TO PETER BLACK WITH COMPLIMENTS

SYNTHESIS REPORT:

# RAPID ECOLOGICAL ASSESSMENT OF PALAU:

# PART I JUNE 1992 NATURAL AND CULTURAL RESOURCES SURVEY OF THE SOUTHWEST ISLANDS OF PALAU


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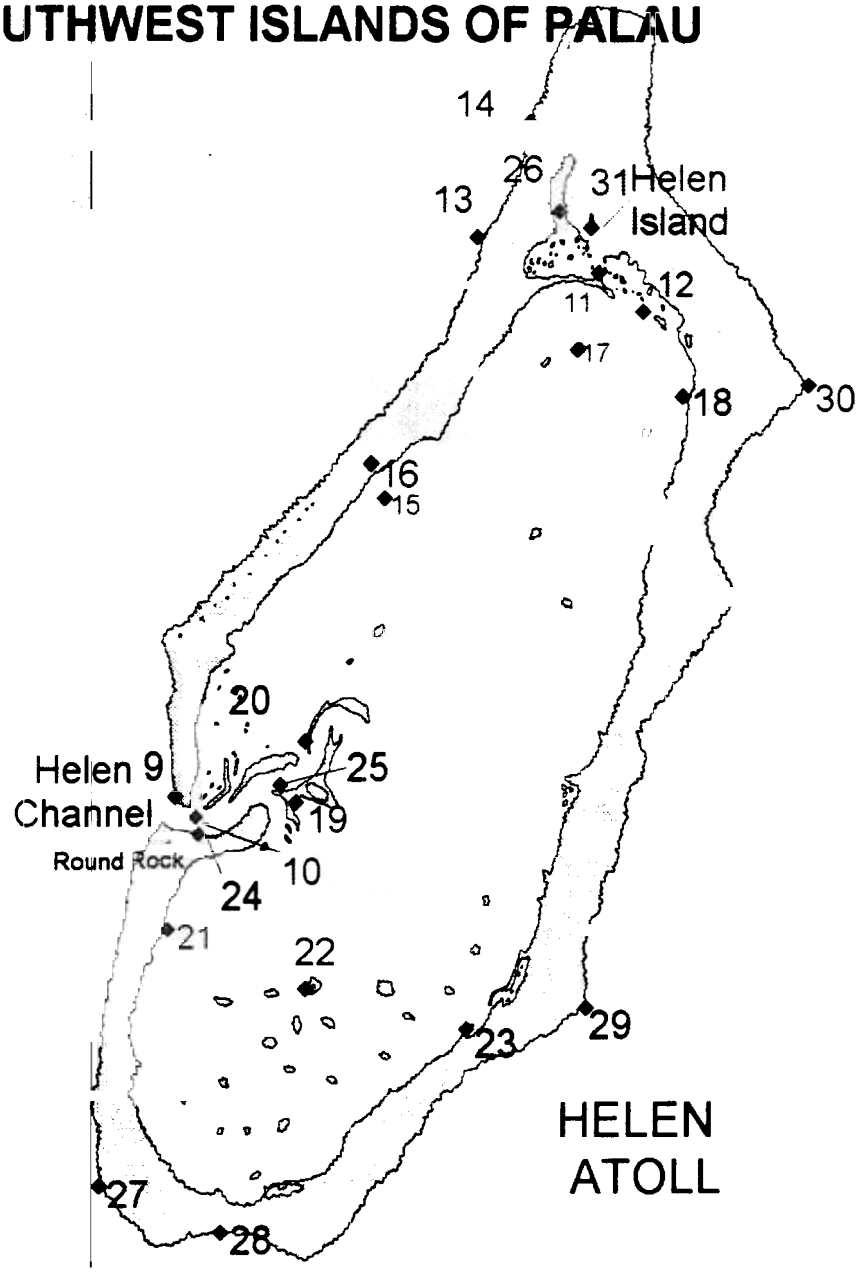
# OF THE SOUTHWEST ISLANDS OF PALAU



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## Introduction

At meetings with the Bureau of Resources and Development, Palau, in April 1991, officials from the states of Sonsorol and Tobi expressed a number of concerns over the conservation of natural resources, the loss of cultural traditions, and an uncertain future for the peoples of the Southwest Islands of Palau. These officials sought advice and assistance on chartering a new future for these islands and requested a scientific survey of the reefs and islands of Palau. The following concerns were expressed and formed the basis for the objectives of a comprehensive scientific expedition to the Southwest Islands, conducted during 1-19 June 1992:

1 The resident populations are very small and out-migration is significant; the islanders would like to see the population trends reversed through promoting jobs for ecotourism and small scale sport diving.

2) There is infrequent and inadequate shipment of food, medicines, and supplies; sand fleas, coconut beetles, and mosquitoes are pests and health problems on islands with interior lakes or swamps.

3) Although sea turtles and coconut crabs are traditionally protected, there are declines in these resources as well as in fish catch; some of these resources are now sold or bartered, upsetting the balance of nature.

4) At least two previous scientific expeditions to the Southwest Islands did not lead to the sharing of the results and reports of the surveys with the islanders.

5) The islanders, especially the elders and chiefs, have a rich knowledge of natural resources which they are willing to share in hopes of ensuring optimum conservation of resources; the resident populations live on a "tight budget" in strict accordance with the principles of conservation to ensure a sustainable food supply and resource base.

6) The islanders seek advice on promoting safe diving for sport divers, and can point out the location of caves, tunnels and other attractions.

7) Besides the six islands, there is also a submerged reef at a depth of 24 m between Sonsorol and Angaur that may be worth investigating.

8) There is unanimous support of a scientific survey, and village communities would assist in logistics and lodging for overnight visitors.

9) Merir has important turtle nesting beaches, and sunken reefs which the islanders would like investigated and explained.

10) Fanna has seabird and coconut crab populations which need to be evaluated and advice provided on monitoring, controlling, or harvesting of populations.

11) The islanders are apprehensive about blanket conservation of seabirds, but are seeking advice on appropriate conservation measures.

12) Helen Reef's giant clam populations are substantial but have been heavily poached by foreign fishing vessels.

13) In terms of calm weather and peak nesting for sea turtles, an expedition to the Southwest Islands should be accomplished between March and June.

The overall goal of the expedition was to conduct the first comprehensive scientific survey of the natural and cultural resources of the Southwest Islands to help develop recommendations on protection, conservation, or sustainable use of those resources.

Although there was strong interest and support for a scientific expedition, the lack of a suitably sized vessel postponed the survey for a year. In June 1992, Greenpeace was successful in chartering and financing the Pegasus II out of New Zealand. The vessel measures 16.4 m in length, and accommodated three rubber skiffs, 15 scientists and crew members, scuba diving support, food, water, fuel and other supplies for a three week expedition. The small size of the vessel imposed limitations on scientific personnel. The scientific expedition was to address the following specific resources:

1) sea turtle feeding and nesting activity (addressed by Suzie Geermans and Noah Idechong)

2) land plants and animals including seabirds, insects, coconut crabs, and fruit bats (addressed by Kay Kepler, Robert Smith, and Chuck Cook)

3) coral reef fisheries (addressed by Terry Donaldson and Noah Idechong)

4) marine plants including algae and seagrasses (addressed by Karla McDermid)

5) stony corals and reef formations (addressed by Jim Maragos)

6) other marine invertebrates including giant clams (addressed by Barry Smith and Noah Idechong)

7) cultural resources including archaeology and anthropology (addressed by Rosalind Hunter-Anderson, Stephen Patris, and Johnny Felix)

In addition, Greenpeace crew members Vicki Getz and Jack Noble handled interviews for Greenpeace projects and activities. Jack was also responsible for underwater photographs and acted as divemaster. Sarah McNab assisted on small boat handling and cooking. Captain Eric Gosse was responsible for navigation and vessel operation aboard the Pegasus II. Jim Maragos served as chief scientist of the expedition, while Noah Idechong served as chief of party for the Palau government. Stephen Patris acted as the Southwest Islands representative.

Although there was compelling need and interest to include a public health/medical scientist, along with ethnological and linguistical expertise on the team, space and logistics could not accommodate more than the fifteen participants named above.

This "synthesis" report summarized the written results of the Southwest Islands expedition that were completed as of May 1993. The synthesis report also reviews the basic findings, conclusions, and recommendations for further study and action. The other chapters in this volume are technical reports prepared by the scientific participants of the expedition. Chapter 2 covers terrestrial ecology (Kay Kepler 1993); chapter 3 covers archaeological investigations (Rosalind Hunter-Anderson 1993); Chapter 4 covers sea turtle populations (Suzie Geermans 1992); chapter 5 covers reefs and corals (Jim Maragos 1993); chapter 6 covers marine flora (Karla McDermid 1993); chapter 7 covers fishes (Terry Donaldson 1993); chapter 8 covers marine invertebrates other than stony corals (Barry Smith, in preparation).

**Expedition Itinerary**

The scientific survey was accomplished between 1-19 June 1992 (see Figure 1). The strategy of the expedition was to cover the most remote islands and reefs first, especially if weather conditions were good, and then move back up the chain towards the main Palau Islands. Except for a few rainy days, weather conditions were mostly sunny with calm seas. Only on the last day did winds and rains increase substantially, causing the expedition to be cut short by one day.

The Pegasus II left Koror on 1 June, arriving at Tobi early on 3 June. Two field days were spent on Tobi before the Pegasus II traveled to Helen Reef. Due to Helen Island's geological instability and small size, and the small likelihood of archaeological sites on Helen Island, the team's archaeologist, Rosalind Hunter-Anderson, elected to remain at Tobi to continue archaeological surveys there. Meanwhile, the Pegasus II and the rest of the party arrived in Helen early on 5

June, and remained until late on 9 June 1992. Five field days were spent at Helen, due to its much larger lagoon and reef habitats. The vessel then returned to Tobi to pick up Rosalind Hunter-Anderson, and Tobi islander Johnny Felix early on June 10. The Pegasus II traveled on to Merir, arriving early on June 11, and two and one half field days were spent there. On 14 June, the Pegasus traveled to Pulo Ana, arriving later on the same day. One field day was spent before the team moved on for Sonsorol late on 15 June. Arriving at Sonsorol early on 16 June, two field days were spent at Sonsorol before moving on to Fanna late on 17 June. The team surveyed Fanna for one day, before foul weather caused our premature departure, arriving in Koror early on 19 June. A total of 14 days were spent at the islands and reefs, with the remaining 5 days spent in transit between islands.

## Methods

### Terrestrial Ecology

Terrestrial surveys consisted of walks around the perimeters of all islands, and straight transects across the islands to record species, take photographs, and collect specimens of plants, lizards, and some insects (see Kepler, this volume). Observations and collections were also made at night for nocturnal and secretive species. Herbarium specimens of all plant species were collected at all islands. Attempts were made to capture each of the lizard species observed. One migrant bird, two fruit bats, and one rat were also collected. Residents were interviewed on abundance and distribution trends regarding island animal species. Specimens were sent to authorities at the Bishop Museum, Honolulu, and the National Museum in Washington, D.C., for positive identification and deposit in their Pacific collections.

### Sea Turtles

Sea turtle surveys consisted of daylight shoreline walks around the perimeter of each island and sand spits to observe and count the tracks of adults and hatchlings, to record the bones and scutes of sea turtles on the beaches, and analyze pits dug by adult females (see Geermans, this volume). Nighttime surveys were conducted to measure adult females, as well as their eggs. None of the eggs or turtles was damaged or collected by the scientific team. Each adult sea turtle was tagged in order positively identify individual turtles, to assist in determining migratory routes, and to estimate the annual nesting population. Due to the large population of sea turtles in the lagoon at Helen Reef, a turtle rodeo was conducted to capture, measure, tag, and release immature and adult sea turtles. Established models and analytical procedures for sea turtles were used to calculate population levels, and to estimate whether the present harvest rates for nesting sea turtles at the Southwest Islands are sustainable (see Geermans, this volume). Residents were interviewed on sea turtle feeding sites, nesting sites and rates, harvest rate, and other important data.

**Archaeology**

Archaeological surveys consisted of detailed oral history interviews with knowledgeable residents and leaders at each island, reconnaissance level (walk-through) surveys of previously reported sites, and along areas likely to contain additional archaeological sites (Hunter-Anderson, this volume). A few test pits, trenches, and cores were excavated at all islands (except Helen) to conduct more detailed archaeological analyses, including examination of soils, charcoal, artifacts, and midden (refuse) remains of animals consumed or utilized for tool making. Organic carbon samples were collected at the five islands to determine the age of cultural deposits using radiocarbon dating techniques (Hunter-Anderson, this volume).

Back in Koror, collected artifacts were compared to those deposited at Palau's National Museum to verify archaeological/cultural origin. In addition, elder Southwest islanders now living in Koror were interviewed. Stephen Patris, a native Southwest Islander acted as interpreter and helped in the interpretations of oral history information (Hunter-Anderson, this volume). Extensive literature reviews of previous archaeological, ethnological, and anthropological studies in Palau were also accomplished.

**Marine Biology**

Surveys of marine algae and to a lesser extent, seagrass beds were conducted on reef slope transects using scuba equipment. Species were noted in the field or specimens collected for later analysis (see McDermid, this volume). Reef flat habitats were also observed and sampled during snorkel surveys or by wading over shallow areas. As with the terrestrial biological surveys, an extensive literature review was carried out for past biological studies in Palau and adjacent island groups.

Reefs and corals were investigated and analyzed by visual techniques during underwater scuba assisted transects. The relative abundance of each coral species was recorded on pre-printed, waterproof forms, and sketch profiles of each survey site were drawn, along with notes on predominant benthic marine life, corals, and reef substrates. Notes on depths, water quality, water currents, wave action, and health of coral communities were also recorded (see Maragos, this volume). In addition, several minutes of underwater video footage was taken by Maragos at each of the dive sites to help in the identification of difficult coral species and to characterize reef bathymetry and geomorphology. A few coral species were collected, but only to of confirm uncertain field identifications (see Maragos, this volume). Aerial photographs and maps were also analyzed to help select sampling sites and to characterize zonation patterns and reef habitats. Kay Kepler computed island and reef areas dimensions, using digital

cartographic techniques at the University of Georgia Dept. of Geography facilities (see Kepler, this volume).

Fish observations were recorded during scuba assisted underwater surveys (see Donaldson, this volume). An attempt was made to record each species observed during each transect survey. Statistical analytical techniques were used after the expedition to estimate patterns of diversity, biogeography, and similarity among the 6 island/reef sites (see Donaldson, this volume). Previous literature on fish data from the Southwest Islands and elsewhere in Palau was also reviewed.

Marine invertebrates other than stony corals were observed by Barry Smith. Species lists were recorded during each of the underwater transect surveys and large mollusks were measured, especially giant clams, trochus (if present), and green snails (only rarely observed). In addition, Barry Smith also made small collections of terrestrial mollusks from several islands.

Each underwater transect survey was generally limited to depths of 0-20 m, and durations of 30 minutes, due to limited bottom time when using scuba, and the need to cover as many habitats as possible. A few areas warranted surveys extended to depths of 30 m, and/or 45 minute duration to collect additional data.

