# OROLUK ATOLL AND MINTO REEF RESOURCE SURVEY

P.F. Holthus, J.E. Maragos, J. Naughton, C. Dahl,
D. David, A. Edward, M. Gawel, and S. Liphei

May, 1993

East-West Center
Program on Environment
1777 East-West Road
Honolulu, HI 96848 USA

The survey and report were funded by a grant to the East-West Center
from the John D. and Catherine T. MacArthur Foundation.

CONTENTS

List of Figures and Tables . . . . . . . . . . v

Executive Summary . . . . . . . . . . 1

Issues and Management Challenges . . . . . . . . . . 3

I. Introduction . . . . . . . . . . 8

1. Background and Purpose . . . . . . . . . . 8
2. Acknowledgements . . . . . . . . . . 8
3. Location . . . . . . . . . . 9
4. Methods . . . . . . . . . . 9
5. Ecosystem Classification and Physiographic Zones . . . . . . . . . . 12

II. Oroluk Atoll . . . . . . . . . . 15

1. General Description . . . . . . . . . . 15
2. Coral Reef and Benthic Communities . . . . . . . . . . 18
3. Benthic Fauna . . . . . . . . . . 25
4. Benthic Flora . . . . . . . . . . 27
5. Fish . . . . . . . . . . 27
6. Marine Turtles . . . . . . . . . . 29
7. Motus and Cays . . . . . . . . . . 32
8. Terrestrial Vegetation and Resources . . . . . . . . . . 33
9. Birds . . . . . . . . . . 34
10. Human Habitation and Resource Use . . . . . . . . . . 34
11. Storm Damage . . . . . . . . . . 36

III. Minto Reef . . . . . . . . . . 39

1. General Description . . . . . . . . . . 39
2. Coral Reef and Benthic Communities . . . . . . . . . . 41
3. Benthic Fauna . . . . . . . . . . 46
4. Benthic Flora . . . . . . . . . . 48
5. Fish . . . . . . . . . . 48
6. Marine Turtles . . . . . . . . . . 49
7. Cays . . . . . . . . . . 49
8. Resource Use . . . . . . . . . . 49
9. Storm Damage . . . . . . . . . . 49

IV. Appendices . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 53

1. Distribution and Relative Abundance of Corals and Relative Level of Storm Damage at Oroluk Atoll . . . . . . . . . . . . . . . . 55
2. Corals Recorded at Oroluk Atoll and Minto Reef . . . . . . . . . . . . . . . . . . 58
3. Distribution and Abundance of Macroinvertebrates at Oroluk Atoll . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 62
4. Macroinvertebrates Recorded at Oroluk Atoll and Minto Reef . . . . . . . . . 65
5. Distribution and Relative Abundance of Algae at Oroluk Atoll . . . . . . . . . 69
6. Algae Recorded at Oroluk Atoll and Minto Reef . . . . . . . . . . . . . . . . . . . 70
7. Distribution of Fish at Oroluk Atoll . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 71
8. Distribution and Relative Abundance of Corals at Minto Reef and Relative Level of Storm Damage at Minto Reef . . . . . . . . . . . . . . . . . 80
9. Distribution and Abundance of Macroinvertebrates at Minto Reef . . . . . 83
10. Distribution and Relative Abundance of Algae at Minto Reef . . . . . . . . . . 86
11. Distribution of Fish at Minto Reef . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 87
12. Oroluk Atoll and Minto Reef: Proposed Zoning Plan . . . . . . . . . . . . . . . . 90
13. Legal, Administrative and Financial Considerations . . . . . . . . . . . . . . . . 93

# LIST OF FIGURES AND TABLES

*FIGURES*

1. Location Map: Oroluk Atoll and Minto Reef . . . . . . . . . . 10
2. Ecosystem Classification of Oroluk Atoll and Minto Reef . . . . . . . . . . 13
3. Oroluk Atoll . . . . . . . . . . 16
4. Oroluk Atoll Survey Site . . . . . . . . . . 19
5. Track of Super Typhoon Owen . . . . . . . . . . 37
6. Minto Reef . . . . . . . . . . 40
7. Minto Reef Survey Sites . . . . . . . . . . 42

*TABLES*

1. Reef Passes at Oroluk Atoll . . . . . . . . . . 17
2. Marine Turtle Sightings at Oroluk Atoll . . . . . . . . . . 31
3. Bird Sightings at Oroluk Atoll . . . . . . . . . . 35

## EXECUTIVE SUMMARY

A scientific survey of Oroluk Atoll and Minto Reef (Pohnpei State, FSM) was carried out in late November/early December 1990 to document the resources, habitat and resource uses of these areas and make recommendations to the Pohnpei State and FSM Governments on conservation and management. The survey visited 45 underwater sites at Oroluk Atoll and 23 sites at Minto Reef, as well as covering the limited land areas. An inventory of fish, marine turtles, algae, corals, giant clams, sea cucumbers, trochus, other important invertebrates and coral reef habitat was conducted at each marine site. The vegetation, birds and land use of terrestrial areas was documented. Interviews were conducted with the inhabitants of Oroluk Island to gather information on resource use. Typhoon Owen passed close to both Oroluk Atoll and Minto Reef a few days before the survey, with winds of up to 140 knots.

Oroluk Atoll is about 15 times larger than Minto Reef and supports a wider variety of habitats, due to its larger size, numerous lagoon patch reefs and pinnacles and numerous passes of various depths and location. Minto Reef had only shallow passes on one side of the atoll reef and a single lagoon pinnacle. Results of the survey reveal that the coral reef and lagoon habitat of Oroluk Atoll and Minto Reef is largely unaffected by human activity and in near pristine condition. Reef fish populations had high diversity and biomass. The presence of large carnivores in the reef fish populations indicate very little fishing pressure, as these species are rapidly depleted by fishing. Other than the small giant clam *Tridacna maxima*, giant clams were not abundant and neither were any other invertebrates of economic value (e.g. pearl shell oyster, sea cucumber, trochus). A total of sixteen marine turtles, mostly juveniles, were encountered at 10 locations at Oroluk Atoll and none at Minto Reef.

Oroluk Island supports typical central Pacific low island vegetation, with introduced subsistence food species (e.g. coconut, breadfruit, banana, taro). Oroluk Island provides the only nesting ground for the green turtle in Pohnpei State. The island and the unvegetated cays scattered around the atoll are important for seabird breeding and nesting habitat and shorebird resting areas. There were no stable, emergent land areas found at Minto Reef.

Overall, the 14 inhabitants of Oroluk Island have a very limited use of and effect on the resources and habitats of Oroluk Atoll. Unfortunately, however, their impact on the endangered green turtle is very significant through: 1) building structures in the nesting area, 2) human activity on the island causing turtles to avoid nesting, 3) harvesting nesting turtles and 4) harvesting turtle eggs. Turtle and turtle egg harvesting rates are unsustainable and turtle nesting and turtle numbers are seriously declining at Oroluk Atoll. Other significant environmental degradation may result from visiting fishermen which reportedly fish with explosives. Habitat damage from explosives was not

detected, although this could have been easily missed in the survey or masked by recent typhoon damage.

Typhoon Owen inflicted major damage to the coral reef habitat of Oroluk Atoll and, especially, to Minto Reef. The outer reef slopes suffered the most impact with large areas of live coral cover removed by wave and surge action which tore out and broke corals. The detached corals subsequently cascaded downslope creating more damage. Large amounts of corals and coral rubble were transported across the reef platform and deposited on the lagoon terrace or slope, breaking corals along the way. The pattern was reversed for parts of Minto Reef, where wave and surge action entered the lagoon through the open southwest side and attacked the lagoon side of the perimeter reef. Oroluk Island and the unvegetated sand cays experienced severe erosion, with the single sand cay of Minto Reef completely disappearing.

Oroluk Atoll and Minto Reef are unique due to their size, isolation, overall pristine condition and lack of human impacts on the natural ecosystems, other than marine turtle populations. The marine turtle situation is serious and requires urgent action. The reef and lagoon habitats and resources of Oroluk Atoll and Minto Reef require management planning to maintain their unique attributes as a contribution to the special natural heritage of Pohnpei State and the FSM.

## ISSUES AND MANAGEMENT CHALLENGES

### A. MARINE TURTLE CONSERVATION

Oroluk Atoll is a critical site for the green turtle (*Chelonia mydas*) in the Caroline Islands, and probably the most important unit for the species in the Eastern Caroline Islands. Historically, Oroluk Island has provided the most important nesting beach for these turtles in the Eastern Carolines. The green turtle is recognized internationally and by the U.S. as an endangered species. A decline in the population of green turtles has been noted throughout Micronesia and, in particular, in Pohnpei State.

Unfortunately, the small number of people inhabiting Oroluk Island are having a significant impact on turtle populations by: 1) building structures in the nesting area, 2) human activity on the island causing turtles to avoid nesting, 3) harvesting nesting turtles and 4) harvesting turtle eggs. As a result, a decline in turtle nesting and turtle numbers has been noted at Oroluk Atoll. Even though only a few people live at Oroluk Island, the level of turtle and turtle egg harvesting is not sustainable.

The most important resource conservation and management issues are: 1) restoring and maintaining marine turtle nesting areas, 2) encouraging continued nesting, 3) maintaining continued foraging and resting habitat, 4) protecting the marine turtle population at Oroluk Atoll, 5) obtaining data on marine turtle nesting, population level and migration and determining and enforcing a sustainable level of subsistence harvest by Oroluk Island inhabitants.

RECOMMENDATIONS

1. Existing legislation prohibiting the harvest of turtle eggs and the taking of turtles on land should be vigorously enforced at Oroluk Atoll.

2. All pig pens and house sites should be removed from the beach nesting areas as soon as possible. The prime nesting habitat along the south and southwest coastline of Oroluk Island should be allowed to revert to natural conditions. If necessary, the nesting area should be surveyed and declared a nesting reserve.

3. A long term program of marine turtle monitoring, censusing and tagging at Oroluk Atoll should be developed and funded, preferably as part of a larger state and FSM program.

4. Quotas for the subsistence harvest of marine turtles should be set based on turtle population size and dynamics.

5. A conservation officer from Pohnpei State Marine Resources Division should be stationed at Oroluk Atoll to census and monitor turtle populations, conduct a tagging program and enforce conservation laws.

6. A program for removing the inhabitants of Oroluk Atoll and resettling them back on Pohnpei Island should be developed for consideration as the most permanent solution to marine turtle conservation, especially if the above measures are not taken or do not work.

B. REEF AND LAGOON HABITAT CONSERVATION

Oroluk Atoll and Minto Reef are unique assets for Pohnpei State and FSM. These two areas are examples of: a) an oceanic atoll with many deep passes and b) an oceanic reef atoll with no deep passes and no land area. Due to their distance and isolation and lack of a significant human population or economic activities, both areas are largely undisturbed, with their ecosystems, habitats and biological diversity largely intact and in pristine condition. They thus have considerable intrinsic natural value on a local, national, regional and global level.

The remote location and inaccessibility of both atolls and the lack of any emerged land and human inhabitants at Minto Reef practically makes these areas a defacto refuge at present. However, more formal conservation status, with associated planning and management actions, is warranted due to the increasing possibility of activities which will compromise the conservation value Oroluk Atoll and Minto Reef.

It is reported that fishing vessels, possibly from Chuuk State, visit Oroluk to conduct fishing in and around the atoll, sometimes using blast fishing techniques. Blast fishing involves the use of explosives to indiscriminately stun and kill fish. When used in coral reef environments, this technique destroys corals and reduces reef habitat to rubble. There is no information on whether fishing practices which destroy habitat are being employed by fishing vessels which visit Minto Reef.

Because of the severe typhoon damage, Oroluk Atoll and, especially, Minto Reef also have significant scientific value for documenting the recovery of an isolated coral reef atoll ecosystem following a major typhoon.

RECOMMENDATIONS

1. Existing legislation prohibiting the possession or use of explosive devices for fishing should be strictly enforced throughout the FSM, in conjunction with an extensive education program.

2. Oroluk Atoll and Minto Reef should be declared Marine Life Conservation Areas by Pohnpei State and a zoning plan developed for the multiple use and conservation of the reef and lagoon habitat.

3. A zoning plan ( see Appendix 12) should designate:
- the bulk of Oroluk and Minto, including the entire lagoon and a portion of the outer reef, as a multiple use zone for subsistence and artisanal use and non-destructive tourist, educational and scientific use;
- strict marine reserve areas for unique, representative and critical habitat; and
- areas where commercial fishing is allowed;

4. A plan for the administration and management of Oroluk Atoll and Minto Reef Marine Life Conservation Areas should also be adopted (see Appendix 13).

C. REEF AND LAGOON LIVING RESOURCES

Sustainable, well managed and limited harvesting of living resources from Oroluk Atoll and Minto Reef is not incompatible with conservation of habitat and resources. The relatively unaltered and pristine conditions of the coral reef habitat, and the apparent lack of fishing pressure, has contributed to a remarkably diverse and abundant population of reef and nearshore fishes at Oroluk Atoll and Minto Reef. Despite the fact that Minto Reef has been seriously impacted by a typhoon it continues to support a relatively diverse and abundant reef fish population.

The value of Oroluk Atoll and Minto Reef as almost unfished oceanic reef environments may outweigh any limited, short-term benefits from commercial fishing for reef fish. There were no abundant populations of marine invertebrate or plant resources of commercial interest found at Oroluk Atoll or Minto Reef. These include giant clams, urchins, trochus, pearl shell oyster, sea cucumber and sponge.

RECOMMENDATIONS

1. Existing regulations against the sale, barter or exchange of marine turtles or turtle eggs for other goods or money should be strictly enforced.

2. Commercial fishing should be allowed only in approved zones on the outer reef of Oroluk Atoll or Minto Reef and not in the lagoon, in accordance with an approved management and zoning plan.

3. All vessels fishing at Oroluk Atoll or Minto Reef should require a limited entry permit from the Pohnpei State Department of Conservation and Natural Resources Surveillance.

4. Quotas for the commercial take of key species should be set.

5. The conservation officer stationed at Oroluk Atoll should monitor fish catches and enforce regulations.

6. No commercial harvest of existing stocks of marine invertebrates should be allowed.

7. A surveillance system should be installed to track ships and warn off illegal visitors, perhaps through the FSM Division of Marine Surveillance.

## D. SEABIRDS

A seabird nesting area on the northern end of Oroluk Island has been designated a conservation area by the Pohnpei State Department of Lands. However, there are no data or monitoring on the kinds and numbers of birds nesting there or on bird population trends. Limited numbers of birds are harvested for consumption by the Oroluk Island inhabitants.

### RECOMMENDATIONS

1. The seabird nesting conservation area should be maintained.

2. Monitoring of seabird populations should be undertaken periodically.

3. The potential for shipwrecks to support seabird populations at Minto Reef should be documented.

## E. MARICULTURE

The potential for mariculture at Oroluk Atoll and Minto Reef is largely unknown. Large stocks of commercially valuable species with mariculture potential do not occur naturally in either area. Logistic considerations may likely make any venture uneconomical. Mariculture proposals should be evaluated in light of the conservation value and priorities for the two areas.

### RECOMMENDATIONS

1. Limited experimental mariculture activities may be undertaken in approved zones, following economic and environmental assessment.

2. The proposed introduction of any alien organism, including those for mariculture, must be subject to a full Environmental Impact Assessment.

## F. TOURISM

The distance, isolation and lack of facilities at Oroluk Atoll and Minto Reef render both areas unsuitable for almost all tourist use possibilities. Regular visits by cruise ships or self-contained, live aboard SCUBA dive vessels built for open ocean conditions are the only possible tourist use of these areas. Although some tour boats have visited Oroluk Atoll, it is unlikely that either atoll would become a major, regular destination.

RECOMMENDATIONS

1. Limited, appropriate tourism activities may be undertaken in approved zones, following environmental and ecological assessment.

G. NAVIGATION

Minto Reef and, to a lesser extent, Oroluk Atoll are a hazard to navigation.

RECOMMENDATIONS

1. Aids to navigation should be installed at both Minto Reef and Oroluk Atoll.

# I. INTRODUCTION

## 1. BACKGROUND AND PURPOSE

A scientific survey of Oroluk Atoll and Minto Reef, Pohnpei State Federated States of Micronesia (FSM) was carried out from 28 November to 6 December 1990, just days after Typhoon Owen passed nearby. The purpose of the survey was to document the resources, habitats and resource uses of the two areas and make recommendations to the Pohnpei State and FSM Governments on the conservation and management of Oroluk Atoll and Minto Reef.

There have been no efforts to describe or inventory the ecosystems and biological diversity of Oroluk Atoll and Minto Reef. With the exception of the Pohnpei Coastal Resource Inventory (USACE, 1986) and the Kosrae Coastal Resources Inventory (USACE, 1989), no recent checklists of marine organisms for any of the Eastern Caroline Islands have been attempted and no published records could be found for Oroluk Atoll or Minto Reef. Myers (1989) estimates 1,149 inshore fish species occurring in the Eastern Caroline Islands, with a clear decrease in diversity as one moves eastward through Micronesia. However, Myers states that 82% of the Micronesian fish fauna may be expected in the Eastern Caroline Islands. A similar situation would be expected for other marine organisms.

The survey was jointly organized and sponsored by the FSM and Pohnpei State Governments, the East West Center Environment and Policy Institute, the University of Hawaii Sea Grant Program and the South Pacific Regional Environment Programme (SPREP) Coastal Management Programme, with the collaboration and expertise of many other agencies and organizations.

## 2. ACKNOWLEDGEMENTS

The authors acknowledge the essential contribution of the FSM for in providing the vessel "Constitution" and her crew to support the undertaking of the survey and the assistance of Mr R. Weilbacher (Secretary of Transportation) in arranging the ship's availability. We are grateful for the support of the Pohnpei State Government, especially the Department of Resources and Development, in allowing the survey to take place and for assisting with arrangements, especially through the efforts of its Director, B. Weilbacher. The efforts of Tashiro Ludwig and Flinn Curren (Pohnpei State Marine Resources Division), Mike Gawel and Moses Nelson (FSM Marine Resources Division) and Kit Dahl (Community College of Micronesia/Sea Grant Extension) were instrumental in keeping the project alive, organizing the survey and providing background information and logistic support.

Pohnpei State Marine Resources Division provided skiffs for the field work and the expertise of Donald David. The FSM Marine Resources Division, Community College of Micronesia (CCM) and the U.S. National Marine Fisheries Service (NMFS) provided the expertise of Mike Gawel, Ahser Edwards and John Naughton, respectively. The CCM/University of Hawaii Sea Grant Extension Service provided the assistance of Kit Dahl to take the lead in planning and coordinating the survey in Pohnpei. Pohnpei State Forestry Division and Lands Division provided the expertise of Simon Liphei.

The East West Center Environment and policy Institute, through support provided by the John D. and Catherine T. MacArthur Foundation, provided financial support for the survey and the expertise of Dr James Maragos, who was the overall project coordinator and leader. The assistance, encouragement and support of Dr Lawrence Hamilton through all stages of the project is gratefully acknowledged. Dr Raymond Fosberg of the Smithsonian Institute provided his time to identify the plants collected by Simon Liphei and John Weilbacher. Dr Lu Eldredge of the Pacific Science Association made available his time to correct the invertebrate species list. The SPREP Coastal Management Programme made available funds, provided by the International Center for Ocean Development (ICOD), and the expertise of Paul Holthus.

The authors acknowledge the crew of the "Constitution" for their forbearance and assistance during the survey and the inhabitants of Oroluk Island for their assistance in welcoming the survey participants to Oroluk Atoll and providing information on the natural resources of the atoll and their uses.

## 3. LOCATION

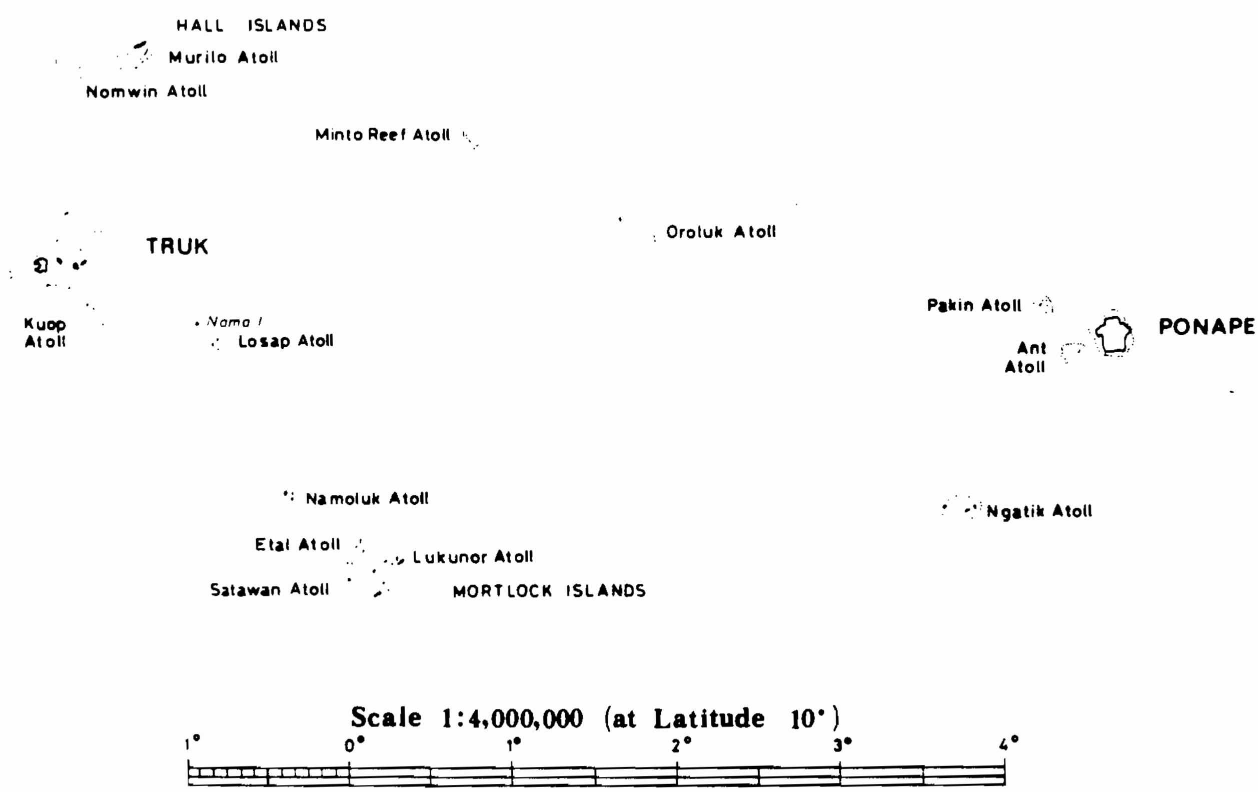
Oroluk Atoll and Minto Reef are part of Pohnpei State of the Federated States of Micronesia (FSM). Oroluk Atoll is approximately 202 miles (325 km) west/northwest of Pohnpei Island and is found at 7° 32.5' N and 155° 17.5' E. Minto Reef is approximately 273 miles (440 km) from Pohnpei Island in the same direction and is found at 8° 09' N and 154° 17' E (Figure 1).

## 4. METHODS

The survey was conducted by a multi-disciplinary team. Each team member specialized in a number of topic areas for the survey. The survey team included the following personnel (listed in alphabetical order), from the agencies indicated:

FIGURE 1

LOCATION MAP: OROLUK ATOLL AND MINTO REEF



Kit Dahl (Sea Grant) - logistics planning and coordination
Donald David (Pohnpei State Marine Resources Division) - fish, resource use
Ahser Edward (CCM) - fish, algae, macroinvertebrates
Mike Gawel (FSM, Marine Resources) - fish, macroinvertebrates
Paul Holthus (SPREP) - reef geomorphology, corals, macroinvertebrates
Simon Liphei (Pohnpei State Forestry Division) - vegetation, birds, resource use
James Maragos (East West Center) - reef geomorphology, corals, macroinvertebrates
John Naughton (NMFS) - fish, marine turtles, marine mammals
John Weilbacher (Pohnpei State Lands Division) - vegetation, birds, resource use

The survey personnel were divided into two marine teams and a terrestrial team. The marine teams conducted underwater and shoreline surveys and the terrestrial team conducted vegetation and bird surveys and resource use interviews. Each marine team consisted of 3 or 4 specialists which carried out underwater surveys using SCUBA and snorkel gear at selected sites. Each specialist recorded on underwater paper or slates semi-quantitative information on the presence and relative abundance of the organisms covered. Organisms were identified in situ in the field to the lowest taxonomic level possible during the limited time available at each site. Limited collection of invertebrates was undertaken and the samples deposited with the CCM.

Wherever possible corals were identified to species level, but generally corals were recorded at the genus level. Additional information on growth form was collected, especially for important genera and those with many species (e.g. *Acropora* and *Porites*). The survey of invertebrates concentrated on conspicuous macroinvertebrates, especially soft corals, those of food or economic value (e.g. giant clam, trochus, sea cucumber) and those particularly important to, or indicative of, reef ecosystem condition (e.g. *Acanthaster*, urchins). Conspicuous algae were also identified to the level possible in the field during the survey. Cryptic corals, macroinvertebrates and algae and nocturnal macroinvertebrates were not well covered by the survey.

Due to the large number of reef associated fishes and the relative short period of time spent at each site, a rapid visual technique was used to obtain estimates of relative species abundance. The survey concentrated on families that included important commercial and subsistence fish species (i.e. Serranidae, Lutjanidae, Lethrinidae, Carangidae, Scaridae, Acanthuridae). The relative abundance of large, desirable food fishes are a good indicator of a pristine environment and low fishing pressure. Families comprised of cryptic species or small, non-food fishes (i.e. Holocentridae, Apogonidae, Gobiidae, Blennidae, Pomacentridae, Chaetodontidae) were generally not recorded unless a particular species was dominant at a site. Nocturnal species were not well covered by the survey.

Sketch profiles were made to record information on reef geomorphology, with notes on substrate type, estimated percent coral cover and storm damage. Photographs were taken to aid data recording and notes were taken on other aspects, e.g. water quality, bird life, etc.

Sites were selected to sample the major habitats and physiographic zones of Oroluk Atoll and Minto Reef and achieve a wide geographic spread. Weather, wave and sea conditions did not permit many sites to be sampled on the ocean slope of the perimeter reef, especially on the north and east sides. A total of 46 stations were surveyed at Oroluk Atoll, including Oroluk Island, and 23 stations were surveyed at Minto Reef.

The terrestrial team surveyed the presence and distribution of vegetation of Oroluk Island, including storm damage, as well as bird populations, other terrestrial resources and human habitation of the island. Interviews with the island inhabitants were conducted to determine resource use levels and patterns, i.e. fishing, marine turtle harvest, seabirds, use by outsiders, etc.

