A Directory of Wetlands in Oceania represents the culmination of a three year project, the Oceania Wetland Inventory, sponsored jointly by the International Waterfowl and Wetlands Research Bureau (IWRB), Asian Wetland Bureau (AWB), South Pacific Regional Environment Programme (SPREP) and the Bureau of the Convention on Wetlands of International Importance especially as Waterfowl Habitat (the Ramsar Convention). The project was funded by the United States Fish and Wildlife Service - Agency for International Development Grant Program for Biological Diversity, the French Secretariat d'Etat aupres du Premier Ministre charge de l'Environnement et de la Prevention des Risques Technologiques et Naturels Majeurs, the National Geographic Society, the South Pacific Regional Environment Programme, the East-West Center of Honolulu through a grant to the Center from the John D. and Catherine T. MacArthur Foundation, the Australian National Parks and Wildlife Service, and the New Zealand Department of Conservation.

The Directory consists of a series of 25 reports describing the principal wetlands in the island nations and territories in the Pacific Ocean from the Republic of Palau in the west to Chile's oceanic territories in the east, and from the Northern Mariana Islands in the north to French Polynesia in the south. Well over 100 individuals and organizations have contributed to the Directory, most providing hitherto unpublished information on wetlands in Oceania. One hundred and eighty-two sites of international importance are described. These have been selected on the basis of criteria developed in relation to the Ramsar Convention. Although special attention is paid to the importance of the wetlands for wildlife, all wetland values, including water storage, flood control, coastal protection and fisheries production, have been taken into consideration.

The Directory thus provides for the conservation community a list of the highest priorities for conservation action. At the same time, it provides for governments and the development assistance community guidance on those sites where future activities will require the most intensive investment in environmental impact assessment and in the design and implementation of appropriate conservation measures.

A DIRECTORY OF WETLANDS IN OCEANIA

Compiled by

Derek A. Scott

for the

International Waterfowl and Wetlands Research Bureau (IWRB)

Asian Wetland Bureau (AWB)

South Pacific Regional Environment Programme (SPREP)

Ramsar Bureau

The International Waterfowl and Wetlands Research Bureau (IWRB)
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FOREWORD

Wetlands are among the world's most productive environments. They are very important for the way they maintain ecological processes, as well as for the diverse flora and fauna they shelter and support. Wetlands provide tremendous economic benefits to humans, through fisheries production, maintenance of water tables, water storage and flood control, shoreline stabilization, water purification and recreational opportunities. Unfortunately, however, wetlands are also amongst the world's most threatened habitats.

The people of the Oceania region share common aspirations towards ecologically sustainable development. We wish to use our resources without using them up. We aim therefore for "human use of wetlands so that they may yield the greatest continuous benefit to present generations while maintaining their potential to meet the needs and aspirations of future generations" (as defined by the Ramsar Convention - the Convention on Wetlands of International Importance especially as Waterfowl Habitat).

However, a number of unique circumstances in the region combine to limit the opportunities for both development and conservation of wetlands and other ecosystems. These include the small land masses of islands and their dispersal over large ocean areas. In some countries, the pressures of population density and increased per capita consumption also threaten ecologically sustainable development.

The South Pacific Regional Environment Programme (SPREP) 1991-1995 Action Plan for Managing the Environment of the South Pacific Region has, amongst others, the objectives to:

* protect terrestrial and marine ecosystems and species which require special attention;
* promote the conservation and sustainable utilization of .... wetlands and coral reefs.

In the development of effective wetland conservation strategies, one of the first steps is the compilation of an inventory of the most important wetland sites. Then regional and national priorities for conservation of wetlands can be drawn up, and projects implemented.

This Directory aims to provide such an essential database, as a basis for action. It provides an inventory of wetlands of international importance in the Oceania region, including twenty-five political entities from Palau, Guam and the Solomon Islands in the west to Easter Island in the east, and from the Mariana and Hawaiian islands in the north to New Caledonia and French Polynesia in the south.

The project was initiated at the Fourth South Pacific Conference on Nature Conservation and Protected Areas held in Port Vila, Vanuatu, in September 1989. The Action Strategy for Nature Conservation revised at that meeting placed emphasis on the need for detailed inventories of the region's natural ecosystems. The lack of attention given to wetlands in Oceania was noted, and the compilation of an inventory of important wetland ecosystems was seen as an appropriate and timely endeavour.

The project was carried out as a joint venture of the Ramsar Bureau, International Waterfowl and Wetlands Research Bureau (IWRB), Asian Wetland Bureau (AWB) and my organization, the South Pacific Regional Environment Programme (SPREP), in close collaboration with other international and national agencies. Emphasis was given to obtaining the maximum participation by conservation bodies and academic institutions in the countries concerned.

The production of the Directory is but one of many important steps designed to address the conservation needs of wetlands. SPREP's South Pacific Biodiversity Conservation Programme, commencing in 1993, will help to establish, and initially manage, a series of large, diverse Conservation Areas, in which human activities will not be excluded, but will be guided to protect important ecological features and to enable sustainable use of the area's natural resources. It is to be hoped that the regions's important wetlands will feature prominently amongst the potential Conservation Areas submitted for funding under this programme.

Foreword

Only by continuing conservation activities can we hope to protect and sustainably use our wetland resources in perpetuity. The compilation of the *Directory of Wetlands in Oceania* is an important first step.

Dr Vili Fuavao
Director, SPREP

INTRODUCTION

In the development of an effective conservation programme for wetlands, one of the first steps is the compilation of an inventory of the most important wetland sites. Such wetland inventories already exist for much of the world, *e.g.* Europe, Africa, South and East Asia and the Neotropical Realm. *A Directory of Wetlands in Oceania* seeks to continue this global coverage by providing a comprehensive review of existing knowledge of the most important wetlands in the island nations and territories of the Pacific Ocean.

When first launched at the Fourth South Pacific Conference on Nature Conservation and Protected Areas in Vanuatu in 1989, the Oceania Wetland Inventory Project was restricted to the small island nations and territories of the Pacific from the Republic of Palau and the Solomon Islands in the west to the Hawaiian Islands and Chile's oceanic territories in the east. The wetlands of Papua New Guinea had already been described in *A Directory of Asian Wetlands*, published by IUCN-The World Conservation Union in 1989, and, with their continental affinities, were somewhat outside the scope of the Oceania Directory. However, a considerable amount of work has been carried out on the wetlands of Papua New Guinea since the *Directory of Asian Wetlands* was published, and so it was thought appropriate to include a short chapter on Papua New Guinea in the present volume.

As the Oceania wetland inventory was getting under way, increasing interest was being expressed in comparable inventories in Australia and New Zealand. Following a series of informal discussions between wetland conservationists in Australia and New Zealand and the sponsors of the Oceania wetland inventory in early 1990, it was agreed that the Australian and New Zealand inventories should follow the Oceania inventory closely in approach and objectives so that the three together would constitute a comprehensive inventory of important wetlands throughout the entire Australasian/Pacific region. Initially it was anticipated that the New Zealand inventory would be included as a chapter in the Oceania volume, while the Australian inventory would be published simultaneously as a companion volume.

Work began on the New Zealand inventory in late 1990 with the Department of Conservation coordinating the compilation of information through its regional Conservancy Offices. As the work progressed, it became increasingly apparent that the inventory would be far too bulky for publication in the same volume as the rest of Oceania, and thus the New Zealand inventory now appears as a separate, companion volume. The Australian inventory project was launched in August 1991 at a special technical workshop convened by the Australian National Parks and Wildlife Service (ANPWS) and the Bureau of Rural Resources. State and Territory agencies throughout Australia participated in the project, with the ANPWS providing overall coordination and compiling the final report for publication.

A Directory of Wetlands in Oceania follows a format similar to that of earlier wetland directories; thus the greater part of the Directory consists of a series of national reports. Each begins with an introduction which summarizes the general situation of the wetlands and provides information on the institutional and legal base for wetland conservation and research. Then follows a series of accounts of those wetlands which are known or thought to be of greatest importance from the point of view of nature conservation. The site descriptions include basic information on size and location, physical features, ecological features, ownership, degree of protection, land use, threats and conservation values.

The term "wetland" is used in the sense defined in the text of the Convention on Wetlands of International Importance especially as Waterfowl Habitat (the Ramsar Convention). Thus, wetlands are "areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres". Coral reefs and other exclusively marine systems are, however, generally excluded from this definition, and have not been considered in this Directory except in so far as they form an integral part of a site containing more typical wetland habitats. The principal reef systems of the Central and Western Pacific have recently been described in volume three of *Coral Reefs of the World*, published jointly by UNEP and IUCN in 1988.

Most country reports include an outline map (or maps) showing the location of the sites described in the Directory. For reasons of space, it has not been possible to include detailed maps of each site. However, the many individual site maps which have been provided by contributors are on file at IWRB headquarters in the United Kingdom, and constitute an important reference source.

Methodology

The compilation of *A Directory of Wetlands in Oceania* has involved the collection of data through three main channels:

- national networks of contacts, each with a "national coordinator" responsible for the compilation of data in his or her country and preparation of a national report.
- direct contact with individuals or institutions with expertise on particular sites or species.
- a review of the recent literature.

In many cases, compilation of a national inventory was coordinated by a single individual (national coordinator) or institution in the country or territory concerned, and a comprehensive report was submitted. However, in several countries it proved impossible to coordinate the collection of information through a single person or institution, and material was received from several independent sources. In the case of Nauru, Niue, the Pitcairn Islands, Tuvalu and Wallis and Futuna, no local contact could be established, and the material presented in the Directory is based entirely on expatriate sources and the literature. Emphasis was given throughout to obtaining recent information from individuals currently working on wetlands, and little attention was given to the older literature.

Site Descriptions

Contributors were requested to submit their information on standard wetland data sheets of a type used in similar wetland inventories in the Palearctic Region, Neotropical Region and Asia. These data sheets are very similar in design to the information sheet currently being used by the Ramsar Bureau in the presentation of information on sites listed under the Ramsar Convention. Information presented on the completed data sheets has been reproduced in this Directory in a slightly modified form, and in many cases with additional information from other sources.

The following data categories have been employed in the site accounts:

Title: The name of the wetland with a reference number used in the accompanying map.

Location: The geographical coordinates (Greenwich) and general location of the site.

Area: The area of the wetland habitat in hectares. In the case of some rivers and coastal zones, only the approximate length of the site is known.

Altitude: The altitude of the wetland in metres above sea level.

Overview: A brief description of the wetland, summarizing the principal physical and ecological features and highlighting the main conservation values.

Physical features: A brief description of the principal physical features of the site, including information on hydrology, soil type and chemistry, water quality, depth, fluctuations and permanence, as well as a note on climatic conditions.

Ecological features: A brief description of the main habitats and vegetation types present, with information on the dominant plant communities and species present.

Land tenure: Details of the ownership of the wetland and the ownership of surrounding areas.

Conservation measures taken: Details of any protected areas established at or around the wetland, and any other conservation measures taken at the site.

Conservation measures proposed: Details of any proposals for the conservation of the wetland.

Land use: Details of the principal forms of land use and human activities at the wetland and in surrounding areas.

Possible changes in land use: Any information available on proposed changes in land use and development plans which might affect the ecological character of the wetland.

Disturbances and threats: Details of existing and possible future threats to the wetland and its wildlife.

Hydrological and biophysical values: Information on the principal hydrological and biophysical values of the wetland.

Social and cultural values: Information on the principal social and cultural values of the wetland.

Noteworthy fauna: The importance of the wetland for wildlife including aquatic mammals, waterbirds, aquatic reptiles, amphibians, fishes and invertebrates.

Noteworthy flora: Information on any plant species or communities for which the wetland is particularly important.

Scientific research and facilities: Information on major research activities at the wetland and any existing facilities for research.

Conservation education: Information on any existing programmes and facilities for conservation education and training.

Recreation and tourism: Information on the present and potential use of the wetland for recreation and tourism.

Management authority and jurisdiction: Details of the authority responsible for the conservation and management of the wetland, and the authority or authorities with territorial and functional jurisdiction over the wetland.

References: Abbreviated references to published literature and unpublished reports relevant to the site. The references are given in full at the end of each national section.

Reasons for inclusion: An indication of those features for which the site is considered to be internationally important, with a numerical reference to the criterion or criteria which justify the inclusion of the site in the Directory. The criteria used in the selection process are those developed for the identification of wetlands of international importance for designation under Article 2 of the Ramsar Convention. These criteria, as adopted by the Fourth Conference of the Contracting Parties in Montreux, Switzerland, in June 1990, are as follows:

(1.) Criteria for representative or unique wetlands.

A wetland should be considered internationally important if:

(a) it is a particularly good representative example of a natural or near-natural wetland, characteristic of the appropriate biogeographical region;

or (b) it is a particularly good representative example of a natural or near-natural wetland, common to more than one biogeographical region;

or (c) it is a particularly good representative example of a wetland which plays a substantial hydrological, biological or ecological role in the natural functioning of a major river basin or coastal system, especially where it is located in a trans-border position;

or (d) it is an example of a specific type of wetland, rare or unusual in the appropriate biogeographical region.

(2.) General criteria based on plants or animals.
A wetland should be considered internationally important if:
- (a) it supports an appreciable assemblage of rare, vulnerable or endangered species or subspecies of plant or animal, or an appreciable number of individuals of any one or more of these species;
- or (b) it is of special value for maintaining the genetic and ecological diversity of a region because of the quality and peculiarities of its flora and fauna;
- or (c) it is of special value as the habitat of plants or animals at a critical stage of their biological cycle;
- or (d) it is of special value for one or more endemic plant or animal species or communities.

(3.) Specific criteria based on waterfowl.
A wetland should be considered internationally important if:
- (a) it regularly supports 20,000 waterfowl;
- or (b) it regularly supports substantial numbers of individuals from particular groups of waterfowl, indicative of wetland values, productivity or diversity;
- or (c) where data on populations are available, it regularly supports 1% of the individuals in a population of one species or subspecies of waterfowl.

A wetland is suitable for inclusion in the Ramsar Convention "List of Wetlands of International Importance" and hence in this Directory if it meets any one of the criteria set out above.

For proper application of the Ramsar criteria, it is essential that a considerable body of information be available on the site in question. For many wetlands in Oceania, the information is so scanty that no objective evaluation of the importance of the site can be made. If all such sites were to be ignored, the Directory would become little more than an inventory of wetlands which have been well studied and well documented, and would lose its value as a basis for the identification of priorities in future wetland surveys and research. In those cases where very little information is available, the selection of sites for inclusion in the Directory has been based almost entirely on the judgement of the contributors.

Source: Names of individuals and institutions providing information on the site.

Some headings, such as "Conservation measures proposed", "Possible changes in land use", "Scientific research and facilities", "Conservation education", "Recreation and tourism" and "References", have been omitted when no relevant information was available to the compiler.

Comprehensiveness

For all countries except Hawaii, it has been possible to provide at least a preliminary inventory of important wetlands on the basis of information received from contributors and the literature. Hawaii was exceptional in that information on the many hundreds of wetlands in the State was compiled as an electronic database and thus in a form unsuitable for publication in this Directory. Furthermore, at the time of going to press, the Hawaiian Islands Wetland Database was still incomplete, lacking information on some 70-80 wetlands including some of the State's largest and most important sites. It is to be hoped that a summary of the data in this important wetland database can be published separately at a later date.

The comprehensiveness of the other country reports varies greatly. In the U.S. Territories and former U.S. Trust Territories, a considerable amount of attention has been given to wetlands, and in some cases, notably American Samoa, Guam and the Northern Mariana Islands, most wetland habitats have now been documented in great detail. In these countries and territories, the chapter in this Directory is thought to be very comprehensive; all sites of international importance have been included, along with a number of sites which are probably of only local or national importance. The inclusion of these latter sites is at least partly justified by the rapid rate at which wetlands are disappearing throughout the region as a whole and consequent rate at which the remaining undisturbed wetlands are increasing in importance.

In most other countries and territories in Oceania, little attention has been given to wetlands, and the wetland inventories remain at a very preliminary stage. In some cases, *e.g.* the Marshall Islands, Nauru, Niue, Tokelau, Tuvalu, the U.S. Unincorporated Territories and Wallis and Futuna, there appear to be few, if any, significant wetlands other than reef systems. However, in other cases it seems that although many important wetlands do exist, only a few have attracted the attention of researchers and conservationists and little information is available on the remainder. This is particularly the case in the Cook Islands, Fiji, French Polynesia, New Caledonia, the Solomon Islands and Tonga. Most of the larger wetlands and other sites of great international importance are now known and have been included in this Directory, but there doubtless remain many smaller wetlands which will in time be found to possess special qualities which justify their designation as wetlands of international importance.

One of the primary objectives of the Directory is to provide the stimulus and basis for the completion of detailed national wetland inventories which should include not only more information on the sites which meet international criteria, but also details of sites of only national or even local importance. In most of the present and former U.S. Territories, work on such national inventories was initiated many years ago, while in Fiji, Vanuatu and Western Samoa, some wetland inventory work has been carried out within the last few years. Only summaries of these national inventories have been incorporated here. Most of the other contributions provide excellent skeletons upon which comprehensive national inventories can be based. More field work needs to be carried out at many of the internationally important sites, and additional sites of national rather than international importance should be considered. Only when detailed national inventories are available for all the countries of the region will it be possible to compile the definitive directory of wetlands of international importance in Oceania.

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March 1993

AMERICAN SAMOA

INTRODUCTION

by Richard D. Volk

Area: 200.47 sq.km.

Population: 47,600 (1990 Census, U.S. Census Bureau).

American Samoa is an unincorporated flag territory of the United States. It lies in the central South Pacific approximately 4,160 km south-southwest of Honolulu and 2,880 km northeast of Auckland. The territory consists of seven principal islands: five inhabited high islands, one inhabited atoll and one uninhabited atoll. Covering an area of 135 sq.km and with a population of over 40,000, Tutuila (14°18'S, 170°41'W) is the governmental and economic centre of American Samoa. This island and the small offshore island of Aunu'u are home for 96% of the population. Most of the remaining 4% reside on the three islands of the Manu'a group, Ta'u (44 sq.km), Ofu (8 sq.km) and Olosega (5 sq.km), situated about 130 km east-southeast of Tutuila.

Tutuila, Aunu'u and the Manu'a group are high volcanic islands of non-continental origin. They rise precipitously from the ocean, and feature narrow coastal strips of relatively flat land and rugged, mountainous interiors. Only 34% of Tutuila's land area has a slope of less than 30%. The other two principal islands are low-lying atolls: Swain's Island (2.1 sq.km), some 360 km north of Tutuila, and Rose Atoll (8 ha), 260 km east of Tutuila. Swain's Island is a raised atoll with a large enclosed lagoon. Until recently, the island was used for the production of copra and supported a population of several hundred workers. However, copra is no longer exported and only about ten inhabitants remain on the island. Rose Atoll is a typical atoll with two tiny islets, Rose Island and Sand Island, a large inner lagoon and extensive fringing reefs. This uninhabited atoll supports a large breeding colony of seabirds and is a nesting area for two species of marine turtles. The entire atoll, an area of 650 ha, was declared a National Wildlife Refuge in 1973, and is managed by the U.S. Fish and Wildlife Service (IUCN, 1991).

American Samoa's climate is warm, humid and tropical, with a mean annual rainfall of 5,080 mm and precipitation occurring on an average of 300 days per year. The rainy season is from November to March; the dry season from June to September. Air temperatures range annually between 21°C and 32°C. Southeast trade winds reach their peak between June and August, and tropical depressions with occasional cyclone development (winds of up to 240 km/hr) occur during the austral summer, usually between December and March.

Summary of Wetland Situation

American Samoa has both saltwater and freshwater swamps and marshes, as well as cultivated and ruderal wetlands and a number of perennial streams. Much the most important wetlands are the mangrove swamps and coastal freshwater marshes.

Mangroves reach their eastern limit in the Central Pacific on Tutuila and Aunu'u, and are absent from the Manu'a Islands. American Samoa lies within a small triangle in the south-central Pacific where the oriental mangrove, *Bruguiera gymnorrhiza,* and the red mangrove, *Rhizophora mangle*, have intersecting ranges. The local form of the red mangrove, *R. m. samoensis*, is recognized by some authors as a distinct species (Woodroffe, 1988). Undisturbed mangrove forest is comprised almost entirely of *Bruguiera gymnorrhiza*, while in disturbed mangrove stands or along their sunny margins, *Rhizophora mangle* predominates. Small stands of a third mangrove species, *Xylocarpus moluccensis*, occur in two areas (at Pala Lagoon on Tutuila and at the south end of Aunu'u). Trees typical of the littoral forest are also found along the margins of the mangrove forest, along with clumps of the fern *Acrostichum aureum* which sometimes also occurs in disturbed areas (Cole *et al.*, 1988).

The total area of mangrove on Tutuila and Aunu'u was estimated at 91 ha by Amerson *et al.* (1982) and at 52 ha by Cole *et al.* (1988). Whistler (1976) gives a figure of 127 acres (51.4 ha), and describes five main stands: at Pala Lagoon (34.4 ha), Masefau (6.1 ha), Leone (3.6 ha) and Aoa (1.6 ha) on Tutuila, and in two patches covering 4.5 ha on Aunu'u. Three other tiny patches of mangroves on Tutuila have a combined area of less than 0.5 ha.

Freshwater marshes usually occur along the coast in areas where stream outlets to the sea are blocked by sand barriers. These barriers cause the streams to spread out into low-lying areas, saturating the soils. The dominant plants are *Cyclosorus interruptus*, *Acrostichum aureum* and *Eleocharis dulcis* (Cole *et al.*, 1988). Of all the types of vegetation in American Samoa, coastal freshwater marshes have been the most affected by man. These wet areas, often in close proximity to villages, are ideal for growing taro (*Colocasia esculenta*) and have been extensively cultivated for hundreds of years. Very little undisturbed coastal marsh remains today, and the only site which appears to be relatively undisturbed is the marsh inside Aunu'u Crater (Whistler, 1976). Whistler (1976) describes eight areas of coastal marsh covering a total of 96 acres (38.9 ha): Vatia marsh (2.8 ha) and Alao marsh (1.6 ha) on Tutuila; Faimulivai Marsh (13.8 ha) and Aunu'u village marsh (8.9 ha) on Aunu'u; Luma marsh (7.3 ha) and Fusi marsh (0.8 Ha) on Ta'u; a small marsh on the west coast of Olosega (2.4 ha); and Vaoto marsh (1.6 ha) on Ofu. All of the marshes except Faimulivai Marsh on Aunu'u have been extensively modified by taro cultivation. However, this has been abandoned at the Fusi and Vaoto marshes, and these are now reverting to a more natural condition.

There are many streams on Tutuila, but virtually none on the Manu'a Islands. The wetlands associated with these streams are of very limited extent, being restricted to the margins of the streams and to channels of intermittent streams. The wetland vegetation is dominated by *Brachiaria mutica*, *Coix* sp. and *Canna* sp., as well as many other weedy species found in wetland taro patches. *Barringtonia samoensis*, a medium-sized tree closely related to the dominant coastal forest tree *Barringtonia asiatica*, is commonly found along mountain streams (Whistler, 1976). The riparian (streamside) vegetation of American Samoa is briefly summarized in the American Samoa Stream Inventory (U.S. Army Corps of Engineers, 1981).

Approximately 100 species of vascular plants have been reported from the wetlands of American Samoa. Four of these are considered to be rare in the territory. The tree *Erythrina fusca*, the mangrove *Xylocarpus moluccensis* and the sedge *Cyperus odoratus* are each known from only two sites, while the herb *Limnophila fragrans* is known from only three sites. Although all four species are common elsewhere in the Pacific, they should be considered as endangered species in this American territory (Whistler, 1976).

Surveys of wetland fauna have recorded at least 78 species of fish and invertebrates, one amphibian (the introduced toad *Bufo marinus*), five species of reptiles, 16 species of birds and three species of mammals. The birds include Pacific Reef Heron (*Egretta sacra*), Pacific Black Duck (*Anas superciliosa*), Banded Rail (*Rallus philippensis*), Spotless Crake (*Porzana tabuensis*), Purple Swamphen (*Porphyrio porphyrio*) and seven species of migratory shorebirds, although only four of the latter, the Pacific Golden Plover (*Pluvialis fulva*), Wandering Tattler (*Heteroscelus incanus*), Bristle-thighed Curlew (*Numenius tahitiensis*) and Ruddy Turnstone (*Arenaria interpres*) are regular.

Most wetland degradation today occurs as a result of increased pressure to convert wetland to dry land for residential or commercial purposes. Suitably flat, developable land on Tutuila is scarce, and the wetlands are often seen as "wasteland", easily converted for private use. This situation is exacerbated by the current annual rate of population increase of 3.7%.

Past wetland degradation occurred on a larger scale earlier this century through government efforts to fill in portions of the reef and mangrove swamps in Pago Pago Harbour to create land for government and U.S. naval operations. Mangroves once existed along various stretches of the harbour where today there are none. Some 10 ha of mangroves were removed and filled to create Pago Pago Park in the inner harbour in the 1960s.

The largest remaining, and most threatened, wetland in American Samoa is the mangrove forest at Nu'uuli Pala Lagoon in south-central Tutuila. This coastal mangrove swamp covers an area of 49.7 ha, and borders an important shallow lagoon extensively used for fishing and recreation. Thirty-three percent of the mangrove swamp has been converted to dry land since 1961. The lagoon's natural circulation patterns were permanently altered in the early 1960s with the construction of American Samoa's international airport. Water quality in the lagoon is of concern and the focus of an on-going toxicity study.

Taro cultivation on a commercial scale occurs in freshwater marshes on Aunu'u and Masefau on Tutuila. Production and marketing data are not available. Other commercial economic uses of wetlands, including aquaculture, are virtually non-existent, due at least in part to the limited productivity and harvest potential of the few remaining wetlands.

The American Samoa Government is working as of late 1991 to complete and implement a wetlands management plan for Tutuila and Aunu'u. Effective wetland management is faced with the general notion that wetlands are communal or private property under no regulatory control of the Government. The Submerged and Tidal Lands Act of 1974 (P.L. 93-435), however, declares that title to submerged and tidal lands in American Samoa, including "artificially made, filled in, or reclaimed lands which were formerly permanently or periodically covered by tidal waters", was conveyed to the American Samoa Government from the U.S. Government in 1974. The issue of ownership thus remains contentious, especially in the case of freshwater wetlands not influenced by tidal waters. Consequently, the American Samoa Government is exploring options for a combined regulatory and non-regulatory management programme, with full participation in the planning and implementation process by the relevant village councils.

Wetland Research

Wetlands-specific research in American Samoa has been limited. Wetland vegetation (Whistler, 1976) and the fauna, flora and human uses specific to the Nu'uuli Pala (Yamasaki *et al.*, 1985) have been studied in some detail. An account of wildlife and wildlife habitat (Amerson *et al.*, 1982a, 1982b), an account of the bird fauna (Engbring & Ramsey, 1989) and a report on terrestrial vegetation (Cole *et al.*, 1988) also provide important information on wetlands. The American Samoa Stream Inventory (U.S. Army Corps of Engineers, 1981) provides information on the stream macrofauna and riparian (streamside) vegetation, while an unpublished report on non-marine aquatic resources of American Samoa (Burger and Maciolek, 1981) gives some descriptive physical data for each of the streams in the territory. The Reconnaissance Report for the Territories Development Study for American Samoa (U.S. Army Corps of Engineers, 1990) provides a brief summary of the information available on stream and wetland resources. The wetlands management plan for Tutuila and Aunu'u prepared by Biosystems Analysis, Inc. (1991) represents the most complete synthesis to date of the wetland information available for American Samoa.

The wetlands of Tutuila and Aunu'u were delineated and mapped in 1991, and total wetland areal gains/losses calculated (Table 1). The total wetland area remaining on Tutuila in 1991 was 141.8 ha. Over a 30 year period, 1961-1991, the net loss of wetland area on Tutuila was calculated to be 23%, or a loss of 55.4 ha. This equates to an average annual rate of loss of 1.9 ha. On Aunu'u, the total remaining wetland area in 1991 was 45.2 ha, with no appreciable losses occurring since 1961. It is important to note that the calculated areas given here include certain portions of tributary stream beds, and thus may differ significantly from earlier data. Details on methodology and the current status of wetlands are available at the American Samoa Coastal Management Program in the Economic Development Planning Office in Pago Pago.

Other efforts either on-going or planned include: (1) a fish and invertebrate survey and a subsistence use survey of the Nu'uuli Pala by the Department of Marine and Wildlife Resources; (2) toxicity testing of the Nu'uuli Pala sediments and waters by the American Samoa Environmental Protection Agency; and (3) additional field surveys and wetland delineations in the Manu'a Group by the American Samoa Coastal Management Program.

Wetland Area Legislation

Two principal statutes govern the protection, management and enhancement of wetlands in the Territory. These are the Coastal Management Act (ASCA 24.05), administered by the Economic Development Planning Office/American Samoa Coastal Management Program (EDPO/ASCMP), and the Environmental Quality Act (ASCA 24.02), administered by the American Samoa Environmental Protection Agency/Environmental Quality Commission. The latter Act includes the territorial Water Quality Standards. The Project Notification and Review System (PNRS), administered by EDPO/ASCMP, operates as a consolidated permitting system, and provides for interagency review of all proposed "major" developments, including those involving potential wetland impacts.

Presently lacking from territorial legislation is a specific wetland definition or delineation criteria. Thus, as alluded to earlier, regulatory control of freshwater wetlands that occur inland from tidal influence is subject to dispute. Elsewhere, the mean high waterline is commonly seen to be the "natural" delineation boundary for wetlands. Efforts to implement the wetlands management plan will include seeking a legal refinement on such issues, as well as a "no net loss" territorial policy.

At the U.S. federal level, the U.S. Army Corps of Engineers has regulatory authority over all waters of the United States, including wetlands, through Section 404 of the Clean Water Act. Applications for a 404 permit are relayed to the U.S. Fish and Wildlife Service and the U.S. Environmental Protection Agency (USEPA) for comment before issuance. The USEPA has veto authority over issuance of 404 permits. In practice, although these agencies have regulatory jurisdiction over American Samoa's wetlands, enforcement of wetlands violations to-date has been left entirely with the American Samoan Government.

Wetland Area Administration

The wetlands of Nu'uuli Pala (49.7 ha) and Leone Pala (8.4 ha) have been designated as Special Management Areas under the Coastal Management Act of 1990, in recognition of their significance to fish and wildlife habitat, recreational value and/or general importance to the community. The EDPO/ASCMP is responsible for developing management plans specific to these two wetlands and any others that may be recommended for similar designation by the Governor. The Coastal Management Program is currently working to produce a guide to the wetlands of American Samoa.

Two candidate Special Management Areas presently under consideration include the freshwater

Faimulivai Marsh (14.9 ha) in the crater lake on Aunu'u, and a pristine freshwater swamp (29.1 ha) at Malaeloa on Tutuila. Dominant vegetation within the Malaeloa swamp includes the langasat tree *Barringtonia samoensis*, the Tahitian chestnut *Inocarpus fagifer* and the beach hibiscus *Hibiscus tiliaceus*. A survey in 1991 discovered the occurrence of bucago *Erythrina fusca*, which had previously been collected only once on Tutuila in 1929.

The Department of Parks and Recreation has the legislative mandate to inventory government lands, including wetlands, and to make recommendations to the Governor for the creation of nature reserves (among other categories of parks). To date, this authority has not been exercised, although implementation of the wetlands management plan will attempt to utilize this legal authority to protect the most critical wetland areas.

Organizations involved with Wetlands

The American Samoa Coastal Management Program, administered by the Economic Development Planning Office, is the primary governmental focal point for wetland management planning and implementation. Responsibilities for project review and enforcement are shared with the American Samoa Environmental Protection Agency. In addition, the Environmental Quality Commission and the Natural Resources Commission are governor-appointed entities responsible for providing direction and oversight for the maintenance of water quality and preservation of critical habitat and ecosystems. The Department of Marine and Wildlife Resources administers a fisheries research programme with special focus thus far on the Nu'uuli Pala.

The local environmental NGO, Le Vaomatua, works to enhance public awareness on environmental issues, and has been a strong advocate for increased management of the Territory's few remaining wetlands.

WETLANDS

Site descriptions compiled from material provided by Carol A. Tanielu of the Economic Development Planning Office, American Samoa Government, and the literature.

Leone Bay (1)

Location: 170°47'W, 14°21'S; on the southwest coast of Tutuila, 12 km southwest of Pago Pago.
Area: The total area of wetland was estimated at 16.2 ha in 1961, but this had been reduced to 8.4 ha by 1991. Whistler (1976) gives the area of mangrove forest as approximately 9 acres (3.6 ha).
Altitude: Sea level.
Overview: A shallow sea bay with extensive intertidal mudflats, the estuaries of two streams and an important area of mangrove forest and salt marsh.
Physical features: Leone Bay (Leone Pala) consists of a shallow bay separated from the ocean by a fringing reef with a generally northwest-southwest orientation. The bay is delineated by Logologo Point to the southeast and Apolima Point to the northwest. Islands in the Bay include: Niuaveve Rock, a small island with a single coconut tree; a rubble island near the centre of the fringing reef; and Papaloa Rock, a row of sandstone islets forming a partial barrier across the northeastern shore. Two streams discharge into the bay: the Leafu and the Fuafua. The Leafu Stream is 9.9 km in length and has a catchment area of 320 ha. The upper reaches of Leafu catchment are covered in undisturbed forest; the lower estuarine reaches support mangrove forest (3.6 ha) with a adjoining

salt marsh. The Fuafua stream is 12.8 km in length, and has a catchment area of 400 ha, most of which is now highly disturbed.

No tidal data are available, but tides in Leone Bay are apparently close in timing and range to those at Apia, Western Samoa. The tide in Apia is mixed semi-diurnal with a spring range of 1.1 metres and a neap range of 0.4 metres. Water circulation in the bay is driven predominantly by waves breaking over the reef flat (particularly to the north), by the tides and by freshwater flow from Leafu Stream. Circulation from the fringing reef is sluggish, flowing generally to the northwest parallel to the reef. The bay inside of the fringing reef has a maximum depth of about one metre at mean lower low water (MLLW). The reef crest is shallow (10-30 cm deep at the northern and southern ends) except for a channel about 1-2 metres deep just south of the rubble island which carries the flow of water exiting the lagoon.

The climate is warm and humid with an average temperature of 26°C and an average humidity of 80%. The mean annual rainfall is 3,200 mm at Pago Pago airport, with the heaviest rains from November to March. Trade winds blow generally from the southeast from May to November, and are variable for the rest of the year. The hurricane season is during the austral winter, with tropical storms sufficient to cause damage occurring about every 3-5 years. Leone Bay is somewhat protected from the trade winds by the hills to the east and by Logologo Point.

Ecological features: The mangrove forest is dominated by *Bruguiera gymnorrhiza*, with a considerable amount of *Rhizophora mangle* mixed in. The forest is dense and mostly less than 5 m in height. Behind the mangrove swamp, there is a small salt marsh consisting of two patches of the marsh grass *Paspalum vaginatum* with some candlebush (*Cassia alata*) and a stand of *Hibiscus tiliaceus* trees. The extensive intertidal mudflats in the bay are largely devoid of macrophytes.

Land tenure: Most land surrounding Leone Bay is communal land. Communal land is land set aside for an extended family (Aiga) and governed by a Matai (High Chief).

Conservation measures taken: The U.S. Fish and Wildlife Service, in accordance with its Mitigation Policy, has designated the mangrove swamps at the mouth of Leafu Stream as "Resource Category 1", meaning that there should be no loss of existing habitat values. Conservation of Leone Bay was identified as a national priority in the SPREP/IUCN Action Strategy for Nature Conservation in the South Pacific (SPREP/IUCN, 1989). The wetland area (8.4 ha) was designated as a Special Management Area under the Coastal Management Act of 1990 in recognition of its significance to fish and wildlife habitat, recreational value and general importance to the community. The Coastal Management Program in the Economic Development Planning Office is responsible for developing a management plan for the site.

Land use: Subsistence fishing in the bay. The mangrove forest is utilized as a source of firewood. As of the 1980 census, Leone village was the fourth largest village in American Samoa and the largest in Western District.

Possible changes in land use: A commercial boat harbour facility was proposed for Leone Bay by the previous administration. A comprehensive feasibility study was conducted by Energy Resources International, Inc. (1989) outlining the positive and negative impacts of the proposed project. The project was shelved during the transition to the new administration and has not been resurrected.

Disturbances and threats: The mangrove forest is slowly losing ground to encroaching settlement. The dumping of litter, illegal landfill and pollution from pig farming are major problems in the area. Problems with groundwater quality have resulted both from infiltration of polluted surface water and from the encroachment of saline water. A recent study of groundwater in the Leone area revealed that during and after heavy rainfall, several well fields exhibited unacceptably high turbidity and total and faecal coliform levels. All active wells in this area have had at least one water sample exceeding the maximum contaminant standards for turbidity and/or coliform levels, and several well-fields have exceeded these standards consistently during rainy periods. Leone village is experiencing pressure as residents seek to expand into inland areas which have traditionally been reserved for agricultural uses. New development, which would potentially draw new businesses and residents to the village, would increase the pressures on environmentally sensitive areas including the reef communities and the wetlands.

Hydrological and biophysical values: No information.
Social and cultural values: Water supply, fishing, agriculture and light tourism. Leone village is rich in archaeological and cultural properties.
Noteworthy fauna: The wetlands support a variety of both native and migratory waterbirds. Resident species include the Pacific Reef Heron (*Egretta sacra*), Banded Rail (*Rallus philippensis*) and Collared Kingfisher (*Halcyon chloris*); migratory species include the Pacific Golden Plover (*Pluvialis fulva*), Ruddy Turnstone (*Arenaria interpres*), Bristle-thighed Curlew (*Numenius tahitiensis*), Bar-tailed Godwit (*Limosa lapponica*), Wandering Tattler (*Heteroscelus incanus*) and Sanderling (*Calidris alba*). Five species of geckoes and seven species of skinks are found in the area, along with one introduced amphibian, the Marine Toad (*Bufo marinus*). Mammals include the Polynesian Rat (*Rattus exulans*), House Mouse (*Mus musculus*) and feral pig (*Sus scrofa*). Mudflats throughout the bay support a dense population of fiddler crabs (*Uca* sp.), while the estuarine sandflats are habitat for a dense population of *Calianassa* mud shrimps. Mangrove crabs (*Scylla serrata*) and freshwater prawns (*Macrobrachium* sp.) are also present.
Noteworthy flora: The mangrove swamp is one of the few important mangrove forests remaining on Tutuila. It is believed that the first specimen of the shrub *Erythrina fusca* from American Samoa (collected in 1929) came from the marsh behind the mangroves.
Scientific research and facilities: A report prepared for the Environmental Quality Commission of the territory by Energy Resources International, Inc. (1989) explored many of the current concerns surrounding Leone Bay, as well as the positive and negative impacts of a proposed commercial boat harbour.
Recreation and tourism: Tourism occurs on only a small scale, although there are several historical sights in Leone Bay of interest to tourists. The proposed boat harbour would provide more recreational and tourist attractions but at great sacrifice to the natural environment.
Management authority and jurisdiction: American Samoa Coastal Management Program and Environmental Protection Agency.
References: Amerson *et al.* (1982a, 1982b); Energy Resources International, Inc. (1989); Kennedy, Jenks & Chilton (1987); Noda & Associates (1987); SPREP/IUCN (1989); U.S. Army Corps of Engineers (1981); Whistler (1976).
Reasons for inclusion: 1a, 2b, 2c. One of the most important mangrove swamps in American Samoa, with a rich and diverse flora and fauna and noteworthy socio-economic and cultural values.
Source: Carol A. Tanielu.

Pala Lagoon (Nu'uuli Pala) (2)

Location: 170°42'W, 14°19'S; on the south coast of Tutuila, 5 km south-southwest of Pago Pago.
Area: Bay area 300 ha. The total area of wetland was estimated at 74.7 ha in 1961, but this had been reduced to 49.7 ha by 1991.
Altitude: Sea level.
Overview: A shallow sea bay with extensive fringing mangrove swamps and rocky wooded promontories. The lagoon is an important nursery and spawning ground for fish and invertebrates.
Physical features: Pala Lagoon is a shallow sea bay with a relatively narrow exit to the open sea. Estuarine conditions are created by the influx of fresh water from two principal streams, the Vaitele and the Papa, and seven springs near the western and northern shores. The lagoon is roughly circular in shape. Approximately two thirds of the inner lagoon area is very flat and shallow, with a depth ranging from 0.3 to 1.5 metres depending upon tide. The bottom is muddy, coral sand to silty mud, and the overlying water is usually turbid. The mean residence time for water in the lagoon is about 30 hours. The mean total volume of the lagoon is about two million cubic metres; a volume equal to about forty percent of this is exchanged during a semidiurnal tidal cycle. There are approximately 49.7 ha of mangrove forest which extends in a broad fringe around much of the

lagoon. The largest stands are found along the north and east shores and at Coconut Point, north of the entrance to the lagoon.
Ecological features: The algal flora is dominated by the red algae *Acanthophora spicifera*, which covers much of the muddy and sandy bottom of the lagoon. Other algae include the green algae *Caulerpa* sp. and the brown algae *Dictyota* sp. and *Padina* sp. The calcareous green algae *Halimeda* sp. and the sea grass *Halophila minor* occur on the sandflats bordering Coconut Point. Small springs along the rocky western shore of the lagoon support dense mats of the filamentous algae *Enteromorpha* sp. (Yamasaki *et al.*, 1985). Most of the mangrove vegetation consists of well-developed stands of large *Bruguiera gymnorrhiza* trees forming a continuous canopy 8-16 m high. Ground cover is absent except for *Bruguiera* seedlings. *Rhizophora mangle* occurs in small stands along the seaward margin of the *Bruguiera* forest, and also as a band of vegetation along the western edge of Nu'uuli peninsula between the village and the lagoon. This is the only large stand of red mangrove in American Samoa. A few "puzzlenut" trees (*Xylocarpus moluccensis*) have been found growing along the seaward margin of the swamp at Coconut Point and on the rocky western shore of the lagoon (Whistler, 1976). Yamasaki *et al.* (1985) failed to find any *Xylocarpus* on the western shore, and suspected that the trees had been cut during one or more of the landfill projects in the early 1980s. The uncommon shrub *Sophora tomentosa* occurs at Coconut Point (Yamasaki *et al.*, 1985).
Land tenure: Areas surrounding the lagoon are generally communally owned land, *i.e.* land set aside for an extended family and governed by a Matai/high chief.
Conservation measures taken: Various authors have recommended that Pala Lagoon be afforded protected status, *e.g.* Dahl (1980), UNEP/IUCN (1988) and Engbring and Ramsey (1989). Conservation of Nuu'uli Pala Lagoon was identified as a national priority in the SPREP/IUCN Action Strategy for Nature Conservation in the South Pacific (SPREP/IUCN, 1989). Pala Lagoon has subsequently been declared a Special Management Area under the Coastal Management Act of 1990, in recognition of its significance to fish and wildlife habitat, recreational value and general importance to the community. The Coastal Management Program in the Economic Development Planning Office is responsible for developing a management plan for the area. The following activities are prohibited in the Special Management Area: dumping or discharge of solid or industrial waste materials; construction of animal pens over or adjacent to the shoreline; dredging and filling activities, except when in compliance with applicable permits and water quality standards; discharge of hazardous and radio-active waste; and discharge of oil sludge, oil refuse, fuel oil or bilge water from any vessel or shoreside facility. The support and propagation of marine resources and mariculture development are encouraged. A public sewerage system has been connected to surrounding areas, thereby eliminating pollution by raw sewage.
The Nu'uuli village council is apparently becoming more aware of the need to protect the lagoon, and has been very cooperative regarding land use regulations.
Conservation measures proposed: Yamasaki *et al.* (1985) have provided a series of recommendations for the management of the mangrove and lagoon areas of Pala Lagoon.
Land use: Subsistence fishing and the harvesting of crabs are permitted in the bay. The large mangrove crab *Scylla serrata* is a favourite local food item, and is trapped with nets and wire-mesh traps. Some mangrove is cut for firewood. The village of Nu'uuli, which borders on the lagoon, is a residential and business area.
Disturbances and threats: In recent years, there has been some use of dynamite and poisons for fishing, but this is now prohibited. The northern edge of the wetland is slowly being encroached upon by landfills from Nu'uuli village. Mangroves have been cut and filled to provide land for home sites. At several sites, rubbish has been used as the initial fill material, over which layers of cinders have been packed (Yamasaki *et al.*, 1985). Landfill violations are now subject to litigation, and two such cases are pending. The dumping of rubbish continues to be a problem, especially in one area, where the illegal dumping of solid waste, including old automobiles, creates pollution of the surrounding water. In 1971, a study on the expected impact of a dredging project in the lagoon revealed that coliform and faecal coliform counts were 6,000 per 100 ml and 57 per 100 ml, respectively. Bacterial contamination appeared to be the cause of an outbreak of hepatitis in people

eating clams from the lagoon. Following the installation of the public sewerage system, microbial contamination has decreased.

Hydrological and biophysical values: The mangroves are valuable for land-building, protection against erosion and storm damage, and as breeding and nursery grounds for many species of offshore and coastal fish and invertebrates.

Social and cultural values: Subsistence fishing is still the major social function of the lagoon. The high levels of pollution are a deterrent to swimming and other recreational activities.

Noteworthy fauna: The lagoon supports an abundance of fish and invertebrates. Yamasaki *et al.* (1985) found a surprisingly high diversity of fish species in the inner lagoon and a great abundance of mullet (Mugilidae). These authors also found an abundance of small predatory fish, notably juvenile *Sphyraena barracuda* and *Caranx ignobilis*. Common invertebrates include the scyphozoan *Cassiopeia* sp., the holothurians *Stichopus* sp. and *Actinopyga* sp., the gastropods *Littorina* sp. and *Nerita plicata*, the mangrove oyster *Isogamon* sp., the edible clam *Gafrarium tumidum*, mantis shrimps *Lysiosquilla* sp., fiddler crabs *Uca* sp., land crabs *Cardisoma* sp., and the mangrove crab *Scylla serrata* (Yamasaki *et al.*, 1985). Due to the low salinity and high turbidity of the lagoon water, corals are virtually non-existent within the lagoon, although there is some live coral in and around the entrance channel. Marine turtles are occasionally reported in the lagoon, probably Hawksbill (*Eretmochelys imbricata*).

The wetlands formerly provided habitat for the Pacific Black Duck (*Anas superciliosa*), which still occurred in the area as recently as 1975 (Amerson *et al.*, 1982), but this species is now probably extinct in American Samoa. The tidal mudflats are of considerable importance for migratory shorebirds, mainly Pacific Golden Plover *Pluvialis fulva*, Wandering Tattler *Heteroscelus incanus* and Ruddy Turnstone *Arenaria interpres* (Engbring & Ramsey, 1989). The Bar-tailed Godwit (*Limosa lapponica*) has also been recorded. Birds occurring in the mangrove forest include Banded Rail (*Rallus philippensis*), Collared Kingfisher (*Halcyon chloris*), Wattled Honeyeater (*Foulehaio carunculata*) and Cardinal Honeyeater (*Myzomela cardinalis*) (Amerson *et al.*, 1982). The Sheath-tailed Bat (*Emballonura semicaudata*) forages in the mangroves.

Noteworthy flora: Pala Lagoon contains by far the largest stands of mangrove forest in American Samoa, as well as the only large stand of red mangrove (*Rhizophora mangle*) and one of only two stands of the puzzlenut tree (*Xylocarpus moluccensis*), a potentially threatened species in American Samoa.

Scientific research and facilities: Various general floral and faunal surveys have been carried out, and Yamasaki, Itano and Davis (1985) conducted a detailed study of the mangrove and lagoon areas. There are no research facilities at the present time.

Conservation education: Various public awareness programmes have been undertaken in conjunction with the American Samoa Coastal Management Program, the Department of Education, Marine and Wildlife Resources and the Environmental Protection Agency. These public awareness activities have focused on the preservation and restoration of the lagoon, and have been met with mixed reactions from local residents.

Recreation and tourism: There is very little recreation or tourism in the area at present. A small boat harbour was proposed, but the idea was shelved as it would have meant the destruction of much of the "naturalness" of the bay.

Management authority and jurisdiction: The American Samoa Coastal Management Program, under the aegis of the Economic Development Planning Office.

References: Amerson *et al.* (1982); Dahl (1980); Engbring & Ramsey (1989); Helfrich (1975); Preston (1988); Shleser & May (1977); SPREP/IUCN (1989); Takata (1986); UNEP/IUCN (1988); U.S. Army Corps of Engineers (1980, 1986); U.S. Department of Commerce (1980); Whistler (1976); Yamasaki *et al.* (1985).

Reasons for inclusion: 1a, 2b, 2c. The site contains the largest stands of mangroves in American Samoa, and supports a rich and diverse estuarine flora and fauna.

Source: Carol A. Tanielu.

Wetlands of Aunu'u (3)

Location: 14°17'30"S, 170°33'E; on the island of Aunu'u, 1.6 km off the southeastern tip of Tutuila.
Area: 45 ha.
Altitude: Sea level to 6 m.
Overview: A freshwater marsh in a dormant volcanic crater; a unique "mud" lake with fringing mangrove forest; a large area of taro fields in a former freshwater marsh; and a small area of mixed mangrove forest. These wetlands include the largest and least disturbed freshwater marsh in American Samoa and one of only two stands of the "puzzlenut" tree *Xylocarpus moluccensis*.
Physical features: Aunu'u Island is a small volcanic island (2.6 sq.km) with a 61 metre cone. There are four significant wetlands on the island: a large freshwater marsh (Faimulivai Marsh) in Aunu'u Crater; an area of taro fields in a former marsh near Aunu'u village; a mud lake (Pala Lake) with fringing mangroves near the north end of the island; and a small patch of mixed mangrove forest on poor rocky soils on the south coast of the island. With an area of 14.9 ha, Faimulivai Marsh is the largest freshwater wetland in American Samoa. The wetland is about six metres above sea level, and consists of several open-water ponds surrounded by extensive marshes. It is drained by a stream that flows out of the eastern end of the crater. Faimulivai Marsh is somewhat anomalous in that it was formed not by sedimentation in a lagoon but from poor drainage in a low-lying crater. The Aunu'u taro fields, covering about 11.0 ha, are situated in a large depression between the western slope of the crater and the village of Aunu'u. This area was formerly an extensive coastal marsh, but little of the original marsh vegetation remains. Pala Lake is an area of "quicksand" inland from the north coast of the island. It is slightly above sea level, and consists of reddish-brown mud covering an area of about 1.2 ha. The mud is totally devoid of vegetation, and is completely surrounded by a narrow strip of tall mangrove trees. The mangrove forest extends in a northwesterly direction, and becomes mixed with trees of the coastal and lowland forests. The whole wetland covers an area of about 18.1 ha.
Ecological features: Faimulivai Marsh has two main zones of vegetation. The western half is composed almost entirely of two species, *Eleocharis dulcis* and *Cyclosorus interruptus*, which form a dense vegetation 1.0-1.5 m high. On the eastern side and around the margins of the central pond, the vegetation is dominated by large clumps of *Acrostichum aureum* up to 3 m in height. Along the edges of the marsh, there is a dense thicket of *Hibiscus tiliaceus* trees which separates the marsh from the coconut groves and secondary forest on the inside slopes of the crater. *Ludwigia octovalvis* and *Rhynchospora corymbosa* appear in disturbed portions of the marsh. The marshy depression near Aunu'u village is largely under cultivation for taro (*Colocasia esculenta*). Some *Acrostichum*, *Cyclosorus*, *Eleocharis*, *Rhynchospora* and *Ludwigia* persist, along with a number of weeds that have invaded the area, such as *Canna indica*, *Alternanthera sessilis*, *Paspalum conjugatum*, *Mikania micrantha* and *Commelina diffusa*. The fringe of mangrove around Pala Lake consists of tall *Bruguiera gymnorrhiza* trees (up to 15 m high) with small *Rhizophora mangle* trees around the edge. The mixed mangrove forest on the south coast consists of *B. gymnorrhiza* mixed with a few *Xylocarpus moluccensis* trees and several species of the littoral forest. The surrounding open forests contain typical littoral species such as *Hernandia sonora*, *Pisonia grandis* and *Barringtonia asiatica*, as well as a coastal ridge species, *Planchonella costata*.
Land tenure: No information.
Conservation measures taken: Part of Aunu'u Island (123 ha), including Faimulivai Marsh, was designated a National Natural Landmark in 1972 (Amerson *et al.*, 1982; IUCN, 1991).
Conservation measures proposed: Whistler (1976) considered the marsh inside Aunu'u Crater to be a unique type of wetland vegetation, and recommended that any proposal for nature reserves in American Samoa should give this site priority. He also identified the mud lake as a unique type of wetland worthy of special protection. Dahl (1980), Amerson *et al.* (1982) and Engbring and Ramsey (1989) recommended the establishment of a reserve at Faimulivai Marsh, and the conservation of this wetland was identified as a national priority in the SPREP/IUCN Action Strategy for Nature

Conservation in the South Pacific (SPREP/IUCN, 1989). Faimulivai Marsh (14.9 ha) is currently being considered for designation as a Special Management Area under the Coastal Management Act of 1990.
Land use: There is one small village on the island. The marshy depression near Aunu'u village is intensively cultivated for taro. These taro patches are probably the best in Samoa, with extensive canals and a paved walkway crossing the area (Whistler, 1976).
Disturbances and threats: The mixed mangrove forest on the south coast of the island has been degraded by severe cutting for firewood by local villagers. The disappearance of the Pacific Black Duck has been attributed to hunting, rat predation and human disturbance in the marshes (Amerson *et al.*, 1982). Purple Swamphens are both hunted for food and killed as pests on crops.
Hydrological and biophysical values: No information.
Social and cultural values: No information.
Noteworthy fauna: The Pacific Black Duck (*Anas superciliosa*) formerly occurred as a breeding species in the wetlands. Seven were observed in Faimulivai Marsh in November 1976 (Amerson *et al.*, 1982), but there do not appear to have been any records on the island since about 1980, and the species may now be extinct as a breeding bird in American Samoa (Engbring & Ramsey, 1989). The Purple Swamphen (*Porphyrio porphyrio*) remains fairly common despite some persecution. Engbring and Ramsey (1989) observed seven at one time in Faimulivai Marsh in 1985. These birds belong to the subspecies *P. p. samoensis*, endemic to the high islands of American Samoa and Western Samoa. Other waterfowl recorded on Aunu'u include Pacific Reef Heron (*Egretta sacra*), Banded Rail (*Rallus philippensis*) and three species of migratory shorebirds: Pacific Golden Plover (*Pluvialis fulva*), Wandering Tattler (*Heteroscelus incanus*) and Ruddy Turnstone (*Arenaria interpres*) (Amerson *et al.*, 1982; Engbring & Ramsey, 1989). Collared Kingfishers (*Halcyon chloris*) and Wattled Honeyeaters (*Foulehaio carunculata*) frequently forage in the mangrove areas.
The Polynesian Rat (*Rattus exulans*) and Brown Rat (*R. rattus*) are common on the island and both occur in the freshwater marshes. Other mammals include the flying fox *Pteropus samoensis* and the Sheath-tailed Bat (*Emballonura semicaudata*), the latter frequently foraging in the mangroves.
The Marine Toad (*Bufo marinus*) was introduced in 1953 by the U.S. Department of Agriculture as a general control on insect pests, and is now common in the wetlands (Amerson *et al.*, 1982).
Noteworthy flora: Faimulivai Marsh is the only site in American Samoa with an intact *Eleocharis dulcis* marsh community. The mangroves of Aunu'u are at the extreme eastern limit of natural mangrove distribution in the Central Pacific. The *Xylocarpus moluccensis* trees at the south end of the island comprise one of only two stands of this rare species in American Samoa.
Scientific research and facilities: The wetland flora has been surveyed by Whistler (1976) and Cole *et al.* (1988). The wildlife has been investigated by Amerson *et al.* (1982), and detailed surveys of the bird fauna have been conducted by Engbring and Ramsey (1989).
Management authority and jurisdiction: No information.
References: Amerson *et al.* (1982); Cole *et al.* (1988); Dahl (1980); Engbring & Ramsey (1989); IUCN (1991); SPREP/IUCN (1989); Whistler (1976).
Reasons for inclusion: 1a, 1d, 2b. Faimulivai Marsh is the largest area of freshwater marsh in American Samoa, and the only one which remains in a relatively undisturbed condition. Pala "Mud" Lake is a unique type of wetland. The mangroves are of interest as the easternmost stands in the Central Pacific.
Source: See references.

Lake Namo (4)

Location: 11°03'S, 171°05'E; in the centre of Swain's Island, 360 km NNW of Tutuila.
Area: Approximately 100 ha.
Altitude: Sea level.
Overview: A enclosed brackish lagoon with a small area of salt marsh in the centre of a raised coral atoll.
Physical features: Swain's Island is a raised, ring-shaped atoll with a total area of 326.34 ha, a maximum elevation of 9.1 m and a shoreline of 6.2 km. Geographically and floristically, the island is closely related to the Tokelau Islands, 160 km to the northwest. The entire central portion of the island is occupied by a large brackish lagoon, Lake Namo, which has apparently been isolated from the sea only in recent times. The lagoon is approximately 1.5 km long and 1.0 km wide. There is a small patch of marsh on the north side of the lagoon. The annual rainfall is about 2,500 mm.
Ecological features: The salt marsh on the north side of the lagoon is dominated by *Paspalum distichum* and *Eleocharis geniculata*. Swain's Island was originally covered with littoral forest dominated by species of *Pisonia*, *Hernandia*, *Pandanus*, *Neisosperma*, *Calophyllum* and possibly *Barringtonia* and *Cordia*. This original vegetation was almost totally removed and replaced with coconut plantations for the production of copra. Most of the plantations have recently been abandoned, and the coconut trees are slowly being replaced by littoral forest, chiefly *Hernandia* and *Pandanus* (Amerson *et al.*, 1982). *Scaevola* is the dominant plant in the littoral scrub vegetation.
Land tenure: The customary owners of Swain's Island were the Tokelauans of Fakaofo. The island came into private ownership in 1856, when the coconut plantations were established, and remains a private estate owned by the Jennings family. The island is a sovereign (flag) possession of the U.S.A.
Conservation measures taken: None.
Conservation measures proposed: Swain's Island was recommended for protected area status by UNEP/IUCN (1988).
Land use: Until recently, the production and exportation of copra were major activities on the island, and several hundred Tokelau Islanders were employed for this purpose (Amerson *et al.*, 1982). Copra production has now apparently ceased. By 1987, the population had declined to 18-20, and there are now only about ten people living on the island.
Disturbances and threats: None known at the lagoon. A severe storm in early 1987 caused devastating damage to the coral reefs, and destroyed all buildings at Taulaga, the only village on the island (UNEP/IUCN, 1988). The paucity of breeding birds has been attributed to disturbance from the human inhabitants (Amerson *et al.*, 1982). The harvesting of turtles and turtle eggs in the early 1980s may have been responsible for the disappearance of *Chelonia (mydas) agassizi* as a breeding species on the island.
Hydrological and biophysical values: No information.
Social and cultural values: No information.
Noteworthy fauna: Seven species of reptiles occur on the island, including three species of gecko, three species of skink and the Black Turtle *Chelonia (mydas) agassizi*. The turtle formerly nested on the island, but now occurs only as a visitor to inshore waters. Swain's Island is the only known locality for the Micronesian Skink (*Emoia adspersa*) in American Samoa. The Pacific Reef Heron (*Egretta sacra*) breeds in the coconut plantations and feeds in shallow portions of the lagoon. The Pacific Black Duck (*Anas superciliosa*) has been reported in the past, and could still occur as a visitor. Five species of migratory shorebirds have been recorded: the Pacific Golden Plover *Pluvialis fulva*, Wandering Tattler *Heteroscelus incanus*, Bristle-thighed Curlew *Numenius tahitiensis*, Ruddy Turnstone *Arenaria interpres* and Sanderling *Calidris alba* (rare). Four species of seabird breed: White-tailed Tropicbird *Phaethon lepturus*, Brown Noddy *Anous stolidus*, Black Noddy *A. minutus* and White Tern *Gygis alba*, but numbers are relatively low. The Polynesian Rat *Rattus exulans* is common, and feral pigs are found in the coconut plantations.
Noteworthy flora: Lake Namo is the only known locality for *Eleocharis geniculata* in Samoa.
Scientific research and facilities: The fauna and flora of Swain's Island have been surveyed by Amerson *et al.* (1982). Work on the coral reefs has been summarized in UNEP/IUCN (1988).
Management authority and jurisdiction: No information.

References: Amerson *et al.* (1982); UNEP/IUCN (1988).
Reasons for inclusion: 1a, 2a, 2b. A good example of an enclosed brackish lagoon; habitat for shorebirds including *Numenius tenuirostris*.
Source: See references.

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Table 1: Summary of the change in total wetland acreage for the wetland areas of Tutuila and Aunu'u Islands.