Color aerial photography sponsored by The Nature Conservancy, the Republic of Palau, and the U.S. Dept. of Interior was flown throughout Palau in May of 1992, during a period of clear weather conditions. The Southwest Islands of Palau were covered at scales of 1:4,000 to 1:8,000, and include about 225 photographs of Helen Reef, and 40 photographs of the remaining Southwest Islands. The photographs were flown by Air Survey Hawaii (ASH). The original negatives are stored in Honolulu at ASH.

These photographs proved invlauable in several respects. They 1) helped to characterize the various terrestrial and marine habitats, 2) allowed detailed mapping of vegetation zones on the islands (see Figures in Kepler, this volume), and 3) greatly assisted in selecting sites for marine biological surveys. The aerial photo mission also detected a fishing boat of Indonesian origin in the lagoon at Helen Atoll, in the act of poaching giant clams. The vessel was later apprehended, confiscated, and the crew arrested for violating Palau conservation and sovereignty statutes.

## Literature review: previous scientific studies in the Southwest Palau Islands

Table 1 lists the references of previous scientific studies and other accounts of the natural resources of the Southwest Islands of Palau, including selected

regional surveys and overviews of relevance to Palau. Full citations for these references are provided in the reference section and in the accompanying technical reports by the various participants (chapters 2-7; Kepler, 1993; Hunter-Anderson, 1993; Geermans, 1992; Maragos, 1993; McDermid, 1993; and Donaldson, 1993).

The earliest recorded visits to the Southwest Islands were by shipwrecked sailors (Holden, 1836), and naturalists making brief visits to the islands before World War II, especially during the German and Japanese eras (Seidel, 1905; Fritz 1907; Eilers, 1935-36; Hasebe, 1928; Motoda, 1939; and others). Important post war anthropological and archaeological surveys include Osborne (1966; 1979), Black (1977), and Johannes and Black (1981).

**Table 1. Listing of scientific reports on the Southwest Islands of Palau and adjacent areas organized by subject**

Italicized references are the technical reports in this volume. Full citations are provided in the references section.

Anthropology and history
Holden (1836)
Seidel (1905)
Fritz (1907)
Hasebe (1928)
Eilers (1935)
Eilers (1936)
Someke (1938)
Motoda (1939)
Fosberg (n.d.)
Black (1977)
Johannes (1981)
Johannes & Black (1981)
Sinoto (1988)

Archaeology
Osborne (1966)
Osborne (1967)
*Hunter-Anderson (1993)*

Coconut & land crabs
*Kepler (1993)*

Birds
Yamashina (1940)
Baker (1951)
King (1967)
Owen (1970a)
Engbring (1972)
Muller (1973)
Owen (1977a)
Owen (1977b)
Bright (1978)
King *et al* (1980)
Engbring (1983)
Pratt *et al* (1978)
Engbring (1988)
*Kepler (1993)*

Conservation & Protection
Owen (1970b)
Elliott (1973)
Republic of Palau (n.d.)
Dahl (1980)
Dahl (1986)
USFWS (1990)
IUCN (1991)

Climate
Weir (1983)
Nunn (1990)

Fishes
Johannes (1981)
Myers (1989)
*Donaldson (1993)*

Giant clams
Hester & Jones (1974)
Bryan & McConnell (1976)
Hirschberger (1980)

Land mammals
*Kepler (1993)*

Land reptiles
Brown (1956)
Owen (1970a)
Rodda (1991)
*Kepler (1993)*

Coral Reefs
Motoda (1939)
UNEP/IUCN (1988a)
UNEP/IUCN (1988b)
*Maragos (1993)*

Marine plants
Okamura (1904)
Okamura (1916)
Yamada (1928)
Motoda (1939)
Tokida (1939)
Yamada (1944)
Trono (1968)
Trono (1969)
Trono (1971)
Tsuda & Wray (1977)
Tsuda (1981)
Ogden & Ogden (1982)
*McDermid (1993)*

Sea turtles
Pritchard (1977)
Pritchard (1991)
*Geermans (1992)*

Vegetation
Fosberg (1960)
Fosberg (1976)
Fosberg *et al* (1980)
Stemmermann (1981)
Cole *et al* (9187)
Merlin & Keene (n.d.)
*Kepler (1993)*

Previous scientific studies to the Southwest Islands have concentrated on censusing bird populations (summarized in Engbring, 1983; and Kepler, 1993), and collections and identifications of marine plants, especially algae or seaweeds (summarized in McDermid, 1993). Although there have been numerous vegetational studies in Palau, no organized ecological surveys or mapping were conducted until the 1992 survey (Kepler 1993). Land crabs, terrestrial reptiles, and mammals lacked attention. In the post World War II era, the giant clam populations of Helen Atoll have been studied on several occasions (Hester and Jones, 1974; Bryan and McConnell, 1976; Hirschberger, 1980) some of which included anecdotal notes on coral reefs. Otherwise, field data on the coral reefs are limited to the regional overviews (see Maragos, 1993), literature reviews by UNEP/IUCN (1988a, b), and the descriptions of some reef flats by Motoda (1939). Similarly, nearshore fish populations are not well documented (see Donaldson, 1993, for an overview) and are limited to descriptions of fishing techniques and lore (Johannes and Black, 1981).

Despite the importance of sea turtle populations in the Southwest Islands, only Pritchard (1977, 1991) and Johannes (1986) provided published information before the 1992 expedition (summarized in Geermans, 1992).

In summary, previous surveys and expeditions to the Southwest Islands provided cultural and historic surveys and incomplete collections and observations of specific groups of organisms. There has been no comprehensive overview of the cultural and natural resources of the Southwest Islands prior to the June 1992 expedition.

## Physiography

The Southwest Islands of Palau consist of six islands and surrounding reefs spanning latitudes between 3° and 6° N and longitudes 131° to 133° E. As their name suggests, the islands are 339 to 599 km southwest of the main Palau archipelago and consist of the following from NE to SW (see Tables 2 and 3):

Fanna [Fanna] Island
Sonsorol [Dangosaro] Island
Pulo Anna [Purr] Island
Merir [Meilieli] Island
Tobi [Hatohobei] Island, and
Helen [Hotsari hie] Reef

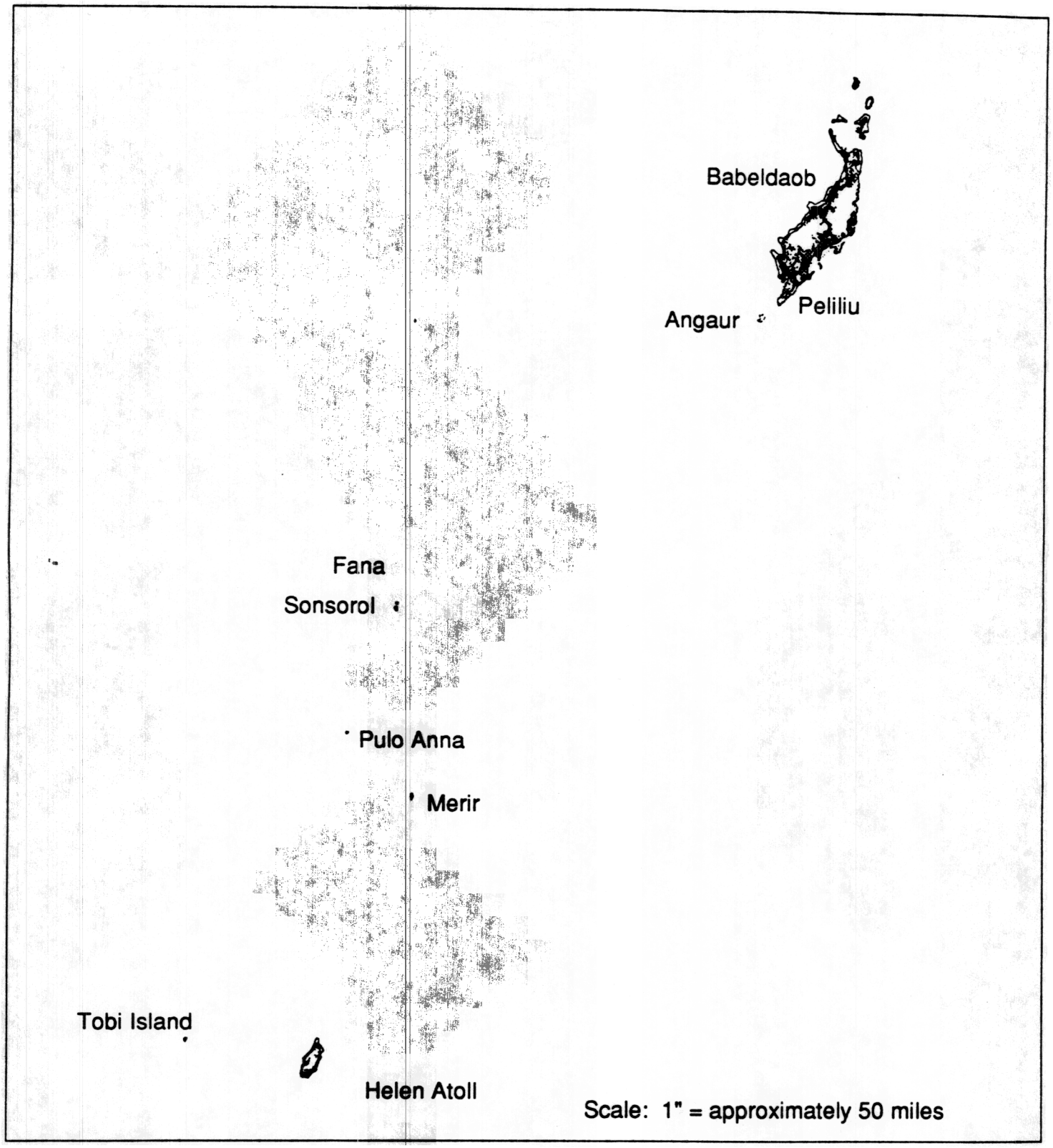

Babeldaob
Angaur
Peliliu
Fana
Sonsorol
Pulo Anna
Merir
Tobi Island
Helen Atoll
Scale: 1" = approximately 50 miles

Table 2. Southwest Palau Island reefs: geographical data measurements (from planimeter and digital computer programs). After Kepler (1993) and Maragos (1993).

| | Helen | Tobi | Merir | Pulo Anna | Sonsorol | Fanna |
|---|---|---|---|---|---|---|
| Longitude | 131°49' E | 131°11' E | 132°19'E | 131°58'E | 132°13'E | 132°13'E |
| Latitude | 2°59'N | 3°01' N | 4°19'N | 4° 40'N | 5° 9'N | 5°21'N |
| Reef Perimeter km | | | | | | |
| Ocean slope | 61.7 | 7.0 | 9.5 | 4.7 | 7.0 | 4.3 |
| Lagoon slope | 53.8 | - | - | - | - | - |
| Pass complex | 19.8 | - | - | - | - | - |
| Lagoon area ($km^2$) | 103 | - | - | - | - | - |
| Reef area ($km^2$) | 58.7 | 2.0 | 4.4 | 1.1 | 1.9 | 0.9 |
| Perimeter flats | 56 | 2.0 | 4.4 | 1.1 | 1.9 | 0.9 |
| Linear and patch flats | 0.85 | - | - | - | - | - |
| pass flats | 1.9 | - | - | - | - | - |
| Reef length and width (km) | | | | | | |
| Long axis | 24 | 2.7 | 5.0 | 1.6 | 2.8 | 1.3 |
| Short axis | 9 | 1.3 | 1.4 | 1.2 | 1.5 | 1.3 |
| Reef flat width range (m) | | | | | | |
| minimum | 460 | 250 | 250 | 150 | 200 | 160 |
| maximum | 2200 | 800 | 500 | 500 | 470 | 400 |
| Number of lagoon reefs | 85 | - | - | - | - | - |

Table 3. Southwest Palau Islands: geographic data measurements (from planimeter and computer digital programs). After Kepler (1993).

| | Helen | Tobi | Merir | Pulo Anna | Sonsorol | Fanna |
|---|---|---|---|---|---|---|
| Longitude | 131°49' E | 131°11' E | 132°19'E | 131°58'E | 132°13'E | 132°13'E |
| Latitude | 2°59'N | 3°01' N | 4°19'N | 4° 40'N | 5° 9'N | 5°21'N |
| Area (ha) at mean low tide | 8.4 | 80.4 | 109.5 | 42.5 | 127.0 | 44.3 |
| Area (ha) at mean high tide | 3.1 | 74.9 | 99.1 | 37.9 | 120.5 | 39.8 |
| Island length and width | | | | | | |
| long axis (m) | 395 | 1,466 | 2,428 | 867 | 1,976 | 836 |
| short axis (m) | 67 | 780 | 704 | 592 | 912 | 669 |
| perimeter shoreline (m) (mean low tide) | 1,973 | 3,768 | 5,785 | 2,432 | 4,745 | 2,436 |
| Vegetation habitats (ha) | | | | | | |
| mixed forest | - | 28.1 | 55.9 | 16.8 | 59.3 | 19.8 |
| coconut forest | - | 30.4 | 5.6 | 13.3 | 11.5 | 3.7 |
| strand | - | 1.3 | 6.7 | 1.4 | 3.8 | 5.3 |
| taro marsh | - | 2.1 | - | - | - | - |
| mixed scrub forest | - | 11.4 | - | - | - | - |
| *Tournefortia* scrub forest | 2.3 | - | 0.7 | - | - | - |
| *Lepturus* meadow | 0.3 | - | - | - | - | - |
| mangroves | - | - | 30.0 | 2.8 | - | - |
| coconut/mixed forest | - | - | - | - | 42.5 | - |
| *Pisonia* forest | - | - | - | - | - | 9.9 |

Fanna and Sonsorol are often considered a group together (an open atoll) since the two islands are only 3 km apart. All but Helen are small islets resting on Table reefs, with only exposed fringing reef flats and slopes separating the islets from open seas. Helen is an atoll consisting of one islet (Helen) and a large perimeter reef system enclosing a lagoon with many reef formations and with a deep pass through the perimeter reef along the west side. Helen islet is the smallest of the six islands in terms of land area (approximately 3 ha) but the associated reef systems are much more diverse and more abundant than the total of the five other islands combined.

The nearest islands to the southwest group are all about 240 - 270 km away; the raised limestone island of Angaur [Ngeaur] in Palau to the northwest of Fanna and Sonsorol; the high volcanic island of Morotai in the Maluku province of Indonesia to the west of Tobi, and the atoll of Kepulauan Asia, also in Indonesia, to the south of Helen and Tobi. The Southwest Island group is the furthest west of any other archipelago in Oceania (the combined Micronesian, Melanesian and Polynesian regions) and lies closest to the complex island and reef region of Southeast Asia.

The total land area of all six islands is very small, totaling about 3.75 $km^2$ (375 ha). Although human populations were much higher at the turn-of-the-century (see Eilers, 1935; 1936; Hunter-Anderson, this volume), the present population levels on the islands are low, varying from zero at Fanna, between five to eight on Helen and Merir, and between 15 to 30 on the remaining islands of Pulo Anna, Tobi, and Sonsorol.