Most measurements of distances and estimations of lagoon areas are made from the two best charts available for these areas, i.e. Oroluk Lagoon (U.S. Navy Hydrographic Office, Chart No. 6043, scale 1:50,000, originally published 1944, with corrections up to 1966 and U.S. Army Map Service, Sheet 5244 I, Series W756, scale 1:50,000)) and Minto Reef (U.S. Army Map Service, Sheet 5046 II, Series W756, scale 1: 50,000, published 1960). Map and field measurements are presented in the units in which they were obtained, either US and metric units, with conversions from one to the other rounded off.

## 5. ECOSYSTEM CLASSIFICATION AND PHYSIOGRAPHIC ZONES

The proposed marine ecosystem classification for conservation management in the island Pacific (Maragos, et.al, 1992) can be used to classify Oroluk Atoll and Minto Reef (Figure 2).

Oroluk Atoll and Minto Reef can be divided into a series of physiographic zones to aid in their description. They can be broadly divided into the perimeter reef and the lagoon. On the ocean side the perimeter reef includes the crest, margin, terrace and outer slope. On the lagoon side the perimeter reef includes the lagoon margin, terrace and lagoon slope. Between the ocean and lagoon margins is the shallow reef platform, which may be described from its oceanward (outer) zones to the lagoonward (inner) zones. Depositional sand cays (motus) are found on the shallow platform, although only on Oroluk Atoll is a permanently vegetated motu found.

## FIGURE 2

## ECOSYSTEM CLASSIFICATION OF OROLUK ATOLL AND MINTO REEF

Oroluk Atoll and Minto Reef are classified as:

- Non-Continental
  - Reef Island
    - Atoll with many deep passes (Oroluk Atoll)
    - Atoll with no deep pass (Minto Reef)

Both Oroluk Atoll and Minto Reef include:

- Shore Area
  - Undifferentiated coast - outer/ocean
    - boulder/gravel beach
    - sand/gravel beach
    - boulder/cobble field
  - Undifferentiated coast - inner/lagoon
    - boulder/cobble beach
    - sand/gravel beach
    - sand flat
- Barrier Reef Area
  - Reef top
    - reef flat
    - surge channel
    - rubble platform
    - storm blocks
    - sand and gravel sheets on reef flat
    - sand cay
    - false pass
  - Outer slope
    - terrace
    - groove and spur
    - vertical cliff
    - notch and cave
    - detrital boulders on slope and terrace
  - Lagoon slope
- Lagoon Area
  - Lagoon patch reef and pinnacle
  - Lagoon floor

The perimeter reef is bisected by passes of various depth, which can be described in terms of the pass walls and bottom and, longitudinally, as the inner or outer pass. The lagoon includes the lagoon bottom enclosed by the perimeter reef. Lagoon reefs include pinnacles, which are steep sided reefs of limited surface area, and patch reefs, which have a significant shallow reef flat and may support a sand cay.

## II. OROLUK ATOLL

### 1. GENERAL DESCRIPTION

### 1.1 Atoll Shape and Size

Oroluk Atoll is an irregular shaped atoll reef stretching about 19.2 miles (31 km) along the elongated northwest/southeast axis and roughly 12.4 miles (20 km) from north to south (Figure 3). The outer edge of the shallow reef platform, linking across the passes, forms a perimeter of approximately 61.1 miles (98.5 km). The irregular atoll perimeter reef can be divided into 5 sections for descriptive purposes based primarily on orientation, i.e. North, East, South, Southwest and West (Figure 3).

### 1.2 Perimeter Reef and Cays

The perimeter reef of Oroluk Atoll generally averages from 660-980 ft (200-300 m) wide, but may range from 490-2460 ft (150-750 m) wide in places. The notable exception to this is in the extreme northwest of the atoll. Here the sharp corner of the perimeter reef extends up to 4920 ft (1500 m) from ocean to lagoon. This wide reef platform is the location of the only permanent, vegetated motu of the atoll, Oroluk Island. There are numerous unvegetated sand cays scattered along the perimeter reef, mostly on the North reef, with a few on the East reef as well. The patch reef just inside the deep pass through the North reef also supports a sand cay.

### 1.3 Passes

There are 16 passes through the perimeter reef (Figure 3). All but two of these are located on the West, Southwest and South sides of the atoll. One deep pass is found along the North reef (Keltie Pass) and another relatively shallow pass occurs on the East reef. Of the passes, four are elatively deep with depths of 168-180 ft (51-55 m), seven range from 66-126 ft (20-3 ) in depth and five are only 9-30 ft deep (3-9 m) (Table 1). The single deep pass ng the North reef and the deep pass along the Southwest reef have lagoon patc eefs just inside the pass entrance. An elongate patch reef is inside the wide, dee ass on the South reef and overlaps with the adjacent perimeter reef, forming a double" perimeter reef.

FIGURE 3

OROLUK ATOLL

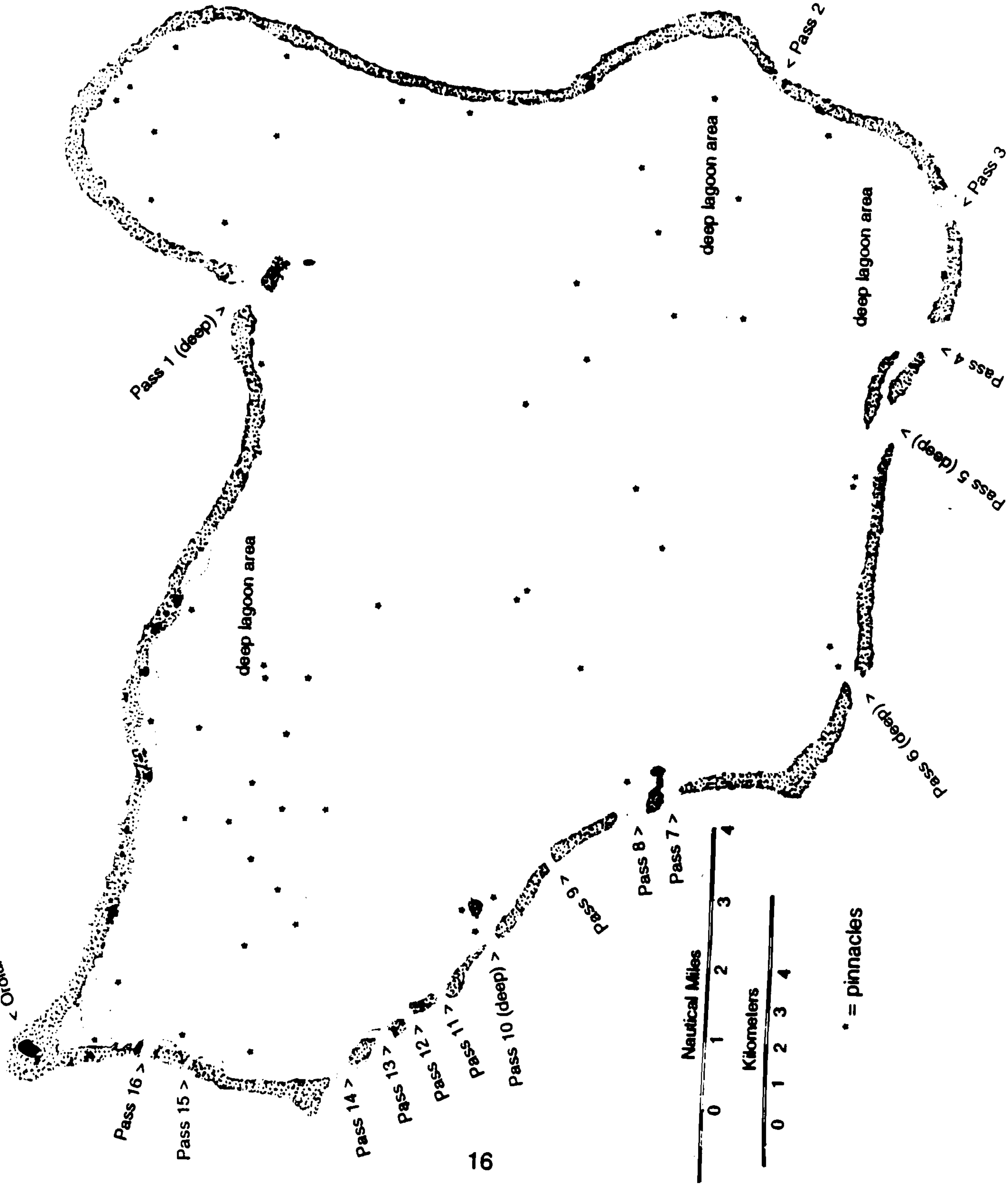


TABLE 1

REEF PASSES AT OROLUK ATOLL

| Pass No. | Depth (ft) | Width (ft) | Remarks |
|---|---|---|---|
| 1 | 168 | 2600 | Keltie Pass, patch reef in pass |
| 2 | 30 | 1150 | |
| 3 | 72 | 2600 | |
| 4 | 96 | 2800 | |
| 5 | 180 | 3600 | "double" perimeter reef |
| 6 | 180 | 1300 | |
| 7 | 126 | 1500 | narrow reef area between Passes 7 and 8 |
| 8 | 90 | 2600 | |
| 9 | 28 | 800 | |
| 10 | 168 | 1300 | patch reef in pass |
| 11 | 28 | 1000 | |
| 12 | 32 | 1300 | |
| 13 | 72 | 1300 | |
| 14 | 66 | 2100 | West Channel |
| 15 | 9 | 500 | |
| 16 | 72 | 800 | Pioneer Pass |

## 1.4 Lagoon and Lagoon Reefs

The lagoon of Oroluk encloses an area of approximately 159 sq mi (412 sq km) with average depths of 120-180 ft (37-55 m). Some areas of the lagoon are deeper, particularly along the central portion of the North reef and in the southeast bulge of the lagoon, where depths reach 210-246 ft (64-75 m). Two of the passes have a patch reef at their entrance. In addition to these few patch reefs, there are about 50 reef pinnacles are scattered across the lagoon. These are more common in the northwest and northeast corners of the lagoon, are broadly scattered across the southeast lagoon and are common near some of the passes.

# 2. CORAL REEFS AND BENTHIC COMMUNITIES

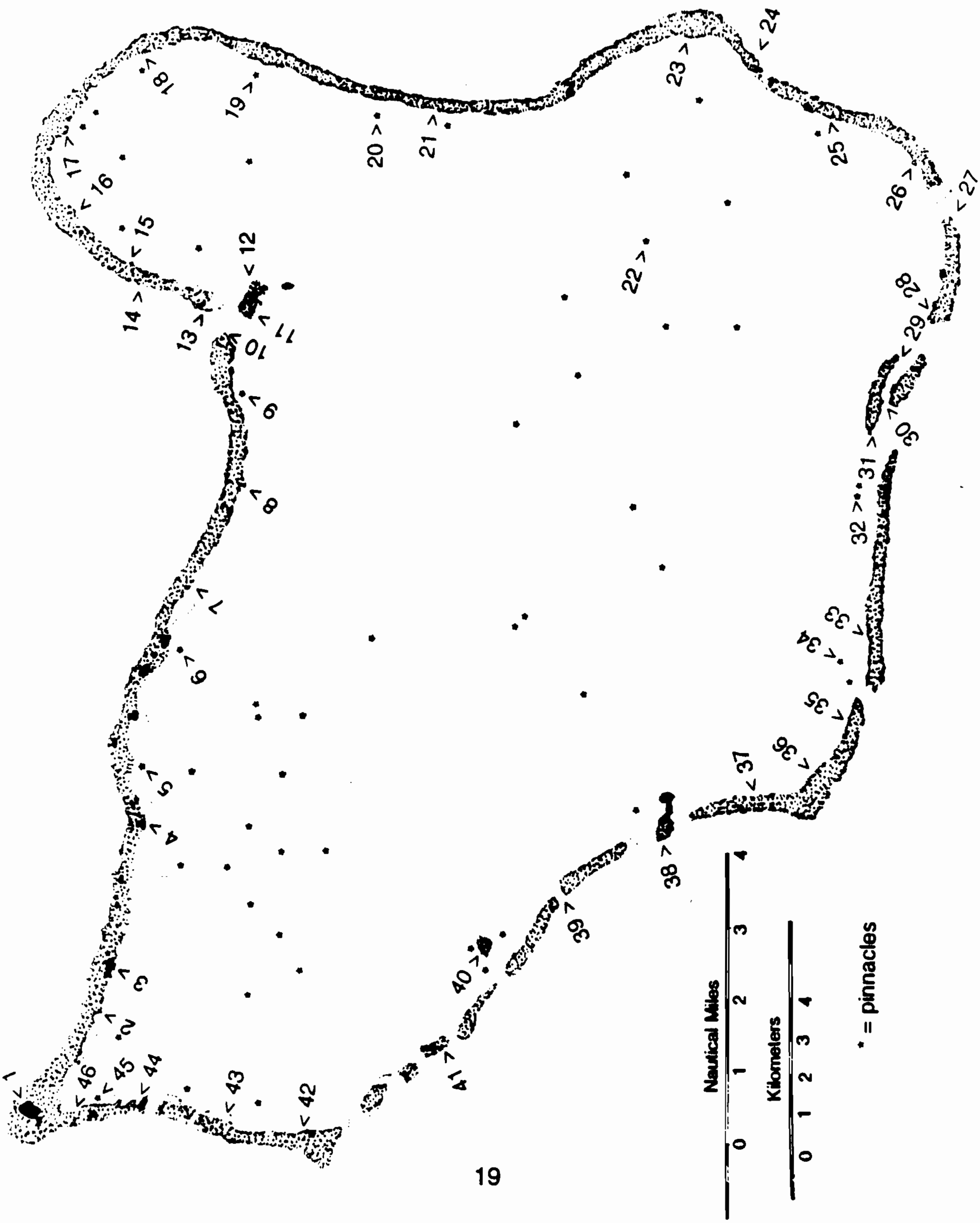
Coral reefs and coral communities are described for the major reef sections and the physiographic zones in each section, based on the information recorded at the 46 survey sites for Oroluk Atoll (Figure 4). The dominant, abundant and common corals are indicated, along with conspicuous algae and macroinvertebrates. The distribution and relative abundance of all coral genera recorded are presented in Appendix 1. A coral species list is found in Appendix 2. The distribution and relative abundance of macroinvertebrates and a species list are presented in Appendices 3 and 4, respectively. The distribution and relative abundance of algae and a species list are found in Appendices 5 and 6, respectively.

## 2.1 Ocean Reef and Pass: North Perimeter (Sites 10, 13, 14)

The outer reef slope along the north dropped off fairly steeply from the shallow reef platform down to 100-120 ft (31-37 m) where a gradually sloping shelf was found. The reef face was dissected by channels and descended irregularly, with areas of outcrops and sheer slope faces breaking up the slope. Overall coral cover varied from 40-80%, with fairly high diversity. Massive *Porites* colonies were the dominant coral on the outer slope. Abundant and common corals included columnar *Millepora* and *Acropora*, small massive corals such as *Favia*, *Favites*, *Pavona*, *Goniastrea* and encrusting colonies of *Leptastrea* and *Montipora*. Storm damage was very high with large areas of disturbed or destroyed corals and accumulations of rubble, reef blocks and broken colonies in the channels and in pockets along the reef face. *Halimeda* algae was abundant in places and the small giant clam *Tridacna maxima* was common on the upper slope.

FIGURE 4

OROLUK ATOLL SURVEY SITES



A single deep pass bisected the almost 18.5 mi (30 km) long North reef. The walls of the outer pass reef descended nearly vertically into the pass. The shallow upper areas were less steep and supported 50-70% coral cover with moderate to high diversity. Algal paint and large patches of soft corals were common in the shallow areas. Small massive colonies of *Astreopora* were the dominant coral, with massive *Porites*, columnar and branching *Millepora*, *Goniastrea* and digitate *Acropora* abundant or common on the upper pass slope. Although storm damage was considerably less than on the outer reef, large number of columnar *Millepora* colonies were broken off.

Towards the lagoon the inner pass wall became a broader slope, although a short steep drop off from the shallow platform sometimes occurred found at the top of the slope. The bare, scoured reef substrate supported little coral cover and limited diversity, with coral cover of only 0-30%. This consisted of scattered columnar *Millepora*, digitate *Acropora*, *Pocillopora*, encrusting *Pavona* and *Millepora*, and massive corals, such as *Porites*, *Astreopora*, *Goniastrea* and *Favites*. Towards the lagoon less sturdy corals, such as foliose *Montipora* and *Leptoseris* and branching *Millepora,* were abundant or common as well. Portions of the pass reef on the east side were very steep walls with little coral growth, but with crinoids and urchins locally abundant on the scoured substrate. Other areas supported high cover of *Microdictyon* algae. At the lagoon end of the pass, a veneer of sand sometimes covered the reef substrate and at the lagoon end of the pass a talus slope of recently deposited rubble occurred.

2.2 Ocean Reef and Passes: South Perimeter (Sites 24, 27, 30, 31, 35, 38, 39, 41)

This long extent of perimeter reef stretched 26 mi (42 km) and was broken by 13 passes, three of which were deep and three shallow. The bottom of the shallow and moderate depth passes formed a sill. These sills often had coral mounds or large platforms of moderate to high coral cover located between the sand chutes and channels running along the sill towards the ocean drop off. Recently broken coral was accumulated in a number of the shallow and moderately deep passes. In some areas the sill extended as a sloping terrace 15-30 ft deep (5-10 m) on the adjacent ocean front of the perimeter reef. The reef slope above the sill or terrace generally had moderate coral cover dominated by columnar *Millepora* with digitate *Acropora* common at the shallow crest.

Where a terrace was formed, coral cover was usually very high, ranging from 50-100%. Columnar *Acropora* dominated the coral community with large monospecific stands. Abundant and common corals included *Pavona*, *Porites rus*, *Coscinaraea*, *Goniopora*, *Goniastrea*, *Favia*, massive and encrusting *Porites*, Fungiids (mushroom corals), *Stylophora*, *Pocillopora*, *Heliopora*, *Montipora* and large stands of branching *Acropora*. Large soft corals, *Microdictyon* algae and *Tridacna maxima* were common at almost all sites. *Halimeda* and *Caulerpa* algae, *Echinostrephus* urchins and sponges were common at some sites. Where there was no terrace, or at the edge of the terrace, the ocean slope dropped off more steeply, with decreasing coral cover and increasing bare substrate and rubble.

The deep passes along the south reef had very steep slopes which descended directly into the pass or adjacent ocean depths. Coral cover was variable and ranged up to 5-50% on the upper slope, with most of the same corals which occur in the shallower passes. Additional corals which were common included *Leptastrea*, small plate and bushy *Acropora*, *Hydnopora*, encrusting and branching *Millepora*, encrusting *Porites*, finger coral and plate *Porites* and *Turbinaria*. Crinoids were often abundant in areas of strong current.

The upper pass slope was sometimes indented with grooves and rubble chutes which were offset by steep promontories and overhangs. In places this irregular topography continued down into the pass itself. On the adjacent ocean reef face, the mid and lower slope was often consolidated reef structure with little relief and increasing sand and rubble with depth. *Microdictyon* algae was abundant and covered much of the substrate in these mid-slope areas. *Distichopora* coral was common on the lower slopes and in overhangs.

2.3 Reef Platform and Lagoon Reef: North Perimeter (Sites 2, 3, 4, 7, 8, 9)

Other than the exceptionally wide reef platform found in the northwest corner of Oroluk Atoll, the reef platform on the North reef varied in width from 820-1640 ft (250-500 m) and had four zones of varying width across the platform. The ocean side of the perimeter reef platform was generally a bare, flat reef pavement scoured by wave action and currents. Coral cover was absent in this zone and there was no algal ridge. Lagoonward of the bare reef pavement, scattered coral boulders and plates were deposited on the solid substrate. This second zone supported very little coral cover, only 0-5%. Further towards the lagoon, a third zone consisted of small boulders and up to 15% coral cover, mostly small *Porites* massives and microatolls.

The most lagoonward portion of the reef platform was usually the widest of the four zones, sometimes covering up to 40% of the platform width. This zone often had an irregular topography of solid substrate and supported the greatest level of coral cover on the shallow reef, ranging from 10-40%. Abundant corals included massive *Porites*, *Favia*, *Favites*, *Goniastrea*, *Platygyra*, digitate *Acropora* and encrusting *Millepora*, with soft corals common in places. *Astreopora* and columnar *Millepora* were sometimes dominant on the lagoon edge of the reef platform, the latter often with much breakage, presumably due to storm damage from the movement of reef material across the reef platform and into the lagoon.

The lagoon edge of the solid reef platform often dropped immediately down 5-10 ft (2-3 m) to the upper portion of the lagoon talus slope. The hard lagoon platform edge usually supported moderate coral cover similar to the adjacent reef platform. The lagoonward zone of the perimeter reef platform was usually the location of the numerous depositional cays found along the North reef.

The upper lagoon slope of the perimeter reef in this area consisted of coral blocks and boulders, mixed with sand, rubble and some live coral fragments. The upper slope generally had only 0-5% coral cover, and small molluscs were sometimes common. In places, large mounds on the upper lagoon slope, ranging from 6-32 ft (2-10 m) in diameter, provided suitable substrate and topography for 25-70% coral cover. Fingers of solid reef substrate, not connected to the reef platform, or patch reefs very close to the main reef platform are included in the upper lagoon slope in other places.

These mounds, reef fingers and patch reefs supported moderate to high coral diversity with species composition similar to the adjacent reef platform as well as commonly including *Montastrea*, *Pocillopora*, *Cyphastrea*, *Leptastrea*, *Acanthastrea*, *Platygyra*, *Stylophora*, *Montipora*, *Heliopora*, *Pavona* and *Porites* finger coral. These areas also often provided habitat for *Tridacna maxima*, with *Hippopus hippopus* sometimes common as well. The urchins *Heterocentrotus* and *Culcita* and *Microdictyon* algae were also occasionally common in the lagoon slope habitat. Otherwise, sand and gravel became more predominant as the slope descended broadly into the lagoon. At 30-40 ft (9-12 m) the sand slope dropped off more steeply into lagoon depths.

2.4 Reef Platform and Lagoon Reef: Northeastern Perimeter (Sites 15, 16, 17, 18, 20, 21)

To the east of Keltie Pass, in the northeast lobe of the lagoon and down along half of the East reef, a sand terrace bordered the lagoon side of the perimeter reef. The reef platform in this area varied from around 1640 ft (500 m) wide in the north to an average of 820 ft (250 m) wide along the east. The lagoon edge of the perimeter reef was a coalescing reef with a series of pools and channels with reef mounds which extended onto the sand terrace of the upper lagoon slope. The pools and channels provided favorable habitat for corals and had high aesthetic value. Coral cover and diversity were high.

Abundant and common corals included *Astreopora*, *Acanthastrea*, *Lobophyllia*, *Pocillopora*, *Stylophora*, *Goniastrea*, *Montastrea*, *Favia*, *Echinopora*, massive, encrusting and finger coral *Porites*, columnar, branching and encrusting *Millepora*, digitate and columnar *Acropora*, *Pavona* and *Montipora*. The clam *Tridacna maxima* was often abundant in the area. *Hippopus hippopus* and smaller molluscs were sometimes common, as was soft corals, urchins and *Halimeda* algae. Storm damage was evident, with many recently detached corals deposited on the reef flat.

The reef mounds which extended out onto the gently sloping sand terrace of the upper lagoon continued to support high coral diversity with coral cover up to 90%. In addition to the corals mentioned above, coral cover included *Euphyllia* and large *Goniopora* and *Heliopora* colonies. The sand of the terrace was largely composed of foraminifera and extended away from the reef in series of rippled hummocks until dropping off more steeply into the lagoon. In a few locations (e.g. site 20), a shallow finger of the perimeter reef reached out onto the surrounding terrace and dropped off more steeply into the lagoon. These reef extensions supported only 5-15% coral cover on the solid substrate margin and upper slope which was otherwise dominated by *Microdictyon* algae.

### 2.5 Reef Platform and Lagoon Reef: South Perimeter (Sites 23, 25, 26, 28, 33, 36, 37)

Reef platform width along this long extent of perimeter reef with numerous passes is more variable than elsewhere around the atoll, ranging from 490-2300 ft (150-700 m). The oceanward portion of the perimeter reef was scoured reef pavement with reef block and rubble patches and almost no coral growth. this condition sometimes continued nearly to the lagoon margin of the reef. In many areas, however, depth increased to 3-5 ft (1-1.5 m) on the backreef and a zone of microatolls, coral mounds and sand patches was found. The microatolls were often monospecific stands of columnar *Acropora* or *Heliopora*, with massive and finger coral *Porites* and *Astreopora* also very abundant.

The backreef along the Southeast side also often had rubble deposits, sometimes forming cays which were awash at all but low tide. In a few locations (e.g. site 36), relatively large false channels 15-20 ft (5-7 m) deep , with sand deposits and large monospecific coral stands, indented the lagoonside of the perimeter reef. The fleshy green algae *Caulerpa* was sometimes very abundant, and the algae *Microdictyon* sometimes common, on the backreef substrate.

The backreef platform usually ended abruptly with a margin of hard substrate and irregular topography. The hard substrate supported stretches of increased coral cover and diversity at the reef edge and upper slope. Columnar *Millepora* often dominated the lagoon margin, where overall coral cover was variable, ranging from 10-70%. Abundant and common corals included branching *Millepora*, *Favia*, *Goniopora*, encrusting *Porites*, *Pocillopora*, *Seriatopora*, *Stylophora*, *Goniastrea*, bushy and digitate *Acropora*, *Montastrea*, *Pavona*, encrusting *Millepora* and *Montipora*. In places, the backreef zone in these areas supported abundant populations of the giant clams *Tridacna maxima*, *T. crocea* and *Hippopus hippopus*.

The reef usually dropped sharply to a sand and rubble terrace 10-15 ft (3-5 m) deep, with an accumulation of storm rubble and recently broken or toppled corals at the base of the short drop off. In some areas, though, the lagoon edge was a more gradual rubble and shingle slope. Although there were some reef rock outcrops and coral mounds in these areas, coral cover was generally low where the hard substrate reef margin was lacking, although small molluscs were usually common or abundant. In all cases, a rubble and sand slope gradually descended towards lagoon depths.

2.6 Reef Platform and Lagoon Reef: West Perimeter (Sites 42, 43, 44, 46)

This relatively short section of the perimeter reef, only 5.3 mi (8.5 km) long averaged 820-1310 ft (250-400 m) wide and was broken by two narrow passes, one shallow and one moderately deep. The oceanward portion of the perimeter reef in this area was a solid reef pavement with encrusting and turf algae and virtually no coral growth. Corals became more abundant on the irregular reef surface at the lagoon margin of the reef platform. Columnar *Millepora*, digitate *Acropora*, massive *Porites* and *Goniastrea* were usually common at the margin.