Wetland	**1961 Wetlands (acres)**	**1991 Wetlands (acres)**	**Loss (Gain) (acres)**	**Percent change (%)**	**Rate of change (acre/yr)**
Tutuila Island	488.12	350.93	137.19	28%	4.57
Nu'uuli Pala	184.49	122.90	61.59	33%	2.05
Leone Pala	40.10	20.74	19.36	48%	0.64
Malaeloa	92.20	72.06	20.14	22%	0.67
Aua	11.63	9.18	2.45	21%	0.08
Masefau	48.48	43.06	5.42	11%	0.18
Vatia	33.60	34.05	(0.45)	+1.3%	+0.01
Alofau	3.17	2.03	1.14	36%	0.04
Aoa	36.60	23.45	13.15	36%	0.44
Alao	18.66	15.47	3.19	17%	0.11
Tula	19.19	7.99	11.20	58%	0.37
Aunu'u Island	111.76	111.93	(0.17)	+0.1%	Insignificant
Pala Lake	44.76	44.76	No change	0	No change
Taro Fields	27.30	27.30	No change	0	No change
Crater Lake	36.84	36.84	No change	0	No change
School Swamp	2.86	3.03	(0.17)	+0.1%	Insignificant
TOTAL	**599.88**	**462.86**	**137.02**	**23%**	**4.57**

Source: Biosystems Analysis, Inc. (1991).

CHILEAN TERRITORIES

INTRODUCTION

by Roberto Schlatter

A Directory of Neotropical Wetlands, published in 1986, contains a chapter on wetlands in Chile (Schlatter & Espinosa, 1986). This includes a brief account of the progress that had been made in wetland conservation and research in Chile up to 1985, and describes 50 of the principal wetland systems. However, no information was available at that time on the wetlands of Chile's remote offshore islands in the South Pacific, and these islands were therefore omitted from the *Directory*. The following account is confined to a description of the wetlands of Chile's oceanic islands, and the reader is referred to *A Directory of Neotropical Wetlands* for more general information on wetlands and wetland conservation in Chile as a whole.

Area of oceanic islands: 359.5 sq.km.

Population: Isla de Pascua 2,100; Juan Fernandez Archipelago 550 (1982).

Chile's oceanic islands comprise the Islas Desventuradas, Juan Fernandez Archipelago, Isla de Pascua (Easter Island) and Isla Sala y Gomez.

The Islas Desventuradas are situated some 972 km from the Chilean mainland. They include two main islands, Isla San Felix (26°17'S, 80°05'W) and Isla de San Ambrosio (26°20'S, 70°58'W), a small islet to the southeast of Isla San Felix, Islote Gonzalez (26°19'S, 80°04'W), and several tiny rocks and stacks. Together, the islands have a surface area of only 10.3 sq.km. The topography is very rugged, with peak elevations of 193 m on Isla San Felix and 479 m on Isla de San Ambrosio.

The Juan Fernandez Archipelago National Park and Biosphere Reserve consists of three islands, Isla Robinson Crusoe (33°37'S, 78°53'W), Isla Santa Clara (33°42'S, 79°01'W) and Isla Alejandro Selkirk (33°45'S, 80°45'W), with a combined area of 183 sq.km. Isla Robinson Crusoe Island (93 sq.km) and the nearby, much smaller Isla Santa Clara (5 sq.km) are situated about 670 km west of Valparaiso. Isla Alejandro Selkirk (85 sq.km) is 167 km west of Isla Robinson Crusoe and about 835 km west of Valparaiso. All three islands are mountainous, with maximum elevations of 915 m, 375 m and 1,650 m respectively.

Isla Sala y Gomez (26°27'S, 105°28'W), a Nature Sanctuary, lies about 3,400 km west of the Chilean mainland and about 415 km east of Isla de Pascua. This small volcanic island, with an area of only 2.5 sq.km, consists of two hills of bare rock joined by a narrow isthmus. The maximum elevation is only about 30 m.

Isla de Pascua, or Easter Island, (27°09'S, 109°23'W), is much the largest of Chile's oceanic islands, with an area of 163.7 sq.km. This high volcanic island, most of which is a National Park, is situated about 3,790 km west of the Chilean mainland and about 2,200 km east of the Pitcairn Island, which is the nearest inhabited island. The island is roughly triangular in shape, with an extinct volcano at each corner. The interior consists of high plateaus and craters surrounded by coastal bluffs. The maximum elevation is 560 m at the summit of the main volcano, Mauna Terevaka. Many parasitic craters exist on the southern and southeastern flanks of Maunga Terevaka, and three of these, Rano Aroi, Rano Raraku and Rano Kau, contain crater lakes. The island was once extensively wooded with an endemic tree species *Sophora toromiro*, but all the trees were cut down by the indigenous inhabitants and grasslands now cover the island.

Chile's oceanic islands have recently been described in some detail in Castilla (1987). This summarizes available information on the geology, climate, terrestrial fauna, marine fauna and flora of the islands, and identifies priorities for future investigation. All four island systems support a variety of breeding seabirds, but populations have been sadly depleted on all but Sala y Gomez (the only one of the four to remain uninhabited) because of egg collecting by islanders and depradation by introduced predators. The status and conservation of seabirds in Chile's oceanic islands have recently been summarized by Schlatter (1984, 1987). Only Isla de Pascua has significant coral communities, which are described by UNEP/IUCN (1988).

The only significant wetlands are on Isla de Pascua, the most important of these being the three crater lakes: Rano Kau (the largest), Rano Rarako and Rano Aroi (the smallest). All three are approximately circular in shape, and support extensive stands of reeds and floating bogs of peat. There are no perennial freshwater streams on the island.

WETLANDS

Site descriptions compiled by Roberto Schlatter of the Instituto de Zoologia, Universidad Austral de Chile, and Roger Hicks.

Rano Kau (1)

Location: 27°09'S, 109°27'W; near the southwestern tip of Isla de Pascua (Easter Island).
Area: 100 ha.
Altitude: 120 m.
Overview: A freshwater crater lake almost completely covered by emergent and floating aquatic vegetation.
Physical features: Rano Kau is a collapsed cone now in the form of a caldera filled by a freshwater lake. The lake is about one km in diameter, and is fed by local run-off. More than 80% of the water surface is covered by a thick floating mat of reeds and peat. The pH of the water is 4.65. The lake is surrounded by crater walls which rise to 400 m above sea level on the east (island) side, with a lower saddle on the southern edge facing the sea.
Easter Island has an equatorial-oceanic climate, with an average annual rainfall of 1,126 mm and a mean annual temperature of 20.7°C (mean monthly minimum 15.5°C, mean monthly maximum 27.3°C). March to June are the wettest months; July to October the driest and coolest. Southeast trade winds dominate from October to April; during the rest of the year North and Northwest winds are more common.
Ecological features: Most of the wetland is covered with an emergent swamp of *Polygonum* and *Scirpus* and floating mats of the endemic moss *Campylopus turficola*. The surrounding grasslands are dominated by species of *Stipa* and *Nasella* as well as introduced *Sporobolus indicus* and *Cyndodon dactilon*. The vegetation of the island has been described by Etienne *et al* (1982).
Land tenure: State owned (Chilean Government).
Conservation measures taken: Protected within Rapa Nui National Park (4,755 ha) established in 1935 by Decree 103, Ministry of Lands and Colonization. A management plan for the park was published with the assistance of FAO in 1976 (Zentilli *et al*, 1976).
Land use: Tourism and water supply for the village of Hanga Roa.
Disturbances and threats: A species of *Gambusia* has been introduced into the lake for mosquito control, and there are many other introduced species of animal and plant on the island. Erosion, uncontrolled burning and damage caused by tourists may also pose problems to the wetland.

Hydrological and biophysical values: No information.
Social and cultural values: On the southwest slopes of the Rano Kau crater there are the remains of the ceremonial city of Orongo, consisting of 47 stone houses, and rocky outcrops covered in petroglyphs honouring the birdman and the god Make Make.
Noteworthy fauna: No waterbirds are known to have occurred at the lake (or indeed on Easter Island). The introduced Common Diuca Finch (*Diuca diuca*) occurs around the crater rim, and Red-tailed Tropicbirds (*Phaethon rubricauda*) occasionally visit the crater. There are no mammals on the island, other than introduced rodents and carnivores. Two terrestrial reptiles, *Lepidodactylus lugubris* and *Ablepharus boutoui poecilopleurus* occur on the island, but it is not known if they occur at the wetland.
Noteworthy flora: An endemic moss, *Campylopus turficola*, is present.
Scientific research and facilities: Limnological research is being carried out in the crater lakes in the National Park (Steffen and Palma, 1992), but no detailed studies have been made of the fauna and flora of the wetlands. The Chilean Navy is currently promoting scientific research on the island under the "Projecto Oceanografico Integrado", and is constructing a research laboratory.
Conservation education: There is a museum in the national park, but this is dedicated totally to archeological and anthropological material, and there is no interpretive material dealing with the natural environment.
Recreation and tourism: Rano Kau is an site of outstanding archeological interest and scenic beauty, and is a very popular destination for tourists.
Management authority and jurisdiction: Corporacion Nacional Forestal.
References: Dahl (1986); Etienne *et al* (1982); IUCN (1991); UNEP/IUCN (1988); Steffen & Palma (1992); Zentilli *et al*, 1976.
Reasons for inclusion: 1a, 2b, 2d. Rano Kau and the other two freshwater lakes on Easter Island are of considerable interest because of their extreme isolation. Easter Island (with the small rocky islet of Sala y Gomez) is the most isolated island in the Pacific Ocean, and is thus of great importance in the study of biogeographical dispersion and colonisation.
Source: Roberto P. Schlatter and Roger Hicks.

Rano Aroi (2)

Location: 27°09'S, 109°27'W; on the southern slopes of Maunga Terevaka volcano, near the centre of Isla de Pascua (Easter Island).
Area: 1 ha.
Altitude: 250 m.
Overview: A small freshwater crater lake with rich emergent aquatic vegetation.
Physical features: No information.
Ecological features: No information.
Land tenure: Privately owned.
Conservation measures taken: None.
Land use: A water supply for domestic livestock. Surrounding grasslands are intensively grazed.
Disturbances and threats: Possible excessive use of water.
Hydrological and biophysical values: No information.
Social and cultural values: No information.
Noteworthy fauna: No information.
Noteworthy flora: No information.
Management authority and jurisdiction: No information.
Reasons for inclusion: 1a, 2b. Rano Aroi and the other two freshwater lakes of Easter Island are of considerable interest because of their extreme isolation.
Source: Roberto P. Schlatter.

Rano Raraku (3)

Location: 27°09'S, 109°27'W; near the eastern end of Isla de Pascua (Easter Island).
Area: 10 ha.
Altitude: 50 m.
Overview: A small freshwater crater lake with extensive emergent aquatic vegetation.
Physical features: A freshwater lake in the crater of Rano Raraku volcano, roughly cirucular in shape and approximately 350 m in diameter. The lake, which has a volume of 206,100 cubic metres, is fed by local run-off. The pH of the water is 7.15.
The climate is equatorial-oceanic, with an average annual rainfall of 1,126 mm and a mean annual temperature of 20.7°C. March to June are the wettest months, and July to October the driest and coolest. Southeast trade winds dominate from October to April; during the rest of the year North and Northwest winds are more common.
Ecological features: The lake is fringed with stands of *Polygonum* and *Scirpus californicus* which cover 45% of the surface, mostly in the southern third of the lake, and there are floating mats of the endemic moss *Campylopus turficola.*
Land tenure: State owned (Chilean Government).
Conservation measures taken: Protected within Rapa Nui National Park (4,755 ha) established in 1935 by Decree 103, Ministry of Lands and Colonization. A management plan for the park was published with the assistance of FAO in 1976 (Zentilli *et al*, 1976).
Land use: Water supply and tourism. A pipe takes water from the lake to a nearby homestead. Domestic livestock visit the lake to drink.
Disturbances and threats: Erosion, uncontrolled fires and damage caused by tourists may pose problems to the wetland. Islanders do not recognise the Chilean Government's authority to declare their lands a national park and consequently respect few of its rules (UNEP/IUCN, 1988).
Hydrological and biophysical values: No information.
Social and cultural values: The southern wall of the volcano was the quarry for most of the stone statues (moai) for which Easter Island is famous. About 200 statues remain in the quarry, in various stages of completion.
Noteworthy fauna: No waterbirds are known to have occurred at the lake (or indeed on Easter Island). Large numbers of introduced Common Diuca Finches (*Diuca diuca*) and House Sparrows (*Passer domesticus*) utilise the reed beds, while introduced Chimango Caracaras (*Milvago chimango*) and Chilean Tinamous (*Nothoprocta perdicaria*) occur in the area. Dragonflies (Neuroptera) are present.
Noteworthy flora: An endemic moss, *Campylopus turficola*, is present.
Scientific research and facilities: Limnological research is being carried out in the crater lakes in the National Park (Steffen and Palma, 1992), but no studies have been made of the fauna and flora of the wetlands. A research laboratory is currently being constructed.
Recreation and tourism: The quarry in the southern wall of the crater is frequently visited by tourists.
Management authority and jurisdiction: Corporacion Nacional Forestal.
References: Dahl (1986); IUCN (1991); UNEP/IUCN (1988); Steffen & Palma (1992); Zentilli *et al*, 1976.
Reasons for inclusion: 1a, 2b. Rano Raraku and the other two freshwater lakes of Easter Island are of considerable interest because of their extreme isolation.
Source: Roberto P. Schlatter, Wladimir Steffen and Roger Hicks.

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COOK ISLANDS

INTRODUCTION

based on information provided by Anna Tiraa

Area: 241 sq.km.

Population: 16,455 (1986 Census).

The Cook Islands comprise 15 small oceanic islands in the central South Pacific, defined by statute as all the islands between latitudes 8° and 23° South and longitudes 156° and 167° West. The islands are situated about 3,200 km northeast of New Zealand, and are a self-governing country in free association with New Zealand. Although the total land area of the islands is only about 241 sq.km, the territorial seas and Exclusive Economic Zone cover an area of nearly two million sq.km.

The islands are divided geographically into a Northern Group of six islands and a Southern Group of nine islands. Five of the islands in the northern Group (Suwarrow, Penrhyn, Manihiki, Rakahanga and Pukapuka) are low-lying coral atolls with central lagoons, while the sixth (Nassau) is a tiny sand cay. Of the nine islands of the Southern Group, Palmerston and Manuae are typical atolls, Aitutaki is an "almost atoll" with a central volcanic cone rising to 119 m, and Takutea is a tiny sand cay on a coral foundation. The other five islands, Rarotonga, Mangaia, Mauke, Mitiaro and Atiu, are volcanic "high" islands with fringing barrier reefs. Rarotonga, the largest island in the group and much the highest island with a peak at 650 m, is now deeply dissected by erosion. The others have much lower volcanic cores surrounded by raised coral limestone platforms (makatea). Almost 90% of the land area is in the Southern Group, with the island of Rarotonga (67.2 sq.km) accounting for over a quarter.

All of the islands are inhabited except Suwarrow in the Northern Group and Manuae and Takutea in the Southern Group. About 59% of the population (9,678 in 1986) reside on Rarotonga, the capital of the group. Oral tradition suggests that the group was settled by several waves of migrating Polynesians between 1000 and 1300 AD, and that the migrants came mainly from Eastern Polynesia. The islands were placed under British protection between 1888 and 1901, becoming a New Zealand dependency in 1901. They became internally self-governing in 1965, although their association with New Zealand continues. The population of the Cook Islands is declining slightly (0.3% per annum) due to emigration to New Zealand.

The economy is based on tourism, fruit and vegetable exports, and remittances from New Zealand. Many of the islanders are subsistence farmers and fishermen. Export crops include copra, citrus fruits, pineapples and bananas, and fruit processing is a major industry. Tourism is rapidly increasing in importance, especially on Rarotonga and Aitutaki.

The climate is tropical oceanic, influenced by winds from the northeast and southeast. The average annual rainfall on Rarotonga is about 2,100 mm, while that for the other islands ranges between 1,500 mm and 2,800 mm. The mean annual temperature on Rarotonga is 23.9°C. There is a pronounced wet season from November to April, when about two-thirds of the annual rainfall occurs, and a relatively cool dry season from May to October. The main hurricane season is from January to March. The mean surface temperature of the sea varies from 27.3°C in January to 25.5°C in June. Tides are semi-diurnal with an amplitude of approximately one metre.

Dahl (1980, 1986) has given a brief account of the natural ecosystems of the islands, and has reviewed their importance for nature conservation. The terrestrial vegetation includes montane forest on Rarotonga, lowland limestone rainforest on several of the high islands, beach forest on atolls and reef islets, and scrub and grassland formations. Natural vegetation in the coastal lowlands has been largely modified by man, and lowland forest has been almost totally destroyed. The coastal vegetation on Rarotonga, in particular, has been heavily modified, and burning has spread to such a degree that most valleys are now covered by introduced grasses and weeds (IUCN, 1991).

All of the Cook Islands have extensive coral formations, generally as fringing and lagoon reefs. UNEP/IUCN (1988) provide a general account of the coral reef systems and the reef resources, and also give detailed information on four of the atolls (Aitutaki, Manihiki, Pukapuka and Suwarrow) and the reef systems of Ngatangiia Harbour and Muri Lagoon on Rarotonga.

Summary of Wetland Situation

There are four main types of wetlands in the Cook Islands:

- Freshwater marshes and swamps: on Rarotonga, Mangaia, Atiu, Mitiaro and Mauke.
- Permanent freshwater lakes: Lake Tiriara on Mangaia, Lake Tiroto on Atiu, and Lake Rotonui and Lake Rotoiti on Mitiaro.
- Tidal salt marsh: at Ngatangiia Harbour on Rarotonga.
- Mountain streams: on Rarotonga.

There are no mangroves in the islands.

On Rarotonga, freshwater marshes and swamps occur widely in flat-bottomed depressions between the coastal ridge and the base of the alluvial fans of streams rising in the interior. These depressions, which may be several hundred metres wide but are generally less than one metre deep, contain finer sediments than the adjacent ridges, and are widely used for taro cultivation. The island's rugged interior attracts abundant rainfall which gives rise to a number of perennial streams with their headwaters on or immediately below the 400 m contour. The surface drainage is controlled by the escarpments of the collapsed caldera, with most of the drainage system captured by three major streams, the Takuvaine, Avana and Avatiu.

On Atiu, Mangaia and Mauke, extensive freshwater swamps are present in a broad zone around the central volcanic cores of the islands. These wetlands have formed in depressions between the volcanic interiors and the surrounding raised limestone terraces (makatea). On Mitiaro, large portions of the central volcanic core of the island are at a lower elevation than the outer limestone plain, and much of the interior is covered by swamps and peat bogs. Small freshwater lakes are present in the swampy zones on Mangaia (Lake Tiriara), Atiu (Lake Tiroto) and Mitiaro (Lake Rotonui and Rotoiti). On all four islands, the freshwater swamps are extensively used for the cultivation of taro.

Palmerston Atoll, Manuae Atoll and Takutea Island in the Southern Group and most of the islands in the Northern Group are amongst the most important breeding areas for seabirds and marine turtles in the Central Pacific. Suwarrow and Takutea, in particular, support huge breeding colonies of sea-birds. However, it is doubtful if there are any significant wetlands on these islands.

The principal threat to wetlands in the Cook Islands is conversion to agricultural land. Large areas of freshwater swamp on Rarotonga, Mangaia, Atiu, Mitiaro and Mauke have been modified for the cultivation of taro (*Colocasia esculenta*). Increased siltation as a result of soil erosion is a problem at some of the wetlands in the coastal zone of Rarotonga, and landfill for urban development has also resulted in the loss of some wetland habitat on this island. There has been some pollution with pesticides, and there have been reports of wildlife being killed as a result of the dumping of oil in streams on Rarotonga.

Little information seems to be available on the fauna and flora of the wetlands. The lakes on Mitiaro are home to an endemic species of eel (*Anguilla* sp.). There are very few species of birds associated with the wetlands. The only resident species are the Pacific Reef Heron (*Egretta sacra*), Pacific Black Duck (*Anas superciliosa*) and Spotless Crake (*Porzana tabuensis*). The Black Duck is now probably extinct on Rarotonga, but apparently still survives in small numbers on Atiu, Mangaia, Mitiaro, Mauke and Aitutaki. Only three species of migratory shorebirds occur with any regularity, the Pacific Golden Plover (*Pluvialis fulva*), Wandering Tattler (*Heteroscelus incanus*) and Bristle-thighed Curlew (*Numenius tahitiensis*), although at least four others have occurred as vagrants (Pratt *et al.*, 1987). Six species of land birds are endemic to the Cook Islands; the Cook Islands Fruit Dove (*Ptilinopus rarotongensis*), Atiu Swiftlet (*Aerodramus sawtelli*), Mangaia Kingfisher (*Halcyon ruficollaris*), Rarotonga Monarch (*Pomarea dimidiata*), Cook Islands Reed Warbler (*Acrocephalus kerearako*) and Rarotonga Starling (*Aplonis cinerascens*). However, these are mostly forest birds, and only the kingfisher and the reed warbler commonly occur in wetland habitats.

Wetland Research

Little if any serious research has been carried out on the wetlands of the Cook Islands, except in relation to taro cultivation, and the wetland systems on the whole remain poorly known.

Wetland Area Legislation

There is no legislation specifically relating to wetlands. Until 1987, the Conservation Act (1975) was the principal legislative instrument for the conservation of nature and natural resources, protection of historic sites and the environment, and the establishment of national parks and other protected areas (Anon., 1985). The 1975 Act was largely unused, and was repealed and replaced in April 1987 by the 1986/87 Conservation Act. This Act is essentially similar to the 1975 Act, but is equally binding on both government and the public. The principal difference is that the Conservation Service is established as an independent corporation, whereas previously it had been within the Ministry of Internal Affairs and Conservation. The 1986/87 Act, which applies in full only to Rarotonga and Aitutaki, gives the Conservation Service wide-ranging powers to protect, conserve, manage and control parks, wildlife, forests, water catchments and resources. Under Sections 27 and 28 of the Act, any land, lagoon, reef or island, or portion of the seabed with its superadjacent waters, can be declared a national park or reserve (IUCN, 1991).

Specific provisions within the 1986/87 Act provide for the Protection of the Coastal Zone and Cook Island Waters. The Coastal Zone includes coastal waters and the foreshore. The former are defined as the area seaward of the mean low water mark to the outer limit of the territorial seas, including every lagoon and its sea-bed. The foreshore is defined as the area extending 50 m landward of the mean low water mark and including all streams and the area extending five metres outward of the stream edge. The Act states that no alterations are to be carried out in the foreshore or coastal waters without the prior written consent of the Conservation Council. Cook Island Waters are defined as the waters of the territorial seas and internal waters of the Cook Islands, and include waters of any rivers, streams and lakes. This section of the Act provides for the protection of Cook Island waters from pollution of any kind (Anon., 1989). The Conservation Act of 1986/87 also has provisions for the control of soil erosion, siltation, extraction of aggregate, pollution and agricultural encroachment.

As the Conservation Act of 1986/87 does not provide adequate protection for islands other than Rarotonga and Aitukaki, the Conservation Service, in liaison with each Island Council, has started to prepare separate conservation plans for these islands. The Service has proposed developing legal mechanisms under which parks and reserves could be established on native freehold land (IUCN, 1991).

Other legislation with some relevance to wetland areas includes: the 1966 Local Government Act, which provides for the creation of Island Councils and empowers them to pass bye-laws controlling land use and to establish local reserves to protect flora and fauna; the Public Health Act and Ordinances, which control contamination of water; the Harbour Control Act (1971), which prohibits pollution of harbours; and the Territorial Sea and Exclusive Economic Zone Act (1979), which controls the management, conservation, exploitation and exploration of marine resources within the territorial seas.

At international level, the Cook Islands has ratified the Convention on the Conservation of Nature in the South Pacific (the Apia Convention) and the Convention for the Protection of the Natural Resources and Environment of the South Pacific (SPREP Convention), and has signed but not yet ratified the Convention on Biological Diversity. It is not as yet a party to the World Heritage Convention or Ramsar Convention.

Wetland Area Administration

The Conservation Act of 1986/87 is administered by the Conservation Service which is run by a Council appointed by the Minister of Conservation. This Service has responsibility for management of national parks and nature reserves, but to date, the protected areas network of the Cook Islands includes only a single protected area, the Suwarrow Atoll National Park. This small national park of 160 ha was established in 1978 primarily to protect the huge breeding colonies of seabirds on the atoll, and does not include any wetland habitat. Three additional areas are currently being considered for establishment as nature reserves: two in the forested interior of Rarotonga (Kakerori and Te Manga) and one encompassing the tiny sand cay of Takutea in the Southern Group. The only wetland habitats in these proposed reserves are the headwaters of several streams in the two sites on Rarotonga. Suwarrow National Park and the three proposed nature reserves are described in some detail in IUCN (1991).

Organizations involved with Wetlands

The Conservation Service

Responsible for administration of the 1986/87 Conservation Act. The function of the Service is to promote the conservation of the environment for the use and enjoyment of present and future generations.

WETLANDS

Site descriptions compiled from information received from Anna Tiraa of the Cook Islands Conservation Service and the literature.

Tupapa Valley (1)

Location: 21°13'S, 159°45'W; in the northeastern interior of Rarotonga, 4 km southeast of Avarua.
Area: Unknown.
Altitude: 10-80 m.
Overview: Traditional terraced taro swamps in the Tupapa Valley, of considerable historical and cultural interest.
Physical features: A series of terraced taro swamps extending for approximately 2.5 km along either side of the Tupapa stream from near its headwaters to the edge of the coastal plain. Water is channelled from the stream by way of a trench to the top of the top terrace, then down through the lower terraces to rejoin the main stream at the bottom. Traditionally, small stones were used to line the trenches to prevent erosion; in recent years, some trenches have been replaced with plastic and concrete piping. The taro plots generally follow the contours of the land and are laid out according to the patterns of customary ownership. The soils (Avana) on the levees adjacent to the streams are formed on fresh, weakly argillised, medium- and coarse-textured, basaltic alluvium (Leslie, 1980).
Ecological features: The terraced swamps were constructed for the cultivation of taro (*Colocasia esculenta*), and continue to be used for this purpose. The dominant plants in and around the swamps are the grasses *Echinochloa colonum* and *Paspalum orbiculare*, the sedges *Cyperus brevifolius*, *C. ferax*, *Eleocharis geniculata* and *Fimbristylis dichotama*, and the water grass *Commelina diffusa*. However, an introduced species, *Azolla mexicana*, is fast becoming the dominant plant, as it rapidly colonizes water surfaces throughout the taro swamps. Plant communities on the adjacent slopes include *Fagraea-Fitchia* ridge forest, *Metrosideros* cloud forest, *Dicranopteria* fernlands and degraded scrub and grassland.
Land tenure: Customary ownership.
Conservation measures taken: Although there is no legal protection, the taro swamps have been protected by their customary land owners for centuries.
Land use: Cultivation of the traditional food crop taro (*Colocasia esculenta)*, a staple food of the Cook Islanders.
Possible changes in land use: The Government has put forward several proposals for the development of the Tupapa valley for water storage and supply. These proposals have so far been rejected by the traditional land owners.
Disturbances and threats: *Azolla mexicana* is rapidly becoming the dominant aquatic plant in the taro swamps. This was introduced into the Cook Islands from the Philippines by the Department of Agriculture to maintain moisture in the soil during the dry season, to inhibit the growth of weed species, and to enrich the soil. The effects of the *Azolla* are still thought to be beneficial, but as this invasive species spreads throughout the swamps, some harmful effects may become apparent. The vegetation of the adjacent slopes has been severely degraded by burning and overgrazing, and soil erosion is becoming a serious problem.
Hydrological and biophysical values: No information.
Social and cultural values: The Tupapa valley has a timelessness and serenity as yet scarcely affected by the modern progress and development which has occurred elsewhere on Rarotonga. The terraces are of particular interest because of the pre-contact skill that went into their construction and the minimal change that has occurred in the overall design of the terraces down through the ages.
Noteworthy fauna: The freshwater eel *Anguilla obscura*, mosquito fish *Bambusia affinis*, tilapia *Oreochromis mossambicus* and gudgeon *Eleotris fuscus* occur in the taro swamps. Invertebrates include freshwater prawns of the genus *Macrobrachium* and the freshwater snail *Melanoides tuberculata*.
Noteworthy flora: No information.
Management authority and jurisdiction: Customary land owners.
References: Dahl (1986); Leslie (1980).
Reasons for inclusion: 1a.
Source: Anna Tiraa.

Ngatangiia Harbour (2)

Location: 21°14'S, 159°44'W; on the east coast of Rarotonga, north of Muri.
Area: Unknown.
Altitude: Sea level.
Overview: An area of tidal salt marsh and intertidal sand and silt flats in a sheltered natural harbour with the estuaries of two streams. The site contains the only saline marshes in the Cook Islands.
Physical features: Ngatangiia Harbour is a natural harbour on the east coast of Rarotonga, with extensive intertidal silt and sand flats and the estuaries of two streams, Avana Stream (the largest stream on Rarotonga) and Turangi Stream. The muddy delta of Avana Stream filled much of the harbour after forest clearance early in the century. The shallow grassy marshes which occur in the intertidal zone around the harbour are the only saline marshes in the Cook Islands. Ngatangiia Harbour and the adjacent Muri Lagoon are sheltered by a chain of islets, mainly rubble and sand except for Taakoka which is volcanic. Motutapu, the largest and northernmost island, is a simple cay with wide intertidal expanse of sand and silt on its leeward side.
Ecological features: Saline grassy marshes. No details are available.
Land tenure: No information.
Conservation measures taken: None.
Land use: Artisanal and subsistence fishing are important activities in the area. Ngatangiia Harbour is the site of unsuccessful growth trials of the green mussel (*Perna viridis*) in 1985. Muri Lagoon is extensively used by tourists and water sports operators.
Disturbances and threats: There has been extensive dredging in the harbour north of the Avana Stream mouth, and the lagoon is reported to be considerably degraded.
Hydrological and biophysical values: No information.
Social and cultural values: The salt marshes probably play an important role in maintaining the inshore fishery.
Noteworthy fauna: No information is available on the fauna of the salt marshes, although they are believed to be important breeding and nursery areas for certain marine and freshwater species, *e.g.* *Macrobrachium* shrimps. The reef flats in the harbour have particularly large numbers of the holothurian *Holothuria atra*.
Noteworthy flora: The only area of saline marsh in the Cook Islands.
Scientific research and facilities: Some studies of estuarine and lagoon hydrology and productivity in relation to prospects for commercial bivalve culture have been carried out.
Management authority and jurisdiction: No information.
References: Dahl (1986); UNEP/IUCN (1988).
Reasons for inclusion: 1d, 2c. A unique wetland habitat in the Cook Islands.
Source: See references.

Mangaia Swamps and Lake Tiriara (3)

Location: 21°55'S, 157°56'W; on the island on Mangaia in the Southern Group, 200 km east-southeast of Rarotonga.
Area: Approximately 150 ha.
Altitude: c.30 m.
Overview: A series of freshwater marshes and one freshwater lake around the edge of the volcanic hills in the centre of Mangaia Island.
Physical features: Mangaia (51.8 sq.km) is a volcanic island with a broad terrace of raised coral limestone (makatea) surrounding the remains of the original volcanic cone. The low volcanic hills in the centre of the island reach a peak at 169 m; the makatea is mostly at 30-90 m above sea level.

Freshwater marshes have formed around the inner edge of the makatea where water collects between the volcanic hills and the limestone plain. There are five main areas of swamp, each of about 20-30 ha in extent, distributed around the perimeter of the volcanic hills, as well as a permanent freshwater lake (Tiriara) of about 20 ha on the southern edge of the hills. Large portions of the swamp have been modified for the cultivation of taro (*Colocasia esculenta*).
Ecological features: No information.
Land tenure: Customary ownership.
Conservation measures taken: None.
Conservation measures proposed: Hay (1985) recommended the establishment of some form of protected area on the island to safeguard the endemic kingfisher and reed warbler. Such a reserve should include at least a part of one of the main swamps and/or Lake Tiriara.
Land use: The swamps are extensively utilised for the cultivation of taro. The population of Mangaia was 1,235 in 1986, having fallen from about 2,000 in the mid-1970s. The volcanic interior of the island is intensively cultivated, principally for pineapples, while the settlements are on the makatea.
Disturbances and threats: Soil erosion is a problem in the volcanic areas, and could result in excessive siltation in the wetlands. The introduced Common Myna (*Acridotheres tristis*) may pose a threat to the endemic kingfisher through competition.
Hydrological and biophysical values: No information.
Social and cultural values: The swamps are important for their taro production, a staple food for the islanders.
Noteworthy fauna: The Pacific Black Duck (*Anas superciliosa*) is listed for Mangaia, and presumably still occurs in the wetlands. No other information is available on the wetland fauna. Mangaia has one endemic bird species, the Mangaia Kingfisher (*Halcyon ruficollaris*), and an endemic subspecies of the Cook Islands Reed Warbler (*Acrocephalus kerearako kerearako*) discovered as recently as 1973. Both are reported to be fairly common on the island, although the kingfisher is listed as threatened in the IUCN Red Data Book. The kingfisher is primarily a bird of woodland and scrub, although it may occasionally forage around wetlands. The reed warbler frequents a wide variety of habitats including reed-beds.
Noteworthy flora: No information.
Management authority and jurisdiction: Customary land owners.
References: Dahl (1986); Hay (1985); Pratt *et al.* (1987).
Reasons for inclusion: 1a, 2b, 2d.
Source: See references.

Atiu Swamps and Lake Tiroto (4)

Location: 20°00'S, 158°07'W; on the island of Atiu in the Southern Group, 215 km northeast of Rarotonga.
Area: Unknown.
Altitude: c.20 m.
Overview: A series of freshwater marshes and one freshwater lake around the edge of the volcanic plateau in the centre of Atiu Island.
Physical features: Atiu (26.9 sq.km) is a volcanic island with a broad terrace of raised coral limestone (makatea) surrounding the remains of the original volcanic cone. The undulating volcanic plateau in the centre of the island reaches a peak at 91 m. Freshwater marshes have formed around the inner edge of the makatea where water runs off the volcanic plateau. Three large areas of swamp fringe much of the northern half of the plateau, and there is a permanent freshwater lake (Tiroto), a few ha in extent, and a small marsh along the southern edge of the plateau. A subterranean channel runs through the makatea from a cave on the west side of the lake to the sea.

Large portions of the swamps have been modified for the cultivation of taro (*Colocasia esculenta*).
Ecological features: No information.
Land tenure: Customary ownership.
Conservation measures taken: None.
Conservation measures proposed: Hay (1985) recommended the establishment of some form of protected area on Atiu to safeguard the endemic fruit dove, swiftlet and kingfisher. Such a reserve should include at least a part of one of the main swamps and/or Lake Tiroto.
Land use: The swamps are extensively utilised for the cultivation of taro, and eels, a popular island delicacy, are fished from Lake Tiroto. The volcanic interior of the island is intensively cultivated. The population of Mangaia has fallen in recent decades, from over 1,400 in the 1960s to only 955 in 1986.
Disturbances and threats: Soil erosion is a problem on the volcanic plateau, and could result in excessive siltation in the wetlands.
Hydrological and biophysical values: No information.
Social and cultural values: The swamps are important for their taro production, a staple food for the islanders, while Lake Tiroto supports a small eel fishery.
Noteworthy fauna: Lake Tiroto supports a large population of eels (*Anguilla* sp.). The Pacific Black Duck (*Anas superciliosa*) is listed for Atiu, and presumably still occurs in the wetlands. No other information is available on the wetland fauna. Atiu has one endemic bird species, the Atiu Swiftlet (*Aerodramus sawtelli*), and endemic subspecies of the Cook Islands Fruit Dove (*Ptilinopus rarotongensis goodwini*) and Chattering Kingfisher (*Halcyon tuta atiu*). To what extent, if any, these species utilise the wetlands is not known.
Noteworthy flora: No information.
Management authority and jurisdiction: Customary land owners.
References: Dahl (1986); Hay (1985); Pratt *et al.* (1987).
Reasons for inclusion: 1a, 2b.
Source: See references.

Mitiaro Lakes and Swamps (5)

Location: 19°49'S, 157°43'W; on the island of Mitiaro in the Southern Group, 45 km east-northeast of Atiu and 260 km northeast of Rarotonga.
Area: Approximately 400 ha.
Altitude: 1 m.
Overview: A large area of freshwater swamps and peatlands with two permanent freshwater lakes in the volcanic interior of Mitiaro Island.
Physical features: Mitiaro (22.3 sq.km) is a volcanic island with a broad terrace of raised coral limestone (makatea) surrounding the remains of the original volcanic cone. The island is unusual in that much of the volcanic plateau in the centre of the island is only about one metre above sea level, and is considerably lower than the surrounding makatea, which rises to about 9 m above sea level. Large areas in the volcanic interior are permanently swampy, and there are extensive peat deposits. In the lower, eastern portion of the interior, there are two lakes, Lake Rotonui (about 50 ha) in the south and Lake Rotoiti (a few ha) in the north. The two lakes are connected by a narrow channel. Large portions of the swamps and peatlands have been modified for the cultivation of taro (*Colocasia esculenta*).
Ecological features: No information.
Land tenure: Customary ownership.
Conservation measures taken: None.
Conservation measures proposed: Dahl (1980) proposed the creation of a reserve to protect the lakes and their endemic eel; Hay (1985) recommended the establishment of some form of

protected area to safeguard the endemic reed warbler; and the Tourism Council of the South Pacific proposed that a protected area be established to protect the lakes and freshwater swamps (TCSP, 1990).
Land use: The swamps are extensively utilised for the cultivation of taro, while eels and small fish are harvested from the lakes. The population of Mitiaro has fallen slightly in recent years, from 334 in the 1960s to 272 in 1986.
Disturbances and threats: None known.
Hydrological and biophysical values: No information.
Social and cultural values: The swamps are important for their taro production, a staple food for the islanders, while the lakes support a small fishery.
Noteworthy fauna: The lakes have an endemic species of eel (*Anguilla* sp.). The Pacific Black Duck (*Anas superciliosa*) is listed for Mitiaro, and presumably still occurs in the wetlands. No other information is available on the wetland fauna. A subspecies of the Cook Islands Reed Warbler (*Acrocephalus kerearako kaoko*) is endemic to the island. This species, which is known only from Mitiaro and Mangaia, was described as recently as 1973, and was originally considered to be a subspecies of *A. vaughani*. It is reported to be common in reed-beds, gardens and woodland.
Noteworthy flora: A variety of Sandalwood, *Santalum insulare* var. *mitiaro*, is known only from this island.
Management authority and jurisdiction: Customary land owners.
References: Dahl (1980, 1986); Hay (1985); Pratt *et al.* (1987); TCSP (1990).
Reasons for inclusion: 1a, 2b, 2d.
Source: See references.

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THE FEDERATED STATES OF MICRONESIA

INTRODUCTION

by Christopher R. Dahl

Area: 705 sq.km.

Population: Kosrae: 6,607 (1986). Yap: 10,139 (1987). Pohnpei: 28,671 (1985). Chuuk: 52,000 (estimated 1989). Federated States of Micronesia total: 100,789 (estimated 1990).

The Federated States of Micronesia (the FSM) consist of about 45 distinct islands or island complexes scattered over a vast expanse of ocean between latitude 10°N and 1°N and longitude 137°E and 168°E. These islands have in the past been known and are still often referred to by the geographic name the Caroline Islands[1]. Most are low atolls or raised limestone islands, while four are high volcanic islands. As such, each island is typically comprised of many closely associated smaller islands or islets; thus the total number of individual islands exceeds 600. The four high islands represent most of the land area (92%) within the nation and serve as state centres for the four states within the FSM's federal system of government. These islands, from east to west Kosrae (formerly Kusaie), Pohnpei (Ponape), Chuuk (Truk) and Yap, also provide the state names. Pohnpei and Kosrae, respectively the largest and second largest islands in the FSM, are mountainous extinct and eroded shield volcanos. Chuuk is a large atoll-like formation with numerous volcanic islands in its lagoon. Yap was formed on a tectonic plate boundary by volcanic and tectonic forces. Government services, infrastructure and population are concentrated in the state centres. It is also on these islands that virtually all significant wetland areas are found. The nation, once part of the United Nations Trust Territory of the Pacific Islands administered by the United States, achieved qualified independence in 1986, when it entered into a Compact of Free Association with the U.S. This arrangement governs various security and defence matters and guarantees substantial aid over a fifteen year period while recognising the full sovereignty of the FSM. A two-tiered economy obtains throughout the nation. Much of the population lives primarily within the subsistence sector, depending on agro-forest cultivation and fishing for their primary needs. The money economy is overwhelmingly dependent on foreign aid obtained through the Compact. The climate is hot and humid year round. The daily mean temperature is 27°C, with very little annual variation. Rainfall varies from island to island due to orographic effects. It also varies significantly from east to west. Kosrae receives 6,527 mm per year distributed fairly evenly throughout the year, while Yap, in the extreme west, receives 3,087 mm per year with a distinct dry season from January to May. Tidal fluctuation varies within the FSM, being greater in Kosrae and Yap (1.0 m and 0.9 m mean) and less in Pohnpei and Chuuk (0.7 m and 0.5 m mean). This area experiences the highest frequency of typhoons (cyclones) in the world.

[1] While the Palau Islands (Republic of Belau) are usually considered part of the Caroline Islands, for the purposes of this report this term will refer to only those islands that are now part of the present FSM.

Generally, the western half of the FSM (Chuuk and Yap) are much more subject to typhoons that the eastern half (Pohnpei and Kosrae).

Summary of Wetland Situation

Because all significant wetlands are on high islands and surveys on the low, coralline "outer islands" are limited, this summary is confined to a description of the wetlands on the high islands of Kosrae, Pohnpei, Chuuk and Yap. Wetlands on the low coralline islands are limited to cultivated taro (*Colocasia esculenta* and *Cyrtosperma chamissonis*) swamp and, in a few cases, limited mangrove areas comprised primarily of dwarf *Rhizophora mucronata*, *Bruguiera gymnorrhiza* and *Lumnitzera littorea*.

Like many environments in Micronesia, wetlands have undoubtedly been affected by the continuous presence of humans on these islands for several thousand years. The region experienced declines in human population after contact with the West in the mid-19th century; populations are only now attaining pre-contact levels. Wetland areas were extensively exploited for timber and charcoal during the Japanese era of administration (1914-1945). Many of these areas have recovered, but given the long history of habitation, no wetlands can be considered pristine. This is most especially true of freshwater areas which are commonly turned over to the cultivation of taro. However, well developed and in some cases unique wetlands are to be found along the shoreline on all four islands. While species diversity generally increases as one moves west toward the Indo-Malay archipelago, the most extensive and significant wetlands in the FSM are found on the more eastern islands of Pohnpei and Kosrae. On both these islands, roughly 15% of land area, if mangroves are included in land area, are wetlands. This is due to the large size of these islands and their wide low-lying coastal plains where hydrologic conditions create extensive wet areas. Greater topography generates more siltation allowing the expansion of mangrove areas on the reef flat. Finally, population densities are lower on these two islands so human disturbance has been correspondingly less. Stemmermann and Proby (1978) divide wetlands in Micronesia into nine major categories: mangrove forest, coastal saline marsh, lowland swamp forest, upland high canopy swamp forest, upland marsh, savannah wetland, cultivated wetland, bomb craters and artificial reservoirs, riparian wetlands and ruderal wetlands. Based on the vegetation surveys of Falanruw *et al.* (1987a and 1987b), MacLean *et al.* (1986) and Whitesell *et al.* (1986), slightly over 85% of wetlands by area are mangrove swamp. The vegetation survey of Chuuk (Falanruw *et al.*, 1987a) omits some islands including the Tol island complex which has significant mangrove forests. These islands were surveyed by Stemmermann and Proby (1978), but no tabular data on wetland areas is included in that report. Based on soil type from USDA soil surveys, the total area of wetlands can be estimated as 1,143 ha of mangroves and 449 ha of freshwater wetlands, giving a total of 1,592 ha. (This is almost triple the area shown for Chuuk in Table 1).

Freshwater swamp forest (found on Pohnpei, Kosrae and Yap) makes up an additional 7%. Other categories used in these surveys correspond imperfectly with Stemmermann and Proby's earlier wetland categories. The remaining distinguishable types are freshwater and saline marshes and native ivory nut palm forests (see Table 1). It is only on Pohnpei that all of these wetland types occur.

Table 1: Wetland areas in the FSM (in hectares). Adapted from the U.S. Forest Service vegetation surveys.

Note: Chuuk data is for Moen, Dublon, Fefan and Eten islands only.

	Kosrae	Pohnpei	Chuuk	Yap	Totals	Per cent
Mangrove forest	1,562	5,525	306	1,171	8,564	85.43%
Swamp forest	345	214	0	155	714	7.12%
Marsh, freshwater	25	149	234	165	573	5.72%
Ivory nut palm forest	0	137	2	0	139	1.39%
Marsh, saline	0	29	0	6	35	0.35%

Total	1,932	6,054	542	1,497	10,025	100.00%

Mangrove forests are most extensive on Pohnpei; approximately 65% of the mangrove forests in the FSM are on this island. Kosrae possesses an additional 18%. While Yap's mangroves are close to Kosrae's in total area, they are generally less well developed. On Kosrae, *Sonneratia alba* dominates on the seaward margin of mangrove forests, while on Pohnpei, *Rhizophora mucronata* var. *stylosa* (or *Rhizophora stylosa* according to some authors) is found on the outer margin. On both islands, *Xylocarpus granatum* and *Lumnitzera littorea* are occasionally found towards the landward margin of the forest. In estuarine areas around river mouths or bays, *Rhizophora mucronata* and *R. apiculata* occur as pure stands or mixed with some *S. alba* and *Bruguiera gymnorrhiza*. Upstream the *Rhizophora* component drops out. *Nypa fruticans* can become dominant in narrow bands along riverine portions of the inner mangrove. On Chuuk, mangrove forests comprise a relatively narrow shoreline band in which *R. mucronata* dominates, while *R. apiculata* and occasionally *Bruguiera* are found behind the seaward fringe in more extensive areas. *X. granatum* and *S. alba* occur occasionally on the landward fringe. Yap, like Chuuk, has poorly developed mangroves but slightly greater species diversity than the islands to the east. Of tree species, *Dolichandrone spathacea* and *Ceriops tagal* are found along the landward edge of the mangroves only on Yap. *Derris trifoliata*, *Dalbergia candenatensis* and *Smythea lanceata* are common lianas typically found on the inner mangrove fringe. A more detailed discussion of Micronesian mangrove floral assemblages and distribution is given by Fosberg (1975).

On most of the east and south coasts of Kosrae, a sand berm varying in width from several hundred yards to a few feet wide separates the mangrove forest from open reef flat. *Sonneratia* is the most common and typically the largest tree species in the mangrove forest; usually it is festooned with the epiphytic ferns *Nephrolepsus acutifolia* and *Asplenium* spp. On Pohnpei, an offshore barrier reef encloses a large lagoon which protects the shoreline from significant wave action, allowing mangroves to grow on most of the shoreline. Mangrove forests are most extensive, up to two km wide, along the leeward west and south coasts. Extensive areas of low dense growth, with *Rhizophora* sp. dominating, in the interior of large mangrove areas is a salient characteristic of Pohnpei's mangrove forest. In some areas, trees are dwarfed and scattered creating an open canopy.

Swamp forest and cultivated marsh are common on the landward side of the mangroves. These wetlands are also characteristic of river bottoms. Stemmermann and Proby (1978) further delineate swamp forest as high canopy, low canopy, open canopy and cultivated phases, and regard these as related to the level of human disturbance. They note that because rainfall is extremely high (Kosrae: 6,527 mm/year, Pohnpei: 4,928 mm/yr) there may be many localised small wetlands in upland forest areas, but no detailed surveys have been undertaken. Indeed, even delineating classifiable wetland areas in the uplands is difficult when rainfall is so great. Most soils are saturated all year round, especially in flat areas. In the high canopy phase common on Kosrae and Pohnpei, *Terminalia carolensis* often dominates; *Horsfeldia nunu* may co-dominate in the swamps of Kosrae. There is usually a distinct break between the landward margin of mangrove forest and high canopy swamp forest where the shoreline abruptly rises about one metre above sea level. *Heritiera littoralis* is common along this strand on all high islands. This high canopy swamp forest is limited on Yap and non-existent in Chuuk. (Of the 155 ha of swamp forest on Yap, only 41 ha are classed as trees averaging over 30 cm diameter at breast height). Other tree species include *Campnosperma brevipetiolata*, *Pandanus* spp. and *Barringtonia racemosa*. The low canopy phase, which are generally areas of disturbed high canopy forest, is characterised by *Hibiscus tiliaceus*, *Barringtonia* spp. and *Macaranga* spp. The open canopy or freshwater marsh phase is unusual; it is most common on Pohnpei where four sites have been identified; one site is known from Kosrae. These freshwater marshes are found adjacent to or even in mangrove areas and surrounded by swamp forest. Thus they are typically difficult to reach and have not been fully surveyed. These marshes are characterised by sedges but may also have 50% or more cover of woody species. Tree species are *Campnosperma brevipetiolata* and *Lumnitzera littorea*. Common herbaceous species include *Eleocharis geniculata* and *Lycopodium scandens*. Possibly endemic members of the genus *Liparis* (Orchidaceae) were found in the single marsh on Pohnpei surveyed by Stemmermann and Proby. The only marsh of this type on Kosrae was found to be partially cultivated and without any unique associated plants.

Ivory nut palm forests where the species *Metroxylon amicarum* (endemic to Pohnpei and Chuuk) predominates can also be considered a wetland as this tree grows in swampy areas. *Metroxylon* swamps are mainly found on Pohnpei at all elevations.

Of the other types of wetlands identified by Stemmermann and Proby, none is especially significant. Saline marshes are found on all four islands but are limited in extent and poorly developed. These marshes occur along the coastal strand, especially in Chuuk where mangrove forests have been more disturbed by clearing and blockage of water circulation. However, because of their small size, none was distinguished in the Chuuk vegetation survey (Falanruw *et al.*, 1987a). On Kosrae and Yap, they may be found in an occasional narrow band between the mangroves and the coastal strand and are uncommon on Pohnpei. *Paspalum distichum*, *Vigna marina*, *Cyperus javanicus*, *Wedelia biflora* and *Fimbristylis cymosa* are common species. On Chuuk and Yap, the fern *Acrostichum aureum* may also be found. Most freshwater swamps are cultivated as taro swamps. Taro swamps are the major wetlands found on the many low coralline islands that comprise the rest of the FSM. Aside from the cultivated species, a relatively diverse assemblage of weeds, virtually all cosmopolitan species, are found. Upland marshes on Pohnpei and savannah wetlands on Yap may be either anthropogenic or natural in origin. As noted above, upland marshes have not been adequately surveyed.

Mangrove forests are of great subsistence and commercial importance on all four islands. They are exploited on both a subsistence and commercial basis for firewood, timber, wood for carved handicrafts and fisheries products. Mangrove forests are also a source of building materials for more traditional dwellings (mangrove poles and nipa thatch) and various medicinal products. Fish species commonly captured in the mangroves include members of the genera *Lutjanus*, *Labroides* and *Siganus*. The mangrove crab (*Scylla serrata*) is of commercial importance on Pohnpei and Kosrae where a significant local fishery and limited export fishery exists. Commercial saw mills have operated intermittently on all the islands but most consistently on Pohnpei where at least two mills have been in operation at any given time since just after World War II. High canopy swamp forests are not at the moment being commercially logged. The most well developed stands of *Terminalia* and *Horsfeldia* are in fairly inaccessible parts of Kosrae. However, as noted, much swamp forest had been degraded and/or converted to agricultural use.

Mangroves are also recognised for a variety of environmental services they provide. Mangrove forest is prime habitat for a variety of sea and shore birds including the Great Frigatebird (*Fregata minor*), Pacific Reef Heron (*Egretta sacra*), terns (*Sterna* spp.), noddies (*Anous* spp.) and the Micronesian Kingfisher (Pohnpei subspecies: *Halcyon cinnamomina reichenbachii*) as well as the Marianas Fruit Bat (*Pteropus mariannus*). On small tropical islands, mangrove forests are also one element in a dynamic hydrological system that allows coral reefs, which require clear nutrient-low water, to exist in close proximity to islands with very high rates of freshwater run-off. In the more typhoon-prone islands of Chuuk and Yap, mangroves protect shorelines from storm wave inundation and erosion.

Human impacts on wetlands vary from island to island. Because of historic high population densities on Yap and current high densities on Chuuk, the wetlands of these islands have been more significantly degraded than those of Pohnpei and Kosrae. The FSM as a whole is experiencing a very rapid rate of population growth (3.1% per year) accompanied by rising material expectations. These demographic trends are putting increasing pressure on all natural environments including wetlands. Major threats to wetlands in all states include unmanaged timber harvests, filling and/or conversion of wetlands for agriculture or to create developable land, development-related changes in local salinity due to impoundment, dumping of toxic materials into coastal areas, and dredging. Impacts in Kosrae are relatively minor; some semi-commercial firewood and timber harvesting occurs, but their effects tend to be fairly localised. Ongoing construction of a coastal circumferential road, aside from direct impacts, has resulted in an increase in unregulated firewood harvesting in now accessible areas. Planned road expansion will allow access to significant areas of mature *Terminalia* swamp forest. Virtually all of Pohnpei's mangrove forest show evidence of wood harvesting. Devoe (1991) notes that "field reconnaissance indicates that active degradation of mangrove is extensive... of all the mangrove covered (during surveys) in 1990 and 1991, not a single site was without evident harvesting." Little information exists on the current status of wetlands in Chuuk; however filling, conversion and over cutting, impoundment and waste oil pollution are known problems. Filling to create developable land is another significant threat, particularly on Pohnpei, Chuuk and Yap. Road construction and/or improvement, occurring on all the islands, has had localised impacts where mangrove areas are impounded by turnpike type roads that have an inadequate number of culverts, thus reducing salinity level. Toxic pollution has killed mangroves in localised areas on Pohnpei and, as mentioned, on Chuuk.

Five wetland areas of national and possibly international significance have been thus far identified. Three are on Kosrae and two are on Pohnpei. On Kosrae the Okat mangrove forest is a relatively extensive forest on the north coast of the island bordering the Okat river drainage. It boasts the largest examples of *Sonneratia alba* found anywhere in the Caroline Islands with individuals as high as 30 m. The Yela river drainage, also on the north coast, is probably the most extensive and least disturbed example of *Terminalia* dominant high canopy swamp forest. This area was extensively logged during the Japanese administration, but has apparently now recovered. Finally, the swamp forest and mangrove system stretching from the village of Utwe on the south coast to the village of Walung on the western tip of the island is typical of a variety of interesting and unique wetland characteristics of Kosrae. The whole of this wetland is bounded on the seaward side by a berm or barrier island averaging approximately 10 m in width. Extensive areas of open brackish water connected by narrow channels are found within the mangrove forest. All typical wetland vegetation assemblages can be found within this wetland complex. On Pohnpei, the unusual freshwater swamp, mentioned earlier and classified by Stemmermann and Proby as an open canopy phase swamp forest, and adjoining wetland areas are of significance because the swamp is a unique wetland type and harbours an endemic plant species of the genus *Liparis*, while adjoining areas display three other typical wetland types: full stature mangrove, dwarf mangrove and high canopy swamp forest. Kitti Municipality in southern Pohnpei possesses the most extensive mangrove areas within the Caroline Islands. Interest at both the community and state government levels has developed in affording the mangrove area between Dauen (river or channel) Semwei and Dauen Rakis protected status. Both these areas have been recommended for protection by Devoe (1991).

Wetland Research

Most wetland research in the FSM has been confined to basic surveys carried out by U.S. federal agencies, primarily the U.S. Forest Service. An inventory of wetland vegetation in the Caroline Islands by Stemmermann and Proby (1978), although dated, is still the most comprehensive guide to wetland areas and plants in the FSM. The U.S. Forest Service has published a variety of surveys of vegetation and timber volume (Falanruw *et al.*, 1987a; Falanruw *et al.*, 1987b; MacLean *et al.*, 1986; MacLean *et al.*, 1988; Pettys *et al.*, 1986; Whitesell *et al.*, 1986).

Dr Nora Devoe, a research forester with U.S. Forest Service, is currently conducting two projects: "Mangrove Areas Use Classification Study" and "Phytosocial Analysis of Pohnpei's Mangrove".

This survey will assist the State Government in implementing protection measures for these areas. Fr Greg Muckenhaupt of the University of Hawaii is currently conducting research on Pohnpei into nutrient flux in the mangrove forest. Miyagi and Funimoto (1989) have investigated the geomorphology of mangroves and impact of historic sea level fluctuations on Pohnpei and Chuuk.

Lal (1989) investigated mangrove use and made management recommendations in connection with the development of a coastal resources management plan for Kosrae State. The East-West Center in Hawaii has sponsored the survey of two of the significant wetland areas in Kosrae, and made recommendations for conservation and sustainable tourism development (Wilson and Hamilton, 1992).

Wetland Area Legislation

In the FSM, with its federal system of government, the individual states have virtually exclusive jurisdiction over the management of natural resources. In Kosrae and Pohnpei States, submerged lands (those below the high tide mark) are public land and under the jurisdiction of the State Government. In Chuuk and Yap, water areas are privately or customarily owned. Little legislation exists dealing specifically with wetland areas. In Pohnpei, the 1987 Watershed Protection and Mangrove Management Act gives the State Forestry Division broad authority to manage mangrove areas. Thus far pursuant regulations have not come into effect. However, the Forestry Division instated a temporary ban on direct timber harvest by commercial saw mills which has proved difficult to enforce fully. Much of Devoe's research is directed towards the development of recommendations to be implemented through this legislation. In Kosrae, legislation exists to prevent development along specified river drainages. Thus far this has not become a significant problem, and there has not been a real need to enforce the law.

The FSM has ratified the Convention for the Protection of the Natural Resources and Environment of the South Pacific (the SPREP Convention) and has signed but not yet ratified the Convention on Biological Diversity. It is not, however, as yet a party to the Unesco Man and the Biosphere Programme, Ramsar Convention or World Heritage Convention, nor has it signed or ratified the Convention on the Conservation of Nature in the South Pacific.

Wetland Area Administration

No protected areas exist in the FSM. Because of traditional attitudes towards land, government acquisition or control of privately held land for protection is difficult if not impossible. Because sub-tidal areas in Kosrae and Pohnpei are publicly controlled, some possibility exists for establishment of protected areas in these two states. Devoe's preliminary recommendations (1991) include the establishment of eleven mangrove reserve areas on Pohnpei. Three reserve categories are proposed: preserves where access is severely restricted; sustainable use areas allowing multiple use exclusive of timber harvest; and sustainable use areas where managed timber harvest would be allowed. In Kosrae, the State Government has expressed some interest in developing protected areas for the mangrove forests given special mention above. As noted, the East-West Center has surveyed these areas and developed management recommendations (Wilson and Hamilton, 1992).

Organizations involved with Wetlands

(a) United States Federal Agencies

- Forest Service (Department of Agriculture)
  Provides technical assistance to state governments
- Soil Conservation Service (Department of Agriculture)
  Currently providing technical assistance in Pohnpei State.

- Army Corps of Engineers
  Published surveys and keys of Micronesian wetland vegetation; produced atlases and inventories of coastal resources for Kosrae, Pohnpei and Yap.

(b) FSM

- FSM Department of Resources and Development
  Coordinates outside technical assistance for state agencies.
- Pohnpei Division of Forestry
  Has management authority over mangrove and watershed areas.
- Kosrae Division of Agriculture and Forestry
- Chuuk Division of Agriculture and Forestry
- Yap Division of Agriculture and Forestry

(c) Academic Institutions

- College of Micronesia: Land Grant Programs
  Assisting Pohnpei State Division of Forestry with mangrove management plan
- College of Micronesia: Sea Grant Extension Service
  Assisting in the development of coastal resource management plans, parks and protected areas.

WETLANDS

The site descriptions for Kosrae, Pohnpei and Chuuk were compiled by Christopher R. Dahl of Sea Grant at the Community College of Micronesia, Ron Cannarella of the Division of Parks and Recreation, Pohnpei State, and Glasstine Cornelius of the Division of Agriculture and Forestry, Department of Conservation and Development, Kosrae State. No new information was received on the wetlands of Yap, and the account given below is based on the literature.

Kosrae State Mangrove Forest and Freshwater Swamp Forest (1)

Location: 5°00'-5°23'N, 162°53'-163°03'E; except for some areas on the southeast part of the island in Malem Municipality and in the northeast in Tafunsak Municipality, the island of Kosrae is entirely surrounded by mangrove forest. The mangrove is found behind a narrow sand island or cay except along the north coast. Swamp forest is found interior of mangrove forests and is best developed along the north and southeast coasts.
Area: Mangrove forest 1,562 ha; swamp forest 345 ha.
Altitude: Mangrove forest 0-2 m; swamp forest 0-10 m.
Overview: Kosrae is a volcanic island with steep sided mountains, a fairly narrow and flat coastal plain and a fringing coral reef. (This coastal plain is largely filled over lagoon and/or reef flat). Swamp forests are low wet areas just inland of the mangrove forest, especially around river mouths. The transition between the two forest types is fairly abrupt. The mangroves of Kosrae are unusual in occurring behind sandy coastal barrier islands except on the north coast. Three wetlands of

outstanding importance, Okat Mangrove Forest, Utwa-Walung Mangrove Forest and Yela River *Terminalia* Swamp Forest, are described separately as sites 1a, 1b and 1c, respectively.

