituratus	R
Zebrasoma scopas	C
Z. veliferum	O
SIGANIDAE	
Siganus argenteus	R
BALISTIDAE	
Balistipus undulatus	R
MONACANTHIDAE	
Oxymonacanthus longirostris	O
TETRAODONTIDAE	
Canthigaster solandri	O

Number of Families : 22
Number of Species : 75

APPENDIX G

RESOURCE USERS SURVEYS FOR MĀJRO ATOLL, REPUBLIC OF THE MARSHALL ISLANDS

prepared by

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INTRODUCTION

The Republic of the Marshall Islands (RMI) has embarked on a period of development which is attempting to meet the needs of a growing population and develop a self-sufficient economy. Like most of Micronesia, the bulk of the easily developable land and other resources lies within the coastal area. Using coastal resources requires careful planning so that non-renewable resources are used judiciously and renewable resources are exploited on a sustainable basis. This is especially true in the Marshall Islands where atolls are primarily coastal areas.

In order to carefully plan for the use of coastal resources, the RMI government requested technical assistance from the U.S. Army Corps of Engineers Pacific Ocean Division, Environmental Branch and the University of Hawaii Sea Grant Extension Service. In response, Sea Grant Extension Service, under the sponsorship of the Corps of Engineers, conducted coastal resource inventories of Majro and Arņo atolls.

An important part of the resource users survey was to gather information regarding the distribution and use of coastal resources. Because of the lack of records on resource use, the primary method for gathering this information was through interviews with atoll residents.

This report details the results of interviews with fishermen on M̄ajro Atoll. These artisinal and part-time commercial fishermen are the users of M̄ajro's living marine resources, the atoll's most important coastal resource. This report is one of several which have been compiled for the M̄ajro Atoll Coastal Resource Inventory. The inventory is to be used in conjunction with the M̄ajro Atoll Coastal Resource Atlas published by the U.S. Army Corps of Engineers in 1989. The inventory report presents in greater detail the data graphically displayed in the atlas.

Background

M̄ajro Atoll is one of the thirty-four atolls and islands that make up the Republic of the Marshall Islands (RMI). Located in the Ratak (sunrise) or eastern chain, M̄ajro has a dry land area of approximately 3.7 square miles surrounding a lagoon of approximately 113 square miles (Stanley, 1985). M̄ajro is the capitol of the RMI and the Republic's most urban atoll. The population of M̄ajro is 19, 695 according to a 1988 census (Marshall Island Journal, 1988). The Teļap (Delap), W̄ulka (Uliga), and Jar̄oj (Djarrit) area, hereafter referred to as urban M̄ajro, is the commercial and governmental center of M̄ajro as well as its population center. Urban M̄ajro is located at the eastern end of the atoll (see Figure 1.).

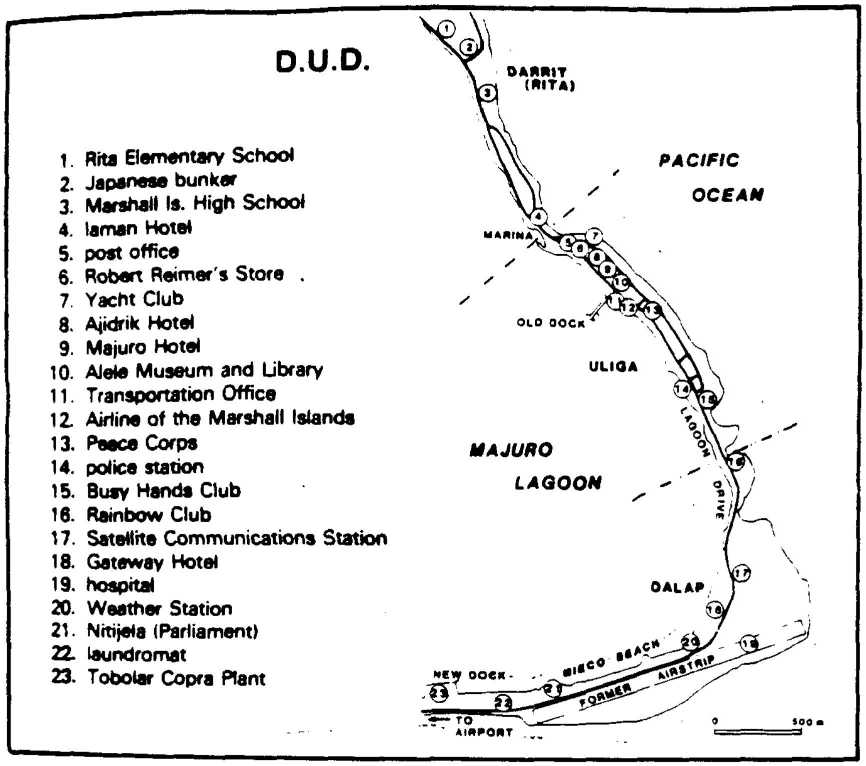

Figure 1. Urban Mājro.

The southern islets are connected by a thirty-one mile-long paved road, which connects the islands in urban Mājro to Mājro Island.

The Republic of the Marshall Island's international airport is located on Mājro Atoll approximately halfway between urban Mājro and Mājro islet (Laura). The 6,000 foot reef runway is large enough to accomodate Boeing 727 jets. Mājro is served by Continental/Air Micronesia with flights four days a week from Guam and Honolulu.

RMI's commercial harbor is also located on Mājro Atoll in the urban Mājro area. Most of RMI's consumer goods and imported food arrive via ship.

Tourism is one of the economic activities which the RMI government would like to develop (RMI, 1985). There exists an opportunity to develop the atoll as a tourist destination because of the relative ease of travel from Guam and Honolulu, its year-round warm climate, and some of the world's best diving. However, because of the high cost of travel to Mājro, the lack of first class tourist facilities, and the general unattractive appearance of its urban areas, Mājro's potential remains unrealized.

Commercial fishing is another area for development. The government is seeking to promote Mājro as a fishing base and transhipment point for fish. At present, Mājro supports a small-scale commercial fishery which primarily serves the retail and restaurant markets (Milone at al., 1985).

The development of both the tourism and fisheries sectors can create employment opportunities for the local population. However, it can also cause problems such as crowding and depletion of nearshore fisheries resources if not carefully planned for.

Inventory and Resource Users Survey

Rational development, which maximizes benefits while minimizing costs, takes place after careful consideration of relevant information. Resource inventories supply some of the needed information. Important questions to ask are, "what types of development are being considered and where?" so that relevant information is gathered. This is especially true for the Marshall Islands Coastal Resource Inventory since time and funding are limited.

Prior to undertaking the resource inventory, a list of planning issues dealing with development projects for Mājro Atoll was drafted by the RMI government. The types of data needed and field activities necessary for addresssing the issues were decided on by the survey team and compiled into a work plan approved by the RMI government prior to engaging in data collection. The resultant work plan summarized in Table 1 guided the individual efforts of the survey team members.

The inventory included marine and terrestrial field surveys as well as interviews with fishermen. Survey sites as well as villages in which the interviews took place are depicted in Figure 1. The results of the marine and terrestrial surveys can be found elsewhere in the appendix section of the Mājro Atoll Coastal Resource Inventory report.

Interviews with fisherman took place in the two main areas of Mājro atoll, urban Mājro and Mājro (Laura) islet. Fishermen are one of the prime users of the atoll's most important coastal resource, fishery products. Interview questions were based on consideration of the planning issues chosen for Mājro atoll.

METHODOLOGY

Throughout Micronesia, adequate records and documentation of resource use, particularly fisheries information, are lacking. The RMI government has only recently begun to collect commercial fishing statistics. There are no records of the subsistence catch which on Mājro makes up the bulk of the fishing effort, and little in the way of any other documentation (Milone, et al, 1985). Consequently, information pertaining to fisheries was obtained from Mājro Atoll's fishermen during a series of interview sessions. This method has proven successful in extensive fishery interviews conducted by Johannes (1981) in Palau. An abbreviated interview method was subsequently utilized by Holthus (1987) to prepare a draft Pohnpei Coastal Resource Management Plan. This technique has since been incorporated into coastal reef inventories on Kosrae (U.S. Army Engineers, 1989), Yap (Orcutt et al, 1989) and Kwajalein (Titgen et al, 1988).

During a six day period from July 21-26, 1988, groups of fishermen from the main population centers on the atoll were interviewed. The dates, places and names of all the interviewed participants are listed in Appendix 1. Micronesian social values view fishing as primarily a man's task, consequently all interviewees were male.

Prior to the interview sessions, a list of popularly harvested fisheries resource was developed by the authors in consultation with Mr. Michael Molina, fishery consultant to the RMI and Federated States of Micronesia and a member of the inventory survey team. The list developed for Arno was based on a list developed earlier by Ms. Anne Orcutt and Mr. Virgil Alfred used in the Kwajalein coastal resource studies (see Titgen et al, 1989). Included in this list were Marshallese and common names for each of the species chosen. For simple demarcation on the maps during the interview session, numbers were assigned to each item on the list. This list, Table 2, served as a working template with subsequent additions and deletions of items as the interviews progressed.