The lagoon reef edge sloped to a sand, shingle and gravel terrace 10-20 ft deep (3-4 m), either gradually or with a relatively steep drop. In either case, the back reef slope supported fairly high coral cover, sometimes up to 50-80%. *Astreopora* was often dominant in the coral assemblage, with *Heliopora*, *Stylophora*, *Porites* finger coral, *Favia*, bushy *Acropora*, foliose *Montipora* and *Acanthastrea* abundant. Where the lagoon reef edge dropped quickly down to a terrace, mounds of reef development were scattered across the terrace, with coral growth sometimes reaching the surface. These mounds also supported moderately high coral cover, commonly including, in addition to the corals mentioned, *Palauastrea*, *Pocillopora*, *Montastrea*, *Cyphastrea*, *Acanthastrea*, branching *Millepora*, *Pavona* and *Platygyra*. Soft corals, several algae (*Halimeda, Caulerpa, Gracilaria, Codium, Udotea*) and three giant clam species (*Tridacna maxima*, *T. crocea*, *Hippopus hippopus*) were also common in places.

In most of this area the sand and gravel terrace gradually sloped lagoonward, becoming a barren plain, sometimes with swales of reef rubble accumulation. Much of the rubble appeared to be recent, with coral fragments, especially *Millepora* and *Acropora* branches, among the rubble. In some locations, especially near the passes, the back reef was scoured and live coral cover was much less than in adjacent areas. In these locations, rubble was commonly accumulated at the base of the reef edge and large tongues of recently deposited reef material, including large blocks, extended into the lagoon.

2.7 Lagoon Patch Reefs and Pinnacles (Sites 5, 6, 11, 12, 19, 22, 29, 32, 34, 40, 45)

In addition to the approximately 50 pinnacles, lagoon reefs included two patch reefs and the lagoon portion of the elongate "double" perimeter reef along the southern side of the atoll. All of these reefs had similar characteristics. The center area of the patch reefs and the larger pinnacles, whose upward extent reached low tide levels, generally had accumulations of sand and sediment, which supported small molluscs. Only the patch reef associated with Keltie Pass, in the north, supported a substantial cay of coral plate, rubble and sand. The patch reef at Pass 9, in the southwest, had a few large reef blocks projecting above high tide but did not have a cay as indicated on the chart.

The margins of the patch reefs and pinnacles usually consisted of solid reef rock with a fair amount of topographic variability, providing good conditions for high coral cover and diversity. Coral cover ranged from 20-70% along the margins and upper slope and contained the highest level of coral diversity of the major habitat types of Oroluk Atoll. Abundant corals included *Astreopora*, *Goniastrea*, columnar *Millepora*, encrusting and finger coral *Porites*, *Pavona*, *Acanthastrea*, *Heliopora*, *Stylophora*, digitate *Acropora* and *Merulina*. The diverse assemblage of corals also commonly included *Coscinaraea*, *Favia*, *Favites*, *Pocillopora*, fungids, massive *Porites*, *Heliopora*, *Turbinaria*, *Leptastrea*, *Platygyra*, *Distichopora*, columnar *Acropora*, *Palauastrea*, *Echinophyllia* and soft corals. Some species formed very large colonies right on the reef margin. *Tridacna maxima* was abundant or common on most of the lagoon reefs, with the occasional *Hippopus hippopus*.

The slope of patch reefs and pinnacles often dropped steeply, but irregularly, down to lagoon depths. In places, a very steep wall descended almost immediately from the upper reef directly to the lagoon bottom, sometimes with sand chutes. Coral cover decreased rapidly below the upper 10-20 ft (3-6 m), often to 0-10% for most of the reef slope. Although coral cover was low, diversity remained fairly high. Table and bushy *Acropora* were often abundant and common corals included branching *Millepora*, *Euphyllia*, *Lobophyllia*, *Oulophyllia*, *Leptoseris*, foliose *Montipora*, *Herpolitha*, *Cyphastrea*, *Psammocora*, *Stylaster*, *Coscinaraea*, *Cycloseris*, *Physogyra*, *Seriatopora* and *Goniopora*. Pinnacles near the perimeter reef and the patch reefs sometimes had a more gradual and complex slope on one side with mounds, outcrops, terraces and sand patches. These areas supported greater coral cover than steeper slopes, with 20-60% cover.

The slope substrate without coral cover was usually dominated by a carpet of the low, fleshy algae *Microdictyon*. The algae covered hard substrate, coral rubble and the occasional dead standing coral, which was often plate *Acropora*. *Halimeda* algae was occasionally abundant on the slope. Storm damage was evident on a number of the pinnacle and patch reefs, especially on the ocean side of reefs near passes or the perimeter reef. Typically plate corals were broken or toppled over and recent coral fragments accumulated along the reef slope or at the reef base.

## 3. BENTHIC FAUNA

### 3.1 Corals

A total of 149 coral species were recorded at Oroluk Atoll (Appendix 2). However, due to the difficulties in identifying corals to the species level in the field, most corals were only recorded to the genus level, and a total of 50 genera were observed at Oroluk Atoll (Appendix 1). The number of genera at any site ranged from 6 to 34. Of the 45 underwater survey sites, however, the majority of sites (33 sites or 73%) had 11-20 genera. Nine sites (20%) had more than 20 genera and only three sites (7%) had less than 10 genera.

Pinnacles and patch reefs generally supported higher diversity and included the four most diverse sites surveyed. The lagoon side and ocean side of the perimeter reef had fairly similar levels of coral diversity. The lagoonside south sections of the perimeter reef supported somewhat less diversity than other portions of the reef. There were 12 coral species found at Oroluk Atoll that were not later recorded at Minto Reef. These species belonged to eight coral genera: *Distichopora*, *Hydnophora*, *Leptoria*, *Pachyseris*, *Plerogyra*, *Physogyra*, *Seriatopora*, and *Stylaster.*

## 3.2 Giant Clams

At numerous locations around Oroluk Atoll, different species of giant clam were recorded (Appendix 3). *Tridacna maxima* was the most common, having been noted at 39 sites, and considered abundant or common at 27 of these. *Hippopus hippopus* was recorded at 20 sites and was abundant or common at almost half of these. *Tridacna crocea*, *T. squamosa* and *T. derasa* were rarely encountered and were usually very limited in numbers. Giant clam presence and abundance was somewhat greater in the northeastern and western portion of the atoll, although no striking patterns of distribution were evident. *Tridacna gigas* was not encountered at Oroluk Atoll.

## 3.3 Trochus and Peal Shell Oyster

Trochus was observed at only two of the sites visited and was rare in abundance. Pearl shell oyster (*Pinctada* sp.) was noted at only two sites, where its was also rare in abundance (Appendix 3).

## 3.4 Sea Cucumbers

Holothurians were seen at only four sites on Oroluk Atoll, with abundance only rare (Appendix 3). The recent passage of the typhoon may have affected the presence of sea cucumbers, although there is no direct evidence of this.

## 3.5 Lobster

No lobster were observed during the survey of Oroluk Atoll (Appendix 3).

## 3.6 *Acanthaster planci*

The coral eating Crown-of-Thorns Starfish (*Acanthaster planci*) was rarely observed at Oroluk Atoll (Appendix 3). Only a few individuals were recorded at scattered sites on the reefs visited, usually hidden in crevices or under corals and occasionally feeding. No areas of recent *Acanthaster* feeding scars or dead standing coral were observed, although the latter would have probably been affected by the typhoon passage. The coral eating cushion star *Culcita* was abundant at one of the three sites were it was found (Site 9), although active feeding was not observed.

### 3.7 Sea Urchins

Of the seven genera of sea urchins recorded at Oroluk Atoll, none was very widely distributed (Appendix 3). *Echinostrephus* was the most common, having been seen at 9 sites. The boring sea urchin *Echinometra* was also abundant in one location (Site 13) of the two where it was recorded.

## 4. BENTHIC FLORA

The relative abundance and distribution of the algae recorded at Oroluk Atoll are found in Appendix 5 and a species list in Appendix 6. Two algae were noted at most of the sites visited, *Halimeda* and *Microdictyon*. *Halimeda* occurred, usually in moderate abundance, at 27 sites around the atoll. *Microdictyon* was noted at 28 sites and was common, abundant or dominant at 20 of these sites, often blanketing the mid-slope substrate. Although *Caulerpa* was only recorded at nine sites, where it did occur, the algae was common or abundant more than half of the time.

## 5. FISH

### 5.1 Fish Habitat Conditions

The great diversity of habitats at Oroluk Atoll, including numerous lagoon pinnacles and passes connecting the lagoon to the outer reef slope, provided a large variety of possible niches, all of which are inhabited by numerous species of fish. In addition to the diversity of natural habitats, several "artificial reef" shipwrecks on the reef flat (e.g. Sites 25 and 33) supported a substantial biomass of certain fish species (e.g. *Mulloides vanicolensis*, *Caranx sexfasciatus*, *Kuhlia mugil*, *Acanthurus guttatus*, *Kyphosus cinerascens*). It is interesting to note that these artificial reefs support such a large biomass of reef fish at an atoll whose natural reef habitats are largely unaffected by human activities.

Recent reports indicate that Oroluk Atoll is being subjected to reef fishing, including illegal dynamite fishing by fishermen from Chuuk State (formerly Truk). No indication of reported dynamite fishing could be detected at Oroluk Atoll. However, Typhoon Owen caused considerable damage to the coral reefs and would have masked evidence of dynamite fishing, if any. Despite the typhoon damage, the coral reef habitat and other marine habitats of Oroluk are in excellent condition and support a diverse and abundant population of fishes.

## 5.2 General Fish Observations

The distribution and relative abundance of major reef associated fish species observed at Oroluk Atoll are found in Appendix 7. Higher biomass of reef fish were found at the ocean drop-offs, passes and lagoon pinnacles. Although the diversity of fish species may not necessarily be higher in these areas, density and biomass are great, primarily because of the relatively large, mobile carnivores which occur there.

The presence of these large carnivores is an excellent indicator of a lack of much fishing pressure. Their voracious appetites and curiosity render large individuals highly vulnerable to depletion by pole-and-line fishing and they are generally the first species fished-out in an island environment. At Oroluk, there was an abundance of these large carnivores (i.e. *Lutjanus bohar*, *Caranx melampygus*, *C. sexfasciatus*, and groupers in the genus *Epinephelus* and *Plectropomus*). The sighting of two giant groupers (*Epinephelus lanceolatus*) over 100 kg in size at Sites 6 and 11 in Oroluk lagoon further indicates a lack of fishing pressure, as this species is rapidly depleted by spearfishing.

The second group of fishes which are good indicators of a lack of fishing pressure are the herbivorous Scarids and Acanthurids. Species in these families are particularly susceptible to net and spearfishing. There is little indication of fishing pressure being exerted on these families, as species were diverse, numerous and of large size (Appendix 7). Scarids were particularly abundant at most sites, often traveling in large mixed-species schools. The only indication of possible fishing pressure were the low numbers of giant humphead parrotfish (*Bolbometopon muricatum*) which were observed. This species is extremely vulnerable to fishing pressure, particularly by spearfishing at night, and possibly has been depleted at Oroluk Atoll.

Large schools of baitfish (*Spratelloides* sp.) were observed at many sites, especially on the lagoon terrace. They were often being pursued by schooling predators such as the rainbow runner (*Elagatis bipinnulatus*) and the leatherback (*Scomberoides lysan*). Rainbow runner were particularly common at a number of sites (Appendix 7). The abundance of baitfish may have been the major reason for numerous schools of piscivorous Carangids recorded at Oroluk Atoll.

There was a noticeable absence of moray eels at all the sites visited at Oroluk Atoll. The smaller morays may have been overlooked because of their cryptic habits; however the larger individuals in the genus *Gymnothorax* should have been observed if they were common. The abundance of large groupers at Oroluk may effectively suppress the moray eel population through competition for prey such as fishes and cephalopods.

Reef associated sharks were encountered at a number of sites (Appendix 7). In order of abundance these were: gray reef shark (*Carcharhinus amblyrhynchos*), blacktip reef shark (*C. melanopterus*), whitetip reef shark (*Triaenodon obesus*) and nurse shark (*Nebrius concolor*). However, in comparison with surveys conducted at other remote Micronesian atolls, the shark population at Oroluk was relatively sparse (Thomas, P.E.J., et al., 1989).

### 5.3 Unique Reef Fish Sites Oroluk Atoll

Several sites surveyed contained a uniquely diverse and abundant population of fishes (Appendix 7). Along the north side of Oroluk Lagoon, Sites 5, 6 and 11, were unique. All of these sites are associated either with lagoon pinnacles or a pass (Keltie Pass) and therefore offered a greater range of bathymetric relief and habitat types. Reef overhangs and caves provided unique habitat for the giant grouper, *Epinephalus lanceolatus*. Large individuals were recorded at Sites 6 and 11. The abundant reef fish may have attracted predators to these sites as grey reef sharks were particularly common at Sites 5 and 6.

Other uniquely abundant and diverse populations of reef fish were observed, primarily at sites along the south side of Oroluk Atoll. Sites 27, 30, 31 and 33 contained large numbers of reef fish. Site 27 was located just seaward of Southeast Pass and contained probably the greatest biomass of fish of any station at Oroluk. Large schools of jacks and snappers (*Caranx sexfasciatus, Lutjanus bohar, Macolor niger*) were observed as well as numerous large individual groupers. A large and relatively rare haemulid (*Plectorhinchus obscurus*) was observed at this site. A number of individuals of three species of sharks also occurred here (gray reef, whitetip and nurse).

Also in the south, Sites 30 and 31 were associated with the unique "double" perimeter reef along the south-central portion of the atoll. The protected environment between the reefs provided preferred habitat for numerous species. Particularly abundant were jacks (*Caranx lugubris, C. melampygus*), snappers (*Lutjanus gibbus, L. bohar, Macolor niger*), several species of scarids and the large grouper *Plectropomus laevi*. The shipwreck at Site 33 also provided unique habitat which contributed to a concentrated biomass of reef fish at this very specific location.

## 6. MARINE TURTLES

### 6.1 Background

Oroluk Atoll is well known as an important nesting site for the green turtle (*Chelonia mydas*). Pritchard (1977) states that Oroluk Atoll is apparently the only nesting ground of importance for the green turtle in Pohnpei State. He estimated that during the nesting season between nine and fifteen turtles nested on Oroluk Island on an average night, with up to twenty on a good night. Nesting activities continue at Oroluk Island, although at a reduced level from that reported in the 1970's by Pritchard (Edson and Curren, 1978). There is little data from Oroluk Island as nesting censuses have been conducted only in 1985 and 1987.

Prior to this expedition little observational work had been done underwater at Oroluk Atoll to document the importance of the atoll as foraging habitat for sea turtles. Underwater observations at other sites relatively close to Oroluk (i.e. Pingelap, Mokil, Kosrae, Pohnpei, Nukuoro) indicate some importance of these sites as foraging habitat (Pritchard, 1977). Because there is little nesting reported at these atolls and islands the populations of green turtles found there may be using Oroluk Island for nesting purposes. However, there is little information on turtle migration patterns to and from Oroluk Atoll. Turtle tagging conducted during 1985-87 by the Marine Resources Division, FSM have yielded only one long range recovery from the fifteen adult female green turtles tagged. A 99 cm female green turtle tagged while nesting on Oroluk Island on June 2, 1986 was captured alive in Nan-Way Bay, Taiwan on April 18, 1987 (Edson and Curren, 1987).

## 6.2 Turtle Observations

A total of sixteen turtles were sighted during underwater surveys and from the vessel at anchor during the five day period at Oroluk Atoll (Table 2). Fifteen of the turtles sighted were green turtles and one was a hawksbill turtle (*Eretmochelys imbricata*). Of the fifteen green turtles sighted fourteen were estimated to be juveniles or sub-adults less than 75 cm in carapace length. The one adult green turtle was sighted at anchor (Site 45) off Oroluk Island and was approximately 100 cm in carapace length. None of the turtles observed had been tagged and all appeared to be free of fibropapilloma, a life-threatening tumor disease which occurs in the Hawaiian green turtle population.

## 6.3 Turtle Habitat

Ten of the turtle sightings were made at lagoon pinnacle sites, indicating that the lagoon pinnacles probably contain the most desirable foraging and/or resting habitat. *Caulerpa racemosa* was one of the common forms of benthic algae found on the pinnacles and is a major green turtle food source in other areas (Balazs, 1990).

TABLE 2

MARINE TURTLE SIGHTINGS AT OROLUK ATOLL

| Site Number | Habitat Type | Green Turtles | | Hawksbill Turtles |
|---|---|---|---|---|
| | | Juvenile | Adult | |
| 5 | pinnacle | 6 | | |
| 19 | pinnacle | 1 | | |
| 22 | pinnacle | 1 | | |
| 27 | ocean reef/pass | 1 | | |
| 31 | ocean reef/pass | 1 | | |
| 35 | lagoon reef | | | 1 |
| 42 | lagoon reef | 2 | | |
| 45 | pinnacle | | 1 | |
| 46 | lagoon reef | 1 | | |
| from anchorage | pinnacle | 1 | | |

Natural predators of sea turtles were recorded when observed during the surveys. Numerous sharks of the four species previously noted were observed at most sites. Although these four species of sharks are not known predators of sea turtles they are capable of feeding on hatchlings and small juveniles. No sightings were made of the tiger shark (*Galeocerdo cuvier*), the only known major predator of juvenile, sub-adult and adult green turtles. However, this shark is nocturnal and likely occurs at Oroluk Atoll. Several large groupers (*Epinephelus lanceolatus*) well over 100 kilograms were observed. They have been known to occasionally take juvenile green turtles (Balazs, 1980).

Survey results reveal that juvenile and sub-adult green turtles utilize Oroluk Lagoon for foraging purposes. Juvenile abundance at prime nesting sites is not always the case in Micronesia. As an example, during a similar expedition to the northern Marshall Islands in September 1988 (Thomas, P.E.J. et al, 1989) intensive green turtle nesting activity was recorded at Bikar and Erikub Atolls and Jemo Island, however virtually no juvenile turtles were sighted during numerous underwater surveys at these sites. Therefore, unlike other turtle nesting islands, Oroluk Atoll may be important as a resident area for most of the life cycle of a population of green turtles.

### 6.4 Haul Out and Nesting

The survey of the coastline of Oroluk Island revealed no turtles, haulout tracks or nesting pits. However, Typhoon Owen had caused considerable damage to the island and reefs and much of the sand and rubble beach on the north and northwest side of the island had eroded. The most viable nesting beaches occur on the south side of the island close to the small village. Although the sand beach here was intact, pig pens and house platforms severely encroached on the limited turtle nesting habitat.

According to an inhabitant of Oroluk Island, between five and eight turtles haul out at Oroluk Island every month, except June and July when they are "too numerous to count." The island inhabitants reported that turtle populations appear to have declined over time. Turtle harvesting is discussed in Section II.10.3.

## 7. MOTUS AND CAYS

### 7.1 Oroluk Island

Oroluk Island was a roughly elliptical shaped island of approximately 44 acres in the extreme northwest comer of the atoll where the perimeter reef almost doubles back on itself, forming the largest area of shallow reef platform. The island was situated more towards the northeast and oceanward portion of this large platform. The lagoon side (southern) shore is primarily sand, with a cobble back beach and signs of erosion and storm damage. This is the location of the village, where strand vegetation has been cleared and pig enclosures constructed right out onto the beach. The southwest shore was a shorter, steeper beach composed of gravel and cobble, and backed by mixed strand vegetation and coconut palms.

Coral plate and boulders formed the northwest shore of the island, which had a 5 ft (1.5 m) high erosion scarp along the beach. Large reef blocks were scattered on the wide reef platform between the island and the ocean. The northeast side of the island was closest to the open ocean. The lower beach of boulders extended out onto the reef platform towards the reef edge. This stretch of shore had been subjected to considerable erosion. Trees had toppled onto the beach from the otherwise solid strand of *Messerschmidia* which occupied the beach berm along the east shore. No beachrock was found around the shores of Oroluk Island, in spite of the evidence of major recent erosion.

### 7.2 Unvegetated Sand Cays

Numerous sand cays (uninhabited, unvegetated motus) are indicated on the chart of Oroluk Atoll, primarily along the northern perimeter reef, with a few also shown along the eastern reef. The lagoonward zone of the perimeter reef platform was the usual location of the depositional cays, which were constructed primarily of coral plate and cobble on the oceanside, with the main body of the cay built of rubble and some sand on the lagoonward side.

The recent passage of Typhoon Owen had obviously adjusted the outline and composition of the cays. Some showed evidence of added deposits of coral rubble while others may have lost sand and finer sediments to the lagoon. Among the sand cays of Oroluk Atoll, the "sand island" along the lagoon side of the southeast section of the perimeter reef (just north of Site 25) was unique. A solid conglomerate platform 1-2 ft (.3-.6 m) above low water and approximately 15x75 ft (5x25 m) in size occurred seaward of the much larger, elongate rubble and sand cay in this location. No other sand cay visited or seen had an exposed core of cemented reef material or any exposed beachrock. Some sand cays which were indicated on the chart of Oroluk Atoll did not exist at the time of the survey, e.g. the sand cay on the western patch reef (Site 40).

## 8. TERRESTRIAL VEGETATION AND RESOURCES

The vegetation of Oroluk Island's 44 acres (0.18 sq km) was dominated by coconut palms (*Cocos nucifera*), with occasional large breadfruit trees (*Arctocarpus* sp.) punctuating the crown cover. Strand vegetation was primarily *Messerschmidia* trees and *Scaevola* bush, with *Pandanus*, coconut palms and *Thespesia populnea* mixed in. *Pemphis* shrub was added in along the southeast shore. Other tree species which were scattered around the interior of the island, and occasionally near the strand, included: *Ficus tinctoria*, *Morinda citrifolia*, *Hibiscus tiliaceous* and *Herriteria littoralis*. Undergrowth was dominated by the common grasses *Eleustine indica*, *Lepturus repens* and *Crinum asiaticum* and two species of ferns. Coconut crab were reported to be relatively common on the island.

A few *Pisonia grandis* were found in the northwest of the island, in the bird nesting area, and three young *Callophyllum inophyllum* were noted surrounding the inhabited portion of the island. In addition to breadfruit, vegetation which has been introduced to the island includes banana (*Musa* sp.), papaya (*Carica papaya*), lime (*Ocimum sanctum*) and taro. There have been no major changes to the vegetation of the island over the past 17 years according to the village chief. Vegetation damaged by salt spray was common along the northern facing shoreline and along the northeast coast *Messerschmidia* trees had been undermined by shoreline erosion and toppled onto the beach.

## 9. BIRDS

A portion of Oroluk Island in the north, in the vicinity of the *Pisonia* tress, is known as a bird nesting area by the inhabitants. This area has been designated as a conservation area by the Pohnpei State Department of Lands. All species are reportedly harvested occasionally for consumption. Bird counts on Oroluk Island and a few of the coral cays yielded additional information on the kinds and numbers of birds which occur on the atoll. The birds on some of the cays were very wary of humans, probably due to visits to the cays, perhaps to harvest birds or eggs. Birds observed on Oroluk Island and the coral cays visited, and the number seen, are presented in Table 3.

## 10. HUMAN HABITATION AND RESOURCE USE

### 10.1 Human Use and Archeological, Historical and Cultural Values

There are apparently no known archeological, historical or cultural sites of importance on Oroluk Island, which has been continuously inhabited since 1958. However, no professional archaeological surveys have been conducted at Oroluk Atoll. There are a number of shipwrecks scattered around the atoll, some of which are on the lagoon side of the perimeter reef providing artificial reef habitat.

In 1990 there were 14 inhabitants on Oroluk Island, some of which had been residing on the island for 17 years, along with a few dogs and cats. The inhabitants maintain a primarily subsistence lifestyle based on breadfruit, banana and coconut crops and a small taro patch. Protein is obtained from fishing, pigs (which are kept in pens) and chickens (which run loose), along with the occasional marine turtle, coconut crab or bird which is harvested. Drinking water is supplied by rain catchment and wells. Coconuts are harvested for copra, which is sent out on the occasional visits of the field trip ships. The ships, which visit about 3 times/year from Pohnpei and twice a year from Chuuk, supply the island with rice and other imported goods.

### 10.2 Fishing and Reef Resources

Fishing is undertaken on an almost daily basis to supply subsistence needs. The islanders have no boat. Fishing effort is thus concentrated on the reefs which are at daylight wading distance from the island. Net fishing is the most common method employed and is undertaken approximately three times/week. Spearfishing and handlining and the next most common fishing methods. Giant clam is also harvested from the lagoon for consumption. Fishing boats from Chuuk visit Oroluk occasionally and are reported to fish with explosives. No evidence of reef damage from explosives was noted during the survey, although this would have been easily masked by the extensive storm damage.

TABLE 3

BIRD SIGHTINGS AT OROLUK ATOLL

| Bird Species | Oroluk Is. (Site 1) | sand island (Site 25) | sand cay (Site 11/12) | sand cay (Site 3) |
|---|---|---|---|---|
| Little Fairy Tern | > 10 | | | |
| Black-naped Tern | ? | | | |
| Crested Tern | | 30 | | |
| Black Noddy | > 100 | | | 30 (a) |
| Brown Noddy | > 10 | 50 (b) | | |
| Blue-gray Noddy | ? | | | |
| Masked Booby | 1 | | 8 | |
| Brown Booby | | 6-8 | 30 (c) | |
| Great Frigate Bird | > 10 | | | |
| Bristle-thighed Curlew | 2 | | | |
| Ruddy Turnstone | > 20 | 2 | | |
| Wandering Tattler | 1 | 2 | | |
| Pacific Golden Plover | 1 | | | |
| Micronesian Starling | ? | | | |

(a) all birds were nesting, no eggs seen
(b) some birds were breeding
(c) all birds were nesting, one egg seen

## 10.3 Marine Turtles

When they haul out, marine turtles are harvested by Oroluk Island inhabitants for consumption and to trade with visiting vessels. Of the 5-8 turtles which haul out on the island during non-nesting months, islanders reportedly harvested all they find. During nesting season, in June and July, not all turtles found are taken. The shell from a recently butchered large adult green turtle was observed drying next to a village hut. Eggs are apparently also harvested for consumption.

An enclosed pond had been constructed on the adjacent reef flat about 75 ft (25 m) southwest of the island. This was reportedly for rearing turtle hatchlings, although it had been broken and unusable since the previous year. Large turtle bones were seen on the lagoon reef flat both within and outside the enclosure, indicating that it may have served as a holding pen for turtles bartered or later butchered. Pig pens and house platforms have been constructed on the southern, lagoonward beach and occupy part of the beach used by the turtles to haul out and nest.