Physical features: Kosrae is one of the four constituent states of the Federated States of Micronesia. Kosrae is the only island within the State. Its administrative centre is in Tofol on the east coast and the population is mostly clustered in five villages: Tafunsak in the northeast coast, Lelu on the east coast, Malem on the southeast coast, Utwe on the south coast, and Walung on the western tip of the island.

Kosrae's coastal plains were formed by rapid erosion off steep volcanic mountain slopes and deposition on the inner portion of a fringing reef. This coastal plain is generally swampy and dominated by mangrove forest and freshwater swamp forest. Due to high wave energy, sandy barrier islands or cays, often very narrow in width, form on the seaward side of the mangrove forest except on the more protected north coast. In some areas these sand barriers are only 2-3 m wide and 1 m high. Along portions of the southeast and south coast, the distance between the inner edge of the barrier island and the outer reef margin may be less than 100 m. The hydrology of these wetlands has not been studied, but is probably complex as there is a distinct transition between adjacent fresh and brackish-water wetland types that must be mediated by the balance between freshwater influx and tidal inundation. The predominant soil type in the mangroves is Naniak-Insak. Naniak-Insak is a moderately deep and very deep, very poorly drained soil formed in alluvium derived dominantly from basic igneous rock. It is loamy and mucky. The soil types associated with swamp forest are Nansepsep-Inkosr and Ngerungor. Both are very deep poorly or somewhat poorly drained level or nearly level soils. They are loamy soils formed from alluvium derived from igneous rock. Ngerungor soils overlie coral sand. Tidal variation in Kosrae is about 3 m at maximum. The catchment area for these wetlands is the whole of Kosrae island. Major rivers include the Yela, Okat, Tofol, Malem and Finkol-Menka. The climate on Kosrae is humid tropical. The annual rainfall is very high at about 5,000 mm.

Ecological features: *Sonneratia alba* is the dominant mangrove species in most areas of Kosrae, and is the largest mangrove species occurring on the island. Some of the trees attain a height of 25-30 m and support numerous epiphytes in their branches. *Sonneratia* reaches its greatest height towards the middle of the mangrove, but is also the most seaward species, with *Rhizophora mucronata* occurring at the mouths of channels. *Rhizophora apiculata* and *Bruguiera gymnorrhiza* occur mixed with *Sonneratia* toward the middle of the mangrove, with patches of *Nypa fruticans* and stands of *Xylocarpus* found toward the landward edge (Stemmermann & Proby, 1978). Adjacent communities include coastal strand vegetation on barrier islands seaward of the mangroves around most of the island, and swamp forest or agro-forest on the landward side.

High canopy swamp forest on Kosrae is characterised by *Terminalia carolinensis* and *Horsfeldia nunu*. Species in the lower strata include: *Barringtonia racemosa*, *Neubergia celebica* and *Scirpodendron ghaeri*. This forest is found on low, swampy ground adjacent to the mangrove forests. At slightly higher elevations, *Campnosperma brevipetiolata* becomes a component of the high canopy wet rainforest, which is often not easily distinguished from swamp forest, as the two forest types have many species in common. The swamp forest is well developed in an area in Malem Municipality and along the Yela River (Stemmermann & Proby, 1978).

Land tenure: Mangrove areas are under the jurisdiction of the State Government. Freshwater swamp areas are privately owned.

Conservation measures taken: There are no protected areas on Kosrae.

Conservation measures proposed: Draft legislation to control harvesting of forest resources has been developed but not yet passed by the State Legislature. In July 1991, a team sponsored by the East-West Center carried out surveys in the Okat and Utwe-Walung mangrove forests to develop a protected area management plan for these areas. The State Government has committed some funding to the development of a protected area in the Utwe-Walung area.

Land use: Mangroves are primarily exploited for firewood. Mangrove timber and nipa fronds are used for house construction, but use of these traditional materials is declining. There is limited exploitation of *Xylocarpus* for handicrafts (wood carvings). There is one small portable saw mill on the island which has been used in timbering operations in the Utwe mangroves. The island experienced serious depopulation due to disease in the late 19th century. Population moved to village centres and is only now reaching pre-contact levels.

Possible changes in land use: Current changes in land use are associated with road construction (see below).

Disturbances and threats: There has been little conversion of wetland areas in Kosrae to date. Some freshwater swamps have been converted to agro-forest, mainly in Malem Municipality. During the Japanese administration, *Terminalia* forests were logged but these have apparently fully recovered as there has been no significant exploitation in the last 50 years. The principal threat to the mangrove forest and swamp forest comes from the expansion of the road network around the island. The Japanese built a simple road network on the eastern side of the island during their administration. That road was upgraded in the mid-1970s. The road network was expanded along the south coast in the mid-1980s, and is currently being expanded along the north coast. Completion of a circumferential road is a high priority in the State Government's development plans. Aside from direct impacts which include limited filling of mangrove areas and possible changes in local hydrographic patterns, the road is allowing greater access to previously inaccessible wetland areas. Clear-cutting of mangroves for firewood is most noticeable in the Okat area, where the road has most recently been completed. The road will eventually reach the Yela River swamp forest. This is privately owned and there is some interest in logging the area, once access is available.

Hydrological and biophysical values: Because of the very steep terrain of the interior and high rainfall, there is significant erosion and run-off. The freshwater swamp forests and mangrove forests doubtless intercept much of this run-off, and act as sediment traps. Because Kosrae has very rich oceanic fringing reefs, these wetlands are important in maintaining the requisite water quality that allows these coral reefs to grow in close proximity to land.

Social and cultural values: Wetlands are a source of a variety of useful products including firewood, timber, thatch and fishery products. Important fisheries products include the mangrove crab (*Scylla serrata*) and certain species of snapper (*Lutjanus* sp.). Numerous archaeological sites are also found along the interior margin of the mangrove forest, especially in the Okat and Utwe-Walung areas.

Noteworthy fauna: Vertebrates include an introduced monitor lizard (*Varanus indicus*), Marianas Fruit Bat (*Pteropus mariannus*), White-tailed Tropicbird (*Phaethon lepturus*), Pacific Reef Heron (*Egretta sacra*), White Tern (*Gygis alba*), Black Noddy (*Anous minutus*), Brown Noddy (*A. stolidus*), Micronesian Starling (*Aplonis opaca*) and Micronesian Honeyeater (*Myzomela rubratra*). Marine species include the mangrove crab (*Scylla serrata*), land crab (*Cardisoma* sp.), coconut crab (*Birgus latro*), popol clam (*Diplodonta* sp.), the snail *Littorina scabra*, the clam *Asaphis violescens*, mullets (Mugilidae), rabbit fishes *Siganus* spp., cardinal fishes (Apogonidae), Common Slipmouth (*Leiognathus equulus*), Mangrove Snapper (*Lutjanus argentimaculatus*) and Mono (*Monodactylus argenteus*).

Noteworthy flora: Mangroves include *Sonneratia alba*, *Rhizophora mucronata*, *R. apiculata*, *Bruguiera gymnorrhiza*, *Barringtonia racemosa*, *Davallia solida*, *Derris trifoliata*, *Nephrolepsus acutifolia*, *Ophioglossum pendulum* and *Xylocarpus granatum*. Swamp forest species include *Terminalia carolinensis*, *Horsefieldia nunu*, *Campnosperma brevipetiolata*, *Barringtonia racemosa*, *Neubergia celebica* and *Scirpodendron ghaeri*.

Scientific research and facilities: An expedition sponsored by the East-West Center (Hawaii) surveyed various wetland areas in July 1991, and made recommendations for protected area status (Wilson and Hamilton, 1992). A study entitled "Utilisation and Management of Coastal Wetland Resources" was conducted by Dr Padma Narsey Lal in 1988 in connection with development of a coastal resources management plan for Kosrae State (Lal, 1989).

Recreation and tourism: Wetland areas are not used for recreation by the local populace. The study sponsored by the East-West Center made some recommendations for the utilisation of wetland areas for tourism. A brochure was produced by Sea Grant at the Community College of Micronesia for the Kosrae State Division of Tourism describing two canoe trips that could be taken in the mangrove areas of Kosrae.

Management authority and jurisdiction: The Kosrae State Government has jurisdiction over mangrove areas, but no legislation to direct management of forest resources has yet been

implemented.
References: Hosokawa (1954); Laird (1983b); Lal (1989); MacLean *et al.* (1988); Stemmermann & Proby (1978); Whitesell *et al.* (1986); U.S. Army Corps of Engineers, Pacific Ocean Division (1987, 1989a); Wilson & Hamilton (1992).
Reasons for inclusion: Swamp forest: 1a, 2b; mangrove forest 1a, 2b, 2c.
Source: Glasstine Cornelius and Christopher R. Dahl.

Okat Mangrove Forest (1a)

Location: 5°18'-5°22'N, 162°55'-162°59'E; the contiguous mangrove forest along the north coast of Kosrae Island, stretching northeast from Molsron Mwot (inlet) to Tafunsak village. The mangrove forest is at its widest and most developed in the estuary of the Okat River. The mouth of the Okat River is just inland from Kosrae airport and port facilities.
Area: 453.2 ha.
Altitude: 0-2 m.
Overview: A coastal belt of mangrove forest averaging about 500 m in width except in the estuaries of the Okat and Lemwot rivers where it is somewhat wider. Unlike mangroves on the rest of the island, the Okat mangrove forest is not separated from the fringing reef by a barrier island. This area is significant because it has the largest examples of *Sonneratia alba* in the Caroline Islands.
Physical features: The coastal plains of Kosrae were formed by rapid erosion off steep volcanic mountain slopes and deposition on the inner portion of a fringing reef. This coastal plain along the north coast is narrow, generally swampy and dominated by swamp forest and mangrove. The predominant soil type in the mangroves is Naniak-Insak. Naniak-Insak is a moderately deep and very deep, very poorly drained soil formed in alluvium derived dominantly from basic igneous rock. It is loamy and mucky. The major rivers are the Yela, Okat and Lemwot. The climate is humid tropical, with an average annual rainfall of about 5,000 mm.
Ecological features: *Sonneratia alba* is the dominant mangrove species. Some of the trees attain a height of 25-30 m and support numerous epiphytes in their branches. *Sonneratia* reaches its greatest height toward the middle of the mangrove, but is also the most seaward species, with *Rhizophora mucronata* occurring at the mouths of channels. *Rhizophora apiculata* and *Bruguiera gymnorrhiza* occur mixed with *Sonneratia* toward the middle of the mangrove, with patches of *Nypa fruticans* and stands of *Xylocarpus* found toward the landward edge (Stemmermann & Proby, 1978). The mangroves are bordered on their landward side by freshwater swamp forest or agro-forest.
Land tenure: The mangrove forest is under the jurisdiction of the State Government.
Conservation measures taken: None.
Conservation measures proposed: Draft legislation to control harvesting of forest resources has been developed but not passed by the State Legislature.
Land use: The mangroves are primarily exploited for firewood. Mangrove timber and nipa fronds are also used for house construction but use of these traditional materials is declining. There is limited exploitation of *Xylocarpus* for handicrafts (wood carvings).
Disturbances and threats: The island's circumferential road is currently being expanded along the north coast into the Okat River drainage. Aside from direct impacts which include limited filling of mangrove areas and possible changes in local hydrographic patterns, the road is allowing greater access to previously inaccessible wetland areas. Clear-cutting of mangroves for firewood for up to 100 m from the roadside is very noticeable in those parts of the Okat forest where the road has been located along the inner fringe of the mangroves. A major fisheries complex is under construction at the nearby port, and a cannery is proposed for this complex. Once in operation, the cannery will require substantial amounts of water and generate large amounts of waste. If treatment facilities are inadequate, local water quality will be affected.
Hydrological and biophysical values: The mangrove forest probably intercepts much run-off

from the mountainous interior of the island, thereby acting as a sediment trap and helping to maintain the requisite water quality that allows coral reefs to grow in close proximity to the land.
Social and cultural values: The mangrove forest is a source of a variety of useful products including firewood, timber, thatch and fishery products. Important fisheries products include the mangrove crab (*Scylla serrata*) and certain species of snapper (*Lutjanus* sp.). Numerous archaeological sites are found along the interior margin of the mangrove forest.
Noteworthy fauna: As for the wetlands of Kosrae Island in general (Site 1).
Noteworthy flora: Excellent stands of mangrove forest with *Sonneratia alba*, *Rhizophora mucronata*, *R. apiculata*, *Bruguiera gymnorrhiza*, *Barringtonia racemosa*, *Davallia solida*, *Derris trifoliata*, *Nephrolepsus acutifolia*, *Ophioglossum pendulum* and *Xylocarpus granatum*.
Scientific research and facilities: No research has been carried out specifically at this site.
Recreation and tourism: None at present. A recent survey sponsored by the East-West Center (Hawaii) developed recommendations for utilisation of wetland areas, including the Okat area, for tourism (Wilson and Hamilton, 1992).
Management authority and jurisdiction: The Kosrae State Government has jurisdiction over the mangrove forest, but no legislation to direct the management of forest resources has yet been implemented.
References: Stemmermann & Proby (1978); Whitesell *et al.* (1986); Wilson & Hamilton (1992).
Reasons for inclusion: 1a, 2b, 2c.
Source: Christopher R. Dahl.

Utwa-Walung Mangrove Forest (1b)

Location: 5°16'-5°17'N, 162°54'-162°58'30"E; the contiguous mangrove forest along the south coast of Kosrae Island, extending from Soaksa on the western tip of the island east to Molsron Taf, immediately to the west of Utwa village.
Area: 637.2 ha.
Altitude: 0-2 m.
Overview: A broad belt of mangrove forest on the south coast of Kosrae Island, between 500 and 1000 m in width. There are two large brackish lakes, Lulu Nefalil and Lulu Utwa, in the interior of the central portion of the mangrove. The Utwa-Walung mangrove forest is representative of mangrove physiography in Kosrae, with a narrow barrier island on the seaward margin and a typical assemblage of mangrove fauna and flora. The central and western portions of the wetland remain relatively undisturbed.
Physical features: Kosrae's coastal plains were formed by rapid erosion off steep volcanic mountains slopes and deposition on the inner portion of a fringing reef. On the south coast, the dry land aspect of this plain is very limited; the mangrove forests are for the most part adjacent to steep mountain slopes, except at the extreme eastern end around the estuary of the Finkol-Menka River and in the west at the estuary of the Falwe River. The forest overlies the inner part of the fringing coral reef. Due to high wave energy, a coastal strand or barrier island has formed between the protected waters of the mangrove forest and the open fringing reef. In some places, the distance from this narrow islet to the outer reef margin is as little as 50 m. The barrier island is bisected by a single channel (Tukunsru) near its western end. The predominant soil type in the mangroves is Naniak-Insak. Naniak-Insak is a moderately deep and very deep, very poorly drained soil formed in alluvium derived dominantly from basic igneous rock. It is loamy and mucky. Run-off from the southwestern part of the island drains into the wetland primarily through the Finkol-Menka and Falwe rivers. The climate is humid tropical with an average annual rainfall of about 5,000 mm.
Ecological features: The mangrove forest is typical of Kosrae, and has been described by Stemmermann and Proby (1978). *Sonneratia alba* is the dominant mangrove species. *Sonneratia*

reaches its greatest height toward the middle of the mangrove, but is also the most seaward species with *Rhizophora mucronata* occurring at the mouths of channels. *Rhizophora apiculata* and *Bruguiera gymnorrhiza* occur mixed with *Sonneratia* toward the middle of the mangrove, with patches of *Nypa fruticans* and stands of *Xylocarpus* found toward the landward edge. Adjacent communities include coastal strand vegetation, upland forest and swamp forest.
Land tenure: The mangrove forest is under the jurisdiction of the State Government.
Conservation measures taken: None.
Conservation measures proposed: Draft legislation to control harvesting of forest resources has been developed but not yet passed by the State Legislature.
Land use: The mangroves are exploited primarily for firewood. Mangrove timber and nipa fronds also used for house construction, but use of these traditional materials is declining. There is limited exploitation of *Xylocarpus* for handicrafts (wood carvings). The Utwa-Walung mangrove forest was inaccessible by vehicle until 1987, when a new section of the circumferential road skirting the mountain sides on the landward side of the mangrove forest was completed. This has allowed some people to move back to ancestral lands in the area. The brackish lakes (lulu) within the mangroves and Utwa harbour in the east are important to subsistence fisheries.
Possible changes in land use: The recent construction of a road along the landward side of the mangrove forest has allowed increased access to the area and renewed settlement along the south coast. Both the State Government and Utwa Municipality are interested in developing the mangrove forest for tourism as the area has great aesthetic value. No major development projects are known that will significantly alter land use or compromise the quality of the area in the near future.
Disturbances and threats: A small portable saw mill has been operating in the eastern part of the forest on an occasional basis. Logging practices are poor, and the impact has been greater than warranted by the level of exploitation. Dredging associated with road construction has led to extensive siltation in the western part of Utwa harbour (Molsron Utwa).
Hydrological and biophysical values: The mangrove forest probably intercepts much run-off from the mountainous interior of the island, thereby acting as a sediment trap and helping to maintain the requisite water quality that allows coral reefs to grow in close proximity to the land.
Social and cultural values: The mangrove forest is a source of a variety of useful products including firewood, timber, thatch and fishery products. Important fisheries products include the mangrove crab (*Scylla serrata*) and certain species of snapper (*Lutjanus* sp.).
Noteworthy fauna: As for the wetlands of Kosrae Island in general (Site 1).
Noteworthy flora: Excellent stands of mangrove forest with *Sonneratia alba*, *Rhizophora mucronata*, *R. apiculata*, *Bruguiera gymnorrhiza*, *Barringtonia racemosa*, *Davallia solida*, *Derris trifoliata*, *Nephrolepsus acutifolia*, *Ophioglossum pendulum*, *Xylocarpus granatum* and *Nypa fruticans*.
Scientific research and facilities: No research has been carried out specifically at this site.
Recreation and tourism: Very little at present. A brochure has been prepared for the State Division of Tourism describing canoe and hiking opportunities in the mangrove and coastal strand. A recent survey sponsored by the East-West Center (Hawaii) investigated opportunities for the development of tourism in the area (Wilson and Hamilton, 1992).
Management authority and jurisdiction: The State Government has jurisdiction over the mangrove forest, but no legislation to direct the management of forest resources has yet been implemented.
References: Stemmermann & Proby (1978); Whitesell *et al.* (1986); Wilson & Hamilton (1992).
Reasons for inclusion: 1a, 2b, 2c.
Source: Christopher R. Dahl.

Yela River *Terminalia* Swamp Forest (1c)

Location: 5°19'N, 162°57'E; located in the Yela River drainage in Tafunsak Municipality, on the north coast of Kosrae Island.
Area: 77.3 ha.
Altitude: 0-20 m.
Overview: The Yela River *Terminalia* forest is reported to be the finest example of this unique wetland type in FSM. It is situated in a flat valley floor surrounded by mountain slopes on all sides except the north, where the valley opens to the coast. Although periodically logged during the Japanese era, the forest has now been undisturbed for more than forty years.
Physical features: A large area of tall freshwater swamp forest in the lower basin of the Yela River, almost entirely surrounded by steep mountain slopes. The river drains out through a gap in the hills to the north.
Ecological features: High canopy swamp forest dominated by *Terminalia carolinensis* and *Horsfeldia nunu*. Species in the lower strata include *Barringtonia racemosa*, *Neubergia celebica* and *Scirpodendron ghaeri*. In the north, the forest is adjacent to the coastal mangrove forests. At slightly higher elevations, the forest merges into high canopy wet rainforest with *Campnosperma brevipetiolata* (Stemmermann & Proby, 1978).
Land tenure: The forest is privately owned.
Conservation measures taken: None.
Conservation measures proposed: Draft legislation to control harvesting of forest resources has been developed but not yet passed by the State Legislature.
Land use: The swamp forest has been relatively inaccessible and undisturbed since the Japanese era. There is currently no human population resident in the area.
Disturbances and threats: The major threat to the wetland is associated with the construction of a new road through the area. The State Government is currently extending the island's circumferential road along the north coast. Eventually it will reach this area. The road will probably span the mouth of the valley on a filled road-bed, and this could cause a change in hydrographic patterns in the valley. Once the valley becomes readily accessible, it is likely that the forest will be logged, as the timber is of some value.
Hydrological and biophysical values: No specific information is available.
Social and cultural values: None, because of the inaccessibility of the site.
Noteworthy fauna: No information.
Noteworthy flora: Undisturbed mature stands of freshwater swamp forest dominated by *Terminalia carolinensis*, with *Horsfeldia nunu*, *Campnosperma brevipetiolata*, *Barringtonia racemosa*, *Neubergia celebica* and *Scirpodendron ghaeri*.
Scientific research and facilities: This swamp forest was first described in 1952 by Hosokawa (1954), and may have been visited in connection with a U.S. Forest Service survey of timber volumes (McLean *et al.*, 1988).
Management authority and jurisdiction: No information.
References: Hosokawa (1954); MacLean *et al.* (1988); Stemmermann & Proby (1978); Whitesell *et al.* (1986).
Reasons for inclusion: 1d, 2b.
Source: Christopher R. Dahl.

The Wetlands of Pohnpei State (2)

Location: 6°57'N, 158°12'E; the wetlands of Pohnpei State, primarily mangrove forests surrounding the main island of Pohnpei.
Area: 5,525 ha.
Altitude: 0-772 m.
Overview: Pohnpei State consists of the main island of Pohnpei, and the atolls Ngatik, Mokil,

Oroluk, And, Kapingamarangi, Nukuoro, Pingalap and Pakin. There are extensive mangrove and freshwater swamp forests on Pohnpei island along with freshwater marshes, ivory nut palm forests (*Metroxylon amicarum*) and upland swamps. Taro swamps (*Colocasia esculenta* and *Cyrtosperma chamissonis*) are found on both Pohnpei and the outer island atolls. Limited stands of dwarf *Rhizophora* and *Lumnitzera* are found on some of the atolls. Two wetlands of outstanding importance, Enipein Mangroves and Palikir Freshwater Marsh, are described separately as sites 2a and 2b, respectively.

Physical features: Pohnpei is a volcanic island with both fringing and barrier reefs. Wetland areas are most extensive along the flat coastal plain and adjacent inner reef flat, although wet areas are encountered at all altitudes due to high rainfall (recorded at about 5,000 mm/yr on the coast and estimated to exceed 10,000 mm/yr in upland areas). Mangroves are found on the lower portions of rivers and on tidal mudflats built over inner fringing reef flat. They also surround small coral islets on the barrier reef. Freshwater swamp forest is common adjacent and inland to mangroves. Marshes and taro swamps are considered to be variations of the swamp forest community. The soil types in wetlands (United States Department of Agriculture soil series taxonomy) are Inkosr series silty clay loam in swamp forests, Mesei Variant mucky peat in marshland and Naniak series mucky silt loam in mangrove areas (Laird, 1982). Water quality is variable around Pohnpei but generally good. There is some localised sewage contamination of rivers and rather serious pollution from sewage, oil products and other contaminants in estuarine areas around the urban centre of Kolonia. Freshwater wetlands have little standing water, generally no more than 0.5 metre, while the soil is constantly saturated and mucky. In mangroves, water depths vary from a few centimetres to 2 metres in channels. Tidal fluctuation on Pohnpei has a 0.7 m mean and 1.0 m diurnal range. Because of high rainfall, there are many significant perennial river systems on Pohnpei. The Nanpil, in the north, and the Lehn Mesi, in the south, are the two largest drainages. Total dry land area, or drainage, is 335.5 sq.km. The climate is wet tropical with recorded rainfall exceeding 5,000 mm/yr, and a fairly constant year-round temperature averaging 27°C.

Ecological features: Mangrove forest is well developed and in some areas extends more than two km from the shore. The forests are characterised by channels bordered by large trees with a canopy height of up to 30 metres. Away from the channels, canopy height decreases markedly, reaching only two metres in some areas (Stemmermann & Proby, 1978), and creating dwarf forest. Mangrove species are not uniformly distributed throughout the forests of Pohnpei. Along the channels and toward the leeward edge of the mangrove forest, *Rhizophora mucronata* and *Sonneratia alba* tend to dominate. Other common tree species are *R. apiculata*, *Xylocarpus granatum*, *Lumnitzera littorea* and occasionally *Bruguiera gymnorrhiza* (Stemmermann & Proby, 1978). Marine crocodiles are not found on Pohnpei. As elsewhere in Micronesia, the mangroves of Pohnpei do not support abundant bird life, although the seaward margins are used by roosting seabirds. Freshwater swamp forest is usually found in flat coastal areas adjacent to the inside of the mangroves. It is characterised by *Terminalia carolinensis*, *Campnosperma brevipetiolata* and *Pandanus comminsii*. *Metroxylon amicarum* may be found as an emergent species in the high canopy phase, but is more typically associated with the low canopy phase (Stemmermann & Proby, 1978). The low canopy phase is characterised by *Phragmites karka*, *Hibiscus tiliaceus*, *Barringtonia racemosa*, *Macaranga* spp. and *Glochidion* sp. Four lowland marsh areas were identified by Stemmermann and Proby; they are adjacent to, or in one case, surrounded by mangrove forest. They are characterised by sedges (*Eleocharis* spp.) with dwarf tree species (*Lumnitzera* or *Rhizophora*) sparsely interspersed. Cultivated taro swamps are another common type of wetland.

Land tenure: Land below the high tide mark is under the jurisdiction of Pohnpei State Government. Most of the land adjoining the mangroves is owned privately by deed.

Conservation measures taken: The Pohnpei State Government passed a Watershed and Mangrove Protection Act in 1987 giving management jurisdiction over mangrove areas to the State Division of Forestry. The Division has instituted a state-wide mangrove logging ban until adequate management measures can be implemented. This same act also protects publicly owned watershed areas in the interior of the island as a Watershed Reserve. However, effective implementation of watershed protection has not yet occurred.

Conservation measures proposed: In connection with the above mentioned legislation, Devoe (1991) has proposed 11 reserve areas in the mangroves. Protection would vary from strict habitat protection to sustainable harvest managed by the State Division of Forestry.
Land use: According to recent population estimates, there are about 30,000 people on Pohnpei island. Of these, approximately 7,000 are concentrated in the urban centre of Kolonia. The majority of the population are subsistence farmers and fishermen. Freshwater swamp is occasionally converted for taro production. The mangrove forests of Pohnpei have been logged on both a commercial and subsistence basis. Many marine products are harvested in the mangrove, including the mangrove crab (*Scylla serrata*), other shellfish and various species of fish.
Possible changes in land use: Most significant development is currently concentrated in the urban centre of Kolonia. Population growth and urbanisation has led to localised impacts on wetlands from conversion and pollution. Extension of infrastructure, including a circumferential road and electrical transmission lines, may increase rural development and consequent environmental impacts. Secondary road construction may affect wetlands by increasing erosion rates. A few proposals for major resort development have been mooted, but none are currently under construction. Such resorts would include golf courses; their construction and maintenance could have downstream impacts on wetlands and estuarine areas. The State Government has considered two sites either in or adjacent to wetlands for the development of a new, larger airport. As of this writing, no decision has been taken on this matter.
Disturbances and threats: Aside from the problems mentioned above, the main threat to forested wetlands, particularly mangroves, is unmanaged timber harvest, both subsistence and commercial. Devastation of the upland forest is affecting downstream water quality and sediment loads, and this in turn is threatening the mangrove and lagoon systems. As noted above, the State Government is trying to establish a viable management regime for mangrove and watershed areas.
Hydrological and biophysical values: Mangroves are important for shore protection. They also serve as a natural filtering and buffering system which settles silt and provides for a slow release of nutrients into the lagoon (MacLean *et al.*, 1986). The hydrology of adjacent freshwater swamps and mangroves is no doubt complex and has not been studied.
Social and cultural values: The principal social values of the wetlands include timber, marine products, traditional medicines, tourism and recreation, and scientific research. There is a also strong cultural attachment to mangrove areas (as there is to all areas of Pohnpei). Numerous legends exist that relate to specific name locations in the mangroves. The mangroves also play an important role in the origin myth of Pohnpei.
Noteworthy fauna: Wetland areas provide habitat for a variety of seabirds, waterbirds and forest birds, some endemic and others threatened. Notable seabirds and waterbirds include the Great Frigatebird (*Fregata minor*), Pacific Reef Heron (*Egretta sacra*), terns (*Sterna* spp.), noddies (*Anous* spp.) and the Micronesian Kingfisher (Pohnpei subspecies: *Halcyon cinnamomina reichenbachii*). There are a number of endemic birds on Pohnpei. While these are generally inhabitants of the mountain forests, they may be encountered in and around wetlands. They include the Pohnpei Lory (*Trichoglossus rubiginosus*), Pohnpei Flycatcher (*Myiagra pluto*), Pohnpei Fantail (*Rhipidura kubaryi*), Long-billed White-eye (*Rukia longirostra*), the Pohnpei subspecies of Cicadabird (*Coracina tenuirostris insperatum*) and Pohnpei Mountain Starling (*Aplonis pelzelni*), although the latter may now be extinct. The Caroline Islands Ground Dove (*Gallicolumba kubaryi*) is endemic to Pohnpei and Chuuk. The only indigenous mammal in the mangrove and swamp forests is the Marianas Fruit Bat (*Pteropus mariannus*). There are a number of endemic freshwater gobies (Gobidae) in the rivers and streams of Pohnpei.
Noteworthy flora: Typical mangrove species include *Rhizophora mucronata* var. *stylosa*, *R. apiculata*, *Sonneratia alba*, *Bruguiera gymnorrhiza*, *Xylocarpus granatum*, *Lumnitzera littorea* and *Nypa fruticans*. Characteristic tree species in freshwater swamp forest are *Terminalia carolinensis*, *Campnosperma brevipetiolata*, *Pandanus comminsii* and *Metroxylon amicarum* and in the low canopy phase *Phragmites karka*, *Hibiscus tiliaceus*, *Barringtonia racemosa*, *Macaranga* spp. and *Glochidion* sp.
Scientific research and facilities: The College of Micronesia has limited research facilities at the Community College and Land Grant facility in Kolonia. Current research on mangrove use is being

carried out by Dr Nora Devoe, a research forester with the USDA Forest Service. Fr Greg Muckenhaupt of the University of Hawaii is currently conducting research on nutrient flux within the mangrove forest (pers. comm.).

Conservation education: While Pohnpei wetlands have high potential as a site for educational activities, no facilities or programmes utilising wetland areas currently exist.

Recreation and tourism: Enipein Marine Park, Inc. has begun giving mangrove channel tours on an irregular basis employing traditional dugout canoes. There appears to be significant potential for expansion of this activity as the mangrove forest is of high scenic value, adjacent reefs are in excellent condition and the mangrove forests do not harbour dangerous animals (*e.g.* crocodiles) or large numbers of biting insects. A private entrepreneur is building a boardwalk through mangrove forest adjacent to the village of Pwudoi (Kitti) on the southwest coast of Pohnpei.

Management authority and jurisdiction: Division of Forestry, Kolonia, Pohnpei.

References: Devoe (1991); Holthus (1987); Laird (1982); MacLean *et al.* (1986, 1988); Miyagi & Kiyoshi (1989); Pettys *et al.* (1986); Stemmermann & Proby (1978); U.S. Army Corps of Engineers, Pacific Ocean Division (1985, 1986).

Reasons for inclusion: 1a, 1c, 1d, 2a, 2b, 2c, 2d.

Source: Christopher R. Dahl and Ron Cannarella.

Enipein Mangroves (2a)

Location: 6°51'N, 158°13'E; the Enipein mangrove forest is on the south-southeast side of Pohnpei island in the municipality of Kitti. It is approximately 18 km from the urban centre of Kolonia. This forest is part of contiguous mangrove forest that surrounds virtually all of Pohnpei. The Enipein forest is defined as the area bounded by Dauen (channel) Rakis on the west and Dauen Semwei on the east.

Area: 755 ha.

Altitude: Sea level.

Overview: This mangrove forest is one of the most extensive on Pohnpei, approximately 2 km wide (from inner to outer boundaries) at its widest point. The forest is well developed with excellent examples of *Sonneratia alba*, *Lumnitzera littorea* and *Xylocarpus granatum*. This area is being considered for protected status by Pohnpei State.

Physical features: The Enipein mangrove forest has formed on the inner reef flat by the gradual deposition of eroded material. Pohnpei is a volcanic island that experiences high rates of rainfall (approximately 5,000 mm/year) and thus high erosion rates. Stratigraphy analyzed by Miyagi and Fujimoto (1989) from the Enipein area indicates that about 1.7 metres of mangrove peat overlies the original coralline reef flat. The soil type in mangroves (United States Department of Agriculture soil series taxonomy) is Naniak series mucky silt loam (fine loamy mixed non-acid, isohyperthermic, Typic sulfaquents). Water quality is generally typical of mangrove areas (tea-coloured due to tannins) with little pollution caused by humans. Coastal waters around the island are bearing heavier sediment loads due to land clearance, construction and agriculture. This is no doubt the case in Enipein as well. Water depths vary from a few centimetres to two metres in mangrove channels. Tidal fluctuation on Pohnpei has a 0.7 m mean and 1.0 m diurnal range. Five rivers flow into this mangrove area. The catchment area for the Enipein mangroves is very roughly estimated at 22 sq.km. The climate on Pohnpei is wet tropical, with an annual rainfall approaching or exceeding 5,000 mm. Temperature varies little throughout the year, averaging 27°C. Humidity is high, especially from May to October when the trade winds cease to blow.

Ecological feature: Enipein is a wide dense mangrove area forming part of an extensive and contiguous mangrove fringe that surrounds Pohnpei island. It is bisected by a system of channels except in the central parts of the widest areas where poor water circulation has resulted in dwarf forest. *Rhizophora mucronata* is found on the outer margin. Well developed groves of *Xylocarpus* *granatum* and *Lumnitzera littorea* are found towards the landward margin of the forest. Large *Sonneratia alba* are also found in the middle and landward zones. In estuarine areas around river mouths or bays, *Rhizophora mucronata* and *R. apiculata* occur as pure stands or mixed with some *S. alba* and *Bruguiera gymnorrhiza*. Upstream the *Rhizophora* component drops out. *Nypa fruticans* can become dominant in narrow bands along riverine portions of the inner mangrove.

Land tenure: Land below the high tide mark is under the jurisdiction of Pohnpei State Government.

Conservation measures taken: The Pohnpei State Government passed a Watershed and Mangrove Protection Act in 1987 giving management jurisdiction over mangrove areas to the State Division of Forestry. The Division has instituted a state-wide mangrove logging ban until adequate management measures can be implemented.

Conservation measures proposed: Devoe (1991) has proposed Enipein as a reserve area. 76 ha would be classified as strict preserve for wildlife habitat with limited access; 163 ha as park area where timber is not harvested, and hunting and fishing are allowed by permit only; and 365 ha for managed timber harvest under the direction of the State Division of Forestry. The village of Enipein Pah has established a corporation, Enipein Marine Park, Inc., that wishes to utilise this area for tourism. The village supports park status for the area.

Land use: The Enipein mangrove forest has been logged on both a commercial and subsistence basis. However, most of this has had low impact except for an 8 ha clear-cut in the western section of the tract (Devoe, 1991). Many marine products are harvested in the mangrove including the mangrove crab (*Scylla serrata*), other shellfish and various species of fish. Adjacent lands are mostly settled agro-forest. There are extensive freshwater wetlands adjacent to the inner margin of the mangroves. These include swamp forest, freshwater swamp and *Metroxylon amicarum* palm forest. Much of the freshwater swamp was turned over to the production of taro in a state agricultural development project. Population densities are relatively low. The most recent census (1985) enumerated a population of 4,572 for all of Kitti Municipality. Most residents engage in subsistence activities while some commute to Kolonia for wage employment (primarily in the government sector) on a daily basis.

Possible changes in land use: The State Government has considered development of a new airport along the inner margin of this mangrove area. As of this writing, no decision has been taken on this matter.

Disturbances and threats: No major threats currently exist. Unmanaged subsistence and commercial logging has probably had the greatest impact, but this is still modest.

Hydrological and biophysical values: Mangroves are recognised for their value in shore protection and stabilisation. The lagoonal and barrier coral reefs adjacent to Enipein are of high quality; mangroves intercept silt run-off which might otherwise degrade these reefs.

Social and cultural values: The mangroves are of subsistence value for a variety of products including timber, shellfish and fish. Timber has also been harvested on a semi-commercial basis. This are of mangroves is also being used in a tourism venture and as a research site. Areas within the mangroves are named and often have legends associated with them. Particular resources or areas may be associated with certain clans. According to legend, *Xylocarpus granatum* originated from a particular grove in Enipein and then spread to the rest of the island.

Noteworthy fauna: Mangroves provide habitat for various seabirds and waterbirds. However, it is not primary habitat for any of the endemic, rare or threatened species on Pohnpei. The mangrove crab (*Scylla serrata*) is common and an important subsistence and commercial species. Two bivalves of subsistence importance that are abundant in the Enipein mangroves are the "lipwei" clam (*Anadara* sp.) and "kopil" clam (*Pitar* spp.). A number of economically important fish are transient in the mangroves; these include *Lutjanus argentimaculatus*, *Lutjanus fulvus* (groupers), *Lethrinus harak* (snapper), *Liza vaigiensis*, *Valamugil seheli* (both mullets), *Siganus* spp. (rabbitfish) and *Parupeneus barberinus* (goatfish).

Noteworthy flora: Characteristic trees are *Rhizophora* spp., *Bruguiera gymnorrhiza*, *Lumnitzera littorea*, *Nypa fruticans* and *Sonneratia alba*. The Enipein area encompasses some fine examples of undisturbed high stature mangrove forest with groves of *Lumnitzera* and *Xylocarpus* and quite large *Sonneratia*

trees. *Asplenium* spp., *Nephrolepsis acutifolia* and species of Orchidaceae are characteristic epiphytes; *Nephrolepsis* is particularly associated with *Sonneratia*.
Scientific research and facilities: No research facilities exist in the area. Devoe (1991) has a study site here for her research on mangrove forest utilisation. Fr Greg Muckenhaupt of the University of Hawaii is currently conducting research on Pohnpei into nutrient flux in the mangrove forest (pers. comm.) and has a study site at Enipein.
Conservation education: There are no conservation education programmes at Enipein. Potential for basic educational activities here is high given the nascent interpretive potential of the Enipein Marine Park Corporation.
Recreation and tourism: Enipein Marine Park Corporation has begun giving tours on an irregular basis employing traditional dugout canoes. There appears to be significant potential for expansion of this activity as the mangrove forest is of high scenic value, adjacent reefs are in excellent condition and the mangrove forests do not harbour dangerous animals (*e.g.* crocodiles) or large numbers of biting insects.
Management authority and Jurisdiction: Division of Forestry, Kolonia, Pohnpei.
References: Devoe (1991); Holthus (1987); Laird (1982); MacLean *et al.* (1986, 1988); Miyagi & Kiyoshi (1989); Pettys *et al.* (1986); U.S. Army Corps of Engineers, Pacific Ocean Division (1985, 1986).
Reasons for inclusion: 1a, 2a, 2b, 2c.
Source: Christopher R. Dahl.

Palikir Freshwater Marsh (2b)

Location: 6°55'N, 158°07'E; this marsh is located on the most westerly tip of Pohnpei Island in Sokehs Municipality. It is approximately 10 km southwest of Kolonia, the main population centre on the island, and 4 km west of the site of the national capital. The freshwater swamp is bounded on three sides by mangrove forest and on its inland side by freshwater swamp forest.
Area: Stemmermann and Proby (1978) give the area at "roughly 11 ha". According to the Pohnpei vegetation survey (MacLean *et al.*, 1986), the area of open sedge is only 2 ha. If the surrounding unit they classify as freshwater swamp forest is included then the total area is 19 ha.
Altitude: 0.5-2.0 m.
Overview: Stemmermann and Proby (1978), who categorised this wetland type as a phase of lowland swamp forest, state that this was "one of the most intriguing wetlands (type) encountered." It is open marshland bordered on three sides by mangrove and by freshwater swamp forest on its interior border. This wetland type is unusual; Stemmermann and Proby (1978) identify four sites on Pohnpei, although two of the others are close to one another and found in the centre of an extensive mangrove forest and may have somewhat different physical and ecological characteristics. In addition, they collected an endemic orchid (*Liparis* sp.) that is apparently specific to this site. (On a recent visit to this site, this orchid was not observed).
Physical features: The hydrology of the area is undoubtedly unusual given that it is a freshwater area bounded on all but one side by mangrove swamp. The landward boundary does have a steep bank about seven metres high. It may be that laterally flowing ground water reaches the surface in this area. Brackish water circulation in the adjacent mangroves is also poor as evidenced by nearby stands of dwarf trees. The hydrology may be similar to the other site discussed by Stemmermann and Proby, at Mutok, Kitti Municipality. This is in the centre of a relatively extensive mangrove forest and may have such poor water circulation that a freshwater environment can be maintained by rainfall. In both cases land elevation, even if slight, may play a role. Vegetation zonation in this wetland may indicate a higher elevation at its centre where dense stands of *Pandanus* grow with an understorey of *Melastoma malabathricum* and a few other woody species such as *Ficus tinctoria*, *Campnosperma brevipetiolata* and even one fairly large *Albizia lebbeck*. It appears, however, to be

occasionally inundated by brackish water around its borders. In the vegetation zone adjacent to the mangrove forest (in this case primarily *Lumnitzera*), the soil is wetter and much dead wood is found. Stemmermann and Proby speculated that this was evidence that the area had been previously forested. However, it appears to be arrayed as if it had settled on a receding water. In addition, bits of flotsam such as an empty plastic bottle of suntan lotion were observed. Since the area is isolated and infrequently visited, it seems unlikely that such flotsam was brought there by a visitor. Thus an alternative explanation may be that unusual spring tides inundate the borders of the wetland and deposit deadfall and flotsam from the mangrove forest. It may be that with rising sea level, the wetland is slowly shrinking in size. This border area is populated by more salt tolerant species: stunted *Pandanus*, *Lumnitzera littorea* and one sedge, *Scirpodendron ghaeri*. While a series of ponds are shown within this wetland on the USGS topographic map and were noted by Stemmermann and Proby, they were not observed during a recent trip. This trip was undertaken during a relatively dry period, and it may be that these ponds are ephemeral. The soil in this area is classified as Inkosr gravelly sandy clay loam (Laird, 1982).

The wetland is natural in origin. Stemmermann and Proby state that: "in openings in adjacent high closed canopy *Campnosperma* swamp forests, a large sedge can be seen from the air (near the site at Mutok, Kitti). This may imply that, if undisturbed, the open canopy swamp forest may mature to high closed canopy swamp forest. This would then be the climax of the lowland freshwater marsh. If this succession does occur, then the high canopy swamp forest could be considered the climax of lowland freshwater marsh. However, any succession such as this must be very slow, since there has been no apparent change in the area between 1945 and 1976 as shown on aerial photographs" (Stemmermann & Proby, 1978: pp 61-62). Recent observations suggest that another alternative, at least at this site, is a slow invasion by mangrove forest. As noted, the margin of the wetland on its north and south sides is mucky with standing water and fairly barren. Stranded deadfall and flotsam suggest it is occasionally inundated on high tides. Along its western border, clumps of *Lumnitzera* suggest that this low salinity mangrove species is slowly invading. Detailed examination of aerial photographs from 1945, 1975 and 1984 would be necessary to determine what changes, if any, are occurring at this wetland.

Ecological features: Three vegetation zones can be observed within the wetland. Around most of its border, the soil is mucky with standing water and vegetation is scarce, primarily clumps of the large sedge *Scirpodendron ghaeri*, *Pandanus* c.f. *odoratissimus* and stunted (1-2 m) *Lumnitzera littorea*. Roughly in the centre of the wetland, *Pandanus* grows fairly densely as an overstorey. *Melastoma malabathricum* grows as a shrub understorey. *Melastoma* is a facultative wetland plant also found in upland areas. In open areas, sedges, notably *Eleocharis ochrostachys*, the fern *Cycolsorus gongylodes* and *Lycopodium cernuum* grow as ground cover. Occasional tree species were observed, most notably *Campnosperma brevipetiolata*. To the west of the *Pandanus* area is a large open area of low sedges, primarily *Eleocharis ochrostachys*, with *E. geniculata* dominating more towards the southern part of this area. The soil here is quite firm in comparison to the border zone. This zonation is probably due to variations in elevation and hydrology. The wetland is bordered to the south and west by almost pure stands of *Lumnitzera* which are perhaps 100 m wide, beyond that taller mangrove species such as *Sonneratia alba* could be observed. To the north mangrove, primarily *Rhizophora* sp., borders directly on the wetland. The inland margin borders on lowland swamp forest.

Land tenure: This land is most probably privately owned but the details of ownership are not known.

Conservation measures taken: None.

Conservation measures proposed: Devoe (1991) proposes adjacent mangrove areas as a reserve. Because this wetland is above the high tide mark, it is not directly under the jurisdiction of the State so no proposals have been made for its protection.

Land use: The wetland is in a relatively remote and lightly populated area. There is some taro (*Cyrtosperma*) cultivation along the inland margin of the wetland. Numerous signs of deer were observed at the wetland; it may be a popular hunting spot.

Possible changes in land use: None are being contemplated although the nearest road, which is about one km distant, is to be improved at some future date. This may induce more settlement in

the area.
Disturbances and threats: None known.
Hydrological and biophysical values: Because of its small size and location, the wetland probably does not have great hydrological or biophysical significance.
Social and cultural values: None known, although, as noted, it may be a good area for deer hunting.
Noteworthy fauna: This is probably a popular site for various seabirds, shorebirds and migrants. The Pacific Golden Plover (*Pluvialis fulva*) Brown and Black Noddies (*Anous stolidus* and *A. minutus*), Whimbrel (*Numenius phaeopus*) and Wandering Tattler (*Heteroscelus incanus*) were observed at the wetland during a short visit. Numerous deer trails and footprints were also seen suggesting that this is good habitat for the introduced Asian and European deer.
Noteworthy flora: Notable flora include *Cyclosorus gongylodes*, *Eleocharis geniculata*, *E. ochrostachys*, *Lumnitzera littorea*, *Lycopodium cernuum*, *Melastoma malabathricum*, *Pandanus* c.f. *odoratissimus* and *Scirpodendron ghaeri*. Of special interest is a species of orchid of the genus *Liparis* which is apparently endemic to this site. The orchid was first observed and collected by Stemmermann and Proby (1978), who state that: "this may be an undescribed taxon. A single specimen of this terrestrial orchid was found (at this wetland). It is certainly rare, and because of its limited distribution should be considered endangered".
Scientific research and facilities: Stemmermann and Proby (1978) are the only scientists known to have visited the site, and the account of their findings is the only published source of information on the site.
Conservation education: No education programmes directed specifically to this wetland or wetland type exist. Because it is an unusual and probably unique site, it should have significant interpretive value.
Management authority and jurisdiction: Division of Forestry, Department of Conservation and Resource Surveillance, Pohnpei State Government.
References: Devoe (1991); Laird (1982); MacLean *et al.* (1986); Stemmermann & Proby (1978); U.S. Army Corps of Engineers, Pacific Ocean Division (1985).
Reasons for inclusion: 1d, 2d.
Source: Christopher R. Dahl.

Wetlands of Chuuk State (3)

Location: 151°45'E, 7°30'N: the wetlands of Chuuk State, primarily mangrove forests surrounding the volcanic islands within Chuuk Lagoon.
Area: 1,592 ha (based on the total area of wetland soil types). This total can be subdivided into 1,143 ha of mangrove forest and 449 ha of freshwater wetland.
Altitude: Sea level.
Overview: *Rhizophora mucronata* dominant mangrove forest forms a narrow broken band around the ten major islands (over one ha in size) of Chuuk Lagoon. The other major wetland type is freshwater swamp dedicated to the cultivation of taro.
Physical features: Mangrove forests have formed in sheltered areas along the shores of the volcanic islands of Chuuk Lagoon. Wetlands typically form by silt deposition on inner reef flats. In Chuuk, the islands are small with a narrow fringing reef limiting mangrove forest development. Insufficient silt deposition also limits mangrove growth. Because the islands are subjected to significant wave action (especially during typhoons) mangrove forest development is further limited. Soil types of wetlands (United States Department of Agriculture soil series taxonomy) are Chia mucky peat, Insak Variant sandy peat, Ngerungor peaty much and Naniak mucky silt loam. Insiak Variant soil has a shallow rooting depth (25-50 cm) and thus affords poor growth. Sewage and silt are the major threats to water quality. Around urbanised areas and on heavily populated

islands, large amounts of untreated sewage enter coastal waters. Siltation may be caused by run-off of sediments or from coastal dredging activities. Water depth within the mangroves varies from a few centimetres to two metres in the channels. Tidal fluctuation in Chuuk is moderate; mean diurnal tidal range is 1.5 feet (0.46 m) and the maximum is 2.0 feet (0.61 m). Total dry land area in Chuuk Lagoon is 100.26 sq.km giving a rough indication of total catchment area for wetlands.
Ecological features: In mangrove areas, *Rhizophora mucronata* is dominant with *R. apiculata* found behind the seaward fringe in areas where the forest is fairly wide. *Bruguiera gymnorrhiza* is present but not extensive in the inner mangrove. Swamp forest typically adjoins mangrove areas in Chuuk, but most freshwater wetlands have been turned over to the cultivation of taro (*Colocasia esculenta* and *Cyrtosperma chamissonis*). *Phragmites* spp., *Hibiscus tiliaceus*, *Barringtonia racemosa*, *Macaranga* spp., *Glochidion* sp. and *Metroxylon amicarum* are typical of freshwater swamp that has been converted but is not being actively cultivated.
Land tenure: Wetland and reef areas are owned by matrilineal clans or individuals.
Conservation measures taken: None.
Land use: The islands of Chuuk Lagoon are densely populated (approximately 1,200/sq.mile). Most terrestrial wetlands have been converted to agricultural use. Mangrove areas are also occasionally impounded and slowly turned over to taro cultivation once the salinity has fallen. Mangrove poles and nipa thatch (*Nypa fruticans*) are used in house construction. Mangrove forests are also important fishing areas for certain marine species.
Disturbances and threats: Due to high population density and a rapidly expanding population, there is much demand for usable land. As noted, freshwater wetlands have been mostly converted for agricultural use and mangrove areas are marginally threatened by agricultural conversion. Mangroves are also occasionally filled to create usable land for building construction. Construction of roads with few drainage culverts causes impoundment of mangroves on a localised basis. The municipal dump for the urban centre island of Weno (Moen) is located in the mangroves.
Hydrological and biophysical values: Mangroves are important for shore protection. Chuuk is in the most typhoon prone region of the world. Mangrove forests can protect against storm wave inundation. They may also be important in stabilising the shoreline against erosion.
Social and cultural values: None known.
Noteworthy fauna: No information.
Noteworthy flora: Characteristic mangrove species are *Rhizophora mucronata*, *R. apiculata* and *Bruguiera gymnorrhiza*; freshwater species include two species of taro, *Colocasia esculenta* and *Cyrtosperma chanissonis*, and *Phragmites* spp., *Hibiscus tiliaceus*, *Barringtonia racemosa* and *Metroxylon amicarum*.
Scientific research and facilities: There are no research facilities in Chuuk nor any on-going wetland research there.
Management authority and jurisdiction: Division of Agriculture and Forestry, Chuuk State.
References: Falanruw *et al.* (1987a); Kogo *et al.* (1985); Laird (1983a); MacLean *et al.* (1988); Miyagi & Kiyoshi (1989).
Reasons for inclusion: 1a, 2b, 2c.
Source: Christopher R. Dahl.

Wetlands of Yap State (4)

Location: 9°33'N, 138°09'E; the wetlands of Yap State, chiefly mangrove forests surrounding the four main islands of Yap, Gagil-Tamil, Maap and Rumung.
Area: 1,592 ha; including 1,171 ha of mangroves (26 ha of which is classed as scrub), 155 ha of freshwater swamp forest, 165 ha of freshwater marsh, 6 ha of saline marsh and 38 ha of ponds and other water bodies.
Altitude: 0-10 m.
Overview: Mangrove forest dominated by *Rhizophora mucronata* occurs in a broken band of variable

width around all four of the main islands of Yap State and forms extensive stands in sheltered embayments. Other wetland types include freshwater swamp forest, saline marsh, freshwater marsh and ponds, but these are very limited in extent.

Physical features: Yap State comprises four metamorphic, old volcanic high islands, 15 outlying atolls and low coral islets, and the raised coral island of Fais. The four high islands, Rumung (4.3 sq.km), Maap (10.6 sq.km), Gagil-Tamil (28.8 sq.km) and Yap Proper (56.0 sq.km), lie within a broad fringing reef system and are separated by narrow channels Only these four islands possess significant wetlands, although there are some unusual stands of mangrove in the interior lagoons of some of the outer atolls. Much the most extensive wetland type is mangrove forest, which covers about 1,171 ha or approximately 32.2% of the total forested area of Yap. Mangrove forest occurs widely around the coasts of all four of the main islands, and is especially well developed on mudflats at the mouths of drainage systems. Sheltered coasts and embayments support broad continuous belts of mangrove 150-450 m wide, but along exposed shorelines, the mangrove stands become much narrower and discontinuous. The largest stands are found in Munguuy Bay and Yunearawey Passage between Maap and Tamil-Gagil, near Gachpar on the southeast coast of Tamil-Gagil, around the inner margin of Qatliirow Embayment and in the northern portion of the Tagireeng Canal between Tamil-Gagil and Yap Proper, along the east coast of Yap Proper from Peelaek Channel south to Dechumur village, and along the west coast of Yap Proper between the villages of Qokaaw and Raeng. A continuous belt of mangroves, on average about 450 m wide, lines almost the entire coastline of southeastern Yap Proper, and is most extensive between the villages of Yinuuf and Luweech, where it penetrates 1.5 km inland. The mean tidal variation in Yap is 0.9 m.

Other types of wetland are very limited in extent. There are a few small saline marshes, generally along the coast adjacent to mangroves. Small stands of swamp forest occur in low wet areas just inland of mangroves (above tidal influence), in low areas along streams and in areas of impeded drainage. Many areas which probably once supported swamp forest have been converted into taro patches, and the remaining forests are now heavily disturbed, with about 85% of the forest containing secondary vegetation or agro-forest inclusions. There are also a number of small freshwater marshes in water-logged areas slightly above sea level landward of the mangroves and in depressions in upland areas. Other wetlands include a number of streams, most of which are intermittent, several small ponds, a small water storage reservoir near the capital, Colonia, and numerous small taro patches. Only one of the ponds, Machbaab Pond near the old airport in southern Yap, is permanent.

The climate is humid tropical with an average annual rainfall of 3,087 mm and a mean annual temperature of 27°C. A season of trade winds and drought extends from December to April. The wet season, between July and October, accounts for about half of the annual rainfall. Typhoons are especially prevalent in May-June and November.

Ecological features: The mangrove forests of Yap are more diverse than those of Chuuk, Pohnpei and Kosrae, and include three species which are not known to occur on the other islands: *Schypiphora hydrophyllacea*, *Ceriops tagal* and *Dolichandrone spathacea*. The most conspicuous species in the mangrove forests are *Rhizophora mucronata*, *R. apiculata*, *Bruguiera gymnorrhiza* and *Sonneratia alba*. *Rhizophora mucronata* is dominant along the seaward fringe, with *R. apiculata* occurring behind this fringe in areas where the forest is fairly wide. *Sonneratia alba* becomes common along channels and towards the leeward edge of the mangrove forest, while *Bruguiera gymnorrhiza* and *Xylocarpus granatum* tend to dominate along the landward edge of the mangrove. Other species which generally occur along the landward edge of the mangrove forests are *Lumnitzera littorea*, *Ceriops tagal* and *Dolichandrone spathacea*. *Nypa fruticans* is generally found in the more brackish areas, in narrow bands along the margins of channels (Falanruw *et al.*, 1987b).

Species characteristic of swamp forest adjacent to mangrove forest include *Dolichandrone spathacea*, *Heritiera littoralis*, *Pongamia pinnata*, *Cynometra ramiflora*, *Dalbergia candenatensis*, *Derris trifoliata* and *Acrostichum aureum*. A few almost pure stands of *Dolichandrone spathacea* can be found, and *Barringtonia racemosa* is common in wetter areas. In the of swamp forests along streams and in wet inland depressions, characteristic tree species include *Barringtonia racemosa*, *Hibiscus tiliaceus*, *Semecarpus* *venenosus*, *Inocarpus fagifer*, *Ficus tinctoria*, *Pandanus japensis*, *Cerbera manghas*, *Ixorea casei* and *Derris elliptica* (Falanruw *et al.*, 1987b).

The plant community of the saline marshes includes *Acrostichum aureum*, *Cyperus javanicus*, *Eleocharis geniculata*, *Fimbristylis cymosa*, *Paspalum distichum*, *Ipomoea pes-caprae*, *Excoecaria agallocha*, *Derris trifoliata* and *Clerodendron inerme* (Stemmermann & Proby, 1978). The vegetation of the freshwater marshes may consist of tall reeds, especially *Phragmites karka*, sedges, and herbaceous species such as *Ludwigia hyssopifolia*, *L. octovalvis* and *Hanguana malayana* (Falanruw *et al.*, 1987b). Most of the ponds are in open savannah and support considerable rooted vegetation, including emergent species, such as *Eleocharis ochrostachys*, *Eriocaulon sexangulare* and *Ischaemum polystachum*, and the submerged species *Blyxa* sp. *I. polystachum* dominates the stream flora in open areas and mosses are common in cascades, but rooted vegetation is very restricted (Lobban *et al.*, 1990). Lobban *et al.* (1990) collected periphyton and other visible algae from the streams and ponds, and found 12 blue-green algae, two red algae, two charophytes, seven genera of filamentous green algae and five flagellates. No endemic species were found, and it was concluded that the freshwater algal flora of the Yap Islands did not show characteristics of the biota of "oceanic" islands. These authors also summarized the physico-chemical characteristics of Yap's ponds and streams.

The four main islands of Yap have long been densely populated, and most natural terrestrial ecosystems have been extensively modified, with reduction in species diversity and degradation of forests to savanna grasslands or conversion to agro-forests.

Land tenure: Almost all of Yap's land and nearshore waters are privately owned (customary ownership).

Conservation measures taken: No conventional protected areas have been established on Yap. However, in the past, the use of land and marine resources, including mangroves, was traditionally subject to many regulations and restrictions. A complex system of ownership and rights of usage established limitations and helped to prevent over-exploitation (Yinug *et al.*, 1989). There has been some replanting of mangroves in Nimpal Embayment on the west coast of Yap Proper to protect fishing grounds from siltation caused by construction work.

Conservation measures proposed: Yap State Marine Resources Management Division is working on a Marine Resources and Coastal Management Plan incorporating traditional customs and laws (IUCN, 1991). This is likely to include recommendations for the protection of specific areas.

Land use: The four main islands are densely populated, with the 10,000 inhabitants living in over 100 villages. A subsistence lifestyle dominates; fishing is important and tourism is still a relatively minor industry. The mangrove forests are widely utilised for construction materials, wood for handicrafts, firewood and fishing, and land crabs and mangrove crabs are harvested in large numbers in some areas. In most areas, the cutting of mangrove for local building projects continues on a small scale as it has done for centuries, but in one area south of Peelaek Channel, there has been some commercial logging. Many of the freshwater swamp forests and marshes have been converted to taro fields (*Colocasia esculenta* and *Cyrtosperma chamissonis*), and in recent years, shallow ponds have also been used for the cultivation of the introduced aquatic plant *Ipomoea aquatica* (Nelson, 1989).

Disturbances and threats: Freshwater wetlands have been extensively modified for agricultural use, and some mangrove areas are threatened by uncontrolled harvesting of timber, filling to create land for houses and other development, and the dumping of rubbish and toxic materials. Some mangroves were destroyed by siltation during the construction of a new airport, but there has been some recovery since then. The construction of roads with too few drainage culverts has resulted in localised impoundment of mangroves, and the building of a solid causeway between Gagil-Tamil and Maap islands has resulted in the death of mangroves along part of the Yunearawey Passage. A small amount of commercial logging has been reported, but a proposal (with Taiwanese backing) to undertake commercial logging in the mangroves on a large scale has been rejected. At least two proposals to clear mangroves for aquaculture and a proposal to utilise mangrove wood as fuel to smoke fish have also been rejected, but a proposal to use mangrove areas as rubbish dumps is still under discussion. Oil spills and pesticides have had localised impact, although Mowbray (1988) has reported a leakage of endrin and sodium arsenite into a freshwater stream and coastal lagoon which caused a large-scale kill of fish, wildlife and domestic animals. The greatest threat to the sustainable use of mangrove forests and other natural resources in Yap is the removal of traditional limitations on their exploitation, generally as a result of new technologies, outside inputs and commercialized exploitation (Yinug *et al.*, 1989).