Each of the interview sessions was conducted in Marshallese and English. Each interview was conducted by Peter Rappa and Virgil Alfred with Alfred acting as translator/interpretor for the portion conducted in Marshallese. Each session began with a brief introduction describing the scope and goals of the project. A copy of the Pohnpei Coastal Resource Atlas (Manoa Mapworks, 1985) was passed around as an example of the final product that would result from the interviews and surveys. Fishermen were then asked to mark ranges where the particularly desirable fishing area for each item could be found. Numbers corresponding to the particular marine species under consideration were then placed on maps by the fishermen. The fishermen were also queried about the gear and methods used for fishing, the relative abundance of the item in the particular area under discussion, and seasonal or daily variations of that species.

In addition to the listed fisheries items, the fishermen were asked to give their opinions to a series of questions about fisheries resources and about development projects which might be located in the vicinity. The questions are listed in Table 3. Each interview session took approximately four hours to complete.

Fishing Methods

Marshallese fishermen employ a number of techniques and gear to harvest living marine resources. Gear and technique use is dictated by the type and amount of fish sought, weather conditions, and seasonality. During the interview with fishermen from Arņo and Mājro atolls and subsequent discussions with fisheries officers from the Marshall Island Marine Resources Authority (MIMRA), ten different types of gear or techniques were identified. Each of them is described briefly below:

1) Pole & line. Pole and line is a traditional fishing technique still in use today. Tobin (1958) refers to it in his examination of marine property rights in the Marshall Islands. Fishermen stand in water waist deep and cast their line towards the edge of the reef. The poles can be anywhere from three to seven feet long with the line attached at the end. The line has one hook, usually baited. This technique is used to catch reef fish and shallow water snappers.

2) Handline. As the name suggests, a line is held in the fisherman's hand and dropped or thrown in the area to be fished. When a strike is made on the single hook, the fisherman jerks the line to set the hook and pulls the fish in. Up to 100 feet of line, which may be wound around a stick or a wooden or plastic frame, is used. The line may have a sinker attached. Handlines are used both from shore or a boat. The strength of the line ranges from 20 lb. - 40 lb. test.

This method is reportedly used to catch groupers, snapper, emperors and other deeper dwelling reef fish.

3) Trolling. Trolling is done from a moving fishing vessel usually oceanside of the perimeter reef. A line is paid out from the aftersection of the vessel and pulled through the water. The line, usually 80 lb. test but sometimes as low as 40 lb. test, can be attached to a rod & reel or be held by the fisherman. In general, trolling is used to catch pelagic species such as tuna, dolphinfish or wahoo. This method is usually done from a powered craft.

4) Cast Net. Cast nets are used by a single fisherman in shallow reef areas. The net with an eye size of approximately one inch is thrown or cast over a school of fish and then gathered in. Nets were made of traditional materials in the past but are now made of nylon monofilament.

5) Gillnet. Gillnetting is a relatively new technique but is among the most popular. A single fisherman may spread the net out in a favored fishing spot, wait a period of time then pull it in or use it as a surround net to capture whole schools of reef fish. The nets are usually made of nylon monofilament with no limit on eye size.

6) Alwelwe. The Alwelwe is a traditional style of harvesting a great deal of fish for special occassions. A net is made from coconut palm fronds strung together with a twine made from the pandanus root. The net may be as long as 1/2 mile and require the cooperation of thirty or more able- bodied men.

7) Spearfishing. Spearfishing is done either during the day or at night with a flashlight. Spearfishing has become one of the most popular means of harvesting fish. Skin divers may use a pole spear, which is a metal or fiberglass shaft with a three prong spear head attached on one end and a piece of looped surgical tubing on the other, or a homemade or manufactured speargun. The skin diver can spear a myriad of reef and shallow water snappers and groupers in a single session.

8) Vertical Longline. Vertical longline is used mainly to catch yellowfin tuna, marlin, and sailfish. The longline consists of a line with a single baited hook attached to one end and a heavy sinker attached up-line from the hook. A 300-400 lb. test line is attached from the hook to the sinker. A very heavy polypropolene rope is attached from the sinker to the boat. Up to 50 fathoms of line may be used. The line is worked by hand or mechanical reel.

9) Scoop/hoop net. Scoop nets are circular or hoop shaped nets attached to long handles. The hoop is made out of aluminum, galvanized metal, or woven from the fiber of the pandanus root. A small basket net made of fiber or monofilament is woven onto the hoop. The hoop is attached to a wooden handle made from tree branches with the bark peeled off. The handle may be 3-4 yards long. The scoop net is popular for catching flying fish and some reef fish such as rabbitfish, rudderfish and sometimes parrotfish. The scoop is used at night with a torch or flashlight to attract and catch flying fish.

10) Bottomfishing. Similiar to handlining. This method is used to fish deeper reef areas for grouper and snapper. Line is hand held and lowered into deeper areas along the reef drop-offs. A single baited hook is used per line.

In addition to the gear and techniques outlined above, the Marshallese also built stone fish traps or weirs. Fishermen from Mājro islet reported using traps near the islet of Ron̄ron̄, but no traps were visible from there. According to Tobin

(1958) this method was once important in the economy but has fallen into disuse. Interviews with local fishermen seem to bear this out as fishtraps were mentioned only once as a current fishing technique.

Of the different types of gears and techniques, spearfishing, gillnetting and bottomfishing were mentioned as the preferred and most frequently used methods for catching reef fish. Many fishermen still use the pole and line method, however, based on fishermen's comments it appears that other methods are beginning to replace pole and line fishing such as spearfishing or netting.

Trolling is by far the favorite method for catching pelagic species on the oceanic and lagoon sides of the atoll. The Marshallese exhibited a preference for reef fish, however, and thus did not spend much time trolling for the large pelagic fish. However, boat owners from urban Mājro reported spending most of their time fishing using the trolling method. Milone and his colleagues pointed out in their 1985 report that the principal fishing method employed by fishing vessels was trolling.

The traditional method called alwelwe is used very rarely today. This method was used for catching great quantities of fish during feasts, holidays or other special occasions but has been replaced by other methods such as surround nets. It is interesting to note that various forms of this traditional fishing technique are used throughout the Pacific Islands. Johannes (1981) reported a similiar technique known as "ruul" in Palau and "hukilau" in Hawaii. Ashby (1985) reports that on the island of Kosrae in the Federated States of Micronesia fisherman used the "koamule" a method described as being similiar to the "alwalwe" used on Kwajelein. In all these areas the use of this method has greatly declined.

Table 2. Key to fish names in the resource users surveys.

Number	Marshallese Name	Common Name
1.	Bwebwe Lojabwil	Skipjack tuna Yellowfin tuna
2.	Al	Wahoo
3.	Koko	Dolphinfish
4.	Jure Jujukop Niitwa	Barricuda
5.	Lojkaan Lojkaan Lojkaan Wujinleep	Billfish Marlin Swordfish Sailfish
6.	Jojo	Flying Fish
7.	Looj	Frigate Tuna
8.	Lane Deltokrok Ikbwij Dedep	Jackfish
9.	Ikaidik	Rainbow Runner
10.	Pati	Mackeral Scad
11.	Kuro Lojepjep Ojalo Jawe Pooklim	Groupers
12.	Kentol	Sweetlips
13.	Jato Jeplo Jaj	Snappers
14.	Dijin Not Weo Mejmej Mojani	Emperors

Table 2. Key to fish names used in the resource users surveys (cont'd)

Number	Marshallese Name	Common Name
15	Jera Mǭn Malij	Squirrelfish
16.	Merā Ekmouj	Parrotfish
17.	Bwilak M̧ǫņe Kwi Ael Kupan̄	Surgeonfish
18.	M̧ǫle	Rabbitfish
19.	Iōōļ	Mullet
20.	Jo Jome	Goatfish
21.	Ļappo Likōb Dāpijdekā	Wrasses
22.	Pājrōk	Rudderfish
23.	Im̧im̧ Būb Liele	Triggerfish
24.	Jerwōt	Flagtail
25.	Māj Dāp	Eels
26.	Bobed Pajōj	Fusiliers
27.	Ļwōl	Bigeye
		Non Fish Resources
30.	Mejānwōd Tōtwōd Dimuuj Kapwor	Giant Clams

31.	Likōppejdat	Trochus
32.	Aorak	Conchs
33.	Jidduul	Turbans
34.	Bukbuk	Helmets
35.	Kweet	Octopus
36.	Nōt	Squid
37.	Wōn	Turtles
38.	Wōr	Lobster
39.	Baru Atūn Baru Waan	Land Crabs
40.	Barulep	Coconut Crabs

Table 3. Interview questions for Majro's fishermen

Each of the following questions was asked of each of the items on the marine resource list:

1. Where do you catch this particular fish (or other marine animal?). Please indicate on the map by writing the number that corresponds to the fish.
2. When is the best time of the year to harvest this fish?
3. When is the best time of the day to harvest this fish?
4. What is the best method(s) to harvest this fish? What gear do you use?
5. How often do you fish for this particular fish (How many times of the week or month do you go out to catch this fish)?
6. When you fish for this kind of fish how many do you usually catch?