# 11. STORM DAMAGE

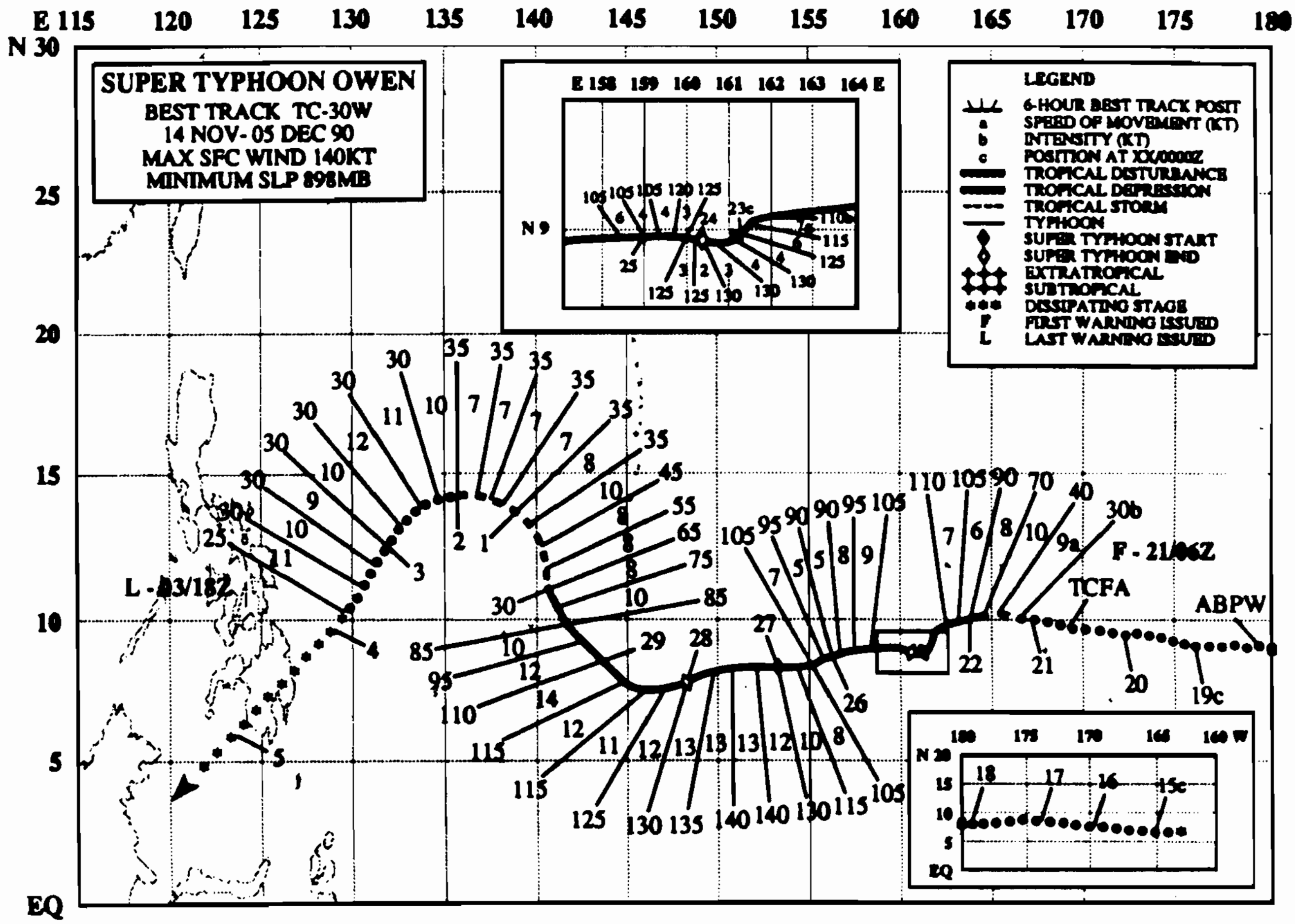
## 11.1 Typhoon Owen

The tropical depression that became Typhoon Owen started near Palmyra Island and moved westward. As it crossed the international dateline and passed the Marshall Islands, the tropical depression rapidly intensified to typhoon strength on 21 November 1990 and continued towards the Caroline Islands (Figure 5). On 23 November, Typhoon Owen was upgraded to super typhoon with speeds of 130 knots while moving from 161° E to 160° E at a latitude of about 9° N. On 24 November Super Typhoon Owen decreased to typhoon strength and continued on a west/southwest trajectory with wind speeds of 105-125 knots (Joint Typhoon Warning Center, 1991).

Typhoon Owen crossed 155° E at about 8° 20' N on 26 November 1990, passing approximately 48 nautical miles north of Oroluk Atoll and 11 nautical miles north of Minto Reef with wind speeds of 105-115 knots (Figure 5). On 27 November, the typhoon reintensified to super typhoon strength with winds of 130-140 knots, impacting the central and western Caroline Islands where Chuuk and Yap States suffered extensive damage and were declared U.S. federal disaster areas. Super Typhoon Owen continued on a west/southwest trajectory, away from Oroluk Atoll and Minto Reef. The winds decreased below 130 knots on 28 November and Typhoon Owen veered northwest, diminishing below typhoon strength on 30 November (Joint Typhoon Warning Center, 1991).

FIGURE 5

TRACK OF SUPER TYPHOON OWEN



## 11.2 Storm Effects of Corals and Reef/Cay Geomorphology

The effects of recent storm damage, presumably from Typhoon Owen, were observed at more than half of the sites visited (Appendix 1), with 14 of these sites having relatively high levels of damage. The northern reef appeared to have suffered more from the storm impacts, although the effects were scattered completely around the atoll. The damage usually included accumulations of coral colonies or fragments in deposits along the ocean reef slope, pinnacle slope or on the lagoon terrace or upper lagoon slope. These accumulations were generally made up of small massives completely torn off the reef, toppled plate *Acropora* and, especially common on the lagoon side, fragments of columnar *Millepora* and other branching corals.

Occasionally, large massives, i.e. greater than 3 ft (1 m) in diameter, were rolled onto their sides on the lagoon terrace. In places, extensive coral rubble banks of recent origin extended from the lagoon terrace or backreef out onto the lagoon slope. In a few locations, sand accumulations at the base of the lagoon backreef had been scoured out to reveal the lower portions of massive corals which had previously been buried.

Many of the sand cays on the perimeter reef appeared to have eroded, changed outline and shifted lagoonward. Extensive shoreline erosion was noted, and confirmed by residents, around Oroluk Island, particularly on the northwest, north and northeast shore. On the latter side of the island, shoreline erosion resulted in *Messerschmidia* trees being undermined and toppled over. Much of the vegetation on Oroluk Island was damaged by salt spray and many trees were knocked down, especially banana and papaya trees.

# III. MINTO REEF

## 1. GENERAL DESCRIPTION

### 1.1 Shape and Size

Minto Reef is an irregular shaped atoll reef, elongated in the southeast corner (Figure 6). Minto Reef encompasses an area that extends about 5.5 mi (8.8 km) from northwest to southeast and 4.3 mi (6.9 km) from east to west. The outer edge of the shallow reef platform forms a perimeter of approximately 16.1 mi (26 km). The perimeter reef can be roughly divided into 3 sections based on orientation, i.e. Southwest, Northwest and East (Figure 6).

### 1.2 Perimeter Reef and Cays

The perimeter reef of Minto Reef generally averages from 980-1312 ft (300-400 m) wide, but may range from 490-2300 ft (150-700 m) wide in places. An exception to this is the northern point of the reef where the shallow reef platform is about 3280 ft (1000 m) wide. This is also the area in which a sand cay is indicated on the chart, although the cay was not present during the field investigations. Storm rubble banks were found along the southeast portion of the perimeter reef, although these appeared to be very recent and were probably the result of Typhoon Owen.

### 1.3 Passes

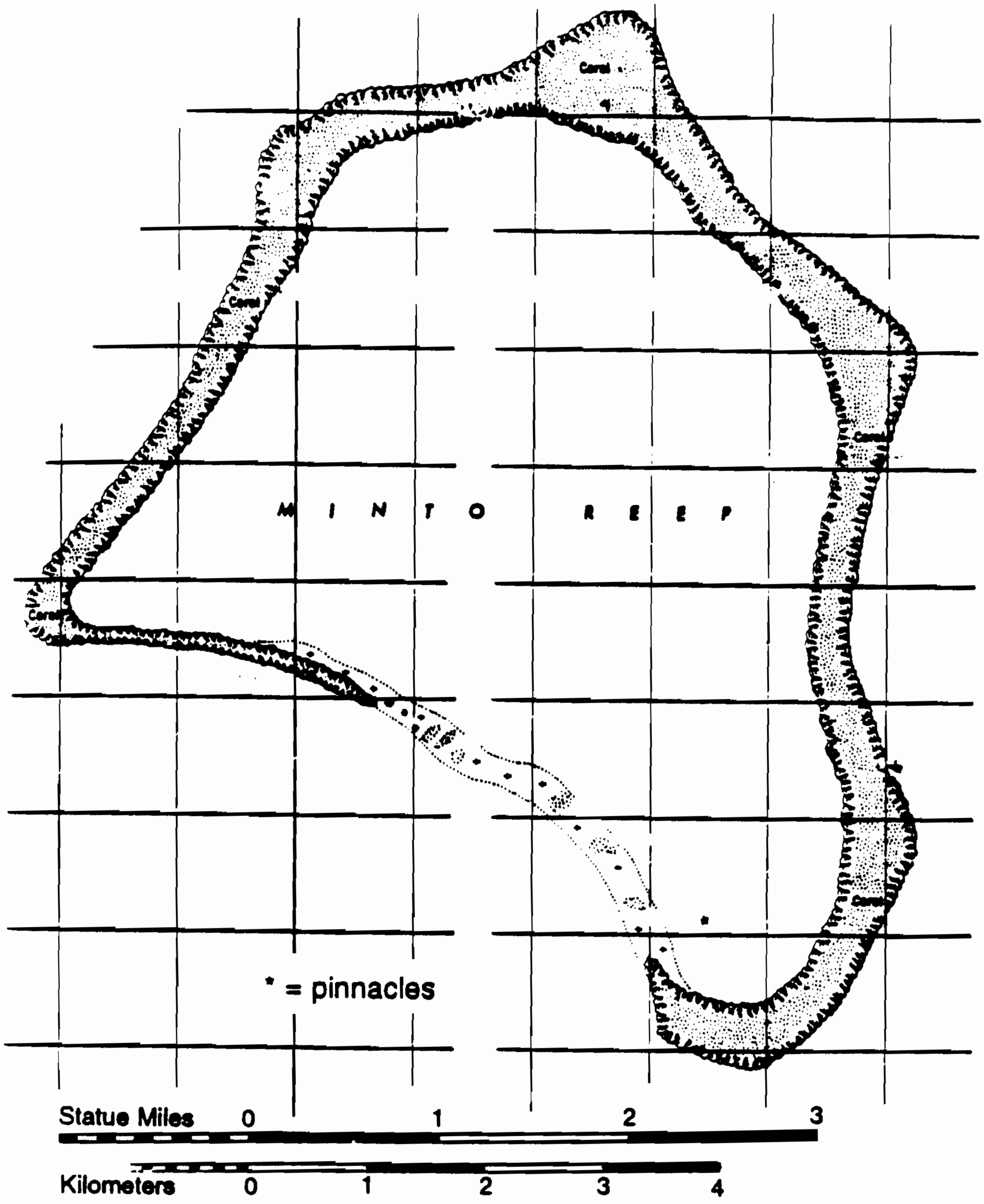
There are no deep passes through the perimeter reef of Minto Reef. However, about half of the Southwest section of Minto was a submerged reef sill, with areas of shallow reef interspersed along the sill, effectively forming a series of shallow passes. The center of this stretch of reef had a somewhat wider "main" pass, which was less obstructed by shallow reef or coral mounds.

### 1.4 Lagoon and Lagoon Reefs

The lagoon of Minto Reef encloses an area of approximately 10.5 sq mi (27 sq km). No information is available on the depths of the lagoon. Only one lagoon pinnacle reef was definitively identified, located in the southeast corner of the lagoon, although there may possibly be a few more.

FIGURE 6

MINTO REEF



## 2. CORAL REEFS AND BENTHIC COMMUNITIES

Coral reefs and coral communities are described for the major reef sections and the physiographic zones in each section, based on the information recorded at the 23 survey sites for Minto Reef (Figure 7). The dominant, abundant and common corals are indicated, along with conspicuous algae and macroinvertebrates. The distribution and relative abundance of all coral genera recorded are presented in Appendix 8. A species list is found in Table 2. The distribution and relative abundance of macroinvertebrates and a species list are presented in Appendices 9 and 4, respectively. The distribution and abundance of algae and a species list are found in Appendices 10 and 6, respectively.

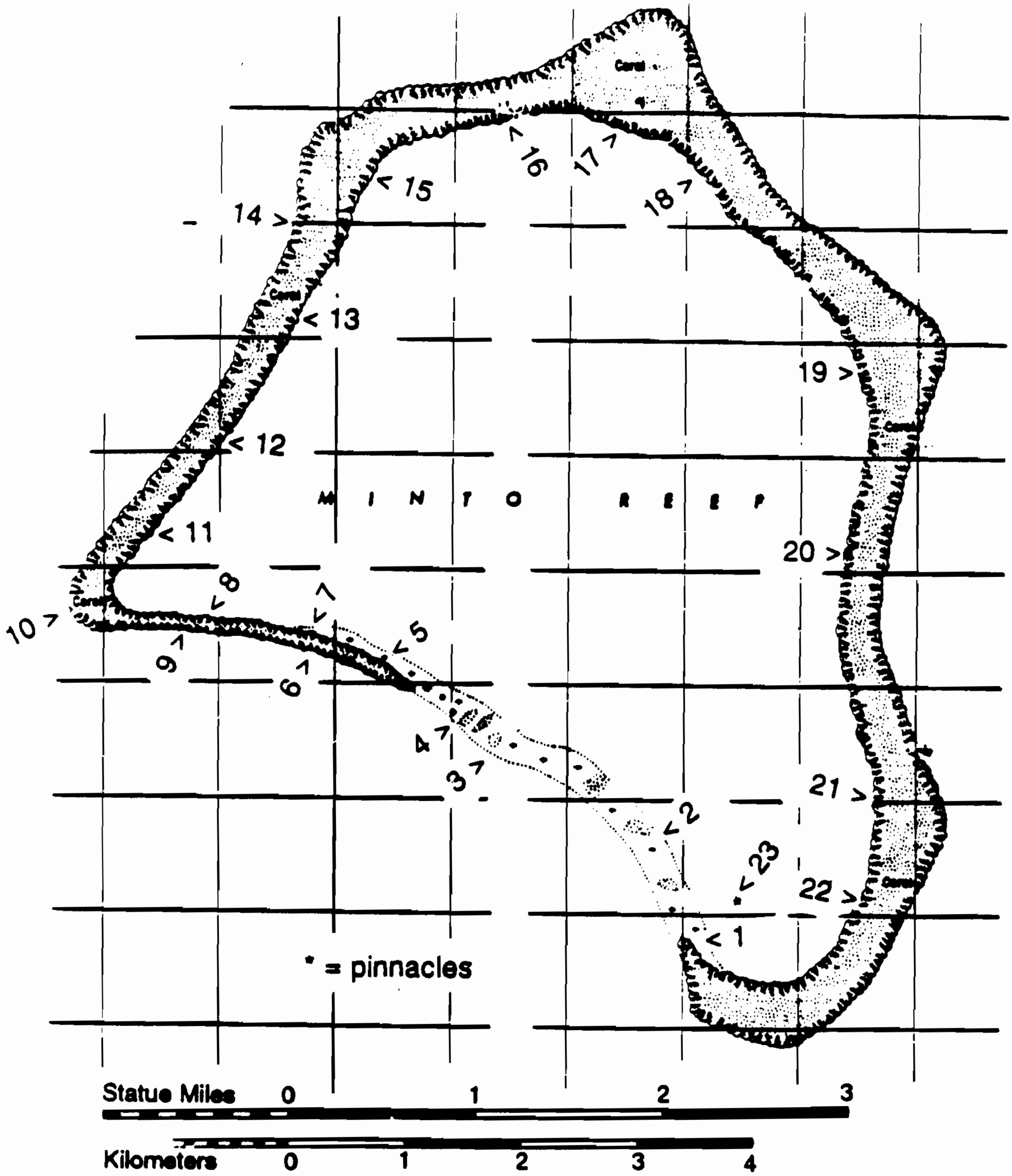
### 2.1 Ocean Reef: Northwest Perimeter (Sites 10, 14)

The outer reef in this area sloped directly from the reef pavement of the shallow reef platform down the reef face at a moderate angle, without a terrace with only limited spur and groove development, . The upper reef slope supported variable 20-50% coral cover, primarily small massives and low, robust branching colonies. Further down the slope, massive *Porites*, both mounds and thick plates, were the dominant coral, with *Favia* and *Goniastrea* colonies common. At the western point of the reef (Site 10), coral diversity was higher and additional corals were common, including: *Pocillopora*, *Porites rus*, branching and columnar *Millepora*, *Lobophyllia*, *Acanthastrea*, *Fungia*, *Leptastrea* and *Pavona*. On the deeper slope, *Acropora* tables and *Turbinaria* were common as well.

Storm damage was much more evident in the northern portion of this reef area, with less damage towards the southwest. In general, the upper slope of the ocean reef had moderate damage. However, at 9-12 ft (3-4 m) depths, down to about 30 ft (10 m), was a zone of extensive destruction, with large areas of reef front denuded. Coral cover was as low as 0-15%. The surviving coral was dominated by massive *Porites* colonies, although the outer edges of the plate-like *Porites* colonies were often broken off. Large blocks of coral and reef material were scattered throughout the slope, with scars on the reef face where these had been torn from the reef and accumulations of coral fragments and rubble in pockets on the slope. Below this area of destruction, the reef front dropped off more steeply, with little coral cover. The bottom of the ocean reef slope was not visible.

FIGURE 7

MINTO REEF SURVEY SITES



2.2 Ocean Reef: Southwest Perimeter (Sites 3, 4, 6, 9)

The ocean reef along the Southwest side of Minto Reef consisted of a consolidated reef flat in the wave zone with very little coral cover. This descended slightly oceanward with more irregular topographic relief, which supported patches of coral and soft coral cover and some *Tridacna maxima*. The slope then dropped off more steeply into a series of spurs and grooves along the upper slope, with occasional overhangs. The spur and groove zone supported, in places, moderate coral diversity, with coral cover ranging from 30-60%. Abundant corals were: columnar *Acropora*, *Platygyra*, *Astreopora*, massive *Porites* and columnar *Millepora*. A variety of corals were commonly found, including: table, digitate and bushy *Acropora*, *Leptastrea*, *Tubastrea*, *Favia*, *Goniastrea*, *Pocillopora*, *Acanthastrea*, *Lobophyllia*, *Oulophyllia*, massive and encrusting *Porites*, *P. rus*, *Montipora*, *Stylophora*, *Gardineroseris*, *Echinopora*, *Psammocora* and *Pavona*. At one location (Site 9) *Acanthaster* was common.

Much of the upper slope, however, suffered extensive damage from the typhoon. Large areas of outer reef were denuded, with corals broken and coral colonies and reef blocks ripped or knocked out of the reef framework, leaving holes in the reef face. This material scoured the grooves during their descent to the base of the gutters where piles of corals, rubble and occasional large blocks accumulated. In some areas, sand cascaded down the grooves and accumulated at their base.

Below this zone, the steep lower slope of the outer reef was mainly of sand, rubble and hard reef substrate. The little coral cover which occurred consisted of those species found higher up the slope, as well as *Echinophyllia* and branching *Millepora*, along with the occasional crinoid and gorgonian. The bottom of the ocean slope was not visible.

2.3 Reef Platform and Lagoon Reef: Northwest Perimeter (Sites 11, 12, 13, 15, 16, 17)

The bulk of the reef platform along the Northwest facing perimeter reef was a consolidated reef flat with coralline algae and limited coral development. Towards the lagoon margin of the platform, the reef surface had more topographic relief. In places this supported variable coral cover of up to 30-60%, primarily digitate *Acropora* and small massives such as *Astreopora* and *Goniastrea*. Other portions of the lagoon margin had very little coral cover. In some areas deposits of coral colonies which had been recently torn from the reef were found on the lagoon margin of the reef flat.

The lagoon edge of the reef platform dropped or sloped quickly down about 4 ft (1.5 m) to a sloping sand and rubble terrace. This depositional terrace was wider along the wider northern reef platform. In many areas, mounds of coral with 20-50% coral cover and massive coral colonies occupied much of the terrace, with massive *Porites* the dominant coral. Other corals which were abundant or common included: *Acanthastrea*, bushy *Acropora*, *Heliopora*, columnar *Millepora*, finger coral and encrusting *Porites*, *P. rus*, *Montastrea*, *Echinopora*, *Favia*, *Favites*, *Pocillopora*, *Leptastrea*, *Pavona* and *Cyphastrea*. Soft corals and the giant clam *Tridacna maxima* were also occasionally found among the corals. Beyond the area of coral mounds, the lagoon terrace became primarily rubble and sand and then became a sand slope which dropped more steeply into the lagoon.

Much of the coral on the mounds on the lagoon terrace was damaged and broken by the typhoon. The lagoon margin often showed evidence of scour and sand movement, especially adjacent to the wide northern reef platform where a cay had reportedly been present (i.e. Site 17). Beyond the zone of coral mounds and massives on the terrace, a ridge of coral rubble and coarse sand had been deposited on the pre-existing sand and rubble terrace. Where the lagoon margin and terrace had little coral cover, a cascading front of recently deposited sand and rubble prograded out onto the terrace directly from the edge of the reef platform, with the occasional large coral blocks or colonies included in the wave of deposited material.

### 2.4 Reef Platform and Lagoon Reef: East Perimeter (Sites 18, 19, 20, 21, 22)

The reef platform along the East perimeter was generally a bit wider than the rest of Minto Reef, ranging from 1312-2300 ft (400-700 m) wide. The oceanward limit of the platform had scattered coverage of digitate *Acropora*, encrusting *Millepora*, encrusting *Platygyra* and patches of the colonial zooanthid *Palythoa*. Moving towards the lagoon, the outer reef flat was a barren pavement followed by a zone of recently deposited reef rubble and corals with occasional older reef blocks. In the southern portion of the East perimeter, this outer reef depositional zone was a wide bank consisting mainly of small massive corals torn from the reef front and deposited on the reef flat.

The lagoonward half of the shallow reef platform was a sand and gravel veneer on the reef flat. The platform gradually sloped from 1-2 ft (0.5 m) deep to 4-5 ft (1.5 m) depths towards the lagoon. As the reef platform deepened, *Porites* massive microatolls became increasingly abundant, along with small massive corals and a mixed coral assemblage. Overall coral cover was 5-20%. The other abundant and common corals included *Astreopora*, *Favia*, columnar and branching *Millepora*, encrusting *Porites*, *Heliopora*, *Pavona*, *Acanthastrea*, *Goniastrea*, *Echinopora*, *Cyphastrea*, *Pocillopora*, *Montipora*, *Lobophyllia* and *Acropora* bushes.

Similar to the lagoon margin of the Northwest perimeter, the lagoon margin of the East perimeter dropped off to a sand and rubble terrace 3-6 ft (1-2 m) deep which sloped lagoonward. Massive corals and mounds of mixed corals, with moderate diversity and coral cover of 30-60%, were scattered on the terrace. In addition to the coral species found on the lagoonward reef flat, these mounds also commonly supported *Goniopora* and *Montastrea*. *Tridacna maxima*, and some *T. squamosa*, were also common on the mounds. Beyond the area of coral mounds, or where there were no mounds to support coral development, the terrace was composed of sand, rubble and occasional reef blocks and sloped gradually to the sandy lagoon drop off.

A ridge of recently broken or torn off coral fragments and colonies had been deposited along much of the lagoonward edge of the terrace, similar to the ridge found along the lagoon terrace of the Northwestern perimeter. Microscopic and filamentous algae colonized the new rubble ridge. On the southern portion of the East perimeter, a berm of storm deposited coral rubble and colonies had formed on the lagoon margin of the reef platform. The main berm was up to 7 ft (2 m) high, 80 ft (24.4 m) wide and extended about 3000 ft (915 m) along the lagoon margin of the platform, tapering off towards the north. The shape of the berm, the fact that corals on the seaward side of it were undamaged and the presence of large undamaged *Porites* massives, 3-6 ft (1-2 m) in diameter, indicated that the berm materials had been uplifted from the lagoon and deposited onto the reef platform. The berm was mainly constructed of coral colonies, coarse rubble and cobbles on the lagoon side, with fine gravel and sand on the seaward side. Normal wave action across the reef flat at high tide appeared to be dissipating the deposited material and opening gaps in the berm.

### 2.5 Reef Platform and Lagoon Reef: Southwest Perimeter (Sites 1, 2, 5, 7, 8)

The southwest facing perimeter reef was a narrow reef platform less than 165 ft (50 m) wide along its western half. The eastern half was a slightly submerged sill, which ranged in depth from 9-20 ft (3-7 m), with many irregularities in bottom topography and few passes straight through to the lagoon. This area had incipient reef platform development and coral patches on the sill, resulting in a series of shallow passes and false passes. The reef flat was generally a scoured pavement with virtually no coral growth. The platform sloped gradually into the lagoon and the lagoon portion of the sill areas with irregular topography of hard substrate and coral mounds, dominated by *Astreopora* and large *Porites* massives and microatolls.

Coral cover on the lagoon side ranged from 20-60% and consisted mainly of *Goniastrea*; digitate, small table and columnar *Acropora*; *Stylophora*; branching and columnar *Millepora*; *Pocillopora*; *Montipora*; *Pavona*; *Favia*; *Heliopora*; *Symphyllia*; *Lobophyllia*; *Montastrea*; *Acanthastrea* and *Platygyra*. Soft corals were often common or abundant on the mounds, as were *Tridacna maxima*. Between the coral mounds and outcrops the bottom was either scoured substrate or accumulations of rubble, coral fragments and detached corals, with the latter more common further towards the lagoon. The lagoon reef continued a gradual, irregular slope lagoonward, with many smaller molluscs common. As depth increased, some portions of the reef were more protected from wave action allowing extensive *Porites* finger coral colonies to flourish occasionally. At 15-25 ft (5-9 m) the hard substrate gave way to sand and talus which then dropped steeply into the lagoon.

Storm damage was heavy and many corals were broken or damaged, especially branching species which were often broken down to the colony base. Greatest damage was on the reef flat and immediately lagoonward of the narrow and incomplete reef flat. A ridge of corals and fragments had been deposited along some stretches of the lagoon margin of the reef flat (i.e. Site 2) or closer to the drop off of the lagoon sand slope (i.e. Site 8). Many small massives had been detached, and some larger massives tilted, by the force of storm waves or surge.

### 2.6 Lagoon Pinnacle (Site 23)

Only one reef pinnacle was detected from aerial photography of the atoll reef and was subsequently visited. The pinnacle is in the southeast corner of the Minto Reef lagoon, near to the southwest perimeter reef (not close to the southeast perimeter reef as indicated on the chart). The pinnacle had a limited shallow area of irregular substrate which had coral diversity similar to the lagoon reef elsewhere. The following genera were abundant or common on the shallow reef: *Astreopora*, *Favites*, *Pocillopora*, digitate *Acropora*, *Acanthastrea*, *Montipora* and *Platygyra*.