Table 2 summarizes the statistics and geography of the islands, while Table 3 presents a statistical summary of the reefs. Helen Island has the smallest land area (3.1 ha) but important seabird populations and larger reef habitats than all other islands combined. Helen Island has four types of land habitats, of which *Tournefortia* scrub forest and *Lepturus* grass meadows were not reported elsewhere in the Southwest Islands. The reefs at Helen encompass 13 major habitat types, including all those found in the remaining Southwest Islands except ocean terraces and dredged channels.

Tobi is the third largest island (74.9 ha) and has the third most abundant reef habitat. Tobi Island consists of six types of land habitats including taro marshes, the only island with this habitat still present. There are only four types of reef habitats including a dredged channel and deeper reef flat pools and moats, the latter occurring elsewhere only at Helen.

Merir is the second largest island (99.1 ha) and supports the second most abundant reefs after Helen. Six major land habitats are found on the island including mangroves in a central depression which was not reported elsewhere in the Southwest Islands. Merir supports three major reef habitat types including broad ocean terraces off the north point, which was not encountered elsewhere in the Southwest Islands.

Pulo Anna is the second smallest island (37.9 ha) and has the second smallest reef area of the six Southwest Islands. Seven major habitat areas are found on land including two that are unique to the Southwest Islands: open swamp and mangrove forest. Reef habitats are limited to two types: reef flats and ocean reef slopes.

Sonsorol is the largest of the Southwest Islands, but supports only the fourth most abundant reef area. There are five major types of land habitats, including coconut/mixed forests, a type unique to Sonsorol. There are only three types of reef habitats including reef flats, ocean reef slopes, and a dredged channel.

Fanna is the third smallest island (39.8 ha) and has the least abundant reef habitat. Fanna Island is unique in supporting the only large stand of *Pisonia* forest. Reef habitats are limited to reef flats and ocean slopes although much of the flats are slightly deeper than those reported from the other islands.

Overall the most abundant land habitats on the Southwest Islands were indigenous mixed forests and coconut forests. Excluding Helen atoll, the most abundant reef habitats were reef flats and ocean reef slopes. However, Helen also supports a variety of abundant lagoon and pass reef habitats.

**Climate**

The climate of the Southwest Islands is typical of low tropical latitudes and is generally hot, wet, and humid. Precipitation averages about 3,000 mm (118 inches) per year. Wind patterns in the Southwest Islands are not typical of the rest of the Carolines due to their close proximity to the Southeast Asia region. Winds are generally mild, except during rain squalls and tropical storms. Winds appear to be seasonal, shifting from the eastern trade winds during March through August to southwest "monsoon" winds during September through February. The lack of robust (spur and groove) reef formations except along the eastern side of the northern Southwest Islands, suggests that there are no consistent or strong wind and swell patterns. The proximity of the Southwest Islands to Southeast Asia greatly influences weather conditions and is responsible for the seasonal wind patterns.

The Southwest Palau Islands are well south of the major typhoon belt north of the main Palau islands. However, major destructive typhoons struck the islands near the turn-of-the-century (Fritz, 1907; Eilers, 1935; 1936; Hunter-Anderson, this volume); causing droughts, famine, loss of land and island habitat, and loss of human life.

**Oceanography**

The Southwest Palau Islands are situated within two prevailing ocean current systems. One is the Pacific Equatorial Countercurrent (PEC) which forms south of Helen and Tobi and sets from west to east across the entire Pacific. Further east, the PEC is centered around Latitude 5° N. The other major current system is north of the PEC, and is the broad North Pacific Equatorial Current (NPEC) which sets from east to west across the expanse of the Pacific between latitudes of 20° N to 5° N. Both current systems, especially the PEC are responsible for the rich pelagic fisheries in the vicinity

of the islands, especially migratory tunas and game fish. To the south of these current systems is found the westward flowing South Pacific Equatorial Current (SPEC), which sometimes moves northward in the vicinity of Tobi and Helen.

The winds and currents prevailing during some seasons also set up wake eddies and unusual current patterns on the leeward sides of at least the southern islands, including Tobi. The island fishermen have taken advantage of the knowledge about these currents to develop unique and efficient fishing methods (see Johannes and Black, 1981).

## Geology

All six of the Southwest Islands are composed of the remains of coral reef carbonates, primarily skeletons of reef-building corals, coralline algae, and reef mollusks. Benthic foraminiferan tests and *Halimeda* flakes compose the bulk of submersed sand reservoirs and the beaches along the island coastlines. All six are typically "low" coral islets with a maximum elevation of less than 5 m.

The interior portions of the islets (except Helen) are depressions. For three of these: Tobi, Pulo Anna, and Merir, the depressions intercept the water Table to form or support open swamps, mangrove stands, or taro cultivation areas. The perimeters of all islands are higher with dunes or mounds often situated adjacent the shoreline. Beaches are composed mostly of sands, cobbles, boulders, exposed beach rock, reef conglomerates, and breccias. Shoreline erosion is evident along some stretches of the islands, including western Helen and western Tobi.

The islands and reefs all rest on top of ancient volcanic sea mounts formed many millions of years ago. The ancient volcanoes are a part of a north-to-south trending submarine ridge, or mountain range, which extends south, past Kepulauan Asia atoll to the New Guinea-Australian continental plate. The mountain range also extends north to encompass the remaining Palauan islands and farther north to where the submarine range is referred to as the Parege Vela Ridge. The southern (Palau end) of the ridge is the westernmost in the broad Pacific basin, connecting with the Japan archipelago to the north and the Irian Jaya portion of Indonesia to the south.

There is little available information on the geological origin and age of the Palau ridge, although deep sea bathymetry suggests considerable seismic activity over recent geological time. The deep Palau-Yap trenches occur to the east and the very deep Philippine trench occurs to the west, suggesting that the Palau submarine region is subject to compression, up-thrusting, and earthquakes.

However, the only sign of geological or seismic activity in the Southwest islands is the presence of a possible slumped reef off the northern reef at Merir. The possible slumping of the reef flat to form a deeper reef terrace could be attributed to earthquake activity or the increasing weight of the growing reef, leading to faulting and slumping.

## Population and Culture

The native cultures of the Southwest Islands were first systematically recorded by German ethnographers near the turn of the century (Eilers 1935; 1936) and later by an American (Black, 1977). The Southwest Islands show closest cultural and linguistic affinity to the Micronesian cultures of outer Yap State, especially Fais, Sorol, Euaripik, Ngulu, and other nearby atolls. They are less aligned to Palauan Micronesian culture, although politically a part of the Republic of Palau. Archaeological research summarized by Hunter-Anderson (this volume) indicates the islands have been occupied for several hundred to over one thousand years by Micronesians, based upon examination of artifacts, carbon dating and other archaeological analyses. The southwest Palauan islanders also show affinities to Malayan culture which is not surprising considering the close proximity to Southeast Asia.

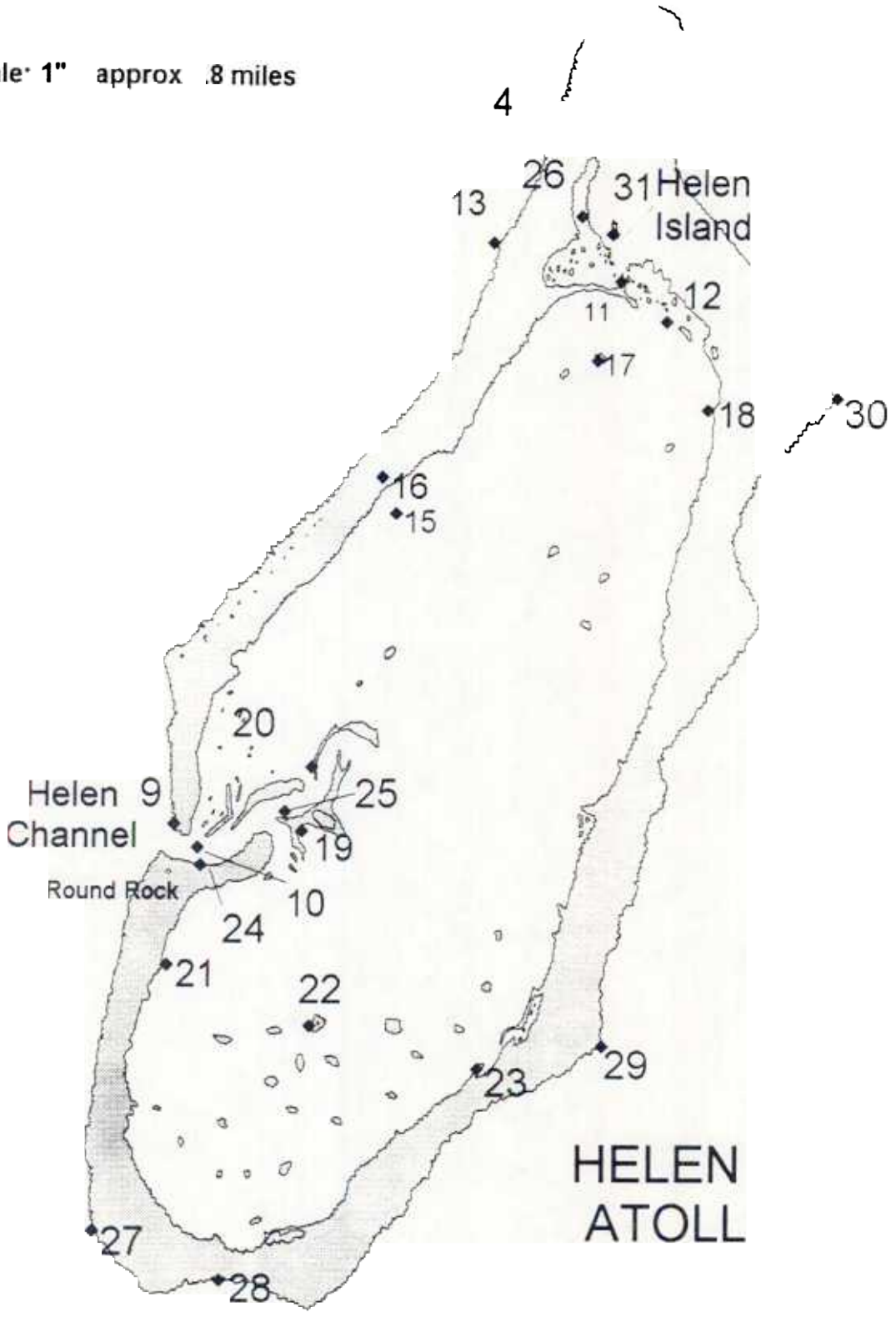
Population levels appeared to have been much higher in the islands, as little as 90 years ago. Accounts by Seidel (1905), Fritz (1907), Eilers (1935; 1936), Motoda (1939) and others indicates the human populations of Tobi and Merir may have approached 1,000 or more before a devastating typhoon of 1905 led to food shortages and mass migrations to other islands. Numerous village sites (see Figures 2 & 3) on Tobi reported by earlier ethnographers serve as additional evidence of higher population levels at the turn of the century. More extensive and intensive cultivation (of taro and other crops) may have been responsible for supporting large populations on the small islands.

The Japanese Mandate era (1914-1944) involved some agriculture development, and phosphate mining operations on Sonsorol and Tobi. After 1935, the Japanese fortified several of the islands and established military garrisons on Sonsorol, Tobi, and Merir. After Japan's defeat in World War II, all Japanese were removed from the islands.

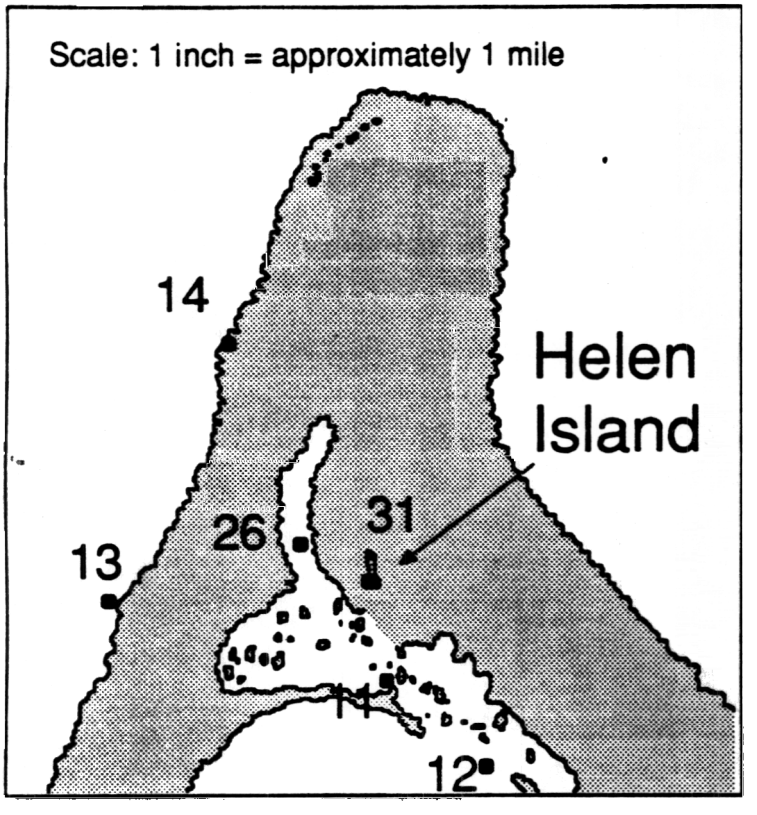
During the post-war American and Trust Territory administration of Palau, the population levels in the Southwest Islands have steadily declined. For example, the population at Tobi declined from 986 at the turn-of-the-century to about 70 people in 1979 (Johannes, 1981; Eilers, 1936; Engbring, 1983). Between 1977 and 1992 the population has declined to less than 30 people. Merir's population decline is even more dramatic: from 1,100 in 1904 to 5 in 1992. The present population of Pulo Anna is about 20, and on Sonsorol the population is about 25. Helen's population in 1992 was 5 "permanent residents". Residents of Tobi irregularly visit Helen for a few weeks or months). Fanna has no residents although it is visited frequently by residents of nearby Sonsorol. The total population now residing in the Southwest Islands is less than 80. Most of the remaining islanders have moved to Koror and other more urbanized areas. Lack of economic opportunities, inadequate education for children, infrequent visits from supply vessels, and inadequate medicines and other supplies have increasingly isolated the Southwest Islands, forcing many people to move away. Stemming and reversing the present population decline is a major goal of the state and national governments in Palau.

Results: Island and reef resource descriptions from the 1992 surveys

Scale: 1" approx .8 miles



**Helen Atoll [Hotsari hie]** (Figures 1 in Maragos & 4 in Kepler)
Helen is located at the southern end of the Southwest Islands at 2° 59′ N and 131° 49′ E. Its nearest neighbor is Tobi located about 75 km to the west. Until recently, Helen was uninhabited and only visited occasionally by Tobi islanders. The atoll has been long renowned for its productive reef, lagoon, green turtle rookery, seabird colonies, and giant clam stocks. Helen Island constitutes the only dry land in the atoll and is essentially a vegetated sand spit at the far northern end of the lagoon. The island can be approached by a shallow sand channel connected to the lagoon along the southwest side using small skiffs. At high tide, the eastern side of the island can also be approached by small skiff.