Hydrological and biophysical values: Mangroves serve as natural filtering and nutrient buffering systems between the islands and the adjacent fringing reefs, protecting the reefs from sedimentation and providing for a slow sustained release of nutrients. The mangrove forests afford some protection against storm damage, and may also be important in stabilising the shoreline against erosion. They play a critical role as nursery habitat for larval and juvenile fishes and thereby help to maintain the coastal fishery.

Social and cultural values: Many of Yap's inhabitants are dependent on the mangrove forests as a source of timber for house posts, wood for handicrafts and firewood, and make extensive use of the inshore fishery which these forests support.

Noteworthy fauna: The mangrove forests provide habitat for a wide variety of marine organisms as well as many birds and fruit bats. They provide shelter and feeding habitat for reef fish, the most conspicuous families being Chaetodontidae (butterfly fish), Lutjanidae (snappers), Apogonidae (cardinal fish), Acanthuridae (surgeon fish), Siganidae (rabbit fish), Pomacentridae (damsel fish), Gobidae (gobies) and Gerreidae (mojarras). Gastropods such as the periwinkle *Littorina scabra*, the cerithiid *Clypeomorus pellucida* and the muricid snails *Naquetia capucina* and *Thais aculeata* are common, as are land crabs (*Cardisoma* sp.) and mangrove crabs (*Scylla serrata*) (U.S. Army Corps of Engineers, Pacific Ocean Division, 1989b).

The pond and stream fauna includes at least 50 species of aquatic insects, eight species of decapod crustacean, and 14 species of gastropods (Nelson, 1989). The most abundant fishes in the stream environments are the eleotrids *Eleotris fuscus* and *Ophieleotris aporos*, and the freshwater eel *Anguilla marmorata*. Other stream fishes include the mudskipper *Periophthalmus vulgaris*, the flagtail perch *Kuhlia rupestris* and the spotted scat *Scatophagus argus*. The introduced tilapia *Oreochromis mossambicus*, which escaped from an aquaculture project in the 1970s, is now well established and is abundant in some of the freshwater ponds, streams and estuarine habitats (Nelson & Hopper, in Nelson, 1989).

There are only three resident species of waterbirds on Yap; the Yellow Bittern (*Ixobrychus sinensis*), Pacific Reef Heron (*Egretta sacra*) and White-browed Crake (*Porzana cinerea*). The Yellow Bittern is particularly common, occurring in a wide variety of wet habitats. Situated only 1,300 km east of Mindanao in the Philippines and only 1,250 km north of western Irian Jaya, Yap lies sufficiently close to the continental island systems of eastern Asia to serve as a staging area for significant numbers of migratory shorebirds using the East Asian/Australasian flyway. Twenty-six species of shorebirds have been recorded, and at least 12 of these are fairly common on migration and/or in winter. These are: Pacific Golden Plover (*Pluvialis fulva*), Mongolian Plover (*Charadrius mongolus*), Greenshank (*Tringa nebularia*), Wood Sandpiper (*T. glareola*), Wandering Tattler (*Heteroscelus incanus*), Grey-tailed Tattler (*H. brevipes*), Common Sandpiper (*Actitis hypoleucos*), Whimbrel (*Numenius phaeopus*), Ruddy Turnstone (*Arenaria interpres*), Sanderling (*Calidris alba*), Rufous-necked Stint (*C. ruficollis*) and Sharp-tailed Sandpiper (*C. acuminata*) (Pratt *et al.*, 1987). At least 175 shorebirds of 17 species were recorded during a brief survey of two islands in early September 1990 (D.A. Scott, unpublished). Other migratory waterbirds from eastern Asia which have been recorded on the islands include four species of herons and egrets, two ducks and the Whiskered Tern (*Chlidonias hybrida*).

The only indigenous mammal is the Marianas Fruit Bat (*Pteropus mariannus*), which frequently forages in the mangrove and swamp forests. Two endemic subspecies occur in Yap: *P. m. yapensis* on the main islands and *P. m. ulithiensis* on Ulithi atoll.

Noteworthy flora: Most of the mangrove forests are still in relatively pristine condition. Mangrove species include seven species shared with the other islands of FSM: *Rhizophora mucronata*, *R. apiculata*, *Bruguiera gymnorrhiza*, *Xylocarpus granatum*, *Lumnitzera littorea*, *Nypa fruticans* and *Sonneratia alba*, and three species of more westerly distribution: *Schypiphora hydrophyllacea*, *Ceriops tagal* and *Dolichandrone spathacea*.

Scientific research and facilities: The U.S. Forest Service has carried out a vegetation survey of

Yap in cooperation with the State Government (Falanruw *et al.*, 1987b). Detailed studies of Yap's inland aquatic habitats were carried out by a team of aquatic biologists from the University of Guam Marine Laboratory, Yap State Department of Natural Resources and the College of Micronesia in 1988. The limnological characteristics of the streams and ponds, the vegetation and the freshwater fishes, aquatic insects, decapod crustaceans and freshwater gastropods were investigated (Nelson, 1989). Lobban *et al.* (1990) have described the periphyton of Yap, excluding the diatoms and desmids.

Management authority and jurisdiction: No information.

References: Falanruw *et al.* (1987b); IUCN (1991); Lobban *et al.* (1990); MacLean *et al.* (1988); Mowbray (1988); Nelson (1989); Pratt *et al.* (1987); Stemmermann & Proby (1978); U.S. Army Corps of Engineers, Pacific Ocean Division (1988, 1989b); Yinug *et al.* (1989).

Reasons for inclusion: 1a, 1c, 2b, 2c.

Source: See references.

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FIJI

INTRODUCTION

by Alistair J. Gray

Area: 18,272 sq.km.

Population: 715,000 (1989).

Fiji is an independent island republic in the South Pacific, situated between latitudes 15° South and 21° South and straddling the 180th meridian from 177° West to 175° East. The 320 or so islands form a complex group of high islands of volcanic origin, with barrier reefs, atolls, sand cays and raised coral islands. The two largest islands, Viti Levu (10,386 sq.km) and Vanua Levu (5,535 sq.km), together comprise 87% of the total land area. Two smaller islands, Taveuni (435 sq.km) and Kadavu (408 sq.km), account for a further 4.6% of the land area, and most of the remaining islands are very small. Less than a hundred of the islands are inhabited, most of the population being concentrated in the towns, villages and lowlands of the two larger land masses. The annual population growth is 2% and the population density is 39 inhabitants per sq.km. Suva, the capital city, is located on a peninsula near the southeastern corner of Viti Levu.

Fiji has an equable maritime climate, a consequence of its high topography and prevailing winds, the Southeast Trades. The west coast of Viti Levu is in a rain shadow, and thus experiences a distinct dry season. Maxima and minima temperatures for Suva are 30°C and 20.5°C respectively. The dry season extends from May to October, and the wet season from November to April. Mean relative humidities are 80% and 75% at 0800 hrs and 1400 hrs respectively on the east coast, and about 10% lower on the west coast. Relative humidities as low as 40% can occur during the dry season.

Both Viti Levu and Vanua Levu have mountainous interiors, with peaks rising to 1,323 m and 1,032 m respectively. The uplands of both islands were formerly covered in tropical rainforest, but much of this has now been replaced with secondary forest and grassland on the lower slopes. Farm land occupies most flattish lowland, and large areas on both islands are under cultivation for sugar cane. Mangrove forest occurs widely along the coastline and at river mouths. Coral cays tend to be dominated by palms, pandanus and casuarinas.

The large number of islands, their differing geological origins, the large size of some of the islands, the varying climates and their isolation from other islands have all contributed to provide Fiji with a large number of different ecosystems and habitat types with a very rich diversity of flora and fauna. Many species are endemic. There are about 1,500 native species of vascular plants, of which 40-50% are endemic. All 26 palm species are endemic. There are 39 species of butterfly (including seven endemics), 27 species of reptiles and amphibians (including eight endemics) and about 120 species of birds (including 22 endemics) (Dahl, 1986; Pratt *et al.*, 1987). Dahl (1980 & 1986) has given a brief account of the natural ecosystems of the islands, and has reviewed their importance for nature conservation. UNEP/IUCN (1988) provide a general account of the coral reef systems and the reef resources, and also give detailed information on seven of the most important reef systems.

Summary of Wetland Situation

The wetlands of Fiji can be broadly divided into five main categories: mangrove forests, peat bogs, rivers, lakes and reservoirs.

Mangroves

The largest stands of mangroves are found in deltaic formations at the mouths of the larger rivers, notably the Ba, Rewa and Nadi Rivers on Viti Levu and the Labasa River on Vanua Levu. Climatic conditions are important. In dry leeward areas (western shores), hypersaline mudflats characteristically occur in the mangrove areas, while these are virtually absent from the wetter, windward mangrove areas (eastern shores). It has recently been estimated that of an original 41,000 ha of mangrove forest, 38,543 ha remain, the other 2,457 ha (6%) having been reclaimed for other uses (Watling, 1985). All but about 2,000 ha of the remaining mangrove are on the two large islands of Viti Levu and Vanua Levu, with the Rewa, Ba and Labasa deltas alone supporting a combined total of 10,683 ha, or 28% of the national resource.

Only a small fraction of the mangrove forest is affected by non-sustainable exploitation, principally uncontrolled gathering of fuelwood. Consequently, the majority of the mangrove can be considered to be still in a natural condition. The total area of mangrove actively managed for fuelwood production is less than 50 ha.

The Fijian mangrove vegetation is floristically simple. Three species and a putative hybrid of the family Rhizophoraceae overwhelmingly dominate the vegetation. These are: *Bruguiera gymnorrhiza*, *Rhizophora stylosa*, *R. samoensis* and *R.* x *selala*. Less common species include: *Xylocarpus granatum*, *X. moluccensis*, *Lumnitzera littorea*, *Excoecaria agallocha* and *Heritiera littoralis*. The broad zonation consists of a seaward fringe of *R. stylosa*; *R.* x *selala*, or occasionally *R. samoensis*, is found along the river margins, and a mixed forest of *B. gymnorrhiza*, *X. granatum* and *Lumnitzera littorea* (with *R. samoensis* and *E. agallocha* in the Ba Delta) grows on the higher ground on the landward edge (Woodroffe, 1987). *R. stylosa* is dominant in all exposed locations and is particularly associated with sandy or coarse substrates, while *R. samoensis* is most frequently encountered bordering the depositional side of rivers and creeks over soft fine-grained substrates. Fiji's mangrove swamps have developed in their present form since the last glacial period, with the transgression of sea level to its present level.

Formerly mangroves were of major importance as a source of fuelwood. In 1952, over 50,000 cubic metres of mangrove wood were harvested and processed by the Forestry Department. However, with the increased availability of fuel oil, the demand for mangroves dropped to less than 5,000 cubic metres per year after 1967, and is now negligible. A limited amount of mangrove is used for poles and charcoal.

By far the greatest loss of mangroves in Fiji has been caused by reclamation for agriculture, *e.g.* in the Labasa River delta. However, about 300 ha of mangroves have been converted for aquaculture of penaeid prawns, and in recent years the principal threat has been reclamation of mangroves for urbanisation and industrial development. There is also some over-exploitation of mangroves to satisfy the demands for fuelwood, but this is localized.

Mangroves play an important role in Fiji's sewerage treatment programme, with most sewage disposal sites being associated with mangroves. Mangroves also provide breeding and nursery grounds for a wide variety of economically important fish and crustaceans. It has been estimated that more than 60% of Fiji's commercially important food fishes utilize the mangrove resource at some stage of their life history. In 1983, the value of Fiji's mangrove forests to the fisheries industry was estimated at over Fiji$ 20 million.

Peat swamps

Freshwater wetlands occupy only 0.3% of Fiji's land area. Much the most extensive freshwater wetlands are peat swamps which occur widely on the two main islands. The largest peat swamp is Bonatoa (870 ha) on Viti Levu, which provides a good example of zoned vegetation. Reclamation of swamp land has taken place on a large scale, and few freshwater wetlands now survive undisturbed. Tonuve Swamp (the only site in Fiji with Navosa reed peat) has been totally reclaimed for agriculture, while many others have suffered a smaller percentage loss to development. Much of the original swamp on Vanua Levu is likely to have been reclaimed, but information on precise areas is unavailable.

The vegetation of the peat bogs typically consists of a continuous cover of sedges (*Scleria polycarpa*) up to 1.5 metres high with sphagnum moss (*Sphagnum cuspidatum*) in wetter areas and scrambling ferns (*Dicranopteris linearis*) in drier areas. Pandanus (*Pandanus pyriformis*) is often present and generally forms small clumps. A few dicotyledonous shrubs such as *Barringtonia aquatica* occur in association with the pandanus. On colluvium peat, the vegetation is transitional and often zoned. Sphagnum moss ceases to occur, but dense stands of the grass *Brachiara mutica* (up to 2 metres high) and various herbs and woody shrubs occur. This zone passes to medium-sized trees (5-15 metres high) and then to forest on higher ground.

On gley soils, the vegetation varies greatly according to the extent of human interference. Patches of forest are interspersed with areas of pasture land, cultivated land, abandoned cultivation and secondary scrub. Pure stands of *Metroxylon vitiense* (sago palm) are found on wet gley soils at Vunimoli on Viti Levu. Freshwater marsh typically comprises a sedge/fern community with *Athyrium* sp. On brackish soils, this is replaced by a mixed community of *Pandanus*, the fern *Acrostichum aureum* and woody shrubs and trees. The woody community passes either into a mangrove forest in coastal areas or into a taller band of trees alongside brackish creeks. Permanently flooded habitats include abandoned river channels, streams and ditches which support a relatively restricted aquatic flora of mainly floating species, such as *Lemna perpusilla*, *Nymphaea capensis* and *Spinodela punctata*, and submerged aquatics such as *Hydrilla*, *Potamogeton* and *Ceratophyllum*.

Rivers

The larger islands are well-watered, with many permanent rivers and streams. However, only Viti Levu has rivers of any considerable size. Over 70% of this island is drained by three large river systems, the Rewa, Navua and Sigatoka, which enter the sea along the south coast. The catchment area of the largest of these, the Rewa, covers nearly one third of the island. Fiji's two most economically important rivers, the Ba and the Nadi, have a combined catchment of only 15% of Viti Levu, all of which is in the dry zone. The rivers of Vanua Levu are short with only the Dreketi River being of any considerable size (55 km long). Riverine forest occurs along the lower reaches of some of the larger rivers, and is sometimes characterized by distinctive species such as the endemic palm *Neoveitchia storckii*.

Lakes

There are few freshwater lakes in Fiji, and those that do exist are small and generally limited to mountainous regions. The largest, Lake Tagimaucia on Taveuni Island, is only 213 ha in area. The only significant brackish and saline lakes are Ngalongalo Lake, Ngasauva Salt Lagoon and Lake Ndrano on Vanua Levu, and a small marine lake on Vuaqava (Vuanggava) Island in the Lau Group.

Reservoirs

Two major dams have been constructed in Fiji, both on Viti Levu. The smaller Vaturu Dam (160 ha) provides water to the dry western division of Viti Levu, and the larger Monosavu Dam (670 ha) provides hydro-electricity. A smaller dam (80 ha) has recently been built at the Wainikavika Creek near Navua to provide water for rice irrigation.

At present, the protected areas system in Fiji comprises 18 forest reserves, seven nature reserves (established within the forest reserves) and a number of forest parks and amenity reserves. There is only one National Park, established in 1988 to protect the Sigatoka sand dunes, and one Wildlife Sanctuary, established in 1981 to protect a large population of the endemic Crested Iguana (*Brachylophus vitiensis*) on Yadua Taba Island (Anon., 1989; IUCN, 1991a). None of these protected areas contains any significant wetland habitat. However, two proposed reserves currently under consideration by the Government contain wetlands: Vaturu Forest Amenity Reserve (Vaturu Dam) and Taveuni National Park (Lake Tagimaucia). Of the many other areas which have been proposed for establishment as protected areas, the following include significant wetlands:

- Swamps in the Navua Delta, Viti Levu
- Samabula River and mangroves, Viti Levu
- Naulu-Lokia Swamps, Viti Levu
- Upper Wainimala River, Viti Levu
- Wainibuka River, Viti Levu
- Riverine forest at Waindrandra Agricultural Station, Viti Levu
- Ngalongalo Salt Lake, Vanua Levu
- Naisongothauthau Creek, Vanua Levu
- Brackish pools on Vatulele Island
- Swamp forest and bog on Moturiki Island
- Marine lake on Vuaqava Island

While the fauna of Fiji's mangroves is now well known, that of the freshwater wetlands has received very little attention. Mangrove fauna has been documented by Macnae (1968), Richmond and Ackerman (1975), Lal *et al.* (1983), Lal (1984a, 1984b), Fiji Mangrove Management Committee (1987) and others. Ryan (1980, 1984) has described the brackish and freshwater fish and the amphibians of Fiji, while Southern *et al.* (1986) have described the fauna of Lake Tagimaucia on Taveuni.

Rather few species of birds are dependent on the wetlands of Fiji. Undoubtedly the most interesting of these is the Barred-wing Rail (*Nesoclopeus poecilopterus*), a large flightless rail known only from Fiji (although a closely related form, *N. woodfordi*, occurs in the Solomon Islands). Until recently, the Barred-wing Rail was known only from about 12 specimens taken last century on Viti Levu and Ovalau. However, the species was apparently rediscovered in 1973 on the Nadrau Plateau on Viti Levu (Holyoak, 1979). The rail is believed to inhabit damp forest, swamps and thick taro gardens. The introduction of the mongoose is undoubtedly an important factor in the rail's decline (Hay, 1985). The other four species of Rallidae in Fiji, the Banded Rail (*Rallus philippensis*), White-browed Crake (*Porzana cinerea*), Spotless Crake (*P. tabuensis*) and Purple Swamphen (*Porphyrio porphyrio*), are also threatened by predation from mongooses and feral cats. Two of these, the Banded Rail and Purple Swamphen, have become extinct on Viti Levu and Vanua Levu, although they remain common on some of the outer islands which are mongoose-free. The Pacific Black Duck (*Anas superciliosa*) remains fairly common and widespread in the islands, but the Wandering Tree Duck (*Dendrocygna arcuata*), which was possibly a resident in the 19th century, is now extinct. Other resident waterbirds include the widespread Pacific Reef Heron (*Egretta sacra*) and the Little Heron (*Butorides striatus*); the latter is more or less confined to mangroves (Watling and Talbot-Kelly, 1987).

Seven species of migratory shorebirds occur regularly on passage or during the boreal winter: Pacific Golden Plover (*Pluvialis fulva*), Wandering Tattler (*Heteroscelus incanus*), Grey-tailed Tattler (*H.*

brevipes), Whimbrel (*Numenius phaeopus*), Bristle-thighed Curlew (*N. tahitiensis*), Bar-tailed Godwit (*Limosa lapponica*) and Ruddy Turnstone (*Arenaria interpres*). A further nine species of shorebirds have occurred as rare stragglers (Pratt *et al.*, 1987).

Wetland Research

Relatively little research has been carried out on wetlands in Fiji. By far the most attention has been given to the mangrove ecosystems, although studies on mangroves have been piecemeal and uncoordinated. Work on the mangroves has been summarized by Nedwell (1974), Vodonaivalu (1982), Lal *et al.* (1983) and the Fiji Mangrove Management Committee (1987). Pillai (1987) has reviewed the traditional uses of mangroves in Fiji. Ash and Ash (1984) have conducted the only extensive study of freshwater wetlands in Fiji, but this was restricted to Viti Levu. Elsewhere, only Lake Tagimaucia on Taveuni Island has been well documented (Southern *et al.*, 1986). Very little information is available on the wetlands of Vanua Levu, as few ecological surveys have been undertaken on this island, and almost nothing is known about the wetlands of the outer islands.

The Institute of Marine Resources at the University of the South Pacific has two on-going programmes relevant to wetlands: (i) a study of the community structure and functional relationships between organisms and non-biotic factors; and (ii) a study of the fisheries of mangrove-related habitats. The Institute of Natural Resources at the University of the South Pacific is monitoring water quality at Monosavu Dam. This is mainly concerned with chemical analysis of the water for the Fiji Electricity Authority.

Wetland Area Legislation

There is a severe lack of environmental protection legislation in Fiji and no policy relating specifically to wetland protection. At present, only the mining industry is required by law to carry out comprehensive environmental impact assessments before new developments are started. There is little protective legislation concerning mangroves. The Government recognises that the land between the mean high water mark and the low water mark is Crown Land. In 1933, all mangroves were designated as Reserved Forest to be managed by the Forestry Department. However, in 1975 these Reserved Forests were de-notified, and all mangroves were placed under the jurisdiction of the Department of Lands and Survey as an integral part of the foreshore.

The environmental objectives of Fiji's Development Plan Nine (1986-90) were to protect and conserve unique features of Fiji's environment, and to ensure that environmental assessments are incorporated into programmes and projects. In this Development Plan, the National Trust for Fiji was given responsibility for implementing the country's National Parks and Reserves Plan. It was envisaged that during the implementation of this Plan, certain mangrove areas would be declared as National Parks or other types of reserve.

An inter-ministerial National Mangrove Management Committee was established by the Department of Lands and Survey in 1983 and produced a National Mangrove Management Plan (Phases I and II) in 1986. This plan is a comprehensive framework intended to assist decision-makers in Government, but unfortunately it still has no legal status.

At international level, Fiji has ratified the Convention on the Conservation of Nature in the South Pacific (Apia Convention) and the Convention for the Protection of the Natural Resources and Environment of the South Pacific (SPREP Convention), and has signed but not yet ratified the Convention on Biological Diversity. A Cabinet decision to accede to the World Heritage

Convention has been taken (IUCN, 1991a). However, Fiji is not yet a part to either the UNESCO Man and the Biosphere Programme or the Ramsar Convention.

Wetland Area Administration

The only wetlands in Fiji which are under direct management are the reservoirs, which are controlled by the Fiji Electricity Authority and Water Department. Large portions of the catchments of these reservoirs are in native land, and are thus under no conservation obligation. There are no wetlands where there is "restricted access" specifically for conservation purposes.

Organizations involved with Wetlands

There is no single body concerned specifically with wetland protection or management in Fiji. There are, however, a number of organizations and government departments who indirectly have a responsibility to ensure the preservation of the environment in general. Most are members of the National Environmental Management Committee which includes representatives of the following:

- Ministry of Primary Industries (land use, drainage, irrigation and fisheries)
- Ministry of Forestry
- Ministry of Lands and Mineral Resources
- Ministry of Health
- Native Land Trust Board (NLTB)
- University of the South Pacific
- Bureau of Meteorology
- National Trust for Fiji
- National Museum

An Environmental Management Unit was created in 1982, but this did not become fully operational until 1989. The role of the Environmental Management Unit is to develop a national environmental policy, to co-ordinate environmental impact assessments, and to develop environmental awareness programmes.

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WETLANDS

Site descriptions based on a report prepared by Alistair J. Gray of the National Trust for Fiji, information provided by Birandra Singh, also of the National Trust for Fiji, and the literature.

Mangroves of the Rewa Delta (1)

Location: 17°58'-18°10'S, 178°30'-178°43'E; at the southeast corner of Viti Levu, east of Suva.
Area: 5,130 ha.

Altitude: Sea level.
Overview: A large area of rich and diverse mangrove forest in the delta of the Rewa River.
Physical features: The Rewa River is the largest river in Fiji, draining approximately 2,980 sq.km or about one third of Viti Levu and discharging an estimated 7,897 million cubic metres of water per year. It has been estimated that about 1,600 tonnes of suspended sediment are transported to the mouth of the river each year. This alluvium has formed Fiji's most fertile and productive delta with over 5,100 ha of mangrove forest. The mangrove communities are the most diverse in Fiji. The high, regular rainfall prevents the formation of bare, hypersaline mudflats which are a feature of mangrove formations on dry, leeward coasts. Situated on the windward side of Viti Levu, the delta is exposed to the full force of the Southeast Trades, and as a consequence much of the mangrove is in backwater locations. The mean tidal range is about 0.9 m during neap tides and 1.3 m during spring tides. The delta has a Wet Eastern climate with a dry season rainfall of 1,200-1,600 mm and a wet season rainfall of 2,000-2,400 mm.
Ecological features: Watling (1985) recognizes six main vegetation zones.

(1) A mixed fringing forest, found predominantly on the more exposed seaward banks but extending up some of the larger creeks (4.9% of the total area). Somewhat stunted *Rhizophora stylosa* often forms a single belt on the seaward edge with taller trees abruptly behind mixed with *Rhizophora* x *selala*, *Bruguiera gymnorrhiza* and *Rhizophora samoensis*. Levees in these situations support in addition *Xylocarpus granatum* and *Excoecaria agallocha* as well as other landward species such as *Cocos nucifera*.

(2) An extensive formation in the northern part of the delta consisting of shrub forest dominated by *Rhizophora samoensis* (14.5% of the total area). Stunted *B. gymnorrhiza*, *X. granatum* and *R. stylosa* are commonly present.

(3) A uniform closed forest of *B. gymnorrhiza*, with well-developed stands exceeding 18 m in height (35.6% of the total area). Within the forest, occasional *R.* x *selala* occur with *X. granatum* and *Lumnitzera littorea*.

(4) A heterogenous open forest of variable and mixed composition with an uneven canopy (29.1% of the total area). *B. gymnorrhiza* and *R.* x *selala* are the dominant species, sometimes forming small discrete stands. *R. samoensis* occurs commonly and also forms limited pure stands, occasionally stunted. The presence of *X. granatum*, *L. littorea*, *E. agallocha* and landward vegetation varies greatly with location.

(5) A heterogenous closed forest of mixed composition, found only in the least exposed situations (12.6% of the total area). The most common tree species are *X. granatum*, *B. gymnorrhiza* and *E. agallocha*. *R. samoensis* and *R.* x *selala* occur more rarely and on creek banks. Other common trees include *Terminalia littoralis*, *Heritiera littoralis*, *Inocarpus fragiferus*, *Ficus obliqua*, *Hibiscus tiliaceus*, *Pandanus pyroformis* and *Cocos nucifera*. The presence of an extensive epiphytic and climbing flora indicates that this community is stable, well drained and well protected from storm damage.

(6) Large areas of poorly drained flats supporting a dense growth of the fern *Acrostichum aureum* (3.6 % of the total area).

Land tenure: State (Crown Land).
Conservation measures taken: All mangroves in Fiji were designated as Reserved Forests and managed by the Forest Department from 1933 to 1975. These Reserved Forests were denotified in 1975, and the mangroves have since been under the jurisdiction of the Department of Lands and Survey as an integral part of the foreshore. There are some restrictions on cutting, but traditional exploitation is still permitted.
Conservation measures proposed: Watling (1985) has made some recommendations for management.
Land use: The mangrove flora and fauna provide a variety of products and services to the local people including: firewood, construction material, household items, fishing devices, dyes, clothing, fish poison, food and medicine (Pillai, 1987). Seventy-two of 87 fish species caught in the mangroves are considered edible, as well as several species of molluscs and crustaceans. Formerly the Rewa Delta was an important source of mangrove for industrial and domestic fuelwood. In

1945, the "Suva area" produced 20,089 tons of fuelwood, most of this presumably coming from the Rewa Delta. In recent years, approximately 5,000 cubic metres of fuelwood have been extracted annually for domestic needs (Watling, 1985).
Possible changes in land use: The high population density and anticipated community development in the Rewa Delta will increase pressure on the mangroves, with traditional uses evolving into non-sustainable activities (Watling, 1985).
Disturbances and threats: The major long-term threat to the mangrove forests is reclamation for agriculture. A reclamation project in the early 1980s resulted in the loss of over 200 ha of mangroves in the Waidamu River area (Lal, 1984b). The construction of new sea walls in recent years has also resulted in the loss of some mangrove. Illegal felling of timber is a serious problem locally, and may become more widespread as access to the area is improved.
Hydrological and biophysical values: The delta supports an important artisanal fishery which supplies not only the delta communities but much of the needs of greater Suva.
Social and cultural values: In pre-European contact times, the Rewa Delta is believed to have supported one of the densest human populations in the Pacific. The population has declined since then, but in 1976 there were still nearly 5,000 Fijians living in over 100 village communities dispersed through the delta. This is by far the largest community closely associated with mangroves in Fiji.
Noteworthy fauna: No information.
Noteworthy flora: The mangrove forests of the Rewa Delta are floristically the most diverse mangrove communities in Fiji.
Management authority and jurisdiction: Department of Lands and Survey.
References: Lal (1984b); Pillai (1987); Watling (1985).
Reasons for inclusion: 1a, 2b, 2c.
Source: Birandra Singh and references.

Bonatoa Swamp (2)

Location: 18°04'S, 178°33'E; in the Rewa Delta, approximately 4 km south of Nausori, Viti Levu.
Area: 870 ha.
Altitude: Sea level.
Overview: A peat swamp.
Physical features: Bonatoa Swamp is the largest peat swamp in Fiji and provides a good example of zoned vegetation due to soil differences. The wetland is bordered by low hills and the levees of the Rewa and its anabranch in the west, by the Toga River to the north and east, and by beach ridges to the south. The soils are well-drained sandy loams, poorly drained gley clay loams and peat. The region has a Wet Eastern climate with a dry season rainfall of 1,200-1,600 mm and a wet season rainfall of 2,000-2,400 mm.
Ecological features: Where the peat is more than one metre deep, *Pandanus pyriformis*, ferns and patches of *Sphagnum cuspidatum* are common. The inner colluvium peat zone is herbaceous with sedges, grasses and dicotyledonous herbs. This passes abruptly into a zone of trees, shrubs and grasses.
Land tenure: Native land.
Conservation measures taken: None.
Land use: Grazing by domestic livestock.
Disturbances and threats: Approximately 11% of the swamp has been drained for agriculture. The swamp vegetation is occasionally burned to improve the grazing for domestic livestock.
Hydrological and biophysical values: No information.
Social and cultural values: There are several interesting examples of ring ditch fortifications on raised areas around the swamp, and one site, Nakasi, on an island within the limits of the swamp

(Parry, 1977).
Noteworthy fauna: Unknown.
Noteworthy flora: Unknown.
Management authority and jurisdiction: Customary owners. The National Trust for Fiji is involved in the management of the site as an area of outstanding natural beauty and cultural significance.
References: Ash & Ash (1984); Parry (1977).
Reasons for inclusion: 1a. An area of outstanding natural beauty and cultural significance.
Source: Alistair J. Gray.

Melimeli Swamp (3)

Location: 18°12'S, 178°11'E; on the eastern margins of the Navua Delta, 3 km northeast of Navua, Viti Levu.
Area: 507 ha.
Altitude: Sea level.
Overview: A peat swamp.
Physical features: A large area of peat swamp bounded by hills to the northwest, by coastal and estuarine mangroves to the east, and by levees of a former distributary of the Navua River to the southeast. The wetland soils and those beneath the peat are fine textured alluvium to the north and west and coarser coastal deposits to the southeast. Brackish salt water extends 50-150 metres inland from the mangroves and there is a gradual transition from freshwater to saline wetlands. The peat has a maximum depth of two metres deep in the inland section of the swamp and becomes shallower towards the margins. Parts of the abandoned distributary channel to the west of the swamp contain peat and standing water.
The region has a Moist Coastal climate with a dry season rainfall of 1,200-1,600 mm and a wet season rainfall of 2,000-2,400 mm.
Ecological features: The vegetation is extremely varied. On the peat, the most abundant species are the fern *Dicranopteris linearis* and the sedges *Scleria polycarpa* and *Eleocharis dulcis*. There are extensive patches of *Pandanus pyriformis* on the deeper peat and occasional small trees and shrubs such as *Fagraea berteriana*, *Glochidion cordatum*, *Psidium guajava* and *Melastoma denticulatum*. The transition from the peat to the saline gley soils is zoned with the following sequence of species: *Eleocharis dulcis* and *E. ochrostachys* - *Nephrolepis biserrata* - *Sphaerostephanos unitus* - *Acrostichum aureum* - *Pandanus pyriformis* and *P. whitmeanus* - *Lumnitzera littorea*, *Bruguiera gymnorrhiza* - *Rhizophora samoensis*. Where the peat is bounded by brackish streams, there is a zone of shrubs and trees including *Annona glabra*, *Barringtonia racemosa*, *Fagraca berteriana*, *Glochidion cordatum* and *Hibiscus tiliaceus*. The wet gley pastures and abandoned cultivation are usually dominated by *Rhynchospora corymbosa*, whereas slightly better drained areas support a variety of dominants including *Fimbristylis dichotoma*. A few patches of shrubs and trees remain, and these have the typical woody flora of wet gley soils with abundant *Hibiscus tiliaceus*, *Annona glabra* and *Barringtonia racemosa*.
Land tenure: Freehold land (Ross Estate).
Conservation measures taken: None.
Conservation measures proposed: Peat swamps in the Navua Delta have been identified as sites of conservation interest meriting special protection (Dahl, 1980 & 1968; TCSP, 1990).
Land use: The alluvial soils are now mostly drained, and are used as pastures or for cultivation of rice, taro and maize.
Disturbances and threats: The principal threat is reclamation for agriculture. An estimated 12% of the swamp has already been drained.
Hydrological and biophysical values: No information.
Social and cultural values: There are areas of abandoned reticulated drainage gardens and ring

ditch fortifications on the wet gley soils southwest of the peat swamp, and also several ring ditch fortifications near the Vatuloa River.
Noteworthy fauna: No information.
Noteworthy flora: No information.
Management authority and jurisdiction: No information.
References: Ash & Ash (1984); Dahl (1980, 1986); TCSP (1990).
Reasons for inclusion: 1a, 2b.
Source: Alistair J. Gray.

Vunimoli Swamp (4)

Location: 18°14'S, 178°05'E; in the delta of the Navua River, about 6 km west of Navua, Viti Levu.
Area: 461 ha.
Altitude: 100 m.
Overview: A peat swamp.
Physical features: A large area of peat swamp and swamp forest on fine-textured alluvium brought down by the Qaraniqio River, and on sandy coastal deposits from the Navua Delta to the east. The river and its eastern tributaries have been diverted westwards along the inner margin of the coastal plain, and this forms the northern boundary of the swamp. Most of the wetland comprises peat bog, with peat depths of up to two metres.
The region has a Moist Coastal climate with a dry season rainfall of 1,200-1,600 mm and a wet season rainfall of 1,800-2,200 mm.
Ecological features: The wet gley soils of the colluvium and the alluvium in the valleys upstream of the coastal plain support nearly pure stands of *Metroxylon vitiense* (sago palm). This also occurs on adjacent hill sides in association with a variety of trees. This is the only extensive swamp forest (262 ha) in Fiji, and includes most of the *Metroxylon* population. The least disturbed eastern part of the swamp supports a typical peat swamp flora of ferns, sedges, *Sphagnum* mosses and *Pandanus*. A waterlogged, peat-filled channel supports a flora of *Eleocharis ochrostachys, E. dulcis* and *Lepironia articulata* in submerged areas, and *Sphagnum* hummocks colonized by ferns and bryophytes on the better drained patches of peat.
Land tenure: Native land.
Conservation measures taken: None.
Conservation measures proposed: Peat swamps in the Navua Delta have been identified as sites of conservation interest meriting special protection (Dahl, 1980 & 1968; TCSP, 1990).
Land use: The peat swamp is scarcely utilised.
Disturbances and threats: The principal threat is drainage for agriculture and residential development. An estimated 60% of the swamp has already been drained. The western part of the peat swamp (270 ha) has been developed as a resort and housing complex. Southeastern parts have been partially drained, and ferns and grasses are more abundant in these areas. The swamp vegetation is occasionally burned, and this apparently destroys the *Sphagnum* and favours sedges, grasses and *Pandanus* rather than ferns *e.g. Dicranopteris linearis*.
Hydrological and biophysical values: No information.
Social and cultural values: There are a few ring ditch fortifications along the southern margins of the swamp, including one site within a raised area of the bog, but this region seems to have been less intensively settled than the central part of the delta around the Navua and Deuba river levees.
Noteworthy fauna: No information.
Noteworthy flora: No information.
Management authority and jurisdiction: No information.
References: Ash & Ash (1984); Dahl (1980, 1986); TCSP (1990).

Reasons for inclusion: 1a, 2b.
Source: Alistair J. Gray.

Mangroves of Nadi Bay (5)

Location: 17°31'-17°41'S, 177°20'-177°29'E; between Yako and Nacilau Point on the west coast of Viti Levu.
Area: Formerly 3,614 ha; 3,068 ha in 1986.
Altitude: Sea level.
Overview: Extensive mangrove formations in the deltas of the Nadi, Sabeto and Vitogos rivers, and stands of fringing mangroves along the intervening coasts.
Physical features: The Nadi Bay mangroves, as described by Watling (1986), extend for about 70 km along the coast from the headland north of Yako village in the south to Nacilau Point in the north. The small offshore islands of Yakuilau (20 ha), Via (2 ha), Bekana (20 ha) and Yawalau (2 ha) are included. Three substantial rivers flow into the sea at the site, the Nadi, Sabeto and Vitogo. The protected situation of the coastline has resulted in the retention of alluvial sediments allowing the formation of extensive mangrove-dominated deltas at the mouths of all three rivers and the formation of extensive fringing mangroves, especially along the coast between Vuda Point and Lautoka. Hypersaline flats are a characteristic feature of the site; they are formed as a consequence of the very high evaporation rates during the severe dry season. The hinterland is an extensive alluvial plain.
The site lies in Viti Levu's dry climatic zone and experiences strongly seasonal annual rainfall averaging 1,650 mm. Situated in a protected bay on Viti Levu's leeward coast, the site is sheltered from the Southeast Trades. However, it is exposed to cyclones which normally arrive from the northwest.
Ecological features: Two principal mangrove communities have been identified: a closed shrub forest overwhelmingly dominated by *Rhizophora stylosa* (29% of the mangroves), and an open forest dominated by the hybrid *Rhizophora* x *selala* (71% of the mangroves). In the closed shrub forest, the canopy height varies from 2-4 m at the seaward edge to 5-7 m in the most vigorous stands. In poorly drained areas, stunted stands of *R. stylosa* down to 1 m in height occur alongside hypersaline mudflats. *Rhizophora samoensis* is associated with fine, soft sediments and fresh water, and is dominant along some creeks. In the open forest dominated by *R.* x *selala*, the canopy is uneven, varying between 4 m and 12 m. *R. samoensis* occurs commonly in these forests, and there is also some *Bruguiera gymnorrhiza*. In the more elevated areas, species such as *Xylocarpus granatum*, *Excoecaria agallocha*, *Scaevola taccada* and *Hibiscus tiliaceus* appear. In the Nadi and Sabeto deltas, extensive levees have been formed. Some of these are of considerable size and have been cultivated; others have a typically terrestrial flora with *Cocos nucifera*, *Leucaena leucocephala*, *Morinda citrifolia*, *Tamarindus indica*, *Cordia subcordata*, *Thespesia populnea*, *Calophyllum inophyllum*, *Samanea saman* and *Xylocarpus moluccensis* (Watling, 1986).
Land tenure: State (Crown Land).
Conservation measures taken: All mangroves in Fiji were designated as Reserved Forests and managed by the Forest Department from 1933 to 1975. These Reserved Forests were denotified in 1975, and the mangroves have since been under the jurisdiction of the Department of Lands and Survey as an integral part of the foreshore. There are some restrictions on cutting, but traditional exploitation is still permitted.
Conservation measures proposed: Watling (1986) has prepared a management plan for the mangroves of Nadi Bay. He recommends that the mangroves north of the Waibitu Creek and in the Vitogo mangrove complex be protected as a Resource Reserve to help sustain the fisheries of Nadi Bay. The mangrove overwash island of Yawalevu should also be included in the reserve. Elsewhere, the majority of the mangroves should be zoned for traditional uses. Small areas of

mangrove which help to protect the FSC railway line in exposed situations should be retained and managed for this purpose. Watling (1986) does not consider the mangroves of this area to be suitable for the large-scale production of fuelwood.
Land use: Formerly the mangroves were used for fuelwood by light industry and bakeries in Nadi and Lautoka, and especially by the Cane Crushing Mill at Lautoka. This practice declined in the 1950s, and today there are no mangrove fuelwood concessions for industrial purposes. However, the mangroves continue to be heavily utilised for domestic fuelwood. Between 1983 and 1986, 23 Mangrove Cutting Licenses were issued by the Divisional Forestry Office Western for domestic fuelwood. All licensed sites were in remnant mangroves behind recently rehabilitated sea walls (Watling, 1986). The mangroves of Nadi Bay border on a dense rural population of small-holder cane farmers and lie in close proximity to two major urban centres; Lautoka City (population 29,000) in the north, and Nadi/Nadi Airport (population 13,000) in the south.
Possible changes in land use: Further areas of mangrove are likely to be cleared for tourist and industrial development. Watling (1986) has identified several small development zones.
Disturbances and threats: The major threats are land-fill for industrial and tourist development, and reclamation for agriculture. There is also some illegal cutting of timber. In some areas the demand for fuelwood is exceeding the sustainable yield, and mangroves are being completely removed. At the turn of the century, the Colonial Sugar Refining Company constructed sea walls at several places in the bay, but most extensively north of Lautoka on the Lovu-Drasa-Vitogo flats. Some mangrove was lost (perhaps as much as 100 ha), but the sea walls eventually fell into disrepair and mangrove recolonized the original areas. Between 1976 and 1983, the old sea walls were rehabilitated and some new sea walls were constructed. This resulted in the loss of 233 ha of mangroves. A further 366 ha of mangrove had been lost by 1986 as a result of other reclamation projects: 234 ha for four tourist developments, 109 ha for three industrial developments, 10 ha for an urban sewerage system, 6 ha for a rubbish dump, 4 ha for urban development and 3 ha for agriculture (Watling, 1986). By 1986, reclamation (either developed or approved) had accounted for approximately 600 ha of mangroves or about 15% of the original resource. According to Lal (1984b), nine reclamation projects involving 813 ha of mangroves were approved between 1980 and 1984. Most were for agricultural purposes, although the largest (493 ha) was for tourist development and fiscal industries at Sawena Beach.
Hydrological and biophysical values: The mangroves help sustain the inshore fisheries of Nadi Bay which is very intensively fished. They also play an important role in coastal protection, particularly by dampening the effects of cyclones and storm surges.
Social and cultural values: No information is available specifically for this site.
Noteworthy fauna: No information.
Noteworthy flora: No information.
Recreation and tourism: Nadi Bay is an important focus of the tourist industry.
Management authority and jurisdiction: The coastline from the north of Lautoka to the south of Vuda Point lies within the Port of Lautoka-Vuda and is under the jurisdiction of the Ports Authority of Fiji. Mangroves elsewhere are under the jurisdiction of the Department of Lands and Survey.
References: Gangaiya *et al.* (1988); Lal (1984b); Watling (1986).
Reasons for inclusion: 1a, 1c, 2c.
Source: See references.

Mangroves of the Ba Delta (6)

Location: 17°26'-17°31'S, 177°35'-177°45'E; in the delta of the Ba River near Ba, on the northwest coast of Viti Levu.
Area: 3,995 ha including 3,714 ha of mangroves and 281 ha of mudflats.

Altitude: Sea level.
Overview: A large area of deltaic mangrove forest and hypersaline mudflats in the delta of the Ba River.
Physical features: The delta of the Ba River contains the largest contiguous stand of mangroves in Fiji. The more elevated and less well-drained portions of the delta are hypersaline because of the high evaporation rates and low rainfall. These areas are either bare mudflats or covered in stunted mangrove forest. The water catchment of the Ba River is approximately 940 sq.km or about 10% of the area of Viti Levu, all of it in the dry, leeward zone. The total volume of water discharged is estimated at 1,636 million cubic metres per year.
The delta receives an average annual rainfall of 1,905 mm and experiences a pronounced dry season.
Ecological features: Watling (1985) recognizes two main mangrove communities; one dominated by *Rhizophora stylosa* and *R. samoensis* (62% of the total), and the other dominated by the hybrid *Rhizophora* x *selala* (31% of the total). In the first community, *R. stylosa* forms an almost pure closed shrub forest on the extensive less well-drained flats behind the banks of the rivers and creeks. The least well-drained areas, often surrounding or adjacent to hypersaline mudflats, are stunted with a canopy height of less than 2 m. Elsewhere, the canopy height increases to 5 m. In some localities, *R. stylosa* is mixed with and occasionally replaced by *R. samoensis*, while in other localities, *R.* x *selala* appears and can dominate. Along or near the main river bank in upstream locations, *R. samoensis* dominates, occasionally forming pure stands with a canopy height of 5-7 m, but more frequently occurring in mixed open forest with some *R. stylosa* and *R.* x *selala*. Landward species such as *Excoecaria agallocha* and *Heritiera littoralis* appear as the mangrove merges into terrestrial forest dominated by the Rain Tree *Samanea saman* on poorly drained soils. The second community comprises an open forest dominated by the *selala* hybrid. This is found to varying extents along almost all banks of rivers and streams and on associated levees. *Bruguiera gymnorrhiza* and *Xylocarpus granatum* occur infrequently with either *R. stylosa* or *R. samoensis*. The canopy is very uneven and varies between 6 and 12 m in height.
Land tenure: State (Crown Land).
Conservation measures taken: All mangroves in Fiji were designated as Reserved Forests and managed by the Forest Department from 1933 to 1975. These Reserved Forests were denotified in 1975, and the mangroves have since been under the jurisdiction of the Department of Lands and Survey as an integral part of the foreshore. There are some restrictions on cutting, but traditional exploitation is still permitted.
Conservation measures proposed: Watling (1985) makes some recommendations for management.
Land use: The principal activity in the delta is fishing. The customary fishing rights for the entire delta are held by the residents of Votua village. Inhabitants of other villages in the area make extensive use of a variety of forest products. There is, however, no legal commercial wood production in the delta (Watling, 1985).
Possible changes in land use: The Ba Delta has long been identified as a site for large-scale reclamation for agriculture. In 1973, the Lands Department identified 2,367.5 ha (or 55% of the gross delta area) as being potentially suitable for reclamation. Although only small areas of mangrove have been reclaimed since 1980, there remains the possibility that proposals for large-scale reclamation will re-surface.
Disturbances and threats: The major threats are reclamation for agriculture and aquaculture. In the early 1970s, some 308 ha of mangroves were cleared and polderized at Raviravi, and half of this was intended for aquaculture, especially the culture of penaeid prawns. According to Lal (1984b), two reclamation projects for agriculture, involving 95 ha of mangroves, were approved between 1980 and 1984. In all, an estimated 541 ha of mangroves have been reclaimed for agriculture and aquaculture and a further two ha for industrial development. Illegal cutting of timber takes place, and in some areas this illegal felling is causing severe damage to the forest (Watling, 1985).
Hydrological and biophysical values: The Ba Delta mangroves sustain one of the most important offshore fisheries in Fiji.

Social and cultural values: No information is available specifically for this site.
Noteworthy fauna: No information.
Noteworthy flora: The Ba Delta supports the largest contiguous stand of mangroves in Fiji.
Management authority and jurisdiction: Department of Lands and Survey.
References: Lal (1984b); Watling (1985).
Reasons for inclusion: 1a, 1c, 2c.
Source: Birandra Singh and references.

Vaturu Dam (7)

Location: 17°44'S, 177°40'E; in the valley of the Nadi River, 25 km southeast of Lautoka and 25 km north-northeast of Nadi, Viti Levu.
Area: 160 ha.
Altitude: 510 m.
Overview: Freshwater reservoir.
Physical features: A water storage reservoir approximately 5 km long and up to 1.5 km wide on the edge of a plateau in the upper drainage of the Nadi River. The catchment area rises to about 800 metres above sea level. The dam has a maximum depth of 37 metres and a total storage volume of 27 million cubic metres. The average water flow into the reservoir is 2.4 cubic metres per second. Access is very difficult except along the ridge routes, the plateau falling away steeply on all sides.
The region has a Dry Western climate with an average annual rainfall of about 3,600 mm and a mean temperature of 19.7°C. Sunshine hours total 157, and a wind speed of 2.6 knots is average. Most of the precipitation falls during storms and cyclones.
Ecological features: The water catchment is covered in dense closed montane tropical rainforest. No detailed botanical description of the forest is available.
Land tenure: The reservoir and its catchment are on Native land, ownership being shared by the Mataqali, Qoqa and Nasaucoke from Nagado, and the Naivua and Navunito from Yaloku.
Conservation measures taken: None.
Conservation measures proposed: The reservoir and forests of its catchment area were proposed as an Amenity Reserve (Vaturu Forest) in the Ninth Development Plan (Anon, 1989).
Land use: Vaturu Dam supplies water to Nadi and Lautoka. There is some fishing by local people.
Disturbances and threats: None known.
Hydrological and biophysical values: The reservoir supplies Nadi and Lautoka with water and is thus of considerable economic importance.
Social and cultural values: No information.
Noteworthy fauna: At least 42 species of birds have been recorded in the vicinity of the reservoir, including the Long-tailed Cuckoo (*Eudynamis taitensis*), a non-breeding migrant from New Zealand. Giant geckoes and skinks are found in the area as well as the Pacific Boa (*Camdoia bibronii*). Amphibians such as the cane toad (*Bufo marinus*) are present, as well as the Pacific Fruit Bat (*Pteropus tonganus*). The Indian Mongoose (*Herpestes semipunctatus*), mice, rats and the domestic pig are present.
Noteworthy flora: No information.
Recreation and tourism: Recreational-based activities have potential on the reservoir, but at present there is insufficient local utilisation to make it financially viable. It is in both the landowners' interest and the government's interest to make Vaturu a viable tourist attraction.
Management authority and jurisdiction: The Native Lands Trust Board and the Public Works Department are the authorities concerned with development.
References: Anon (1989); Fawcett, Wilton and Bell Ltd (1983).
Reasons for inclusion: 2b.
Source: Alistair J. Gray.

Nadrau Swamp (8)

Location: 17°42'S, 177°58'E; in the upper drainage of the Rewa River, close to the watershed of the Sigatoka River, central highlands of Viti Levu.
Area: 114 ha.
Altitude: 2,500 m.
Overview: Peat bog.
Physical features: A montane peat bog in a side valley of the Nanuku Creek in the headwaters of the Rewa River. The Nanuku Creek passes along the downstream edge of the swamp, which receives water from several short streams and also by flooding from the creek. In the deeper parts of the valley, the peat is several metres deep. Colluvium is found along the valley sides, and there is a major alluvial levee along Nanuku Creek. A small pond is located at the western end of the swamp within 50 metres of the Sigatoka River catchment. It appears that the Sigatoka River has captured the headwaters of the valley in which the swamp is situated, but the drainage patterns including the direction of flow are complicated by tectonic tilting.
The region has a Wet Eastern climate with a dry season rainfall of 800-1,200 mm and a wet season rainfall of 2,000-2,400 mm.
Ecological features: The wetland vegetation is herbaceous and differs in several respects from that of lowland peat swamps. The dominant upland peat species are *Urena lobata*, *Adenostemma lavenia*, *Cuphea carthagensis*, *Desmodium heterophyllum* and *Polygala paniculata*. Typical lowland species such as *Pandanus pyriformis*, *Sphagnum cuspidatum* and *Eleocharis ochrostachys* are absent. The pond contains aquatic plants notably *Limnanthemum indicum*, *Eleocharis dulcis* and *Nymphaea capensis*.
Land tenure: Native land.
Conservation measures taken: None.
Land use: Cattle graze the margins of the swamp, but avoid those areas dominated by sedges and ferns.
Disturbances and threats: The slopes around the swamp are being cleared and used as pastures.
Hydrological and biophysical values: No information.
Social and cultural values: No information.
Noteworthy fauna: There is an unconfirmed report of the endangered Barred-wing Rail (*Nesoclopeus poecilopterus*) in swamps on the Nadrau Plateau in 1973 (Holyoak, 1979).
Noteworthy flora: No information.
Management authority and jurisdiction: No information.
References: Ash & Ash (1984); Holyoak (1979).
Reasons for inclusion: 1d, 2b.
Source: Alistair J. Gray.

Monosavu Dam (9)

Location: 17°45'S, 178°02'E; 60 km northwest of Suva, in the headwaters of the Rewa River on the Nadrau Plateau, central highlands of Viti Levu.
Area: 670 ha.
Altitude: 750 m.
Overview: A water storage reservoir.
Physical features: The reservoir lies immediately upstream of the original Monosavu Falls where the Nanuku Creek drops off the edge of the Nadrau Plateau. The sides of the valley are very steep

and hence the reservoir is long and narrow (18 km long but no more than one km wide). The reservoir has a volume of 142 million cubic metres, with a 625 metre head of water.
The area receives approximately 3,600 mm of rainfall per year, distributed unevenly. The reservoir is on the wet side of the Monosavu catchment area.
Ecological features: The catchment is covered by tropical rainforest, although most of this is commercial forest. Dominant emergents are *Endospermum macrophyllum*, *Canarium* sp., *Parinari* sp. and *Agathis vitiensis*. The exposed pebbly shores of the reservoir are scantily covered with a native shrub, *Acalypha rivularis*, and a variety of reeds and sedges, notably *Cyperus brevifolius*. There is, however, no *Miscanthus*. Where the shore is muddy, the grass *Brachiaria mutica* is abundant.
Land tenure: Native land and Fiji Electricity Authority.
Conservation measures taken: None.
Land use: Generation of hydro-electric power, fishing and some recreation.
Disturbances and threats: None known.
Hydrological and biophysical values: The dam provides an important input into the electricity grid, with a generating capacity of 80 MW.
Social and cultural values: The reservoir supplies the local population with fish (tilapia), and is a popular recreation area.
Noteworthy fauna: No information is available on the wetland fauna. The forests of the catchment area support a varied bird life.
Noteworthy flora: No information.
Management authority and jurisdiction: Native land owners and the Fiji Electricity Board.
References: Brodie (1984); Brodie & Gibbons (1986); Brodie *et al.* (1987); Gibbons (1985); Institute of Natural Resources (undated); Raj *et al.* (1977).
Reasons for inclusion: 2b.
Source: Alistair J. Gray.

Mangroves of the Labasa Delta (10)

Location: 16°21'-16°26'S, 179°14'-179°25'E; in the delta of the Labasa River near Labasa, on the north coast of Vanua Levu.
Area: 1,473 ha.
Altitude: Sea level.
Overview: A large area of deltaic mangrove swamps on the north coast of Vanua Levu.
Physical features: The Labasa Delta is the combined alluvial fans of three rivers, the Labasa, Qawa and Wailevu, which drain the fertile Labasa plains and adjacent foothills. The combined annual discharge of the rivers is estimated at about 1,063 million cubic metres. Mangrove forest covers much of the delta. The seasonal dry climate has resulted in the formation of hypersaline mudflats with adjacent stunted mangroves in the less well-drained areas.
The Labasa Delta lies in the leeward dry zone of Vanua Levu, receiving a mean annual rainfall of 2,309 mm and experiencing a distinct dry season.
Ecological features: Watling (1985) recognizes two main mangrove communities. A closed shrub forest occurs well behind the river banks and seaward edge, generally with hypersaline mudflats at its centre. *Rhizophora samoensis* dominates the association, forming pure stands towards the centre. *Bruguiera gymnorrhiza* and the hybrid *Rhizophora* x *selala* become increasingly common towards the outer edge. The canopy height declines from 5-8 m at the periphery to 1-2.5 m near the mudflats. This mangrove community comprises approximately 25.9% of the mangroves in the delta. The other community (comprising about 68.6%) is dominated by *Bruguiera gymnorrhiza* which in many areas forms pure stands with a canopy at 10-15 m. *R.* x *selala* and *R. samoensis*, either separately or combined, form a distinct, vigorous association of limited extent along the banks of rivers and creeks. *Rhizophora stylosa* forms a fringing belt along many parts of the seaward edge, but is

occasionally displaced by pure *R. samoensis*. Conversely, *R. stylosa* occasionally replaces *R. samoensis* in its more usual riverbank locations. The more landward species *Xylocarpus granatum*, *Lumnitzera littorea* and *Excoecaria agallocha* are locally common, especially at the head of the delta where there are some small pockets of typically terrestrial vegetation (Watling, 1985).
Land tenure: State (Crown Land).
Conservation measures taken: All mangroves in Fiji were designated as Reserved Forests and managed by the Forest Department from 1933 to 1975. These Reserved Forests were denotified in 1975, and the mangroves have since been under the jurisdiction of the Department of Lands and Survey as an integral part of the foreshore. There are some restrictions on cutting, but traditional exploitation is still permitted.
Conservation measures proposed: Watling (1985) has made some recommendations for management.
Land use: Formerly the mangroves were used for fuelwood by a cane crushing mill and bakeries in Labasa. This practice declined in the 1950s, and there is no longer any commercial extraction of fuelwood. The principal activity in the delta at present is fishing. The customary fishing rights east of the Wailevu River are owned by the Vanua of Labasa, while those west of the Wailevu are owned by the Vanua of Wailevu. Labasa Town is a major fish supply centre, with much of the produce from the Labasa Delta being retailed in Viti Levu (Watling, 1985).
Possible changes in land use: Labasa Town is the rapidly growing capital of Vanua Levu. As there is a shortage of land suitable for development, it is inevitable that there will be further proposals for reclamation of mangroves for urban and industrial expansion.
Disturbances and threats: Major reclamation has occurred in the Labasa mangroves. Large areas of mangrove were lost as a result of the construction of three sea walls by the Colonial Sugar Refining Company between 1896 and 1904. Watling has estimated that about 650 ha of mangroves were lost at this time, but Lal (1990) puts the figure at 2,334 ha, while Baines (1979) gives a figure of 2,713 ha. In recent years, 145 ha of mangroves have been reclaimed for agricultural development, 30 ha for industrial development, and 0.2 ha for a rubbish dump. Twenty-four ha of mangroves have been converted into sewerage oxidation ponds. Pollution is also a problem in the delta, as effluents from Labasa Town and the Fiji Sugar Company Mill are discharged into the rivers at the head of the delta. Fish kills as a result of mill discharge are of almost annual occurrence (Watling, 1985).
Hydrological and biophysical values: The mangroves of the Labasa Delta form an important productive unit which contributes greatly to the rapidly growing fisheries industry centred at Labasa.
Social and cultural values: No information is available specifically for this site.
Noteworthy fauna: No information.
Noteworthy flora: No information.
Management authority and jurisdiction: The mangrove areas are under the jurisdiction of the Department of Lands and Survey.
References: Baines (1979); Lal (1990); Watling (1985).
Reasons for inclusion: 1a, 1c, 2c.
Source: Birandra Singh and references.

Lake Tagimaucia (11)

Location: 16°49'S, 179°56'W; in the highlands of Taveuni Island, 6 km southeast of Somosomo.
Area: 213 ha.
Altitude: 820 m.
Overview: A freshwater crater lake, mostly covered with a floating mat of sedges and reeds.
Physical features: Lake Tagimaucia is the largest natural freshwater lake in Fiji. It is a crater lake

with extensive floating mats of aquatic vegetation and only about 16 ha of open water. The lake is situated on the eastern side of the central mountain ridge of Taveuni Island, and overflows into the Wainisairi Creek. The catchment has a total area of 619 ha, of which 35% is swamp and open water, and the remainder is forested. Sedge peat swamp is gradually filling the lake basin. The floating mats of peat are dissected by fissures to form a number of interlocking islands. The lake is about 2.5-5.5 metres deep.
The climate is very wet, with an average annual rainfall of over 6,800 mm. The climate is strongly influenced by the prevailing humid southeasterly winds which rise over the centre of the island and produce abundant rainfall. The mean daily temperature is 15-21°C in July and 18-24°C in January. Relative humidity remains in the range 94%-98% throughout the year. Annual evapo-transpiration rarely exceeds 900 mm.
Ecological features: The swamp vegetation is dominated by *Lepironia articulata* and algae which form floating sedge-peat islands, and *Pandanus taveuniensis* and other small trees where alluvium and colluvium are infilling the margins of the crater. The surrounding slopes are forested.
Land tenure: Native Land.
Conservation measures taken: None.
Conservation measures proposed: Various recommendations have been made for the establishment of some form of protected area on the island of Taveuni (Anon., 1989; Dahl, 1980 & 1986; TCSP, 1990), and the entire island has been proposed for listing under the World Heritage Convention. A proposal to establish a national park on the island is currently being considered by the government (Lenoa *et al.*, 1989). In all cases, the proposed protected areas have included Lake Tagimaucia.
Land use: None. The lake is a six hour walk from the nearest village and is seldom visited.
Disturbances and threats: None known.
Hydrological and biophysical values: No information.
Social and cultural values: None known.
Noteworthy fauna: The fauna of the lake and swamp is low both in species diversity and in abundance. The only aquatic vertebrates which have been observed at the lake are eels (*Anguilla* sp.) and the introduced cane toad (*Bufo marinus*). The Swamp Harrier (*Circus approximans*) occurs in the area, but no true waterbirds have been recorded. A variety of aquatic insects are present, but crustaceans and other invertebrate taxa are poorly represented.
Noteworthy flora: A rare endemic flowering plant, the Tagimauthea Flower *Medinella waterhousei* (Melastomataceae), is known only from the vicinity of the lake and Mt Seatura on Vanua Levu. Other interesting plants include *Freycinetia storkii*.
Research and facilities: The lake has been the subject of extensive limnological studies (Southern *et al.*, 1986).
Management authority and jurisdiction: No information.
References: Anon. (1989); Dahl (1980, 1986); Lenoa *et al.* (1989); Southern *et al.* (1986); TCSP (1990).
Reasons for inclusion: 1a, 2b, 2d.
Source: Alistair J. Gray.