The east side of the pinnacle sloped steeply into the lagoon with a slight terrace at about 10 ft (3 m). The west side dropped to a wider terrace at about the same depth which sloped off more gradually at first, before dropping off relatively steeply. There was extensive storm damage to the corals down to 30 ft (10 m), with many colonies torn from the reef leaving holes in the reef face. Below this depth storm damage was minor, but still evident. In addition to the corals found on the upper reef, the following were also abundant or common on the deeper reef slope: table *Acropora*, *Porites* finger coral, *Goniopora*, *Goniastrea* and *Lobophyllia*. The bottom of the pinnacle slope was not observed due to limited water visibility, but exceeded a depth of 50 ft (15 m).

## 3. BENTHIC FAUNA

### 3.1 Corals

A total of 139 coral species were recorded at Minto Reef (Appendix 2). However, due to the difficulties in identifying corals to the species level in the field, most corals were only recorded to the genus level, and a total of 45 genera were observed at Minto Reef (Appendix 8). The number of genera at any site ranged from 3 to 28 for Minto, as opposed to a range of 6-34 for Oroluk. Of the 23 underwater survey sites at Minto Reef the majority of sites (18 sites or 78%)) had 11-20 genera. Only 2 sites (9%) had more than 20 genera and 3 sites (13%) had less than 10 genera.

Although three coral genera were recorded at Minto Reef which were not found at Oroluk Atoll, i.e. *Alveopora*, *Scapophyllia* and *Scolymia*, Minto Reef generally had reduced coral diversity when compared to Oroluk Atoll. Only 9% of sites had more than 20 coral genera at Minto, as opposed to 20% for Oroluk. In contrast to Oroluk

Atoll, however, it was the sites on the ocean reef slope at Minto Reef which had the highest coral diversity for Minto. The lagoon side reefs and the pinnacle had moderate diversity and the sites with the lowest coral diversity occurred on the northwest and east lagoon areas.

The reduced coral diversity at Minto Reef, in comparison to Oroluk Atoll is likely due to the reduced habitat diversity. Minto Reef had a much reduced lagoon area and did not have the numerous pinnacles, patch reefs and variety of passes found at Oroluk Atoll, which supported greater coral variety.

### 3.2 Giant Clams

The giant clam *Tridacna maxima* was recorded at 20 of the 23 sites around Minto Reef and was usually common or abundant (Appendix 9). *Hippopus hippopus* was also seen at a few lagoon reef sites, in very limited quantities, as was *T. squamosa*. *Tridacna gigas* was not seen at any of the sites visited at Minto Reef.

### 3.3 Trochus and Pearl Shell Oyster

Trochus was observed at only one of the sites visited, where it was rare in abundance. Pearl shell oyster was noted at only two sites, with abundance also only rare (Appendix 9).

### 3.4 Sea Cucumbers

Sea cucumbers were seen at eight sites, usually with only limited abundance (Appendix 9). As with Oroluk Atoll, the recent passage of the typhoon may have affected the presence of sea cucumbers at Minto Reef, although there is no direct evidence of this. However, at one location (Site 17), *Holothuria atra* was abundant.

### 3.5 Lobster

A single *Panulirus* lobster was observed at only one site at Minto Reef, with no other lobster encountered during the survey (Appendix 9).

### 3.6 *Acanthaster planci*

The coral eating Crown-of Thorns starfish (*Acanthaster planci*) was observed at five sites around Minto Reef (Appendix 9). The starfish was common at only one of these locations, Site 9. No areas of recent *Acanthaster* feeding scars or dead standing coral were observed, although the latter would have probably been affected by the passage of the typhoon.

### 3.7 Sea Urchins

Limited numbers of sea urchins were found at only seven sites (Appendix 9). No large population aggregations of sea urchins were observed at any location.

## 4. BENTHIC FLORA

The relative abundance and distribution of the algae recorded at Minto Reef are found in Appendix 10 and a complete species list in Appendix 6. Algae was much less evident at Minto Reef than at Oroluk Atoll. None of the species of algae observed at Minto Reef were relatively common or abundant where they occurred. *Halimeda* was the most frequently encountered algae, occurring at nine sites, but with only low relative abundance at each site.

## 5. FISH

The major reef associated fish species observed at 23 underwater sites conducted at Minto Reef are listed in Appendix 11. Despite the devastation to the reefs rendered by Typhoon Owen, the reef fish population at Minto Reef was fairly abundant and diverse. Most of the species recorded at Minto Reef were also recorded at Oroluk Atoll approximately 60 miles away.

An abundance of large carnivores (primarily snappers, groupers and jacks) also was recorded at Minto Reef, along with large numbers of herbivorous Scarids and Acanthurids (Appendix 11). The giant humphead parrot fish, although only occasionally sighted, appeared to be more common at Minto Reef than at Oroluk Atoll. Almost all large individuals of the various species of important food fishes were recorded at ocean drop offs or passes. The abundance of these species indicates minimal fishing pressure at Minto Reef.

With the exception of nurse sharks there was a noticeable absence of the other reef sharks within the lagoon at Minto Reef. The larger groupers and snappers also were rare at the lagoon sites. This may have been an artifact of the recent typhoon which perhaps drove the larger, more mobile fishes into the deeper lagoon or surrounding ocean slope waters.

The major difference concerning reef fish populations between the two atolls is the reduced habitat complexity at Minto Reef. During the survey only one small pinnacle was observed in the lagoon at Minto Reef in comparison with numerous lagoon pinnacles in Oroluk Lagoon. There is also a lack of passes connecting the lagoon to the outer reef slope at Minto Reef, where a series of only shallow passes connects the lagoon with the ocean. These passes are all clustered along the south reef. There are at least six shipwrecks at Minto Reef which potentially create artificial reef habitat. However, the majority of these wrecks are hard aground on very shallow reef flat pavement and therefore have minimal value as artificial reefs.

## 6. MARINE TURTLES

No marine turtles were sighted during the survey of Minto Reef. The small sand cay at the north end of Minto Reef was reported to have supported limited turtle nesting. However, in the aftermath of Typhoon Owen the cay had disappeared.

Regardless of the dramatic changes to Minto Reef rendered by Typhoon Owen, it is doubtful that the area supported many marine turtles. Only one small pinnacle was observed in the entire lagoon, indicating a greatly reduced area of potential shallow foraging habitat, particularly in comparison to Oroluk Atoll. In addition, Minto Reef lagoon encompasses an area less than one quarter the size of Oroluk Atoll lagoon.

## 7. CAYS

An unvegetated sand cay was situated on the lagoonward portion of the wide northern reef flat. The cay reportedly covered an estimated 0.48 acres (1930 sq m) in 1980. At the time of this survey, the cay had been completely removed from the reef flat. This may have occurred prior to Typhoon Owen, or been a result of the typhoon.

A ridge of emergent reef rubble and corals had been created on the lagoonward portion of the southeastern reef flat during the typhoon and is described further in Section 9.1. Normal wave action across the reef flat was already dissipating this material. However, many large massive corals up to 6 ft (2 m) in diameter were deposited on the reef flat and will probably remain for some time.

## 8. RESOURCE USE

With no permanent land mass, Minto Reef has no resident human population and resource users. No information was available on resource use by visiting vessels, or on the numbers and kinds of vessels which visit the reef.

There are numerous shipwrecks at Minto Reef. Most of these are on the reef flat, including a pair of fishing vessels stranded side-by-side on the shallow reef. The numerous shipwrecks at Minto Reef would indicate that the atoll reef is a hazard to navigation. The shipwrecks were not investigated during the survey, but they may provide important resting or nesting habitat for seabirds since dry land is otherwise very limited at Minto Reef.

## 9. STORM DAMAGE

### 9.1 Storm Effects on Corals and Reef/Cay Geomorphology

Typhoon Owen passed about 11 nautical miles north of Minto Reef on 26 November (see Section II. 11.1). Serious recent storm damage, presumably from the passage of

Typhoon Owen, was observed at all of the sites visited on Minto Reef (Appendix 8). The ocean slope of the perimeter reef sustained very heavy damage at all outer reef sites, which were located on the southwest and northwest facing reef. On the ocean reef margin and upper slope, most branching corals, except low robust growth forms, were broken, often at the base. Small massives and other corals were often torn off the reef, as were large massives and blocks of reef framework, leaving holes ("sockets") of newly exposed reef matrix where they had been attached, some reaching many feet in diameter and depth.

The removal of coral material by direct wave and surge action was compounded by the movement of the debris downslope. Large areas of the reef front were virtually denuded on the mid-reef slope by these combined effects. The downward movement of debris was often channeled into grooves, gutters or chutes, where these existed, which were newly scoured by the debris. Much of the debris moving downslope accumulated at the base of these channels or in pockets on the reef face at depths below the zone of wave and surge effects, although a lot of debris was also presumably carried further downslope.

Much of the debris from the shallow ocean reef was also transported onto and over the reef flat by wave and surge action. On the reef flat and the upper lagoon reef, the effects of wave and surge action and movement of debris also combined to break and remove large numbers of corals. This cumulative load of reef debris from the upper ocean reef, the reef flat and the lagoon margin was deposited in a ridge of coral fragments, corals and reef rubble on the lagoon terrace along most of the perimeter reef.

This pattern of storm debris deposition was altered significantly only in the southeast comer of Minto Reef. Here, wave and surge action approached the reef from the lagoon, presumably due to the passage of wave energy through the numerous shallow openings in the southwestem perimeter reef. The wave and surge action uplifted reef materials and corals, including massive corals 3-6 ft (1-2 m) in diameter, from the lagoon terrace and deposited them on the lagoon edge of the reef flat. The main berm extended about 3000 ft (915 m) along the lagoon margin of the platform, tapering off towards the north. Storm energy affecting the reef platform in this area from the lagoon side also counteracted the wave and surge action from the oceanside, blocking the transport of debris from the outer reef. As a result, corals, coral fragments and rubble from the oceanside were deposited in a wide bank on the ocean portion of the reef flat rather than being carried across to the lagoon terrace.

Along the northern portion of the perimeter reef, sand and gravel sized reef sediment from the reef platform was deposited immediately onto the lagoon terrace, forming tongues of new material extending out onto the lagoon terrace, sometimes engulfing coral colonies. In other areas immediately adjacent to the reef platform, the pre-existing sand of the lagoon terrace was eroded away exposing the lower portions of massive corals which had been buried. The redeposition of this material often partially buried corals elsewhere.

Along the wide northern point of the perimeter reef (Site 17) large amounts of sand were apparently moved during the storm. Sand was excavated from around corals on the lagoon terrace to depths of 3 ft (1 m). This caused, or contributed to, many coral colonies toppling over. At the lagoon edge of the wide terrace, a large sand ridge was found to have been deposited. The former sand cay on the reef platform in this area may have been swept of the reef and its material deposited as part of the sand ridge on the lagoon terrace, or on the lagoon slope.

## 9.2 Storm Effects on Fish

At Minto Reef some of the reef fish which live in close association with the reef or within the reef structure actually had visible injuries, presumably from being dashed against the coral during the storm. In a large area along the southeast portion of the reef a coral rubble berm had been thrown up on the lagoon side of the reef which cut off circulation at low tide causing a number of trapped reef fish and some benthic invertebrates to die.

## 9.3 Storm Effects on Water Quality

Lagoon water quality was also apparently affected by the storm. Horizontal visibility was rarely greater than about 30 ft (10 m), except along the lagoon edge of the reef platform where clean ocean water was being carried across the reef flat at high tide. Otherwise, lagoon water was a murky dark green to black color with a faint hydrogen sulfide smell, presumably from eutrophication resulting from the death of reef organisms. The decay of these organisms would have released nutrients into the lagoon, causing secondary production. The lack of significant circulation and flushing, except along the reef platform, resulted in the green nutrient and algae charged water remaining in the lagoon with a dense "wall of murk" commencing at the edge of the lagoon terrace.

## REFERENCES

Balazs, G.H. 1980. Synopsis of biological data on the green turtle in the Hawaiian Islands. U.S. Dept. Commerce, NOAA Tech. Memo NMFS-SWFC-7 and University of Hawaii Sea Grant Cooperative Report UNIHI-SEAGRANT CR-81-02, 141 pp.

Balazs, G.H., R.G. Forsyth B. L. Becker, T.C. Johannes, B.K. Choy and R.L. Westlake. 1990. Status and Ecology of marine turtles at Johnston Atoll: 1987 assessment. Administrative Report H-90-08. Southwest Fisheries Center, Honolulu Laboratory, National Marine Fisheries Service, NOAA.

Edson, C. and F. Curren. 1987. Report from Oroluk. Marine Turtle Newsletter, Number 41, Sept. 1987.

Joint Typhoon Warning Center. 1991. 1990 Annual Tropical Cyclone Report. JTWC. Guam, Mariana Islands.

Manoa Mapworks. 1986. Pohnpei Coastal Resource Inventory. U.S. Army Corps of Engineers, Honolulu District.

Manoa Mapworks. 1989. Kosrae Coastal Resource Inventory. U.S. Army Corps of Engineers, Honolulu District.

Maragos, J.E.,et. al. 1992. Classification of Ecosystems for Conservation in the Tropical Insular Pacific. (working manuscript)

Myers, Robert F. 1989. Micronesian Reef Fishes. Coral Graphics Production, Territory of Guam. 298 pp.

Pritchard, P.C.H. 1977. Marine Turtles of Micronesia. Chelonia Press, San Francisco, 83 pp.

Thomas, P.E.J., et al. 1989. Report of the Northern Marshall Islands natural diversity and protected areas survey, 7-24 September 1988. South Pacific Regional Environmental Program, Noumea, New Caledonia. East-West Center, Honolulu, Hawaii.

# APPENDICES

Appendix 1 Distribution and Relative Abundance of Corals and Relative Level of Storm Damage at Oroluk Atoll.
Left column names: coral genera and/or growth form. Top row numbers: survey site numbers at Oroluk Atoll.
Relative abundance symbols: D = dominant; A = abundant; C = common; O = occasional; R = rare and
- = not observed/absent. Relative level of storm damage is indicated using same scale.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Acanthastrea* | - | O | C | A | - | A | O | O | C | O | A | O | - | O | A | - | C | O | C | R | C | - | - | - | - | - | - | - | - | - | - | - | - | - | - | C | - | - | - | - | D | C | - | O | C | A |
| *Acropora* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Small bushes | - | R | A | A | O | C | C | O | C | A | C | O | O | C | A | O | - | O | A | R | A | - | C | O | A | O | C | O | C | C | O | O | O | C | - | A | O | C | O | A | A | C | - | C | C | D |
| Large tables | - | - | O | - | C | A | - | - | - | C | - | R | - | - | - | - | - | - | A | O | - | - | - | R | - | - | - | - | O | - | - | R | - | - | - | C | - | - | - | O | - | - | R | - | - | O |
| Staghorns | - | - | - | - | - | - | - | - | - | - | - | - | - | R | - | - | - | - | - | - | - | - | - | C | - | - | A | - | - | - | - | - | - | - | - | - | - | - | R | - | - | - | - | - | - | - |
| Columnar (Isopora) | - | - | - | - | - | - | - | - | - | - | C | - | - | C | - | D | - | A | - | - | O | C | - | D | - | D | D | - | O | O | R | - | - | - | - | - | D | - | - | - | O | - | - | O | O | - |
| *Alveopora* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Astreopora* | - | C | A | D | A | A | C | D | A | A | A | A | D | O | D | A | D | C | D | C | A | A | A | R | - | C | - | D | C | - | O | C | - | A | - | C | A | - | O | C | - | A | C | A | D | D |
| *Barabattoia* | - | - | R | - | - | - | - | - | - | - | O | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | R |
| *Coscinaraea* | - | - | - | C | C | R | - | - | - | - | C | R | - | O | - | - | O | - | O | - | - | - | - | R | - | - | A | O | - | - | O | - | - | - | - | - | - | - | R | - | - | - | O | - | O | - |
| *Cycloseris* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | C | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Cyphastrea* | - | C | A | C | O | C | O | - | - | - | C | O | O | - | - | O | O | R | C | O | - | - | R | - | - | R | R | - | O | - | R | O | - | C | - | O | - | - | - | O | O | C | O | O | C | O |
| *Distichopora* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | C | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | C | - | - | - | - | - | - | - | - |
| *Echinophyllia* | - | - | - | - | - | O | - | - | - | R | - | - | - | - | - | - | - | - | O | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | C | - |
| *Echinopora* | - | - | - | - | - | O | - | - | - | O | - | - | - | - | - | - | A | - | - | - | C | - | - | - | - | - | O | - | - | - | - | - | - | O | - | - | - | - | - | - | - | - | - | - | - | R |
| *Euphyllia* | - | - | - | - | R | C | - | - | - | - | - | - | - | - | - | O | A | O | C | R | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Favia* | - | A | C | A | C | O | C | O | A | C | C | O | O | C | - | O | A | O | C | O | A | C | A | C | - | R | A | C | O | C | A | C | R | O | C | C | C | C | O | A | A | A | C | C | A | A |
| *Favites* | - | A | - | O | - | O | - | C | O | - | - | - | - | - | - | - | - | - | R | - | - | - | R | - | - | O | - | O | R | - | - | - | - | - | - | - | - | - | - | O | - | - | - | - | C | C |
| *Fungia* | - | - | - | - | R | C | - | - | - | - | C | - | O | O | - | - | - | R | A | R | - | - | - | R | - | C | A | - | O | C | R | O | - | C | - | O | R | - | - | C | - | - | - | - | O | O |
| *Gardineroseris* | - | - | - | - | - | R | - | - | - | - | - | - | - | R | - | - | - | R | - | - | - | - | - | O | - | R | R | - | - | - | R | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Goniastrea* | - | A | A | C | C | A | C | D | C | C | C | C | C | C | A | A | C | A | C | - | C | C | C | O | - | C | A | O | O | A | A | C | - | C | C | C | C | - | - | C | A | - | C | A | C | A |
| *Goniopora* | - | - | - | - | R | R | - | - | - | - | - | - | - | - | - | - | A | O | C | O | - | C | R | - | - | - | A | C | - | - | - | - | - | - | - | - | - | - | - | - | - | O | - | - | O | - |
| *Halomitra* | - | - | - | - | - | - | - | - | - | - | R | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | O | - | - | - | - | C | - |
| *Heliopora* | - | - | O | C | - | - | - | O | O | - | C | R | O | O | C | C | D | A | - | - | A | C | O | R | - | C | C | R | A | A | O | - | - | - | - | D | D | C | - | C | O | A | - | C | - | C |
| *Herpolitha* | - | - | - | - | R | A | - | - | - | O | - | R | - | - | - | - | - | - | C | R | - | C | R | - | - | - | - | - | - | - | R | O | - | - | - | O | - | O | R | - | - | - | - | - | - | - |
| *Hydnophora* | - | - | - | - | - | O | - | - | - | - | O | - | - | - | - | - | - | - | - | - | - | - | - | R | - | - | O | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Leptastrea* | - | R | C | - | R | C | R | R | C | O | C | R | - | C | - | R | - | - | C | C | - | C | O | - | - | - | - | R | - | C | O | C | - | C | O | O | - | A | A | O | O | - | R | R | C | O |
| *Leptoria* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | R | R | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | R |
| *Leptoseris* | - | - | - | - | - | C | - | - | - | C | C | R | - | - | - | - | - | - | A | O | - | - | - | - | - | - | - | - | - | - | R | R | - | - | - | - | - | R | - | - | - | - | - | - | C | - |

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Lobophyllia* | - | - | O | C | - | O | - | R | - | - | C | - | - | - | A | R | C | R | C | - | C | - | - | - | - | R | - | R | O | - | - | - | - | - | - | R | - | - | - | O | O | C | - | - | O | - |
| *Merulina* | - | - | - | - | C | C | - | - | - | - | C | O | - | R | O | - | C | - | C | R | - | - | R | - | - | - | - | - | - | - | R | R | - | C | - | - | - | O | - | - | - | - | - | - | A | - |
| *Millepora* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| encrusting | - | A | O | - | - | R | - | - | C | C | - | O | - | - | C | O | C | - | - | R | O | - | C | - | C | C | - | - | R | - | - | - | - | - | - | C | O | - | - | O | O | - | - | O | - | - |
| columnar | - | O | A | - | - | A | A | C | A | A | A | A | A | A | A | R | - | C | A | - | A | A | C | C | A | - | A | D | A | A | - | - | D | A | - | A | C | A | A | A | D | A | D | O | C | A |
| branching | - | - | - | - | - | - | - | - | C | A | - | - | A | O | - | C | - | A | - | - | - | - | - | - | - | - | - | A | - | - | C | O | R | - | O | - | - | C | A | - | C | C | - | - | A | C |
| *Montastrea* | - | - | C | C | - | - | - | O | C | - | - | - | - | - | C | C | C | O | - | - | - | - | - | R | - | - | - | - | O | O | A | - | - | - | - | C | O | - | A | - | - | C | - | - | O | A |
| *Montipora* | - | R | A | A | O | A | - | R | - | A | A | O | O | C | C | - | C | O | A | R | C | C | O | R | - | R | C | R | C | C | O | O | - | A | O | C | R | O | C | A | O | C | - | O | A | A |
| *Mycedium* | - | - | - | - | - | O | - | - | - | - | R | - | - | - | - | - | - | - | - | R | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | O | - |
| *Oulophyllia* | - | - | - | - | R | O | - | R | - | - | O | - | - | R | - | - | - | R | - | R | - | - | - | - | - | - | - | - | O | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | C | O |
| *Oxypora* | - | - | - | - | R | - | - | - | - | - | O | - | - | R | - | - | - | - | O | - | - | - | - | - | - | - | - | - | - | - | O | R | - | - | - | - | - | - | R | - | - | - | - | - | - | - |
| *Pachyseris* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | O | - | - | - | - | - | - | - | - | - | - | O | R | - | - | - | - | - | - | - | R | - | R | - | - | - | - | - |
| *Pavona* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| encrusting | - | R | - | C | - | C | R | R | C | C | A | R | O | - | - | R | - | O | C | R | - | O | - | R | C | C | A | O | - | C | O | R | R | C | - | - | - | - | - | C | R | - | O | R | C | A |
| heads | - | - | O | - | - | C | - | - | - | - | O | O | - | C | C | - | C | - | C | - | C | - | - | C | C | R | A | R | O | - | R | - | - | C | - | C | R | - | - | - | O | - | - | O | C | C |
| *Platygyra* | - | A | - | C | O | - | - | - | A | - | O | - | O | O | - | - | - | R | C | - | C | - | O | O | O | R | C | R | - | - | R | - | - | - | - | - | - | O | - | - | R | - | O | - | O | C |
| *Physogyra* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | C | O | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Plesiastrea* | - | - | - | - | - | - | C | O | - | - | - | - | - | - | - | - | - | - | - | - | - | - | O | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Plerogyra* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | R | - | - | - | - | - | - | - | - | - | - | - | - | R | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Pocillopora* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| finely branched | - | - | - | - | - | - | - | - | - | - | - | R | - | - | - | - | - | - | O | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | O | - | - | - | O |
| medium branched | - | O | C | C | R | C | R | - | A | C | C | R | O | O | A | R | - | R | C | R | A | - | - | O | A | R | A | C | O | - | O | R | R | C | C | C | O | C | C | C | O | A | O | - | C | C |
| large branched | - | - | - | O | - | C | - | - | - | - | C | - | R | O | - | - | - | - | - | R | - | C | - | O | C | - | C | - | - | C | R | - | O | O | O | - | - | - | R | - | O | - | R | - | - | - |
| *Porites* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| fingercoral | - | - | C | C | C | A | - | A | C | - | C | O | - | - | - | O | C | O | C | - | - | - | - | - | - | C | - | - | C | A | - | O | - | A | - | A | - | - | - | C | O | - | - | D | A | - |
| massive | - | A | C | - | O | C | O | C | C | A | C | A | C | D | - | A | C | - | C | C | A | A | O | C | A | C | - | C | - | C | A | - | - | C | - | A | C | C | A | A | C | D | O | C | A | A |
| encrusting | - | - | C | O | - | C | - | - | - | - | A | - | - | O | - | O | A | C | A | - | R | - | R | C | - | - | C | O | O | C | - | - | A | O | - | C | - | - | - | - | C | - | - | - | O | C |
| (Synaraea) | - | - | - | - | - | C | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | R | - | - | R | A | - | - | C | - | - | - | - | - | - | - | - | - | - | - | - | R | - | O | - |
| *Psammocora* | - | - | - | - | - | C | - | R | - | C | C | - | - | R | - | - | - | R | C | - | - | - | - | - | - | - | - | - | - | O | R | - | - | - | - | - | - | - | - | - | - | - | - | - | O | - |
| *Sandalolitha* | - | - | - | - | - | C | - | - | - | - | - | - | R | R | - | - | - | - | O | R | - | - | - | - | - | - | - | - | - | C | O | R | - | - | O | - | - | C | R | O | - | - | - | - | - | - |
| *Scapophyllia* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Scolymia* | - | - | R | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Seriatopora* | - | - | - | - | - | - | - | - | - | - | O | R | - | - | - | - | - | - | A | - | - | - | - | - | - | - | - | C | - | O | - | O | - | - | O | O | - | - | - | - | R | - | - | - | A | - |
| *Stylaster* | - | - | - | - | - | - | - | - | - | - | C | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Stylocoeniella* | - | - | - | - | - | O | - | - | - | - | - | - | - | - | - | - | - | - | O | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Stylophora* | - | O | C | - | - | - | R | - | - | - | C | O | - | - | C | O | C | O | - | C | A | A | O | R | - | O | C | O | O | - | R | O | - | - | C | C | C | - | - | C | - | A | - | O | C | A |
| *Symphyllia* | - | - | O | O | R | - | - | R | - | O | - | - | R | R | - | - | - | R | O | R | - | - | R | R | - | - | O | - | - | - | - | - | - | - | - | - | - | - | - | - | O | - | R | O | O | O |
| *Tubastraea* | - | - | - | - | - | C | - | - | - | - | O | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Tubipora* | - | - | - | - | - | - | - | - | - | - | - | - | - | R | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | O | - | - | - | - | - | - | - | - | - | - |
| *Turbinaria* | - | - | - | - | - | - | - | - | - | - | C | R | - | R | O | - | - | R | - | - | - | - | - | - | - | R | C | R | - | C | R | - | - | - | - | - | - | - | O | - | O | O | - | - | - | - |
| **Total Coral Genera** | - | 15 | 19 | 17 | 19 | 31 | 13 | 18 | 14 | 17 | 31 | 20 | 15 | 23 | 14 | 15 | 18 | 23 | 34 | 23 | 15 | 14 | 19 | 19 | 6 | 18 | 20 | 19 | 17 | 17 | 26 | 20 | 6 | 14 | 9 | 20 | 13 | 14 | 15 | 18 | 17 | 15 | 13 | 14 | 29 | 23 |
| Storm Damage | - | - | O | C | C | C | A | - | O | C | - | - | O | A | A | - | - | - | - | - | - | R | C | O | C | - | - | A | O | - | O | - | O | C | - | - | C | A | - | C | - | - | A | - | R | - |