**Oceanography**
Both Tobi and Helen are located far south of the remaining Southwest Islands and are situated in an area of transition with regard to prevailing ocean currents. During the northern spring the westward flowing South Pacific Equatorial Current (SPEC) shifts north of the equator, flowing past the islands and reefs (Johannes, 1981). In the summer this current retreats southward and both islands lie near the boundary of the westward flowing SPEC and the eastward flowing North Pacific Equatorial Countercurrent (PEC). Later during the fall the currents shift farther southward so that the PEC flows strongly past both Tobi and Helen. Thus, over a year long period currents mingle from opposite compass directions, and connect Tobi and Helen with four other biogeographical areas: the Pacific, Philippines, East Indonesia, and Australo-Papua. Because of this unique location, Tobi and Helen's reef and island ecosystems are likely to contain biotic species of non-Pacific origins enhancing their marine and terrestrial biodiversity.

The complex ocean currents also may affect the seasonal abundance of in-shore and pelagic fish, which in turn affect seabird movements. Tobian fisherman believe that the return of large numbers of tuna and seabirds in February is linked to the current shifts and increased availability of pelagic juvenile reef fish (Johannes, 1981). The currents themselves may explain the high levels of reef coral, reef fish, and marine algae biodiversity on the reefs at both Helen and Tobi (see Kepler, Maragos, Donaldson, and McDermid, this volume).

### Vegetation

The sole natural habitats on Helen Island are *Tournefortia* scrub forest (2.3 ha) and a small *Lepturus* grass meadow (0.3 ha). However, the first is slowly being cut and reduced to supply firewood for the islet's few inhabitants. At the present rate of clearing, the forest would be eliminated in about 20 years (Kepler, this volume). Vegetational species diversity was low in 1992, consisting of only eight species (Table 2 in Kepler). However, 84% of Helen's land area is covered with the native scrub and grass habitats (Kepler, this volume).

### Birds

Until 1992, Helen supported the most abundant and diverse seabird populations in Palau. The islet is also a known magnet for vagrant and migrant land birds. The 1992 surveys revealed 14 species of birds (Tables 5 & 6) including one (Greater Sand Plover) sighted for the first time in the Southwest Islands and another (Cattle Egret) sighted for the first time in the islet. Although the number of species of seabirds remains comparable to those of previous surveys, population levels are down with all but one species in poor health. Human activities have decimated Helen's breeding seabirds, from 91,000 - 96,000 in 1979 to 5,600 - 7,100 in 1992 (see Kepler, this volume). Only the Black Noddy breeding population showed high nesting success. Breeding and non-breeding populations of five species of seabirds (all larger seabirds) have dropped drastically, especially Sooty Terns, Red-footed Boobies, Great Frigatebirds, and Black-naped Terns. In addition, Masked Boobies which used to breed in small numbers were missing, and nesting colonies of Great Crested Terns were being depleted from egg collecting and abandonment of other eggs due to the islander disturbance. White Terns, although not declining, are also vulnerable to disturbance due to cutting of scrub forest trees and egging.

### Reptiles

One species of lizard, a skink, hither to known only from Kayangel Atoll (Table 8 in Kepler, this volume) was reported at Helen. Helen Islet was formerly an outstanding green turtle site. However, during the five days of surveys , only one turtle nested on the beach and the eggs were collected by the crew of a visiting Palau government ship. The eggs were later replaced after discussions with the crew. Surveys of the beaches also revealed some turtle bones and scutes, which indicate possible consumption of turtles by residents or visitors on the islet. Green and hawksbill sea turtles were numerous on lagoon and ocean reefs, evidence that Helen may support a resident feeding population of sea turtles (Geermans, this volume).

### Mammals

Surprisingly, Helen showed no signs of rats. The presence of rats could further devastate seabird populations. One dog lived on Helen at the time of the 1992 surveys. Dogs are notorious for disturbing and preying upon seabirds. An Indonesian bark confiscated in May 1992 was anchored a few meters offshore. This bark or other vessels could be a source of rat introductions to Helen (Kepler, this volume).

### Crabs

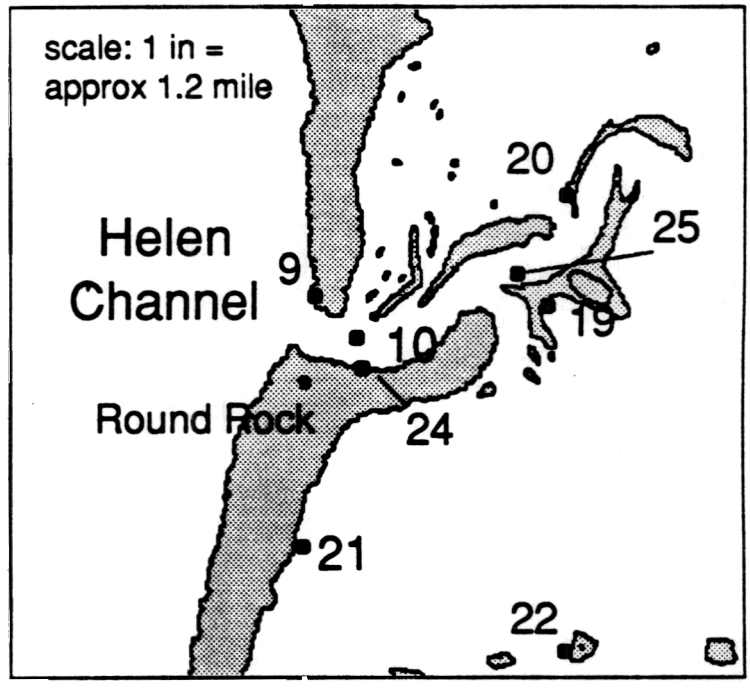
No resident land crabs or coconut crabs live at Helen, although residents have released a few coconut crabs from Tobi in the hopes of establishing a permanent population and source of food. Ghost crabs which usually occur in beach habitat, were numerous in the scrub forest understory.

### Marine Plants

Sea grass beds occurred in the shallow sand flats to the east and west of Helen islet. A total of 44 taxa of marine algae were reported from Helen, the highest of any of the six reef areas, including 22 red algae, 17 or more green algae and four brown algae. Several of the seaweed species collected at Helen were not reported elsewhere during the expedition (McDermid, this volume).

### Stony Corals

A total of 248 species of stony corals were reported at Helen Reef during the 1992 surveys (Table 4 in Maragos) the most of any of the six islands, and the most of any Pacific atoll reported in the literature. Thirteen species and two genera were first time sightings for Palau. Corals flourished in many habitats, including ocean and lagoon reef slopes, patch and pinnacle reefs in the lagoon, and on the floor and walls of the pass reefs. The reef habitat abundance and diversity at Helen are much higher than for those of all the other areas combined, explaining Helen's exceptional coral development (Maragos, this volume).




### Other marine invertebrates

Giant clam populations were abundant at Helen, including a few large individuals of the rarest and most sought after species (*Tridacna gigas*). Interviews with several islanders and the recent confiscation of an Indonesian bark point to the long-standing problem of illegal clam harvests. The crown-of-thorns starfish (*Acanthaster*) was reported in low numbers at Helen; the starfish is a predator of reef corals.

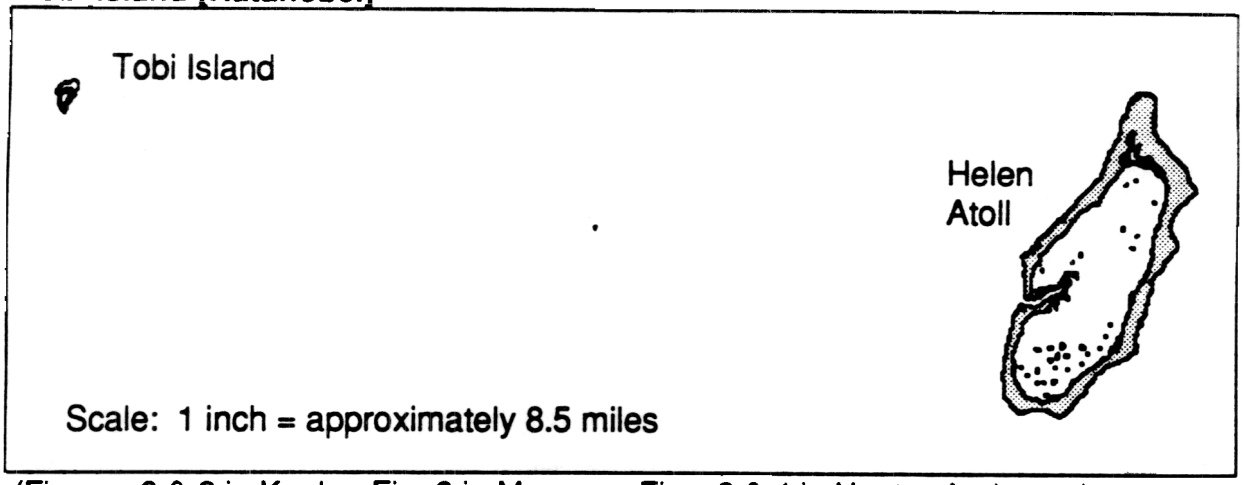
**Reef fishes**

A total of 488 species of fish (Tables 1 & 2 in Donaldson) were reported during the transect surveys at Helen's reef environments, the most of any of the six reef/islands surveyed during the 1992 expedition (Donaldson, this volume). Forty-three species were seen for the first time in Palau on Helen's reefs. The greater reef habitat abundance and diversity was responsible for the high fish populations and diversity. No evidence of over-fishing or depleted fishery stocks were evident at any of the reef sites visited at Helen Atoll.

**Archaeological and Historical Resources**

Archaeological surveys were not conducted at Helen islet due to the low probability of detecting any cultural deposits and artifacts. The land area has traditionally been considered a resource zone by Tobians but not a suitable place for permanent residents. In addition, the islet is very small and proportionally more vulnerable to the effects of the ocean. Finally, there is also evidence that Helen islet and the rest of the sand spits upon which it rests are constantly shifting locations (see Motoda, 1939). Evidence of this during the 1992 expedition was extensive erosion along the western shoreline. These factors argue against any likelihood of finding historical resources at Helen. The archaeologist concentrated effort at nearby Tobi, known for extensive cultural features and higher populations in the past. Interviews with Tobians revealed that Helen Atoll was visited to collect food and raw materials for heavy tools, especially *Tridacna* clams for adzes.

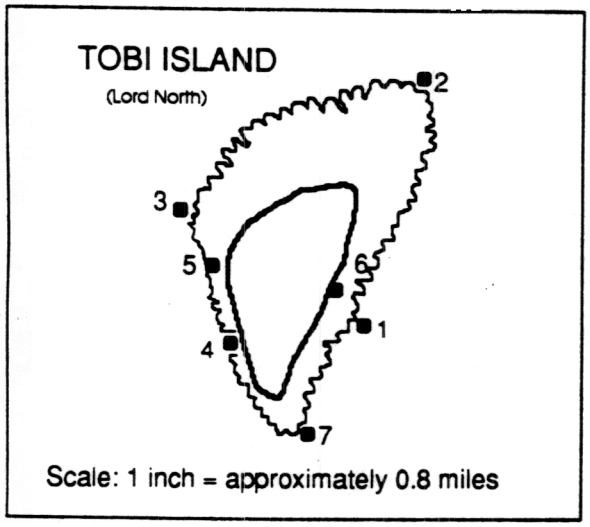
**Tobi Island [Hatahobei]**




(Figures 2 & 3 in Kepler, Fig. 2 in Maragos, Figs. 3 & 4 in Hunter-Anderson)

Tobi is the second most southern island and Table reef of the Southwest Palau Islands, situated at 3° 01′ N Latitude and 131° 11′ E Longitude. Tobi Island is triangular in shape and surrounded by fringing reefs varying in width between 250 - 800 meters. Tobi's nearest neighbor is Helen Atoll, some 75 km to the east. Together, Tobi and Helen form Tobi State. Tobi is also the most distant of the Southwest Islands from the main islands of Palau, which are 575 - 600 km to the northeast. Tobi is the third largest

of the Southwest Islands (75 ha) and supports the third most abundant reef habitat. Although there are no roads on the island, three trails cross the island and one skirts the mid-western shore. The village of less than 30 residents is situated along the southwestern shore beside a boat channel blasted through most of the reef flat during the years of the Japanese Mandate.




**Population**

Present day Tobians live in a traditional and healthy lifestyle and are proud of their tasty taro, neat village, fishing lore, ethnobotanical traditions, and well-tended coconut plantations. Tobians are also very knowledgeable about wildlife species and habits. They use a large proportion of Tobi's plants as medicines.

**Vegetation**

The island is densely clothed in coconut plantations and indigenous mixed forest (Table 2 in Kepler). Except for the tended plantations, Tobi's coconut forests are reverting to indigenous mixed forests (Kepler, this volume). Unique among the Southwest Islands is Tobi's open centrally located swamp where portions are still used to cultivate taro (*Colocasia esculenta*). Tobi is the only Southwest Island where taro cultivation is still practiced. Figure 2 is a 1909 map of Tobi showing the greater extent of taro cultivationand other crops at the turn-of-the-century.

The flowering plants number 75 species including seven ferns. Fifty-nine percent of Tobi's plant species are indigenous, and 53% of its land area is in native forest (Kepler, this volume). Mangroves used to be present on Tobi, according to residents and past literature, but it longer occurs except for a single *Barringtonia racemosa* tree. Another noteworthy tree at Tobi was a large banyan fig measuring 27 - 28 m in height (Kepler, this volume). Large *Calophyllum inophyllum* trees were once an important resource for canoes, houses, and wood artifacts.

**Birds**

Twelve species of birds were reported at Tobi during the 1992 expedition including four seabirds, three shorebirds, three waterbirds, and two land birds (Table 5 in Kepler). One, the Providence Petrel, is the first sighting of this species in Palau and another, the Bulwer's Petrel, was sighted for the first time on Southwest Islands. Three others were the first sighting of this species in Tobi Island: Rufous-necked Stint, Black-naped Tern, and Dollarbird. The islanders also described 27 species of birds which visit the island periodically or as one-time vagrants. One was a large heron, possibly a Great-billed Heron, which resides in Southeast Asia. Tobi's limited seabird populations are healthy due to the presence of many tall trees which provide nesting refuges. The

Tobians appear to eat only a few of the birds and eggs. The total breeding seabird population is estimated at 3,000 - 4,000 birds. The most common breeders are White Terns and Brown Noddies. Three other species breed in small numbers (Kepler, this volume).

### Reptiles

Approximately six species of small lizards were collected from Tobi (Table 3 in Kepler) all of uncertain identification at this time. Eilers (1935) also noted the presence of a "sea snake" which is now unknown to residents (Kepler, this volume).

Green sea turtles nest at Tobi Island in small numbers. On June 9, 1992 one nesting green was captured and eaten by the islanders on Tobi after successfully laying eggs. Green turtle scutes and bones were also present on the island (Geermans, this volume).

### Mammals

Black rats are abundant on Tobi and are tree climbers and a possible nuisance to the villagers, copra plantations, and to resting seabirds (Kepler, this volume). Fruit bats (kalong) no longer inhabit Tobi, but were formerly present (Eilers, 1935).