Other Wetlands

Insufficient information is available on the following wetlands to provide more than a very sketchy account, and in most cases their national and international significance is uncertain. Some of the sites have been identified as being of conservation interest by workers such as Dahl (1980, 1986), Dunlap and Singh (1980) and the Tourism Council of the South Pacific (TCSP, 1990), while most of those on Vanua Levu have been identified from the 1:50,000 maps published by the Directorate of Overseas Survey in 1961. It can be assumed that many of the Vanua Levu wetlands are now much reduced in size as a result of reclamation activities.

Waindrandra Palms (12)

Location: Coordinates unknown; at the Waindrandra Agricultural Research Station at Nanggali on Viti Levu.
Area: Unknown.
Altitude: Unknown.
Overview: A unique stand of riverine forest with the only known population of the endemic palm *Neoveitchia storckii* (an endemic genus). This population numbered less than 200 trees in 1972, and continues to decline as a result of clearing (Gorman & Siwatibau, 1975; Dahl, 1980). Recommended for protection in the 1980 Parks and Reserves Plan (Dunlap & Singh, 1980) and by Dahl (1980, 1986)
Land tenure: No information.

Vatulele Pools (13)

Location: 18°32'S, 177°38'E; on Vatulele Island, 33 km off the south coast of Viti Levu, almost due south of Korolevu.
Area: Unknown.
Altitude: Sea level.
Overview: Two brackish tidal ponds on rocky shores, with an endemic red prawn (Crustacea). The prawn is strictly protected by traditional taboos. The site was recommended for protection in the 1980 Parks Plan (Dahl, 1986; TCSP, 1990).
Land tenure: Native land.

Moturiki Swamp (14)

Location: 17°46'S, 178°45'E; on the small island of Moturiki, off the southwest coast of Ovalau Island in the Lomaiviti Group.
Area: Unknown.
Altitude: Near sea level.
Overview: An area of freshwater swamp forest and bog on the small volcanic high island of Moturiki (10 sq.km). Identified as an ecosystem of conservation interest and recommended for protection by Dahl (1980 & 1986) and TCSP (1990).
Land tenure: No information.

Lake Rovurovu (15)

Location: 16°44'S, 178°40'E; near the west end of Vanua Levu.
Area: Length: 400 metres, Width: 50 metres.
Altitude: 50 metres.

Overview: Freshwater lake.
Land tenure: Native Reserve.

Pond at the source of the Ndranoumbamba River (16)

Location: 16°38'S, 178°56'E; in the interior of western Vanua Levu, 6 km southeast of Nabavatu.
Area: 2.5 ha (500 m long, 50 m wide).
Altitude: 400 m.
Overview: Freshwater swamp.
Land tenure: Native land.

Nairirileka Swamp (17)

Location: 16°34'S, 178°52'-178°53'E; near the mouth of the Ndreketi River on the north coast of Vanua Levu.
Area: 250 ha.
Altitude: Sea level.
Overview: A brackish swamp.
Land tenure: Freehold land.

Ndrano Yalewa and Ndrano Tangane (18)

Location: 16°31'S, 178°56'E; in the hills near Navidamu on the north coast of Vanua Levu.
Area: 5 ha (1 km long, 50 m wide).
Altitude: 100 metres.
Overview: Two small freshwater lakes.
Land tenure: Native land.

Ndoindoi Swamp (19)

Location: 16°30'S, 178°57'E; northeast of Navidamu on the north coast of Vanua Levu.
Area: 100 ha.
Altitude: 50 m.
Overview: Freshwater swamp.
Land tenure: Native land, plus 10% freehold.

Swamps of the upper Ndereketi River (20)

Location: Within a large triangle with co-ordinates: 16°30'S, 179°03'E; 16°32'S, 179°04'E; and 16°31'S, 179°05'E. In the upper drainage of the Ndreketi River in the north-central hills of Vanua Levu, 15 km east of Navidamu.
Area: 500 ha.
Altitude: 100 m.
Overview: Six freshwater swamps: Korowaiwai Swamp, Nduriwailevu Swamp, Ndranowakalevu Swamp, Narualango Swamp, Vunimolau Swamp and Ndangau Swamp.
Land tenure: Native land.

Taketakelo Pond (21)

Location: 16°35'S, 179°06'E; near Naravuka in the north-central interior of Vanua Levu.
Area: 20 ha.
Altitude: 50 m.
Overview: Freshwater pond.
Land tenure: Native land.

Ponds along the Ndreketi River (22)

Location: 16°31'S, 179°07'E; 16°31'S, 179°08'E; and 16°30'S, 179°09'E; in the upper drainage of the Ndreketi River in north-central Vanua Levu, southwest of Naduri.
Area: Total of all ponds approximately 20 ha.
Altitude: 100 m.
Overview: A series of freshwater ponds along creeks close to the Ndreketi River.
Land tenure: Native land.

Mbalawa Swamp (23)

Location: 16°14'S, 179°46'E; near the mouth of the Nasuvu River, on the northeast coast of Vanua Levu.
Area: 100 ha.
Altitude: Sea level.
Overview: Brackish swamp.
Land tenure: Native reserve.

Ngasauva Salt Lagoon (24)

Location: 16°10'S, 179°59'E; near the extreme northeastern tip of Vanua Levu.
Area: 150 ha.
Altitude: Sea level.
Overview: Salt water lake.

Land tenure: Native reserve.

Lake Ndrano (25)

Location: 16°09'S, 180°00'E/W; near the extreme northeastern tip of Vanua Levu.
Area: 5 ha.
Altitude: Sea level.
Overview: Brackish lake.
Land tenure: Native reserve.

Lake Navesiwaka (26)

Location: 16°25'S, 179°40'E; in the upper drainage of the Nasuvu River in the interior of eastern Vanua Levu.
Area: 10 ha.
Altitude: 500 m.
Overview: Freshwater lake.
Land tenure: Native land.

Ngalongalo Salt Lake (27)

Location: 16°46'S, 179°31'E; in the narrow isthmus south of Natewa Bay, 19 km east of Savusavu, Vanua Levu.
Area: 150 ha.
Altitude: Sea level.
Overview: Salt lake. Recommended for protection (Dahl, 1986; TCSP, 1990).
Land tenure: Surrounded by freehold land.

Lake on the Songatiri River (28)

Location: 16°42'S, 179°16'E; near the mouth of the Songatiri River, east of Wailevu on the south coast of Vanua Levu.
Area: 20 ha (1 km long, 200 m wide).
Altitude: Sea level.
Overview: Freshwater pond.
Land tenure: Bordering native reserve and freehold land.

Un-named wetland (29)

Location: 16°53'S, 179°00'E; near Nadivakarua, on the south coast of Vanua Levu.
Area: Length: 1.5 km, Width: 150 metres.
Altitude: 50 m.
Overview: A freshwater pond.
Land tenure: Native reserve.

Muanithula Marsh (30)

Location: 16°53'S, 178°55'E; at the mouth of the Wainunu River southeast of Daria, on the south coast of Vanua Levu.
Area: 500 sq.m.
Altitude: Sea level.
Overview: Saltmarsh.
Land tenure: Freehold land.

Delaimoala Lake (31)

Location: 18°36'S, 179°54'E; on the island of Moala, in the Moala Group.
Area: Unknown.
Altitude: Unknown.
Overview: A small freshwater lake on Delaimoala Peak, with matted sedges and a reed fringe (Dahl, 1986).
Land tenure: No information.

Tuvuca Lakes (32)

Location: 17°41'S, 178°49'W; on the island on Tuvuca in the Lau Group.
Area: Unknown.
Altitude: Unknown.
Overview: A group of four or five small brackish lakes in a depression in the interior of Tuvuca Island, a raised coral island with an area of 13 sq.km (Dahl, 1986).
Land tenure: No information.

Vuaqava Salt Lake (33)

Location: 18°52'S, 178°54'W; on the island of Vuaqava (Vuanggava) in the Lau Group.
Area: Unknown.
Altitude: Sea level.
Overview: A tidal saltwater lagoon (marine lake) in the central basin of Vuaqava Island, a raised coral atoll with an area of 7.7 sq.km. The lagoon is used as a turtle pen by Kambara Islanders. The

site was recommended for protection in the 1980 Parks Plan (Dahl, 1980 & 1986).
Land tenure: No information.

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FRENCH POLYNESIA

INTRODUCTION

by Yolande Fontaine
Delegation a l'Environnement

Area: The approximately 130 islands and islets of French Polynesia have a total land area of 3,521 sq.km, distributed over more than 4,198,000 sq.km of territorial seas. Tahiti, the largest island and centre of government and commerce, has an area of 1,042 sq.km.

Population: 188,814 according to the 1988 census (with over 50% on Tahiti).

French Polynesia is an Overseas Territory of France. It lies in the South Pacific between latitudes 7°50' and 27°36' South, and longitudes 134°28' and 154°40' West, and is made up of over 120 islands and atolls grouped into five archipelagos:

- the Society Islands include nine volcanic high islands and five atolls, divided into the "Windward Islands" (Tahiti, Moorea, Maiao, Mehetia and Tetiaroa) and the "Leeward Islands" (Huahine, Raiatea, Tahaa, Bora-Bora, Maupiti, Tupai, Maupihaa, Manuae and Motu One) for the purposes of administration.
- the Marquesas, 1,300 km northeast of Tahiti, are a group of volcanic high islands comprising seven major islands (Eiao, Nuku Hiva, Ua Huka, Ua Pou, Hiva Oa, Tahuata and Fatu Hiva) and about six islets, rocks and banks. Motu One (Ilot de Sable) is the only coral island in the group. The islands of the Marquesas group are at a greater distance from a continent than any other islands in the world.
- the Australs, 600 km to the south of Tahiti, are a chain of seven islands separated from each other by distances ranging from 160 km to 230 km. Six islands (Marotiri, Rapa, Raivavae, Tubuai, Rurutu and Rimatara) are volcanic high islands; the seventh (Maria), at the west end of the chain, is an atoll.
- the Gambiers, 1,600 km southeast of Tahiti, are a group of about 12 islands including four major volcanic high islands (Mangareva, Aukena, Akamaru and Taravai), several small volcanic islets and a low coral atoll (Temoe). These islands are often considered a part of the Tuamotu Archipelago to the northwest.
- the Tuamotu Archipelago comprises 76 atolls extending in a broad belt approximately 1,500 km from northwest to southeast, between latitudes 14° and 23° South and longitudes 135° and 148° West. All are low atolls, except for Makatea, near the west end of the archipelago, which is a raised atoll with a maximum elevation of 113 m (the only raised atoll in French Polynesia). Fakarava Atoll, in the central Tuamotus, is the second largest atoll in the world.

The Governor of French Polynesia also has authority for Clipperton Island, an isolated "near atoll" in the eastern Pacific some 5,200 km northeast of Tahiti, although this is not a part of French Polynesian Territory.

There are two main types of islands. Those referred to as "high" islands are of volcanic origin; they are mountainous with rugged and sometimes almost inaccessible interiors. These include Tahiti, Moorea, the Marquesas, the Gambiers and most of the Australs. Those referred to as "low" islands are coral formations resting on undersea plates, barely rising above the water. Most of these are in the Tuamotus.

The climate is humid tropical, greatly moderated by the trade winds. There are two seasons: a hot and humid season with torrential rains lasting for three months from December to February, and a cooler, drier season, from March to November. The driest months are July and August. Daily variation in temperature is noticeable, especially on Tahiti, where the presence of high mountains gives rise to land breezes that cool the air considerably at night. On Tahiti, the maximum temperature rarely exceeds 34°C in January, the warmest month, and rarely falls below 28°C in July, the coldest. The average maximum temperature is 30°C. Night-time temperatures seldom fall below 22° in the warm season or below 17-20°C in the cool season. On the east coast of Tahiti, the heat is moderated by the trade winds. In the mountains, there is a one degree Centigrade drop for every 200 metres of change in elevation. Given their geographical locations, the Australs are more temperate and the Marquesas more equatorial. Atmospheric humidity is very high. The average relative humidity at Papeete (Tahiti) is 78%, with a daily range of 7%. In the Tuamotus it is 75%, with a less noticeable daily variation of 2%.

Dahl (1980, 1986) has given a brief account of the natural ecosystems of the islands, and has reviewed their importance for nature conservation. UNEP/IUCN (1988) provide a general account of the coral reef systems in each island group, and also give detailed information on ten of the most important islands and reef systems (Rapa Island in the Australs; Scilly Atoll and the Temae and Tiahura Reefs on Moorea in the Society Islands; and Mataiva, Moruroa, Rangiroa, Takapoto, Tikehau and Taiaro atolls in the Tuamotus).

Summary of Wetland Situation

Very little information is available on the wetlands of French Polynesia. Although marine ecosystems, and especially the coral reefs, have received a considerable amount of attention, very few studies have been carried out on the Territory's non-marine environments, and these environments, including the aquatic habitats, remain poorly understood.

There are rather few wetlands in French Polynesia, and most of these are very small in size. They include mountain streams and torrents (on several of the larger high islands), a freshwater lake (Lac Vaihiria on Tahiti), riverine forest and lowland rivers (on Tahiti only), a number of brackish to hypersaline lagoons (on several high islands and some atolls), and many tiny freshwater marshes generally under cultivation for taro (*Colocasia esculenta* and *Cyrtosperma* sp.). There are also some interesting brackish ponds with salinities in the range 10-20 p.p.t. on some of the atolls. The Marquesas are relatively dry islands, apparently lacking any significant freshwater or brackish wetlands. Similarly, there do not appear to be any significant wetland habitats in the Gambier Islands or in most of the Austral Islands, although there are large seabird colonies in each of these three island groups.

The tidal rise and fall throughout the islands is very low (generally less than 40 cm), and there is little exposed reef flat or mudflat at low tide. In contrast to many Pacific islands, there are no indigenous mangroves in French Polynesia, although *Rhizophora stylosa* was introduced to Tahiti, Moorea and Bora-Bora in the Society Islands in the 1970s (Taylor, 1979). The natural littoral vegetation of the high islands consists primarily of forests of "purau" (*Hibiscus tiliaceus*). This vegetation has now almost entirely disappeared because of coastal development. Similarly, most swampy areas in the coastal zone and many reef flats have been filled in to increase the area of land available for development. In Tahiti and Raiatea, for example, it is estimated that more than 50% of the coastline is now artificial. Pollution has also been a problem, at least locally. Mowbray (1988) reports on a kill of fish in rivers caused by detamethrin and other agricultural chemicals.

This extensive coastal development on many of the high islands has resulted in the loss of much of the former wetland habitat, and with it a decline in two species associated with this habitat, the Little Heron (*Butorides striatus*) and Pacific Black Duck (*Anas superciliosa*). The endemic subspecies of the Little Heron, *B. s. patruelis*, is confined to Tahiti, and with the loss much of the littoral and riverine vegetation on this island, has now become very rare. The population of Black Ducks on Tahiti has also shown a serious decline in recent decades, and may now number only 200-300 individuals. Other resident species associated with wetlands in French Polynesia include the Pacific Reef Heron (*Egretta sacra*), Spotless Crake (*Porzana tabuensis*), Great Crested Tern (*Sterna bergii*), Tahiti Kingfisher (*Halcyon venerata*) and Tuamotu Kingfisher (*H. gambieri*). The Swamp Harrier (*Circus approximans*) was introduced in the Society Islands around 1885, and is now common and widespread (Thibault & Rives, 1975).

Undoubtedly the most interesting waterbirds of French Polynesia, however, are the two endemic species of shorebirds, the Tahiti Sandpiper (*Prosobonia (Aechmorhynchus) leucoptera*) and Tuamotu Sandpiper (*P. cancellatus*). The Tahiti Sandpiper is known only from three specimens collected in 1773 and 1777 on Tahiti and Moorea in the Society Islands. Apparently a bird of stream sides, this small sandpiper was already very limited in its distribution at that time, and its extinction was very swift. Predation by introduced rats seems to be the most likely explanation for its rapid disappearance.

The Tuamotu Sandpiper was first described from a specimen collected on Christmas Island (Kiribati) in 1778. The species has never been found there again, but it was collected or reported from at least 16 atolls in the Tuamotu Archipelago in the 1920s. The species has disappeared from a number of inhabited atolls in recent decades, and it seems probable that the introduction of rats and cats has eliminated it from all but the least frequently visited islands. Hay (1985) and Collar and Andrew (1988) were aware of recent records from only six localities, Marutea du Sud, Maturei-Vavao, Tenararo, Pinaki and Nukutavake in the southern Tuamotus and Rangiroa in the northern Tuamotus. However, Collar and Andrew noted that 12 of the sites where the species was found in the 1920s had not been visited since then, and a further 24 atolls in the Tuamotus, some apparently suitable, had never been surveyed for birds. In April 1989, an ornithological expedition to seven atolls in the north-central part of the archipelago discovered good populations of Tuamotu Sandpipers on four uninhabited islets (motus) in Tahanea Atoll, and was informed that the species still occurred on some other atolls in the area, notably Hiti, Taunake and Tepoto in the Raevski Group (Lovegrove *et al.*, 1989).

Only three species of migratory shorebirds occur regularly in French Polynesia, the Pacific Golden Plover (*Pluvialis fulva*), Bristle-thighed Curlew (*Numenius tahitiensis*) and Wandering Tattler (*Heteroscelus incanus*), but all three of these are widespread and fairly common. Lovegrove *et al.* (1989) estimated that at least 600 Bristle-thighed Curlews were present in the northern half of the Tuamotu Archipelago in early 1989. French Polynesia is probably the main wintering area for this threatened species. Very few other migratory waterbirds ever reach French Polynesia, although two species of ducks, the Northern Pintail (*Anas acuta*) and Northern Shoveler (*A. clypeata*), and at least four species of shorebirds have occurred as rare vagrants (Pratt *et al.*, 1987).

Three species of *Acrocephalus* warbler, the Tahiti Reed Warbler (*Acrocephalus caffra*), Marquesas Reed Warbler (*A. mendanae*) and Tuamotu Reed Warbler (*A. atypha*) are endemic to French Polynesia, and one of these, the Tahiti Reed Warbler (confined to the islands of Tahiti and Moorea) is rare and local (Pratt *et al.*, 1987). However, these are primarily birds of bamboo thickets, secondary growth and dense scrub, and have no special affinity for wetland habitats.

Wetland Research

Very little research has been carried out on wetlands in French Polynesia, scientists on the whole being more interested in the reef systems. Nevertheless, some studies have been conducted under the auspices of ORSTOM and the École Pratique des Hautes Études at the Museum National d'Histoire Naturelle. These have included a study of the hydrology and chemical and biological characteristics of the rivers of Tahiti, Lake Vaihiria and Maeva Lagoon. Maeva Lagoon, on the island of Huahine, has been particularly well studied from an archaeological point of view by a team of archaeologists led by Prof. Y.H. Sinoto of the Bishop Museum in Hawaii. Detailed soil surveys have been carried out, and ORSTOM has recently produced an atlas of natural resource systems in the Territory. A study of the avifauna of French Polynesian is currently being coordinated by the Delegation a l'Environnement.

Wetland Area Legislation

The provisions of the statute for self-government, Law No.84-620 of 6 September 1984, grants the Territory of French Polynesia complete authority over its environmental protection policy. Regulatory power lies with the Territorial Assembly; executive power rests with the President of the Territorial Government and his Council of Ministers. Nevertheless, enforcement of regulations and legal proceedings remain in the hands of the French Government. France is represented in the Territory by the High Commissioner of the Republic.

There are no specific regulations concerning wetlands, nor any particular regulations governing the creation and management of parks, reserves and other protected areas. A text is, however, being drafted. Currently, measures for the protection of sites derive from the Planning Code of French Polynesia, and in particular from Title V of Book I: "on the natural and cultural heritage of the Territory, on the designation and protection of sites, monuments, objects and elements pertaining thereto." It is through this mechanism that seven islets and atolls have been designated as nature reserves, and a valley on Tahiti designated a territorial park (Parc Naturel Territorial). However, this Planning Code also provides for the draining of swampy land, in Book I, Title II: "general measures against the spread of mosquitos" (Article 0.320-2). Regulations covering water and forests contain provisions concerning the protection of the soil, vegetation and waterways. The hunting and destruction of all species of birds is prohibited by a decree enacted in 1967, but this is apparently seldom enforced (Hay, 1985).

At international level, France has ratified the Convention on the Conservation of Nature in the South Pacific (the Apia Convention), after consultation with the Territorial Assembly. France is also a party to the Convention for the Protection of the Natural Resources and Environment of the South Pacific (SPREP Convention), the Convention on Wetlands of International Importance especially as Waterfowl Habitat (the Ramsar Convention) and the World Heritage Convention, and has signed but not yet ratified the Convention on Biological Diversity.

Wetland Area Administration

At present, the protected areas network in French Polynesia includes a small reserve covering the lagoon area of Manuae (Scilly Atoll) in the Society Islands, four reserves comprising the volcanic islands of Eiao, Hatutaa, Motu-One and Mohotani in the Marquesas, a Strict Nature Reserve and Biosphere Reserve of 2,000 ha at Taiaro Atoll in the Tuamotu Archipelago, and a Territorial Park of 750 ha in the Faaiti Valley in the Papenoo drainage on Tahiti (IUCN, 1991). None of these was established specifically to protect wetland habitat, although the Taiaro Atoll reserve includes an interesting enclosed saline lagoon, and the Faaiti Territorial Park includes some undisturbed mountain stream habitats. A proposal to designate Miti Rapa Lagoon, located on the island of Tahiti opposite the Isthmus of Taravao, is currently being studied. This proposal was put forward by the Societe d'Ornithologie de Polynesie (MANU), and is receiving the support of the Delegation a l'Environnement.

The body currently in charge of protected areas in French Polynesia is the Delegation a l'Environnement (Environmental Commission), which was created on 30 May 1985. This is an administrative service of the Territory, with a coordinating role in the formulation and application of an environmental policy. Its principal mission is to ensure the proper management of the environment and maintenance of the quality of life, as well as to define and recommend those elements necessary to formulate a coherent environmental policy. Within this framework of general responsibilities, the Delegation is instructed to give special attention to the following:

- protection, safekeeping and restoration of the natural environment;
- prevention, reduction or elimination of pollution, degradation and other environmental hazards that may result from the spread of human activities of all kinds;
- development and coordination of studies and research in environmental matters;
- training and dissemination of information to increase awareness of environmental issues.

With its very limited staff (only 11 employees in 1991), the Delegation a l'Environnement has not as yet been able to put into place an effective policy for environmental protection or for the management of protected areas.

Organizations involved with Wetlands

(a) Governmental bodies

- Ministere de la Qualite de la Vie, de la Culture, de l'Environnement et des Transports Terrestres
    * Delegation a l'Environnement

(b) Academic institutions

- ORSTOM (Office of Overseas Scientific and Technical Research)
- Faculty of Biology, French Pacific University
- Ecole Pratique des Hautes Etudes, Museum National d'Histoire Naturelle

(c) Non-governmental conservation bodies

- La Federation des Associations de Protection de l'Environnement
- Societe d'Ornithologie de Polynesie (MANU)
- Atuatu te Natura (on Bora-Bora)

WETLANDS

Site descriptions compiled by Yolande Fontaine, Claude Monnet and Jules Cheffort of the Delegation a l'Environnement.

Lac Vaihiria (1)

Location: 17°41'S, 149°25'W; in the central highlands of Tahiti, 10 km north of Mataiea, Society

Islands.
Area: 16 ha to 22 ha, depending on water level.
Altitude: 473 m.
Overview: Originally a natural lake, retained in a basin formed by crumbling of the surrounding rock faces. Since 1981, the lake has been used as a supply reservoir for hydro-electric development.
Physical features: A small natural lake at an altitude of 473 m in the interior of Tahiti. The lake has a maximum depth of 22 m. In the east and west, the shoreline is steep and rocky; to the south, the shore is gently sloping with mud and gravel. To the north, there was formerly a deltaic swamp, with gravelly and muddy areas. However, the level of the lake has been raised for the production of hydro-electricity. The lake is fed by streams rising on the south slope of Mt Urufa (1,493 m) and drains south via the Tahiria River to the coast just east of Mataiea. The region receives very heavy rainfall, with as much as 8,000 or 9,000 mm per year.
Ecological features: The aquatic formations, which are particularly extensive on the west bank of the lake, comprise *Egeria densa* with a little *Polygonum glabrum*. A riparian formation, more or less typical of waste areas, occurs on mudflats which are exposed for the greater part of the year. In 1983, J. Florence found an unusual stand of *Saccharum spontaneum* at the lake. The lake is surrounded by humid forests invaded by various introduced species.
Land tenure: Public riverine waters.
Conservation measures taken: None.
Conservation measures proposed: Dahl (1980) recommended the establishment of a reserve to protect the lake and its fauna.
Land use: The lake is utilized for the generation of hydro-electricity; it currently produces 25% of the Territory's needs.
Possible changes in land use: There are plans to double the production of hydro-electricity.
Disturbances and threats: Widespread invasion of the plant species *Miconia calvescens*, introduced from Central America at the beginning of this century. Its growth has exploded as the forested slopes around the lake have been denuded by cyclones (in 1983) and construction work for hydro-electric development.
Hydrological and biophysical values: The only high-altitude lake in Polynesia.
Social and cultural values: Vaihiria valley possesses a number of interesting archaeological structures, some of which have been restored for the public.
Noteworthy fauna: The only fish native to the lake seems to be the eel *Anguilla megastoma*. The lake is a feeding area and probably also a breeding site for the Pacific Black Duck (*Anas superciliosa*).
Noteworthy flora: No information.
Recreation and tourism: The lake lies close to the only track crossing the island, and is often visited by hikers.
Management authority and jurisdiction: No information.
References: Dahl (1980); Ricard *et al.* (1983).
Reasons for inclusion: 1a, 2b. The lake is of considerable interest as the only high-altitude lake in Polynesia.
Source: Yolande Fontaine, Claude Monnet and Jules Cheffort.

Miti Rapa and Port Phaeton (2)

Location: 17°45'S, 149°19'W; on the west side of the Isthmus of Taravao, south of Taravao village, Tahiti, Society Islands.
Area: Miti Rapa, 36 ha; Port Phaeton, unknown.
Altitude: Sea level.
Overview: A brackish lagoon and sheltered sea bay with stands of *Hibiscus tiliaceus* vegetation, some brackish marshes and stands of introduced mangroves.

Physical features: Miti Rapa is a small brackish lagoon separated from the sea by a causeway carrying a main road. The lagoon receives an inflow of fresh water from the Paea River rising in the hills of the Presqu'ile de Taiarapu to the southeast. Port Phaeton is a sheltered sea bay on the west side of the Isthmus of Taravao with some fringing brackish marshes and mangroves. The climate is tropical oceanic, with a cool dry season from May to October and a warm rainy season from November to April. Easterly trade winds predominate from October to March.
Ecological features: Primary vegetation with *Hibiscus tiliaceus* still persists along the edge of Miti Rapa lagoon. There are some areas of brackish marsh with *Acrostichum aureum* and *Phragmites* sp. and stands of the introduced mangrove *Rhizophora stylosa* on the shores of Port Phaeton.
Land tenure: Public maritime and riverine waters. Surrounding areas are privately owned.
Conservation measures taken: None.
Conservation measures proposed: A proposal for the protection of Miti Rapa Lagoon has been formulated by the Societe d'Ornithologie de Polynesie (MANU) and is currently under consideration.
Land use: None at the lagoon. There are some fish pens in the bay, and pastures and fallow plots in surrounding areas.
Disturbances and threats: The wetlands are under severe pressure from urban development, and some land on the west shore of Port Phaeton has already been reclaimed for development. The introduction of mangroves has disturbed the natural ecosystem of the bay.
Hydrological and biophysical values: No information.
Social and cultural values: None known.
Noteworthy fauna: Miti Rapa is one of the most important sites for the Little (Striated) Heron, *Butorides striatus patruelis*, a threatened subspecies endemic to the island of Tahiti. Flocks of up to 20 Pacific Black Ducks *Anas superciliosa* occur in Port Phaeton, and the species probably breeds around the Miti Rapa lagoon. Pacific Reef Herons (*Egretta sacra*), Pacific Golden Plovers (*Pluvialis fulva*), Wandering Tattlers (*Heteroscelus incanus*) and Great Crested Terns (*Sterna bergii*) occur commonly in the bay, and the introduced Swamp Harrier (*Circus approximans*) is common in the area.
Noteworthy flora: Miti Rapa is one of the last remaining sites on Tahiti where primary vegetation with *Hibiscus tiliaceus* still persists at the edge of the water.
Scientific research and facilities: Some studies have been conducted on the biology of *Butorides striatus*.
Conservation education: Members of the "Manu" group have approached landowners with a view to developing a conservation education programme at the lake.
Management authority and jurisdiction: No information.
Reasons for inclusion: 1a, 2a, 2b. The most extensive coastal wetland on Tahiti, and an important refuge for the threatened endemic subspecies of the Little Heron (*Butorides striatus patruelis*).
Source: Yolande Fontaine, Claude Monnet and Jules Cheffort.

Papenoo Valley (3)

Location: 17°38'S, 149°25'W; in the interior of north-central Tahiti, Society Islands.
Area: Unknown.
Altitude: 150-670 m.
Overview: Riverine wetlands along the middle and upper reaches of the Papenoo River and its tributaries in the north-central highlands of Tahiti.
Physical features: The Papenoo River and its tributaries comprise the largest river system in French Polynesia. This system drains the eastern slopes of the Mt Orohena massif (2,241 m) and the northern slopes of the Mt Tetufera massif (1,799 m). There are interesting caves at Pufau and Farehape, and three impressive waterfalls, Cascade Maroto on the Vaituoru River (the principal tributary of the Papenoo) and Cascade Puraha and Cascade Vaiharuru on the main Papenoo River.

The climate is tropical oceanic with an average annual rainfall of 5,300 mm. There is a warm rainy season from November to April and a relatively cool dry season from May to October.
Ecological features: No information.
Land tenure: Privately owned by the Territory.
Conservation measures taken: The Faaiti River (a small tributary on the west bank of the Papenoo) and its catchment area are protected in the Parc Naturel Territorial de Faaiti (750 ha), established by Decree No.678/CM in June 1989.
Conservation measures taken: Dahl (1980) recommended the establishment of a reserve to protect montane forest types and cloud forest in the upper Papenoo drainage, or some combination of conservation areas and recreation areas if a proposal to construct a dam in the valley went ahead.
Land use: Hunting, fishing and harvesting of forest products. A cross-island track follows the valley almost to the source of the Vaituoru River before crossing the Tetufera ridge to Lac Vaihiria.
Possible changes in land use: There is a proposal to dam the Papenoo Valley for the production of hydro-electricity.
Disturbances and threats: The lower reaches of the Papenoo River are now much degraded by mining for sand and gravel. The forests are threatened by clearing for agriculture, heavy grazing by domestic livestock, feral pigs and feral goats, and invasion by the introduced plant species *Miconia calvescens*.
Hydrological and biophysical values: No information.
Social and cultural values: The Papenoo valley is rich in archaeological remains which are currently being studied by the Centre Polynésien des Sciences Humaines. These include alluvial terraces, dwellings, platforms and erect stones.
Noteworthy fauna: No information is available on the aquatic fauna of the rivers and streams. A tiny population of the endangered Polynesian Pigeon (*Ducula aurorae*) still survives in the forests of the Papenoo Valley. This population was thought to number only 10-12 birds in 1975. Other threatened bird species in the area include the Tahiti Swiftlet (*Aerodramus leucophaeus*) and Tahiti Monarch (*Pomarea nigra*).
Noteworthy flora: No information.
Management authority and jurisdiction: Responsibility for management of the territorial park rests with the Delegation a l'Environnement.
References: Dahl (1980); IUCN (1991).
Reasons for inclusion: 1a, 2b. The largest river system in French Polynesia.
Source: Yolande Fontaine, Claude Monnet and Jules Cheffort.

Lac Temae (4)

Location: 17°29'S, 149°46'W; at the northeast tip of Moorea island, northwest of the airport, Society Islands.
Area: 18 ha.
Altitude: Sea level.
Overview: A small brackish lagoon surrounded by marshes.
Physical features: Lac Temae is a brackish lagoon with fringing marshes behind a raised beach and barrier reef. The lagoon was formed after the rise in sea level about 5,000 years ago, but is now almost completely silted up. It is fed by brackish groundwater from a layer of sediment that communicates with the sea, and by fresh water from small streams and rivers that drain the surrounding slopes. There is a more or less functional outlet at the northwest end. The maximum depth is over 10 m. The climate is tropical oceanic, with a cool dry season from May to October and a warm rainy season from November to April. Easterly trade winds predominate from October to March.

Ecological features: There is a belt of *Typha domingensis* on the beach side of the lagoon and a belt of *Acrostichum aureum* on the southwest (mountain) side.
Land tenure: Non-transferable public property.
Conservation measures taken: None.
Conservation measures proposed: It has been proposed that the lagoon be designated as a protected area, especially the southeastern part.
Land use: A road passes along the western shore of the lake. There is a hotel near the south end, and an airport immediately to the southeast.
Possible changes in land use: There are proposals to create an 18-hole golf course in the area, and to extend the runway of the nearby airport into the catchment area of the lagoon.
Disturbances and threats: In 1979, a natural sill at the outlet of the lagoon was lowered; since then the salinity of the lake and the swamps has risen considerably, destroying the natural vegetation, disturbing the aquatic fauna, and favouring the spread of *Culicoides belkini* (a blood-sucking gnat introduced accidentally). Other threats include disturbance from the nearby airport, pollution from unregulated discharge of domestic waste, the spread of housing along the adjacent coast and the introduction of mangroves.
Hydrological and biophysical values: No information.
Social and cultural values: No information.
Noteworthy fauna: A feeding area for the Pacific Black Duck (*Anas superciliosa*) and a stopover site for migratory shorebirds, notably Wandering Tattler (*Heteroscelus incanus*) and Pacific Golden Plover (*Pluvialis fulva*).
Noteworthy flora: No information.
Scientific research and facilities: The hydrological aspects of the lagoon have been described by Burlot *et al.* (1985), Pouchon *et al.* (1985) and Faissolles (1988). Studies have also been carried out on the biology of *Culicoides belkini* and migratory birds.
Management authority and jurisdiction: No information.
References: Burlot *et al.* (1985); Faissolles (1988); Polynesian Society of Water, Electricity and Waste (1990); Pouchon *et al.* (1985).
Reasons for inclusion: 1d, 3b. The lagoon is an example of a hydrobiological system which is rare in Polynesia, and is important habitat for *Anas superciliosa* and migratory shorebirds.
Source: Yolande Fontaine, Claude Monnet and Jules Cheffort.

Roto Rahi and Roto Itii (5)

Location: 17°40'S, 150°38'W; in the interior of Maiao Island, Society Islands.
Area: Roto Rahi c.300 ha; Roto Iti c.150 ha.
Altitude: Sea level.
Overview: Two large brackish lagoons with extensive marshes on an "almost atoll".
Physical features: Maiao is an "almost atoll" of 9.5 sq.km with a volcanic ridge to 154 m and fringing coral flats and barrier reef. Much of the interior of the island is occupied by two large brackish lagoons with extensive fringing marshes. Both lagoons are connected to the sea by narrow channels and are connected to one another by a channel which links the southeast corner of Roto Iti to the northern end of Roto Rahi. The climate is tropical oceanic, with a cool dry season from May to October and a warm rainy season from November to April. Easterly trade winds predominate from October to March.
Ecological features: Fresh to brackish water marshes.
Land tenure: Public (Domaine Public Maritime et Fluvial).
Conservation measures taken: None.
Land use: Crab harvesting; coconut plantations in surrounding areas.
Disturbances and threats: No information.

Hydrological and biophysical values: No information.
Social and cultural values: There is a site of archaeological interest on the southeast shore of Roto Iti (Ahu Tii).
Noteworthy fauna: No information.
Noteworthy flora: No information.
Management authority and jurisdiction: No information.
References: Dahl (1986).
Reasons for inclusion: 1a.
Source: Yolande Fontaine.

Lac Maeva (6)

Location: 16°42'S, 151°00'W; at the north end of Huahine island, west of the village of Maeva, Society Islands.
Area: 375 ha.
Altitude: Sea level.
Overview: A brackish pond, almost closed off from the sea and bordered in the west by a wide, intermittently flooded swampy area.
Physical features: Maeva Lake (Lac Fauna Nui) is a relict of the once much larger Maeva Lagoon, a lagoon of Quaternary origin which has now largely silted up. The maximum depth is 6.1 m. The lagoon is connected to the open sea by a narrow channel at its southeast end, but variations due to the tide are slight, as the tidal range in the area is only about 20 cm. The climate is tropical oceanic, with a cool dry season from May to October and a warm rainy season from November to April. Easterly trade winds predominate from October to March.
Ecological features: No information.
Land tenure: Non-transferable public waters (riverine, lagoonal or maritime according to the degree of salinity).
Conservation measures taken: Certain archaeological structures around the lake have been listed.
Conservation measures proposed: It has been proposed that an administrative management plan be developed, taking into account, in particular, the archaeological sites. Additional archaeological structures should be listed, and a protection zone designated around the listed sites.
Land use: None at the wetland. The small village of Maeva lies close by, and some adjacent land is used for agricultural purposes. Sand extraction occurs in the area, and there are numerous fallow plots.
Possible changes in land use: There are proposals for a large-scale hotel project and urban development project in the area.
Disturbances and threats: The swampy area to the west of the lake, important for bird life, is gradually being encroached upon by human settlement, and a major development project has recently been initiated in the area. There is some disturbance from the nearby Huahine airport. The cultivation of melons and water melons on the adjacent coral formations uses techniques that threaten the environment and pollute the groundwater. In particular, there is a risk that pesticides and fertilizers will enter the lagoon. Numerous land-fills have been permitted on public property.
Hydrological and biophysical values: No information.
Social and cultural values: There is an important archaeological site at the wetland. In recent years, local inhabitants have supplemented their incomes by harvesting cockles.
Noteworthy fauna: No information.
Noteworthy flora: No information.
Management authority and jurisdiction: No information.
References: Gabrie (1988); Universite de Bordeaux (1988).
Reasons for inclusion: 1a. A noteworthy cultural and archaeological site and a lagoon with high

primary productivity.
Source: Yolande Fontaine, Claude Monnet and Jules Cheffort.

Wetlands of Tuherahera Motu (7)

Location: 15°00'S, 148°10'W; in Tikehau Atoll, between Mataiva Atoll and Rangiroa Atoll near the northwestern end of the Tuamotu Archipelago.
Area: Unknown.
Altitude: Sea level.
Overview: Small swampy areas located in the middle of a tiny coral islet ("motu") in Tikehau Atoll.
Physical features: Tikehau is a circular atoll with a diameter of 25-28 km and over 150 small islets or "motu" around the central lagoon. On one of these motu (Tuherehera), there are several low, elongated basins, running east to west in the centre of the island, which are temporarily flooded after heavy rains. When the basins are dry, the groundwater is located at a depth of about 20 cm. The climate is tropical oceanic, with an annual rainfall of 1,000-1,900 mm. There is a cool dry season from May to October and a hot rainy season from November to April. Easterly trade winds predominate except during bad weather when the winds are from the west.
Ecological features: No information.
Land tenure: No information.
Conservation measures taken: None.
Land use: None at the wetlands. The wetlands are surrounded by coconut palm plantations, and there is an airstrip on the island. The population of Tikehau Atoll was 266 in 1983.
Disturbances and threats: The proposed expansion of the airstrip would destroy much of the wetland habitat.
Hydrological and biophysical values: No information.
Social and cultural values: No information.
Noteworthy fauna: The Spotless Crake (*Porzana tabuensis*) occurs in the swampy vegetation. Tikehau Atoll supports good populations of the Atoll Fruit Dove (*Ptilinopus coralensis*), Blue Lorikeet (*Vini peruviana*) and Tuamotu Reed Warbler (*Acrocephalus atypha atypha*).
Noteworthy flora: No information.
Management authority and jurisdiction: No information.
References: Dahl (1986).
Reasons for inclusion: 1d. A good example of a natural swampy area in the interior of a motu; a rare habitat type in the Tuamotus.
Source: Yolande Fontaine, Claude Monnet and Jules Cheffort.

Niau Atoll (8)

Location: 16°10'S, 146°22'W; near the west end of the Tuamotu Archipelago, 280 km west of Makemo and 350 km east-northeast of Tahiti.
Area: 5,400 ha (lagoon 3,300 ha, land area 2,100 ha).
Altitude: Sea level.
Overview: A large enclosed lagoon with fringing marshes on a small atoll.
Physical features: Niau is an elliptical atoll comprising a single island with a broad fringing reef and completely enclosed central lagoon. The narrow strip of land surrounding the lagoon has a maximum elevation of 5 m. There is a narrow belt of marsh vegetation around the edge of the lagoon, which is presumably brackish, and there is apparently some freshwater marsh (Dahl, 1980).

The climate is tropical oceanic, with an annual rainfall of 1,000-1,900 mm. There is a cool dry season from May to October and a hot rainy season from November to April. Easterly trade winds predominate except during bad weather when the winds are from the west.
Ecological features: No information.
Land tenure: No information.
Conservation measures taken: None.
Land use: The island is intensively cultivated (gardens and coconut plantations), and there is a small village (Tupana) on the northeast side.
Disturbances and threats: No information.
Hydrological and biophysical values: No information.
Social and cultural values: No information.
Noteworthy fauna: No information is available on the fauna of the lagoon. The subspecies *gertrudae* of the Tuamotu Kingfisher (*Halcyon gambieri*) is endemic to the island of Niau. The bird is widespread in gardens and coconut groves; the population was estimated at 400-600 birds in 1974. The nominate race of this species, confined to the island of Mangareva, became extinct, probably before 1922 (Collar and Andrew, 1988). The island also has an endemic subspecies of the Tuamotu Reed Warbler (*Acrocephalus atypha niauensis*), which is reportedly common.
Noteworthy flora: No information.
Management authority and jurisdiction: No information.
References: Collar & Andrew (1988); Dahl (1980, 1986).
Reasons for inclusion: 1d. Possibly the most extensive fresh to brackish water marshes in the Tuamotus.
Source: Yolande Fontaine.

Taiaro Atoll (9)

Location: 15°42'S, 144°34'W; in the Tuamotu Archipelago, 230 km west of Raroia Atoll and 540 km east-northeast of Tahiti.
Area: 2,000 ha.
Altitude: Sea level to 5 m.
Overview: A small circular atoll with an enclosed saline lagoon permanently isolated from the sea since about 1900.
Physical features: Taiaro Atoll is an almost circular atoll comprising a single island 5 km in diameter with a large enclosed lagoon. The lagoon is permanently isolated from the sea, except possibly during severe storms. It is more or less uniformly deep (20-25 m) with a maximum depth of 29 m. The emergent rim of the island is 700 m wide at its widest, and has a circumference of 12 km. This rim is now continuous, but there are 18 closed channels ("hoa") blocked by boulders which were probably deposited by a tidal wave between 1878 and 1906. With a salinity of 43 p.p.t., the water of the lagoon is slightly saltier than that of the ocean (36 p.p.t.), this being due to excessive evaporation. In recent years, the water level has been falling slowly and the salinity gradually increasing.
The climate is tropical oceanic, with an annual rainfall of 1,000-1,900 mm. There is a cool dry season from May to October and a hot rainy season from November to April. Easterly trade winds predominate except during bad weather when the winds are from the west.
Ecological features: There are three main habitats along the lagoon shore: sandy detritus, coral pavement and algae. Most of the island is covered with an open bush vegetation including *Lepidium* spp., *Morinda citrifolia*, *Pandanus* spp., *Suriana* spp., *Pemphis acidula*, *Erithalis polygama*, *Petesia carnosa*, *Guettarda speciosa*, *Scaevola* sp., *Tournefortia* spp., *Pentacarya anoniala*, *Myoporum* spp., *Boerhavia* spp., *Achyrantes* spp., *Cassytha* spp., *Euphorbia ramosissima*, *Urtica* spp., *Digitaria* spp., *Psilotum* spp., *Polypodium* spp., *Asplenium* spp. and *Ramalina* spp. There are some coconut palms (*Cocos nucifera*), but

far fewer than on most other atolls in the Tuamotus.
Land tenure: Private property; owned by W.A. Robinson.
Conservation measures taken: The lagoon was proclaimed a strict nature reserve (Reserve Integrale W.A. Robinson) by its owner, with the agreement of the Governor of French Polynesia by Decree No.2456/AA of 1 August 1972. In February 1973, the reserve was extended to cover the entire atoll and a surrounding protective offshore buffer zone one km wide. The reserve was accepted as a Biosphere Reserve in January 1977. There is close cooperation between the owner of the atoll, the Administrative Committee of the reserve and the Governor of French Polynesia for the protection of the atoll, lagoon and surrounding sea. The management objectives are currently being reviewed.
Land use: Scientific research. Until recently, the atoll was inhabited by the guardian of the reserve and his family. Access to the reserve is restricted to scientists who have been granted permission by the Administrative Committee, and there is no fishing or tourism.
Disturbances and threats: Several plant species, including the coconut palm, appear to have been introduced onto the island in the past. The only known threat at present is the natural threat of cyclones.
Hydrological and biophysical values: No information.
Social and cultural values: During the 1700s, the island was the centre of a small but flourishing Polynesian kingdom, and is now of some archaeological interest.
Noteworthy fauna: The lagoon supports an abundant fish and invertebrate fauna with 55 species of fish, 104 species of molluscs, three sponges and two echinoderms. Of the molluscs, the giant clam *Tridacna maxima*, *Pinctada maculata*, *Codakia divergens* and *Gafrarium pectinatum* are particularly abundant. There is, however, only one species of coral, *Porites lobata*, which occurs down to a depth of 1.5 m. In the past, the lagoon coral fauna was much richer, several fossil species having been recorded.
Coconut crabs (*Birgus latro*) occur on the island, and there are some breeding seabirds. The fauna of the outer reefs is summarized by UNEP/IUCN (1988).
Noteworthy flora: No information.
Scientific research and facilities: Research has been carried out on two species of mosquito (one indigenous and one introduced) by the Pacific Research Section of the National Institute of Allergy and Infectious Diseases based in Honolulu, Hawaii. Scientists from the Museum National d'Histoire Naturelle (Paris) and the Ecole Pratique des Hautes Etudes (Tahiti) visited the atoll in 1972 to study the fauna, flora and geomorphology of the island and the hydrology of the lagoon. The owner of the island provides accommodation for visiting scientists.
Management authority and jurisdiction: The reserve is administered by the Administrative Committee Secretariat based at the Delegue de la Commission des Monuments Naturels et Sites in Tahiti.
References: Dahl (1986); IUCN (1991); UNEP/IUCN (1988).
Reasons for inclusion: 1a, 2b. The atoll offers excellent opportunities for research into the ecology and evolution of atoll lagoon ecosystems as well as the archaeology of the region.
Source: See references.

Tahanea Atoll (10)

Location: 16°50'S, 144°45'W; in the west-central Tuamotu Archipelago, 100 km west-southwest of Makemo and 475 km east-northeast of Tahiti.
Area: Unknown.
Altitude: Sea level.
Overview: A large uninhabited atoll with numerous tiny islets ("motu"), important for the Tuamotu Sandpiper.

Physical features: Tahanea is a large atoll, approximately 48 km long by 15 km wide, with about 55 small islets ("motu") around a large lagoon. There are three deep channels between motu on the north side of the lagoon. The tides are semi-diurnal with an amplitude of about 40 cm. The climate is tropical oceanic, with an annual rainfall of 1,000-1,900 mm. There is a cool dry season from May to October and a hot rainy season from November to April. Easterly trade winds predominate except during bad weather when the winds are from the west.
Ecological features: Beach communities, atoll scrub and coconut plantations.
Land tenure: Many of the key motu for Tuamotu Sandpipers are owned by Michael Tapi on Faaite Atoll.
Conservation measures taken: None.
Conservation measures proposed: Lovegrove *et al.* (1989) recommended that some of the motu be given reserve status to safeguard their breeding populations of Tuamotu Sandpipers. Recognizing that there was already much sympathy and fondness for the sandpipers ("titi") amongst the inhabitants of neighbouring atolls, Lovegrove *et al.* suggested that an education programme be developed with appropriate islanders to help persuade them of the importance of maintaining the Tuamotu Sandpipers, and how this might be done.
Land use: The atoll is not permanently inhabited, although there are coconut plantations on some of the motu.
Disturbances and threats: The Tuamotu Sandpiper is extremely vulnerable to predation from introduced rats and cats. Every effort should be taken to prevent the accidental introduction of these or other predators onto motu with breeding sandpipers. Pigs have already been introduced onto some of the larger motu, and these would almost certainly render the islets unsuitable for the birds by destroying the dense vegetation and leaf litter which seems to be important to the species (Lovegrove *et al.*, 1989).
Hydrological and biophysical values: No information.
Social and cultural values: No information.
Noteworthy fauna: Good populations of Tuamotus Sandpipers (*Prosobonia cancellatus*) were discovered on four tiny motu on the south side of the atoll in April 1989 (Lovegrove *et al.*, 1989). The one motu which was surveyed properly (Tohete motu, only 100 m long by 60 m wide) held 12-15 sandpipers. Similarly high densities were found on the three other motu visited, and it was thought that there could be many more motu with sandpipers. Five other species of waterbirds were recorded in small numbers during this brief survey: Pacific Reef Heron (*Egretta sacra*), Pacific Golden Plover (*Pluvialis fulva*), Wandering Tattler (*Heteroscelus incanus*), Bristle-thighed Curlew (*Numenius tahitiensis*) and Great Crested Tern (*Sterna bergii*). Breeding seabirds included large numbers of Greater Frigatebird (*Fregata minor*), Red-footed Booby (*Sula sula*), Brown Noddy (*Anous stolidus*) and Black Noddy (*A. minutus*). The only land birds on the atoll, Atoll Fruit Dove (*Ptilinopus coralensis*) and Tuamotu Reed Warbler (*Acrocephalus atypha*), were both moderately common.
Noteworthy flora: No information.
Scientific research and facilities: Four of the motu on the south side of the atoll were visited by ornithologists in April 1989 (Lovegrove *et al.*, 1989).
Management authority and jurisdiction: No information.
References: Lovegrove *et al.* (1989).
Reasons for inclusion: 2a. One of the few atolls still known to support a good population of the Tuamotu Sandpiper.
Source: See references.

Raevski Atolls (11)

Location: Tepoto Atoll 16°50'S, 144°16'W; Hiti Atoll 16°45'S, 144°05'W; Tuanake Atoll 16°40'S, 144°12'W; in the west-central Tuamotu Archipelago, 45-65 km southwest of Makemo.

Area: Unknown.
Altitude: Sea level.
Overview: A group of three small uninhabited atolls in the west-central Tuamotus, thought to be important for the Tuamotu Sandpiper.
Physical features: Tepoto Atoll is a small atoll, approximately 4 km long by 3 km wide, with two main islands and one small pass into the central lagoon. Hiti Atoll, 20 km to the east-northeast, is slightly larger (9 km by 6 km), with one large island and no deep entrance to the central lagoon. Tuanake Atoll, 20 km north-northeast of Tepoto, is intermediate in size (8 km by 6 km), with two large and four small islands and a single narrow pass into the central lagoon. The tides are semi-diurnal with an amplitude of about 40 cm. The three atolls together comprise the Raevski Group.
Ecological features: Atoll scrub, sandy beaches and reef flats.
Land tenure: No information.
Conservation measures taken: None.
Land use: None of the atolls is permanently inhabited, although there is some seasonal occupation.
Disturbances and threats: No information.
Hydrological and biophysical values: No information.
Social and cultural values: No information.
Noteworthy fauna: Tuamotu Sandpipers (*Prosobonia cancellatus*) were discovered on all three atolls in the 1920s. The islands do not appear to have been visited by ornithologists since then. However, Lovegrove *et al.* (1989) were informed by fishermen from neighbouring atolls that there were still "plenty" of sandpipers (locally known as "titi") on Hiti and Taunake when they last visited these atolls in 1984. The fishermen had no reason to suppose that the birds had disappeared since then, and also indicated that the species might still exist on Tepoto.
Noteworthy flora: No information.
Management authority and jurisdiction: No information.
References: Dahl (1986); Lovegrove *et al.* (1989).
Reasons for inclusion: 2a. Possibly an important group of atolls for the Tuamotu Sandpiper.
Source: Yolande Fontaine and references.

Maturea du Sud and Maturei Vavao Atolls (12)

Location: Maturea du Sud, 22°00'S, 135°00'W; Maturei Vavao 21°45'S, 136°00'W; in the southeastern part of the Tuamotu Archipelago.
Area: Unknown.
Altitude: Sea level.
Overview: Two uninhabited, rat-free atolls in the southeastern Tuamotus, important for the Tuamotu Sandpiper.
Physical features: Maturea du Sud is a large atoll, approximately 18 km long, with many small islets ("motu") and one deep pass into the central lagoon. Maturei Vavao, in the Actaen Group, is a low atoll with an enclosed lagoon. The tides are semi-diurnal with an amplitude of about 40 cm.
Ecological features: Atoll scrub, sandy beaches and reef flats. Both atolls are free of introduced Brown Rats (*Rattus rattus*).
Land tenure: No information.
Conservation measures taken: None.
Conservation measures proposed: Dahl (1980) has recommended the establishment of reserves on some of the motu in Maturei Vavao Atoll to protect the threatened birds (Tuamotu Sandpiper and Polynesian Ground Dove) and the atoll vegetation.
Land use: Both atolls are used for the cultivation of coconuts, and are visited for the harvest, but neither is permanently inhabited. There is some pearl fishing at Marutea du Sud.

Disturbances and threats: Vegetation on Maturei Vavao has been cleared for replanting of coconut plantations, and this may have affected bird habitats (Dahl, 1986).
Hydrological and biophysical values: No information.
Social and cultural values: No information.
Noteworthy fauna: The Tuamotu Sandpiper (*Prosobonia cancellatus*) was found commonly on both atolls in 1969, and was presumed to be breeding. The threatened Polynesian Ground Dove (*Gallicolumba erythroptera erythroptera*) was recorded as uncommon on Maturei Vavao in 1968 (Lacan and Mougin, 1974). This is the only site at which the species has been recorded in recent decades (Hay, 1985). (The other subspecies, *G. e. pectoralis*, which is known only from the Society Islands, may now be extinct).
Noteworthy flora: No information.
Scientific research and facilities: Lacan and Mougin (1974) have surveyed the avifauna of the two atolls, while Renaud-Mornant *et al.* (1970) have studied the benthos of the lagoon. The atolls do not appear to have been visited by biologists since the 1960s.
Management authority and jurisdiction: No information.
References: Dahl (1980, 1986); Hay (1985); Lacan & Mougin (1974); Renaud-Mornant *et al.* (1970).
Reasons for inclusion: 2a. Important atolls for two threatened species, the Tuamotu Sandpiper and Polynesian Ground Dove, when last surveyed in the 1960s.
Source: See references.

Wetlands of Rurutu Island (13)

Location: 22°28'S, 151°20'W; near the western end of the Austral Islands, 550 km south-southwest of Tahiti.
Area: Unknown.
Altitude: Sea level.
Overview: Small riverine wetlands along the lower courses of the island's major rivers, utilized for the cultivation of taro.
Physical features: Rurutu Island is a volcanic high island with a fringing coral reef, some elevated limestone reefs, and a rugged interior rising to a peak at 389 m. The island is approximately 11 km long by 3.5 km wide and has an area of 29 sq.km. Small rivers rising in the interior of the island create swampy areas along their lower courses, and these have been modified by the local inhabitants for the cultivation of taro.
Ecological features: Riverine wetlands under cultivation for taro (*Colocasia esculenta* and *Cyrtosperma* sp.). Natural plant communities on the island include limestone forest in the lowlands, and grassland and fernland on the upper slopes with forest remnants in ravines. However, most of the native forest has been destroyed by burning and overgrazing by feral goats and cattle.
Land tenure: No information.
Conservation measures taken: None.
Land use: Cultivation of taro. There were about 1,970 inhabitants on the island in 1983.
Disturbances and threats: Reclamation of land from public maritime waters to circumvent the problem of collective ownership of land. Several hectares of wetland have already been filled for collective use.
Hydrological and biophysical values: No information.
Social and cultural values: No information.
Noteworthy fauna: No information.
Noteworthy flora: No information.
Management authority and jurisdiction: No information.
Reasons for inclusion: 1a. Traditional agricultural areas threatened with destruction by land fills.

Source: Yolande Fontaine, Claude Monnet and Jules Cheffort.

Clipperton Island (14)

Location: 10°18'N, 109°13'W; in the East Pacific, 1,300 km from the Pacific coast of Mexico, 2,800 km from Hawaii and 5,200 km from Tahiti.
Area: 600 ha.
Altitude: Sea level to 5 m (volcanic plug 29 m).
Overview: An isolated "near atoll" with a completely enclosed lagoon; the only atoll in the East Pacific east of Ducie (Pitcairn Islands). The lagoon is of considerable limnological interest, and the fauna and flora are of biogeographical interest on account of their Indo-Pacific and American relationships.
Physical features: Clipperton Island is an egg-shaped "near atoll" with a completely enclosed lagoon oriented northwest-southeast. The atoll rim consists of a narrow band of rock generally 100-200 m wide, but reaching 400 m wide in the west and narrowing to 45 m in the northeast where waves occasionally spill over into the lagoon. There is a small volcanic plug covered with lichens and guano at the southeast end of the island. The island is surrounded by a reef flat exposed at low tide. The closed lagoon has permanently deoxygenated water; there is a strong halocline, and the waters are highly eutrophic and almost fresh at the surface. The climate is tropical oceanic. Northeasterly trade winds predominate, but are replaced occasionally in the summer by tropical storms and sometimes cyclones from the southeast.
Ecological features: Higher plants and algae are reported to be abundant in the lagoon. The island is largely covered with scrub vegetation, but there are a few coconut palms.
Land tenure: French Government.
Conservation measures taken: None.
Conservation measures proposed: The island is to be legally protected by the French Government, but this is expected to take some time to implement. Visits by tuna fishermen should be prohibited. It has been recommended that the island be protected as a natural laboratory for scientific studies.
Land use: Phosphate was worked from 1898 to 1917, but the island is now uninhabited although it is sometimes visited by U.S. tuna fishermen. Meteorological stations have occasionally been set up on the island. Access is difficult because of the heavy oceanic swell.
Disturbances and threats: Coconuts were planted in 1897. Introduced pigs were destroyed in 1958 to prevent a decline in seabird populations. There is a possibility that a permanent meteorological and/or satellite observation post could be set up on the island. This would be likely to have a major effect on the atoll. There is also a proposal to open up the lagoon in order to build a port.
Hydrological and biophysical values: The closed lagoon is of particular interest as a model for modern formation and sedimentation of phosphate and carbonate diagensis. Apatite has been discovered in the intertidal modern deposits along the shore.
Social and cultural values: None known.
Noteworthy fauna: The lagoon supports an impoverished invertebrate fauna. Breeding seabirds include a frigatebird (*Fregata* sp.), two boobies (*Sula* spp.), two noddies (*Anous* spp.) and two terns (*Sterna* spp.). Other fauna includes the lizard *Emoia cyanura* and the crab *Geocarcinus planatus*.
Noteworthy flora: No information.
Scientific research and facilities: A number of scientific expeditions have visited the islands; these are listed by Sachet (1958) and UNEP/IUCN (1988). Studies of the invertebrate fauna of the lagoon are listed in UNEP/IUCN (1988).
Management authority and jurisdiction: The island is under the authority of the Governor of French Polynesia.

References: Sachet (1958); UNEP/IUCN (1988).
Reasons for inclusion: 1a, 2b. Clipperton is one of the least altered island systems in the Pacific. The fauna and flora consist of an unusual assemblage including both Panamic (American) and Indo-Pacific forms.
Source: UNEP/IUCN (1988).

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GUAM

INTRODUCTION

by Gary J. Wiles and Michael W. Ritter

Area: 540 sq.km.

Population: 133,150.

Guam (13°28'N, 144°45'E), a territory of the United States, is the largest and southernmost island of the Mariana Islands in western Micronesia. Northern Guam is characterized by a large uplifted limestone plateau fringed near the ocean by tall cliffs and steep hillsides that descend to narrow terraces or directly into the sea. The southern portion of the island is volcanic in origin, although some hills are capped with limestone, with a tall ridge dissected by deeply eroded ravines running along the southwestern coast. Elevations range from sea level to 180 m in the north and 400 m in the south.