In addition, the following questions were asked during each interview session:

1. In your opinion, is fishing here the same, better, or worse than 10 years ago.
2. What kind of fish, if any, that you used to catch can no longer be found in this area? Please name them.
3. In your opinion why do you think you no longer see them?
4. Do you sell any fish?
5. Is there any fish you would not sell?
6. How do you feel about having more tourists coming to Majro?

RESULTS

General Findings:

Fishing is one of the most intensive uses of coastal resources on Mājro. However, it seems to be carried out intensively by a smaller percentage of people than on Arņo atoll. Many people are employed in the cash economy and no longer rely on catching their own fish. Fresh and frozen fish is generally available in the retail stores in urban Mājro. However, many Marshallese still fish to supplement their diet by targeting particularly favored fish or for recreational purposes. Many men could be seen wading into the lagoon daily to catch fish using pole and line.

It is estimated that Micronesians depend on marine resources for 90% of their animal protein (Johannes, 1988). Although no data on protein intake exists for Mājro Atoll, a household survey conducted in Yap, FSM in 1986 found that fresh fish accounted for 75% of the daily protein consumption by weight (Yap, MRMD, 1986). It is likely that a similiar figure would be obtained for Mājro. However, unlike their Yapese counterparts, Mājro residents catch a smaller proportion of their fish for themslves reportedly obtaining 27 percent of their fish as canned imports (JICA, 1983)

Many fishermen on Mājro Atoll are involved in commercial fishing as a livelihood. Although there were no records as to how many people fish for a living, many of the fishermen from Mājro Island stated that they receive most of their income from the sale of fish. Thus, it seems that a small scale fishing industry is thriving on Mājro.

A question exists though as to whether the fishery can be sustained. In both interviews, fishermen mentioned that the mollusc populations had declined greatly in the last decade. They stated that trochus, turban, and others had become depleted through overharvesting. Could the same be happening to reef fish? The interviewees didn't think so but there are no records on which to base a judgement on. Fishermen from Mājro islet stated that they see fewer mullet today than ten years ago.

Because there is an active commercial reef fishery, maintaining the sustainability of the fishery should be a high priority of the local and national government.

Boat fishermen noticed no change in their catch over the past decade. Most felt that resources were so plentiful that the small number of fishermen involved could not seriously deplete the resource.

SECTORAL FINDINGS

The result of the two fishermen interviews held on Mājro Atoll are summarized in Appendix 2. These interviews formed the basis of the fisheries information depicted on the Mājro Atoll Coastal Resource Atlas. A more detailed description of the information obtained during the interview including information of special note will be presented in this section. This information will add greater description to the general patterns graphically depicted on the atlas. All fish cited in this section will include next to them in parenthesis the corresponding Marshallese fish name.

Urban Mājro

This is the most heavily populated area in the Marshall Islands with the exception of Epja (Ebeye) Island. It is also home to two types of fishermen, powered vessel owners who berth their vessels in this area and more traditional reef fishermen. Each group was represented during the interviews. A total of four fishermen took part in the interviews from this area.

Boat owners were more knowledgable about pelagic fish. They troll for all the large gamefish such as skipjack tuna (bwebwe) yellowfin (lōjabwil), dolphin fish (koko), wahoo (al), and marlin (lōjkaan). Fish aggregating devises are used regularly by local fishermen. Most of the fish that is caught is sold to restaurants.

Reef fishermen reported that the waters between Mājro and Arņo are a rich fishing area for the flying fish (jojo). Jackfish (ļāne, deltokrōk, dedep, ikbwij) are caught incidently by boat fishermen. Reef fishermen catch jacks throughout the lagoon using spear fishing techniques. The mackerel scad (pati) was reported to be caught by rock fish trap, out near Rǫn̄rǫn̄ Island in the western portion of the atoll. This was the only fish reportedly caught in this manner. Mullet (iōōl) used to be caught near the airport during low tide using a scoop net but this has not been the case since completion of the runway.

Wrasses (ļappo, likōb, dāpijdekā), triggerfish (iņiņ, bub, liele), flagtail (jerwot), fuisilier (bobed, paļōj) are not preferred. All others seet are harvested all year round.

Mollusks such as giant clams (mejānwōd, tōtwōd, dimuuj, kapwor), conch (aorak), turbans (jidduul), helmets (bukbuk) and trochus (likōppejdat) used to be plentiful according to the participants, but are rarely seen today due to over harvesting. Lobster (wōr), turtle (wōn), and land crabs (buru, atūn̄, baru waan), also were plentiful at one time but scarce today.

Fishermen reported that they feel there will soon be no more reef fish because fishing pressure is too great in the area. Boat fishermen reported that catch was as good as ever and that there are no signs of decline in catch.

All fishermen reported were indifferent to the expansion of tourism although the boat fishermen felt that they could earn more charters with increased tourism.

Mājro Islet (Laura)

This is the more rural end of the island. It is the western terminus of the causeway which connects the southern islands in the atoll. The dozen or more fishermen who gathered (only six accepted an invitation to sign-in) to take part in the interview said that the reef north of Mājro islet was a good spot for fishing. They reported most fish commercially as well as for personal consumption. They estimated that as many as 150 people in this area fish. Most derive all or a large part of their income from the sale of fish.

Fishermen reported that they fish tuna (lōjabwil, bwebwe) almost every day during the winter months. It is plentiful during this time, they can sell it as fresh or processed fish or use it for home consumption. They don't fish for other pelagic except the barracuda (jure, jujukōp, n̄iitwe) during the winter season.

Flying fish (jojo) are a popular species for both personal consumption and sale. During the months of June-August in the western end of the atoll and during the months of February-June in the southern end fishermen fish for them using a lantern and scoop net especially on night with no moon.

Mackerel scad (pati) are trapped in shallow areas during the summer on the reef flats when they are likely to be found in big schools.

Snappers (jato, jeplo, jāj) are a popular target species especially for spear fishermen who go out almost every night for them.

The very best and most sought after are the reef fish. Fishermen reported having an affinity for emperors (dijin̄, nōt, weo, mejmej, mōjani), squirrelfish (jerw, mon, malij), surgeonfish (bwilak, mōn , kwi, ael, kupan̄), rabbitfish (mole), mullet (iōōl), goatfish (jo, jome) and rudderfish (pājrōk). The rabbit fish (mole) and mullet (iool) were deemed to be the best. Parrotfish (merā, ekmouj) are not highly prized because they are not as oily. As in urban Mājro area wrasses (lappo, likōb, dāpijdekā), triggerfish (imim, būb, liele), flagtail (jerwot), fuisiliers (bobed, palōj) are not preferred and are rarely taken thought plentiful.

The situation with mollusks is similar to urban Mājro with all types being reported as depleted.

Octopus (kweet) is caught for bait for bottomfishing and occasionally eaten. Lobster (wōr) were caught in the northern island, from Ro̧n̄ro̧n̄ to Teļap on request from restaurants.

Fishermen said they don't believe this area will be over harvested. They intend to go on catching and selling fish until they are too old to do so. Most fishermen own cars and other consumer goods with money they receive from the sale of fish.

Most fishermen had no opinions of tourists other than it might increase the sale of fish to restaurants.

Impact of Proposed Development on Fishing Resources

Seven planning issues calling for some type of developmental activities on Mājro Atoll were indicated by the RMI national government and are summarized in Table 1. Each of the seven have the potential for affecting fishing resources either in a positive or negative manner. Each of the potential impacts on fishing resources will be analysed in this section.

Commercial Fishing

This activity has the greatest potential for impacting fishing resources. The Marshall Island Five Year Development Plan (RMI, 1985) has as one of its goals that "all potential resources must be exploited both to the maximum possible capacity and to the maximum level of efficiency".

Fishermen on Mājro Atoll are actively involved in a small-scale commercial fishery. The potential problem with the reef fishery is that there are no data on the size of the stocks and sustainable yield of the fishery. Inshore fishery stocks are highly susceptible to over-exploitation to the point of where the fishery could collapse (Kearney, 1979). Furthermore, there are few management regulations on the taking of marine resources in the RMI and no traditional tenure system in force that would limit commercial harvests (Tobin, 1958). Thus the possibility exists that the reef resource may be overfished.

Overfishing is a particularly damaging impact on living marine resources. However, it can be avoided by instituting data collection programs and undertaking periodic stock assessments. Longer term measures would include the promulgation of fishing regulations based on the analysis of collected data, institution of marine parks and reserves and the creation of a management plan for the use of marine resources.

Large scale commercial development of pelagic fishery resources is another possiblity. However, due to the lack of infrastructure required for a maintaining a distant water fleet such as shoreside storage facilities, boat repair facilities, and trained crews, it is doubtful that this type of commercial fishing will have an impact on pelagic resources in the near future.

Tourism Development

Tourism's impact on fisheries resources on M̄ajro would vary from very miniscule to very great depending on the scale of tourism developed.