### Crabs

The Tobians indicated that coconut crabs are disappearing fast through over-harvest and land clearing. Sizable crabs may still exist in the wild but are difficult to find, even using coconut baits. Small numbers of a terrestrial hermit crab were recorded in inland habitats (Kepler, this volume).

### Marine Plants

Well developed sea grass beds occur along the inner margins of deeper reef flats and moats. Sea grasses were also growing on the floor of the dredged channel. A total of 35 different taxa of marine algae were reported from Tobi's reefs, the second highest total after Helen's 44 seaweeds. Tobi's marine algae included 20 red forms, 10 green forms and two brown forms. Several species were reported only from Tobi, including species of *Dictyota*, *Acanthophora*, *Corallophora*, *Galaxaura*, and *Lomentaria* (McDermid, this volume).

### Stony Corals

A total of 174 species of stony corals were reported (Table 5 in Maragos) from Tobi's reefs during the June 1992 expedition, a surprisingly high number given the limited habitat area, diversity, and sampling efforts. Seven of the coral species were seen for the first time in Palau on Tobi's reefs. These totals exceed species lists for some larger Marshall atolls where habitats are much more abundant and diverse and where surveys were more extensive. A possible explanation is the transportation of many coral larvae to Tobi's reefs by the many convergent water current systems operating in the surrounding ocean waters. The coral populations, and the reefs in general, appeared

to be in excellent condition with no obvious signs of anthropogenic stress or pollution (Maragos, this volume).

**Other Marine Invertebrates**

Giant clams of the genera *Tridacna* and *Hippopus* were common on both reef flat and ocean reef slope habitats.

**Reef Fishes**

Approximately 318 species of fish were reported during the June 1992 surveys at Tobi. Fifteen of the species were seen for the first time in Palau on Tobi's reefs (Table 1-3, Donaldson). These totals are highest for any of the Southwest Island reefs except for those of Helen atoll (Donaldson, this volume). Again, the variable, and at times convergent, ocean current systems in the vicinity of Tobi and Helen may indirectly contribute higher numbers of colonizing species than would otherwise occur. An alternative hypothesis is the Palau Islands -- Caroline Islands -- Marshall Islands "conduit" along which species richness increases to the west and species endemism increases to the east (see Donaldson, this volume; Myers, 1989). Also the close proximity of the Southwest Islands to the species rich Indonesian archipelago may also be responsible for higher species diversity (Donaldson, this volume).

As with the case at Helen, over-fishing of sought-after or commercially important fish species at Tobi was not evident. Fish populations appear abundant and healthy.

**Archaeological and Historical Resources**

Maps prepared by Hambruch in Eilers (1936) show the extent of a larger, more complex Tobian society of nearly 1,000 residents at the turn-of-the-century (Figures 3 & 4 in Hunter-Anderson). Land-use was divided among agricultural and residential zones which included many specialized structures: family houses, taro-cooking houses, turtle-cooking houses, fish-cooking houses, resting houses, canoe houses, spirit houses, etc. (Hunter-Anderson, this volume). Stone-lined wells were located among residences and rows of stone sub-divided and delineated the interior taro patches.

Along the island's west side as shown on Hambruch's map was a iporu: an earthen mound where menstrual seclusion houses and a children's cemetery were located (Figure 3). This area was examined during the June 1992 archaeological survey (Hunter-Anderson, this volume). The seaward side is actively eroding into the sea, possibly caused by the excavation of the dredged channel through the nearby reef which set-up strong lateral and rip currents.

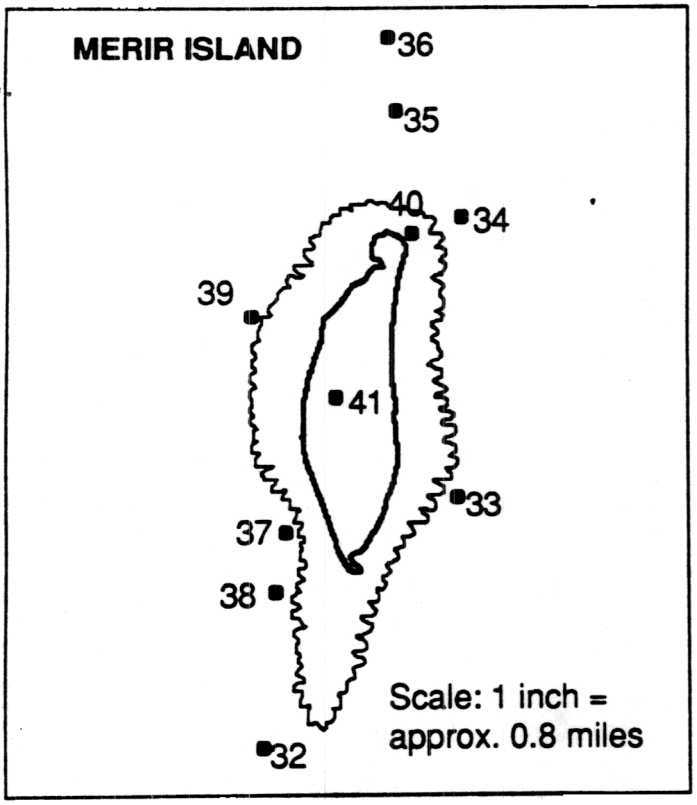
Other archaeological features surveyed at Tobi included 17 bonum or "refuse" mounds consisting of spent earth-oven rocks and carbon-rich soils. The bonum were among the sites subjected to carbon-dating. The three radio-carbon dates varied between 210 - 250 years before present ± 50 to 80 years. These ages are consistent with oral history accounts which maintain that the ancestral islanders reached Tobi 17 generations ago from Fais Atoll in western Yap. The iporu bonum were also subjected

to test excavations and the eroded face of the iporu mound was profiled (Hunter-Anderson, this volume).

A variety of artifacts were observed during the Tobi surveys including *Tridacna* lures, turtle bone fish hooks, *Conus* beads, *Trochus* bracelet fragments, *Tridacna* adzes, Palauan pottery sherds, bivalve scrapers, *Tridacna* gouge adzes and human infant bones.

Historic era features and activities included Japanese phosphate mining depressions which destroyed a large portion of the interior taro patch. Remains of the phosphate mining company office, residence, store house, and drying room can still be seen in the present village. Several concrete water cisterns and the concrete remains of a communication station both built by the Japanese were observed but not surveyed during the June 1992 expedition (Hunter-Anderson, this volume). Paleosediment coring was conducted in the northern interior, resulting in a basal soil date of 250 ± 50 years before present.

**Merir [Melieli] (Figures 3 in Maragos and 5 in Kepler)**




Merir Island occurs approximately 420 km south of Koror and is located at 4° 19′ N Latitude and 123° 19′ E Longitude. Merir (99 ha) is irregularly elliptical and fringed by extensive shallow reef flats varying between 250 - 500 m in width. Politically, Merir is a part of Sonsorol State. Merir is the second largest island after Sonsorol and supports the second largest reef system after Helen in the Southwest Islands group. The boat landing on the western side of the island is not dredged and is only usable at high tide and calm seas. A small village of several buildings are situated on an earthen mound, and a single cross-island trail of coral chunks originates at the principal dwelling. There are no vehicles on the island.

**Population**

The present population consists of a five-member family unit: a father and four children. Last century, Merir supported a thousand people (Motoda, 1939) many of whom died as a result of the 1905 typhoon and over 100 others were later evacuated. In 1935 there were 17 islanders and nine Japanese, and at the end of World War II the

island was uninhabited. Merir has been continuously occupied over the past 20 years by five to seven people. The present family tends a garden and subsists off of fish, sea turtles, coconut crabs and seabirds.

### Vegetation

Merir is densely forested with indigenous trees (56 ha) and an inland mangrove depression (30 ha) (Table 2). Remaining vegetation habitats are coconut forest (5.6 ha), strand forest (6.7 ha), and a small *Tournefortia* scrub forest (0.7 ha). About 94% of the land area is covered with native forest, and 68% of the plant species are indigenous. Humidity is high and the dense forest is nearly airless and choked with tangled vegetation and debris. Chiggers and mosquitoes are major nuisances.

The land plants consist of 63 species, including six species of ferns (Table 2 in Kepler). The strand and mixed forests are well-developed and the large mangrove depression was formerly an open, shallow, salty marsh (Motoda, 1939). Storms or wave action closed off the shoreline connection to the sea and the depression eventually became choked with mangroves (Kepler, this volume).

### Birds

Merir has few birds. Only 10 species were reported, all with very low populations. The total estimated population is 500 - 700 birds or an average of six to seven per hectare. In 1979 Engbring estimated 3,100 - 5,350 breeding seabirds on Merir. The lack of avifauna is likely caused by several factors: an inhospiTable environment, disturbance by dogs, and past typhoon damage (Kepler, this volume).

Of the 10 bird species, six are seabirds, one a shorebird, one a water bird, and two are land birds (Table 5 in Kepler). One seabird (Bulwer's Petrel) reported 25 km off shore from Merir is the first sighting of this species in the Southwest Islands. In addition, an unpublished 1991 sighting of a vagrant Kookaburra is also the first sighting of this species, confirming land bird colonization of Micronesia via the Australo-Papua route (Kepler, this volume). Three of the seabird species nest at Merir including the Brown Noddy (now 200 - 300 birds, but in 1979 2,000 - 3,000 birds), and the White Tern (in similar numbers). Frigatebirds formerly nested on Merir (Kepler, this volume).

### Reptiles

Three species including one new species of gecko and two unidentified species of skinks were collected at Merir (Table 3 in Kepler). No crocodiles have been seen in the interior depression since the 1908 record (Eilers, 1935).

Swimming and feeding sea turtles were very common at Merir and reported at nearly all the dive sites. Merir is certainly the most productive green sea turtle nesting island in Palau, but not for the the island archipelagos under United States jurisdiction, as some of the islands in Yap (such as Gielop and Iar) have larger nesting populations (Pritchard, 1977; 1981; Geermans, this volume). During the survey of 11-13 June 1992, 54 sets of turtle tracks one to five days old were reported. The tracks were

concentrated in two areas, the southeast and northwest beaches. No hatchling tracks were sighted. Green turtle bones and scutes were observed on the island. During the two nights of observation, 12 beachings and three successful nestings were observed. One nesting adult was captured by the islanders on 12 June 1992 and killed before she had laid her eggs. The total green turtle nesting population of Merir for 1992 is less than 100. The islanders kill and consume a turtle every two weeks on an average. This rate is not sustainable over the long-term which will result in steady declines in the nesting populations (Geermans, this volume).

### Mammals

Black rats were superabundant at Merir, and may contribute to the decline in nesting seabirds. No fruit bats or large fig trees were seen. A pack of 27 dogs maintained by the resident family ran loose over the island and forage on both the land and reef flats.

### Crabs

Coconut crabs, formerly present throughout the island, now occupy a much reduced area. The mangrove depression serves as a refuge for the crab populations; no doubt the impenetrable vegetation and water-saturated soils have discouraged more intensive harvesting. Twenty-two crabs were found in a 1,000 m long and 30 m wide swath; crab densities are low, less than 10 per hectare. Males were twice as common as females. The average size of the crabs were small. The largest crab was a male weighing 4 kg. Coconut crabs are harvested and are considered a delicacy. On Merir gravid (egg-bearing) females are eaten (Kepler, this volume). Some crabs are collected by passing boats for sale in Koror and other localities. As on the other islands, coconut crab populations are in steady decline but are most likely to survive in small numbers due to their primary remaining mangrove habitat.

Two other common land crab species were also collected at Merir. Both species were common at Merir. One species: *Coenobita perlatus* was seen only at Merir during the expedition, but is a common inhabitant of central Pacific islands (Kepler, this volume).

### Marine plants

Merir had the second highest number of seaweed taxa (35) recorded during the expedition after Helen's 44 types. The greatest number of green algae were reported at Merir (19 species). Thirteen red algae and brown alga were also recorded at Merir. The green alga *Caulerpa ambigua*, the brown alga *Sargassum,* and the red alga *Eupogodon* were seen only at Merir (McDermid, this volume).

### Stony corals

A total of 132 species of stony corals were reported from Merir during the 1992 expedition (Table 6 of Maragos), the third highest total after Helen and Tobi, and slightly more than that of Sonsorol. Despite comparable sampling intensity, reef dimensions, and habitat diversity, 40 fewer coral species were reported from Merir than Tobi. The closer proximity of Tobi to Southeast Asia and the converging current patterns may explain Tobi's higher coral diversity. Only one Merir species was a first

sighting in Palau, *Acropora latistella*, which was also reported at four of the remaining five islands (Maragos, this volume).

Coral communities were very healthy on the reef slopes. Due to the shallow nature of the reef flats, only a few corals were reported alive on the middle and inner zones of the reef flat. Filamentous algae were particularly common on the reef flats, especially close to the shore. There was no sign of lingering damage to corals or reef formations from previous typhoons and storms.

**Fishes**

A total of 288 species of fish were recorded during the 1992 scuba surveys at Merir, the third highest total after Helen and Tobi. Ten of the Tobi species were first time sightings in Palau. Two species: *Istigobius rigilus* and *Chilomycterus reticulatus* were seen only at Merir. Fish populations looked healthy and with little sign of harvesting pressure. Many species of commercial or subsistence importance were observed at Merir.

**Archaeological and Historical Information and Resources**

Previous archaeological surveys at Merir (Osborne, 1966; 1979) made note of a large high mound at a site called Meteriharingamahoh. As with Tobi's mound, the western (ocean) face of the Merir mound is being eroded by waves and currents. The mound is used as a settlement site and undoubtedly affords protection to those who take refuge on it during typhoons and storm waves. There is no dredged channel at Merir, and the settlement site is accessible by boat at high tide over the reef flat during moderate to light seas. A natural raised reef ramp does provide some protection for boats at the shoreline. A few shell artifacts, including *Tridacna* lures, and cut shells, were seen on the beach next to the mound. According to interviews with Mr. Andres Antonio, the chief of the island, several structures were once built and used on top and on the sides of the mound, including residences, menstrual seclusion houses, an infant burial site, and shark-eating areas, in accordance with traditional customs of the early islanders. Canoe houses were also constructed nearby (see Figs. 23 & 24 in Hunter-Anderson).

Prior to the war, one Japanese man lived on Merir, who smoked fish and sent it to Japan. During the war, 1,500 Japanese soldiers were stationed on the island, and in 1945, were repatriated by the United States military. Japanese built stone-lined wells, and a Japanese memorial to their war dead is also located near the mound/settlement.