The climate is warm and humid throughout the year. Daily temperatures vary from 31-33°C in the daytime to 24-26°C at night. There is a dry season from January to April and a rainy season from July to mid-November. The other months are transitional periods that may be either rainy or dry depending on the nature of the particular year. Mean annual rainfall ranges from 2,100 mm in central Guam to 2,850 mm on the upper slopes of the southern mountains. On average, about 55% of the rainfall occurs in the rainy season and 15% during the dry season, with the remainder falling during transitional months. The prevailing winds blow from the northeast or east for much of the year. The island is regularly affected by typhoons, which bring heavy winds and rains.

Guam shares a large number of plant and animal species with the Commonwealth of the Northern Mariana Islands, which administers the other 14 islands in the archipelago. The native biota of the island chain have strong Australasian affinities. Most of Guam's human population lives in suburban areas in the central and north-central parts of the island. During the last decade, the economy has progressively become based more on tourism and less on military spending and federal and local government programs.

Summary of Wetland Situation

Guam has considerably more wetlands and a wider variety of types than any of the other Mariana Islands. All of its rivers and nearly all wetlands occur in the southern and central parts of the island, where clay or argillaceous limestone soils retard water percolation and permit surface waters to accumulate. Many interior wetlands are located along the upper drainages of rivers and smaller tributaries. In contrast, the northern limestone plateau allows rapid water seepage, and consequently only a few marshy areas and ephemeral streams exist in the vicinity of Mt Santa Rosa. Four basic categories of wetlands are described below, with larger sites often having more than one type.

Freshwater swamps of woody vegetation are the largest category of wetland (Yuen, in press) and may be found on the edges of marshes, along river courses, and in wet depressions in forests. *Hibiscus tiliaceus* is usually the major species involved, although the largest tract of swamp forest on the island, the Talofofo River Valley, is dominated by *Barringtonia racemosa* (Fosberg, 1960). Other trees that may be present are *Pandanus tectorius*, *Cynometra ramiflora* and *Areca catechu*.

Natural freshwater marshes are also common, with individual sites varying in size from the Agana Swamp (with about 96 ha of marshland) to many that are less than 0.5 ha. Most are dominated by dense, nearly pure stands of *Phragmites karka* that are 2-5 m tall (Fosberg, 1960). Other grasses (*e.g. Panicum muticum*), sedges (*e.g. Eleocharis ochrostachys* and *Cyperus* spp.) and the fern *Acrostichum aureum* are often present but usually less prevalent.

Man-made freshwater wetlands were originally constructed as water impoundments for humans, cattle and crop irrigation, and are found widely through southern Guam. Many are no longer used but they continue to collect water and maintain aquatic ecosystems. The largest is Fena Lake (81 ha), which still functions as an important reservoir for drinking water. Other sites are much smaller and tend to have deeper, more open water than natural marshes. Vegetation is variable, but *Phragmites* and *Hibiscus* are usually minor components. A number of these sites are crucial to the preservation of Common Moorhens (*Gallinula chloropus guami*) (Stinson *et al.*, 1991). Ten of the 19 wetlands described in this report are artificial.

Estuarine wetlands occur in areas of tidal intrusion or brackish water, and consist primarily of mangroves and the lower channels of rivers. These habitats are facilitated by a daily tidal variation of about 75-90 cm. The largest concentrations of mangroves exist along the eastern shores of Apra Harbor, with smaller zones present in Merizo and Inarajan. Although they only total about 70 ha (Yuen, in press), Guam's mangroves are the most extensive and diverse in the Mariana Islands. Species include *Rhizophora mucronata*, *R. apiculata*, *Bruguiera gymnorrhiza*, *Avicennia marina*, *Lumnitzera littorea*, *Nypa fruticans*, *Xylocarpus moluccensis*, *Heritiera littoralis*, *Hibiscus tiliaceus* and *Acrostichum aureum* (Fosberg, 1960; Moore *et al.*, 1977). Nine of the island's 46 rivers that empty into the ocean have true estuarine zones. The lower channels of these rivers, which are typically only 5-20 m wide and 1-4 m deep, have elevated salinity levels that extend 0.5-1.6 km upstream (Wilder, 1976). *Nypa fruticans* is a common indicator plant of river zones with brackish water regimes. Marshes of bulrushes (*Scirpus littoralis*) are a third estuarine community, and are found at several locations in Apra Harbor. The largest area is the artificial San Luis Ponds.

Significant losses of wetland have occurred historically on Guam, although it is difficult to quantify the extent of the losses. Reclamation of wetlands by the U.S. military was extensive in and around Apra Harbor from 1945 to 1950 during the expansion of port facilities by the Navy. An estimated 500 ha of land area was filled during this period (U.S. Navy, 1978), and involved the destruction of mangrove communities fringing the eastern harbour and freshwater wetlands along the Sasa, Atantano and Namo Rivers and at the present-day Naval Station. Smaller fills have also occurred more recently at several of these sites, one of which was the expansion of a garbage dump into the Naval Station Marsh. At the Agana Swamp, filling along the edges was a chronic problem until about 1980. The original building of a coastal highway around the southern half of Guam by the Spanish, and subsequent improvements, resulted in the laying of a roadbed across wetlands next to river mouths and likely altered natural drainage patterns. From the 1970s to mid-1980s, several sets of aquaculture ponds were constructed in wetlands along the Talofofo, Agfayan and Ajayan Rivers, and resulted in vegetation loss. These businesses have not been highly profitable and there has been little desire to build additional facilities. About 20 ha of ponds at four sites are currently in operation.

General land development has accelerated on Guam during the last several decades. Despite the wishes of many developers, regulatory agencies have been successful in greatly reducing the number of wetland fills during the past decade. This has been accompanied by improved enforcement of protective regulations. One well-publicized violation occurred in Yona during the early stages of construction of the huge Manengon Hills resort, which is Japanese owned. Contractors filled 2.5 ha of marshes and diverted several stream channels without approval.

Government agencies placed a stop-work order on the project and halted all work for several months at a tremendous loss to the owners, who were eventually fined US$1.3 million for their violations. The company was also forced to restore the damaged sites to their original condition.

Grassland fires during the dry season have been a serious ecological problem for many years. Many of the fires are deliberately started, and can produce significant soil erosion, resulting in large amounts of sediments being washed into rivers and wetlands. Heavy soil loads have undoubtedly altered many wetland ecosystems by greatly increasing turbidity and sedimentation. Infilling allows the encroachment of new plant species, particularly *Phragmites*, and may eventually result in the shrinkage or loss of wetlands.

Poorly planned developments may affect wetlands adversely in other ways, particularly by increasing erosion through careless construction practices. The owners of several proposed golf courses and resorts have requested that they be allowed to pump water from rivers to meet their irrigation and drinking water needs. Such pumping of large volumes of water may result in reduced seasonal stream-flow and increased saltwater intrusion upstream.

Nearly half of the wetlands (nine of the 19 sites) described in this report suffer from various forms of pollution. The most serious cases have been oil spills in the Atantano and Sasa Bay wetlands, contamination from hazardous wastes and heavy metals at the Shell Oil, Atantano, Namo River and Naval Station sites, and chronic run-off of pollutants from adjoining urban areas at the Agana Swamp and Barrigada Ponding Basin.

Prehistoric cultivation of crops was probably widespread in Guam's wetlands. Rice, taro and vegetables were grown at many sites from the 1800s until World War II (Safford, 1905; Thompson, 1947). Farming of wetlands has declined significantly since the war and is no longer widely practised. Most former fields have reverted to marshy or swampy vegetation, but it is not known how closely these resemble the original floral conditions. It is likely that few undisturbed freshwater swamps remain (Stemmermann, 1981).

As previously noted, many marshes are characterized by dense *Phragmites* growth. Although this reed is indigenous to Micronesia, it is possible that various disturbances to wetlands (*e.g.* farming) have increased its abundance. It generally provides marginal habitat for most wetland birds, is a severe fire hazard during the dry season and chokes out other wetland plants.

Historically, four species of birds were dependent on Guam's wetlands. Three of these, the Marianas Mallard (*Anas oustaleti*), White-browed Crake (*Porzana cinerea*) and Nightingale Reed-warbler (*Acrocephalus luscinia*), became extirpated between 1945 and 1970. The fourth species, the Common Moorhen, is endangered and has an estimated population of 100-125 birds (U.S. Fish and Wildlife Service, 1991; Stinson *et al.*, 1991). Over-hunting of mallards and loss of habitat for moorhens are thought to be the major reasons for their declines. Recent observations suggest that tilapia (*Oreochromis mossambicus*) may reduce moorhen densities through competition (Stinson *et al.*, 1991). Causes for the losses of the crake and reed-warbler are unclear, but may have included pesticide use, predation by introduced Brown Tree Snakes (*Boiga irregularis*) and marsh fires (Reichel *et al.*, 1992).

Small numbers of migratory shorebirds, ducks and herons annually visit and overwinter in the island's wetlands (see Reichel and Glass, 1991). Yellow Bitterns (*Ixobrychus sinensis*) commonly nest and feed in freshwater marshes (Jenkins, 1983). Guam's native forest birds, which have been almost totally eliminated because of snake predation (Savidge, 1987; Engbring and Fritts, 1988), no longer reside in any of the island's swamp forests. Over-hunting and perhaps snake predation have caused the nearly complete loss of Marianas Fruit Bats (*Pteropus mariannus*) from these same forests (Wiles, 1987).

A variety of native fish and aquatic invertebrates inhabit the island's rivers and larger freshwater wetlands. These include several gobies (*Awaous guamensis*, *Sicyopterus macrostetholepis* and *Stiphodon elegans*), a flagtail (*Kuhlia rupestris*), a sleeper (*Eleotris fusca*), two eels (*Anguilla marmorata* and *A. bicolor*) and a number of shrimp (*Macrobrachium* spp., *Caridina* spp., *Atya serrata* and *Atyoida pilipes*). Many of the fish have pelagic larval stages. Only one, *Awaous guamensis*, is endemic to the Mariana Islands. All are believed to be fairly widespread on Guam. Various gastropods are also present, including members of the genera *Neritina*, *Neritodryas*, *Septaria*, *Clithon*, *Melanoides*, *Thiara* and *Stenomelania* (B.D. Smith, pers. comm.).

The mangroves in Apra Harbor serve as nursery grounds for jacks (Carangidae), barracudas (Sphyraenidae), snappers (Lutjanidae) and groupers (Serranidae) (G. Davis, pers. comm). Estuarine areas are also inhabited by adult ponyfish (Leiognathidae), rabbitfish (Siganidae), mojarras (Gerreidae), milkfish (*Chanos chanos*), mullets (Mugilidae), mudskippers (*Periophthalmus koelreuteri*), crabs (*Uca* spp., *Cardisoma carnifex* and *Scylla serrata*) and various snails, clams and oysters.

A number of introduced vertebrates have become established in Guam's wetlands. Alien fishes include tilapia (*O. mossambicus* and *Tilapia zilli*), catfish (*Clarius macrocephalus*), tucunare (*Cichla ocellaris*), mosquitofish (*Gambusia affinis*), carp (*Cyprinus carpio*) and guppies (*Poecilia reticulatus*). Several other species are believed to have escaped from aquaculture ponds and started populations in the Ajayan and Agfayan Rivers (R.A. Hensley, pers. comm.). Two species of amphibians, the Marine Toad (*Bufo marinus*) and Dwarf Tree Frog (*Litoria fallax*), breed at many sites, while two types of turtles, the Red-eared Slider (*Trachemys scripta*) and a soft-shelled turtle (*Pelodiscus* sp.), now appear to be reproducing at several locations (M.J. McCoid, pers. comm.). The skink *Carlia fusca* is abundant throughout the island, and is found in many wetlands with seasonally dry substrates.

Wetlands provide little direct economic gain for island residents. A limited amount of fishing and crab hunting takes place, but this is primarily for personal consumption or recreation. The only businesses that are wetland-dependent are four aquaculture facilities and a small tourist boat operation on the Talofofo River. However, Guam's wetlands are more valuable for indirect reasons. They act as natural filters and settling ponds for eroded soils, thereby greatly reducing the amount of sediment dumped on the island's fringing coral reefs. These reefs are a major source of fish for local fishermen and an important tourist attraction. Mangroves serve as important breeding areas for a wide variety of harvestable reef fish. The Agana Swamp has long played a beneficial role by limiting downstream flooding in the city of Agana.

The major criteria for selecting the wetlands listed in this report are size, uniqueness of the site and the presence of moorhens, particularly locations where nesting regularly occurs. Four of the 19 sites contain mangroves and 12 are used by moorhens. Each of the listed sites was field checked in 1990 or 1991. Other important wetlands may be added to the list in the future as more information becomes available.

Wetland Research

A fair amount of research on freshwater and estuarine wetlands was conducted during the 1970s and early 1980s, primarily by staff from the University of Guam (see References). These studies consisted mainly of biological inventories and assessments of basic water quality parameters at several major sites. A largely comprehensive map of the island's wetlands was prepared in 1983 by the U.S. Fish and Wildlife Service. The Division of Aquatic and Wildlife Resources studied the distribution of Common Moorhens at Fena Lake and a number of other locations from 1987 to 1990 (Ritter, 1989; Stinson *et al.*, 1991). Little active field research is currently underway.

Wetland Area Legislation

Regulatory authority for Guam's wetlands rests with the U.S. Federal Government and Government of Guam (Bureau of Planning, 1991). The U.S. Army Corps of Engineers is the primary federal agency with responsibility for wetlands. Its authority is derived mainly from Section 404 of the Clean Water Act, but two other laws also apply, Section 10 of the Rivers and Harbors Act of 1899, and Section 103 of the Marine Protection, Research and Sanctuaries Act of 1972. The U.S. Fish and Wildlife Service, through the U.S. Endangered Species Act, reviews all wetland projects that may affect endangered species. Federal Executive Order 119900, Protection of Wetlands, applies to all federal agencies including the military that have projects involving the wetlands.

The Guam Environmental Protection Agency, acting under the authority of the U.S. Environmental Protection Agency, issues Water Quality Certificates through Section 401 of the federal Clean Water Act. In addition, several executive orders apply to wetlands (Bureau of Planning, 1991). These include:

- Executive Order 78-21, which allows the Territorial Land Use Commission to designate wetlands as Areas of Particular Concern and promulgate a set of Wetland Rules and Regulations;
- Executive Order 78-23, which established conservation districts to protect wetlands and other natural resources;
- Executive Order 78-20, which established flood hazard zones;
- Executive Order 90-13, which requires several local agencies to update wetland regulations;
- Executive Order 90-10, which requires that an Environmental Impact Assessment be written for all new development.

Wetland Area Administration

None of Guam's wetlands is specifically designated as a protected area. The Government of Guam owns parcels of land in several wetlands, including the Agana Swamp and Achang Bay mangroves. It has recently begun to consider the acquisition of high priority wetlands from private landowners, with the goal being to protect these areas. All wetlands on U.S. Navy property have been recommended for preservation in a series of recently drafted management plans for natural resources (Biosystems Analysis Inc., 1990; Anon., in press, a, b, c).

Organizations involved with Wetlands

a) Government of Guam

Department of Agriculture
: The Division of Aquatic and Wildlife Resources conducts research on wildlife and fisheries, and assesses proposed developments that affect wetlands.

Guam Environmental Protection Agency
: Reviews proposed development projects and issues Water Quality Certificates under the authority of Section 401 of the U.S. Clean Water Act. Investigates wetland violations.

Bureau of Planning
: The Coastal Zone Management Program reviews permit applications for development, including those in wetlands, and determines that projects are

consistent with federal regulations.

Department of Land Management

The Planning Division processes development permits to be examined by the Territorial Land Use Commission.

Department of Commerce

Responsible for the planning of aquaculture activities.

b) U.S. Government

Army Corps of Engineers

Reviews and issues Section 404 permits, and investigates wetland violations.

Environmental Protection Agency

Reviews Section 404 permits; however, much of this agency's responsibility has been delegated to the Guam Environmental Protection Agency.

Fish and Wildlife Service

Reviews wetland development projects that are authorized by federal permits, occur on federal lands, or receive federal funding and affect endangered species. Has prepared a recovery plan for moorhens.

Soil Conservation Service

Provides technical assistance to other government agencies on the delineation of wetlands.

c) Universities

University of Guam

Biology Department

Maintains a herbarium and has staff familiar with wetland ecology and plant identification.

Marine Laboratory

Conducted various wetland research projects in the 1970s and early 1980s. Staff are knowledgeable of estuarine and freshwater fauna.

Water and Energy Resources Institute

Conducts research on surface and groundwater quality, including studies on pesticide and heavy metal contamination and soil run-off.

College of Agriculture and Life Sciences

Administers extension programs relating to aquaculture.

d) Non-Governmental Organizations

Marianas Audubon Society

Conducts bird counts at several wetlands and promotes conservation of natural resources on the island.

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WETLANDS

Site descriptions compiled by Gary J. Wiles and Michael W. Ritter of the Division of Aquatic and Wildlife Resources, Guam.

Agana Swamp (1)

Location: 13°28'N, 144°45'E; the marsh is located in west-central Guam in the municipalities of Agana, Sinajana and Mongmong-Toto-Maite. It is found 250 m southeast of the intersection of Highway 4 and O'Brien Street (Highway 7).
Area: 112 ha.
Altitude: 1-3 m.
Overview: Long referred to as the Agana Swamp, this is Guam's largest natural freshwater marsh. It is vegetated primarily with dense stands of *Phragmites karka*. Common Moorhens (*Gallinula chloropus guami*) nest here. The site is largely surrounded by urban and suburban development.
Physical features: Randall and Tsuda (1974) described the physiography and geology of the Agana Swamp and its surrounding environment. The main body of the marsh lies in a broad low-lying basin along the Agana River, with several narrow fingers of marshland extending up to 1.5 km to the north, east, and south. Important sources of water for the wetland are run-off from surrounding hills, rainfall, several springs (including the Agana Springs) and the Chaot River, which enters from the south. Drainage occurs via a channelized section of the Agana River, 800 m long, which empties into Agana Bay. Inside the marsh, the Agana River channel is poorly defined and silted in. The marsh's water level ranges from 5-30 cm in the rainy season, but only depressions and the river channel retain standing water during the dry season (Randall and Tsuda, 1974). Soils consist of deep poorly drained muck derived from decomposed organic matter (Randall and Tsuda, 1974; Young, 1988).
The Agana Springs are located on the south side of the marsh at the base of a limestone ridge. A pair of retaining walls and a low dam are present, and were once part of a municipal water pumping station (Smalley and Zolan, 1981). Maximum depth at this site is 2-3 m. Water quality characteristics and hydrology of the marsh and Agana Springs are described and discussed by several authors (Smalley and Zolan, 1981; Ayers and Clayshulte, 1983; U.S. Army Corps of Engineers, 1985).
Low limestone hills and ridges border the marsh and project inward at a number of locations. Isolated limestone hills and hummocks occur inside the marsh and are 6-12 m high. The entire Agana-Chaot river basin covers 2,700 ha (U.S. Army Corps of Engineers, 1985).
Ecological features: The wetland is dominated by dense stands of *Phragmites karka*, with *Hibiscus tiliaceus* common along the edges and scattered throughout (Randall and Tsuda, 1974; Moore *et al.*, 1977; Smith & Hedlund, 1978). A fairly large bed of *Eleocharis ochrostachys* is present in the northeast (Wiles, pers. obs.). A few small openings in the *Phragmites* exist, but only several have open water. The opening at the Agana Springs is choked with *Eichhornia crassipes*, while the channel for the Agana River at the O'Brien Street bridge is covered by *Pistia stratiotes*, *Panicum muticum* and a small amount of *E. crassipes*. Two small plots on the north and northwest sides of the wetland have been cleared of *Phragmites* and planted with taro (*Cyrtosperma chamissonis* and *Colocasia esculenta*). Other plants in the marsh include *Acrostichum aureum*, *Thelypteris interrupta*, *Eleocharis geniculata*, *Polygonum minus*, *Cyperus polystachyos*, *Lemna perpusilla* and *Ipomoea aquatica*. The habitat classification of the marsh is PEM1F, PFO3C, PEM1Ff, R2EM1Hx and R2AB4Hx (Cowardin *et al.*, 1979).
Dryland vegetation on the boundaries of the marsh is variable and highly disturbed (Randall and

Tsuda, 1974). *Momordica charantia*, *Passiflora foetida*, *Mikania scandans*, *Chromolaena odorata* and *Antigonon leptopus* are common in weedy openings. Scrubby forests contain *Leucaena leucocephala*, *Heterospathe elata*, *Cocos nucifera*, *Pandanus tectorius*, *Triphasia trifolia* and *Morinda citrifolia*.

Land tenure: Most of the wetland is privately owned. The Government of Guam owns two tracts of property in the marsh totalling about 17 ha. Surrounding areas are mostly private.

Conservation measures taken: A small area around the Agana Springs was declared a conservation preserve in the 1970s by the Guam Department of Parks and Recreation, and developed as a park for nature education (Belk *et al.*, 1971), but the facilities have fallen into disrepair in recent years. The entire marsh is considered a wetland of primary importance for Common Moorhens (U.S. Fish and Wildlife Service, 1991). In order to protect moorhen habitat, the U.S. Fish and Wildlife Service issued a "jeopardy opinion" on a filling and construction project that was proposed for a corner of the marsh in 1987.

Conservation measures proposed: A recovery plan for moorhens also lists a variety of activities needed to protect this species on Guam (U.S. Fish and Wildlife Service, 1991). Actions that apply to the marsh include: (1) the development and implementation of a habitat management plan through a cooperative management agreement among the landowners, the Government of Guam and the U.S. Fish and Wildlife Service; (2) the conducting of regular censuses for moorhens; (3) the control of introduced predators such as Brown Tree Snakes (*Boiga irregularis*) and feral dogs and cats; and (4) the periodic monitoring of the site for toxic substances.

A proposal to designate land owned by the Government of Guam in the marsh and along the Chaot River as conservation reserves was submitted by the Guam Department of Agriculture to the Guam Departments of Land Management and Parks and Recreation in 1989. Recent consideration has also been given by the government to acquire privately owned land in the marsh for conservation purposes.

Land use: Colonial administrations dating back to at least the 1850s regularly considered or attempted to drain the marsh to encourage farming and for public health reasons (Safford, 1905; E.G. Johnston in Randall and Tsuda, 1974). The Spanish built a set of dikes in the marsh in the 1800s in an apparently unsuccessful effort to grow rice. In 1933-1934, a channel six metres wide was cut from the north side of the marsh to the Agana Springs, a distance of 1,750 m (Seabury, 1934; Randall and Tsuda, 1974). This resulted in two-thirds of the marsh being drained of standing water and allowed corn to be planted. Safford (1905) and Thompson (1947) both reported that some of the marsh was used for taro and vegetable gardening. The Agana Springs was used as a municipal water source from 1937 to 1957, with 3.8-9.5 million litres of water pumped daily (Smalley and Zolan, 1981). During the last 20-30 years, most of the marsh has been unused. Currently, taro is cultivated on two small plots.

The Agana Swamp occurs in a large urban centre. Land surrounding the marsh is occupied by a number of businesses and homes. Only the hills on the southeast side of the marsh remain relatively undeveloped.

Possible changes in land use: No development of the marsh is currently planned. However, continued commercial and residential growth on adjacent lands is expected in the future.

Disturbances and threats: Over the years, drainage patterns have undoubtedly been modified by development in and around the marsh. Two important factors in this process have been small- and large-scale filling along the edges (Stinson *et al.*, 1991) and siltation caused by human activity and the deposition of decaying wetland vegetation. An electrical powerline and gravel access road bisect the north end and have reduced drainage except through one depression. The Agana Shopping Center was built in 1978 on a four-hectare fill in the northwest corner of the marsh. Proposals were put forth in the 1970s and again in the 1980s to construct large flood control projects inside the marsh and along the lower Agana River (U.S. Army Corps of Engineers, 1985). The projects would have resulted in the building of several levees along the northern boundaries of the marsh. Neither project was initiated but the plans could be revived in the future.

Thick beds of *Phragmites* clog the wetland and prevent other more favourable emergent plants from becoming established. This probably reduces the attractiveness of the wetland for moorhens and other wildlife. Intense dry season fires occasionally burn off large areas of *Phragmites*. Four major fires (in 1983, 1987, 1988 and 1990) occurred between 1981 and 1991. Fires during the 1960s may have played a role in the decline of the Nightingale Reed-warbler (*Acrocephalus luscinia*) at this site (Reichel *et al*., 1992).

The Chaot River has been chronically polluted with raw sewage since at least 1981. Other probable sources of pollution are run-off from adjacent urban areas and illegal dumping of garbage. A military fuel pipeline crosses two upper sections of the wetland and is a pollution threat should a leak occur.

In 1989, the Public Utility Agency of Guam installed two new water wells near the Agana Springs. A total of 5.7 million litres/day is removed from the wells. This could have some affect on the amount of water entering the marsh.

Hydrological and biophysical values: The marsh is valuable for a number of reasons including sediment trapping, flood control and maintenance of water quality.

Social and cultural values: The dikes dating from the Spanish era remain in the marsh, but are heavily overgrown with *Phragmites*. The dikes are listed on the National Register of Historic Places. Potsherds and shell artifacts have been found on hummocks in the swamp, suggesting prehistoric use by Chamorros.

Noteworthy fauna: Common Moorhens were commonly recorded in the Agana Swamp in 1945 (Baker, 1951), but the population has been relatively small during the last 20-30 years. This may result from the presence of large *Phragmites* stands. Regular nesting occurred in one of the taro plots in the 1980s. The marsh is believed to be an important roosting site for significant numbers of Yellow Bitterns (*Ixobrychus sinensis*). It is the only recorded location for the White-browed Crake on Guam (*Porzana cinerea*) (Baker, 1951), which disappeared sometime after World War II. It is also the last site inhabited by the Nightingale Reed-warbler, which became extirpated in about 1969 (Reichel *et al*., 1992). The preservation of the marsh would assist in reintroductions of these species from other islands, should such efforts ever be attempted. Feral pigs (*Sus scrofa*) were a nuisance to taro farmers in 1991 and may be fairly common in parts of the marsh.

Randall and Tsuda (1974) and Smith and Hedlund (1978) describe the aquatic fauna of the marsh. Native species include shrimp (*Macrobrachium lar*), freshwater eels (*Anguilla marmorata* and *A. bicolor*), two gobies (*Awaous guamensis* and *Stiphodon elegans*) and a sleeper (*Eleotris fusca*). Introduced fish include tilapia (*Oreochromis mossambicus* and *Tilapia zilli*), catfish (*Chlarius macrocephalus*), mosquitofish (*Gambusia affinis*) and a guppy (*Poecilia reticulatus*).

Noteworthy flora: Checklists of plants are given by Randall and Tsuda (1974), Moore *et al.* (1977) and Smith and Hedlund (1978).

Scientific research and facilities: Limnological, hydrological and biological surveys were made by Randall and Tsuda (1974), Moore *et al.* (1977), Smith and Hedlund (1978), Smalley and Zolan (1981) and Ayers and Clayshulte (1983).

Conservation education: Efforts were made in the 1970s to use the Agana Springs Nature Preserve as a teaching site for conservation education (Belk *et al*., 1971), but the program was abandoned by 1980. The marsh's location in the population centre of Guam makes it an ideal site for future education efforts.

Management authority and jurisdiction: Management authority: Division of Aquatic and Wildlife Resources. Territorial jurisdiction: Territory of Guam. Functional jurisdiction: Division of Aquatic and Wildlife Resources

References: Ayers & Clayshulte (1983); Baker (1951); Belk *et al.* (1971); Moore *et al.* (1977); Randall & Tsuda (1974); Reichel *et al.* (1992); Safford (1905); Seabury (1934); Smalley & Zolan (1981); Smith & Hedlund (1978); Stinson *et al.* (1991); Thompson (1947); U.S. Army Corps of Engineers (1985); U.S. Fish & Wildlife Service (1991); Young (1988).

Reasons for inclusion: 1a, 2a, 2b. This is the largest freshwater marsh on Guam. It contains habitat for Common Moorhens.

Source: Gary J. Wiles and Michael W. Ritter.

Barrigada Ponding Basin (2)

Location: 13°28'N, 144°48'E; this site is located in central Guam in the village and municipality of Barrigada. It occurs about 75-100 m southeast of the intersection of Highways 8 and 10.
Area: 0.3 ha.
Altitude: 61 m.
Overview: A wetland created to eliminate flooding in the surrounding residential and commercial area. It is used nearly year-round for nesting by Common Moorhens (*Gallinula chloropus guami*).
Physical features: This man-made site is comprised of an excavated basin ten metres deep that occupies about one ha of land. The bottom of the basin holds water throughout most years. Water comes from surface run-off from surrounding lands after heavy rainfall. Drainage occurs by slow percolation into the ground. The water level fluctuates about one metre between the wet and dry seasons. The upper perimeter of the basin is surrounded by a dilapidated chain link fence. Soils in the area are derived from argillaceous limestone and are shallow and well drained (Young, 1988).
Ecological features: The flooded bottom of the ponding basin has developed into a true wetland. It contains about 75% open water, all of which is covered by *Lemna perpusilla*. *Panicum muticum*, *Alocasia macrorrhiza* and *Cassia alata* grow along the fringes of the water. The site is classified as PAB4Hx and PEM1Fx (Cowardin *et al.*, 1979). The slopes of the basin are covered by dense secondary scrub, particularly *Leucaena leucocephala* and several species of weedy vines.
Land tenure: The wetland is owned by the Government of Guam; surrounding areas are privately owned with both residential and commercial areas.
Conservation measures taken: The ponding basin is listed as a wetland of secondary importance for Common Moorhens (U.S. Fish and Wildlife Service, 1991).
Conservation measures proposed: A recovery plan for moorhens lists the activities needed to protect this species on Guam (U.S. Fish and Wildlife Service, 1991). Actions that apply to the ponding basin include: (1) the development and implementation of habitat management plans through cooperative management agreements between the Government of Guam and the U.S. Fish and Wildlife Service; (2) the periodic monitoring of the site for toxic substances; (3) the conducting of regular censuses for moorhens; and (4) the control of introduced predators such as Brown Tree Snakes (*Boiga irregularis*) and feral dogs and cats.
Land use: The site was built in the mid-1970s. It functions as a ponding basin to collect surface water run-off and prevent flooding. During the late 1970s, the Guam Department of Public Health reared mosquitofish in the basin, then distributed the fish to other bodies of water around the island. The basin is bordered by homes on the east and south, a gasoline station on the north, and a busy seven-lane highway on the west.
Possible changes in land use: No major changes are expected to occur in the near future, although further residential development will probably continue.
Disturbances and threats: The main threat appears to be polluted run-off water entering the basin, particularly from the gasoline station. Some illegal dumping of garbage from neighbouring houses and the gasoline station occurs on the slopes above the water. Predation by pet or stray cats may occur on moorhens.
Hydrological and biophysical values: The site helps prevent flooding.
Social and cultural values: None known.
Noteworthy fauna: The ponding basin is large enough to support a breeding pair of Common Moorhens during most of the year. Up to three clutches of chicks are raised per year, making it one of the most productive sites currently known. Mosquitofish (*Gambusia affinis*) are present.
Noteworthy flora: None known.
Conservation education: The site has much potential for educating the public about moorhens.
Management authority and jurisdiction: Management Authority: Division of Aquatic and Wildlife Resources and the Department of Public Works. Territorial jurisdiction: Territory of Guam. Functional Jurisdiction: Division of Aquatic and Wildlife Resources.
References: U.S. Fish & Wildlife Service (1991); Young (1988).

Reasons for inclusion: 2a. Habitat for moorhens.
Source: Gary J. Wiles and Michael W. Ritter.

Masso Reservoir (3)

Location: 13°27'N, 144°42'E; this pond is located in central Guam in the municipality of Piti. It lies about 600 m east of the intersection of Highways 1 and 6, or about 300 m east of the Guam Veterans Cemetery in Piti village.
Area: 2 ha.
Altitude: 12 m.
Overview: A small man-made pond built as a potable water reservoir. Common Moorhens (*Gallinula chloropus guami*) occur on the site.
Physical features: The reservoir was created by damming the Masso River. A dike and spillway, 65 m long, are present on the west bank. Water depth in the pond is about 4 m (Biosystems Analysis, Inc. 1989a) and falls slightly during the dry season. Hosmer (1982) reported on a variety of water analyses conducted here. The reservoir's watershed covers approximately 200 ha. Soils in the area are derived from argillaceous limestone and are shallow and well drained (Young, 1988).
Ecological features: This wetland has 75% open water, with large aquatic beds of *Hygrophila difformis* common. Dense stands of *Phragmites karka* grow along the southeastern and northeastern shores. The site is classified as PAB2Hh, PEM1F and POWHh (Cowardin *et al.*, 1979). Small to medium-sized trees were planted on the dike in the late 1970s. Extensive grasslands grow on the east and south sides, while secondary forest occurs to the north and west.
Land tenure: The wetland and surrounding property are owned by the U.S. Navy but have been pending transfer to the Government of Guam for several years.
Conservation measures taken: The Navy and Government of Guam signed a perpetual use agreement in 1976, allowing the Guam Department of Agriculture to manage the reservoir and immediate area (2.2 ha) for public use. The reservoir is listed as a wetland of secondary importance for Common Moorhens (U.S. Fish and Wildlife Service, 1991).
Conservation measures proposed: A recovery plan for moorhens lists the activities needed to protect this species on Guam (U.S. Fish and Wildlife Service, 1991). Actions that particularly apply to this wetland include: (1) the development and implementation of habitat management plans through cooperative management agreements between the Government of Guam and the U.S. Fish and Wildlife Service; (2) the conducting of regular censuses for moorhens; (3) the periodic monitoring of the site for toxic substances; and (4) the control of introduced predators such as Brown Tree Snakes (*Boiga irregularis*) and feral dogs and cats.
Land use: The Masso Reservoir was constructed by the U.S. Navy in about 1945 for the storage of drinking water, however, excessive siltation caused it to be abandoned in 1951 (Tucker and Kock, 1979). In 1978, the Guam Division of Aquatic and Wildlife Resources renovated the site with the goal of turning it into a public park and fishing area (Tucker and Kock, 1979). This involved the removal of one ha of *Phragmites*, the repair of the spillway and the planting of exotic trees and shrubs on the banks of the reservoir. In 1980 and 1981, the Division stocked the pond with hybrid tilapia (*Oreochromis mossambicus* x *O. niloticus*), mosquitofish (*Gambusia affinis*) and tucunare (*Cichla ocellaris*) (Hosmer 1982). However, vandalism and illegal fishing with chlorine caused the management program to be terminated in 1983 (Molina, 1983). The reservoir and surrounding grasslands are currently unused.
Possible changes in land use: No changes in land use are foreseen at the reservoir, but a condominium complex is proposed for construction 1.3 km upstream of the reservoir.
Disturbances and threats: Siltation of the reservoir is a chronic problem and is worsened by grassland fires that cause increased erosion in the catchment area. Proposed development is likely to worsen soil run-off. Illegal fishing with chlorine occurs infrequently in the pond and threatens

aquatic animal life.
Hydrological and biophysical values: Useful in holding eroded soil sediments.
Social and cultural values: None known.
Noteworthy fauna: Common Moorhens are seen occasionally at the reservoir. Further observations may find that nesting occurs here. In 1978, the aquatic fauna of the reservoir included two species of eel (*Anguilla marmorata* and *A. bicolor*), three gobies (*Awaous guamensis*, *Stiphodon elegans* and *Sicyopterus macrostetholepis*), a sleeper (*Eleotris fusca*) and several shrimp (*Macrobrachium lar*, *Atya* sp. and *Caridina* sp.) (Tucker and Kock, 1978). In 1980 and 1981, the pond was stocked with hybrid tilapia, mosquitofish and tucunare (Hosmer, 1982). Some of these species may have since disappeared from the reservoir because of poisoning with chlorine.
Noteworthy flora: None known.
Scientific research and facilities: Limnological and faunal surveys were made by Tucker and Kock (1978) and Hosmer (1982).
Conservation education: There is little potential for education purposes under present conditions.
Recreation and tourism: A minor amount of recreational fishing still occurs at the reservoir.
Management authority and jurisdiction: Management authority: Division of Aquatic and Wildlife Resources and U.S. Navy. Territorial jurisdiction: Territory of Guam and U.S. Navy. Functional Jurisdiction: Division of Aquatic and Wildlife Resources and U.S. Navy.
References: Biosystems Analysis, Inc. (1989a); Hosmer (1982); Molina (1983); Tucker and Kock (1979); U.S. Fish & Wildlife Service (1991); Young (1988).
Reasons for inclusion: 2a. Habitat for moorhens.
Source: Gary J. Wiles and Michael W. Ritter.

Sasa Bay Wetland (4)

Location: 13°27'N, 144°41'E; this wetland is found along the eastern shore of Apra Harbor in west-central Guam. It occurs in the municipality of Piti and lies about 0.75 km southwest of Piti village.
Area: 102 ha.
Altitude: Sea level to 6 m.
Overview: A large coastal wetland with estuarine and freshwater habitats present. The largest stand of mangroves in the Mariana Islands is found here.
Physical features: This is a large natural wetland that fringes about 4 km of the northern, eastern and part of the southern shorelines of Sasa Bay in eastern Apra Harbor. The wetland occurs on flat low-lying ground and generally extends 50-500 m inland, where portions of it abut a series of hills to the east. Highway 1 divides the wetland into two areas and acts as a dike by altering drainage patterns. The largest portion of the wetland, about 65 ha, occurs west of the highway. Mucky clay soils that are deep and poorly drained characterize the mangrove zone along the shore (Young, 1988). The surface is hummocky in many areas. Further inland, a second band of wetland soils is also comprised of poorly drained clay but has a higher sand content (Young, 1988).
Wetlands east of the road occur primarily along the drainages of the Sasa, Laguas and Aguada Rivers, which flow westward from the neighbouring hills to Sasa Bay. Two narrow fingers of wetland penetrate 1.0-1.3 km inland along the Sasa and Aguada Rivers. Both rivers are about 4-8 m wide and appear to be channelized (Moore *et al.*, 1977). The Sasa has banks that are 1-2 m high and stops flowing during the dry season. Mean water quality parameters of the Sasa River are reported in Biosystems Analysis, Inc. (1989a). The Aguada River has lower banks and overflows during the wetter parts of the year, which helps to maintain the adjacent swamp forest. The soils of these areas are predominantly deep and poorly drained clays (Young, 1988).
The total catchment area for the wetland is about 550 ha. The wetland is bounded by volcanic and limestone hills to the east, significant areas of man-made fill to the north and south, and Sasa Bay to

the west, which is a shallow coastal lagoon containing a number of patchy coral reefs.
Ecological features: This wetland contains a variety of plant communities. Mangroves grow in a strip, 30-175 m wide, along the edge of the bay, and occupy almost 30% of the entire wetland. *Rhizophora mucronata*, *R. apiculata*, *Bruguiera gymnorrhiza*, *Avicennia marina* and *Lumnitzera littorea* are the dominant species (Moore *et al.*, 1977). The mangroves consist primarily of scrubby immature growth although patches of large trees also exist (Moore *et al.*, 1977). Mud sediments are generally 10-60 cm deep. A few *Heritiera littoralis*, *Terminalia catappa* and *Hernandia sonora* grow along the back edges of the mangroves, as does a small grove of *Nypa fruticans* near the Laguas River.
Much of the remaining area west of the highway is occupied by dense disturbed secondary forest with *Hibiscus tiliaceus*, *Cocos nucifera*, *Leucaena leucocephala*, *Pandanus tectorius*, *Thespesia populnea*, *Bambusa vulgaris*, *Pithecellobium dulce*, grasses and weeds present. This forest floods seasonally, then dries out for much of the year. Other habitats in this area include beds of *Phragmites karka*, *Panicum muticum* and *Eleocharis ochrostachys*, and an intertidal mudflat generally lacking in vegetation. The western part of the wetland is classified as E2SS3N, PFO3C and PEM1F (Cowardin *et al.*, 1979).
East of Highway 1, wetlands along the Sasa and Aguada Rivers are comprised primarily of short-statured palustrine forests of *Hibiscus tiliaceus* and *Bambusa vulgaris*. The Laguas River wetlands are well-zoned and reflect the salinity regime of the area (Moore *et al.*, 1977). The centre of the site contains a bed of *Scirpus littoralis* edged with *Acrostichum aureum* and a few *R. apiculata* (Moore *et al.*, 1977). Outward from this is a zone of *Phragmites*, with a band of *Hibiscus* behind this at the rear edge of the wetland. This eastern side is classified as PFO3C, PEM1C, E2EM1N and E2SS3N.
Adjacent uplands are covered largely by disturbed secondary forest with *Leucaena leucocephala*, *Spathodea campanulata*, *Cocos nucifera*, *Pithecellobium dulce*, *Casuarina equisetifolia* and herbaceous weeds.
Land tenure: Ownership of the wetland lies predominantly with the U.S. Navy (Naval Supply Depot and U.S. Naval Station). Private landowners hold a small area of wetland along the upper reaches of the Aguada River. Surrounding areas are also largely owned by the U.S. Navy (Naval Supply Depot and U.S. Naval Station). The Government of Guam and private landowners own some of the neighbouring lands.
Conservation measures taken: The eastern portion of the marsh is listed as a wetland of secondary importance for Common Moorhens (*Gallinula chloropus guami*) because of its potential for being managed as suitable habitat for this species (U.S. Fish and Wildlife Service, 1991). In 1980, a project was initiated to restore several hectares of mangroves at the mouth of the Laguas drainage that were killed by an oil spill (Pacific Basin Environmental Consultants, 1981). Several thousand hypocotyls, seeds and seedlings of mainly *R. mucronata* and *Avicennia* were planted. The seedlings, especially *Rhizophora*, have shown good survival. They are now 2-3 m tall and cover most of the damaged area.
Conservation measures proposed: Two natural resource management plans drafted by the Navy call for the prohibition of all activities in and adjacent to the wetland that might cause significant alterations or damage (Anon., in press, a, b). Other management recommendations are: (1) the rehabilitation and enhancement of areas with dense *Phragmites* growth; (2) the designation of two small areas east of Highway 1 as Common Moorhen sanctuaries; (3) the maintaining of a buffer zone 30 metres wide around the perimeter of the wetland, in which no development will be permitted; (4) the posting of signs around the wetland to note its protected status; and (5) assisting the Government of Guam and the U.S. Fish and Wildlife Service in moorhen censuses. A recovery plan for moorhens lists a variety of activities needed to protect this species on Guam (U.S. Fish and Wildlife Service, 1991). Actions that apply to the Sasa Bay Wetland include: (1) the development and implementation of a habitat management plan through a cooperative management agreement between the U.S. Navy, the Government of Guam and the U.S. Fish and Wildlife Service; (2) the periodic monitoring of the site for toxic substances; (3) the conducting of regular censuses for moorhens; and (4) the control of introduced predators such as Brown Tree Snakes (*Boiga irregularis*) and feral dogs and cats.
Land use: Before World War II, portions of the wetland were used for growing rice and vegetables (Thompson, 1947). Currently, crab hunters and fishermen occasionally visit the wetland. A variety of commercial, industrial and military developments exist in or near the wetland. Highway 1 passes

through the centre and has about two active oil pipelines and four old pipelines buried under the shoulder of the road. The Navy manages a large fuel storage area with a number of storage tanks in the Sasa River watershed east of Highway 1. Two other Navy installations operate adjacent to the wetland. A service base for submarines, known as Polaris Point, occurs to the south, and a ship repair facility on Dry Dock Island is found to the west. The Government of Guam and the Navy have several electrical power plants about 0.5 km northeast of the wetland. Other developments include a small private marina on Dry Dock Peninsula and a petroleum pipeline and pump house in the northeast corner of the wetland.

Possible changes in land use: The Government of Guam is considering the building of a large incinerator to burn municipal trash in the northeast portion of the wetland.

Disturbances and threats: The wetland has undergone considerable alteration over the years (Biosystems Analysis, Inc., 1988). The mangroves and associated wetlands were once much larger, but filling has reduced their size and divided them from neighbouring wetlands. The construction of Highway 1 probably modified parts of the wetland by blocking the natural flow of saline water upstream and impounding the palustrine wetlands east of the road (Biosystems Analysis, Inc., 1989a). Other major fills and road building, which occurred during the construction of Dry Dock Peninsula and Polaris Point in the late 1940s, cut across mangrove forests. The Laguas River has been completely dammed and the lower river channel no longer reaches Sasa Bay, passing instead into a reed marsh which eventually drains into the bay.

An oil spill involving an estimated 38,000 litres of diesel fuel occurred at the mouth of the Laguas drainage in June 1980 (Pacific Basin Environmental Consultants, 1981). The oil leaked from one of the pipelines buried along Highway 1 and killed or damaged about 1.8 ha of mangroves. Approximately 4,000 mangrove trees were lost (Pacific Basin Environmental Consultants, 1981). Oil saturated several centimetres of sediments in the worst areas of the spill. Cleanup operations were sufficiently successful to allow the replanting of mangrove trees on the site. Biosystems Analysis, Inc. (1989a) observed a visible sheen of oil in the *Scirpus* marsh east of the highway near the Laguas River in 1987. They speculated that the oil emanated from a leak in one of the pipelines along the road, although it was possibly left over from the 1980 spill.

Thick *Phragmites* stands are common in the marsh and probably prevent other more favourable emergent plant species from becoming established. This may reduce the attractiveness of the wetland for wildlife.

During much of the year, the wetland is downwind from several power plants, which represent potential polluting sources. The building of an incinerator could similarly lead to additional contamination of downwind sites, including the wetland.

Hydrological and biophysical values: Valuable in sediment trapping and support of food chains.

Social and cultural values: The area contains a significant prehistoric or early historic Chamorro site, with about a dozen fish weirs made of stacked coral rocks lying on the reef flat near the edge of the mangroves at the Laguas River (Anon., 1990). The traps form a chain, 100 m long, of roughly rectangular enclosures, the largest of which is about 20 x 30 m in size. The site also has an abundance of broken pottery lying exposed in the wetland and at least three partial sets of latte stones. The central portion of the wetland also contains what appears to be the remains of a historic fishing camp dating back to the 1940s (Anon., 1990).

Noteworthy fauna: This area is important for a number of aquatic organisms that are specific to mangroves, including molluscs, bivalves, crustaceans and fish. Common species include several gastropods (*Littorina scabra* and *Cerithium* sp.), a clam (*Gafrarium tumidum*) and an oyster (*Crassostrea cucullata*) (Amesbury *et al.*, 1977; Pacific Basin Environmental Consultants, 1981). Fiddler crabs (*Uca chlorophthalmus* and *U. volans*), land crabs (*Cardisoma carnifex*) and mangrove crabs (*Scylla serrata*) inhabit mud substrates. The mangroves act as nursery grounds for jacks (Carangidae), barracudas (Sphyraenidae), snappers (Lutjanidae) and groupers (Serranidae) (G. Davis, pers. comm). They are also used by adult ponyfish (Leiognathidae), rabbitfish (Siganidae), mojarras (Gerreidae), milkfish (*Chanos chanos*) and mudskippers (*Periophthalmus koelreuteri*). An undescribed species of *Siganus* is restricted to the mangroves here and at the Atantano Wetland (Site 5). Hawksbill Turtles (*Eretmochelys imbricata*) occasionally approach the edges of the mangroves to feed on certain species

of sponges (G. Davis, pers. comm).
Biosystems Analysis, Inc. (1989a) provides a partial list of the aquatic animals inhabiting the Aguada, Laguas and Sasa Rivers. The fauna includes three species of shrimp (*Caridina* sp., *Atyoida pilipes* and *Macrobrachium lar*), two tilapia (*Oreochromis mossambicus* and *Tilapia zilli*), two gobies (*Awaous guamensis* and *Sicyopterus macrostetholepis*) and a flagtail (*Kuhlia rupestris*). Small numbers of migrant shorebirds forage on nearby tidal mudflats and roost on exposed coral rocks in the mangroves. There are no records of Common Moorhens in the freshwater emergent portions of the wetland, but they are likely to use these areas seasonally.
Noteworthy flora: The wetland contains the largest area of mangroves on Guam. Moore *et al.* (1977) compiled a list of plants for the site.
Scientific research and facilities: Preliminary plant and animal lists were compiled by Amesbury *et al.* (1977), Moore *et al.* (1977), and Biosystems Analysis, Inc. (1989a). Pacific Basin Environmental Consultants (1981) discussed rehabilitation of the mangroves.
Conservation education: The mangroves have high potential for conservation education. The site is well-suited for the construction of a boardwalk and other visitor facilities (Anon., 1990).
Management authority and jurisdiction: Management authority: Division of Aquatic and Wildlife Resources and U.S. Navy (U.S. Naval Supply Depot and U.S. Naval Station). Territorial jurisdiction: Territory of Guam and U.S. Navy. Functional Jurisdiction: Division of Aquatic and Wildlife Resources and U.S. Navy.
References: Amesbury *et al.* (1977); Anon. (1990); Anon. (in press, a, b); Biosystems Analysis, Inc. (1988, 1989a); Moore *et al.* (1977); Pacific Basin Environmental Consultants (1981); Thompson (1947); U.S. Fish & Wildlife Service (1991); Young (1988).
Reasons for inclusion: 1a, 2b, 2c. This is one of Guam's largest wetlands. It contains a significant area of mangroves and an important cultural site, and is potential habitat for Common Moorhens.
Source: Gary J. Wiles.

Atantano Wetland (5)

Location: 13°25'N, 144°41'E; this wetland lies 2.2 km west of Mt Tenjo in west-central Guam. It occurs along the boundary of the municipalities of Santa Rita and Piti, and is found about 2.9 km north of the village of Santa Rita.
Area: 130 ha.
Altitude: Sea level to 4 m.
Overview: One of Guam's largest wetlands, with both freshwater and estuarine areas present. It contains the most developed mangrove forest in the Mariana Islands. Common Moorhens (*Gallinula chloropus guami*) nest here.
Physical features: This is a large natural coastal wetland located on the southeast side of Apra Harbor. The wetland is comprised of two distinct subdivisions that are separated by Highway 1. The area east of the road is a large freshwater marsh formed at the confluence of the Atantano, Tenjo, Aplacho, Big Gautali and Gautali Rivers. This portion of the wetland is about 1.5 km long and up to 750 m wide. Water depths reach an estimated 0.5-1.0 m, but probably fall considerably in most areas during the dry season. Drainage occurs primarily through the Atantano River channel and a smaller creek, both of which pass under the highway. Clay soils in the marsh are mucky, deep and poorly drained (Young 1988).
The area west of the highway is smaller, about 1.2 km long and 500 m wide, and comprised largely of an estuarine mangrove swamp. Soils in the swamp are comprised of alluvial clays, with the sand content highest on the south side of the river channel (Moore *et al.*, 1977).
A distinct channel for the Atantano river forms several hundred metres east of the highway and flows northwestward through the centre of the mangrove swamp. Between the road and the harbour, the channel is distinctly banked and about 12-18 m wide. Moore *et al.* (1977) report a

range in the river's discharge flow of 0.001-0.06 cubic metres per second. The channel is 0.6-1.2 m deep and has water temperatures of 27.4-29.2°C (Wilder, 1976). Water salinity is variable, depending on depth and distance from the river mouth. Salinity measurements of bottom water declined from 34 to 30 parts per thousand in the first 600 m of the channel, then fell to 10 parts per thousand in the next 300 m (Wilder, 1976). Biosystems Analysis, Inc. (1988) report on other water quality parameters in the Atantano and Big Gautali Rivers.

The total catchment area for the Atantano Wetland is about 1,490 ha. The site is surrounded by limestone and volcanic uplands. A number of small limestone hills border the wetland, while Mt Tenjo and other steep hills of volcanic soil occur 0.5-1.0 km to the east.

Ecological features: The freshwater marsh is dominated by monotypic stands of *Phragmites karka* and thickets of *Hibiscus tiliaceus*. *Panicum muticum* and various species of sedges are also present (Moore *et al.*, 1977; M. Ritter, pers. obs.). This section of the wetland is classified as PEM1F and PFO3C (Cowardin *et al.*, 1979).

The mangrove forest is 3-12 m tall. *Avicennia marina* and *Rhizophora apiculata* are dominant, with *Bruguiera gymnorrhiza* and *R. mucronata* also present (Moore *et al.*, 1977). A large pure grove of *A. marina* grows south of the river. Other common species west of the road include *Hibiscus tiliaceus*, *Dalbergia candenatensis*, *Barringtonia racemosa* and *Acrostichum aureum* (Wiles, pers. obs.). A small bed of *Scirpus littoralis* occurs near the Naval Supply Depot. The section of the Atantano channel that flows through this area is lined primarily with *H. tiliaceus*, *Casuarina equisetifolia*, *P. karka*, *Pandanus tectorius*, *Scaevola taccada*, *Scleria polycarpa* and some *Nypa fruticans*. Overall, the western portion of the wetland is classified as E2SS3N, E2FO3N, R1OWL, and PFO3C.

Land tenure: The eastern portion of the wetland is privately owned. The U.S. Navy controls the area west of the highway. Surrounding areas are partly under private ownership and partly owned by the U.S. Navy.

Conservation measures taken: The freshwater portion of the marsh is listed as a wetland of primary importance for Common Moorhens (U.S. Fish and Wildlife Service, 1991).

Conservation measures proposed: A recovery plan for moorhens lists a variety of activities needed to protect this species on Guam (U.S. Fish and Wildlife Service, 1991). Actions that apply to this site are: (1) the development and implementation of a habitat management plan through a cooperative management agreement between the Government of Guam, The U.S. Navy and the U.S. Fish and Wildlife Service; (2) the periodic monitoring of the site for toxic substances; (3) the conducting of regular censuses for moorhens; and (4) the control of introduced predators such as Brown Tree Snakes (*Boiga irregularis*) and feral dogs and cats.

Two natural resource management plans drafted by the Navy call for the prohibition of all activities that might significantly alter or damage the wetlands west of Highway 1 (Anon., in press, a, b). The plans also propose that a buffer zone, 30 m wide, with no development be maintained around that section of the wetland.

Land use: Before World War II, portions of the wetland were used for farming rice and vegetables (Thompson, 1947). Currently, several hectares on the west side (near the intersection of Highways 1 and 2A) are cleared annually during the dry season for vegetable crops. A minor amount of crab hunting occurs in the mangroves.

Various types of commercial, industrial and military development exist in a few areas next to the wetland. The largest of these is the Shell Oil refinery, which is a 45 ha complex located about 100 m east of the wetland. The military operates installations on each side of the mangrove forest. These consist of the Naval Supply Depot, which has a large set of docks and warehouses, and a U.S. Army Reserve facility to the south and a submarine port at Polaris Point to the north. Other developments include several small businesses and homes along the west side of the marsh. Highways 1 and 2A pass through the wetland and along the west of it, respectively.

Possible changes in land use: Several developments are proposed for construction near the southern end of the wetland along Highway 2A.

Disturbances and threats: The Atantano Wetland has experienced considerable disturbance over the years. The mangroves and freshwater marsh were probably continuous before the first road (now Highway 1) was built about 200 years ago. The roadbed functions as a dike and has likely caused significant changes in drainage patterns and salinity characteristics (Moore *et al.*, 1977; Biosystems Analysis, Inc., 1988). In the 1930s, ditches were dug to increase drainage (Eckburg, 1935). The site was probably once connected to other marshes that bordered Apra Harbor, such as the present-day Namo River and Naval Station Marshes, but became separated from them by filling for military and civilian development.

Filling has reduced the original size of this site. In addition to the construction of the highway, major fills preceded the building of naval facilities to the north and south of the mangroves in the mid to late 1940s. Further encroachment occurred with the building of a few homes and businesses along the margins of the wetland. Recently, one developer was required to alter his project and remove an illegal fill at the southern end of the wetland.

In September 1983, a major oil spill involving an estimated 3.8 million litres was discovered in the wetland. The oil emanated from a pipeline on a nearby hillside that had been leaking for an unknown period of time. The oil flowed into the Gautali River and travelled downstream into the marsh. It eventually seeped outward to the channel of the Atantano River and washed into Apra Harbor. Cleanup efforts lasted two and a half years, during which time an estimated 2.8 million litres of oil were recovered from the wetland. The oil's presence had no apparent harmful effects on the *Phragmites*, which continued to persist even in areas with 15-30 cm of standing oil. Also, no die-offs of mangroves occurred. The effect of the spill on the wetland's fauna was never determined; however, cleanup workers failed to observe any aquatic animal life in the immediate area of the spill.

Parts of the wetland may be contaminated with heavy metals and other toxic substances originating from the nearby Shell Oil refinery, which is known to have pollution problems. It is likely that toxic materials have seeped from the refinery downhill into the Atantano marsh.

Soil erosion from hillsides east of the wetland is a continual problem (Eckburg, 1935) exacerbated by annual grassland fires. Soils are washed down the streams of the watershed and deposited in the wetland. Such sedimentation is probably slowly reducing the water capacity of the marsh.

Sedimentation and disturbed conditions resulting from past and present farming may aid the invasion of *Phragmites*, which clogs the marsh. Large fires burn through the *Phragmites* beds on rare occasions.

Hydrological and biophysical values: The wetland has a number of important values including flood control, sediment and pollutant trapping, and support of food chains.

Social and cultural values: A historic monument known as the Atantano Shrine is located on an area of fill in the centre of the wetland a short distance from Highway 1. The shrine commemorates the completion of the road from Piti to Agat, which was originally built in 1784-1785 and further improved in 1832-1834 and again in 1908-1909. The shrine is listed on the Guam Register of Historic Places and is now owned by the Government of Guam.

Noteworthy fauna: Common Moorhens nest in the freshwater marsh, but their abundance and seasonal occurrence are poorly known. Yellow Bitterns (*Ixobrychus sinensis*) also make use of the area. The Nightingale Reed-warbler (*Acrocephalus luscinia*), an endangered species now extinct on Guam, inhabited the wetland until 1968 (Reichel *et al.*, 1992). Introduced catfish (*Clarius macrocephalus*) occur in the marsh.

Biosystems Analysis, Inc. (1988) provided a preliminary list of aquatic animals found in the Atantano River channel between Highway 1 and Apra Harbor. The list includes three species of shrimp (*Caridina* sp., *Atyoida pilipes* and *Macrobrachium lar*), a halfbeak (*Zenarchopterus dispar*), tilapia (*Oreochromis mossambicus*), a goby (*Awaous guamensis*), a flagtail (*Kuhlia rupestris*) and a mullet (*Liza vaigiensis*).

The Atantano mangroves provide important habitat for a number of aquatic organisms, including sponges, molluscs, bivalves, crustaceans and fish (G. Davis, pers. comm). The area is particularly well-suited for molluscs because of its location in inner Apra Harbor, where water turbidity is higher and water circulation is lower than in other mangroves on the island. The mangroves are an important nursery ground for jacks (Carangidae), barracudas (Sphyraenidae), snappers (Lutjanidae) and groupers (Serranidae). They are also used extensively by adult ponyfish (Leiognathidae), rabbitfish (Siganidae), mojarras (Gerreidae) and milkfish (*Chanos chanos*). An undescribed species of

Siganus is restricted to the mangroves here and at Sasa Bay (Site 4). Fiddler crabs (*Uca* spp.), land crabs (*Cardisoma carnifex*) and mangrove crabs (*Scylla serrata*) inhabit mud substrates. The native skink *Emoia caeruleocauda* is also common in the mangrove (Wiles, pers. obs.).
Noteworthy flora: The wetland contains the best developed and most mature stand of mangroves in the Mariana Islands (Moore *et al.*, 1977). Guam's largest grove of *Avicennia marina* occurs here. Moore *et al.* (1977) list the plants found in the wetland.
Scientific research and facilities: Plant and animal lists were compiled by Moore *et al.* (1977) and Biosystems Analysis, Inc. (1988).
Conservation education: The wetland has moderate potential for conservation education, particularly for showing the characteristics of mangroves to the public.
Management authority and jurisdiction: Management authority: Division of Aquatic and Wildlife Resources and the U.S. Navy (U.S. Naval Supply Depot and U.S. Naval Station). Territorial jurisdiction: Territory of Guam and U.S. Navy. Functional Jurisdiction: Division of Aquatic and Wildlife Resources and U.S. Navy.
References: Anon. (in press, a, b); Biosystems Analysis, Inc. (1988); Eckburg (1935); Moore *et al.* (1977); Reichel *et al.* (1992); Thompson (1947); U.S. Fish & Wildlife Service (1991); Wilder (1976); Young (1988).
Reasons for inclusion: 1a, 2a, 2b, 2c. One of the island's largest wetlands, with a significant stand of mangroves. Common Moorhens use the site.
Source: Gary J. Wiles and Michael W. Ritter.