Small scale facility development the kind that is taking place already on M̄ajro will probably have a very minor negative impact on fishing resources. It could have an overall positive impact by creating a larger local market for fresh caught fish. A strictly enforced ban on the taking of marine life by tourists could mitigate any possible conflicts between visitors and subsistence and commercial fishermen and help protect the resource.

Large scale mass tourism with large resort construction could have a very deleterious impact on living marine resources. Short term construction impacts especially increased sedimentation would cause longer term impacts on reef habitats thereby decreasing the fish population. Conflicts may arise between fishermen and recreationalists over the use of lagoonal or oceanic waters. Hotels could block access to favorite fishing spots.

Currently there are no plans for large scale resort tourism in the Marshall Islands development plans.

Docks and Boat Harbors

Most of the RMI's consumer goods and imported food come via ship. The government recently completed development of the main port facilities for the RMI in M̄ajro outside of Teļap. If M̄ajro is to become a fishery transhipment center, more dock space will be needed. A dry dock facility and a larger fueling and cold storage will also have to be developed. These major facilities will have little direct impact on the fisheries resources in M̄ajro lagoon if they are developed in the area of the present marine facilities. The area has already undergone major modification due to construction of the present facilities. The present facilities are located in an area where little fishing is now done. Confining any new construction to this area will limit direct impacts.

A second area of concern will be oil spills from vessels in the lagoon. If more vessels visit M̄ajro, oil spills are likely to become more commonplace. Oil spills could have an adverse impact on fisheries resources. An emergency response procedure should be developed to respond to this potential hazard. Emergency procedures should be considered an important part of an eventual coastal management plan for Majro atoll.

Marine Parks

Several areas within Mājro lagoon were examined for their suitability as marine reserve areas. The question of the suitability of the sites is the subject of a separate report. The potential impacts to fishery resources resulting from the creation of marine parks or reserves varies depending on the size of the park and the regulations placed on its use.

Closing off or totally banning fishing in the Mājro islet area would be an undue hardship to the fisherman there. Banning commercial fishing in the marine parks may be a reasonable alternative to a total ban. It would have little impact on present uses since the fishermen fish primarily for susistence.

There are areas that are less used for fishing. These include the area around the northern islets especially Irooj because it is near the main passage into Mājro lagoon and is very often too rough to be reached by small boat. Areas like these could be set aside as marine parks with little impact on fishing should a total ban on fishing be placed.

Marine parks and reserves should be considered as a part of island resource management strategy because it has proven successful in preserving unique environments and protecting fishing stocks (White, 1986). The creation and regulation of marine parks and reserves should be considered as one of the issues to be taken up in a coastal resource management plan.

Coastal Residential Development

Crowded conditions in urban Mājro has forced residents to build near or on the shoreline on both the lagoon and ocean sides of the atoll. Problems caused by shoreline development on the lagoonside included increased sedimentation, increased solid waste and effluent disposal into the lagoon, and habitat destruction due to filling and dredging for fill material.

Land clearing (grubbing) or removal of natural shoreline protection such as dune structure exposes soil to wind and rain. These elements increase soil runoff into the lagoon which in turn leads to the destruction of reef fish habitat.

Solid waste and effluent created by residential development could find their way into the lagoon or along the shoreline. Present sanitation practices are inadequate to handle the present situation. The extent to which solid waste and effluent disposal into the lagoon impact fish population was not studied during the present survey. However, fishermen cited pollution as one of the reasons they feel fewer fish are caught in the urban Mājro area.

Dredging and filling present the most devastating impacts on fishery habitats and thus, on fishery resources. Dredging works directly destroy nearshore fish habitats while causing an increase in suspended particles which in turn affects a larger area. Fill, especially when carried out improperly, increases sedimentation and will continue to do so as long as the fill material is exposed to erosional forces.

Each of these activities should be regulated by zoning and building restrictions.

SUMMARY AND RECOMMENDATIONS

Mājro is the capital and metropolitan center of the Republic of the Marshall Islands. Its population of 19,695 on 3.5 square miles makes up nearly 50% of the entire population of the RMI.

Fishing is no longer the most important activity on this atoll as in the more rural areas although there are a number of fishermen in the Mājro Island area. The availability of goods through retail stores combined with a fledgling cash economy makes obtaining food from the ocean less appealing.

There is a market for fresh and frozen fish in Mājro because many people no longer have the time to fish or have limited access to good fishing spots. Many fishermen have become part time commercial fishermen as well as fishing for their own needs.

In addition to the part-time small-scale reef fishermen, a number of Mājro residents own motorized fishing vessels and fish part-time for pelagic species such as tuna, marlin, wahoo, and dolphin fish as well as hire out as charter fishing vessels for recreational fishing. These part-time fishermen supply restaurants as well as retailers with fresh fish.

A fishing co-op was in existence from 1978-1982. During the five years of its existence 381,000 lbs. of fish were caught worth $221,000. There are no other records of commercial catch after this time. There are no full time commercial fishermen today. A high seas fisheries exist but it is mostly worked by Japanese, Taiwanese and Korean fishing boats under license to the RMI.

Fishermen use a number of methods on Mājro to catch reef and pelagic species inside and outside the lagoon. Favored methods include spear fishing, gill netting, bottomfishing, hand line, and pole and line. Trolling is the preferred method of fishing by boat owners. They rarely fish for reef species with the exception of gathering bait.

Reef fishermen from both urban Mājro and Mājro (Laura) area felt that the fishery has declined in the last 10 years. Fishermen pointed out that there are fewer lobsters, trochus, turbans, octopus and other marine organisms seen today especially in urban Mājro. Fishermen attribute the decline to overfishing and water pollution especially around urban Mājro. Boat fishermen feel that the pelagic resources have not declined and that they are catching as many fish now as ever.

All fishermen on Mājro sell part of their catch to retailers and prefer to continue to do so. Fish is reported to be the main source of income for Mājro Island residents.

Most fishermen would not be bothered by the prospect of more tourists. Boat owners feel they could charter their vessels out more often. Others feel that there would be a better market for their fish.

Recommendations

The following recommendations apply to the area of fisheries management and are based on ideas generated during interviews with fishermen and with fishery personnel on Mājro Atoll.

1. ENHANCE SMALL SCALE RECREATIONAL AND SUBSISTENCE FISHING IN URBAN MĀJRO.

Most of Mājro's population is concentrated in this area. Many residents, especially those from outer atolls, fish for both recreational and subsistence purposes. Yet fishing in the urban Mājro section of the lagoon has declined in recent years due to lack of water circulation caused by the construction of the causeway, flushing of non-point pollution into the lagoon, unrestricted building and dredging and filling along the shoreline. A first step to enhance the area might be to open the lagoon to the ocean by creating more openings in the causeway, as recommended in a related Inventory Report on Water Circulation (see Rosti, 1989).

Another measure is the regulation of dredging, filling and shoreline construction on the lagoon side of all islands by creating a special management zone in urban Mājro. The zone could include all lagoon area to 200-300' shoreward of the high tide line. Within the area, special building regulations would govern the type of structures, time of year they could be built, what methods can be used to extract materials, and the imposition of mitigative measures.

Finally, institute better sanitation practices. Open dumps and refuse not disposed of properly often end up in the lagoon. Chemical leachates from poorly regulated land fills or poorly maintained septic systems have a negative impact on fish populations.

Removing these hazards and improving the lagoon's flushing characteristics should improve the fishing potential in the long run.

2. ENCOURAGE CHARTER BOAT INDUSTRY.

The waters around Mājro Atoll and nearby Arno atoll teem with big game fish. These fish are not in great demand by the artisanal fishermen and could be harvested by travelling big game fishermen. Loan programs to local entrepreneurs and help in marketing a service are two parts of a program that could encourage the growth of this industry.

3. DEVELOP NATIONWIDE FISHERIES MANAGEMENT PROGRAM.

Legislate or mandate a program of fisheries management that would include:

A. DEVELOPING THE MANAGEMENT SKILLS OF FISHERIES MANAGEMENT PERSONNEL.

The Marshall Island Marine Resources Authority (M.I.M.R.A.) has group fisheries officers who are knowledge in fish behavior, fisheries methods, and the behavior of the Marshallese fishermen. Many were eager to take part in our survey activities and learn from their experience. The government does invest resources in training highly motivated personnel in regional programs. However, these are responses to opportunity offered by other external agencies. M.I.M.R.A. should design a curriculum or course in which each candidate for a position within fisheries must complete. Course work would take place at regional centers such as at U.S.P., S.P.C., Universities of Guam and Hawaii and be interspersed with field training at home.

B. DEVELOP FISHERIES MANAGEMENT REGULATIONS.

Unregulated use of common property resources leads to their being over exploited. This problem may already be occurring in Mājro based on comments from fishermen and can happen on other atolls in the future. Adopting some form of traditional fishery management practices as suggested by Johannes (1988) could be a starting point. After a period of record keeping and analysis other types of management practices such as size limitation and use of reserve areas could be phased in as needed.

C. MAINTAIN DATA COLLECTION FOR COMMERCIAL FISHING AND DEVELOP METHODS FOR ESTIMATING ARTISANAL CATCH.

The government has recently instituted a data collection system for commercial fish catch. Maintaining the collection of data over a long period of time is the first step in managing fish stocks. The next step is to analyze the data in order to predict trends and sustainability of fish stocks. This important step requires training fishery personnel as recommended in Step A.