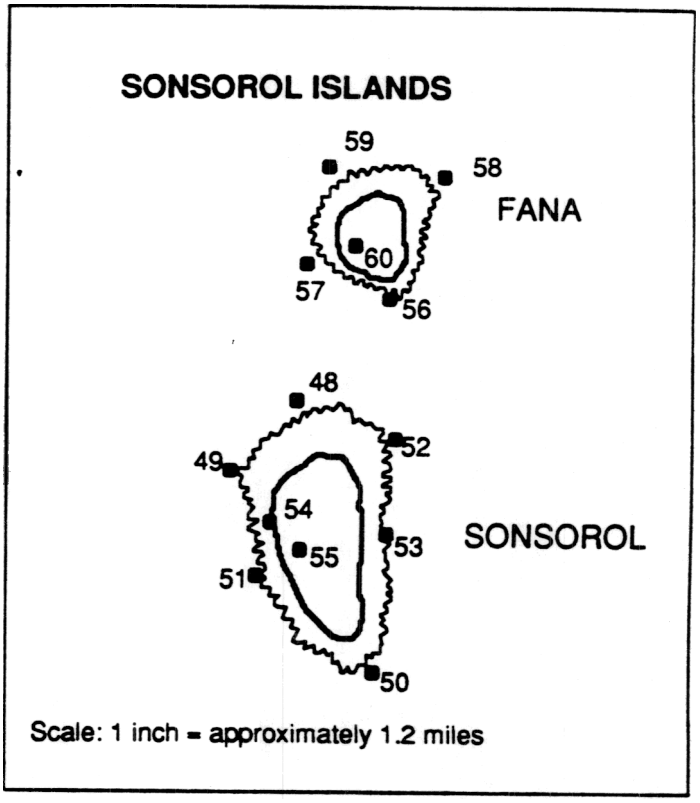
According to Mr. Antonio, Euraipik was the home island of the man (Daukepit) who first discovered Merir.

Archaeological excavations, paleosediment cores, and radiocarbon dating were accomplished during the 1992 visit to Merir. The excavations near the bonum mound revealed white ash lenses, burned coral gravels, sand, turtle bones, and charcoal. The age of the deposit was recent (60 years ± 60 years) (Hunter-Anderson, this volume).

The sediment coring was done at the taro (*Cyrtosperma chamissonis*) patches near the northern part of Merir. The radiocarbon analyses yielded a date of 1,100 years ± 60 years. This is the oldest date recorded during the expedition, but without the corroboration of a similar date from one or more of the domestic features, it is not possible to conclude that human settlement (and taro cultivation) occurred over a millennium ago.

**Pulo Anna [Purr] (Figure 5 of Maragos and Fig. 6 of Kepler)**

With an area of 37.9 ha, Pulo Anna is the second smallest of the Southwest Islands and the reef habitat is also the second least abundant in terms of reef slope length and reef flat area (Table 3, Maragos). The island supports more lush open forests, trails, coconut plantations, lizard species, and land crabs than any other Southwest Island. Pulo Anna lies about 60 km northwest of Merir, the nearest island. The island is surrounded by a fringing reef varying between 150 - 500 m in width. It is the only island with a large central body of open water: a brackish swamp heavily littered with logs. There is no dredged channel or constructed landing to facilitate small boat access to the island.




**Population**

A small village of about 20 people is located at the south end of the island. At the time of the visit, the islanders were busy cooking land crabs, preparing chickens and ducks, husking drinking coconuts, and weaving coconut baskets. These commodities were bound for Koror. The English language is not used by the islanders, hampering some of the interviews. The island has supported more people in the past as evidenced by the extent of abandoned coconut plantations, but not for several decades.

**Vegetation**

The dominant vegetation is indigenous mixed forest (16.8 ha) and coconut forest (13.3 ha). Mangroves (2.8) ha) fringed the open swamp; Pulo Anna and Merir are the only Southwest Islands with mangrove stands. Pulo Anna also supports a small strand forest (1.4 ha) (see Figure 6 of Kepler, this volume). The mangroves were formerly more extensive, but were cleared by the United States military to control mosquitoes. The southern edge of the swamp is partitioned into a series of brackish ponds no

longer in use for aquaculture during the 1992 expedition. The nypa palm was found at Pulo Anna. *Alocasia* taro is grown extensively for food.

The vascular flora of Pulo Anna consists of 50 species, including four species of ferns. The proportion of indigenous plant species is 76%, and the proportion of land area in native forest is 55 per cent. Pulo Anna supported a number of large or otherwise noTable trees including *Artocarpus*, *Callophyllum*, *Neisosperma*, *Pisonia*, and *Syzgium* (see Table 3 of Kepler, this volume).

### Birds

Twelve species of birds were reported from Pulo Anna, including seven seabirds, two shorebirds, one water bird, and two land birds (see Table 5 of Kepler, this volume). An all black, unidentified species of cormorant is a first time sighting in Palau. Two other species: Audubon's Shearwater and Bulwer's Petrel were first time sightings for the Southwest Islands and three species: Red-footed Booby, Black-naped Tern, and Oriental Cuckoo were first time sightings for Pulo Anna.

Bird populations were not high but appeared sTable, and population estimates were comparable to those of 1979 (Engbring, 1983; Kepler, this volume). Some birds are consumed, and juvenile frigatebirds are kept as "homing pigeons", moving between Pulo Anna and Sonsorol. There were four species of breeding seabirds: Brown Noddies, Black Noddies, White Terns and White-tailed Tropicbirds. The total nesting population was estimated at 1,050 - 1,600 birds (see Table 6 of Kepler, this volume).

### Reptiles

Pulo Anna is exceedingly rich in small reptiles, having the highest diversity and density of lizards in the Southwest Islands. Eight different species were collected, and some may be species new to science. Most were reported only from Pulo Anna (Table 8 of Kepler, this volume).

Green sea turtles nest on Pulo Anna, but only in small numbers. One nesting track three to four days old was reported on 15 June 1992, but no hatchling tracks or nesting adults were seen. Green turtle bones and scutes were found on the beaches and swimming turtles were common at the dive sites along the ocean reef slopes of Pulo Anna.

### Mammals

Rats are common on Pulo Anna, especially within the coconut plantations where food is plentiful. They appear not to be harming the nesting bird populations. No fruit bats occur at Pulo Anna, according to the residents.

### Crabs

Coconut crabs occur on Pulo Anna but are heavily harvested; of the eight crabs seen, all were males and five were partly legless and tied-up in the village. The skewed sex

ratios are indicative of over-harvesting, and the residents are aware of the crabs' dwindling numbers.

Large land crabs occurred in prodigious numbers on Pulo Anna. Crab densities are very high, and it was necessary for the scientists to watch each step, especially in the coconut plantations, to avoid crushing or stepping in land crab burrows. The crabs are collected and cooked for off-island shipment by the women villagers. The residents prefer to eat the tastier coconut crabs, which may explain the scarcity of coconut crabs relative to the land crabs (Kepler, this volume).

**Marine plants**

Twenty-seven types of marine algae were reported from Pulo Anna, the second lowest of the Southwest Island totals. Of these, 16 were red algae, 10 were green algae and one was a brown alga species. Surprisingly, no *Halimeda* species were observed or collected on Pulo Anna. No algae species were found exclusively at Pulo Anna (McDermid, this volume).

**Stony corals**

A total of 99 species of reef corals were reported at Pulo Anna, the second lowest total of the six southwest islands. Four species sighted for the first time in Palau, and two of these were reported only from the reefs at Pulo Anna. Coral populations were luxuriant and healthy on the transect stations, and there was no visible sign of pollution or stress (Maragos, this volume).

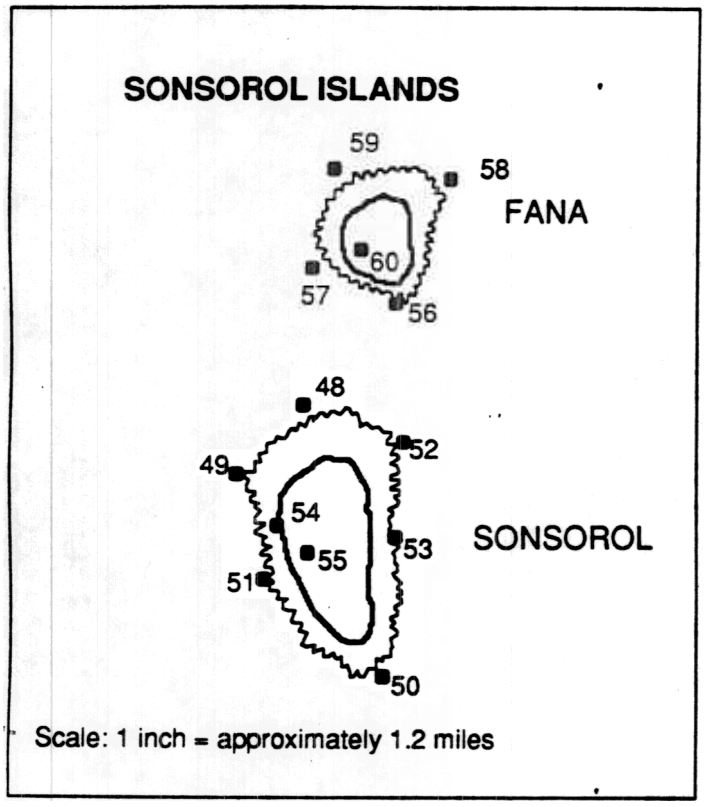
**Reef fishes**

A total of 197 species of fish were reported from Pulo Anna. This number was the second lowest of the totals reported for each of the six islands, as in the case for corals and algae. Only three of the species were sighted for the first time in Palau, and all three were found at one or more of the other Southwest Island/reefs. Fish populations appeared to be abundant and healthy, with many species of subsistence and commercial importance present (Donaldson, this volume).

**Archaeological and Historical Resources**

An ancient mound is situated where the old village was situated, and a new village is presently being built on the mound. Interviews with residents indicated that several traditional structures were located on the mound, including two iporu (menstrual seclusion/childbirth areas). An archaeological trench dug in the mound yielded coral gravels and charcoal. The charcoal samples yielded radiocarbon dates of 130 years ± 50 years, and 290 years ± 80 years. Turtle bones, fish bones, and marine mollusks were present in both layers. A core soil sample from the giant swamp taro cultivation area was also taken, but has not yet been dated. Time was insufficient to conduct more extensive archaeological surveys at Pulo Anna (Hunter-Anderson, this volume).

**Sonsorol [Dangosaro]** (Figure 6 of Maragos, and Fig. 7 of Kepler)




Sonsorol is the largest of the Southwest Islands with a land area of 120 ha (Table 2). Reef habitat area is the third most abundant of the Southwest Islands (Table 3) and comparable to the size of Tobi's reefs. Sonsorol lies about 80 km northeast of Pulo Anna and is the capitol island of the State of Sonsorol. Fanna Island is located 3 km north of Sonsorol. Fringing reefs surround the island with the reef flats varying in width between 200 - 470 m. Seabirds were plentiful, and the extensive forests were diverse and replete with large trees. A wrecked Palauan patrol boat lay on the northwestern beach. The village area was located along the west coast, and a shallow channel was dredged across most of the reef flat during the Japanese Mandate era.

**Population**

The neatly trimmed village is inhabited by 19 people and is tidy with landscaping and ornamental plants. Clipped lawns connect the houses and extend along the trails. The houses were mostly built of wood and corrugated iron. There are only a few inland trails and no roads. The population of Sonsorol was higher in the past. During the Japanese era, phosphate mining was extensive at Sonsorol, and the United States military occupied the Island after the end of World War II, when the Sonsorolese people were removed to Angaur (pers. comm. Gov. Flavian to Rosalind Hunter-Anderson).

**Vegetation**

Mixed forest (59.3 ha), coconut forest (11.5 ha) and a mixture of the two (42.5 ha) dominate the vegetation cover of Sonsorol. A strand forest (3.8 ha) occurs around the perimeter of the island. Approximately 85% of the land area contains forests mostly of native species. A number of noTable trees were recorded at Sonsorol, including: *Artocarpus*, *Calophyllum*, *Ficus*, *Neisosperma*, and *Pisonia* (Table 3 of Kepler, this volume). *Alocasia* taro is grown for food.

The vascular flora consists of 75 species including eight species of ferns. Sixty-five percent of the species were indigenous. Sonsorol and Fanna were the only islands with native orchids (Kepler, this volume).

### Birds

Twenty species of birds were reported at Sonsorol during the 1993 expedition including 11 seabirds, three shorebirds, three waterbirds, and three land birds. Four species (Bulwer's Petrel, Audubon's Shearwater, Common Black-headed Gull and Micronesian Pigeon) were first time sightings for the Southwest Islands. The pigeon is a recent introduction from Palau. Four bird species (Red-tailed Tropicbird, Little Egret, Great Crested Tern, and Dollarbird) were first recorded from Sonsorol Islands during the 1992 surveys.

The islanders have access to birds on both Sonsorol and Fanna and prefer to eat Noddies, terns, and boobies. Bird feathers are also featured in fishing lures and headdresses. Juvenile frigatebirds are kept as pets ("homing pigeons"). Each young frigate is trained to fish at sea and return to a perch. Then a piece of red cloth with a boy's name on it is tied to one leg, and the bird flies to Pulo Anna, some 80 km distant. Afterwards the bird is sent back to Sonsorol with another streamer.

Four species of breeding seabirds numbering 1,700 - 3,050 birds use Sonsorol Island. Most abundant are White Terns, and much less common are Brown and Black Noddies. The noddy populations have dwindled over the past 20 years (Muller, 1973; Engbring, 1983a; Kepler, this volume). White-tailed Tropicbirds also nest in large fig (*Ficus*) trees and *Callophyllum* trees on the island. Red-tailed Tropicbirds may also nest in the trees, according to the residents (Kepler, this volume).

### Reptiles

A total of five species of lizards were collected from Sonsorol, all of uncertain identity (Table 8 of Kepler, this volume). Of particular interest was a gecko resembling a New Guinea species, and a undetermined skink (Kepler, this volume).

Green turtles occasionally nest at Sonsorol but no evidence of recent hatchling or adult tracks were sighted. Green turtle bones and scutes were present. According to residents, nesting occurs on Sonsorol and Fanna between February and August (Geermans, this volume).

### Mammals

Two fruit bat colonies were found with 56 and eight bats respectively. Fruit bats are considered a delicacy by the residents, and their populations are declining.

### Crabs and Other Arthropods

Coconut crabs on Sonsorol are rare or absent. The islanders now harvest them from Fanna for domestic consumption and off-island shipment, and are concerned that their

numbers are dwindling. One land crab species was also observed and collected during the 1992 expedition.

Prior to the expedition, Sonsorolese officials informed us that coconut beetles were damaging coconut palms on Sonsorol. One beetle was collected. The *Scolia* wasp was not observed, which is one of two biological control measures introduced by the Palauan government in 1984 to control coconut beetles (Demei Otobed and Haruo Adebai, pers. comm. with Kay Kepler).

**Marine Plants**

Thirty-three taxa of marine algae were collected from Sonsorol, the fourth highest total compared to those of the rest of the Southwest Island reefs. The largest number of red algae (23) were reported from Sonsorol. Eight species of green algae and two species of brown algae were also recorded. Sonsorol was the only island where *Neomeris Lobophora*, *Dictyuris* and *Gelidiopsis scoparia* were collected (McDermid, this volume).

**Stony Corals**

A total of 130 species of reef corals were reported from Sonsorol, the fourth highest total for the Southwest Island reefs. The numbers were comparable to those of Merir but much lower than those of Tobi and Helen and much higher than those of Pulo Anna and nearby Fanna. Six of the Sonsorol species and one genus (*Australogyra*) are first time sightings for Palau. All of the coral reefs were in good health with no visible signs of pollution or stress to the reefs. The recent grounding of a patrol boat at Sonsorol did not appear to cause any lingering damage to the reef (Maragos, this volume).