Shell Oil Wetlands (6)

Location: 13°25'N, 144°41'E; this site occurs in west-central Guam in the municipality of Piti. The wetlands are found about 3.3 km northeast of the village of Santa Rita and 1.0 km west of Mt Tenjo.
Area: A total of 2.3 ha for four separate ponds.
Altitude: 10-30 m.
Overview: A group of four small ponds located on the grounds of an oil refinery. Common Moorhens (*Gallinula chloropus guami*) nest in several of the ponds throughout the year.
Physical features: The four ponds lie in the drainages of the Big Gautali and Tenjo Rivers and were created during the construction of the Shell Oil refinery (formerly known as the GORCO refinery) in the mid-1960s. Two ponds in the northwest corner of the facility are shallow depressions adjoining each other, and are rimmed by diking one metre high. The western pond is larger, about 125 m by 80 m. The eastern pond is 125 m by 50 m. Both have gently sloping bottoms, with the deepest areas occurring on the north. Water depths reach about one metre during the rainy season, when some overflow of the dikes occurs. The ponds usually retain up to 50% of their water in the dry season. A third pond measuring 125 m by 35 m lies on the southwest side of the refinery, while a fourth pond in the centre of the facility is about 80 m by 40 m in size. Both are diked and have steep sides. Water depths are fairly constant during the year, ranging from about one to two metres. The silty clay soils in the refinery are deep and well drained but were greatly disturbed during construction (Young, 1988).
Ecological features: Although the northwestern ponds lie next to each other, they vary considerably in vegetation. Little plant growth is present in the eastern pond, except for *Panicum muticum* on the dikes and mats of algae in the water. During the wet season, open water comprises about 80-90% of its surface area. The western pond has luxuriant plant growth, with *P. muticum*, *Saccharum spontaneum*, *Fuirena umbellata*, *Eleocharis geniculata*, *Fimbristylis* sp. and other species present. The amount of open water in the pond varies from 10-50% during the year. These sites are classified as POWKh and PEM1Fh (Cowardin *et al.*, 1979).
The southwestern pond has approximately 75% open water. *P. muticum* is the dominant plant

present, while *Phragmites karka* grows on the edges. The pond is classified as POWHh and PEM1Hh. The central pond is also ringed by *Phragmites*, with *Hydrilla verticillata* and *P. muticum* growing in deeper water. The amount of open water is estimated at 50%. The pond is classified as POWHh, PEM1Hh and PAB2Hh. Savanna and secondary forest with *Leucaena leucocephala*, *Hibiscus tiliaceus*, *Vitex parviflora*, *Cocos nucifera* and *Casuarina equisetifolia* border the refinery.
Land tenure: The wetlands are privately owned by the Shell Oil Company; surrounding areas are also privately owned.
Conservation measures taken: The ponds are listed as wetlands of secondary importance for Common Moorhens (U.S. Fish and Wildlife Service, 1991).
Conservation measures proposed: A recovery plan for Common Moorhens lists the activities needed to protect this species on Guam (U.S. Fish and Wildlife Service, 1991). Actions that apply to this site include: (1) the development and implementation of habitat management plans through cooperative management agreements between the landowner, the Government of Guam and the U.S. Fish and Wildlife Service; (2) the periodic monitoring of the sites for toxic substances; (3) the conducting of regular censuses for moorhens; and (4) the control of introduced predators such as Brown Tree Snakes (*Boiga irregularis*) and feral dogs and cats.
Land use: The ponds occur in a 45 ha petroleum refinery with a number of large storage tanks. The two northwestern ponds function to separate minor amounts of oil from storm water run-off coming from the entire refinery facility. The southwestern pond was originally built to aerate oily water discharged during oil refining processes, but has been unused since about 1983. The central pond was created to hold water for fighting fires, although no water has been withdrawn for this purpose in at least 10 years. Public entry into the refinery is generally prohibited. Most adjoining lands are currently idle.
Disturbances and threats: The ponds generally receive little disturbance aside from occasional grass mowing and other refinery maintenance work. The northwestern ponds may contain a variety of toxic substances. Testing is underway to determine the extent of contamination. If severe, both ponds may have to be decontaminated and capped, which will destroy their functional role as wetlands.
The presence of tilapia (*Oreochromis mossambicus*) in at least one of the ponds may be harmful to moorhens by reducing food sources. Two large uncovered sludge ponds near the northwest ponds may also threaten moorhens and shorebirds that occasionally visit them.
Hydrological and biophysical values: Important in trapping refinery pollutants.
Social and cultural values: None known.
Noteworthy fauna: These wetlands are used extensively by Common Moorhens. Pairs of moorhens inhabit each pond for part or all of the year, with regular nesting occurring in at least three ponds. A variety of migratory ducks, shorebirds and egrets visit the site in small numbers. Tilapia occur in the central pond.
Noteworthy flora: None known.
Management authority and jurisdiction: Management authority: Division of Aquatic and Wildlife Resources. Territorial jurisdiction: Territory of Guam. Functional Jurisdiction: Division of Aquatic and Wildlife Resources.
References: U.S. Fish & Wildlife Service (1991); Young (1988).
Reasons for inclusion: 2a. Important nesting habitat for moorhens.
Source: Gary J. Wiles and Michael W. Ritter.

Naval Station Marsh (7)

Location: 13°25'N, 144°40'E; this wetland occurs in west-central Guam at the base of Orote Peninsula. It is in the municipality of Santa Rita about 3 km north of the village of Santa Rita. It is located on the U.S. Navy Public Works Center.

Area: 40 ha.
Altitude: 1-3 m.
Overview: A large marsh suffering from infilling and overgrowth of *Phragmites karka* and *Panicum muticum*. Common Moorhens (*Gallinula chloropus guami*) probably nest here.
Physical features: This natural wetland is located near the coast in Apra Harbor. It is bordered on the east, south and west by buildings, open lawns, a large landfill and stands of scrubby secondary forest. A natural limestone berm and highway occur on the north side. Several small mounds of high ground occur inside the marsh. The water level of the marsh varies considerably during the year. Maximum water depth is probably never more than one metre. Most of the site dries out during the dry season. Only a few pockets of standing water are retained during this time. Water at the north end of the marsh is slightly brackish. The clay soils in the area are deep, mucky and poorly drained (Young, 1988).
Ecological features: The wetland is dominated by dense beds of *Phragmites karka* and *Panicum muticum*. Several small areas of open water occur near the north end of the marsh and cover 1-2% of the total area. One of these openings is surrounded by *Ipomoea aquatica*. A few scattered mangrove trees (*Rhizophora apiculata*) also grow in the northern end, which is nearest the sea coast. The habitat classification of this wetland is PEM1F (Cowardin *et al.*, 1979). *Leucaena leucocephala*, *Casuarina equisetifolia*, *Cocos nucifera*, *Bambusa vulgaris*, a grass (*Saccharum spontaneum*) and weeds grow on areas of higher ground in and around the marsh.
Land tenure: The wetland and surrounding areas are under the control of the U.S. Navy.
Conservation measures taken: The marsh is listed as a wetland of primary importance for Common Moorhens (U.S. Fish and Wildlife Service, 1991).
Conservation measures proposed: A drafted natural resources management plan for the U.S. Navy Public Works Center, Guam, proposes that active management of this wetland be initiated (Anon., in press, c). The major recommendations of the plan are to designate most of the marsh as a Common Moorhen Sanctuary, rehabilitate the marsh by deepening it and controlling *Phragmites* growth, and reestablish appropriate emergent vegetation. The plan proposes that these actions be started in the northwest corner and then enlarged to the remainder of the wetland at a later date. A public education campaign would also be conducted.
A recovery plan for moorhens also lists a variety of activities needed to protect this species on Guam (U.S. Fish and Wildlife Service, 1991). Actions that apply to this marsh include: (1) the development and implementation of a habitat management plan through a cooperative management agreement between the Navy, Government of Guam and U.S. Fish and Wildlife Service; (2) the periodic monitoring of the site for toxic substances; (3) the conducting of regular censuses for moorhens; and (4) the control of introduced predators such as Brown Tree Snakes (*Boiga irregularis*) and feral dogs and cats.
Land use: A small amount of *Ipomoea aquatica* is collected in the marsh. The surrounding upland areas are used by the Navy for various military functions, including administrative and housing purposes. The Navy-operated landfill southeast of the marsh continues to be used as a disposal site for most of the garbage produced by the Navy on Guam.
Possible changes in land use: No changes in land use in or around the marsh are foreseen. Additional construction of new buildings at Camp Covington, located east of the marsh, could occur but is not expected to have a direct impact on the wetland.
Disturbances and threats: Historically, this wetland was probably much larger in size, but some of it was probably filled after World War II to make room for military facilities. Slow infilling from siltation over the years has allowed the invasion of *Phragmites* and *Panicum*, which occupy most of the site. Both plants tend to choke off the wetland, and prevent other more favourable emergent plant species from becoming established. The possible leaching of hazardous materials from the landfill represents a significant threat to the area that the Navy is currently investigating.
Hydrological and biophysical values: Important for trapping sediments and pollutants.
Social and cultural values: None known.
Noteworthy fauna: Small numbers of Common Moorhens were regularly seen here in the past, but increasingly dense reed beds resulted in few sightings from 1988-1990. Nesting has

undoubtedly occurred here. Small migratory flocks of Cattle Egrets (*Bubulcus ibis*) roost in the mangrove trees during the fall and winter months of most years. A few migratory waterfowl are also sometimes observed. Catfish (*Clarius macrocephalus*) are present.
Noteworthy flora: Moore *et al.* (1977) list the plants found on the site.
Scientific research and facilities: Moore *et al.* (1977) conducted a floral survey.
Conservation education: In its current condition, the wetland has little value for conservation education. However, if the program to enhance the marsh is carried out, the site will have significant value for educating the public about wetlands.
Management authority and jurisdiction: Management authority: Division of Aquatic and Wildlife Resources and U.S. Navy. Territorial jurisdiction: Territory of Guam and U.S. Navy. Functional Jurisdiction: Division of Aquatic and Wildlife Resources and U.S. Navy.
References: Anon. (in press, c); Moore *et al.* (1977); U.S. Fish & Wildlife Service (1991); Young (1988).
Reasons for inclusion: 1a, 2a, 2b. One of the largest marshes on Guam. Habitat for moorhens.
Source: Gary J. Wiles and Michael W. Ritter.

San Luis Ponds (8)

Location: 13°26'N, 144°39'E; these marshes are located on the north side of Orote Peninsula adjacent to Apra Harbor in west-central Guam. They occur on the U.S. Naval Station and in the municipality of Santa Rita. They lie 3.5 km east of Orote Point.
Area: A total of 7.5 ha for the two marshes.
Altitude: Sea level.
Overview: Two man-made estuarine ponds. Common Moorhens (*Gallinula chloropus guami*) are present for at least part of the year.
Physical features: A narrow artificial dike with an asphalt road separates the marsh from Apra Harbor. The dike also divides the marsh, creating two ponds that are 7.0 ha and 0.6 ha in size. The east pond is the largest and is triangular in shape. Both were probably created by the U.S. military during the late 1940s. Standing water in the large pond is generally about one metre deep although a moat on the inner edge, from which materials were obtained to construct the dike, has depths of up to two metres. The water level is fairly constant throughout the year. The ponds are primarily supported by freshwater run-off from nearby uplands, although there is some tidal influence (Biosystems Analysis, Inc., 1988). Thus, both are somewhat brackish. The southern sides of the marshes are bordered by limestone uplands that comprise San Luis Point. The soils in the vicinity of the ponds are quarried fill consisting primarily of limestone gravel (Young, 1988).
Ecological features: Both impoundments support lush beds of *Scirpus littoralis*, with *Acrostichum aureum* growing along many of the edges. There is about 20% open water in the larger pond and about 10% open water in the smaller pond. The habitat classification of the ponds is E1EM1Lh and E1OWLh (Cowardin *et al.*, 1979). The shorelines of both ponds support dense weedy growth (*Wollastonia biflora* and *Pluchea* x *fosbergii*) and some woody vegetation, primarily *Casuarina equisetifolia*, *Leucaena leucocephala* and *Thespesia populnea*. Mature limestone forest grows on the hillside to the south.
Land tenure: The wetland and surrounding areas are under the control of the U.S. Navy .
Conservation measures taken: The marsh is listed as a wetland of secondary importance for Common Moorhens (U.S. Fish and Wildlife Service, 1991).
Conservation measures proposed: A drafted natural resources management plan for the Naval Station proposes that active management of this wetland be started (Anon., in press, a). Major recommendations of the plan are to designate both ponds as a Common Moorhen Sanctuary, limit human activities in and around the ponds, and make structural modifications to the ponds that would enhance moorhen production. A public education campaign would also be initiated as part

of the program.
A recovery plan for moorhens also lists a variety of activities needed to protect this species on Guam (U.S. Fish and Wildlife Service, 1991). Actions that apply to this site include: (1) the development and implementation of a habitat management plan through a cooperative management agreement between the Navy, the Government of Guam and the U.S. Fish and Wildlife Service; (2) the conducting of regular censuses for moorhens; and (3) the control of introduced predators such as Brown Tree Snakes (*Boiga irregularis*) and feral dogs and cats.
Land use: The ponds are not used for any purpose. The road encircling the wetland is used recreationally to a minor extent, and the Navy maintains a small picnic and swimming area at NSD Beach on the west end of the small pond. The Navy also runs a small marina east of the large pond.
Possible changes in land use: No changes in land use are foreseen for this area.
Disturbances and threats: The omnivorous habits of tilapia in the ponds may prevent other types of aquatic vegetation from becoming established, and may reduce some populations of invertebrates. These effects may limit moorhen numbers below their potential carrying capacity.
Hydrological and biophysical values: None known.
Social and cultural values: None known.
Noteworthy fauna: Common Moorhens have been recorded at both ponds (Biosystems Analysis, Inc., 1988), but their occurrence is not well documented and historic sightings have been few. Nesting may occur here. Yellow Bitterns (*Ixobrychus sinensis*) also use the ponds. The ponds support dense populations of two species of tilapia (*Oreochromis mossambicus* and *Tilapia zilli*) and flagtails (*Kuhlia rupestris*) (Biosystems Analysis, Inc., 1988).
Noteworthy flora: None known.
Conservation education: The ponds have moderate potential for conservation education.
Recreation and tourism: A little fishing occurs in the ponds. The surrounding areas also receive some recreational use.
Management authority and jurisdiction: Management authority: Division of Aquatic and Wildlife Resources and U.S. Navy. Territorial jurisdiction: Territory of Guam and U.S. Navy. Functional Jurisdiction: Division of Aquatic and Wildlife Resources and U.S. Navy.
References: Anon. (in press, a); Biosystems Analysis, Inc. (1988); U.S. Fish & Wildlife Service (1991); Young (1988).
Reasons for inclusion: 2a. Habitat for moorhens.
Source: Gary J. Wiles and Michael W. Ritter.

Namo River Marsh (9)

Location: 13°24'N, 144°40'E; the marsh is located in west-central Guam in the municipality of Santa Rita. It lies about 1.4 km north of the village of Agat and just east of the intersection of Highways 2 and 2A. Most of the site is found on the U.S. Naval Station.
Area: 33 ha.
Altitude: 1-3 m.
Overview: A moderately-sized wetland that is heavily overgrown with *Phragmites karka*. Common Moorhens (*Gallinula chloropus guami*) probably reside in the area.
Physical features: This is a natural marsh found along the eastern bank of the lower Namo River. The lower 600 m of this river was channelized for flood control purposes in the late 1970s by the U.S. Army Corps of Engineers. A low dike, 50 m wide, was built next to the river channel at that time, along with a second similar dike across a central portion of the wetland. Water depths in the marsh reach at least one metre. They vary somewhat during the year, being lowest in the dry season. Biosystems Analysis, Inc. (1988) report on water quality parameters for the Namo River. The clay soils in the area are deep and poorly drained (Young, 1988).
The drainage area of the Namo River is about 500 ha (Best and Davidson, 1981). The eastern side

of the wetland is bounded by low hills, several of which jut into the site. A large residential area is located on the tops of several of these hills, while smaller areas of homes occur on the south and west. The wetland is bordered by Highway 2A on the northwest and a large concrete parking lot on the north.

Ecological features: The wetland consists predominantly of dense beds of *Phragmites karka* and woody stands of *Hibiscus tiliaceus*. An area of one hectare of *Panicum muticum* grows in the northwest corner on a site that was apparently cleared for farming about 8-10 years ago. Several pools of open water occur in the north-central portion of the marsh and cover an estimated 5% of the total area. The wetland is classified as PEM1F and PFO3C (Cowardin *et al.*, 1979). Scrubby secondary forest, with *Hibiscus tiliaceus*, *Leucaena leucocephala*, *Casuarina equisetifolia*, *Pandanus tectorius* and a variety of other species, is the major vegetation type surrounding the wetland.

The Namo River Wetland was probably once part of a much larger interconnected complex of marshes that bordered inner Apra Harbor. However, these wetlands have been severely fragmented over the years by filling for military activities, civilian development and road construction. The present-day Naval Station and Atantano Marshes were part of this complex.

Land tenure: The wetland and surrounding areas are partly under the control of the U.S. Navy and partly in private ownership.

Conservation measures taken: The marsh is listed as a wetland of secondary importance for Common Moorhens (U.S. Fish and Wildlife Service, 1991).

Conservation measures proposed: A recovery plan for moorhens lists a variety of activities needed to protect this species on Guam (U.S. Fish and Wildlife Service, 1991). Actions that apply to this site include: (1) the development and implementation of a habitat management plan through a cooperative management agreement between the Navy, Government of Guam and U.S. Fish and Wildlife Service; (2) the periodic monitoring of the site for toxic substances; (3) the conducting of regular censuses for moorhens; and (4) the control of introduced predators such as Brown Tree Snakes (*Boiga irregularis*) and feral dogs and cats.

The northern portion of the marsh is located on the Naval Station and is one of a number of wetlands noted in a recently drafted natural resources management plan for the base (Anon., in press, a). Although the plan does not make specific management recommendations for this area, it does provide a list of general recommendations regarding the base's wetlands. Recommendations that apply to the marsh include: (1) protecting the site from development; (2) maintaining a buffer zone 30 m wide around the site; (3) posting of signs around the site to note its protected status; and (4) assisting the Government of Guam and the U.S. Fish and Wildlife Service in moorhen censuses.

Land use: Before World War II, portions of the marsh were used for farming rice and vegetables (Thompson, 1947). From the late 1940s to the mid-1970s, an area immediately north of the wetland known as Camp Busanda provided housing for about 10,000 contract workers and military personnel. An adjacent area bordering the east side of the wetlands was a disposal site for solid wastes and contained several underground storage tanks. At present, the wetland is not used. A large residential area occurs about 300-400 m to the east on adjacent lands, while smaller areas of homes are also present to the south and west. The parking lot on the north side of the marsh is used by the Guam Department of Education for parking school buses.

Possible changes in land use: The Government of Guam is proposing to construct a municipal sewage treatment facility on the north side of the marsh on land that is now partially occupied by the parking lot. The facility will include primary and secondary treatment facilities and a pump station, and will cover about 8-10 ha.

Disturbances and threats: This site suffers from a number of problems, making it one of the more threatened wetlands on Guam. Thick beds of *Phragmites* cover large areas and prevent the establishment of other more favourable wetland plants. The heavy growth of *Phragmites* is probably enhanced by the long-term deposition of eroded soils into the marsh from neighbouring lands. The channelization of the lower Namo River has probably increased drainage and lowered seasonal water levels (Biosystems Analysis, Inc., 1988). Tests for hazardous wastes in the vicinity of the parking lot found oil in the ground and higher than expected levels of heavy metals. These materials probably originated from a vehicle maintenance yard that the Navy operated at the site for

about 30 years. The Navy also believes that underground storage tanks east of the marsh are still in place and may be leaking hazardous substances. The building of the sewage treatment plant may result in additional filling and contamination of the wetland.
Hydrological and biophysical values: Valuable in flood control and sediment trapping.
Social and cultural values: None known.
Noteworthy fauna: Wildlife use of the marsh is not well documented. Common Moorhens probably reside here, particularly in the pools of open water at the north end.
Noteworthy flora: A list of plants in the wetland is given in Moore *et al.* (1977).
Scientific research and facilities: Moore *et al.* (1977) conducted a floral survey of the site.
Conservation education: The wetland has moderate potential for conservation education.
Management authority and jurisdiction: Management authority: Division of Aquatic and Wildlife Resources and U.S. Navy. Territorial jurisdiction: Territory of Guam and U.S. Navy. Functional Jurisdiction: Division of Aquatic and Wildlife Resources and U.S. Navy.
References: Anon. (in press, a); Biosystems Analysis, Inc. (1988); Moore *et al.* (1977); U.S. Fish and Wildlife Service (1991); Young (1988).
Reasons for inclusion: 2a. Habitat for moorhens.
Source: Gary J. Wiles and Michael W. Ritter.

Pulantat Marshes (10)

Location: 13°25'N, 144°44'E; these wetlands are located in central Guam in the municipality of Yona. The smaller eastern marsh occurs 3.7 km west of Yona village, with the larger marsh found 0.5 km further west.
Area: A total of 2 ha for two marshes. The western site covers 1.2 ha.
Altitude: 133 m.
Overview: Two artificial marshes located in savanna along the edge of a large resort currently under construction. Common Moorhens (*Gallinula chloropus guami*) nest seasonally at both sites.
Physical features: The Pulantat Marshes are comprised of two man-made impoundments located near the edge of a high plateau overlooking the Sigua River valley. Both wetlands have small dikes two metres high at their eastern ends and were built in about 1966 by the landowner (H.D. Look, pers. comm.). They are filled by run-off water from somewhat higher ground to the south and west, and have water depths of 0.6-0.8 m during the rainy season. In the dry season, the eastern pond dries out completely while the western marsh retains only one small pool at the east end. The marshes are bounded by gently sloping uplands to the south and west, and by the Sigua River valley to the north. Soils in the marshes have not been classified but are probably derived from the clay soils that occur throughout the area.
Ecological features: Both marshes are comprised primarily of uniform beds of *Eleocharis ochrostachys*. A small stand of *Phragmites karka* occurs at the western end of the larger pond. Depending on the time of year and amount of water present, relatively open water covers between 0-30% of the marshes. Both as classified as PEM1Fh (Cowardin *et al.*, 1979). The savanna grasslands surrounding the marshes are comprised of *Miscanthus floridulus*, *Gleichenia linearis*, a variety of other herbaceous plants and scattered *Casuarina equisetifolia*. Numerous erosional scars of exposed earth exist in the vicinity of both ponds.
Land tenure: The wetlands and surrounding areas are privately owned.
Conservation measures taken: The marshes are listed as wetlands of secondary importance for Common Moorhens (U.S. Fish and Wildlife Service, 1991). In 1989, in response to the impending building of a resort immediately south of the marshes, federal and territorial government agencies

prevailed upon the resort's developer to redesign the project to preserve both sites. The developer is being required to protect the marshes during construction by using silt fences and other methods to control soil run-off. Other practices have also been instituted to protect any Common Moorhens in the western marsh. These include maintaining buffer zones of no activity that are 10-90 m wide around the marsh, and keeping the area free of dogs and pollutants.

Conservation measures proposed: A recovery plan for moorhens lists a variety of activities needed to protect this species on Guam (U.S. Fish and Wildlife Service, 1991). Actions that apply to the marshes include: (1) the development and implementation of a habitat management plan through a cooperative management agreement among the landowners, the Government of Guam and the U.S. Fish and Wildlife Service; (2) the conducting of regular censuses for moorhens; (3) the control of introduced predators such as Brown Tree Snakes (*Boiga irregularis*) and feral dogs and cats; and (4) the periodic monitoring of the site for toxic substances.

The developer of the resort will be required to continue some erosion control practices to protect the marshes after the completion of the resort. For the benefit of moorhens, the U.S. Fish and Wildlife Service will also require that the developer: (1) maintain a suitable water level throughout the year in the western marsh by piping or trucking water to the site; (2) construct or plant a visual barrier of some form around the site to reduce human-related disturbances to the birds; and (3) monitor water quality for pollutants.

Land use: The marshes were constructed in 1966 as a water source for cattle. The animals were removed from the area in 1975 and since then, both sites have remained essentially unused. The surrounding grasslands also received little use until 1988, when work began on the huge 525 ha resort. When completed in about 1994, the resort will comprise 3,000 housing units, a hotel and commercial centre, two and a half golf courses, several artificial lakes and a number of service roads.

Possible changes in land use: In September 1991, a second group of developers presented the Government of Guam with plans for the building of another large resort in the Sigua River valley and immediately south of the marshes. Thus, both marshes may be surrounded by urban growth by the end of the decade.

Disturbances and threats: Both marshes suffer from chronic siltation caused by soil run-off from adjoining lands. The grasslands in the area are prone to dry season fires, which are often set by people and result in erosion. Despite the safeguards taken during the construction of the resort, there is still some possibility that the project will lead to further erosion and disturb resident moorhens. During the dry season, feral pigs (*Sus scrofa*) commonly visit both wetlands to feed on *Eleocharis* tubers. The pigs may root up 10-20% of each marsh while feeding.

Hydrological and biophysical values: Useful in trapping soil sediments.

Social and cultural values: None known.

Noteworthy fauna: Common Moorhens inhabit both marshes during the wet season. Breeding has been recorded at both locations.

Noteworthy flora: None known.

Conservation education: The marshes will have moderate value for education purposes, once the resort is completed and public access into the area is improved.

Management authority and jurisdiction: Management authority: Division of Aquatic and Wildlife Resources. Territorial jurisdiction: Territory of Guam. Functional Jurisdiction: Division of Aquatic and Wildlife Resources.

References: U.S. Fish & Wildlife Service (1991).

Reasons for inclusion: 2a. Habitat for moorhens.

Source: Gary J. Wiles and Michael W. Ritter.

Naval Magazine Pond (11)

Location: 13°23'N, 144°41'E; this pond is located in south-central Guam in the municipality of Santa Rita. It lies about 20-30 m off the south side of Highway 12, approximately 0.9 km east of the village of Santa Rita. It occurs entirely within the boundaries of the U.S. Naval Magazine.
Area: 0.5 ha.
Altitude: 85 m.
Overview: A small marsh found on the U.S. Naval Magazine. Common Moorhens (*Gallinula chloropus guami*) are periodically recorded here.
Physical features: This man-made wetland was probably created when Highway 12 and an adjacent berm were constructed, blocking water flow along a small seasonal stream. The site is bordered by forest to the south and by Highway 12, mowed openings and a chainlink fence to the north. A small culvert under the road drains the pond and prevents flooding. The site holds water year-round, but the level may decline to a depth of 0.5-1.0 m in the dry season. Soils are deep, well-drained, contain a silt and clay mixture, and are volcanic based (Young 1988).
Ecological features: This wetland is 50-75% open water and dominated by an unidentified submergent algae. Emergent vegetation, mainly *Phragmites karka* and *Panicum muticum*, grows along the edges in several shallow areas. Some *Hibiscus tiliaceus* is also present. The site is classified as PAB1Hh and PEM1Hh (Cowardin *et al.*, 1979). The marsh is bounded by secondary limestone forest to the south.
Land tenure: The wetland and surrounding areas are under the control of the U.S. Navy.
Conservation measures taken: The Navy has generally prohibited the entry of civilians into Naval Magazine for the purposes of military security since the base was established in the early 1950s. Although not a deliberate conservation action, this limitation has indirectly protected the base's wildlife and natural habitats. The pond is listed as a wetland of secondary importance for Common Moorhens (U.S. Fish and Wildlife Service, 1991), and the forest bordering the south side has been declared essential habitat for Marianas Fruit Bats (*Pteropus mariannus*) (Wiles, 1990).
Conservation measures proposed: A recovery plan for moorhens lists the actions needed to protect this species at this site (U.S. Fish and Wildlife Service, 1991). These include the development and implementation of habitat management plans, the conducting of regular censuses, the control of introduced predators such as Brown Tree Snakes (*Boiga irregularis*) and feral dogs and cats, and the control of introduced ungulates. A new natural resources management plan for Naval Magazine also calls for the protection of natural habitats and the improvement of moorhen habitat (Biosystems Analysis, Inc., 1990). A proposal to establish Critical Habitat for fruit bats and endangered forest birds throughout Naval Magazine, which would give protection to the forests surrounding this wetland, is now being considered by the U.S. Fish and Wildlife Service.
Land use: Naval Magazine serves as a munitions storage site and public access is completely restricted. The area surrounding the pond is not actively used for any purpose.
Disturbances and threats: Soil run-off from nearby hills into the pond may be a minor problem. Erosion is caused primarily by rooting, trampling and overgrazing by feral pigs (*Sus scrofa*) and Philippine Deer (*Cervus mariannus*) in adjoining forests.
Hydrological and biophysical values: None known.
Social and cultural values: None known.
Noteworthy fauna: Moorhens are periodically observed at this marsh but their occurrence, which appears to be seasonal, has not been well studied. The species may breed here. Deer and feral pigs are common in the forests adjacent to the marshes.
Noteworthy flora: None known.
Conservation education: The pond has limited potential for conservation education.
Management authority and jurisdiction: Management authority: Division of Aquatic and Wildlife Resources and U.S. Navy. Territorial jurisdiction: Territory of Guam and U.S. Navy. Functional Jurisdiction: Division of Aquatic and Wildlife Resources and U.S. Navy.
References: Biosystems Analysis, Inc. (1990); U.S. Fish & Wildlife Service (1991); Wiles (1990); Young (1988).
Reasons for inclusion: 2a. Habitat for moorhens.
Source: Gary J. Wiles and Michael W. Ritter.

Fena Valley Reservoir (12)

Location: 13°21'N, 144°42'E; the reservoir occurs in south-central Guam in the municipalities of Santa Rita, Agat and Talofofo. It is located entirely within the boundaries of the U.S. Naval Magazine.
Area: 81 ha.
Altitude: 33 m.
Overview: The largest open body of fresh water on Guam. The reservoir was built by the Navy in 1951 as a source of drinking water. It holds the largest dry season concentration of Common Moorhens (*Gallinula chloropus guami*) on Guam.
Physical features: The reservoir was formed by the damming of the Mahlac River and is 3 km long and up to 600 m wide. A large dike about 400 m long and 12 m high and a spillway occur on the northeast side of the reservoir. The Maulep, Almagosa, Sadog Gaso and Imong Rivers flow into the reservoir. The areas drained by these rivers occupy approximately 1,500 ha. The reservoir has a stored water capacity of about 9.7 million cubic meters when full (Biosystems Analysis, Inc., 1989b). Maximum water depth in the reservoir is 20 m during the rainy season, but the water level drops 2-9 m during the dry season. The predominant soil types of the area are deep, well-drained volcanic clays (Young, 1988). Average water temperatures range from 27-31°C (Kennedy Engineers, 1974; Biosystems Analysis, Inc., 1989b). Levels of dissolved oxygen are very low at the bottom of the reservoir but increase near the surface. The stratification of oxygen is typical of tropical lakes and is a result of decomposition of organic matter in deeper water (Biosystems Analysis, Inc. 1989b). Nutrient concentrations are reported by Kennedy Engineers (1974). Average outflow of water from the reservoir is about 62 million litres per day (Ward *et al.*, 1965).
Ecological features: The reservoir is an open-water lake surrounded primarily by steep slopes vegetated with ravine forest, grassland and limestone forest. The reservoir contains extensive beds of *Hydrilla verticillata*. Narrow bands of emergent vegetation (*Phragmites karka*, *Panicum muticum* and *Cyperus difformis*) grow along the shoreline. The main body of the reservoir is classified as L10WHh and its edges as PEMIF and PEMIC (Cowardin *et al.*, 1979).
Land tenure: The wetland and surrounding areas are under the control of the U.S. Navy.
Conservation measures taken: The Navy has generally prohibited the entry of civilians into Naval Magazine and the Fena Valley Reservoir for the purposes of military security since the base was established in the early 1950s. Although not a deliberate conservation action, this limitation has served indirectly to protect the base's natural habitats and wildlife. All hunting and most fishing in and around the reservoir is prohibited because of entry restrictions, although these activities occur illegally at low to moderate levels. The reservoir is listed as a primary wetland for Common Moorhens (U.S. Fish and Wildlife Service, 1991), and the entire watershed has been declared essential habitat for Marianas Fruit Bats (*Pteropus mariannus*) (Wiles, 1990). Both species are endangered. A program is ongoing to revegetate a small hillside on the northwest side of the reservoir, thereby reducing soil erosion caused by trampling and overgrazing by feral water buffalo (*Bubalus bubalis*).
Conservation measures proposed: Recovery plans for moorhens and fruit bats list a number of actions that need to be taken to protect these species in the Fena Valley (U.S. Fish and Wildlife Service, 1991; Wiles, 1990). These include the development and implementation of habitat management plans, the conducting of regular censuses, the control of introduced predators such as Brown Tree Snakes (*Boiga irregularis*) and feral dogs and cats, and the control of introduced ungulates. A new natural resources management plan for Naval Magazine also calls for the active management of natural resources on the base (Biosystems Analysis, Inc., 1990). This includes the protection of natural habitats in the Fena Valley watershed, the reduction of soil erosion through reforestation, the establishment of a water quality monitoring program for the reservoir, and the

improvement of moorhen habitat. A proposal to establish Critical Habitat for fruit bats and endangered forest birds throughout the watershed is under consideration by the U.S. Fish and Wildlife Service. Recent discussions between the Navy and the Guam Division of Aquatic and Wildlife Resources may lead to the establishment of a protected area for Common Moorhens in the southern half of the reservoir if greater public entry to the base is allowed in the future.

Land use: Naval Magazine serves as a munitions storage site and public access is completely restricted. The reservoir serves as an important source of drinking water for Navy bases and civilian communities in southern Guam. There is little human use of the reservoir and surrounding areas. Currently, fishing is limited to only a few employees of the base and all hunting is prohibited. However, some illegal hunting and fishing does occur.

Possible changes in land use: Recent discussions have been held regarding the opening of Naval Magazine and the Fena Valley Reservoir to the public for managed fishing, hunting and recreational programs.

Disturbances and threats: Soil sediments are gradually filling the reservoir due to erosion from nearby hills. Soil run-off is increased by grassland fires, which are deliberately set by illegal hunters and other trespassers, and heavy amounts of rooting, trampling and overgrazing by feral water buffalo and pigs in the watershed area. Overgrazing of aquatic vegetation and invertebrates by introduced fish may be affecting the abundance and reproductive success of moorhens.

Hydrological and biophysical values: The reservoir has some value in trapping sediments and preventing their transport down the Mahlac and Talofofo Rivers.

Social and cultural values: Because of restricted entry to civilians, there is currently little social value associated with the reservoir.

Noteworthy fauna: Common Moorhens inhabit the reservoir throughout the year, but numbers increase during the dry season when birds immigrate here as other wetlands on the island dry up (Stinson *et al.*, 1991). Thus, the reservoir is the most important dry season refuge for this species on Guam. Moorhen numbers observed during censuses average about 30-60 birds in the dry season and 10-30 birds in the rainy season (Beck *et al.*, 1988). Breeding commonly occurs on the reservoir. Yellow Bitterns (*Ixobrychus sinensis*) are also common. A small population of Marianas Fruit Bats occurs in the forest surrounding the southern half of the reservoir (Wiles, unpubl. data). Philippine Deer (*Cervus mariannus*), feral pigs (*Sus scrofa*) and feral water buffalo are common in forests adjoining the reservoir.

Aquatic organisms are listed by Biosystems Analysis, Inc. (1989b). They include eels (*Anguilla marmorata* and *A. bicolor*), tilapia (*Oreochromis mossambicus* and *Tilapia zilli*), tucunare (*Cichla ocellaris*), catfish (*Clarius macrocephalus*), sleepers (*Eleotris fusca*), gobies (*Awaous guamensis* and *Sicyopterus macrostetholepis*), flagtails (*Kuhlia rupestris*), mosquitofish (*Gambusia affinis*) and shrimp (*Macrobrachium lar*, *Atyoida pilipes* and *Caridina* sp.) (Kennedy Engineers, 1974; Biosystems Analysis, Inc., 1989b).

Noteworthy flora: Biosystems Analysis, Inc. (1989b) list the aquatic plants and phytoplankton in the reservoir.

Scientific research and facilities: Limnological, plankton, floral and faunal surveys were made by Kennedy Engineers (1974) and Biosystems Analysis, Inc. (1989b). The Division of Aquatic and Wildlife Resources conducted monthly censuses of moorhens in 1987-1988 (Beck *et al.*, 1988).

Conservation education: The reservoir and surrounding watershed is visited several times a year for ecological field trips by university students. There is great potential for increasing the amount of this activity.

Recreation and tourism: A small amount of recreational fishing occurs at the reservoir. Swimming is not allowed. If well-managed programs are adopted, there is significant potential for increasing the amount of public recreation on the reservoir.

Management authority and jurisdiction: Management authority: Division of Aquatic and Wildlife Resources and U.S. Navy. Territorial jurisdiction: Territory of Guam and U.S. Navy. Functional Jurisdiction: Division of Aquatic and Wildlife Resources and U.S. Navy.

References: Beck *et al.* (1988); Biosystems Analysis, Inc. (1989b, 1990); Kennedy Engineers (1974); Stinson *et al.* (1991); U.S. Fish & Wildlife Service (1991); Ward *et al.* (1965); Wiles (1990).

Reasons for inclusion: 2a. Major dry season refuge for Common Moorhens.

Source: Gary J. Wiles and Michael W. Ritter.

Naval Magazine Marshes (13)

Location: 13°22'N, 144°42'E; the marshes occur in south-central Guam in the municipality of Talofofo. They are located approximately 4.3 km west of the village of Talofofo. They are found entirely within the boundaries of the U.S. Naval Magazine.
Area: A total of 2.4 ha for the three marshes.
Altitude: 20-25 m.
Overview: These three small marshes occur on the east side of Naval Magazine in the Talofofo River watershed. Because of their distinct habitat and occurrence on military land, they are discussed as a separate site rather than as part of the Talofofo River Valley. Common Moorhens (*Gallinula chloropus guami*) inhabit two of the marshes for most of the year.
Physical features: These three natural sites are located near the Mahlac Stream, which is a tributary of the Talofofo River. They are orientated on a north-south axis over a distance of 1 km. The northern marsh (0.2 ha) is surrounded entirely by knolls of limestone karst and is filled by water run-off from these hills. The central (0.6 ha) and southern (1.6 ha) marshes are bounded by forested limestone hills on three sides and lowland swamp forest on one side. Drainage of the marshes occurs through seepage into the ground. Only the central and southern sites are believed to hold water throughout most years. Water level in the central marsh is about 1 m deep during the wet season. The marshes occur on deep, clay soils that are poorly drained (Young, 1988).
Ecological features: The southern marsh has about 30% open water. The eastern and northern portions are thickly vegetated with *Phragmites karka*, while the western and southern ends are more open with *Potamogeton* sp. and *Chara corallina* present. The central marsh is oval-shaped and about 30% open water. Most of it is occupied by dense *Phragmites* growing inward from the edges. A large opening in the centre is vegetated with *Eleocharis ochrostachys*, *Potamogeton* sp. and *C. corallina*. Vegetation in the northern marsh has not been determined. Water levels fluctuate between the dry and wet seasons, with an increase in vegetative growth in the dry season. The habitat classification of the marshes is PEM1F and PAB2 (Cowardin *et al.*, 1979).
Land tenure: The wetland and surrounding areas are under the control of the U.S. Navy.
Conservation measures taken: The Navy has generally prohibited the entry of civilians into Naval Magazine for the purposes of military security since the base was established in the early 1950s. Although not a deliberate conservation action, this limitation has served indirectly to protect the base's natural habitats and wildlife. All hunting around these marshes is prohibited because of entry restrictions, although some poaching still occurs. The marshes are listed as secondary wetlands for Common Moorhens (U.S. Fish and Wildlife Service, 1991).
Conservation measures proposed: A recovery plan for moorhens list a number of actions needed to protect these species in the Naval Magazine marshes (U.S. Fish and Wildlife Service, 1988). These include the development and implementation of habitat management plans, the conducting of regular censuses, the control of introduced predators such as Brown Tree Snakes (*Boiga irregularis*) and feral dogs and cats, and the control of introduced ungulates. A new natural resources management plan for Naval Magazine also calls for the active management of natural resources on the base (Biosystems Analysis, Inc., 1990). This includes the protection of natural habitats on the base and the improvement of moorhen habitat. A proposal to establish Critical Habitat for endangered Marianas Fruit Bats (*Pteropus mariannus*) and forest birds on Naval Magazine, which would give protection to the forest habitat surrounding these marshes, is under consideration by the U.S. Fish and Wildlife Service.
Land use: The Naval Magazine serves as a munitions storage site, and public access is completely restricted. The area surrounding these marshes is not actively used for any purpose but does serve as an important watershed area.

Possible changes in land use: Recent discussions have been held regarding the opening of Naval Magazine to the public for managed hunting and recreational programs.
Disturbances and threats: Soil run-off from nearby hills may be gradually filling in these marshes. Erosion is caused primarily by heavy amounts of rooting, trampling and overgrazing by feral pigs (*Sus scrofa*) and deer in the adjoining forests.
Hydrological and biophysical values: None known.
Social and cultural values: None known.
Noteworthy fauna: Moorhens inhabit the southern and central marshes for most of the year, but may depart during the height of the dry season (Ritter and Wiles, unpubl. data). Breeding probably occurs. Island Swiftlets (*Aerodramus vanikorensis*) have a nesting colony close to the central marsh, and forage extensively over the southern and central marshes. Yellow Bitterns (*Ixobrychus sinensis*) are also common. Philippine Deer (*Cervus mariannus*) and feral pigs are common in the surrounding forests.
Noteworthy flora: None known.
Conservation education: The marshes have little value for conservation education because of their remote locations.
Management authority and jurisdiction: Management authority: Division of Aquatic and Wildlife Resources and U.S. Navy. Territorial jurisdiction: Territory of Guam and U.S. Navy. Functional Jurisdiction: Division of Aquatic and Wildlife Resources and U.S. Navy.
References: Biosystems Analysis, Inc. (1990); U.S. Fish & Wildlife Service (1991); Young (1988).
Reasons for inclusion: 2a. Habitat for moorhens and swiftlets.
Source: Gary J. Wiles and Michael W. Ritter.

Talofofo River Valley (14)

Location: 13°20'N, 144°45'E; the wetland extends westward from Talofofo Bay almost to Fena Reservoir, following the basin of the Talofofo River in southern Guam. The valley is located in the municipalities of Talofofo, Inarajan and Santa Rita, with the headwaters found on the U.S. Naval Magazine. The mouth of the valley lies 1.3 km southeast of Talofofo village.
Area: 279 ha.
Altitude: Sea level to 30 m.
Overview: The largest contiguous wetland on Guam, occupying riparian areas along the valley of the Talofofo and lower Ugum Rivers. Most of the wetland is forested but a variety of other habitats are also present. Large stands of *Barringtonia racemosa* occur here. The island's only large population of Island Swiftlets (*Aerodramus vanikorensis*) forages exclusively over the wetland and surrounding watershed.
Physical features: This large natural wetland occupies most of the broad alluvial plain along the Talofofo River and its major tributaries, the Ugum, Maagas, Mahlac, Sarasa and Tinechong Rivers. The river system drains much of southern Guam and has a watershed of 7,300 ha (Best and Davidson, 1981). The wetland is about six km long and varies in width from 100-500 m. Drainage patterns in the wetland probably remain mostly intact. Only one road, located in the Acapulco area, crosses the wetland. The road is raised up about 0.5 m and causes some water to back up behind it. Soil is a deep and poorly drained clay derived from both volcanic rock and limestone (Moore *et al.*, 1977; Young, 1988). A group of 11 fish ponds occurs near the mouth of the Talofofo River and occupies 3.5 ha. The ponds are about 1.2 m deep, have steep sides and level bottoms, and are permanently flooded.
The Talofofo River meanders through the valley and is joined by the Ugum River about 1.2 km from Talofofo Bay. The lower Talofofo River is 10 m wide and 2-6 m deep (Wilder, 1976). Brackish waters extend about 1.6 km upstream (Wilder, 1976). Flow rates, water quality parameters and sediment discharge rates in the Talofofo and Ugum Rivers are described by Randall (1974),

Moore *et al.* (1977) and Shade (1983). Water temperatures in the lower Talofofo River range from 26-28°C (Wilder, 1976).

The wetland is bordered by ridge lines and rolling hills. Areas of volcanic soils occur primarily on the south side of the valley, while limestone-based soils are present on the east, north and west (Young, 1988).

Ecological features: Swamp forest with *Barringtonia racemosa*, *Hibiscus tiliaceus*, *Pandanus tectorius*, *Areca catechu*, *Cocos nucifera* and *Cynometra ramiflora* occupies large sections of the wetland. Relatively pure stands of *Barringtonia* and *Hibiscus* occur at some locations (Fosberg, 1960). *Barringtonia* reaches heights of 10-15 m, with trees often growing on low hummocks surrounded by small muddy channels (Fosberg, 1960). Standing water in these forests is usually present only in the rainy season, with the ground being muddy to relatively dry during the rest of the year. The banks of the Talofofo and lower Ugum Rivers are lined with *H. tiliaceus*, *C. nucifera*, *Bambusa vulgaris* and *Pennisetum* sp., while *Nypa fruticans* extends about 900 m upstream from the river mouth, being limited by the range of brackish water (Wilder, 1976; Wiles, pers. obs.). *Pistia stratiotes* covers portions of the lower Talofofo River channel.

Stands of *Phragmites karka* grow on some sites that are probably old agricultural fields. A few newer fields are scattered throughout the valley and are sometimes cultivated during the late dry season and early wet season. After harvesting, the fields quickly become overgrown with a variety of grasses and weeds. Other plants in the wetland include *Ipomoea aquatica*, *Panicum muticum*, *P. maximum*, *Acrostichum aureum* and *Cyperus* sp. Aside from the river channels, the only open water in the entire wetland occurs in the fish ponds and at two pools in the centre of the valley. Various wetland habitats in the valley are classified as PFO3C, PEM1F, PEM1C, R1OWH and POWHKx (Cowardin *et al.*, 1979).

Upland vegetation in the valley is greatly influenced by soil type. Mixed limestone forest occurs on limestone soils. Ravine forest and savanna grasslands with *Miscanthus floridulus* are found on sites with volcanic soils.

Land tenure: All of the wetland is privately owned except for about 45 ha at the western end which is located on the U.S. Naval Magazine. Most of the watershed is privately owned, with the Government of Guam and Navy owning smaller sections.

Conservation measures taken: Few active measures have been taken to manage this wetland. The Navy has prohibited the entry of civilians into the western end of the valley on Naval Magazine for military security reasons since the early 1950s. Although not a deliberate conservation action, this limitation has indirectly protected the area and its wildlife. The upper portion of the Talofofo watershed, which is found on the base and includes the swamp, has been declared essential habitat for Marianas Fruit Bats (*Pteropus mariannus*) (Wiles, 1990). An area of eight ha near the Talofofo River mouth is designated as a secondary wetland for Common Moorhens (U.S. Fish and Wildlife Service, 1991).

Conservation measures proposed: Recovery plans for Common Moorhens (*Gallinula chloropus guami*) and Marianas Fruit Bats list a number of actions needed to protect these species in the wetland and its watershed (U.S. Fish and Wildlife Service, 1991; Wiles, 1990). These include the development and implementation of habitat management plans, the conducting of regular censuses, the control of introduced predators such as Brown Tree Snakes (*Boiga irregularis*) and feral dogs and cats, and the control of introduced ungulates. A new natural resources management plan for Naval Magazine also calls for the active management and protection of natural habitats on the base (Biosystems Analysis, Inc., 1990). A proposal to establish Critical Habitat for fruit bats and endangered forest birds throughout Naval Magazine, which would give protection to the western swamp forest and its watershed, is now being considered by the U.S. Fish and Wildlife Service. The entire Talofofo Valley should be declared essential habitat for Island Swiftlets.

The owner of the fish ponds is being required by the U.S. Army Corps of Engineers to enhance three of his ponds for moorhens and manage them as a wildlife area, as part of a mitigation plan for his unauthorized building of five ponds from 1985-1987.

Land use: Safford (1905) reported that corn was grown in the bottomlands of the valley. Thompson (1947) indicated that some areas were used for garden crops before World War II. Most of the wetland and surrounding watershed has been unused for at least several decades. *Ipomoea aquatica* was cultivated in several areas in the 1970s (Moore *et al.*, 1977). Currently, vegetable farming occurs seasonally at a few small fields. The aquaculture ponds near the mouth of the Talofofo River produce hybrid tilapia (*Oreochromis mossambicus* x *O. niloticus*). Half of the ponds were built in the early 1970s, with the remainder made in the mid-1980s. A few homes exist in the valley. In early 1991, construction began on a new golf course on the north-central slopes of the valley.

Possible changes in land use: Several additional golf courses and resorts are proposed for the valley. However, none will be built in the wetland.

Disturbances and threats: Soil erosion from hillsides is one of the most severe threats to the wetland. Fires annually burn large amounts of grassland in the watershed, causing a significant soil loss into streams and the wetland after heavy rains. Turbidity of the Talofofo River increases greatly after heavy rains. Deposits of volcanic soil are noticeable in parts of the swamp below some hills. Further erosion will probably result from the careless construction of new golf courses. Feral pigs (*Sus scrofa*) are abundant in the area; their rooting is another cause of erosion on hillsides. Pigs also damage the wetland by disturbing soils and feeding on plant seedlings.

Sedimentation and past farming activities have probably aided the establishment of thick *Phragmites* reed beds, which choke portions of the wetland. The dense beds are largely unsuitable for most wetland birds and prevent other wetland plants from becoming established.

The Public Utility Agency of Guam will install a water diversion structure in the lower Ugum River in 1992. Expected rates of water withdrawal are 7-11 million litres per day. There have also been requests from golf course developers and farmers to pump water from the Talofofo River for irrigation. In the late 1970s, a proposal to build a dam on the upper Ugum River as a municipal water source was considered but eventually scrapped (U.S. Army Corps of Engineers, 1980). The removal of significant amounts of stream water will probably reduce stream flow and increase saltwater intrusion up the Talofofo and Ugum Rivers.

The few farmers in the valley apply pesticides to their fields, which are often located in seasonally flooded areas next to water courses. Under some circumstances, pesticides could easily leach into the adjacent wetland or streams.

The development of fish ponds at the mouth of the valley altered about 3.5 ha of the wetland, and resulted in the flooding of an adjacent one hectare grove of *Barringtonia* and *Hibiscus* forest, which is now mostly dead. Water for the ponds is obtained from the river, with waste water discharged back into the river. High nutrient loads in the waste water undoubtedly affect the river's ecology downstream.

Hydrological and biophysical values: Valuable in sediment trapping and support of food chains.

Social and cultural values: A number of archaeological sites are present, suggesting that a large human population once lived in the valley. Perhaps the most important site is the remains of an ancient village located about one km upstream along the Talofofo River. It contains about 10 sets of latte stones. Radio carbon dating shows that it was inhabited back to at least 300 A.D. (R. Davis, pers. comm.). Other latte sets and cultural deposits are scattered throughout the valley. Some hunting, fishing, shrimping and gathering of betel nut occurs in the valley.

Noteworthy fauna: Guam's only remaining large colony of Island Swiftlets, which contains about 400-500 birds, forages almost exclusively along the entire length of the Talofofo valley from eastern Naval Magazine to Talofofo Bay and the lower Ugum valley (Beck and Wiles, 1989). Feeding occurs over the swamp and hillsides. Preservation of habitat in the valley is extremely important in maintaining the current swiftlet population. Common Moorhens have been recorded sporadically at a flooded field in the Acapulco area and at the fish ponds, but nesting has never been noted. They may reside elsewhere in the valley, but in general the small amount of marshland limits the population. Feral pigs and Philippine Deer (*Cervus mariannus*) are common in the swamp.

A number of aquatic animals have been recorded in the streams and rivers of the wetland. Invertebrates include various shrimp (*Macrobrachium lar*, *M. latimus*, *Atya serrata*, *Caridina typus*, *C. niloticus* and *C. serratirostris*), a limpet-like snail (*Neritina pulligera*) and snails of the family Thiaridae (U.S. Fish and Wildlife Service, 1978). Mangrove crabs (*Scylla serrata*) inhabit the *Nypa* communities. Freshwater and estuarine fish include gobies (*Awaous guamensis*, *Stiphodon elegans* and *Periophthalmus*

koelreuteri), *Eleotris fusca*, *Kuhlia rupestris*, *Gambusia affinis*, an eel (*Anguilla marmorata*), rabbitfishes (*Siganus argenteus*, *S. punctatus* and *S. spinus*), *Liza fulvus* and other mullets, snappers (*Lutjanus fulvus* and *L. argentimaculatus*), a barracuda (*Sphyaena barracuda*), tilapia (*Oreochromis mossambicus*) and a catfish (*Clarius macrocephalus*) (Randall, 1974; U.S. Fish and Wildlife Service, 1978; R.F. Myers, pers. comm.).
Noteworthy flora: The valley contains the largest stand of *Barringtonia racemosa* swamp forest in the Mariana Islands. A checklist of plants found in the lower Talofofo River valley is provided by Moore *et al.* (1977).
Scientific research and facilities: Limnological and biological studies were made by Randall (1974), Moore *et al.* (1977) and Shade (1983). Swiftlet distribution in the valley was mapped by Beck and Wiles (1989).
Conservation education: The swamp forest in the valley has some potential for conservation education. It might be possible to include some form of wetland education as part of the riverboat tour.
Recreation and tourism: A small riverboat operation takes tourists about one km up the river once or twice a day to the ancient village site. The jungle atmosphere of the river is an important part of the trip's attraction.
Management authority and jurisdiction: Management authority: Division of Aquatic and Wildlife Resources and U.S. Navy. Territorial jurisdiction: Territory of Guam and U.S. Navy. Functional Jurisdiction: Division of Aquatic and Wildlife Resources and U.S. Navy.
References: Beck & Davidson (1981); Beck & Wiles (1989); Biosystems Analysis, Inc. (1990); Fosberg (1960); Moore *et al.* (1977); Randall (1974); Safford (1905); Shade (1983); Thompson (1947); U.S. Army Corps of Engineers (1980); U.S. Fish & Wildlife Service (1978, 1991); Wilder (1976); Wiles (1990); Young (1988).
Reasons for inclusion: 1a, 2b. This is the largest wetland on Guam. It contains extensive swamp forest and foraging habitat for Island Swiftlets, and has a small amount of habitat for Common Moorhens.
Source: Gary J. Wiles and Michael W. Ritter.

Sarasa Marsh (15)

Location: 13°19'N, 144°43'E; the site is found in south-central Guam in the municipality of Talofofo. It lies along the Sarasa River, 3.7 km southwest of Talofofo village.
Area: 2.5 ha.
Altitude: 80 m.
Overview: A small freshwater marsh flowing into a man-made pond. Common Moorhens (*Gallinula chloropus guami*) occur at the site.
Physical features: This site consists of a natural marsh along the Sarasa River, with the eastern lower end being dammed to create a shallow pond. The wetland is dog-legged in shape and about 250 m long by 50-125 m wide. The dam is 100 m long and 5 m wide, and also functions as a road. Water depth varies from about 0.5-2.5 m, with depths greatest near the dam. Water level is fairly constant during the year. Soils in and around the wetland are deep and well-drained volcanic clays (Young 1988). The site is surrounded by low rolling hills.
Ecological features: The wetland is characterized by four distinct zones. Open water exists next to the dam and occupies about 30% of the entire site. A large bed of *Eleocharis ochrostachys* grows in a band across the centre of the marsh. As the water becomes shallower further to the west, the *Eleocharis* is replaced by a bed of *Fimbristylis tristachya* and finally a small stand of *Phragmites karka* at the far west end. A species of sedge, *Rhynchospora corymbosa*, grows sparingly throughout the marsh. The site is classified as PEM1H and POWHKh (Cowardin *et al.*, 1979). The marsh is bordered on

all sides by extensive grasslands except for a narrow tract of ravine forest that grows below the dam along the Sarasa River.
Land tenure: The wetland and surrounding areas are privately owned.
Conservation measures taken: None.
Conservation measures proposed: The site should be declared a wetland of secondary importance for moorhens, as defined by the U.S. Fish and Wildlife Service (1991), and appropriately managed. Fencing to prevent access by feral water buffalo (*Bubalus bubalis*) would probably allow the growth of aquatic vegetation in the area of the dam, thus making the site more suitable for moorhens.
Land use: The dam was probably built as a watering pond for cattle several decades ago. Cattle are no longer raised by the landowner, and the wetland is now little used and infrequently visited by people. Most of the surrounding area is vacant, although plots of vegetables are occasionally grown nearby.
Possible changes in land use: The wetland is part of a large piece of property that was recently put up for sale. If purchased by a foreign developer, it is likely that a resort will be built on the land.
Disturbances and threats: Feral water buffalo regularly wallow in the open water near the dam. Their presence prevents the establishment of aquatic vegetation along the edges of this area and greatly reduces water clarity. Grassland fires during the dry season on adjacent land result in soil erosion and increased siltation of the marsh.
Hydrological and biophysical values: Useful in trapping sediments.
Social and cultural values: None known.
Noteworthy fauna: Moorhens have been observed in the marsh during the wet season, but nesting has not yet been recorded. A herd of 70-100 feral water buffalo lives in the general vicinity of the wetland and often visits to drink and wallow.
Noteworthy flora: A fairly rare reed *Philydrum lanuginosum* was recorded in 1989.
Management authority and jurisdiction: Management authority: Division of Aquatic and Wildlife Resources. Territorial jurisdiction: Territory of Guam. Functional Jurisdiction: Division of Aquatic and Wildlife Resources.
References: U.S. Fish & Wildlife Service (1991); Young (1988).
Reasons for inclusion: 2a. Habitat for moorhens.
Source: Gary J. Wiles and Michael W. Ritter.

Assupian Marsh (16)

Location: 13°18'N, 144°45'E; this marsh occurs in southern Guam in the municipality of Inarajan. It lies 1.5 km west of Malojloj village.
Area: 0.5 ha.
Altitude: 80 m.
Overview: A small wetland in southern Guam. It dries out almost entirely during most dry seasons. Common Moorhens (*Gallinula chloropus guami*) nest here in the wet season.
Physical features: This man-made site is located in gently rolling topography near the headwaters of an unnamed tributary of the Aslinget River. The marsh is rectangular in shape and is found at the base of several sloping grass fields. A dike exists along the eastern end. The marsh receives run-off from the adjacent fields, and drainage occurs through seepage into the ground or through an outlet in the dike when water levels are highest. Soils are deep, clayey and derived from volcanic residuum (Young, 1988).
Ecological features: In 1981, the marsh was composed primarily of *Eleocharis ochrostachys*; however, by 1991 it was dominated by *Paspalum* sp. with a small amount of *Fuirena umbellata* also present. *Eleocharis* is no longer present. The amount of open water ranges from 2-50% and varies with season and year. Water depth is 0.6-1.0 m in the wet season, but the site usually dries out except for

a few small pockets of standing water during the dry season. The marsh is classified as PEM1Fh and POWFh (Cowardin *et al.*, 1979). It is surrounded by savanna grassland dominated by *Pennisetum* and several small patches of secondary forest.
Land tenure: The wetland and surrounding areas are privately owned.
Conservation measures taken: The site is listed as a wetland of secondary importance for Common Moorhens (U.S. Fish and Wildlife Service, 1991).
Conservation measures proposed: A recovery plan for moorhens lists the activities needed to protect this species on Guam (U.S. Fish and Wildlife Service, 1991). Actions that particularly apply to this wetland include: (1) the development and implementation of habitat management plans through cooperative management agreements between the Government of Guam and the U.S. Fish and Wildlife Service; (2) the conducting of regular censuses for moorhens; (3) the periodic monitoring of the site for toxic substances; and (4) the control of introduced predators such as Brown Tree Snakes (*Boiga irregularis*) and feral dogs and cats.
Land use: The marsh was probably constructed originally as a source of water for livestock or irrigation, but there are no current uses. Some of the surrounding fields are occasionally cleared and planted with crops for one or two seasons.
Disturbances and threats: Run-off of pesticides and fertilizer residues into the wetland may occur. Grassland fires occasionally burn into the marsh. A fire in 1991 burned about a quarter of the site. Feral pigs (*Sus scrofa*) occasionally root up wetland plants during the dry season.
Hydrological and biophysical values: Probably useful in trapping soil run-off.
Social and cultural values: None known.
Noteworthy fauna: Common Moorhens inhabit the marsh during the wet season and breeding has been recorded. Yellow Bitterns (*Ixobrychus sinensis*) regularly forage here. Small numbers of migratory ducks (*Anas acuta* and *Aythya fuligula*) and shorebirds (*e.g. Gallinago* sp. and *Tringa glareola*) are sometimes present.
Noteworthy flora: None known.
Conservation education: The site has limited potential for conservation education.
Management authority and jurisdiction: Management authority: Division of Aquatic and Wildlife Resources. Territorial jurisdiction: Territory of Guam. Functional Jurisdiction: Division of Aquatic and Wildlife Resources.
References: U.S. Fish & Wildlife Service (1991); Young (1988).
Reasons for inclusion: 2a. Habitat for moorhens.
Source: Gary J. Wiles and Michael W. Ritter.