Appendix 2 Corals Recorded at Oroluk Atoll and Minto Reef

*Alveopora allingi* (Hoffmeister, 1925) +
*Acanthastrea echinata* (Dana, 1846)
*A.* sp.
*A. cerealis* (Dana, 1846)
*Acropora austera* (Dana, 1846)
*A. (Isopora) cuneata* (Dana, 1846)
*A. digitifera* (Dana, 1846)
*A. formosa* (Dana, 1846)
*A. gemmifera* (Brook, 1892)
*A· humilis* (Dana, 1846)
*A. horrida* (Dana, 1846)
*A. hyacinthus* (Dana, 1846)
*A. nasuta* (Dana, 1846)
*A. palmerae* (Wells, 1954)
*A. polystoma* (Brook, 1891)
*A. selago* (Studer, 1878)
*A. valida* (Dana, 1846)
*A. tenuis* (Dana, 1846)
*A. valenciennesi* (Edwards and Haime, 1860)
*A. aculeus* (Dana, 1846)
*A. vaughani* (Wells, 1954)
*A. cytherea* (Dana, 1846)
*A.* (I) *palifera* (Lamarzk, 1816)
*A. paniculata* (Verrill, 1902
*A. spicifera* (Dana, 1846)
*A.* (I) *brueggemanni* (Brook, 1893)
*A. acuminata* (Verrill, 1864)
*A.* sp.
*Astreopora listeri* (Bernard, 1896)
*A. gracilis* (Bernard, 1896)
*A· myriophthalma* (Lamarck, 1816)
*A. explanata* (Veron, 19--)
*A.* sp.
*Barabattoia amicorum* (Edwards and Haime, 1850)
*Cycloseris patelliformis* (Boschma, 1923)
*Cycloseris vaughani* (Boschma, 1923)
*Ctenactis echinata* (Pallas, 1766)
*Coscinaraea columna* (Dana, 1846)
*C. wellsi* (Veron and Pichon, 1980)
*Cyphastrea chalcidicum* (Forskal, 1775)
*C. microphthalma* (Lamarck, 1816)

*C. serailia* (Forskal, 1775)
*Distichopora violacea* (Pallas, 1766) *
*Echinophyllia aspera* (Ellis and Solander, 1788)
*Echinopora lamellosa* (Esper, 1795)
*Euphyllia glabrescens* (Chamisso and Eysenhardt, 1821)
*Favia favus* (Forskal, 1775)
*F. matthaii* (Vaughan, 1918)
*F. rotundata* (Veron, Pichon, and Wijsman-Best, 1977)
*F. pallida* (Dana, 1846)
*F. speciosa* (Dana, 1846)
*F. stelligera* (Dana, 1846)
*F. veroni* (Moll and Borel-Best, 1984)
*Favites abdita* (Ellis and Solander, 1786)
*F. halicora* (Ehrenberg, 1834)
*F. flexuosa* (Dana, 1846)
*Fungia (Pleuractis) paumotensis* (Stutchbury, 1833)
*F. (P.) scutaria* (Lamarck, 1801)
*F. (V.) repanda* (Dana, 1846)
*F. (Verrillofungia) concinna* (Verrill, 1864)
*F. (Danafungia) valida* (Verrill, 1864) *
*F. (D.)* sp. cf. *F. (D.) scruposa* (Klunzinger, 1879) *
*Fungia* (F.) *fungites* (Linnaeus, 1758)
*Goniastrea retiformis* (Lamarck, 1816)
*G. favulus* (Dana, 1846)
*G. pectinata* (Ehrenberg, 1834)
*Goniopora* sp.
*G. columna* (Dana, 1846)
*G. lobata* (Edwards and Haime, 1860)
*Gardineroseris planulata* (Dana, 1846)
*Heliopora coerulea* (Pallas, 1766)
*Halomitra pileus* (Linnaeus, 1758)
*Herpolitha limax* (Houttuyn, 1772)
*H. weberi* (van der Horst, 1921)
*Hydnophora microconos* (Lamarck, 1816) *
*H. exesa* (Pallas, 1766) *
*Leptastrea purpurea* (Dana, 1846)
*L. transversa* (Klunzinger, 1879)
*Lobophyllia hemprichii* (Ehrenberg, 1834)
*L. corymbosa* (Forskal, 1775)
*L. hataii* (Tabe, Sugiyama and Eguchi, 1936)
*Leptoria phrygia* (Ellis and Solander, 1786) *
*Leptoseris explanata* (Yabe and Sugiyama, 1941)
*L. hawaiiensis* (Vaughan, 1907)
*L. scabra* (Vaughan, 1907)

*L. incrustans* (Quelch, 1886)
*L. mycetoseroides* (Wells, 1954)
*Montastrea curta* (Dana, 1846)
*Montipora tuberculosa* (Lamarck, 1816)
*M. danai* (Edwards and Haime, 1851)
*M. verrucosa* (Lamarck, 1816)
*M. foveolata* (Dana, 1846)
*M. aequituberculata* (Bernard, 1897)
*M. informis* (Bernard, 1897)
*M. hispida* (Dana, 1846)
*M. monasteriata* (Forskal, 1775)
*M.* sp.
*M. foliosa* (Pallas, 1766)
*M. hoffmeisteri* (Wells, 1956)
*M. venosa* (Ehrenberg, 1834)
*M.* sp. cf. M. *spumosa* (Lamarck, 1816)
*Merulina ampliata* (Ellis and Solander, 1786)
*Mycedium elephantotus* (Pallas, 1766
*Millepoa exaesa*
*M. platyphylla* (Hemprich and Ehrenberg)
*M. tenera*
*Oulophyllia crispa* (Lamarck, 1816)
*Oxypora lacera* (Verrill, 1864)
*Pavona explanulata* (Lamarck, 1816)
*P. clavus* (Dana, 1846)
*P. venosa* (Ehrenberg, 1834)
*P. minuta* (Wells, 1956)
*P. varians* (Verrill, 1864)
*P. maldivensis* (Gardiner, 1905)
*P.* sp.
*Pachyseris rugosa* (Lamarck, 1801) *
*P. speciosa* (Dana, 1846) *
*Platygyra daedalea* (Ellis and Solander, 1786)
*Platygyra pini* (Chevalier, 1975)
*P. sinensis* (Edwards and Haime, 1849)
*Pocillopora damicornis* (Linnaeus, 1758)
*P. meandrina* (Dana, 1846)
*P. eydouxi* (Edwards and Haime, 1860)
*P. verrucosa* (Ellis and Solander, 1786)
*Porites murrayensis* (Vaughan, 1918)
*P. lichen* (Dana, 1846)
*P. lobata* (Dana, 1846)
*P. lutea* (Edwards and Haime, 1860)
*P. cylindrica* (Dana, 1846)

*P. (S.) rus* (Forskal, 1775)
*P. australiensis* (Vaughan, 1918)
*P. (N.) vaughani* (Crossland, 1952)
*Psammocora haimeana* (Edwards and Haime, 1851)
*P. nierstraszi* (van der Horst, 1921)
*P. profundacella* (Gardiner, 1898)
*Palauastrea ramosa* (Yabe and Sugiyama, 1941) ?
*Plerogyra sinursa* (Dana, 1846) *
*Physogyra lichensteini* (Edwards and Haime, 1851) *
*Plesiastrea versipora* (Lamarck, 1816)
*Scolymia vitiensis* (Bruggemann, 1877) +
*Sandalolitha robusta* (Quelch, 1886)
*Symphyllia recta* (Dana, 1846)
*Stylophora pistillata* (Esper, 1797)
*Seriatopora hystrix* (Dana, 1846) *
*Scapophyllia cylindrica* (Edwards and Haime, 1848) +
*Stylaster* sp. *
*Stylocoeniella guentheri* (Bassett-Smith, 1890)
*Tubipora musica* (Linnaeus, 1758)
*Tubastraea coccinea* (Lesson, 1829)
*Turbinaria stellulata* (Lamarck, 1816)
*T. reniformis* (Bernard, 1896)
*T. frondens* (Dana, 1846)

*=only recorded at Oroluk Atoll
+=only recorded at Minto Reef

Appendix 3

Distribution and Abundance of Macroinvertebrates at Oroluk Atoll.
Left column names invertebrate group, genera or genus/species.
Top row numbers: survey site numbers at Oroluk Atoll.
Relative abundance symbols: D = dominant; A = abundant;
C = Common; O = occasional; R = rare; and - = absent/not observed.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PORIFERA | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| unspecified | - | - | - | - | - | - | - | - | - | O | - | O | - | - | - | - | - | - | - | - | - | - | - | O | - | - | - | - | - | - | O | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| soft brown | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | O | R | - | - | - | - | - | A | - | - | - | - | - | - | - |
| brown demosponge | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| soft black | - | - | - | - | - | R | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | R | - | - | R | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| red | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | A | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | R | - |
| red/orange | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | R | - | - | - | - | - | - | - | - | - | - | - | - | - | - | O | - | - | - | - | - | - | - | - | - | - | - | - |
| CNIDARIA | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Soft Corals | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Cladiella* | - | - | - | - | - | - | - | - | - | - | - | R | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Lobophytum* | - | - | - | - | C | - | - | C | - | - | - | - | C | - | - | - | - | R | - | - | - | O | - | - | - | - | R | - | - | - | - | C | - | - | - | - | C | - | - | - | C | - | - | - | - | - |
| *Sarcophyton* | - | - | - | - | O | - | - | - | - | - | - | - | C | - | - | - | - | - | - | - | - | O | - | - | - | - | O | - | - | C | - | - | - | - | - | - | O | - | O | - | R | - | R | - | - | - |
| *Sinularia* | - | - | - | - | O | - | - | R | - | - | - | - | A | O | - | - | - | - | - | R | - | O | - | - | - | - | C | - | O | O | - | C | - | - | - | - | R | - | - | - | A | - | - | R | - | - |
| *Stereonephthya* | - | - | - | - | - | - | - | - | - | - | - | - | - | R | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | R | - | - | - | - | R | - | - | - | - | - | - | - | - | - |
| unspecified | - | - | - | - | - | - | O | - | A | O | - | O | C | O | C | - | - | - | - | - | - | - | O | C | - | - | - | - | - | - | C | - | - | - | O | O | - | - | - | O | A | C | - | O | O | O |
| Black Coral | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Antipathes* | - | - | - | - | - | - | - | - | - | - | - | O | - | R | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | O | - | - | - | - | - | - | - | - |
| Wire Coral | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Cirripathes* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Gorgonian | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Anenome | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | R | - | - | - | - | R | - | - | - | - | - | - | R | - | - | - | - | C | - | - |
| Hydroid | - | - | - | - | O | - | - | - | - | - | - | - | - | - | - | - | - | R | - | - | - | - | - | - | - | - | - | - | - | - | - | O | - | - | - | - | - | - | - | - | - | - | - | C | - | - |
| Zooanthid | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Palythoa* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| MOLLUSCA | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Gastropoda | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Bursa* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Casmaria* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Cassis* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | R | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Cerithium* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | A | - | - | - | - | - | - | - | - | - |
| *Charonia* | - | - | - | - | O | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Chicoreus* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Clypoeomorus* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Coralliophila* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Conus* | - | A | - | - | - | - | R | R | - | R | - | - | - | - | - | - | - | O | - | - | - | - | - | - | A | - | - | - | R | - | - | R | A | - | - | - | A | - | - | - | - | - | R | C | - | - |
| *Cypraea* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | R | - | - | - | - | - | - | - | - | - | - | - | - | - | - | R | - | - | - | - | - | - | - | - | - | - | C | - | - |
| *Drupa* | - | A | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | C | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Lambis* | - | - | - | - | - | - | O | R | - | - | - | - | - | - | - | - | - | R | - | O | - | O | - | - | - | - | - | - | R | - | - | - | R | - | - | - | O | - | - | R | - | - | - | - | - | - |
| *Mitra* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | R | - | - | - | R | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Morula* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Nassarius* | - | - | - | - | - | - | - | - | - | - | - | C | - | - | - | - | - | C | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Neocancilla* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Oliva* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Polinices* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | R | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Phyllidia* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Rhinoclavus* | - | - | - | - | - | - | - | - | - | - | - | R | - | - | - | R | - | C | - | C | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Stombus* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | C | - | - | - | - | C | - | - | - | - | - | - | - | - | - | - | - | O | - | - | - | - | - | R | - | - | - |
| *Terebra* | - | - | - | - | - | - | - | - | - | - | - | R | - | - | - | - | - | C | - | C | - | - | - | - | R | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | A | - | A |
| *Thais* | - | A | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | A | - | - | - | - | - | - | - | A | - | - | - | - | - | - | - | - | - | C | - | - | - |
| *Tonna* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Trochus* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | R | - | R | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Turbo* | - | - | - | - | - | - | - | - | - | - | - | R | - | - | - | R | - | R | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | R | - | - |
| Vermitidae | - | - | - | - | - | - | - | C | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | C | - | - | - | C | - | - | C | A | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Vexillum* | - | - | - | - | - | - | - | - | - | - | - | R | - | - | - | - | - | - | - | O | - | - | - | - | C | - | - | - | - | - | - | - | - | - | - | - | O | - | - | - | - | - | R | - | - | - |
| MOLLUSCA | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Bivalvia | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Giant Clams | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Hippopus hippopus* | - | C | R | - | - | - | - | - | R | - | - | C | - | - | O | C | R | C | - | C | - | - | R | - | - | R | - | A | O | - | - | O | - | - | - | O | A | - | - | C | - | - | O | A | - | O |
| *Tridacna crocea* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | R | - | - | - | - | - | A | - | - | - | - | - | - | - | - | - | A |
| *T. derasa* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | O | - | - | - | - | - | - | - | - | - | - |
| *T. maxima* | - | C | C | O | A | - | C | C | R | - | - | C | C | C | A | A | R | A | - | C | R | C | O | O | - | O | C | O | C | A | C | A | R | A | C | A | A | R | - | A | C | A | O | A | A | A |
| *T. squamosa* | - | - | - | R | - | - | - | - | - | - | - | - | - | - | O | - | - | - | - | - | R | - | - | - | - | - | - | - | - | O | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Other Bivalves | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Cardiid | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *cf. Trachycadium* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Chama* | - | - | - | - | - | - | - | O | - | - | - | - | - | O | - | - | - | - | - | - | - | - | - | - | - | - | - | - | A | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Lucinid | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Pinctada* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Pteria* | - | - | - | - | - | - | - | - | - | - | - | - | - | R | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Spondylus* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Cephalopoda | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Octopus* | - | R | - | - | - | - | - | - | R | - | - | - | - | - | R | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| ECHINODERMATA | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Crinoidea | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Crinoids | - | - | - | - | - | - | - | - | - | - | - | - | C | C | - | - | - | - | - | - | - | C | - | - | - | - | C | - | - | A | A | - | - | - | O | - | - | - | A | - | C | - | - | - | - | - |
| Asteroidea | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Acanthaster* | - | - | - | - | - | - | - | - | - | - | - | - | R | - | - | - | - | R | R | - | - | O | - | - | - | - | - | R | R | R | - | - | - | - | - | - | - | R | - | - | - | - | - | - | - | - |
| *Culcita* | - | - | - | - | - | - | R | - | A | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | R | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Linkia* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Echinoidea | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Echinometra* | - | - | - | - | - | - | - | - | - | - | - | - | A | - | - | - | - | C | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Echinostephus* | - | - | - | - | - | - | - | - | - | - | - | - | C | - | - | - | - | C | - | C | - | C | - | - | - | - | - | - | - | C | - | C | - | - | - | - | - | - | A | - | C | - | R | - | - | - |
| *Echinothrix* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | C | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | R | - | - | - |
| *Heterocentrotus* | - | D | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Thalanta* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | O | - | - | - | C | - | - | - |
| *Thelenota* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | O | - | - | - | - | R | O | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Holothuroidea | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Actinopyga* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | R | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Holothuria* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | R | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| CRUSTACEA | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Lobster | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Panulirus* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |

## APPENDIX 4

## MACROINVERTEBRATES RECORDED AT OROLUK ATOLL AND MINTO REEF

PORIFIERA (sponges)
soft brown sponge sp.
brown demosponge sp.
soft black sponge sp.
red sponge sp.
red/orange sponge sp.

CNIDARIA (other than hard corals)
Soft Corals
*Cladiella sp.*
*Lobophytum pauciflorum*
*L. sp.*
*Sarcophyton (cf. trocheliophorum)*
*S. sp.*
*Sinularia polydactyla*
*S. sp.1*
*S. sp. 2*
*S. sp. 3*
*S. sp. 4*
*S. sp. 5*
*Stereonephthya sp. (?)*

Black Coral
*Antipathes sp.*

Wire Coral
*Cirripathes sp.*

Gorgonian (sea fans)
Plexanidae sp.

Hydroid

Zooanthid
*Palythoa* sp.

Anemone
*Actinodendron plumosum*
*Stichodactyla sp.*

MOLLUSCA

GASTROPODA (gastropods)

*Bursa sp. (cf. rosa)*
*Casmaria erinaceus*
*Cassis cornuta*
*C. vibex (?)*
*Cerithium nodulosum*
*C. sp.*
*Charonia tritonis*
*Chicoreus ramosus*
*Clypeomorus sp. (?)*
*Coralliophila violacea*
*Conus ebraeus*
*C. flavidus*
*C. lividus*
*C. marmoreus*
*C. miles*
*C. pulicarius*
*C. sponsalis*
*C. striatus*
*C. tessulatus*
*C. vitalinus*
*C. sp. (cf. achatina)*
*C. sp. (cf. planara)*
*C. sp. (cf. rattus)*
*C. sp. (cf. sugillatus)*
*Cypraea annulus*
*C. argus*
*C. arabica*
*C. caputserpentis*
*C. carneola*
*C. erosa*
*C. helvola*
*C. isabella*
*C. lynx*
*C. scurra*
*C. talpa*
*Drupa grossularia*
*D. morum*
*Lambis chiragra*
*L. truncatas*
*Mitra ferruginea*
*M. strictica*
*M. (cf. (Strigatella) acuminata)*

*M. sp.*
*Morula sp.*
*Nassarius graniferus*
*N. papillosus*
*N. sp.*
*Neocancilla papiilo*
*Oliva miniacea*
*Polinices sp.*
*Phyllidia sp.*
*Rhinoclavus asper*
*R. fasciatus*
*R. sinensis*
*R. sp. (cf. vertagus)*
*Strombus dentatus*
*S. luhuanus*
*S. mutabilis*
*Terebra affinis*
*T. crenulata*
*T. guttata*
*T. maculata*
*T. subulata*
*T. sp. (cf. cerithina)*
*T. cp. (cf. babylonia)*
*Thais armigera*
*Tonna (Malea) ponum*
*Trochus maculatus*
*Turbo argyrostomus*
*T. petholatus*
Vermitidae *cf. Dendropoma gigantea*
Vermitidae *cf. Vermetus sp.*
*Vexillum vulpeculum*
*V. sp. (cf. cadaverosum)*

BIVALVIA (bivalves)
Giant Clams
*Hippopus hippopus*
*Tridacna crocea*
*T. derasa*
*T. maxima*
*T. squamosa*

Other Bivalves
Cardiid *(cf. Trachycadium orbita)*
*Chama sp.*

Lucinid *(cf. Codakia)*
*Pinctada margaritifera*
*Pteria brunnea*
*Spondylus sp.*

CEPHALOPODA (cephalopods)
*Octopus* sp.

ECHINODERMATA
CRINOIDEA (crinoids)
*Crinoid spp.*

ASTEROIDEA (sea stars)
*Acanthaster planci*
*Culcita nova-guinea*
*Linkia laevigata*
*L. multifora*

ECHINOIDEA (sea urchins)
*Echinometra mathei*
*E. sp.*
*Echinostrephus aciculatus*
*Echinothrix diadema*
*Heterocentrotus mammillatus*

HOLOTHUROIDEA (sea cucumbers)
*Actinopyga lecanora (?)*
*Holothuria nobilis*
*H. sp. 1 (green)*
*H. sp. 2 (brown)*
*Thelenota ananas*
*T. anax*

CRUSTRACEA (crustaceans)
Lobster
*Panulirus sp. (cf. versicolor)*

Appendix 5 Distribution and Relative Abundance of Algae at Oroluk Atoll. Left column names: algal type or genus. Top row numbers: survey site numbers at Oroluk Atoll. Relative abundance symbols: D = dominant; A = abundant; C = common; O = occasional; R = rare; - = absent/not observed.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Caulerpa* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | R |
| *Codium* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Gracilaria* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Halimeda* | - | - | R | R | C | - | - | - | - | O | O | - | - | A | R | O | C | C | R | - | R | - | R |
| *Microdictyon* | - | - | O | R | C | R | - | - | D | O | R | C | D | - | R | D | C | - | R | A | R | C | C |
| *Neomeris* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Udotea* | - | - | - | O | - | - | - | - | - | - | - | - | - | - | - | - | - | - | R | - | - | - | - |
| red crustose | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| red filamentous | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| green stringy | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |

| | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Caulerpa* | C | - | - | - | A | - | - | - | - | R | - | - | R | D | R | - | - | - | C | - | - | - | A |
| *Codium* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | A | - | - | - | D |
| *Gracilaria* | - | - | R | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | A |
| *Halimeda* | A | - | R | A | O | - | A | - | C | - | - | - | R | A | - | O | C | - | - | R | C | A | C |
| *Microdictyon* | - | - | - | - | - | D | A | D | D | - | C | A | - | A | C | A | D | - | - | - | - | D | - |
| *Neomeris* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Udotea* | - | - | - | - | - | - | - | R | - | - | - | - | - | C | - | - | - | - | - | R | - | - | C |
| red crustose | - | - | - | - | - | - | - | - | - | - | - | - | - | A | - | - | - | - | - | - | - | - | - |
| red filamentous | - | - | - | - | - | - | - | R | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| green stringy | - | - | - | - | - | - | - | - | C | - | - | - | - | - | - | - | - | - | - | - | - | - | - |

## APPENDIX 6

## ALGAE RECORDED AT OROLUK ATOLL AND MINTO REEF

*Caulerpa cupersoides*
*C. serrulata*
*Codium spongiosum*
*Gracilaria arcuata*
*Halimeda cylindracea*
*H. microloba*
*H. opuntia*
*H. tuna*
*Microdictyon japanicus*
*M. sp.*
*Neomeris annulata*
*Udotea sp.*
red crustose algae sp.
red filamentous algae sp.
green stringy algae sp.

Appendix 7

Distribution of Fish at Oroluk Atoll. Left column names: fish family, genus and species.
Top row numbers: survey site numbers at Oroluk Atoll.
Distribution symbol: x = present; no symbol = absent/not observed.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ORECTOLOBIDAE | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Nebrius concolor* | | | | | | | | | | | | | | | X | | | | | | | | | | | | X | | | | | | X | | | | | | | | | | | | | |
| HEMIGALEIDAE | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Triaenodon obesus* | | | | | X | X | | | | | | | X | X | | X | | | | X | | X | | | | | X | | | | | X | | X | | | | | | | X | | X | X | | |
| CARCHARHINIDAE | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Carcharhinus amblyrhynchos* | | | | X | X | X | X | X | | | | X | | | | | | | | X | | X | X | | | | X | | | X | | X | | | | | | | X | | X | X | X | | | |
| *C. melanopterus* | | | X | | | | | | | | | | | | | | X | | | | | X | | | X | | | | X | | X | | | X | | | | | | | | | X | X | | |
| MYLIOBATIDAE | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Aetobatis narinari* | | | | | | | | | X | | | X | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X |
| CONGRIDAE | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Gorgasia sp.* | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Heteroconger hassi* | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| CHANIDAE | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Chanos chanos* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | |
| CLUPEIDAE | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Spratelloides sp.* | | X | X | | | | X | | X | X | | | | | X | X | X | X | | X | X | | | X | | | | | X | X | | X | | | | X | | | | X | X | X | X | X | X | |
| BELONIDAE | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Platybelone platyura* | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Tylosurus crocodilis* | | | X | X | | | | | | | | | | | | | X | X | | | | | | X | | | | | | X | | X | | | | | | | | | | | | | | |
| HEMIRHAMPHIDAE | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Hemiramphus sp.* | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| HOLOCENTRIDAE | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Myripristis adjustus* | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | X | | | | | | | | | | | | | | | | |
| *M. murdjan* | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | X | | | | | | | | | | | | | | | | |

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Neoniphon opercularis* | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Sargocentron caudimaculatum* | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *S. spiniferum* | | | | | | | | | | | | | | | | X | | | | X | | | | | | X | X | | X | | | | | | | | X | | | | | X | | | | |
| *S. tiere* | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | |
| FISTULARIIDAE | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Fistularia commersoni* | | | | | | | | | | | | | | | X | | | | | | | | | X | X | | X | | | | | X | | | X | | | | | | | | | | | |
| SERRANIDAE | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Pseudanthias tuka* | | | | | | | | | | | | | | X | | | | | | | | | | | | | X | | | X | | X | | | | | | | | | | | | | | |
| *Aethaloperca rogaa* | | | X | X | X | | X | | | X | | | | | | | | | | X | | | X | | | | | | | | | | | | | | | | | | | | | | | |
| *Anyperodon leucogrammicus* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | |
| *Cephalopholis argus* | | X | X | X | X | X | X | | | X | | | X | | | X | X | X | | | | X | X | X | | | X | X | X | X | X | X | | X | | | | | | X | X | X | | X | X | X |
| *C. boenack* | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *C. urodeta* | | X | | X | | | X | | | | | | | | | | X | | | X | | | | | | | | | X | | | X | | | | | | | | | | | X | | | |
| *Gracila albomarginata* | | | | | | | | | | | | | | X | | | | | | | | | | | | | X | | | X | X | X | | | | | | | X | | X | | | | | |
| *Epinephelus cyanopodus* | | | | X | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | |
| *E. fuscoguttatus* | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | X | | | | | |
| *E. hexagonatus* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | X |
| *E. lanceolatus* | | | | | | X | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *E. macrospilos* | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X |
| *E. merra* | | | | | | | | | | | | | | | | | | | | | | | | | | X | | X | | | | X | | | | | | | | | | | | X | X | X |
| *E. microdon* | | | X | X | X | X | | X | X | | X | | | | | | | | X | | | X | X | | | | X | | X | X | | | | | | | | | | | X | | | X | X | |
| *E. spilotoceps* | | | | | X | | | X | | | | | | | | X | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *E. tauvina* | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | |
| *Plectropomus areolatus* | | | X | | | | | | | | | | | | | | | | X | | | | | | | | | X | | | | | X | | | | | | | | X | | | | | |
| *P. laevis* | | | | X | X | X | | X | | X | X | X | X | X | | | X | | X | X | | X | | X | | | X | X | X | X | X | X | | X | | | | | X | X | X | | | X | X | |
| *P. leopardus* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | X | X | | X | | | | | X |
| *P. oligacanthus* | | | | | X | | | | | | | | | | | | | | | X | | | | | | | | | | | | X | | | | | | | | | | | | | | |
| *Variola louti* | | X | | X | | | X | X | | X | | | X | | | | | | X | | X | | | | | | X | | X | | X | X | | | | | | | | X | X | | | X | | |