Beyond commercial catch statistics, there are ways to estimate fish stocks in areas without a commercial component. This information could enhance the potential of starting small scale commercial operations in the outer atolls. It would help determine sustainable yield on at least a few key species while at the same time give the subsistence component of the fishery some protection against overharvesting.

D. DEVELOP A FISHERIES MASTERPLAN.

Combine all the above elements into a single comprehensive program. The master plan would address policy issues such as management regulations, access to outer atolls for commercial fisheries, and protection of subsistence fishing, as well as personnel management issues such as training and data collection.

4. DEVELOP COASTAL RESOURCE MANAGEMENT

Land-based activities have a direct impact on fishery management practices. The best management regulations are useless if land based activities including dredging, filling, and solid waste disposal destroy marine habitats. Coastal resource management integrates both marine management and land based management so that resource use is enhanced, maximized and where applicable, sustainable.

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APPENDIX 1

LIST OF FISHERMEN INTERVIEWED FOR MAJRO INVENTORY

NAME	PLACE	DATE
Rick Bush	urban Majro	July 22, 1988
Bill Roberts	urban Majro	July 22, 1988
Lamanbeth Kajon	urban Majro	July 22, 1988
R. Virgil Alfred	urban majro	July 22, 1988
Kiton Laibaij	Majro islet	July 25, 1988
Bonjab Enoch	Majro islet	July 25, 1988
Hilla Enoch	Majro islet	July 25, 1988
Geracki Mueyercea	Majro islet	July 25, 1988
Lari Henry	Majro islet	July 25, 1988
Nginrieth N. Siggra	Majro islet	July 25, 1988

Appendix 2

FISHING METHODS AND SEASONS PRACTICED

URBAN MAJRO

FISH	METHOD	SEASON	TIME
Tuna	Trolling, handline	Summer (yellowfin) Yearound (skipjack)	Day
Wahoo	Trolling	Oct-March	Morning
Dolphinfish	Trolling	Dec-March	Day
Barracuda	Trolling, bottomfishing	Yearround	Day
Billfish	Trolling	Yearround	Day
Flying fish	Scoop net & torch	Winter (south & east) Summer (west)	Night (No moon)
Frigate tuna	Trolling, bottomfishing (also light tackle)	Yearround	Day
Jacks	Bottomfishing, spearfishing	Yearround	Day/Night
Rainbow runner	Trolling, (traditional method;surround school with rope & spear encaptured fish)	Yearround	Day
Mackeral scad	Gillnet, cast net, light tackle rodreel	Summer	Night
Groupers	Bottomfishing, spearfishing	Winter	Day
Snapper	Bottomfishing	Yearround	Day
Emperor	Bottomfishing	Summer	Night/Day

FISHING METHODS AND SEASONS PRACTICED Cont'd

URBAN MĀJRO

FISH	METHOD	SEASON	TIME
Squirrelfish	Trolling (rowboat & canoe) Pole & line (light tackle rod & reel with lures from Pundenus reef (Night)	Yearround	Night
Parrotfish	Gillnet,spearfishing (esp. at night)	Yearround	Day/Night
Surgeonfish	Spearfishing, gillnetting	Yearround	Day/Night
Rabbitfish	Gillnetting, spearfishing	Yearround	Day/Night
Mullet	Gillnetting, castnet	Yearround (high tide)	Day/Night
Goatfish	Gillnetting, castnet	Yearround	Day
Rudderfish	Gillnetting, castnet handline (summer near Calalin Islet)	Yearround	High tides
Big eye	Bottomfishing	Yearround	Day/Night
Trochus	Hand	Rarely harvested	Day
Turbans	Hand (by women and children)	Yearround	Low tides
Octopus	Spearfishing	Infrequently harvested	

FISHING METHODS AND SEASONS PRACTICED Cont'd

MAJRO ISLET

FISH	METHOD	SEASON	TIME
Land crabs	Hand	Infrequent	
Tuna	Trolling, vertical longline	Winter months	Day
Wahoo	Vertical longline	Oct-Nov	Same
Dolphinfish	Trolling	Winter	Same
Barracuda	Trolling, vertical longline	Winter	Same
Billfish	Trolling	Infrequent	Day/Night
Flying fish	Scoop net (night) handline (day)	June-August Feb-June (southern end)	Day/Night
Frigate tuna	Trolling	Yearround (not better in summer)	Day/Night
Jacks	Trolling	Infrequent	Day/Night
Rainbow runner	Trolling	Infrequent	Day/Night
Mackeral scad	Fish traps	Summer	Night
Groupers	Bottomfishing	Winter	Day
Snappers	Bottomfishing gillnets, spearfishing	Yearround	Day/Night
Emperors	Bottomfish	Yearround	Day/Night
Squirrelfish	Bottomfishing, trolling, pole and line	Yearround	Night
Surgeonfish	Spearfish	Yearround	Day/Night
Rabbitfish	Gillnetting, spearfishing	Yearround	Day

FISHING METHODS AND SEASONS PRACTICED Cont'd

MĀJRO ISLET (continued)

FISH	METHOD	SEASON	TIME
Mullet	Cast-net, gillnet	Yearround	Day/Night
Goat fish	Spearfishing, gillnet, Alwelwe	Yearround	Night (low tides)
Rudderfish	Gillnet, spearfishing, castnet	Yearround	Day/Night
Giant clams	Hand with knife	1 or 2 times/year	Day
Trochus (Depleted)	Hand	Regulated	Day
Octopus	Spearfishing (caught for bait)	Yearround	Day/Night
Turbans	Hand (by women and children)	Yearround	Day
Lobster	Hand (Diving)	Occassionally fished	Night

APPENDIX H

TOURISM, EDUCATION, PARK AND RESERVE OPPORTUNITIES FOR SELECTED LAGOON AND REEF ENVIRONMENTS ON MĀJRO ATOLL, REPUBLIC OF THE MARSHALL ISLANDS

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ABSTRACT

Mājro Atoll is the capitol center and the most populated atoll of the Republic of the Marshall Islands. The combination of high population densities, limited land area and natural resources is causing increasing environmental and socio-economic problems throughout the atoll. The development of a nature-based tourism industry that incorporates educational activities, and conservation measures with the establishment of parks and reserves holds great potential to help balance development and preservation needs.

Twenty-eight reef and lagoon sites on Mājro Atoll were surveyed and assessed for tourism, education, park and reserve potential as part of the Marshall Islands Coastal Resource Atlas and Inventory Program. A total of sixteen sites have been recommended for a combination of resource-use options including: tourism, education, marine, coastal or island parks, and marine, coastal or island reserves. Eight sites have been identified that are in desperate need of immediate and long-term clean-up efforts.

Although parts of Mājro Atoll are now extremely polluted there are many areas that are still attractive, healthy and productive environments. Recommendations have been made which will help to develop a nature-based tourism industry that can provide economic diversification and ensure that the beautiful worlds which are the attractions are not destroyed in the process. These include: development of a Tourism Master Plan and Coastal Resources Management for RMI; create legislation to protect species and habitats; initiate public involvement to develop a tourism industry through both the public and private sector; expand infrastructure services; develop education and public awareness activities on tourism and conservation; and establish immediate and long-term clean up projects throughout the atoll.

INTRODUCTION

This report identifies specific coastal and underwater sites on Mājro Atoll in the Marshall Islands that are suitable for tourism development, educational activities and the establishment of marine, coastal and island parks and reserves. Twenty-eight sites were surveyed during an 8 day visit to Mājro Atoll by the author, with four other members of a multidisciplinary team of marine scientists, who inventoried corals, molluscs, fish and coastal oceanography. Observations of the terrestrial environments, cultural artifacts, and interviews with fishermen were conducted concurrently by a land-based team of scientists. These land and water surveys were completed as part of the Marshall Islands Coastal Resource Atlas and Inventory Program.

This report on tourism, education and protected areas for atoll and marine environments is one of nine in this volume. Together these reports provide the first comprehensive assessment of opportunities and constraints for the future development and conservation of Mājro's natural resources. In September 1988 a team, sponsored by the East-West Center of the University of Hawaii and the MacArthur Foundation, visited some of the northern atolls in the Marshalls and proposed that many be nominated as marine reserves.

Mājro Atoll is part of the Republic of the Marshall Islands (RMI), and the capitol of the Republic. While parts of the atoll still offer an unspoiled paradise of traditional villages surrounded by beautiful coral reefs, pristine beaches, and lush coastal-strand forests, these are in sharp contrast to the highly polluted urban areas of nearby urban Mājro, located on the southeastern end of the atoll. Mājro has a growing population of over 20,000 people living on 3.5 square miles of dry land area. Arno, the next closest atoll, 20 miles away, has approximately 1,800 people scattered among five square miles of land area. The density of human settlement and related activities on this atoll has lead to a wide range of ecological and socio-ecomonic problems. A similar inter-disciplinary study was conducted for nearby Arno Atoll in conjunction with the Mājro study, and is the subject of a separate collection of reports. Although the studies for Mājro and Arņo are independent, together they provide valuable comparisons and foster a regional approach to resource-use and habitat management that is necessary to mitigate future environmental and social problems throughout all of the islands in the Marshalls.