**Fishes**

A total of 249 species of fish were recorded at Sonsorol during the 1992 expedition, the fourth highest total among those for the six Southwest Islands. Five of the species first time sightings for Palau but were also reported at one or more of the remaining Southwest Islands during the 1992 surveys. Fish populations appeared diverse, healthy and abundant. Many species of subsistence or commercial importance were observed.

**Archaeological and Historical Resources**

The prehistoric record of human occupation on Sonsorol has been seriously disturbed during the past century by Japanese phosphate mining and American military occupation. Previous archaeological studies at Sonsorol (Osborne, 1966; 1979) revealed a chiefly meeting house site called Faremau. Oral history indicated the site has been deliberately kept free of large trees. The site was mapped (Figure 3 of Hunter-Anderson, this volume), photographed and subjected to test excavation during the 1992 visit. Recent artifacts including glass fragments, tar paper roofing and one turtle bone was uncovered from one pit while turtle bones, charcoal, fish bones, burned coral bits, and worked turtle bones were recovered from another nearby pit. The charcoal yielded radiocarbon dates of 110 ± 60 years. Elsewhere a carved stone head was observed and photographed (Hunter-Anderson, this volume, Fig. 31).

Remnants of hand cart rails used during the phosphate mining activities could be seen Also further inland from the east side was an extensive complex of World War II Japanese fortifications, elevated walkways, tunnels, and gun emplacements, all in excellent condition.

No interior taro patch exists on Sonsorol, so paleosediment coring was not undertaken (Hunter-Anderson, this volume).

**Fanna [Fanna]** (Figure 7 of Maragos and Fig. 8 of Kepler)
Fanna is the third smallest of the Southwest Islands (39.8 ha) and has the smallest amount of reef habitat of any of the six islands (Table 3). Although uninhabited, Fanna is located only 3 km north of Sonsorol. Fanna is regularly visited by the residents of Sonsorol and serves as a traditional "reserve" or pantry island where various resources are periodically harvested. Both the island and reef are rounded. The reef flats appear to be slightly deeper than those off the other islands. The reef flats surrounding the island vary in width between 160 - 400 m. The island itself measures about 670 m wide and 840 m long. A small picnic shelter and house are located near the small boat landing site on the west side. The island supports outstanding indigenous forests, spectacular seabird colonies, and coconut crab populations. Three well maintained trails serve the coconut plantation.

### Vegetation

Fanna's vegetation has two outstanding components: a well developed, centralized *Pisonia grandis* grove (9.9 ha) and a well developed continuous strand or beach forest around the island's perimeter (5.3 ha). Both of these indigenous forests were the best examples reported from the Southwest Islands. The other vegetation communities are indigenous mixed forest (19.8 ha) and coconut forest (3.7 ha).

Twenty-six species of vascular plants were found on the island including three species of ferns (Table 2, Kepler, this volume). About 88% of the land area supports indigenous vegetation and 75% of the species are indigenous. The pure stand of *Pisonia grandis* is one of the finest representatives of this ecosystem in the Pacific. Many of the large trees were stately and noTable including *Artrocarpus*, *Ficus*, *Neisosperma*, and *Pisonia* (Table 3 of Kepler, this volume).

### Birds

Ten species of birds were reported during the 1992 expedition, seven seabirds, two shorebirds, and one water bird. The total population estimate was 23,000 to 29,000, an average of 676 - 853 birds per hectare. Accurate counts of bird populations suffered from the lack of adequate time for the censuses. The Black Noddy nesting colony was estimated at 10,000 birds, and White Terns were nearly as abundant at 8,000 - 10,000 birds. These are the largest colonies of these two species in Palau. Red-footed Boobies also numbered about 6,000 - 8,000 birds and about 1,000 nests were counted during a boat census around the island's perimeter.

The Southwest islanders informed us that many of Helen's Red-footed Boobies have now settled on Fanna, explaining some of the decline in numbers at Helen and the increase in numbers at Fanna compared to earlier censuses. Likewise, some of the Brown Boobies driven from Helen may also have settled at Fanna. The Brown Noddy is a ground nester sensitive to human disturbance. Recently, the Chief of Sonsorol has forbidden the killing of the Brown Boobies on Fanna. However, many rotting carcasses, emaciated fledglings, and unattended nest sites are suggestive of major disturbance. Crested Terns and Masked Boobies also visited Fanna in 1992 but did not nest successfully (Kepler, this volume).

### Reptiles

Three species of small lizards were collected (Table 8 of Kepler, this volume) and all may be species new to science. No activity or evidence of sea turtle nesting was observed on Fanna. Turtle scutes and bones were also absent. However, turtles captured on Fanna may be transported to Sonsorol before they are butchered (Geermans, this volume).

### Mammals

Fruit bats are present and probably roost on Fanna. No information was available on rats.

### Crabs

Prior to the expedition, the State of Sonsorol requested advice on regulating and monitoring Fanna's coconut crab harvests. Populations have declined, and the average size of crabs have dwindled which are of concern to the islanders. Twenty-three crabs were measured on Fanna. Males were more common and there were numerous empty cavities in the bases of *Pisonia* trunks, favored sites for nesting crabs. The small size and number of crabs indicate that the islanders have been over-harvesting coconut crabs for both local consumption and off-island export. Decades of strict controls over hunting may be required for recovery of the crab populations.

### Marine plants

Twenty-one taxa of marine algae were collected off the reefs of Fanna including 11 species of red algae, 10 species of green algae, and no brown algae. These are the lowest totals for any of the six Southwest Islands. None of the algal species were reported only from Fanna (McDermid, this volume).

### Stony corals

A total of 94 species of stony corals were reported on the reefs at Fanna which is the lowest total for any of the Southwest Islands. Two of the Fanna species were first time sightings for Palau, and one species: *Astreopora listeri*, has been reported only from Fanna. The coral community and reef habitats are in excellent condition with no signs of pollution or stress (Maragos, this volume).

### Fishes

A total of 195 species of fish were reported at Fanna, also the lowest total for any of the six Southwest Islands. Four of the species were first time sightings in Palau at Fanna and one: *Parapercis clathrata*, was reported only from Fanna. Fish populations looked abundant and healthy, including many species of subsistence and commercial importance (Donaldson, this volume).

### Archaeological and historical resources

Although not presently inhabited, Fanna was settled earlier this century and probably also prehistorically. An extensive surface cultural deposit (midden) near the picnic area revealed much marine shell, including a *Conus* bead, a *Tridacna* adze fragment and an andesite pounder fragment. The usual source of hard volcanic rocks is the soil embedded in the roots of large drift logs. West of the midden area were rock alignments of coral, possibly marking old house sites.

Oral history reveals that Fanna has two sacred areas: Farepado and Farebos. Test excavations were accomplished at both sites. The Farepado probe yielded no cultural material and a few burnt coral fragments. Another site called Wayreng was also probed but yielded no cultural remains. The test excavations at Farebos yielded burned coral, and a possible *bonum* deposit containing a ceramic pottery sherd of Palauan origin, turtle bones, and marine food shells. Since no charcoal was present, a bulk soil sample was collected for radiocarbon dating. The age was estimated at 101 years ± years, an inconclusive result. An additional sample consisting of a *Spondylus* shell has also been submitted for radiocarbon dating.

## Discussion

The Southwest Palau Islands expedition revealed a wealth of information about the cultural and natural resources of the islands and reefs, and insights on trends in resource abundance and use. Collectively these remote islands support ecosystems and resources of national and international importance: tall indigenous forests, large seabird colonies, a diverse and abundant lizard fauna, including species new to science, notable coconut crab populations, large populations of nesting and feeding sea turtles, diverse fisheries including many large prized species, and a diverse coral and marine invertebrate fauna. The ecological value of these islands and reefs far outweigh their small size. General findings are summarized below.

### Population

The 1992 survey corroborated the fact that human population levels are presently declining steadily on the three most populous islands (Tobi, Pulo Anna, and Sonsorol). Merir's population decline occurred near the turn-of-the-century. Population levels on the two remaining (and smallest) islets have always been low. Reversing the population declines on the three most populous islands will require an increased standard of living and better communication and shipping of foods, supplies and medicines between the southwest and main islands of Palau.

New employment opportunities on the islands, as suggested by the islanders themselves, could bring in revenues to improve living conditions on the islands. A variety of possibilities exist: ecotourism facilities, sport diving tours, exploitation of pelagic fisheries for sale to the main islands and other markets, handicrafts, specialized food production (such as now occurs on Pulo Anna), mariculture of desirable or economically important fin fish and shell fish, and jobs to support research, surveillance and conservation activities if one or more of the Southwest Islands is designated or targeted for long-range protection and monitoring.

In contrast, existing efforts to collect and trade coconut crabs, birds, bird eggs, turtles, turtle eggs, and possibly giant clams are all doomed to failure because the life histories of all these species do not lend themselves to constant and high levels of exploitation. The above species all share in common the following attributes: 1) the adults are large and long-lived with few natural predators; 2) repetitive breeding and egg-laying by older, mature adults is the predominant reproductive strategy. As long as man is not a constant predator, populations of these species can be sTable over long time spans. However, the over-harvesting of the largest individuals (the most important breeders) is defeating the reproductive strategy of these species and is leading to rapid decline in population levels. Fewer and smaller adults are left to reproduce, causing first declines and eventually total loss of reproductive potential. Sustainable harvesting of these species must occur at very slow rates to allow the populations to replenish themselves naturally. The taking of egg-bearing adults (as witnessed for turtles on Merir, and coconut crabs on several islands), depletes both the breeding populations and their ability to reproduce offspring. The islanders are better off in the long run to selectively harvest shorter-lived, faster-growing species which reproduce more rapidly, such as reef fishes and offshore pelagic fishes (tunas). Maricultural development may also be successful in restocking some depleted species of high value, such as giant clams.

**Cultural Resources**

The ongoing rapid population declines in the islands also threatens the culture of the islanders. Elders and teachers that move away from the islands can no longer pass on important cultural information such as traditional lore and customs, conservation practices, harvesting techniques, harvesting sites, and historical knowledge. For example, the decline of Tobi's population from 70 in 1979 to less than 30 in 1993 means that some of the fishing techniques used in the past are no longer practiced (see for example Johannes and Black, 1981). The recent loss of the school teachers will further reduce educational opportunities for children, and elders residing in Koror will not be capable of passing on their knowledge to the remaining islanders.

It is clear that a concerted effort is needed to preserve and transfer cultural information and customs to the next generation through the efforts of villagers, anthropologists, ethnologists, archaeologists, and skilled educators. Formal education and schools on each of the three main islands which include greater emphasis on cultural and traditional values is essential to the cultural survival of the remaining Southwest

islanders on the islands. Once the islanders and their children leave, few will ever return. Those that do must be properly educated and trained, taking advantage of the rich knowledge of the local culture.

**Anchorages and boat landings**

None of the Southwest Islands are large enough to support airstrips. Thus, better communication and trade with off-islanders must depend upon reliable ship transportation and safe areas to load and unload passengers and cargo. Although Tobi and Sonsorol both have shallow channels blasted or dredged through the reefs, these channels are not safe to use except at higher tides when wave action is not severe. Pulo Anna furthermore, lacks any type of docking facility or anchorage. On the other hand, improperly designed or constructed docks and channels can cause environmental impacts. For example, the dredged channel at Tobi has strengthened long shore and rip currents, accelerating shoreline erosion near the important iporu mound. The construction of new channels or improvements to existing channels must be approached with extreme caution, and should require an environmental impact assessment.

**Vegetation**

The lush, indigenous vegetation of the Southwest Islands was healthier and more extensive than anticipated by the survey team. Large areas of abandoned coconut forests have already reverted to relatively weed-free, native plant cover. The diverse mixed forests, although composed primarily of species found elsewhere, are unique to this geographical area. All forests provide invaluable resources for shoreline and typhoon protection, enriched soil for garden crops, breeding seabirds, land birds, and fruit bats, medicinal plants, and refuges for other land biota such as coconut crabs and endemic lizards. Some large trees are prime examples of their species in Micronesia and the Pacific region. Although most of the important forested areas are not in immediate jeopardy (except the *Tournefortia* scrub forest on Helen), long-range planning and foresight is needed now to formally protect the most critical habitats.

The non-traditional clearing and cutting of trees on Helen for firewood will eventually denude the island of its principal vegetation and protection from shoreline erosion. The use of fallen coconut trees, driftwood or off-island sources of wood and charcoal could eliminate tree-cutting and allow the scrub forest to recover. Rehabilitation or reforestation of the scrub may also be an option. Helen Island is a sand bar ill-suited for permanent residents and reducing the population to a few caretakers and occasional visitors would also reduce impacts to the scrub forest.

Mangrove forests are rare in the Southwest Islands, but good stands still persist at Merir and Pulo Anna. Mangroves apparently serve as refuges for the few remaining coconut crabs that have escaped intensive harvesting pressures elsewhere. Harvesting is difficult in mangroves because of the impenetrable vegetation and soggy wet soils.

Forest cover on Fanna and Helen are also critical to the survival of many depleted seabird colonies. For example, Fanna's interior *Pisonia* forest isone of the best remaining stands in the Pacific important for coconut crabs, Black Noddies and White Terns. The strand forest surrounding Fanna at the shoreline is also thick and relatively undisturbed. Smaller patches of forests on other islands also serve important functions and should be considered for greater protection.

**Birds**

Overall, bird populations have seriously declined in the Southwest Islands over the past 15 years. At Helen the declines were attributed to tern egg collection, and the killing or harassment of boobies. Portions of previous nesting colonies apparently have moved to Fanna. Dogs, and perhaps rats, are also serious pests and predators of seabirds on some islands (especially Helen and Merir). Also on Merir, bird populations may also have declined due to disturbance by mosquitoes. It is difficult to remove these pests once established on islands, but their impact can be reduced through control programs.

The forests and beaches at Helen and Fanna are essential habitat for the survival of several rare or vulnerable bird species in Palau: Great Crested Terns, Brown Boobies, Red-footed Boobies, Masked Boobies, and Sooty Terns. The Great Crested Tern colony is the largest known from the Pacific and Southeast Asia. Helen's reefs also support the highest diversity and density of shorebirds and waterbirds in the Southwest Islands. Fanna's White Tern and Black Noddy colonies are the largest in Palau and some of the largest in the Pacific. As a result, both Helen and Fanna should be afforded more extensive or comprehensive protection, which encompasses most or all of both islands.

**Reptiles**

Land reptiles do not appear to be in any danger on any of the islands except for possible rat predation. However, further research on the lizards may be of scientific importance due to the large number of new species.

Marine reptiles reported on the Southwest Islands included an occasional sea snake, one record of a crocodile in Merir's mangrove swamp, and the populations of sea turtles throughout the Southwest Islands. Although both Hawksbill and Green turtles are common on the reef slopes of all islands and in Helen's lagoon, only Green turtles appear to nest in the islands. The eggs and meat of turtles is highly prized. In the old days, harvesting of turtles and their eggs was controlled by traditional rulers since turtles were considered "chiefly food" only to be consumed on special occasions. However, with the loss of traditional customs, the present islanders appear to be taking all nesting sea turtles that appear on the beaches, except on Merir where the turtles are still too numerous for the small family that lives there. It is not surprising that the most populous islands show the lowest levels of sea turtle nesting activity. Only at Merir and

at remote Helen, which was until recently uninhabited, have nesting and feeding turtles remained common due to the low human population on the island.