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| KUHLIIDAE | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Kuhlia mugil* | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | X | | | | | | | | | | | | | |
| MALACANTHIDAE | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Malacanthus latovittatus* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | |
| CARANGIDAE | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Carangoides ferdau* | | | X | X | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | |
| *C. orthogrammus* | | | X | | | | | | | | | | | | | | X | | | | X | | | | | | | | | | | | | | | | | | | X | | | | | | |
| *Caranx lugubris* | | | | | | X | | | | | | | | | | | | | | | | | X | | | | | | | X | | | | | | | | | | | | | | | | |
| *C. melampygus* | | | X | | X | | X | | | | | | X | X | | | | | | X | | | | X | | | | | X | X | X | X | X | | X | | | | | | | X | | | | |
| *C. sexfasciatus* | | | | | | | | | | | | | | | | | | | | | | | | | X | | X | | | | | | X | | | | | | | | | | | | | |
| *Selar crumenophthalmus* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | |
| *Elagatis bipinnulatus* | | | X | | X | X | X | | X | X | X | X | X | X | | | | | | X | | X | X | X | | | X | | | | | X | | | | | | X | X | X | X | | | X | | |
| *Scomberoides lysan* | | | X | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | X | | | | | | |
| *Trachinotus bailloni* | | | | | | | | | | | | | | X | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | |
| LUTJANIDAE | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Aphareus furca* | | | | | X | | | X | | | X | | | X | | | | | X | X | | | | | | | | | | X | X | X | | | | | | | X | | X | | | | X | |
| *Aprion virescens* | | | X | X | | | X | | X | | | X | | | | | | | X | | X | | | | | | | | | | X | | X | | | | | | | | | | | | | |
| *Macolor macularis* | | | | | | | | X | | | | X | X | X | | | | | | X | | | | X | | | | | | | | | | X | | | | | | | | | | | | |
| *M. niger* | | | | | X | X | | | X | | X | | | | | | | | X | X | | X | | X | | | X | | X | X | X | X | | | | | | X | X | | X | | | | | |
| *Lutjanus bohar* | | | X | X | X | | X | X | X | | | X | X | X | | | X | X | | X | | X | X | X | | | X | X | X | X | X | X | | | X | X | X | | X | X | X | X | | | X | |
| *L. gibbus* | | | | | X | X | | X | | | X | | X | X | | X | X | X | | X | X | X | X | X | | X | X | | X | X | X | X | | X | | X | X | | X | | X | | | | X | |
| *L. kasmira* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | |
| *L. monostigmus* | | | | | X | | | X | | | | | | X | | | | | X | X | | | | | | X | X | | | | | | | X | | | X | | | | | | | | X | |
| *L. semicinctus* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | X |
| CAESIONIDAE | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Caesio caerulaurea* | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | |
| *C. lunaris* | | | | | | | | | | | | X | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *C. teres* | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Pterocaesio marri* | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | |
| *P. tile* | | | | | | X | | | X | | X | | | | | | | | X | | | | | | | | X | | | | | | | | | | | | | | | | | | | |
| *P. sp.* | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| HAEMULIDAE | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Plectorhinchus obscurus* | | | | | | | | | | | | X | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | |
| LETHRINIDAE | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Gnathodentex aurolineatus* | | | | | | | X | | | | | | | | | | | X | | | X | | | | | X | | | | X | | | | | | | | | | | | | | | | |
| *Gymnocranius sp.* | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | |
| *Lethrinus amboinensis* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | |
| *L. elongatus* | | | X | | | | | | | | | | | | | | X | | | | X | | X | | | | | | | | | | | | | | | | | | | | | | | |
| *L. harak* | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | |
| *L. hypselopterus* | | | | | | | | | X | | | | | X | | | | | | | | | X | | | | | | X | | | X | | | | | | | | | | | | | | |
| *L. kallopterus* | | | | | | X | | | X | | X | | | | | | | | X | | | | X | | | | | | X | | | X | | | | | | | | | X | | | | | |
| *L. ramak* | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | |
| *L. rubrioperculatus* | | | | | | | | | | | | | | | X | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | |
| *L. xanthocheilus* | | | X | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | X | | X | | | |
| *Monotaxis grandoculus* | | | | | X | X | | X | X | | X | | X | X | X | X | X | X | X | X | X | | X | | | X | X | | X | X | X | X | | | X | X | | | X | X | | | | X | X | |
| MULLIDAE | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Mulloides flavolineatus* | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | X | | | | | | | | | |
| *M. vanicolensis* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | |
| *Parupeneus barberinus* | | | | | | | X | | | | | | | | X | | X | | | X | | | | | | | | | | | | | | | | X | X | | | | | | | X | | |
| *P. bifasciatus* | | | | | | | X | X | | | | | | | X | | | | | | X | | | | | | | | X | | | X | | | | | | | | | | | | | | |
| *P. cyclostomus* | | X | | X | X | | X | X | | X | | | X | | | | | | | | X | | | | | | | | X | | | | | X | | | X | | | | | | | | | |
| *P. indicus* | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *P. multifasciatus* | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | |
| KYPHOSIDAE | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Kyphosus cinerascens* | | | | | | | | | | | | | | | | | | | | | | | | | X | X | | | | | X | X | X | | | | | | | | | | | | | |

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EPHIPPIDAE | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Platax orbicularis* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | |
| *P. tiera* | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *P. sp.* | | | | | X | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| CHAETODONTIDAE | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Chaetodon auriga* | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | |
| *C. citrinellus* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | X | |
| *C. lunula* | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *C. reticulatus* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | |
| *C. trifasciatus* | | X | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| POMACANTHIDAE | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Centropyge flavissimus* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | |
| *C. heraldi* | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Pygoplites diacanthus* | | | | | | | | | | | | | | | | | | | X | | X | | | | | | | | X | X | | | | | | | | | | | | | | | | |
| *Pomacanthus imperator* | | | | | | | | | X | X | | | | | | | | | | | | | | | | | X | | | X | | X | | | | | | | | | | | | | | |
| POMACENTRIDAE | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Amphiprion sp.* | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | X | | | | | | | | | | | | | | | X | | |
| *Chromis atripectoralis* | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | |
| *C. viridis* | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Amblygliphidodon aureus* | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Pomacentrus sp.* | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Stegastes nigricans* | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | |
| LABRIDAE | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Cheilinus celebecus* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | |
| *C. chlorourus* | | X | | | | | X | | | | | | X | | | | | X | | X | | | | | | | | | X | | | | | X | | | | | | | | | | | | |
| *C. digrammus* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | |
| *C. fasciates* | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | X | X | X | | X | | X | | | | | | | | X | X | |
| *C. oxycephalus* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | |

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *C. rhodachrous* | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | X | | | | | | | | | | | | | | | | | |
| *C. trilobatus* | | | | | | | | | | | | | | | | | | | | X | | | | | | | | X | X | | | X | | | | | | | | | | | | | X | |
| *C. undulatus* | | | | X | X | | X | | | X | | | | | | | | | | | | | | X | | | X | | | X | | X | | | | | | | | | X | | | X | | |
| *C. unifasciatus* | | X | | | | | | | | | | | | | | | | | | | | | | X | | | | | X | | | | | | | | | | | | | | | | X | |
| *Epibulus insidiator* | | | | | | | | | | | | | X | X | | | | | X | | | | | | | | | | | X | | | | | | | | | | | | | | X | | |
| *Novaculichthys taeniourus* | | X | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Cirrhilabrus luteovittatus* | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | |
| *Coris aygula* | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *C. gaimardi* | | X | | | | | X | | | | | | | | | | | | | | | X | | | | | | | X | | | | | | | | | | | | | | | | | |
| *Hemigymnus fasciatus* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | |
| *H. melapterus* | | | | | | | | | | X | | | | | X | | | | | | | | | | | | | | X | | X | | | | | | X | | | | X | | | | X | |
| *Macropharyngodon meleagris* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | |
| *Thalassoma purpureum* | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Stethojulis bandanesis* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | |
| *Labroides bicolor* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | |
| SCARIDAE | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Bolbometopon muricatum* | | | | | | | | | | X | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Cetoscarus bicolor* | | | | | | | | X | | | | | | | | | | | X | | | X | X | | | | X | | | | | X | | | | | X | | | | X | X | | X | | |
| *Hipposcarus longiceps* | | | X | | X | | | X | | | X | X | X | X | | | X | | X | | | | | | | | X | | | | | X | | | | X | | | | | | | | X | X | X |
| *Scarus altipinnis* | | | | | | | X | X | | | | | | | | | | | | X | | | | | | | X | X | | | | X | | | | | | | | | | | | | X | X |
| *S. atropectoralis* | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | X | | | | | | | | | | | | | X | |
| *S. dimidiatus* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | |
| *S. festivus* | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *S. forsteni* | | | | | | | X | | | | | | X | X | | X | | | | | | X | | | | | | | X | | | | | | | | | | | | | | | | | |
| *S. frenatus* | | X | X | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | X |
| *S. frontalis* | | X | X | | | X | X | X | | | | | X | X | | X | | X | | X | | X | | | | | | | | | | | | | | | | | | X | X | | | | | |
| *S. gibbus* | | X | X | X | X | X | X | X | X | X | | X | X | X | X | X | X | | X | X | X | X | X | X | | | X | X | X | X | | X | X | X | X | X | X | X | | X | X | | X | X | X | X |
| *S. globiceps* | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | X | X |

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *S. niger* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | |
| *S. oviceps* | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | X | |
| *S. psittacus* | | | | | | | X | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | X |
| *S. rubroviolaceus* | | | X | | X | | | | | | | | | X | | | | | | X | | | | | | | | | X | | | X | | | | | | | | | | | | | | X |
| *S. schlegeli* | | | | | | | | | | | | | | | | | | | X | | X | | | | | | | | | X | | X | | | | | X | | | | | | | | X | |
| *S. sordidus* | | | X | X | | | X | | | X | | | X | | X | | X | X | X | | | | | | | X | | X | X | X | | | | | X | X | X | X | | X | | | | X | X | X |
| *S. sp.* | | | | | | X | | | | X | | | | X | X | | X | | | | X | X | | | | | | X | X | | X | X | | X | X | X | X | X | | X | | | X | X | | |
| SPHYRAENIDAE | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Sphyraena sp.* | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | |
| ACANTHURIDAE | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Acanthurus achilles* | | | | | | | | | X | | | | X | | | | | | | | X | | | | | | | | | | | | | | | | | | | | X | | | | | |
| *A. guttatus* | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | X | | | | | |
| *A. leucocheilus* | | | | | | | | | | | | | | | | | | | | | | X | | | | | | X | | | | | | | | | | | | | | | | | | |
| *A. lineatus* | | | | | X | | | | | | | | | X | | | | | | X | | | | | | X | | | | | | | X | | | | | | | | X | | | X | X | |
| *A. mata* | | | | | | | | | X | X | X | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | |
| *A. nigricans* | | | | | X | | | X | | | | | X | X | | X | | X | | | X | | | | | X | X | | | | X | X | | | X | X | | | | | | | | X | X | X |
| *A. nigrofuscus* | | X | | | | | | | | | | | | | | | | | | | | | X | X | | X | | | | | | | | | | | | | | | | | | | X | |
| *A. olivaceus* | | X | | | | | X | | | X | | | X | | X | | | | | X | | | | | | X | | X | X | | X | | | | X | X | | X | X | X | | | | | X | X |
| *A. pyroferus* | | X | | | | | X | | | | | X | | X | X | | | | X | X | X | | | | | | X | | X | | X | X | | | X | X | | | | X | | | | X | | |
| *A. thompsoni* | | | | | | | | | X | | | | X | | | | | | | | | | | | | | | | | X | X | X | | | | | | | X | X | | | | | | |
| *A. triostegus* | | X | | | | | X | | | | | | | | | | | | | | | | | | X | | | | | | | X | X | | | | | | | | X | | | | | X |
| *A. xanthopterus* | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | X | | X |
| *A. sp.* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | X | X | | | X | | X | | | | |
| *Ctenochaetus striatus* | | | | | | | | X | | | | | X | X | | X | | | | | X | | X | X | | X | | X | | | X | | | | | X | | | | | | | | | X | X |
| *Zebrasoma flavescens* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | |
| *Z. veliferum* | | | | | | | | | | | | | X | | | X | X | | | | | | | | | | | | | | | X | | | | | | | | | X | | | | X | |
| *Naso annulatus* | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *N. brevirostis* | | | | | | X | | | X | | X | X | | | | | | | | | | X | X | | | | X | | X | X | X | X | | | | | | | X | X | X | | | | | |

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *N. hexacanthus* | | | | | | X | | | X | X | X | | | X | | | | | | | | X | | X | | | X | | | X | X | X | | X | | | | X | X | | X | | X | | | |
| *N. literatus* | | X | X | | X | | X | X | X | | | | X | X | X | X | X | X | X | X | | | X | X | | | | X | X | | X | X | | X | | | | X | X | X | X | | | X | X | |
| *N. unicornis* | | | X | X | | | | X | | X | | | X | X | | X | X | | | | X | | X | | | | X | | | | | | | | | | | | | | | | | | X | |
| *N. vlamingii* | | | | | | | | | X | | | | X | X | | | | | | X | | X | | | | | X | | | X | X | X | | | | | | | | | X | | | | | |
| ZANCLIDAE | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Zanclus cornutus* | | | | | | | | | | | | | | X | | | | | X | | | | | | | | | X | | | | | | X | | | | X | | X | | | | | | |
| SIGANIDAE | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Siganus argenteus* | | | | | X | X | X | X | | | | X | X | | X | X | X | X | X | X | X | X | X | | | | | | | X | X | X | | X | X | X | X | | X | | X | | | X | X | |
| *S. punctatus* | | | | | X | | | X | | X | | | | X | | | | X | X | | | X | | | | | | | | X | | X | | | X | | | | | X | | | | X | | |
| *S. punctatissimus* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | |
| *S. sp.* | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| SCOMBRIDAE | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Grammatorcynos bilineatus* | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | X | | | | | | | X | | | | | | | |
| *Gymnosarda unicolor* | | | | | | | | | | X | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| BALISTIDAE | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Balistapus undulatus* | | | | | | | X | | | | | | | X | | | | X | | | | | | X | | | | X | X | | | X | | | | | | | | X | | | | | X | |
| *Balistoides conspicillum* | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | |
| *B. viridescens* | | X | | | | | X | | X | | | | | X | | | | | | X | X | | | | | | X | | X | | X | X | | | | | | | | | X | | | X | | |
| *Melichthys vidua* | | X | X | | | | X | | | | | | X | X | | | | X | | | X | | X | X | | | | X | X | | | X | | X | | | | X | | X | X | | | | | |
| *Odonus niger* | | | | | | | X | | | X | | | X | | | | | | | X | | | | | | | | | | | X | | | X | | | | | | | | | X | | | |
| *Pseudobalistes flavimarginatus* | | | X | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Rhinecanthus aculeatus* | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *R. rectangulus* | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| MONACANTHIDAE | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Oxymonacanthus longirostris* | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| TETRAODONTIDAE | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Arothron meleagris* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | |
| *A. nigropunctatus* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | |

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *A. stellatus* | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | X | | | |
| DIODONTIDAE | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Diodon hystrix* | | | | | | | | | X | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | |

Appendix 8

Distribution and Relative Abundance of Corals at Minto Reef and Relative Level of Storm Damage at Minto Reef. Left column names: coral genera and/or growth form. Top row numbers: survey site numbers at Minto Reef. Relative abundance symbols: D = dominant; A = abundant; C = common; O = occasional; R = rare and - = not observed/absent. Relative level of storm damage is indicated using same scale.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Acanthastrea* | R | - | C | - | - | O | O | C | C | C | A | O | A | - | O | - | C | R | C | R | C | - | C |
| *Acropora* | | | | | | | | | | | | | | | | | | | | | | | |
| Small bushes | R | A | - | R | C | - | A | A | A | C | O | C | A | - | A | - | - | - | A | O | A | R | A |
| Large tables | - | - | A | - | C | R | R | - | C | C | - | - | - | - | - | - | - | - | - | - | - | - | A |
| Staghorns | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Columnar (Isopora) | - | - | A | - | C | D | C | - | A | - | - | - | - | R | - | - | - | - | C | R | - | - | - |
| *Alveopora* | - | - | O | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Astreopora* | C | A | A | O | D | - | D | A | - | O | A | A | - | - | A | - | A | C | A | A | A | R | A |
| *Barabattoia* | - | - | - | - | - | - | - | R | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Coscinaraea* | - | - | - | R | - | O | - | - | - | O | - | - | R | R | - | - | - | - | - | - | - | - | - |
| *Cycloseris* | - | - | - | - | - | - | - | - | - | R | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Cyphastrea* | - | - | - | - | - | - | R | O | - | - | - | O | - | - | O | - | C | - | C | R | C | - | - |
| *Distichopora* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Echinophyllia* | - | - | - | - | - | - | - | - | C | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Echinopora* | - | - | - | - | - | - | - | - | C | O | - | C | - | - | - | - | - | - | C | - | C | - | - |
| *Euphyllia* | - | - | - | - | - | - | - | - | - | - | R | - | - | - | - | - | - | - | - | - | - | - | - |
| *Favia* | O | A | C | O | - | C | O | A | A | O | - | A | C | C | C | - | C | R | A | O | A | - | - |
| *Favites* | R | - | - | - | O | - | R | - | - | R | - | O | R | - | - | - | C | - | - | R | - | - | C |
| *Fungia* | - | - | O | R | - | R | - | - | O | C | - | - | - | R | - | - | - | - | - | - | - | - | C |
| *Gardineroseris* | - | - | - | - | - | R | - | C | C | O | - | - | - | - | - | - | - | - | - | - | - | - | O |
| *Goniastrea* | R | A | A | O | - | A | A | C | O | C | A | O | A | C | O | O | - | C | C | O | A | O | A |
| *Goniopora* | - | - | - | - | - | - | R | - | - | - | - | - | - | - | R | - | - | - | C | - | - | - | C |
| *Halomitra* | - | - | - | - | - | - | - | - | O | O | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Heliopora* | R | C | - | - | C | - | - | - | - | - | R | - | R | R | A | R | C | - | A | - | A | - | - |
| *Herpolitha* | - | - | - | - | - | - | - | - | - | O | - | - | - | - | - | - | - | - | - | - | - | - | O |
| *Hydnophora* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Leptastrea* | - | - | C | C | - | O | O | - | - | C | R | - | R | R | C | - | - | - | O | R | - | R | - |
| *Leptoria* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Leptoseris* | - | - | O | - | O | R | - | - | O | O | - | - | - | - | - | - | - | - | - | R | - | - | - |

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Lobophyllia* | - | C | - | - | - | R | - | C | C | C | R | O | R | - | O | - | O | R | C | O | C | R | C |
| *Merulina* | - | - | - | - | - | R | - | - | O | O | R | - | - | O | - | - | - | - | - | - | - | - | - |
| *Millepora* | | | | | | | | | | | | | | | | | | | | | | | |
| encrusting | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | O | - | C | - | - | O | O |
| columnar | A | A | - | O | A | O | O | A | A | C | O | C | - | - | A | - | - | - | A | C | A | O | - |
| branching | A | C | - | - | - | O | - | - | C | C | - | - | - | - | - | - | - | - | A | - | - | A | - |
| *Montastrea* | - | - | - | - | - | - | R | C | O | - | - | C | R | - | - | - | O | R | C | R | - | - | - |
| *Montipora* | - | A | A | C | - | O | O | - | C | O | O | - | R | R | - | - | - | - | O | O | C | - | A |
| *Mycedium* | - | - | - | - | - | - | - | C | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Oulophyllia* | - | - | C | O | - | R | - | O | C | O | - | - | - | R | - | - | - | - | - | - | - | R | O |
| *Oxypora* | - | - | - | R | - | O | - | - | O | O | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Pachyseris* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Pavona* | | | | | | | | | | | | | | | | | | | | | | | |
| encrusting | - | C | O | O | - | O | O | C | C | C | - | - | R | R | C | - | - | R | - | R | C | - | - |
| heads | - | - | - | R | - | O | R | C | C | O | - | O | - | - | - | - | - | - | - | R | - | - | - |
| *Platygyra* | R | - | A | - | C | - | O | O | O | O | - | O | R | - | - | - | O | O | C | C | - | O | C |
| *Physogyra* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Plesiastrea* | - | - | R | - | - | R | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Plerogyra* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Pocillopora* | | | | | | | | | | | | | | | | | | | | | | | |
| finely branched | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| medium branched | O | C | C | R | C | O | O | - | A | A | O | C | O | R | C | - | C | - | - | - | C | - | A |
| large branched | O | - | C | R | C | O | - | - | - | C | - | - | R | R | - | - | - | - | - | - | - | - | - |
| *Porites* | | | | | | | | | | | | | | | | | | | | | | | |
| fingercoral | - | A | - | - | - | - | - | - | - | - | - | - | - | - | - | - | A | - | - | - | - | - | A |
| massive | O | A | C | C | D | A | D | - | - | C | A | C | D | D | - | C | A | A | A | D | D | D | - |
| encrusting | - | - | - | - | - | - | R | O | O | - | - | C | - | - | - | - | C | R | - | O | C | - | R |
| (Synaraea) | - | - | C | R | - | C | - | - | C | C | - | - | - | O | - | - | C | - | C | R | - | - | - |
| *Psammocora* | - | - | O | - | - | - | - | - | C | O | - | - | - | - | - | - | - | - | - | R | O | - | - |
| *Sandalolitha* | - | - | - | - | - | - | - | - | O | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Scapophyllia* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | R | - | - | - |
| *Scolymia* | - | - | - | - | R | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Seriatopora* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Stylaster* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Stylocoeniella* | - | - | O | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Stylophora* | - | - | - | - | C | - | C | C | C | - | - | - | O | - | - | - | - | - | - | - | - | - | - |
| *Symphyllia* | - | - | - | - | O | - | R | C | - | - | R | - | R | R | - | - | - | - | O | - | - | - | O |
| *Tubastraea* | - | - | C | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Tubipora* | - | - | - | - | - | - | - | - | O | C | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Turbinaria* | - | - | - | - | - | R | - | - | O | C | - | - | - | O | - | - | - | - | - | - | - | - | - |
| **Total Coral Genera** | 11 | 11 | 19 | 14 | 12 | 20 | 18 | 18 | 26 | 28 | 14 | 15 | 17 | 14 | 13 | 3 | 12 | 9 | 17 | 18 | 15 | 9 | 17 |
| Storm Damage | C | A | A | C | A | A | A | C | A | C | O | O | O | D | A | C | C | O | O | C | D | D | A |

Appendix 9

Distribution and Abundance of Macroinvertebrates at Minto Reef.
Left column names invertebrate group, genera or genus/species.
Top row numbers: survey site numbers at Minto Reef.
Relative abundance symbols: D = dominant; A = abundant;
C = Common; O = occasional; R = rare; and - = absent/not observed.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PORIFERA | | | | | | | | | | | | | | | | | | | | | | | |
| unspecified | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| soft brown | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| brown demosponge | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| soft black | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| red | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| red/orange | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| CNIDARIA | | | | | | | | | | | | | | | | | | | | | | | |
| Soft Corals | | | | | | | | | | | | | | | | | | | | | | | |
| *Cladiella* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Lobophytum* | C | - | - | - | C | - | - | - | - | - | - | R | - | - | - | - | - | - | - | - | - | - | - |
| *Sarcophyton* | - | - | C | - | O | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Sinularia* | A | - | O | - | C | - | - | - | - | - | - | - | O | R | - | - | - | - | - | O | - | - | - |
| *Stereonephthya* | C | - | - | - | - | - | - | - | - | - | - | - | - | R | - | - | - | - | - | - | - | - | - |
| unspecified | D | C | - | C | - | - | - | - | - | O | - | - | O | - | - | - | - | - | - | - | - | - | R |
| Black Coral | | | | | | | | | | | | | | | | | | | | | | | |
| *Antipathes* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Wire Coral | | | | | | | | | | | | | | | | | | | | | | | |
| *Cirripathes* | - | - | R | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Gorgonian | - | - | O | - | - | - | - | - | O | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Anenome | - | - | - | - | - | - | - | - | - | - | - | - | - | - | R | - | - | - | - | R | - | - | - |
| Hydroid | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Zooanthid | | | | | | | | | | | | | | | | | | | | | | | |
| *Palythoa* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | O | O | - |
| MOLLUSCA | | | | | | | | | | | | | | | | | | | | | | | |
| Gastropoda | | | | | | | | | | | | | | | | | | | | | | | |
| *Bursa* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | R | - | - | - |
| *Casmaria* | - | - | - | - | - | - | - | R | - | - | - | - | - | - | - | - | - | R | - | - | - | - | - |

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Cassis* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Cerithium* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Charonia* | - | R | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Chicoreus* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Clypoeomorus* | - | - | - | - | - | - | - | - | - | - | - | R | - | - | - | - | - | - | - | - | - | - | - |
| *Coralliophila* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Conus* | - | R | - | - | - | - | - | O | - | - | - | O | - | - | - | - | - | - | - | R | - | - | - |
| *Cypraea* | - | - | - | - | C | - | - | O | - | - | - | - | - | - | - | - | - | - | - | O | - | - | - |
| *Drupa* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Lambis* | R | - | - | - | - | - | - | - | - | - | - | - | - | - | R | - | - | - | - | - | - | - | - |
| *Mitra* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | R | - | R | - | - | - |
| *Morula* | - | - | - | - | R | - | - | - | - | - | - | - | - | - | - | - | - | - | - | R | - | - | - |
| *Nassarius* | - | - | - | - | - | - | - | R | - | - | - | O | - | - | R | - | - | - | - | - | - | - | - |
| *Neocancilla* | - | - | - | - | - | - | - | R | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Oliva* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | R | - | - | - | - | - |
| *Polinices* | - | - | - | - | - | - | - | R | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Phyllidia* | - | - | - | - | - | - | - | - | - | - | - | - | - | R | - | - | - | - | - | - | - | - | - |
| *Rhinociavus* | C | - | - | - | - | - | - | A | - | - | - | C | - | - | - | - | - | C | - | - | - | - | - |
| *Stombus* | C | - | - | - | - | - | - | C | - | - | - | - | - | - | O | - | - | C | - | - | - | - | - |
| *Terebra* | - | - | - | - | - | - | - | - | - | - | - | O | - | - | - | O | - | C | - | - | - | - | - |
| *Thais* | C | - | - | - | - | - | - | C | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Tonna* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Trochus* | - | - | - | - | - | - | - | R | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Turbo* | O | - | - | - | C | - | - | O | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Vermitidae* | C | - | C | - | - | - | - | - | - | - | - | - | - | - | C | - | - | - | - | - | - | - | - |
| *Vexillum* | - | - | - | - | - | - | - | R | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| MOLLUSCA | | | | | | | | | | | | | | | | | | | | | | | |
| Bivalvia | | | | | | | | | | | | | | | | | | | | | | | |
| Giant Clams | | | | | | | | | | | | | | | | | | | | | | | |
| *Hippopus hippopus* | - | - | - | - | - | - | - | - | - | - | - | R | R | - | R | - | - | - | R | O | - | - | - |
| *Tridacna crocea* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *T. derasa* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *T. maxima* | O | C | C | R | A | R | C | C | - | R | - | A | O | O | C | C | C | C | C | C | C | - | R |
| *T. squamosa* | - | - | - | - | - | - | R | - | - | R | - | - | - | - | - | - | - | - | - | - | C | - | - |