Atolls are low coral sand islands made primarily of calcium carbonate. The islands are the emergent tips of subsiding volcanoes, surrounding inner lagoons. Coral reefs are found on the ocean and lagoon sides of the islands. All atoll habitats are part of tightly interconnected ecosystems and constitute some of the most fragile types of island environments. Atolls can only support limited development without depleting the natural resources; therefore, it is crucial that these resources be exploited in a way that can be sustained over the long term. Although Mājro has above average land area for an atoll, receives abundant rainfall, and still has large and diverse fish populations, it is vulnerable to economic and population pressures. A tourism industry based on natural attractions represents a unique development challenge with potentially high economic returns. The establishment of parks and reserves can not only ensure the continuing existence of the natural attractions, but can also provide a means of enhancing tourism income for many sectors of the population. Educational activities can be a valuable part of the visitors recreational experience, just as scientific research can provide information crucial to the economic realities of tourism planning.

This report identifies sites in M̄ajro Atoll that have the potential to support a nature and culture-based tourism industry when integrated with environmental education and the establishment of parks and reserves. The lure of short-term, immediate profits that are possible with tourism development can easily and quickly lead to long-term losses of cultural identity and precious natural resources. The residents of the RMI and M̄ajro Atoll need to insist that conservation measures, such as establishing parks and reserves, are incorporated into the nation's tourism, fisheries and coastal development plans.

METHODOLOGY

At the begining of this study public meetings were held with the village leaders and residents of M̄ajro to inform them of the project and for the team to learn of particular concerns that should be incorporated into the selection of the survey sites. These meetings provided follow-up to earlier meetings held in May of 1988 (see Maragos, et al 1989, in this volume). The Marshall Islands Marine Resources Authority provided logistical assistance with two skiffs, and a support crew. Therefore, the team was able to conduct an average of five marine surveys each day, for 8 consecutive days throughout all of M̄ajro Atoll. While each site was visited by the entire water-based team, each member had specific objectives. Observations of corals, seaweeds, molluscs, and reef fishes are topics of other appendix reports in this volume.

The Alele Museum staff in M̄ajro indicated historically significant sites on topographic maps and nautical charts. Most of the surveys were conducted near these locations. Some sites were surveyed at the villagers request regarding shoreline construction options in specific areas. Others were chosen to survey a representative sample of the different lagoon habitats. The majority of the sites were located on the inside of the lagoon due to the rough conditions on the ocean side and the overall development orientation of the study.

The surveys for this report were qualitative in nature with observations recorded on waterproof paper while snorkeling each area for one-half hour. General physical

General physical descriptions and drawings of the coral reef and coastal environments were made for each site, including: observations of the dominant coral and algae genera, and overall condition of the reef environment. Comments on tourism, education, recreation, and protected areas were made for suitable sites. Slide photographs were taken at most of the sites with a Nikonos V, underwater camera, using a 50mm lens and SB103 Speed Flash system. The slides augmented the field notes. The information was transcribed and is presented in the RESULTS section of this report.

RESULTS

This section presents general descriptions of the coral reef and lagoon survey areas for islands and islets in Mājro Atoll, focusing on the identification of suitable sites for tourism development, educational activities and the establishment of marine, coastal and island parks, and reserves. Although detailed discussions of resource-use opportunities are made for each site in the RESULTS section, this section of this report provides: a) an overview of the opportunities, constraints and interrelationship between tourism, education and protected area development for atoll environments, and b) summarizes the findings for specific village areas or sectoral regions of the atoll.

Sites are listed in the order they were surveyed, using island names to identify each site. Sites are shown in Figure 1. on the following page. The date each survey was conducted is listed to the far right of each site name. The first paragraph of each site description presents a general physical description of each site, and the common genera or species names of typical sessile organisms including seaweeds, and hard and soft corals. Subsequent paragraphs discuss tourism, education and protected area development opportunities for the sites if appropriate. Additional comments on tourism and marine park opportunities are also reported in Maragos and Lamberts (1989), Maragos et al (1989) and Rappa (1989), all in this volume.

The site descriptions and species lists in the other appendix reports of this volume provide additional detailed accounts of observed species and reef descriptions, which should be considered when assessing tourism, education, recreation and conservation options. Corals are described in the report by Maragos and Lamberts; McDermid describes the marine algae; other non-coral invertebrates are described by Harris; and reef fishes are described by Molina. Sites with fisheries and mari-culture potential are discussed in separate reports

Harris. Sites with cultural and historical significance are described by Streck. Galloway reports on terrestrial ecology and shoreline biota.

Key to names and symbols in site descriptions:

1. Categorical abbreviations are provided for sites which may have a high potential for tourism, education, and protected area development. In many cases sites were found to have a different potential uses which could be developed to integrate a range of resource-use options. These categories are discussed in more detail in the DISCUSSION section of this report. Specific suggestions on these resource-use options are presented in each site description. A key to the code letters listed next to the site name is presented below.

TO = Site with potential for **tourism development.**
ED = Site with potential for **educational activities.**
MP = Site with potential to be a **marine park.**
MR = Site with potential to be a **marine reserve.**
CP = Site with potential to be a **coastal park.**
CR = Site with potential to be a **coastal reserve.**
IP = Site with potential to be an **island park.**
IR = Site with potential to be an **island reserve.**

2. Small graphic illustrations are included for many of the sites. These are general impressions only and are not meant to represent true scale.

3. Sites that were documented photographically are designated with the word Photos. The set of reference slides for these sites is located at the University of Hawaii, Sea Grant Extension Office in Honolulu.

Summary of site locations:

01 - 04 Irōōj - Calalin Islands
05 - 08 Rọn̄rọn̄ - Jelte Islands
09 - 13 Mājro Island
14 - 17 Ajeltake - Rairōk, airfield sites

18 - 19 M̄ajro - Teļap Bridge

20 Marshall Sun Hotel, lagoon-side

21 - 23 Jar̄oj - W̄ulka - Teļap, urban M̄ajro area

24 Marshall Sun Hotel, ocean-side

23 - 28 Enigu Islets

DISCUSSION

The site descriptions in the RESULTS section present detailed discussions of many different ideas, options and considerations for tourism, education and conservation projects that are relevant to M̄ajro Atoll. Yet, much of the information described for the individual sites is broadly applicable to tropical islands worldwide. Therefore, it is the purpose of this section to synthesize the discussions from the site descriptions and provide some background and generalities regarding tourism development, educational activities, and parks and reserves. This section is designed to:

1) Present important perspectives on balancing the ecological, economic and social trade-offs that are inherent in developing any tourism industry which is based upon and promotes the conservation of natural environments.
2) Discuss the interrelationships between the tourism, education and protected area categories, and illustrate the need for flexible, multiple-use planning approaches when considering development options for atoll island systems.
3) Present a synthesis of the site descriptions and recommendations from a village or sectoral approach, emphasizing the need to explore how adjacent sites interact in ways which can support or discourage particular development options.

Ecological and Socio-Economic Considerations:

A tourism industry that integrates recreation, education and habitat protection is multi-faceted and has a high potential to initiate economic expansion and diversification. The encouragement of a wide range of accommodation options from camping to exclusive resorts will help to generate an increasing number of retail business opportunities as the private sector becomes more prosperous.

Tourism and conservation can be compatible and reciprocally supportive of commercial and subsistence fisheries and agriculture projects in both the private and public sectors. Tourism businesses are usually initiated through the private sector, yet the management of habitats and public lands and waters is often under the auspices of local, state and national governments. It is usually the government who is ultimately responsible for the insistance of an orderly development that will provide for the long-term benefit of all residents. Since most land is privately owned in the Republic of the Marshall Islands (RMI), cross-sector coordination between private public officials, different government departments and village areas is essential.

There will be an increasing need for cooperation and for cultural sensitivity between local residents, visitors and outside investors. The more outside ownership there is of facilities, land or other investments, the less control residents may have over their own tourism growth process. Small and large scale projects and programs should be conducted with provisions and timetables that provide residents with opportunities to learn the skills necessary to plan and manage the businesses or protected areas themselves.

Island tourism that is based on natural and cultural attractions hold increasing potential because of what it offers to travelers coming from more crowded and mechanized parts of the world. The people of M̄ajro and the RMI need to recognize that it is the beauty and the unspoiled quality of the people and the environments that can both attract visitors and instill a sense of cultural and environmental pride in the residents. M̄ajro can easily provide recreational and educational attractions for the residents of M̄ajro, and business visitors to the RMI. Even though M̄ajro, and the rest of the RMI, is an expensive place to travel to, outdoor sports enthusiasts and nature lovers world wide are increasingly willing to spend large sums of money to enjoy pristine beaches, warm waters, diverse reefs, and quiet uncrowded environments still in their natural state. Therefore, a range of accommodations and support services can be planned to incorporate the different needs of the visitors, skill levels of the residents and financial capabilities of local and foreign investors. The government and people of M̄ajro need to take strong actions to clean up the areas that have already become polluted and to preserve those parts of the atoll that are still healthy, productive and attractive.