Nevertheless, the present rate of turtle harvesting on Merir is not sustainable. Furthermore, turtles are sometimes killed without allowing the nesters to lay eggs first. Merir is Palau's most important Green turtle nesting ground and may be the most important of the United States affiliated islands. At the present rate of harvesting, this most important nesting area will be slowly depleted of its nesting population and go the way of the remaining islands where excessive harvesting has reduced turtle nesting to low and perhaps insignificant levels. Considerable conservation action and education is needed to reverse these trends and save the Green turtle populations in the Southwest Islands.

**Mammals**

Marine mammals were reported during the expedition (see Kepler, this volume) but little meaningful data were obtained. Additional research on whale, dolphin, and porpoise population characteristics is needed throughout Palau, including the Southwest Islands. The endangered dugong, a marine mammal; has not been recorded in the waters of the Southwest Islands.

The most important land mammals were the fruit bat colonies on Sonsorol and Fanna. The bats are vulnerable to depletion since the islanders now consider bats a delicacy. Protection of the few fruit bat roosts and populations remaining in the Southwest Islands is warranted.

**Crabs**

Coconut crabs still occur on Merir, Fanna and Pulo Anna, but all are severely over-harvested and depleted. Remaining crab populations need greater levels of protection and greatly reduced harvesting rates if the crabs are to survive at the islands. None of the other land crab populations appear to be in danger; large numbers on Pulo Anna were cooked and processed for shipment at the time of the June 1992 survey.

**Marine Plants**

In terms of long-range planning and consideration, none of the marine algae species are being depleted or are in danger of extirpation.

**Marine invertebrates**

The giant clam stocks at Helen may be subject to unauthorized and perhaps excessive harvest due to the atoll's remote location and limited on-site surveillance by residents. Likely the larger species *Tridacna gigas*, *T. derasa*, *T. squamosa*, and *Hippopus hippopus* are preferentially taken. On site surveillance or remote operated sensors need to be established to detect and discourage poaching of clams and other wildlife. Off-island sale or shipment of giant clams for any purposes should be prohibited.

**Corals**
Coral populations are healthy and diverse at all islands. Coral diversity was exceptionally high at Helen and Tobi, and Helen's complement of coral species may be the highest of any atoll surveyed in the Pacific. Crown-of-thorns seastar predation is either absent or occurring at very low levels and does not pose a problem.

**Reef fishes**
Similarly, reef fish populations are diverse and healthy, especially at Tobi and Helen, but generally well developed at all 6 islands. This situation contrasts sharply with that of the main Palau Islands, where many preferred food or commercial species are being heavily harvested. The Southwest Islands fish fauna could be researched as a baseline reference or "control" site with the aim of investigating the magnitude and characteristics of over-harvesting fish in the main Palau Islands. Research could focus on fish population composition, size, turnover rates, and life history characteristics. A research station at Helen would be well suited to accommodate such research and encompass a greater variety of fish habitats.

**Reef ecosystems**
In general, coral reef ecosystems off all the islands are healthy and relatively undisturbed. All have beautiful coral, giant clam, invertebrate, reef fish, and swimming sea turtle populations. Natural features include caves, walls, grooves, spurs, canyons, and terraces, most of which should be of interest to sport divers. However, the lack of good boat access, the remote position of the islands, and the lack of suiTable on-island facilities for sport divers (fresh water, accommodations, food, sanitary waste disposal) will require considerable effort. It may not be economically feasible to promote dive tours unless regular, frequent, and predicTable boat visits are maintained for the islands.

**Terrestrial ecosystems**
Forest and wetland ecosystems on Helen, Fanna, Pulo Anna, Sonsorol, and Merir are unique and important for wildlife. The entire islands of Fanna, Helen, and possibly Merir are worthy of protection. The beach and mangrove ecosystems of Merir at the very least warrant protection, as well as a small stand of mixed forest on Pulo Anna. Fanna has exceptional beach and *Pisonia* forests and supports important wildlife populations (seabirds, coconut crabs, lizards, fruit bats). Archaeological resources at Fanna are also significant. Helen's limited native forests are vital for seabirds, shade, and shore protection, but are being cut at excessive and non-sustainable rates for firewood. Helen also has unique meadow habitats, and beaches important for nesting seabirds and sea turtles.

**Cultural and historic resources**
Significant archaeological resources and artifacts were present on all of the islands surveyed (Helen was not visited by the archaeologist). Culturally important residential

mounds dating from pre-historical times were especially noteworthy on Tobi, Merir, and Pulo Anna. The mound at Tobi is being actively eroded by currents, and Merir's mound is also suffering occasional erosion. A portion of the Pulo Anna mound has been damaged by World War II era U.S. military earthmoving activities and possibly by ongoing house construction. Important artifacts include adzes, fishhooks, necklaces, pottery sherds of probable Palauan origin, human infant bones, and the remains of seafood (fish, turtles). Historic era sites include the ruins of pre-World War II Japanese phosphate mining buildings, railways, and tanks at Tobi, Merir, and Sonsorol; military gun emplacements and tunnels at Sonsorol, and the dredged channels at Tobi and Sonsorol. Additional ethnological, oral history, and archaeological research is warranted to help develop a cultural resources protection plan for the Southwest Islands, and immediate action to protect or stabilize the eroding mound at Tobi should be taken.

## Conclusions and Recommendations

The land and reef areas of the Southwest Islands support substantial biological and cultural diversity. Although the area of the lands and reefs is relatively small, the ecological and cultural importance of the Southwest Islands is very high. This is especially important with respect to seabirds, sea turtles, reef fishes, corals, marine invertebrates, archaeological resources, and the living culture.

### Population Decline

Human populations are declining at most of the Southwest Islands. Reversing these trends will require the maintenance of schools for children; more frequent ship and boat visits for supplies, food, fuel and medicine; and expanded economic opportunities for adults. Sport fishing, sport diving tours, mariculture, and support for long term scientific research may be possible if infrastructure is developed, boat schedules are improved, and aids to navigation installed.

### Cultural Survival

Many of the elders and other people knowledgeable about Southwest Island traditions, customs, and practices have died or moved to Koror. Much of the lore (essential for traditional conservation and subsistence) is being lost at the islands. There is an urgent need to conduct oral histories and develop educational materials. Perhaps with guidance and training from specialists, the islanders themselves could accomplish the oral histories.

### Bird and Bat Populations

Fruit bat populations are very small and are confined to Sonsorol and Fanna. Remaining bats and their habitat should be protected, including large roosting trees.

Seabird populations on Helen and Fanna warrant the utmost protection (refer to island recommendations). Elsewhere harvesting rates of seabirds appear low and pose no

serious problems. Disturbance by dogs and rats may be serious on some islands. Educational materials need to be prepared, translated, and provided to the islanders on bird and bat conservation. Off-island sale or shipment of birds or their eggs should be prohibited.

**Coconut Crabs**

Coconut crab populations are seriously depleted or extirpated on all islands. Formerly, large populations on Merir and Fanna have been over harvested, including egg bearing females and small crabs. On Merir, crab populations are now so low (due to overharvesting) that harvesting effort is not worthwhile. Educational materials on crab conservation and much lower harvesting rates for crabs are needed if populations are to survive. Off-island shipment or sale of coconut crabs should be prohibited at all islands. In accordance with the desires of Tobian residents, laws should be passed to protect and conserve coconut crabs. Kepler (this volume) includes a coconut crab appendix.

**Sea Turtles**

Major reductions in the harvesting rates for sea turtles on the islands are needed. Existing laws and regulations against harvesting of turtles need to be honored and enforced; strengthening of regulations may be warranted. Merir nesting turtles and Helen's nesting and feeding sea turtles need protection and monitoring.

**Forests**

Relatively pristine forests on several islands warrant protection as refuges, due to their unique composition and contribution to the support of important wildlife species (see island recommendations).

**Cultural Resources**

A cultural resources protection plan should be developed to cover the protection of archaeological and historic resources on all the Southwest Islands. The plan should be based upon additional ethnographic, oral history, and archaeological research, and include restoration or protection of sites vulnerable to damage or destruction. Research would help to better delineate the affinities of Southwest Islands traditions to other cultures.

**Future Research and Monitoring**

The exceptional marine and terrestrial biodiversity of the Southwest Islands should be subject to long-term monitoring and research, including the establishment of a field station at Helen and regular visits by a research vessel. Brief visits to Merir and Fanna could also
be accommodated by a research program.

## Recommendations by Island

### Helen Atoll

1 Declare the island and reefs an international wildlife refuge for marine and terrestrial resources as previously recommended (Elliott, 1973; Dahl, 1986; UNEP/IUCN, 1986b; IUCN, 1991).

2. Enforce a complete ban on the hunting and egging of seabirds or sea turtles.

3. Initiate a tagging study of sea turtles and seabirds.

4. Establish a field research station at Helen to monitor global climate change, marine resources, and terrestrial wildlife.

5. Prohibit the off-island shipment or sale of sea turtles, seabirds, eggs, and giant clams.

6. Limit fishing activity to subsistence for island residents, and tag-and-release sport fishing.

7. Install electronic surveillance sensors and better radio communications to assist in monitoring and enforcement.

8. Supply the residents with alternative sources of fuel wood to eliminate further cutting of native forest; investigate the feasibility of replanting or reforestation of scrub.

9. The islet is poorly suited for long-term habitation due to its small size, unstable shorelines, limited shade, lack of water, lack of easy boat access, and lack of agricultural potential. Permanent residents could be limited to a conservation officer, lab manager, and communications/electronics specialist.

10. Increase visits by ships to discourage poachers, re-supply residents, and promote scientific research. There should be a total ban on the shipment or sale of organisms collected from the atoll, other than limited scientific specimens.

11. Remove any dogs from the islet and prohibit the importation of other dogs, rats, caged birds, cats, pigs, or other predators or carriers of alien diseases. .

Control the number of people visiting the islands by restricting access during the breedeing season of species sensitive to disturbance (especially Feb.-Aug.)

1 Implement engineering solutions to curtail shoreline erosion and loss of archaeological resources in the vicinity of the dredged boat channel.

2. Evaluate improvements to the channel and aids to navigation to facilitate more frequent ship visits.

3. Conduct oral history research on elders at Tobi and Koror.

4. Hire new teachers to maintain the school.

5. Conduct historical survey and documentation of Japanese ruins.

6. Consider restoring one or two houses for visitor accommodations to promote sport fishing, sport diving, or scientific research.

7 Distribute educational materials on sea turtle conservation and institute a moratorium on sea turtle and egg harvesting at shoreline and nesting sites.

8. Distribute educational materials on coconut crab ecology and conservation (see Kepler, this volume).

**Merir Island**

1 Institute a ban on sea turtle and egg harvesting at Merir until sustainable harvesting levels can be established through research.

2. Institute a long-term tagging and monitoring program for nesting green sea turtles. This could be accomplished as part of the Helen Atoll research station monitoring program.

3. Control, reduce, or preferably remove the large dog population from the island; dogs are known predators of seabirds, sea turtles, and coconut crabs.

4. Establish the mangrove depression as a forest reserve and sanctuary for coconut crabs; conduct monitoring programs for the crabs; ban the harbesting of cocount crabs until monitoring data and population recovery justifies a resumption of harvesting.

5. Conduct research on avian diseases or the causes for reduced bird populations at Merir.

6. Institute rat and mosquito control projects.

7. The relinking of the interior swamp with the open ocean does not appear to be economically feasible and may not result in reduction of mosquito populations, and is therefore not recommended.

8. Protect the residential mound and archaeological resources from shoreline erosion and other damage.

9. Conduct a historic survey and documentation of the pre-World War II Japanese ruins.

10. Conduct an oral history of Andres Antonio and any other surviving elders from Merir who may reside in Koror.

**Pulo Anna**

1. Establish a 2.5 ha grove of mixed forest as a forest preserve within which no cutting or felling of trees or harvesting of wildlife would be permitted (including undescribed species of lizards).

2. Distribute educational materials on sea turtle conservation and institute a moratorium on sea turtle and egg harvesting at shoreline and nesting sites, informal talks wiht the islanders on the need for turtle conservation should also be effective.

3. Assess the aquaculture or mariculture potential of the central pond.

4. Institute mosquito and rat control programs.

5. Establish a small sanctuary for the dwindling coconut crab populations and greatly curtail harvesting.

6. Protect archaeological resources, especially the mound and walls, from further damage.

7. Consider installation of a boat channel and navigation aids.

8. Conduct oral history of the several elders on the island.

9. Promote pelagic (offshore) fisheries, sport diving, and catch-and-release sport fishing.

**Sonsorol**

Establish a small forest reserve for noTable trees and roosting sites for fruit bats.

2. Consider improvements to the boat channel and aids to navigation.

3. Conduct oral history research with the elders on the island and in Koror.

4. Conduct historical documentation of the Japanese ruins.

5. Promote sport diving and sport fishing opportunities.

6. Distribute educational materials on sea turtle conservation and institute a moratorium on sea turtle and egg harvesting at shoreline and nesting sites.

7. Distribute educational materials on coconut crab ecology and conservation.

**Fanna**

1. Declare the entire island as a forest and wildlife reserve to protect native beach forest, *Pisonia* forest, large seabird populations, coconut crabs, sea turtle nesting activity, fruit bats, lizards, and important archaeological sites.

2. Conduct long-term monitoring of coconut crab and seabird populations.

3. Prohibit collecting, harvesting, or harassment of seabirds, fruit bats, and coconut crabs.

4. Continue to allow visits and picnics at Fanna but prohibit permanent occupation of the island.

5. Prohibit the importation of alien plants and soils (both which harbor injurious insects, viruses, nematode, and other undesireable organisms).

6. Prohibit dogs, cats, caged birds, or other alien (non-native) animals, even for visits.

7. Establish harvesting levels for fruit bats to allow for population recovery and sustainable use.

8. Investigate the causes for many dying tree canopies, using a team consisting of an entomologist, botanist, and soil scientist.

## Overall Management Plan for the Southwest Islands

Given the repetitive nature and linkages among many of the recommendations, an overall integrated management plan should be developed for the Southwest Islands. The plan should address the region as a whole, and also include specific island sections. The management plan would be particularly important if the Palau Government is able to encourage people to return to the islands. The management plan could include the following strategies:

- conducting additional research and surveys;
- long term monitoring and surveillance;
- enforcement (including training and resources);
- protected area or resource management;
- promoting ecologically sustainable forms of development;
- restoration of natural and cultural resources;
- education and public awareness; and
- "job" training for conservation and development activities.

The plan should initially be written and approved at the government level, but will need to be verbalized and embraced at the village level to be fully effective. Government assistance in surveillance and enforcement for controlling unauthorized exploitation (especially by outsiders) seems feasible, but most of the day-to-day management would need to occur at the island/village level. In particular, education, research (including oral histories), resource monitoring, nearshore surveillance, communication with national and state government level enforcement authorities can and should involve the islanders. Education and understanding is the key to management in the Southwest Islands, since virtually all controls will need to be self imposed.

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