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Other Bivalves | | | | | | | | | | | | | | | | | | | | | | | |
| Cardiid | | | | | | | | | | | | | | | | | | | | | | | |
| *cf. Trachycadium* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Chama* | C | - | - | - | C | - | - | C | - | - | - | - | - | - | - | - | - | C | - | - | - | - | - |
| Lucinid | - | - | - | - | - | - | - | - | - | - | - | R | - | - | - | - | - | - | - | - | - | - | - |
| *Pinctada* | - | - | R | - | R | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Pteria* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Spondylus* | - | - | O | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Cephalopoda | | | | | | | | | | | | | | | | | | | | | | | |
| *Octopus* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| ECHINODERMATA | | | | | | | | | | | | | | | | | | | | | | | |
| Crinoidea | | | | | | | | | | | | | | | | | | | | | | | |
| Crinoids | - | - | O | - | - | - | - | - | O | - | - | - | - | O | - | - | - | - | - | - | - | - | - |
| Asteroidea | | | | | | | | | | | | | | | | | | | | | | | |
| *Acanthaster* | - | - | - | R | - | O | - | - | C | O | - | - | - | - | - | - | - | - | R | - | - | - | - |
| *Culcita* | R | - | - | R | - | - | R | - | - | - | - | - | - | - | - | - | - | - | - | R | - | - | - |
| *Linkia* | R | - | - | - | - | - | - | - | - | - | - | O | - | - | R | - | - | - | - | - | - | - | - |
| Echinoidea | | | | | | | | | | | | | | | | | | | | | | | |
| *Echinometra* | - | - | - | - | - | - | - | - | - | - | - | C | - | - | - | - | - | - | - | - | - | - | - |
| *Echinostephus* | - | - | R | - | - | - | - | - | - | - | - | C | - | - | - | - | - | - | - | - | - | - | - |
| *Echinothrix* | - | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Heterocentrotus* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Thalanta* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Thelenota* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Holothuroidea | | | | | | | | | | | | | | | | | | | | | | | |
| *Actinopyga* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Holothuria* | - | - | - | R | - | | - | - | - | - | - | - | - | - | - | - | A | - | R | R | - | - | - |
| CRUSTACEA | | | | | | | | | | | | | | | | | | | | | | | |
| Lobster | | | | | | | | | | | | | | | | | | | | | | | |
| *Panulirus* | - | - | - | - | - | - | - | - | - | - | - | R | - | - | - | - | - | - | - | - | - | - | - |

Appendix 10

Distribution and Relative Abundance of Algae at Minto Reef.
Left column names: algal type or genus. Top row numbers: survey site numbers at Minto Reef.
Relative abundance symbols: D = dominant; A = abundant, C = common; O = occasional; R = rare and - = absent/not observed.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Caulerpa* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Codium* | - | - | - | R | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Gracilaria* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Halimeda* | - | - | - | R | - | R | R | - | - | - | O | - | - | R | - | - | R | - | R | C | R | - | - |
| *Microdictyon* | - | - | - | - | - | - | - | - | - | - | - | - | O | - | - | - | - | - | - | - | R | - | - |
| *Neomeris* | - | - | - | R | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Udotea* | - | - | - | - | - | - | R | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| red crustose | - | - | - | - | - | - | - | - | - | - | - | R | - | - | R | - | - | - | - | - | - | - | - |
| red filamentous | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| green stringy | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |

Appendix 11

Distribution of Fish at Minto Reef. Left column names: fish family, genus and species.
Top row numbers: survey site numbers at Minto Reef.
Distribution symbol: x = present; no symbol = absent/not observed.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ORECTOLOBIDAE | | | | | | | | | | | | | | | | | | | | | | | |
| *Nebrius concolor* | | X | | | | | | | | | | | | | | | | | | X | X | | |
| HEMIGALEIDAE | | | | | | | | | | | | | | | | | | | | | | | |
| *Triaenodon obesus* | | | | X | | X | | | | | | | | | | | | | | | | | |
| CARCHARHINIDAE | | | | | | | | | | | | | | | | | | | | | | | |
| *Carcharhinus amblyrhynchos* | | | | X | | X | | | X | X | | | | X | | | | | | | | | |
| *C. melanopterus* | | | | | | X | | | | | | | | | | | | | | | | | |
| MYLIOBATIDAE | | | | | | | | | | | | | | | | | | | | | | | |
| *Aetobatis narinari* | | | | | | X | | | | | | | | | | | | | | | X | | |
| MURAENIDAE | | | | | | | | | | | | | | | | | | | | | | | |
| *Gymnothorax flavimarginatus* | | | | X | | | | | | | | | | | | | | | | | | | |
| *G. javanicus* | | | | X | | | | | | | | | | | | | | | | | | | |
| CLUPEIDAE | | | | | | | | | | | | | | | | | | | | | | | |
| *Spratelloides sp.* | | X | | | | | X | X | | | X | X | X | | | | X | | X | X | | | |
| HOLOCENTRIDAE | | | | | | | | | | | | | | | | | | | | | | | |
| *Myripristis adjustus* | | | X | | | | | | | | | | | | | | | | | | | | |
| *M. murdjan* | | | | | | | | | | X | | | | | | | | | | | | | |
| *Sargocentron spiniferum* | | | | X | X | | | | | X | | | | | | | | | | | | | |
| FISTULARIIDAE | | | | | | | | | | | | | | | | | | | | | | | |
| *Fistularia commersoni* | | | | | | | X | | | | | | | X | X | | | | | | | | |
| SCORPAENIDAE | | | | | | | | | | | | | | | | | | | | | | | |
| *Pterois volitans* | | | | X | | | | | | X | | | | | | | | | | | | | |
| SERRANIDAE | | | | | | | | | | | | | | | | | | | | | | | |
| *Aethaloperca rogaa* | | X | | | X | | | | | | | | | | | | | | | | | | |
| *Anyperodon leucogrammicus* | | | | | | X | | | | X | | | | | | | | | | | | | |
| *Cephalopholis argus* | | | X | X | | X | | | | X | | X | X | | X | | X | | X | | | | |
| *Gracila albomarginata* | | | X | X | | X | | | | X | | | | X | | | | | | | | | |
| *Epinephelus fuscoguttatus* | | | | X | X | | | | | | | | | X | | | | | | | | | |
| *E. hexagonatus* | | | | | | | | | | | | | | | | | | | | | X | | |
| *E. lanceolatus* | | | | X | | | | | | | | | | | | | | | | | | | |
| *E. merra* | | | | | | | | | | | | X | | | X | | X | | X | | | | |
| *E. microdon* | X | | | X | | | | | | X | | | | | | | | | | | | | |
| *E. spilotoceps* | | | | | | | | | | | | | | | | | | | | | | X | |
| *Plectropomus areolatus* | | | | X | | | | | | | | | | | | | | | | | | | |
| *P. laevis* | | X | X | X | | X | | | | X | X | | | X | | | | | | | X | | |
| *P. leopardus* | | | | | | | | | | | | | | X | | | | | | | | | |
| *Variola louti* | X | | | | | | | | | | | | | X | | | | | X | X | | | |
| MALACANTHIDAE | | | | | | | | | | | | | | | | | | | | | | | |
| *Malacanthus latovittatus* | | | | | X | | | | | | | | | | | | | | | | | | |
| CARANGIDAE | | | | | | | | | | | | | | | | | | | | | | | |
| *Caranx lugubris* | | | X | | | X | | | | | | | | | | | | | | | | | |
| *C. melampygus* | | | | X | | X | X | | | X | X | X | X | | | | | | X | X | X | X | |
| *C. sexfasciatus* | | | X | | | | | | | | | | | | | | | | | | | | |
| *Elagatis bipinnulatus* | | | | X | | X | | | | X | | | | | | | | | | | | | |
| *Scomberoides lysan* | | | | | | | | | | | | | | | | | | | | X | | | |
| LUTJANIDAE | | | | | | | | | | | | | | | | | | | | | | | |
| *Aphareus furca* | | | | X | | X | | | | X | | | | | | | | | | | | | |
| *Aprion virescens* | X | | | | | | | | | | | | | X | | | | | | | | | |
| *Macolor macularis* | | | X | | | | | | | | | | | X | | | | | | | | | |
| *M. niger* | | | | X | X | X | X | | | X | | | | X | | | | | | | | | |
| *Lutjanus bohar* | | | X | X | | X | X | | X | X | | X | X | X | | | | | | | | | |
| *L. gibbus* | | X | X | X | X | X | X | | X | X | | X | X | X | X | | | | X | X | X | | |
| *L. kasmira* | | | | | X | | | | | | | | | | | | | | | | | | |
| *L. monostigmus* | | | | X | X | X | | | | X | | X | | X | X | | | | | X | X | | |

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *L. semicinctus* | | | | | | | | | X | | | | | X | X | | | | | | | | |
| CAESIONIDAE | | | | | | | | | | | | | | | | | | | | | | | |
| *Caesio lunaris* | | | | | | | | | X | | | | | | | | | | | | | | |
| *C. teres* | | | | | | | | | X | X | | | | X | | | | | | | | | |
| *Pterocaesio tile* | | X | | X | | X | | | | X | | | | | | | | | | | | | |
| *P. sp.* | | | | | | X | | | | | | | | | | | | | | | | | |
| LETHRINIDAE | | | | | | | | | | | | | | | | | | | | | | | |
| *Gnathodentex aurolineatus* | | | | | | | | | | | X | | X | | | | | | | | | | |
| *Lethrinus elongatus* | | | | | | | | | | X | | | | | | | | | | | | | |
| *L. kallopterus* | | | | | | X | | | | | | | | X | | | | | | | | | |
| *L. rubrioperculatus* | | | | X | | | | | | | | | X | | | | | | | | | | |
| *L. xanthocheilus* | | | | | | | | | | X | | | | | | | | | | X | | | |
| *Monotaxis grandoculus* | | | X | X | X | | X | | | X | X | X | X | | X | | | | X | X | X | | X |
| MULLIDAE | | | | | | | | | | | | | | | | | | | | | | | |
| *Parupeneus barberinus* | | X | | X | | | | | | | X | | X | | X | | X | X | X | | X | | X |
| *P. bifasciatus* | | | | | | | X | | | | | | | | | | | | X | | | | |
| *P. cyclostomus* | | X | | | | | | | | | | | X | | | | X | | X | | | | |
| *P. multifasciatus* | X | | | | | | | | | | | X | | | | | | | | | | | |
| KYPHOSIDAE | | | | | | | | | | | | | | | | | | | | | | | |
| *Kyphosus cinerascens* | | | | | | X | | | | | X | | X | | | | | | | | | | |
| EPHIPPIDAE | | | | | | | | | | | | | | | | | | | | | | | |
| *Platax tiera* | | | | X | | | | | | | | | | | | | | | | | | | |
| CHAETODONTIDAE | | | | | | | | | | | | | | | | | | | | | | | |
| *Chaetodon ephippium* | | | | | | | | | | | | | | | | | | | | | | | X |
| *Heniochus singularis* | | | | | | | | | | X | | | | | | | | | | | | | |
| POMACANTHIDAE | | | | | | | | | | | | | | | | | | | | | | | |
| *Centropyge vrolicki* | | | | | | | | | | | | | | | | | | | | | | X | |
| *Pygoplites diacanthus* | | | | | | | | | | | | | | | | | | | | | | | X |
| *Pomacanthus imperator* | | X | | | X | | | | | X | | | | | | | | | | | | | |
| POMACENTRIDAE | | | | | | | | | | | | | | | | | | | | | | | |
| *Abudefduf saxatilis* | | X | | | | | | | | | | | | | | | | | | | | | |
| *Pomacentrus sp.* | | | | | | | | | | | | | | | | | | | | | X | | |
| LABRIDAE | | | | | | | | | | | | | | | | | | | | | | | |
| *Cheilinus chlorourus* | | | | | | | | X | | | | | | | | | | | | X | | | |
| *C. fasciatus* | | | X | | | | | | | | | | | | | | | | | | | | X |
| *C. trilobatus* | | | | | | | X | | | | | | X | | | | | | X | X | | | |
| *C. undulatus* | | | X | X | | | | | X | X | | | | | | | | | | | | | |
| *Epibulus insidiator* | | | | | | | | | | | | | X | | | | | | | | | | |
| *Hemigymnus melapterus* | | | | | | | | | | | | | X | | | | | | | | | | |
| *Macropharyngodon meleagris* | | | | | | | | | | | | X | | | | | | | | | | | |
| *Thalassoma quinquevittatum* | | | | | | | | | | | | | | | | | | | | | | X | |
| SCARIDAE | | | | | | | | | | | | | | | | | | | | | | | |
| *Bolbometopon muricatum* | | | | X | | | | | | | | | | | | | | | | | | | |
| *Cetoscarus bicolor* | | | | X | | | | | | | | | | | | | | | | X | | | X |
| *Hipposcarus longiceps* | | | | | | | | | X | | X | X | | X | X | | | | | X | | | |
| *Scarus altipinnis* | | | X | | | | | | X | | | | | | | | | | | | | | |
| *S. atropectoralis* | | | | | | X | | | X | | | | | | | | | | | | | | |
| *S. dimidiatus* | | | | | | | | | | | | | | | | | | X | | | | | |
| *S. forsteni* | X | | | | X | | | | | | | | | | | | | X | | X | | | |
| *S. frenatus* | | | X | | X | | | | | | | | | | | | | | | | | | |
| *S. frontalis* | | | X | | X | | | | X | | | | | | X | | | | | X | | | |
| *S. gibbus* | X | X | X | X | X | X | X | | X | X | X | X | | X | | | X | | X | | X | | X |
| *S. globiceps* | | | | | | | | | | | | | | | | | | | | X | | | |
| *S. niger* | | | X | | | | | | | | | | | | | | | | | | | | |
| *S. oviceps* | | X | | | | X | X | | | | | | | | | | | | X | | | | |
| *S. psittacus* | | | | | | | | | | | | | | | | | | | | X | | | |
| *S. rubroviolaceus* | | | | | | | | | | | | | | | | | | | | X | | | |
| *S. schlegeli* | | | X | X | | | | | | X | X | | | | | | | | | | | | X |
| *S. sordidus* | | X | | X | X | X | | | | X | X | | | | | | X | X | | | X | | |
| *S. sp.* | | | | | | | X | | | | | | | | | | | | X | | | | |

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SPHYRAENIDAE | | | | | | | | | | | | | | | | | | | | | | | |
| *Sphyraena barracuda* | | | | | | X | | | | X | | | | X | | | | | X | | | | |
| *S. genie* | | | | | | | | | | | | | | X | | | | | | | | | |
| ACANTHURIDAE | | | | | | | | | | | | | | | | | | | | | | | |
| *Acanthurus achilles* | | | | | | | | | X | | | | | | | | | | | | | | |
| *A. guttatus* | | | | | | | | | | | | | | | | | | | | | | | X |
| *A. leucocheilus* | | | X | | | | | | X | | | | | | | | | | | | | | |
| *A. lineatus* | X | X | X | X | X | X | X | | X | X | X | | | | X | | X | X | X | | | | X |
| *A. mata* | | X | | X | | | X | | | | | | X | | | | | | X | | X | | |
| *A. nigricans* | | X | X | X | X | | | | X | X | X | | X | | X | | X | X | X | X | | | X |
| *A. nigrofuscus* | | | | | | | | | | | | | | | | | X | | X | | | | |
| *A. olivaceus* | X | X | | X | X | | | X | | | | X | X | | X | X | X | X | X | X | X | X | X |
| *A. pyroferus* | | | X | X | | | | | | | | | X | | | | | | X | | | | |
| *A. triostegus* | X | X | | | | | | | | | | | | | | X | | | | | X | | X |
| *A. xanthopterus* | | | X | | | | X | | | | X | | | | | | | | | | X | | |
| *Ctenochaetus striatus* | | X | X | X | X | X | X | X | | X | X | X | | | X | | | X | X | X | | | X |
| *Zebrasoma scopas* | | | | X | | | | | | | | | | | | | | | | | | | |
| *Z. veliferum* | | | | | | | | X | | X | | | | | | | | | | | | | |
| *Naso brevirostis* | | X | | | X | | | | | X | | | | | | | | | | | | | X |
| *N. hexacanthus* | | | X | X | | X | | | X | X | | | | X | | | | | | | | | X |
| *N. tuberosus* | | X | | | | | | | | | | | | | | | | | | | | | |
| *N. literatus* | X | | X | X | X | X | X | | X | X | X | X | X | X | X | | X | X | X | X | X | | |
| *N. unicornis* | X | | | | X | | X | | | | | X | X | | X | | | X | X | X | | | X |
| *N. vlamingii* | | | X | X | X | | | | | | | | | X | | | | | | | | | |
| ZANCLIDAE | | | | | | | | | | | | | | | | | | | | | | | |
| *Zanclus cornutus* | X | X | | X | | | | | | X | | | | | X | | | | X | | | | X |
| SIGANIDAE | | | | | | | | | | | | | | | | | | | | | | | |
| *Siganus argenteus* | | | | | | | | | | | | | X | | | | | | | | | | |
| *S. punctatus* | | X | | | | X | | | | | | | | | | | | | | | | | |
| SCOMBRIDAE | | | | | | | | | | | | | | | | | | | | | | | |
| *Gymnosarda unicolor* | | | | | | X | | | | | | | | X | | | | | | | | | |
| BOTHIDAE | | | | | | | | | | | | | | | | | | | | | | | |
| *Bothus mancus* | | | | | | | | | | | | | | | | | X | | | | | | |
| BALISTIDAE | | | | | | | | | | | | | | | | | | | | | | | |
| *Balistapus undulatus* | X | | X | | | | | | | | | X | | | | | | | | | | | |
| *Balistoides viridescens* | | | | X | X | | | | | | | | | | | | | | | | | | |
| *Melichthys vidua* | X | | X | | X | | | | X | X | | | | X | | | | | X | | | | |
| *Odonus niger* | | | | | X | | | | | | | | | | | | | | | | | | |
| MONACANTHIDAE | | | | | | | | | | | | | | | | | | | | | | | |
| *Cantherhines dumerilii* | | X | | | | | | | | | | | | | | | | | | | | | |
| TETRAODONTIDAE | | | | | | | | | | | | | | | | | | | | | | | |
| *Arothron meleagris* | | | | | | | | | | | | X | | | | | | | | | | | |
| *A. stellatus* | | | | | | | | | | X | | | | | | | | | | | | | |
| DIODONTIDAE | | | | | | | | | | | | | | | | | | | | | | | |
| *Diodon hystrix* | | | | | | | | | | | | | | | | | X | | | | | | |

APPENDIX 12

OROLUK ATOLL AND MINTO REEF: PROPOSED ZONING PLAN

1. Oroluk Atoll (Appendix 12 - Figure 1)

a) Oroluk Island Conservation Areas

The seabird nesting area on the northern end of Oroluk Island should continue to be zoned and managed as a conservation area.

The beaches of Oroluk Island should be declared and managed as a conservation area for the nesting of marine turtles.

b) Multiple Use Zone

The entire lagoon and the outer reef from the northwest point of the atoll counter-clockwise around to the pass in the southeast corner should be zoned multiple-use zone for the following uses:

Subsistence and artisanal fishing allowed
Non-destructive tourism activities
Non-destructive anchoring of vessels
No commercial fishing allowed
Protection of marine turtles and seabirds

c) Commercial Fishing Zone

The outer reef from the northwest point of the atoll clockwise around to the pass in the southeast corner should be zoned a commercial fishing zone for the following uses:

Commercial fishing, in accordance with FSM and Pohnpei State laws

d) Marine Reserves

A number of marine reserves should be designated for complete protection of marine habitat and species. These should include a representative sample of the ocean and lagoon side perimeter reef as well as lagoon pinnacle and patch reefs.

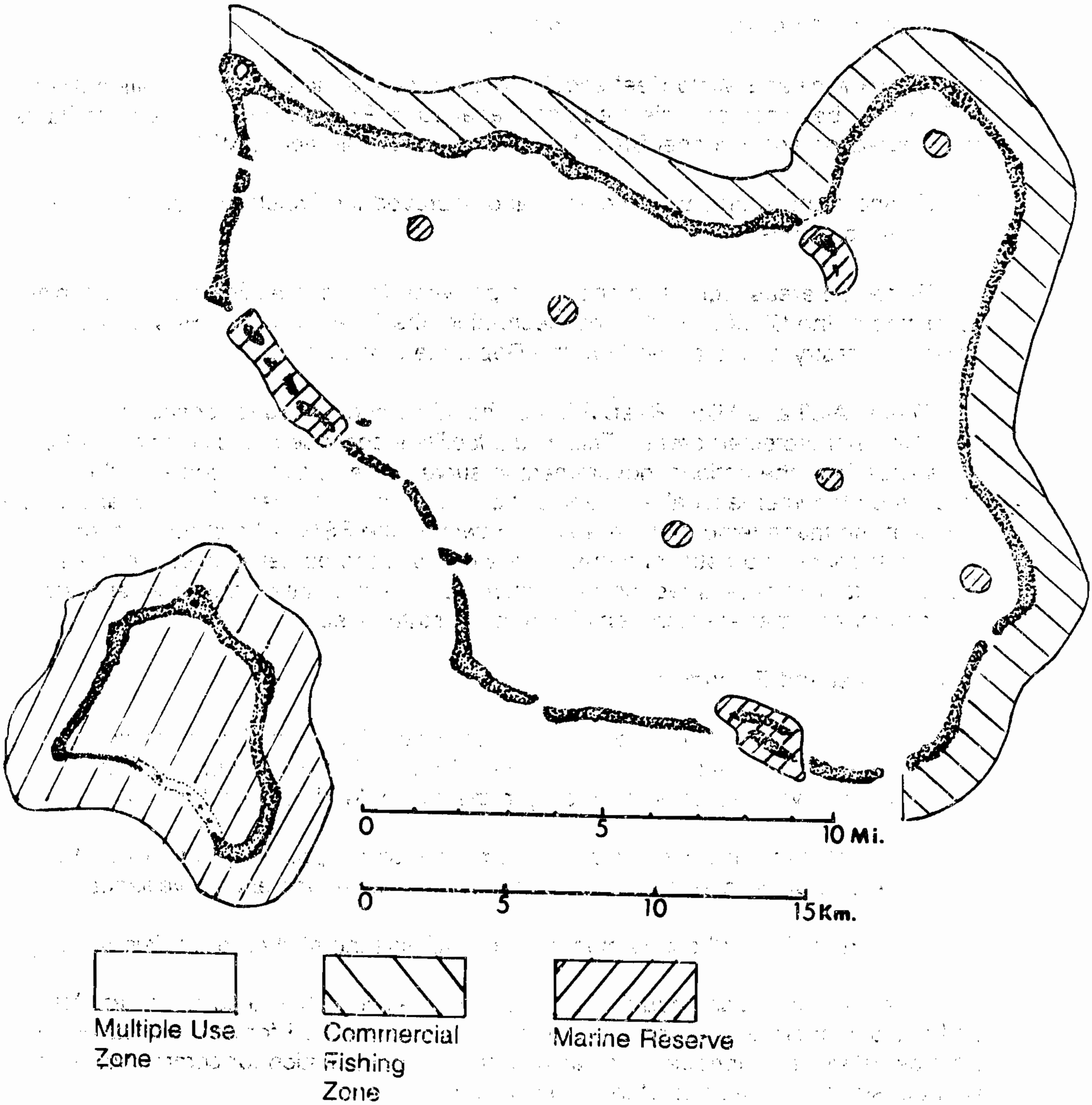
2. Minto Reef

a) Marine Reserve (Appendix 12 - Figure 1)

Minto Reef and the waters to 1 mile surrounding the atoll reef should be designated as a marine reserve.

Appendix 12 - Figure 1

Croiuk Atoll and Minto Reef: Proposed Zones



APPENDIX 13

LEGAL, ADMINISTRATIVE AND FINANCIAL CONSIDERATIONS

1. Legal and Administrative Considerations

1.1 Oroluk Atoll and Minto Reef should be declared Marine Life Conservation Areas (MCLA's) to be jointly administered and managed by Pohnpei State Division of Parks and Recreation and Pohnpei State Marine Resources Division (PMRD).

1.2 Zoning plans should be developed and approved for Oroluk Atoll and Minto Reef by the two divisions.

1.3 Protected areas legislation should be prepared for Pohnpei State by a committee consisting of the Chief of Parks and Recreation, the Chief of Marine Resources, the Chief of Forestry and a lawyer from the Department of Justice.

1.4 Oroluk Atoll and Minto Reef MCLA's should be considered for designation as FSM National protected areas. This would facilitate continued funding from the FSM, assistance from the national government in surveillance, a higher profile for the MCLA's on the international level and better coordination between Pohnpei and Chuuk States in the management of the areas. However, the FSM will first need to enact legislation enabling a national protected areas system to be developed, with states requested to nominate areas for designation as protected areas in a national system with control and management remaining at the state level.

2. Personnel and Equipment

2.1 PMRD plans to station a conservation officer on Oroluk Atoll on a rotating basis. Two officers will be hired and rotate between Oroluk Atoll and Pohnpei Island approximately every 90 days, according to the schedule of the field trip ship.

2.2 PMRD plans to hire two assistants from the resident population at Oroluk Atoll to be trained and undertake marine turtle censusing and tagging and surveillance.

2.3 A PMRD officer will act as manager and will visit the atoll on each field trip ship.

2.4 A small field station should be built at Oroluk Atoll, with a radio room, laboratory and equipment storage space. Radios should include a SSB for communication with Pohnpei Island and portable VHF radios and VHF base station for communications with the station vessel, and other vessels, in the lagoon.

2.5 PMRD has purchased a 23 ft boat and outboard motors for Oroluk Atoll, which will be outfitted with an FAO/UNDP designed emergency sailing rig.

3. Financial Considerations

3.1 Funding was appropriated by FSM Congress to PMRD in FY 1991 to establish a marine station at Oroluk Atoll.

3.2 Funding should be sought from the SPREP Regional Marine Turtle Conservation Programme to support marine turtle research and monitoring.

3.3 Fees should be charged to visiting dive or tour vessels.

3.4 With legal protected area status, international conservation organizations may be interested in supporting the conservation and management of Oroluk Atoll and Minto Reef.

3.5 A mechanism should be established so that funds can be earmarked for the management of Oroluk Atoll and Minto Reef. The establishment of a trust fund capable of receiving appropriations, grants and fees and disbursing funds for administration and management is one possibility.