It is also important to realize how vulnerable isolated places such as M̄ajro and other islands in the RMI are to external factors such as changes in air service, currency fluctuations and government politics. Therefore, the need to develop a self-sufficient economy and sustainable environment is even greater on atolls than for larger islands or continental areas.

The need for education and public awareness for both the residents and the visitors about the positive and negative realities of tourism and the importance of protecting species and habitats cannot be overstated. Education at all levels is essential to bring about a nature-based tourism industry that is conservation oriented. A range of examples includes: field trips for school children, hotel management for residents, or training local men and women as park rangers. Increasing contact from foreign visitors also brings about cultural exposure to different lifestyles and value systems that can threaten or change local traditions. A spirit of cultural appreciation rather than displacement is needed between residents and visitors. It is important to make cultural awareness an active part of the education process for visitors and residents alike through a variety of activities such as handicrafts, traditional sailing demonstrations or designing a pamphlet on cultural history and attitudes for visitors. Such efforts can be easily linked into both economic profits and conservation projects.

Multiple-Use Resource Planning:

Table I on the following page lists the sites under the recommended resource-use category. Many sites are listed under more than one category, for two reasons.

The first reason is that tourism, education and conservation activities are inherently linked and can be mutually supportive through integrated planning and development. Tourism, is often based on natural attractions, especially in an area such as M̄ajro Atoll. If native plant and animal species and their habitats are not managed in a way that ensures their health, longevity, and natural beauty, the essence of the world that was the foundation of the tourism industry is destroyed. The loss of species and habitat can also lead to a loss of sustainable food and shelter for humans. Such losses are already evident in many of the reefs and coastal habitats of M̄ajro due to pollution and unplanned development that was not ecologically sound. This is especially true for isolated and fragile islands such as atolls, where the resources are limited to begin with. As the people of M̄ajro have begun to experience, the destruction of local resources leads to a dependency on imported goods, which can be prohibitively expensive, and create a decline in the quality of life for the residents. All forms of education are needed, from public awareness to scientific research, to bring about an understanding and appreciation of atoll environments. Educational activities can easily be incorporated into recreational opportunities in the tourism sector. Parks and reserves can provide valuable on-site learning experiences while also ensuring that the natural attractions remain intact. Parks and reserves themselves are becoming tourist attractions which encourage residual businesses and increase tourist expenditures.

TABLE I

MĀJRO ATOLL

SITES LISTED BY RESOURCE USE CATEGORIES

TOURISM

3 Kōjaļ-eņ
20 MI Sun Hotel
23 Urban Mājro
25 Enigu
26 Jarōj

EDUCATION

1 Irōōj
3 Kōjaļ-eņ
4 Kōjaļ-eņ
5 Wūlka
6 Wūlka
9 Mājro islet
10 Mājro islet
16 Airport
17 Quarries
20 MI Sun Hotel
22 MI High School
23 Urban Majro
25 Engiu
26 Jarōj
27 Enigu

MARINE PARK

3 Kōjaļ-eņ
4 Kōjaļ-eņ
16 Airport
17 Quarries
20 MI High School
27 Enigu

MARINE RESERVE

1 Irōōj
25 Enigu
26 Jarōj
27 Enigu

COASTAL PARK

3 Kōjaļ-eņ
9 Mājro islet
10 Mājro islet
23 Urban Mājro

COASTAL RESERVE

1 Irōōj
3 Kōjaļ-eņ

ISLAND PARK

25 Enigu
26 Jarōj
27 Enigu

ISLAND RESERVE

26 Jarōj
27 Enigu

The second reason multiple-use options are suggested for each site is to exemplify that these are suggested options only and to encourage the people of Mājro and the RMI to become involved in deciding what might be the best use for an area. No one site is necessarily limited to a particular use option. In most cases different uses such as recreation and educational activities can be compatible and enhance the area. Yet some sites may be more appropriate for particular options depending on a range of considerations, such as: land or sea access, proximity to urban areas, unique plant or animal species, cultural and archaeological artifacts, physiography of the area, ownership and current use patterns, or condition of the habitats such as coral reefs.

While the categories have been briefly defined throughout the report, each is discussed in greater detail here. This is to further explain how the categories are primarily definitions on paper for planning purposes, but when applied to reality, they are represent a range of infinitely related recreation, education, and conservation options.

Tourism

Since tourism is often the basis and incentive for many educational and conservation activities this category has actually been the main topic of this report. As previously discussed, island and nature-based tourism usually relates to recreation and relaxation, which incorporates educational opportunities and supports the need to sustain environments in a productive state. The category "tourism" has been used in a more limited context for the site descriptions. Only those sites which have enough land area and healthy marine habitats to support some style of lodging facilities and marine recreation have been suggested for tourism development. This is based on the assumption that educational activities, parks and protected areas would be part of all tourism efforts. Mājro's lagoon environments are ideal for a wide variety of marine tourism activities including: windsurfing, sailing, snorkeling and SCUBA diving, all of which can be supported by private tourism businesses and public marine parks.

Education

Like tourism, education is a broad category that can be part of every other category, since all of the sites listed under tourism, parks, or reserves have educational opportunities. Yet there are many sites which have a general educational or scientific research value, while they may not be particulary attractive or easy to reach.

Parks - Marine, Coastal, and Island

Areas which have unique features worthy of preserving, such as a beautiful coral reef, a grove of rare trees, nesting areas for birds, or cultural artifacts, are usually designated as parks. Parks are often intended to be an area that can sustain a balance between nature protection and public use, such as recreation or traditional fishing. The concept of parks in this paper has been further categorized into geomorphic types. Marine parks usually include all types of coral reefs (fringing, barrier, patch), seagrass beds and open ocean. Coastal parks generally refer to the reef and seagrass beds adjacent to the shore, estuarine habitats, mangroves, beaches, bays, mudflats, coastal sandy areas and coastal strand vegetation. Island parks are usually established to signify and protect an entire small island, atoll or archipelago.

Since M̄ajro is an atoll, composed only of small islets with coastal and marine environments these terms overlap considerably. Most of the sites surveyed for this project were underwater; therefore, there are more sites listed as marine parks than coastal or island. See the report by Galloway in this volume for additional recommendations of coastal or island parks.

Reserves - Marine, Coastal, and Island

Reserves are areas designated primarily to emphasize protection of species, habitats and/ or ecosystems. There is generally limited public use, and only then for educational or research purposes. These areas are established to maintain natural processes in an undisturbed state so that there will always be representative examples of the species or habitat. The same geomorphic descriptions of marine, coastal and island can be applied to reserves.

Sectoral Site Descriptions:

Table II on the following page presents the tourism, education and protected area categories discussed above for village areas or adjacent sites. As described in the METHODOLOGY section, the site selection process was primarily based upon identified historic marine and coastal areas. Therefore, it is possible that there are many sites on Mājro Atoll, which are equally appropriate, or perhaps more suitable, for specific tourism and conservation options than those which were surveyed and discussed in this report. The suggested range of tourism, education and conservation options presented for the sites are based primarily on physiographic features of coral reef, lagoon and coastal environments and apparent access and village use patterns. Due to the multi-disciplinary nature of this project there was not time to conduct in-depth public meetings or interviews with the villagers to identify local priorities and ownership considerations.

TABLE II

M̄AJRO ATOLL
RESOURCE USE CATEGORIES FOR VILLAGE OR AREA

LOCATION	SITE	RESOURCE USE OPTIONS
Ko̅jaj-eņ	3,4	TO, ED, MP, CP, CR
Ir̄o̅oj	1,2	ED, MR, CP
Wu̅lka	5,6	ED
Ma̅jro islet	9,10	ED, CP
Quarry/Airport	17,16	ED, MP
MI Sun Hotel	20	TO
MI High School	22	ED
Urban Ma̅jro	23	TO, ED, CP
Enigu	25-27	TO, ED, MP, MR, IP, IR

Key to resource use options:

TO = Site with potential for **tourism development.**
ED = Site with potential for **educational activities.**
MP = Site with potential to be a **marine park.**
MR = Site with potential to be a **marine reserve.**
CP = Site with potential to be a **coastal park.**
CR = Site with potential to be a **coastal reserve.**
IP = Site with potential to be an **island park.**
IR = Site with potential to be an **island reserve.**

This report is intended only to generate ideas, provide suggestions and function as an initial planning tool to help the people of Mājro and the RMI begin the intricate process of identifying, establishing and eventually managing tourist and conservation areas. The map presented at the beginning of the RESULTS section provides a visual orientation to the following areas. While this section focuses on clustered sites, those which are isolated but offer a unique opportunity are also presented in TABLE II and described below.

Irooj Island (Sites 1,2)

Irōōj is an isolated island, centered in a pass on the northern side of the atoll. It has high coral cover and species diversity, as well as numerous fish and sea birds. The island and the beach areas are in a pristine state with lush vegetation. The area should be designated primarily as an area for habitat preservation but visitation for traditional or subsistence fishing, local educational groups and scientific researchers should be permitted in limited numbers.

Kōļaļ-eņ Island (Sites 3, 4)

Kōļaļ-eņ is an island centered on the north side of the atoll, and is perhaps the best site on the atoll to set up immediately as a marine, coastal and/or island park. It appears to be currently used as a day-use recreation area now and is well suited for this purpose. The beaches are wide on the lagoon side and it is an easy walk across or around the island to explore the ocean-side reef flats. The lagoon is calm and safe for swimming. There are a few excellent patch reefs, dense with a rich diversity of healthy coral within short swimming distance from the shore. There is a large patch reef just out from the center of the island on the lagoon-side that should be designated as a marine park area and set up with an underwater trail, or signs around the reef for educational purposes. The swim around the reef provides excellent viewing of the animals and plants in this reef community.

Selected areas on the island itself were once cleared of ground level vegetation for a coconut plantation. These cleared areas could make excellent picnic and land-based recreation areas with very little additional landscaping. There could also be outdoor exhibits on reef ecology and conservation of Mājro Atoll. Since this area is easily accessible from Mājro it is also conceivable that a small resort or thatched cottages could be built here, in conjunction with establishing the surrounding marine and land areas as parks. Detailed descriptions of use options for this area are provided in the RESULTS section, Sites 3 and 4.

Wūlka Island (Sites 5, 6)

The wide reef flats and the natural holes on the lagoon-side are excellent sites for educational field trips since a variety of reef environments can be explored in a small area. This site is ideal for short visits by the school children from nearby Jelte Island. Although the site is interesting it may not be worth the long trip from urban Mājro if not done in conjunction with visits to other parts of the atoll.

Mājro (Sites 9, 10)

Mājro is a lovely coastal area located on the southwestern end of the atoll, about 30 miles from urban Mājro. This site is currently used as a recreation area for visitors and residents since it is remote, lush, clean, yet accessible by car. There are wide beaches for sun bathing, extensive reef flats suitable for snorkeling at high tide, and reef-walking at low tide. Although the corals in this area are scattered and not as spectacular as in other parts of the atoll, this area offers other ecological zones for exploring such as seagrass beds and patch reefs. The entire area should be established as a coastal park to promote recreation, education and conservation. It is suggested that the development of private tourism lodging facilities be place away from this area in order to keep it available to the public.

Airport, Quarries (Sites 16, 17)

Site 16 is on the lagoon-side of the airport, while the quarries (Site 17) are on the ocean-side. The reef flat adjacent to the airport (Site 16) was surprisingly healthy and lush in spite of the dense amount of debris in the area. This would be an excellent site to establish as a marine park for snorkeling and local educational field trips since it is easy to reach. An underwater trail, signs, or educational markers would be simple to develop for this reef area. The site would be much more attractive if the debris was cleared out and would be a great educational opportunity for local high school students to learn about the reef as they are uncovering it.

The quarries on the ocean-side of the airport runway (Site 17) could be excellent "natural labs" for local school groups to study reef organisms and fishes. This site also has scientific value for studying recolonization rates of corals and algae since the concrete walls and rocks provide new substrate for organisms to settle upon. Snorkeling and exploring are only recommended at low tide since it is too rough at high tide. This site is suitable for the creation of a marine park which could promote marine recreation and education while at the same time protect the delicate habitats here.

Marshall Island Sun Hotel (Site 20)

The beach at the Marshall Island Sun Hotel is one of the few places near urban Mājro that is desirable for tourists to enjoy swimming and relaxing, yet it still needs to be cleared of debris. The reef flat near the shore is deep enough to swim and snorkel, but the most attractive reef areas are a few hundred yards out. There are numerous projects that the hotel could undertake in order to attract more nature-oriented visitors through developing marine attractions such as: having an aquarium in the lobby, developing reef conservation brochures, showing nature videos, and doing artwork in the gazebo of fish and corals. Projects like these could be collaborative between different groups, and designed for any hotel, schoolroom, library, or other public space to develop a public consciousness for visitors and residents alike about the beauty and fragility of Mājro's atoll environments.

Marshall Island High School (Site 22)

This site does not exemplify a healthy or attractive reef, however it is valuable from an educational perspective since it is located across from the high school. The plant and animal organisms found here can form the basis for some interesting studies on reef and atoll ecology.

Urban Mājro (Site 23)

This was an unusual site located along the shore of the ocean-side of urban Mājro behind "Moss Store". A former residence was built on this point of land which opens up onto a wide reef flat. The now cleared residential area still has landscaped trees, rocks and concrete steps that elicit a park-like quality to this site. This site is well suited for development as a day use coastal park and for educational trips to explore the reef flat. The beaches are narrow but there are many picnicking sites on the land and ample parking is available. The reef flat is best for exploring at low tide, since it would be too rough for snorkeling at high tide. If this site is made into a public park, efforts to keep it clean would be needed due to its proximity to urban Mājro.

Enigu Islands (25-27)

The Enigu Islands are a series of small islets between Kōļaļ-eņ and Jarōj with abundant, healthy and unpolluted reef and coastal habitats. This area is a refreshing change from the more populated and degraded parts of urban Mājro and the islets are easy to reach from the urban center. These sites are ideal for recreational, nature-based tourism and educational development since they are attractive and close to urban areas. This combination of beauty and proximity also makes this area vulnerable to over-development, so it is advised that some of the reefs and islets can be established as marine, coastal, and island reserves as well as parks. Any type of tourism facilities, e.g. hotel, camping, or recreation areas should be integrated with the parks and constructed in a manner that will focus on maintaining the area in its natural state.

Sites that need to be cleaned up:

Most of the sites described above are areas which are appropriate for tourism, recreation, education, or establishing as parks and reserves in their current state. Yet, these and many of the other sites described in the RESULTS section could be much more attractive and ecologically productive if they were cleaned up and continually maintained in the future. It is important to realize that trash does not always stay where it was dumped. Ocean currents, tides and waves carry debris to all parts of the atoll. One of the major problems in Mājro is the excessive number of disposable dispers that are used and dumped into the lagoon. These are not biodegradable, are visually unsightly, and are harmful to the environment. Efforts to promote the use of cloth diapers should be high priority by local health care groups. This is just one example of the urgent need for public education to begin focusing on the interaction of daily lifestyle with conservation practices. Such efforts should be incorporated into all tourism, recreation, education and conservation activities. Of the sites which were surveyed for this project, the following desperately need to be cleaned on a continual basis to make Mājro a more pleasant and safe environment for residents and visitors alike: Sites 9, 10 (Laura), Sites 15, 16 (airport area), Site 20 (MI Sun Hotel), Site 21 (Mājro Yacht Club), Site 22 (MI High School), and Site 23 (behind Moss Store). The cleaning of these sites could be done by any number of local groups e.g. schools, churches, youth groups. Yet it is important that these groups also visit the more attractive sites so that an appreciation for a clean, healthy natural world can be fostered.

(MI Sun Hotel), Site 21 (Mājro Yacht Club), Site 22 (MI High School), and Site 23 (behind Moss Store). The cleaning of these sites could be done by any number of local groups e.g. schools, churches, youth groups. Yet it is important that these groups also visit the more attractive sites so that an appreciation for a clean, healthy natural world can be fostered.

CONCLUSION and RECOMMENDATIONS

More than 50% of the entire population of the RMI now resides on Mājro Atoll, with most of the people living in the southeastern end of the atoll. Such population densities are creating many environmental, social and economic problems for Mājro that cannot be solved by the Government or outside assistance alone. The residents of Mājro and the RMI need to take and active role in learning about environmental processes and implementing progressive conservation measures. Developing a nature-based tourism industry, that incorporates parks and reserve areas provides numerous opportunities to all segments of the population.

It is important that action is taken on Mājro Atoll itself, and that the problems encountered here are not simply transferred to other atoll areas, such as nearby Arno, in search of more fish, cleaner beaches, etc. While Mājro, Arņo, and other parts of the RMI each have specific needs, tourism and conservation planning for the region as a whole must be orchestrated as even Arņo begins to feel the effects of change from a subsistence, crop-based economy to an import-cash economy. The following recommendations are made to generate actions that will encourage a balance between development and conservation through highlighting the beautiful environments and cultures that the Marshall Islands have been blessed with.

1. Develop a Tourism Master Plan for the entire Republic, with specific recommendations for Mājro.

This plan should be done in conjunction with other existing or future plans that concern the development of Mājro and the RMI's natural resources including: the current RMI National Economic Development Plan; fisheries, agriculture, infrastructure and marketing development plans.

2. Develop a Coastal Resources Management Plan for the entire Republic, that has specific sections on Mājro Atoll.

The tourism plan recommended above should be done in concert with a coastal plan. A comprehensive coastal plan should highlight areas that are to be designated or zoned as parks and reserves, focusing on recreation, education and habitat preservation.

management, business accounting, fisheries and biology, and coastal engineering.

8. Establish immediate and long-term clean-up projects and programs for the parts of Mājro Atoll that are now cluttered with debris.

Such activities can be incorporated into a wide range of educational learning experiences about the different habitats on the atoll.