Yabai Wetland (17)

Location: 13°17'N, 144°45'E; this wetland is found in southern Guam in the municipality of Inarajan. It lies 1.3 km northeast of Inarajan Village on the west side of Highway 4, and 0.6 km northwest of Paulilac Bay. It occurs in an area known locally as Yabai.
Area: 1 ha.
Altitude: 5 m.
Overview: A seasonal man-made wetland. Common Moorhens (*Gallinula chloropus guami*) use the site for part of the year and probably nest here.
Physical features: This wetland is essentially a low-lying pasture that is flooded for 4-8 months of the year. It was apparently created inadvertently a number of years ago after the construction of Highway 4 blocked water drainage into the nearby Paulilac River. The bed of the road acts as a dike to hold water on the site. During the wet season, the water depth reaches one metre in a few spots. However, the area dries out completely in the dry season. The clay soils are deep and poorly drained (Young, 1988). The wetland is bordered by the highway on the east, several homes on the north, and low hills on the remaining sides.

Ecological features: The wetland has 0-25% open water, depending on the time of year and amount of water present. The most common plants are *Panicum muticum*, *Eichhornia crassipes* and *Paspalum* sp. Other species include *Echinochloa colonum*, *Ludwigia octovalvis* and *Lemna perpusilla*. The wetland is classified as PEM1Fh (Cowardin *et al.*, 1979). The hills on the northwest, west and south are covered with disturbed secondary forest composed largely of *Leucaena leucocephala*, *Cocos nucifera* and *Hibiscus tiliaceus*.
Land tenure: The wetland and surrounding areas are privately owned.
Conservation measures taken: The marsh is listed as a wetland of secondary importance for Common Moorhens (U.S. Fish and Wildlife Service, 1991).
Conservation measures proposed: A recovery plan for moorhens also lists a variety of activities needed to protect this species on Guam (U.S. Fish and Wildlife Service, 1991). Actions that apply to this wetland include: (1) the development and implementation of a habitat management plan through a cooperative management agreement between the private landowners, the Government of Guam and the U.S. Fish and Wildlife Service; (2) the conducting of regular censuses for moorhens; and (3) the control of introduced predators such as Brown Tree Snakes (*Boiga irregularis*) and feral dogs and cats.
Land use: Residents of the area regularly pasture several water buffalo in the wetland. These animals graze on the site and form muddy wallows. Several homes occur on the north edge of the wetland.
Possible changes in land use: No changes in land use are currently predicted.
Disturbances and threats: Human activity and the presence of domestic water buffalo may disturb moorhens using the wetland. Water hyacinth is thick late in the wet season. Grazing, trampling and wallowing by water buffalo may disturb wetland vegetation.
Hydrological and biophysical values: None known.
Social and cultural values: None known.
Noteworthy fauna: Common Moorhens inhabit the wetland on a seasonal basis when sufficient water is present, and the species probably nests here. The area also attracts small numbers of Yellow Bitterns (*Ixobrychus sinensis*) and occasionally migratory ducks (*Anas acuta* and other species) and egrets (*Bubulcus ibis* and *Egretta intermedia*).
Noteworthy flora: None known.
Conservation education: The site currently has little potential for conservation education.
Management authority and jurisdiction: Management authority: Division of Aquatic and Wildlife Resources. Territorial jurisdiction: Territory of Guam. Functional Jurisdiction: Division of Aquatic and Wildlife Resources.
References: U.S. Fish & Wildlife Service (1991); Young (1988).
Reasons for inclusion: 2a. Habitat for moorhens.
Source: Gary J. Wiles and Michael W. Ritter.

Agfayan River Valley (18)

Location: 13°16'N, 144°44'E; this area occurs in southern Guam in the municipality of Inarajan. It lies along the Agfayan River 1.2 km southwest of Inarajan village.
Area: 28 ha.
Altitude: Sea level to 5 m.
Overview: A remnant stand of estuarine swamp forest bordered by aquaculture ponds on two sides. The forest has a high diversity of tree species.
Physical features: This natural wetland lies along the lower floodplain of the Agfayan River. Most of the site is located immediately behind Agfayan Bay; however, a narrow strip of habitat continues up the river about 1.2 km inland. The wetland is about 300 m wide at its greatest point. Soils consist of a deep and poorly drained mucky clay (Young, 1988). The original drainage patterns of the

wetland were probably changed by the building of the first road around the edge of the bay, and were further altered by the construction of fish ponds. The channel of the Agfayan River is about 10 m wide and 0.3-1.8 m deep near its mouth (Wilder, 1976). A second smaller channel formerly occurred near the existing river mouth (Wilder, 1976), but is no longer present. Data from a monitoring site just above the river mouth indicate average discharge rates ranging from 0.004-0.012 cubic metres per second (Moore *et al.*, 1977). Temperature and salinity profiles for the Agfayan River are described by Wilder (1976).

Almost half of the site is occupied by commercial fish ponds. One group of 10 ponds (8 ha) occurs north of the river and is made entirely of earthen dikes. A second smaller group of 12 ponds (5 ha), most of which are lined by concrete block walls, lies south of the river. The ponds are steep sided, about 1.2 m deep, and flooded year-round.

The river valley is bordered by low sprawling hills on all sides except the east, where Agfayan Bay occurs. The drainage area of the valley is 575 ha (Best and Davidson, 1981).

Ecological features: The original wetland was probably composed almost entirely of swamp forest. This forest is relatively short, 5-10 m tall, and contains a variety of trees including *Nypa fruticans*, *Hibiscus tiliaceus*, *Cocos nucifera*, *Thespesia populnea*, *Xylocarpus moluccensis*, *Heritiera littoralis*, *Rhizophora apiculata* and *Bruguiera gymnorrhiza*. Tidal inundation of portions of the lower floodplain allows *Nypa* and mangroves to grow inland from the river channel. *Nypa* extends at least 700 m up the river to the limit of brackish waters (Wilder, 1976; Wiles, pers. obs.). The vine *Derris trifoliata* is abundant in the swamp, while the introduced tree *Leucaena leucocephala* occurs on slightly higher ground at some locations. *Panicum muticum* is common on the berms of the fish ponds and in other disturbed openings. Various wetland habitats in the valley are classified as PFO3C, POWHKx and R1SB3 (Cowardin *et al.*, 1979). On lands adjacent to the valley, grasslands exist on volcanic soils to the north and west and secondary forest grows on limestone substrates along the south.

Land tenure: The wetland is privately owned. Adjacent areas are private, but much of the upper watershed above the wetland is owned by the Government of Guam.

Conservation measures taken: The site is listed as a wetland of secondary importance for Common Moorhens (*Gallinula chloropus guami*) (U.S. Fish and Wildlife Service, 1991).

Conservation measures proposed: A recovery plan for moorhens lists a variety of activities needed to protect this species on Guam (U.S. Fish and Wildlife Service, 1991). Actions that apply here include: (1) the development and implementation of a habitat management plan through a cooperative management agreement between private landowners, Government of Guam and U.S. Fish and Wildlife Service; (2) the conducting of regular censuses for moorhens; and (3) the control of introduced predators such as Brown Tree Snakes (*Boiga irregularis*) and feral dogs and cats.

Land use: Parts of the wetland may have been farmed for vegetables before World War II (Thompson, 1947). Subsistence farming probably continued after the war. Aerial photos from 1975 show several fields along the edges of the wetland that were probably once farmland or pasture. Aquaculture facilities were built on the south and north sides of the valley in the late 1970s and mid-1980s, respectively. The ponds are used to raise hybrid tilapia (*Oreochromis mossambicus* x *O. niloticus*), milkfish (*Chanos chanos*), mullet (*Mugil cephalus*) and catfish (*Clarius batrachus*). The surrounding land is largely unused, with a few homes and small scale farming present.

Possible changes in land use: A few additional homes are likely to be built near the wetland.

Disturbances and threats: Up to half of the swamp forest has been lost to human activity over the years. Farming caused initial losses, with fish pond construction also a factor. It appears that some clearing of swamp forest occurred to make the southern ponds and that a small side channel of the river was filled in the process. More recently, several additional hectares of forest were cut without the proper permits to build the northern set of ponds. The U.S. Army Corps of Engineers required the owner to remove the fill in one area and replant it with *Hibiscus tiliaceus*. Water for both sets of ponds is obtained from the river, with waste water discharged back into the river. High nutrient loads in the waste water undoubtedly affect the ecology of the river downstream. Other management practices at the ponds, such as maintaining high fish densities and the removal of dense emergent vegetation, generally render the ponds unsuitable for moorhens.

Grassland fires occur annually in the upper watershed and result in heavy soil erosion and greatly

increased river turbidity following heavy rains. High surf and winds from Typhoon Russ caused considerable damage to the swamp forest and southern fish ponds in December 1990.
Hydrological and biophysical values: None known.
Social and cultural values: A minor amount of crab harvesting occurs at the site.
Noteworthy fauna: The fish ponds are occasionally drained, leaving shallow pools of water and exposed mudflats. This produces good habitat for small numbers of various migratory shorebirds and other waterbirds. Common Moorhens may visit the ponds rarely but sightings are lacking. Mudskippers (*Periophthalmus koelreuteri*), fiddler crabs (*Uca* sp.) and land crabs (*Cardisoma carniflex*) occur along the lower banks of the river.
Noteworthy flora: The swamp forest is almost unique in southern Guam. Plant species found in the wetland are listed by Moore *et al.* (1977).
Scientific research and facilities: Moore *et al.* (1977) described the plants of the area.
Conservation education: The site has moderate potential for nature education.
Management authority and jurisdiction: Management authority: Division of Aquatic and Wildlife Resources. Territorial jurisdiction: Territory of Guam. Functional Jurisdiction: Division of Aquatic and Wildlife Resources.
References: Best & Davidson (1981); Moore *et al.* (1977); Thompson (1947); U.S. Fish & Wildlife Service (1991); Wilder (1976); Young (1988).
Reasons for inclusion: 1d, 2b. Presence of estuarine swamp forest.
Source: Gary J. Wiles and Michael W. Ritter.

Achang Bay Mangroves (19)

Location: 13°15'N, 144°41'E; this site is centred around Achang Bay in the municipality of Merizo at the southern end of Guam. It lies 1.2 km east of Merizo village.
Area: 10 ha.
Altitude: Sea level.
Overview: The only sizeable area of mangrove forest in southern Guam. Four species of mangroves and several other coastal tree species are present.
Physical features: The mangroves in this area extend about 2.3 km along the shoreline from Jaotan Point to the mouth of the Suyafe River, with Achang Bay in the middle of the site. The Manell and Achang Streams run through the area and empty into Achang Bay and Manell Channel, which form the eastern boundary of Cocos Lagoon. The streams are narrow and shallow, being only a few metres wide at their mouths. Mangrove soils consist of silty sands and muds (Wilder, 1976).
Several small stone jetties and a dredged boat channel project out through the mangroves in Achang Bay. The site is bordered by a wide, shallow reef flat to the south and a narrow coastal plain and steep hills to the north. Highway 4 runs 50-400 m inland of the mangroves.
Ecological features: The site consists of a strip of mangrove forest, 20-60 m wide, lining the shore. The trees are relatively short, 4-8 m tall, with *Rhizophora mucronata* and *Bruguiera gymnorrhiza* being the most common species (Wilder, 1976; Moore *et al.*, 1977; Wiles, pers. obs.). *R. mucronata* grows throughout but particularly along the seaward edge, while *Bruguiera* occurs closer to shore. *Avicennia marina* is also fairly common. *R. apiculata, Heritiera littoralis* and *Xylocarpus moluccensis* are rare. *Hibiscus tiliaceus*, *Thespesia populnea* and a few *Hernandia sonora* grow on the inland edge of the site. The site is classified as E2SS3N and E2FO3N (Cowardin *et al.*, 1979). Beds of seagrass (*Enhalus acoroides*) occupy large areas of the adjacent reef flat. Shrubby secondary forest with *Cocos nucifera* appears on firm ground behind the mangroves.
Land tenure: The wetland is owned by the Government of Guam. Surrounding areas are mostly private, but some parts are owned by the Government of Guam.
Conservation measures taken: None.

Conservation measures proposed: None.
Land use: The mangroves are unused, but a small marina and restaurant operate in Achang Bay. A few homes and vegetable plots exist nearby.
Possible changes in land use: Further development is expected to occur. A small municipal park will be made next to the marina. The new owners of the marina have discussed the possibility of making a hotel and an apartment building across from the marina.
Disturbances and threats: A small area of mangrove forest was cleared during the building of the marina in the early 1970s (Moore *et al.*, 1977). Two other small clearings of mangroves, both illegal, were made by adjacent landowners at the western end of the site.
Hydrological and biophysical values: The mangroves probably help prevent coastal erosion.
Social and cultural values: None known.
Noteworthy fauna: Yellow Bitterns (*Ixobrychus sinensis*) and migratory shorebirds forage in small numbers in the mangroves or on the nearby reef flat. Mudskippers (*Periophthalmus koelreuteri*), fiddler crabs (*Uca* sp.) and land crabs (*Cardisoma carniflex*) are present. The snail (*Littorina scabra*) has been found on mangrove foliage and prop roots, while the clam *Quidnipagus palatum* is common on adjacent sandflats.
Noteworthy flora: This is the only location on Guam where *Bruguiera* is common (Wilder, 1976). A checklist of plants is given by Moore *et al.* (1977).
Scientific research and facilities: Plant surveys were made by Wilder (1976) and Moore *et al.* (1977).
Conservation education: The site has good potential for nature education.
Recreation and tourism: Visitors and boat owners use the marina.
Management authority and jurisdiction: Management authority: Division of Aquatic and Wildlife Resources. Territorial jurisdiction: Territory of Guam. Functional Jurisdiction: Division of Aquatic and Wildlife Resources.
References: Moore *et al.* (1977); Wilder (1976).
Reasons for inclusion: 1a, 2b. A moderate-sized area of mangroves.
Source: Gary J. Wiles.

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STATE OF HAWAII (USA)

INTRODUCTION

by Karin Z. Meier, James P. Laurel and James E. Maragos

Area: 16,770 sq.km.

Population: 1,250,000.

Hawaii is the only tropical and only island state of the USA. Hawaii consists entirely of islands, mostly of volcanic basalts to the southeast and coral limestone caps atop extinct volcanoes to the northwest. The archipelago is long, stretching 2,600 km along a northwest to southeast axis in the central tropical Pacific, and consisting of about 35 coral or volcanic islands. The northwest end of the chain consists of coral atolls at longitudes 29° to 30° N and at latitudes 176° to 170° W. The large volcanic islands at the southeast end of the Hawaiian chain are situated at latitudes 19° to 23° N and longitudes 155° to 161° E. The largest island is Hawaii (10,500 sq.km), or the "Big Island", followed by Maui (1,900 sq.km), Oahu (1,573 sq.km), Kauai (1,444 sq.km), Molokai (676 sq.km), Lanai (367 sq.km), Niihau (187 sq.km) and Kahoolawe (117 sq.km).

The Hawaiian archipelago has formed over a geological "hotspot" on the floor of the deep Pacific ocean. Over the past 50 million years, the earth's crust has been moving in a northwest direction over the hotspot, allowing a chain of volcanic islands to form and move to the northwest. The volcanic islands, thus, are progressively older to the northwest. As they age, the volcanic islands become eroded, subside, and eventually coral reefs form around their sides. Additional subsidence then causes the volcanic portion of the islands to submerge entirely to form atolls. Eventually the atolls drift out of the warm tropics, and when their upward growth can no longer keep pace with subsidence, they "drown", becoming seamounts. For example, the Emperor Seamounts off the east coast of Japan are the earliest of the Hawaiian volcanoes that have long since drowned many millions of years ago. The oldest of the existing Hawaiian islands are the atolls of Midway and Kure, approximately 25 million years old. At the opposite end of the chain, to the southeast, are found the youngest, and largest islands. For example, Hawaii (the Big Island) is less than one million years old, Maui and Molokai less than three million years, and Oahu less than six million years old. The young volcanic islands are also the highest; Hawaii's highest point is at 13,784 ft (4,202 m), Maui is 10,025 ft (3,056 m) high, Oahu is 4,025 ft (1,227 m) high, Kauai is 5,170 ft (1,576 m) high, Molokai is 4,970 ft (1,515 m) high, Lanai is 3,370 ft (1,027 m) high, Niihau is 1,281 ft (391 m) high, and Kahoolawe is 1,472 ft (449 m) high.

Hawaii has a mild tropical climate with average temperatures varying between 20° and 30°C throughout the year. The high islands trap more rainfall because the prevailing trade winds must rise over them, cool off, and drop moisture. On the low islands and open ocean areas away from the high islands, precipitation averages about 20 inches (508 mm) per year, but off the windward sides and peaks of the high islands, precipitation averages 100-300 inches (2,540-7,620 mm) per year. Mount Waialeale on Kauai is reputedly the world's wettest spot, with an annual precipitation rate of 500 inches (12,700 mm). On the back or leeward sides of the same high islands, rainfall rates are much below average. For example, the leeward sides of the Big Island and Maui average only 10 inches (254 mm) or less of rainfall per year. These climatic factors profoundly affect the distribution and type of wetlands in Hawaii.

Most of the people of Hawaii reside on Oahu (population 836,231), which also serves as the state's capitol. The other inhabited islands have much lower permanent populations, and in descending order of population size are Maui, Hawaii, Kauai, Molokai, Lanai and Niihau. A small Naval Air Station is situated at Midway Atoll, and a small research station is found on the atoll of French Frigate Shoals. The U.S. Coast Guard recently closed their navigation station at Kure, leaving the island abandoned. The remaining Hawaiian islands are uninhabited.

The ancient Hawaiians were the first settlers to reach Hawaii, about 1,000 to 1,500 years ago. The Hawaiians occupied all of the main islands and some of the smaller islands to the northwest, including Kaula and Nihoa, at least for extended periods. The early Hawaiians practised a subsistence lifestyle relying heavily on fish, taro and other garden crops. Meaningful western contact began with Hawaii's "discovery" by Captain James Cook in 1778. In the subsequent 200 years, the population has become more cosmopolitan due to the importation of foreign workers and a decline in the Hawaiian population from exposure to diseases brought in by foreigners. Today, the major ethnic groups in Hawaii include Caucasian, mixed Hawaiian, Japanese, Filipino, Chinese, Samoan, Korean and other groups. No one group achieves a population majority in Hawaii. Over a century ago, the economy of the islands shifted from subsistence to agriculture, with cane sugar, pineapples and coffee being the main export commodities. Later, macadamia nuts, bananas, flowers and papayas were exported. However, since World War II, agriculture has steadily declined in Hawaii relative to the importance of government expenditure and tourism. Military expenditure and tourism now account for more than half of the economic foundation in Hawaii.

Summary of Wetland Situation

Hawaii has many thousands of wetlands and a great variety of wetland habitats. In the compilation of information for the present inventory, most marine wetlands such as coral reefs and lagoons have been excluded, as well as many freshwater bodies such as highly modified or intermittent streams and most man-made reservoirs or ponds. Wetland types which have been considered in this inventory include perennial streams, natural lakes, a few reservoirs important for waterfowl, upland bogs, coastal marshes, mangrove swamps and anchialine pools (open brackish waters with tidal action but no visible surface connection to the sea). Over 450 significant wetlands have been identified throughout the islands.

Coastal marshes are confined to the portions of high islands with floodplains or coastal plains. Upland bogs are also confined to the high islands, especially along the wetter windward slopes and mountain ridges. Anchialine pools in basalt rock are confined to the youngest islands (Maui and Hawaii), where the lava rock is porous and creates broad shallow shelves near the coast. Limestone anchialine pools are also found in karstic formations, consisting of fossilized coral reefs, now positioned above sea level, which have undergone extensive weathering and dissolution to form the anchialine pits and pools. Hawaii has only five large natural freshwater lakes, again all located on the high islands. Mangrove swamps are not native to Hawaii, and began to spread throughout Hawaii when residents brought in alien mangrove species at the turn of the century. Perennial streams are confined to the islands with elevations greater than 3,500 ft (1,078 m). Most streams are located along the wetter windward sides of islands where volcanic rocks have weathered to form more impermeable soils. Kauai, being the wettest and most weathered of the high islands, has the most freshwater wetlands in Hawaii.

Prior to western contact, the human populations exerted little modification or control of wetlands with two notable exceptions: many low lying coastal marshes were walled and modified to support wet taro cultivation in ponds called *lo'i*. The downstream reaches of many streams were also walled and diverted to provide a constant supply of water to the taro patches through channels called *auwai*. The Hawaiians also constructed large rock-walled fishpond enclosures along broad shallow reef flats for the purpose of raising and corralling fish. Few of the taro fields, channels and fishponds are in use today, and many have been destroyed during modern urban development or have fallen into disrepair.

Major reclamation of coastal wetlands occurred due to the expanse of plantation-style sugarcane and pineapple culture during the previous century. Large land areas were flattened and graded and irrigation ditches installed in the drier agricultural areas. Many coastal ponds, lakes and marshes must have been buried or drained at this time. Ranching and livestock production also resulted in soil erosion and infilling of many coastal wetlands during the past century. Water was also diverted from large perennial streams along the windward sides of islands to provide irrigation water for agricultural fields on the leeward (drier) sides. Ditches and tunnels were dug or blasted through mountains, slopes and valleys, to convey the water to the plantations. Rice was grown in Hawaii during the early part of this century, resulting in major loss or modification of wetland habitat. Many marshes and abandoned taro ponds were converted to wet rice culture. Rice did not prove to be economically viable and agricultural operations ceased in the years following World War II. However, taro production never experienced a revival, and many wetland areas remained in a degraded state.

Navigation projects in Hawaii, beginning at the turn of the century, also resulted in the destruction or modification of many coastal wetlands, including port development in Nawiliwili and Hanapepe on Kauai, Honolulu Harbor on Oahu, Kahului and Maalaea harbours on Maui, and Hilo Harbor on Hawaii. Military construction before, during, and after World War II also wrought additional destruction to reefs, fishponds and marshes at the Marine Corps Air Station at Kaneohe Bay, at Honolulu Harbor and at Pearl Harbor. Military airfield construction at Hickam Air Force Base and Bellows Air Force Base, both on Oahu, and channel dredging for Pearl Harbor and Honolulu Harbor modified the salinity and water quality conditions in those areas. Military seaplane dredging at Keehi Lagoon and southern Kaneohe Bay (both on Oahu) destroyed coral reef and estuarine habitats.

Non-military construction for housing and civil works projects has caused the most destruction to Hawaii's coastal wetlands during the post-war era. Large marshes were drained and filled at Ala Wai, Waikiki, Honolulu, Hawaii Kai (Kuapa), Enchanted Lake (Kaelepulu), Kawainui and Salt Lake (all on Oahu), to accommodate major residential or resort projects. Fishponds along the southern shoreline of Kaneohe Bay and some along the coasts of Molokai and Maui were filled for housing projects. Major airfield projects at Keehi Lagoon, Kahului and Hilo resulted in damage or burial of marshes and other wetlands. For example, Kanaha Pond, adjacent to the Kahului airport, has been reduced to less that half its original size, although it still supports large native waterfowl populations.

Stream diversion for agriculture and urban water supply has dried up many streams and degraded habitat for native species of fish which live in streams. Some of the species require migrations to and from the sea as part of their lifestyles, and the diversion of water now prevents these essential life cycle stages in many streams. Stream diversion has also degraded downstream estuarine habitat. The construction of wells and pumping of groundwater have diverted waters that would otherwise feed into streams. Few unmodified and undiverted streams now exist on Oahu, and many others face future diversion on the neighbouring islands (Maui, Molokai, Kauai and Hawaii).

Some public works projects have also benefited wetland habitat. Wetland areas in Pearl Harbor were created as mitigation for airfield construction at Keehi Lagoon. These wetlands are managed by the U.S. Fish and Wildlife Service as successful wildlife refuges. Several reservoirs in the state, including Waita Reservoir on Kauai and the Nuuanu Reservoirs on Oahu, are important habitat for Hawaii's dwindling waterbird populations.

Anchialine pools have been filled for residential or resort development, including a large pond complex at the Waikoloa Resort at Anaeho'omalu, on the island of Hawaii. Other proposed resorts along the western ("Kona") coast of the Big Island threaten additional anchialine pools.

Trash disposal has been implicated in polluting Kawainui Marsh on Oahu. Industrial production of canec board using termicide additives has polluted ponds in Hilo Bay on Hawaii. Light and heavy industrial pollution in Honolulu has polluted the remaining waters of Keehi Lagoon and Honolulu Harbor. Sewage pollution has degraded habitats in Kawainui Marsh, Kaneohe Bay, Hilo Harbor, West Maui and Honolulu Harbor. Soil erosion and sedimentation from excessive grazing by feral ungulates on Molokai, and ranching and sugarcane culture on several high islands have degraded estuaries, marshes and coral reefs.

Introduced plants (alien species), including mangrove and various weedy grasses, have encroached on fishponds and marshes, leaving only a fraction of the original habitat area. Introduced animals have also had major impacts on native waterbirds. Mongoose, dogs, cats, rats and pigs are all potential predators of waterbirds or their eggs, and the access of predators to nesting areas severely depletes or eliminates breeding activity. The consequences of habitat degradation and predation have placed all four endemic Hawaiian waterbirds on the verge of extinction. The Hawaiian Duck (*Anas wyvilliana*), Hawaiian Coot (*Fulica alai*), Hawaiian Gallinule (*Gallinula chloropus sandvicensis*) and Hawaiian Stilt (*Himantopus mexicanus knudseni*) are all listed as U.S. Federal Endangered Species, and another common inhabitant of open grasslands and coastal areas, the Hawaiian Owl (*Asio flammeus sandwichensis*), is depleted on several islands. Two other endemic species include the Laysan Duck (*Anas laysanensis*), whose habitat is confined to a saltwater lagoon at Laysan Island, in the northwest end of the Hawaiian chain, and the Hawaiian Goose (*Branta sandvicensis*), which has evolved into a grassland, rather than a wetland species.

The U.S. Fish and Wildlife Service and Hawaii State Division of Forestry and Wildlife have developed considerable resources and programmes to establish marsh and other wetland areas as refuges to protect the endangered waterbirds. Most of the established wildlife refuges on the high islands concentrate on wetland habitats and protection of waterbirds. The Hanalei National Wildlife Refuge on Kauai, the state wildlife preserve at Kanaha on Maui, and the several smaller national wildlife refuges on Oahu are essential for the preservation of Hawaii's endemic waterbirds. Wetlands which are either unprotected or unrestored, such as Kawainui Marsh on Oahu, Kealia Pond on Maui, Makalawena on Hawaii and several playa lakes on Niihau, are of much less importance for waterfowl.

Wetland Research

Important information on waterbirds and their wetland habitats was first collected by ornithologists and members of the Hawaii Audubon Society, and much of the written findings of bird counts is published in a local journal, *Elepaio*, devoted to Hawaiian ornithology. Of particular importance was the tradition among the birding community to conduct simultaneous bird counts at all important bird habitats in Hawaii during a 1-2 day period during the holiday season. Over the years, these so-called "Christmas counts" have provided valuable insights on wetland habitat changes and losses, and trends in population levels for waterbirds, forest birds and seabirds which frequent Hawaii's wetlands. The state and federal fish and wildlife agencies have collected and continue to collect data on a regular basis on the status and condition of existing refuges or preserves and other wetland areas they desire to acquire and establish as refuges or preserves.

Systematic research on Hawaiian wetlands began in earnest with the passage of U.S. laws designed to protect wetlands in the 1970s. The passage of the Clean Water Act and implementing regulations in 1977 and the U.S. Endangered Species Act in 1973 prompted the U.S. Army Corps of Engineers and the U.S. Fish and Wildlife Service to sponsor statewide inventories of selected wetland habitats.

The Corps' inventories concentrated on coastal marshes, swamps and fishponds with emergent wetland vegetation, as well as describing a few upland bog areas. Each of about 70 sites on the islands of Oahu, Molokai, Hawaii, Maui and Kauai were surveyed in the field, photographed by air, mapped and evaluated. Wetland boundaries, vegetation zones, threats to wildlife and habitat, and species lists of animals and plants were compiled for each site (Elliott and Hall, 1977; Shallenberger, 1977; Elliott, 1981). These early surveys concentrated on wetlands greater than five acres (two hectares) in size. Later, the U.S. Fish and Wildlife Service concentrated on the inventory of a greater variety of wetland habitats and sizes, using high resolution colour aerial photography and mapping procedures. Their inventory classified and delineated all wetlands according to an ecosystem classification scheme devised by Cowardin *et al.* (1979), and produced a series of maps.

The U.S. Fish and Wildlife Service also sponsored a statewide evaluation on streams in Hawaii (Maciolek and Timbol, 1978; Norton *et al.*, 1978). This inventory resulted in mapping and evaluation of all streams in the state, which in turn led to the development of priorities to protect the most important stream systems. The U.S. Fish and Wildlife Service also sponsored the inventory of Hawaii's large natural lakes (Maciolek, 1969). More recently, the University of Hawaii Environmental Center evaluated the ecologically sensitive wetlands and associated groundwater resources responsible for maintaining those wetlands on the islands of Oahu and Maui (Miller *et al.*, 1989). The Hawaii Heritage Program of the Nature Conservancy of Hawaii has also field evaluated some upland bog sites and has established a statewide database on certain wetlands, including upland bogs, anchialine pools, perennial streams and some estuaries and embayments. With time, the Heritage database is expected to expand to include other important wetland habitats.

Some individual wetlands in the state have been surveyed because of their important functions as wildlife habitat, flood control and wastewater management. For example, studies have been conducted at Kahana Stream, Oahu's most important stream estuary (Timbol, 1979; Maciolek, 1972; Archer *et al.*, 1980), Nuupia ponds, an important wetland and fishpond complex under the jurisdiction of the Marine Corps on Oahu (Drigot, 1983; Aecos Inc., 1983), Kawainui Marsh, Hawaii's largest remaining wetland (U.S. Army Corps of Engineers, 1981; Smith, 1978; Drigot and Seto, 1982; Chun and Dugan, 1981), Pearl Harbor, Hawaii's largest estuary and only embayment estuary (Evans, 1974; Turner, 1975; U.S. Department of the Interior, 1969), and Keehi Lagoon, formerly an important coastal wetland and marine lagoon complex on Oahu (Harvey, 1970; Berger, 1971; Bathen, 1970). Other important wetland sites on Oahu subject to intensive study include the Kuapa Pond at Hawaii Kai and the Ala Wai Canal, both now severely degraded by extensive dredging and filling but formerly two of Hawaii's most important wetlands. Several National or State wildlife refuges or preserves on Oahu are monitored on a regular basis as part of their overall management programme. On neighbouring islands, wetlands that have been intensively studied include: Hanalei Stream and wetlands, Alakai Swamp and Waita Reservoir on Kauai; Kealia, Cape Kinau-Ahihi and Kanaha wetlands on Maui; coastal fishponds along the southeast coast of Molokai; Kaloko and Makalawena wetlands on Hawaii Island; and wetland habitats at Laysan Island and French Frigate Shoals in the Northwest Hawaiian Islands.

Wetland Area Legislation

Before 1970, the most important U.S. legislation protecting wetlands included the River and Harbor Act of 1899 and the Fish and Wildlife Coordination Act of 1958. The first restricted the discharge of refuse and work in navigable waters of the United States, including wetlands in these waters. The second mandated the involvement of federal and state fish and wildlife agencies during the review and approval stages for civil works "water" projects (harbours, dams, channelization, hydro-power, water supply *etc.*). Mitigation requirements to compensate for fish and wildlife losses were introduced at this time.

Hawaii

Passage of the National Environmental Policy Act (NEPA) on 31 December 1969 ushered in a new era of environmental protection in the United States, including significant emphasis on wetland protection. NEPA required federal agencies sponsoring or permitting projects to take into consideration the environmental consequences of their proposed actions, and required preparation of environmental impact assessments or statements for projects possibly resulting in significant impacts. The regulatory programme of the U.S. Army Corps of Engineers, which included administration of the River and Harbor Act (Section 10) permits, was substantially strengthened to evaluate the environmental consequences of proposed action.

Passage of the federal Water Pollution Control Act of 1972, and later the Clean Water Act of 1977, authorized the Corps and the U.S. Environmental Protection Agency to administer a permit programme for the express purpose of protecting wetlands and other special aquatic sites in accordance with section 404 of the Clean Water Act. Federal jurisdiction now extended to inland waters, including streams, adjacent wetlands and isolated wetlands (*i.e.* the "waters of the United States"), as well as encompassing the traditional navigable water of the United States. The Clean Water Act and Section 404 programme allowed the Corps to deny permit actions involving the discharge of dredged and fill materials in wetlands and other important ecosystems on the basis of environmental concerns. Implementation of this Act has greatly curtailed but not eliminated the filling and draining of wetlands in Hawaii. For example, the remnant portions of Salt Lake wetland are now protected from additional filling. On the other hand, a substantial number of anchialine pools were allowed to be filled during construction of the Waikaloa Resort at Anaehoomalu, Hawaii. The loss of the ponds was partially compensated by the construction of new "artificial ponds" and protection of adjacent natural ponds. Although the Corps Section 404 and Section 10 permit programme has greatly curtailed the destruction of wetlands in Hawaii, more needs to be done to eliminate discretionary authority and other loopholes that may allow additional wetlands to be filled or drained.

In response to this need, the state and county governments have tried to strengthen their environmental review process to protect wetlands, and have gone so far as to introduce wetlands protection legislation (which has not yet passed).

Other important federal legislation protecting wetlands in Hawaii and the rest of the United States includes the Endangered Species Act of 1973 and the Coastal Zone Management Act of 1972. The Endangered Species Act resulted in the official designation of rare or depleted species as endangered or threatened; as noted earlier, all four endemic Hawaiian waterbird species are now listed as endangered. The listing protects these species from the adverse consequences of federal activities including projects sponsored or funded by the U.S. government, as well as others requiring federal permits.

Section 7 of the Act requires federal agencies to consult with the U.S. Fish and Wildlife Service and the National Marine Fisheries Services during the planning stages of projects to insure that the protective provisions of the Endangered Species Act realized. For example, a Corps permit to a developer can be denied on the grounds that the proposed action could jeopardize the continued existence of an endangered species, according to the biological opinion of the lead federal fish and wildlife agency. The Endangered Species Act also allows funding to carry out research and protect endangered species, and strengthens other authorities which authorize the establishment and management of protected areas including wildlife refuges. A waterbird recovery plan for Hawaii has been developed to help guide future federal fish and wildlife efforts in protecting endangered waterbirds and their important wetland habitat (U.S. Fish and Wildlife Service, 1985).

The Coastal Zone Management Act (CZMA) allows states and territories of the U.S. to develop and implement Coastal Zone Management programmes. Those conforming to federal guidelines are eligible for continuing federal funding under section 306 of the Act. The CZMA has been reauthorized several times during the past 20 years, and continues to serve a strong planning deterrent against unjustified destruction of important coastal habitats. Hawaii received authority for federal funding under the CZMA in 1978, and also passed its own coastal zone management legislation. Both the state and county governments have established permitting procedures to implement their coastal legislation. The counties have a Special Management Area permit system to control or influence development in the coastal zone (usually a zone 300 ft landward from the vegetation line). Also, no development is allowed within a smaller shoreline setback zone of about 40 feet. This ordinance is also administered by the counties. The state has also established a CZM consistency process for permit applications subject to federal approval. Each proposed action must be consistent with the state's CZM programme policies. If not, a permit cannot be issued until the matter is resolved, either by modifying the project in question or elevating the dispute to the lead federal CZM agency, the U.S. Department of Commerce, National Oceanic and Atmospheric Administration.

Although the above account clearly demonstrates federal, state and county resolve in protecting wetlands, still many existing wetlands, especially those along the coast, may be destroyed or degraded by future development or pollution activities. More importantly, little legislation has been passed and funded to restore degraded wetlands, including removal of exotic (alien) species of plants, establishing protected nesting sites, predator removal and control (*e.g.* fencing moats, nesting islands, trapping *etc.*), and to develop a unified regulatory policy for wetland protection. The prospects are good that additional legislation will be passed and implemented in the next few years to provide comprehensive protection to wetlands in Hawaii and elsewhere in the United States.

Wetland Area Administration

Wetlands in the State of Hawaii are administered by several state and one federal agency, and two agencies at county level. The U.S. Fish and Wildlife Service is responsible for managing National Wildlife Refuges in Hawaii, including refuges at the Campbell Complex (northeast Oahu), the Pearl Harbor complex (south Oahu), the Northwest Hawaiian Islands (all islands and reefs north of Kaula and south of Midway), Hanalei, Kilauea and Huleia (on Kauai), and Kakahaia (on Molokai). The State of Hawaii Department of Land and Natural Resources is responsible for administration of state refuges including the important wetland areas and Natural Area Reserves. Recently, administration of Kawainui Marsh was also transferred to the Department of Land and Natural Resources. The City and County of Honolulu is responsible for managing parks, some of which include wetlands, such as the man-made lake and marsh created on Hoomaluhia and the natural wetland and fishpond at Kualoa (both on Oahu). The county governments of the neighbouring islands may also be similarly involved with the management of parks with important wetlands. Upland bogs are found within several preserves administered by The Nature Conservancy of Hawaii, including reserves on Maui, Molokai and Oahu. The Alakai Swamp, Hawaii's largest upland bog and second largest wetland, is administered by the State of Hawaii Department of Land and Natural Resources. A number of other important wetlands in Hawaii are under private ownership.

Organizations involved with Wetlands

a) Governmental Organizations

(1) U.S. Federal Government

U.S. Department of the Interior, Fish and Wildlife Service
- National Wildlife Refuges

Administration of Migratory Bird Treaties; renewal of federal permits for compliance with the Endangered Species Act and Fish and Wildlife Coordination Act.

U.S. Department of Commerce, National Oceanic and Atmospheric Administration

- National Marine Fisheries Service

  Renewal of federal permits for compliance with the Endangered Species Act and Fish and Wildlife Coordination Act.

- Office of Oceans and Coastal Resources

  Administration of the Coastal Zone Management Program; administration of the National Marine and Estuarine Sanctuaries.

U.S. Environmental Protection Agency

Review and veto power over Corps of Engineers Section 404 permits; Section 404(b)(1) guidelines on wetlands and special aquatic sites; oversight responsibility for state managed water quality monitoring programme; various grants and research on wetlands and other valuable ecosystems.

U.S. Department of Defense, Department of Army, Corps of Engineers

Administration of the Section 10 and Section 404 permit programme, wetlands research, mitigation and restoration as part of its civil works mission.

(2) State of Hawaii Government

Department of Land and Natural Resources

- Division of Forestry and Wildlife

  Management of wildlife refuges.

- Natural Area Reserve Commission

  Management of natural area reserves.

- State Water Commission

  Regulates diversion of stream water flow.

- Division of State Parks

  Management of State Parks.

Office of State Planning

Management of the State's Coastal Zone Management Program

Department of Health

- Environmental and Health Services Division

  Management of the State Water Quality Monitoring Program.

Office of Environmental Quality Control, Environmental Quality Commission

Management of the State's Environmental Impact Statement Program.

(3) County Level Governments

Department of Parks and Recreation

Management of county parks.

Department of Land Utilization and Planning

Management of the Special Management Area Permit and Shoreline Setback System.

Department of Public Works

Enforcement of grading ordinances.

b) Non-governmental Organizations

The Nature Conservancy of Hawaii

Administration of the Hawaii Heritage Program, a database of natural communities and rare and endangered species; management of ecological preserves either owned by The Nature Conservancy or other agencies and landowners.

The Hawaii Audubon Society

Lobbying on behalf of wetland protection; organization of annual bird censusing projects.

Kawai Nui Heritage Foundation

Watchdog organization over the future of Kawainui Marsh, Oahu.

Oceanic Institute

Research on anchialine pools.

University of Hawaii

- Departments of Zoology and Botany

  Research on wetland biology and ecology.

- Sea Grant Extension Service

  Extension services on aquaculture and coastal conservation.

Sierra Club, and Sierra Club Legal Defense Fund

Lobbying and watchdog organization with interest in the protection of natural ecosystems.

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The Nature Conservancy of Hawaii provided information on rare natural communities in Hawaii through the Hawaii Heritage Program database.

WETLANDS

An Hawaiian Islands Wetland Database has been established by Karin Z. Meier as the Hawaiian contribution to the Oceania Wetland Inventory. This database, which will eventually contain information on over 450 wetlands, pulls together information on Hawaiian wetlands from numerous sources and presents it in a readily accessible form for use by government departments, conservation bodies and research institutions throughout the State of Hawaii. The database includes information on the location of each wetland, the wetland type (following the wetland classification system of Cowardin *et al.*, 1979), the geology of the area and the soil type, along with basic information on a wide variety of parameters such as protection status, social significance, physical significance, water source, water quality, aquifer system, aquifer type (hydrology and geology), development stage, utility, uniqueness and vulnerability to contamination. In many instances, the database also includes detailed lists of animal and plant species recorded at the site.

All sites included in the database have been identified as being of special conservation importance by one or other of the agencies or institutions involved with wetlands in the State. However, in many instances the information in the database is inadequate to permit evaluation on the basis of the Ramsar criteria, and it is unclear as to how many of the wetlands would qualify as wetlands of international importance in the context of the Ramsar Convention.

By February 1993, the Hawaiian Islands Wetland Database contained information on 386 sites. These included 171 perennial streams, 162 anchialine pool systems, 37 lowland ponds, marshes and coastal wetlands, six montane marshes and bogs, five reservoirs, four hypersaline lakes and one high altitude lake (see Table 1). However, information had still not been compiled for some 70 or 80 wetlands, including many of Hawaii's most important sites, notably the extensive riverine wetlands in Polulu, Waimanu and Waipio valleys in northern Hawaii, Kawainui Marsh on Oahu (the largest freshwater swamp and marsh in Hawaii), about 20 coastal ponds, marshes and riverine wetlands on Kauai, and Alakai Swamp, also on Kauai. The latter is much the largest and most important montane swamp in the State of Hawaii.

Much of the information in the Hawaiian Islands Wetland Database is stored in a form which cannot easily be adapted for presentation as site accounts of the type used elsewhere in this Directory. For this reason, and because of the major gaps in the database at the time of going to press, no attempt has been made to present a series of site accounts here. It is to be hoped that a summary of the data in the database will be published for wider dissemination when the main task of data compilation has been completed.

Table 1: Wetlands included in the Hawaiian Islands Wetland Database (February 1993)

Wetland type	Island	No. of sites
Streams	Hawaii	38
	Maui	51
	Molokai	5
	Oahu	40
	Kauai	37
Anchialine pools	Hawaii	146
	Maui	9
	Kahoolawe	1
	Molokai	1
	Oahu	5
Lowland ponds, marshes and coastal wetlands	Maui	7
	Oahu	30
Montane marshes and bogs	Maui	5
	Oahu	1
Reservoirs	Oahu	5
Hypersaline lakes	Niihau	3
	Laysan	1
High altitude lakes	Hawaii	1

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REPUBLIC OF KIRIBATI

INTRODUCTION

Information on the Line and Phoenix Islands has been provided by K. Teeb'aki.

Area: Approximately 777 sq.km (published figures vary between 684 and 823 sq.km). Gilbert Islands (including Banaba), 319 sq.km; Phoenix Islands, 28 sq.km; Line Islands, 430 sq.km.

Population: 63,843 (1985 census), with all but about 3,000 living in the Gilbert Islands. In 1989, there were about 2,000 people on Kiritimati (Christmas Island) and about 500 each on Tabuaeran (Fanning) and Teraina (Washington) in the Line Group, and a handful of caretakers on Kanton (Canton) in the Phoenix Group.

The Republic of Kiribati consists of 33 low-lying coral islands in three main groups scattered over 3,550,000 square kilometres of the central Pacific Ocean. The islands stretch for about 4,000 km from east to west and span both the equator and the 180th meridian, extending from 8^o North to 13^{o}30 South, and from 168^o East to 147^o West. The westernmost group, the Gilbert Islands, comprise 17 inhabited islands including the capital island, Tarawa. The Phoenix Islands, 1,500 km to the east, comprise eight tiny atolls, only one of which (Kanton) is inhabited. The Line Islands, 1,800 km further east, comprise three inhabited islands (Teraina, Tabuaeran and Kiritimati) and eight uninhabited islands. The three northernmost islands in this group, Palmyra, Kingman and Jarvis, are unincorporated possessions of the U.S.A., outside Kiribati territory. (Two small uninhabited coral islands to the north of the Phoenix Islands, Howland and Baker, are also unincorporated U.S. possessions). The Line and Phoenix Groups are amongst the remotest islands in the world, the nearest continental landmass being California, nearly three thousand miles away.

All of the Kiribati islands except Banaba are low-lying coral atolls usually rising no more than 4 or 5 metres above sea level. In most of the atolls, a reef encloses a lagoon, on the east side of which are long narrow stretches of land seldom more than 100 m wide. Banaba (Ocean Island), about 450 km to the west of the main Gilbert Group, is a raised coral island, 6.5 sq.km in area and with a maximum elevation of 87 m. Most of the surface of this island has been mined for phosphates. Kiritimati (Christmas Island) in the Line Islands is the world's largest atoll. With an area of 327 sq.km, this atoll comprises almost half the total land area of Kiribati.

The southern Gilbert Islands, Phoenix Islands and Banaba have a rather dry maritime equatorial climate, whereas those islands situated further north have a more humid tropical climate. Temperatures range between 24^o and 30^{o}C, with little variation between the islands. The annual rainfall, by contrast, is extremely variable, not only between islands but also from year to year. The average annual rainfall in the Gilbert Islands ranges from 1,000 mm in the vicinity of the equator to over 3,100 mm in the northern islands. In the Phoenix Islands, most islands receive an annual rainfall in the range 750-1,300 mm, while in the Line Islands, the annual rainfall ranges between 690 mm on Malden to 2,900 mm on Teraina. Kiritimati, situated on the border between the wet and dry belts north of the equator, is relatively dry in most years. The main rainy season extends from November to April, with rain falling in sharp irregular squalls. Banaba, the southern Gilberts and the Phoenix Islands are subject to periodic droughts when as little as 200 mm of rain may fall in one year. The predominant winds are the east to southeast trades which blow for most of the year; the stormy season (November to February) is characterized by westerlies.

Formerly part of a British protectorate and colony (the Gilbert and Ellice Islands), Kiribati attained self-government in January 1977 and became an independent sovereign and democratic republic in

July 1979. The people of Kiribati are predominantly of Micronesian stock. The great majority of the population (95%) live in the Gilbert Islands, and all 17 islands in this group are inhabited. Tarawa, the capital island, supports over 33% of the population, and is one of the most densely populated islands in the world. Except for a handful of caretakers on Kanton, the Phoenix Islands are uninhabited, although they have been used for plantations, phosphate mining and military installations in the past. In the Line Islands, only Kiritimati (Christmas Island), Tabuaeran (Fanning) and Teraina (Washington) in the northern group are presently inhabited by I-Kiribati. Virtually all land in the Gilbert Islands is under private ownership in small hereditary holdings, whereas in the Line and Phoenix Islands, all land is owned by the State Government. Following independence in 1979, the State Government has looked towards the Line and Phoenix Islands for further development, and Kiritimati, the administrative centre for these two groups, has now become a commercial centre.

The first major economic use of the islands was as a source of phosphate in the second half of the 19th century, when most of the Central Pacific islands were bonded and exploited under the American Guano Act of 1856. Guano deposits were exhausted by the turn of the century, and attention was then transferred to the coconut (copra) industry. This was successful in the Gilbert Islands, on the northern Line islands and on two of the Phoenix islands, but widely fluctuating world prices of copra prevented a profitable industry. Although the three Northern Line islands of Kiritimati, Tabuaeran and Teraina are still worked regularly, the problems with unfavourable world prices and the high shipping expenses continue to threaten the industry. In recent years, other opportunities for economic development have been investigated, notably commercial fishing, salt production and tourism. Current and proposed developments are discussed by Garnett (1983) and Douglas (1969). There is very little permanent agriculture in Kiribati because of the poor quality of the soil which is composed largely of coral sand and rock fragments.

Dahl (1980, 1986) has given a brief account of the natural ecosystems of the islands, and has reviewed their importance for nature conservation. Garnett (1983) has described the terrestrial flora and fauna of the Line and Phoenix Islands in some detail. Generally, the terrestrial plant communities on the Gilbert Islands have been completely replaced by urban areas, villages, coconut plantations or agriculture, or are seriously degraded. Even in the sparsely populated Line and Phoenix Islands, the flora and fauna of most islands have been radically altered by the introduction of exotic species of plants and animals and large-scale clearance for coconut plantations. Only a few small atolls, notably Birnie in the Phoenix Islands and Vostok in the southern Line Islands, remain in a relatively undisturbed condition.

All of the islands have extensive coral formations, generally as fringing and lagoon reefs. UNEP/IUCN (1988) provide a general account of the coral reef systems and the reef resources, and also give detailed information on three of the atolls (Tarawa and Onotoa in the Gilbert Islands and Kiritimati in the Line Islands).

Summary of Wetland Situation

The most extensive wetlands in the Republic of Kiribati are brackish to supersaline lagoons which are present in the interior of islands in all three groups. Mangrove vegetation occurs only in the Gilbert Islands, and most of the freshwater wetlands are very small, although a large lake and swamp on Teraina (Washington) is a notable exception.

Landlocked lagoons of varying sizes with brackish to supersaline water are found on Nikunau in the Gilbert Group, McKean, Birnie, Phoenix and Manra (Sydney) in the Phoenix Group, and on Kiritimati, Malden, Starbuck and Flint in the Line Islands. Small islets and salt pans are often present. Some of the lagoons, notably those on Birnie and Starbuck, occasionally dry out completely. The saline lagoon on Manra has been partly modified for aquaculture, while that on Flint has been re-opened to the sea by a boat channel which has been blasted through the island, recreating old atoll conditions. The largest system of lagoons, that on Kiritimati, covers an area almost equal to the land area of 321 sq.km.

Most other atolls have deep marine lagoons with many passages to the open sea, but on some islands, such as Tabuaeran (Fanning) in the Line Islands and Orona (Hull) and Nikumaroro (Gardner) in the Phoenix Islands, the lagoon is shallow and almost enclosed, with extensive intertidal mudflats and brackish marshes creating estuarine-like conditions.

Mangroves, consisting of four species, *Bruguiera gymnorrhiza*, *Lumnitzera racemosa*, *Rhizophora mucronata* and *Sonneratia alba*, occur only in the Gilbert Islands, where there are small stands on Tarawa, Abemana and Aranuka atolls (Fosberg, 1975).

Freshwater wetlands are scarce; most are either tiny freshwater lens pools behind the beach or areas of wet soil used for the cultivation of taro. Such wetlands are found on many of the wet atolls in the northern Gilbert Islands. Most of the Phoenix Islands are very arid and lack freshwater wetlands, although there are reported to be some small freshwater pools on Phoenix Island (Dahl, 1980). Similarly, most of the Line Islands are relatively arid and lack freshwater wetlands. However, there is a large freshwater lake on Teraina (Washington) with surrounding freshwater marsh and some swamp forest. There is also reported to be a small area of bog on Flint Island (Dahl, 1980), and Vostok is covered in a layer of peaty soils up to one metre thick.

There no streams on any of the islands. Significant underground sources of fresh water are generally limited to the larger islands, where lenses of fresh water, floating on salt water, have developed. Generally, freshwater lenses exist on those parts of the islands where coral sands form a sufficiently wide central ridge. Lens thicknesses range from two metres to over 30 metres (Anon., 1984).

The isolated stands of mangroves in the Gilbert Islands and the distinctive saline and brackish lagoons in the Line and Phoenix Islands are of conservation interest, as are the freshwater habitats of Teraina (Washington). Most of the interesting saline lagoons in the Line and Phoenix Islands are located within existing protected areas, but the unique freshwater wetlands of Teraina, the extensive "estuarine" wetlands of Tabuaeran and the mangroves of the Gilbert Islands are unprotected.

The protected areas system comprises seven Wildlife Sanctuaries and seven Closed Areas, all in the Line and Phoenix Islands. The islands of Kiritimati, Malden, Starbuck, Phoenix, McKean, Vostok and Birnie are wildlife sanctuaries, and two of these (Malden and Starbuck) are also Closed Areas. The other five Closed Areas are within the Kiritimati Wildlife Sanctuary. All seven sanctuaries contain some wetland habitat and are described in the site accounts. There are no protected areas in the Gilbert Islands, although sanctuary status has been proposed for Butaritari, Nonouti and Abaiang atolls.

Many of the atolls in Kiribati, and especially some of those in the Line and Phoenix Islands, are internationally important for their huge concentrations of breeding seabirds. Twenty-three species breed in the islands, in several cases in larger numbers than anywhere else in the world. There are important breeding colonies on all eight atolls in the Line Group (notably Kiritimati, Malden, Starbuck and Caroline), on at least five atolls in the Phoenix Group (Enderbury, Phoenix, Birnie, McKean and Hull), and on Butaritari and Nonouti atolls in the Gilbert Group (Garnett, 1984; Perry, 1980). Many of these islands are also important for nesting Green Turtles (*Chelonia mydas*).

Only one true waterbird is resident in the islands, the Pacific Reef Egret (*Egretta sacra*). This occurs in all three island groups, but is scarce in the Line Islands, occurring regularly only at Caroline Atoll where it evidently breeds. Two former residents are now extinct, Coue's Gadwall (*Anas strepera couesi*) and Tuamotu Sandpiper (*Prosobonia cancellatus*). Coue's Gadwall is a small, dark race of the Gadwall known only from two specimens collected on Teraina (Washington) in 1874, and presumed to have become extinct during the early years of settlement. The type specimen of the Tuamotu Sandpiper was collected on Kiritimati in January 1778 during Captain Cook's third voyage, but the species has not been recorded in these islands since then, although it still occurs widely in the Tuamotu Archipelago in French Polynesia. Five species of migratory shorebirds occur regularly on passage and in winter in all three island groups: the Pacific Golden Plover (*Pluvialis fulva*), Wandering Tattler (*Heteroscelus incanus*), Bristle-thighed Curlew (*Numenius tahitiensis*), Ruddy Turnstone (*Arenaria interpres*) and Sanderling (*Calidris alba*). One other species, Grey-tailed Tattler (*Heteroscelus brevipes*) is regular in the Gilbert Islands. A goose, four ducks, eight shorebirds and three gulls have occurred as vagrants from East Asia or North America (Pratt *et al.*, 1987).

There are very few land birds in Kiribati and only one passerine, the Christmas Island Warbler or Bokikokiko (*Acrocephalus aequinoctialis*) which is known only from Teraina, Tabuaeran and Kiritimati in the Line Islands and Baker (a U.S. possession) at the northern end of the Phoenix Group.

Of the wetland ecosystems, only the mangroves would appear to be under imminent threat from development activities and pollution. However, the prospect for global sea level rise is particularly ominous for Kiribati where there are no high or volcanic islands. Wildlife generally is threatened by introduced animals, especially cats and rats, although feral pigs and goats have caused a problem on some islands. The feral cats and introduced rats pose a particularly serious problem for breeding seabirds, and several island populations of mainly ground-nesting species have been extirpated in the Line and Phoenix Islands (Garnett, 1984). A major eradication programme commenced in 1989 with the assistance of predator control experts from New Zealand.

Wetland Research

There has been very little research relating specifically to the wetlands of Kiribati. Guinther (1971) made some observations of the ecology of the estuarine environment on Tabaueran Atoll, and has also investigated the feasibility of brine shrimp production on Kiritimati. In the 1960s, the Smithsonian Institution's Pacific Ocean Biological Survey Program visited all of the Central Pacific islands and carried out extensive research on seabirds. A considerable amount of research has been carried out on the seabirds since then, particularly on Kiritimati (*e.g.* Garnett, 1982; Schreiber and Schreiber, 1984 & 1989). The endemic Christmas Island Warbler (*Acrocephalus aequinoctialis*) has also been studied in some detail (Milder & Schreiber, 1982 & 1989). Wildlife conservation in the Line and Phoenix islands has been reviewed by Perry (1980) and Garnett (1983), and management plans for all the islands in these two groups have been drafted.

Wetland Area Legislation

In 1980, the Government of the Republic of Kiribati published a statement of its policy concerning nature conservation in the Line and Phoenix Islands, This recognised the need to integrate conservation with development with respect to the islands' natural resources. The role of conservation was defined in terms of providing for the present and future social and economic needs of the country (Garnett, 1983).

There is no legislation relating specifically to wetlands. The legal basis for nature conservation is the Wildlife Conservation Ordinance (1975), amended in 1979. Under this new Ordinance, the Gilbert and Ellice Islands Colony Wildlife Birds Protection Ordinance of 1938 was repealed, and the status of bird sanctuaries was changed to wildlife sanctuaries. The object of the 1975 Ordinance was "to provide for the conservation and protection of birds and other animals". It basically makes two kinds of provisions for conservation:

i) Protection of species of birds and other animals. All regularly occurring species of birds, their eggs and nests are fully protected throughout Kiribati. Thirty-one species are listed, including 19 species of seabirds, Pacific Reef Egret, Northern Pintail, four regularly occurring migratory shorebirds and the resident land-birds. The Ordinance also provides full protection for Green Turtles, their eggs and nests in most of the Line and Phoenix Islands with Tabuaeran, Teraina, Kanton and Enderbury being excluded.

ii) Protection of areas of conservation importance. Two types of protected areas may be established: Wildlife Sanctuaries and Closed Areas. Wildlife Sanctuaries are areas where no person shall hunt, kill or capture any bird or other animal (other than a fish) or search for, take or wilfully destroy, break or damage the eggs or nests of any kind of bird or other animal. Closed Areas must be enclosed within Wildlife Sanctuaries. The protection status is similar except that no person shall enter or be in a Closed Area without a valid written license.

This current legislation is weak because measures for the protection of vegetation, prohibiting the introduction of animals and plants, preventing fire, removal of soil and dumping of refuse are lacking (IUCN, 1991). Furthermore, there is no environmental impact legislation.

At international level, the Republic of Kiribati is not yet a party to any of the international conventions or programmes that directly promote the conservation of natural areas and their wildlife (IUCN, 1991). Although it is a member of the South Pacific Regional Environment Programme (SPREP), it has not ratified the Convention for the Protection of the Natural Resources and Environment of the South Pacific (SPREP Convention). All of the wildlife sanctuaries except Kiritimati and all of the Closed Areas except Northwest Point Reserve have been proposed for designation under the Convention on Wetlands of International Importance especially as Waterfowl Habitat (the Ramsar Convention), but Kiribati has yet to ratify that Convention.

Wetland Area Administration

The Wildlife Conservation Ordinance of 1975 paved the way for the creation of a Wildlife Conservation Unit on Kiritimati in 1977. This Unit was established under the then Ministry of Local Government and Rural Development, and later became an integral part of the Ministry of the Line and Phoenix Groups (now the Ministry of Line and Phoenix Development). The major aims of the Unit were to survey and monitor seabirds populations on Kiritimati, enforce strict wildlife conservation legislation, control feral cats and pigs, and provide a conservation education programme. This work was subsequently extended to the other Line and Phoenix Islands, and the Unit was given responsibility for administering and managing all of the wildlife sanctuaries and closed areas. In practice, the three-man unit only manages the wildlife sanctuary and closed areas on Kiritimati on a regular basis, the other sanctuaries being uninhabited and seldom, if ever, visited. Wider duties of the Unit have been to advise on conservation matters throughout Kiribati, and to oversee the teaching of wildlife and conservation biology in schools.

Organizations involved with Wetlands

The Wildlife Conservation Unit in the Ministry of Line and Phoenix Development is the only government body which has direct responsibility for the conservation of nature, although the

Ministry of Home Affairs and Decentralisation and the Ministry of Natural Resources Development in Central Government have some responsibilities which relate to the conservation of natural resources.

WETLANDS

Site descriptions based on a report prepared by Aobure Teataata and K. Teeb'aki of the Wildlife Conservation Unit, Ministry of the Line and Phoenix Group, and the literature, particularly Garnett (1983) and IUCN (1991).

Mangroves of Tarawa Atoll (1)

Location: 1°30'N, 173°00'E; in the Gilbert Islands.
Area: Area of mangroves unknown; land area of atoll 21 sq.km, lagoon area 375 sq.km.
Altitude: Sea level.
Overview: Patches of mangrove and intertidal mudflats on the shores of an atoll lagoon; one of the few areas of mangroves in Kiribati.
Physical features: Tarawa is an L-shaped atoll with over 35 small islets (motu) on the south and northeast sides and a sunken reef in the northwest. Rural North Tarawa comprises 12 major islets with a land area of 14.7 sq.km; urban South Tarawa comprises five elongated islets (mostly linked by causeways) with an area of 7.2 sq.km. The lagoon is shallow and fairly turbid, with an average depth of 10-15 m, and has many sand shoals and numerous coral patch reefs. The mean tidal range is 1.5 m. Mangroves occur in patches along part of the coast. The climate is oceanic-equatorial, with an average annual rainfall of 1,729 mm and a mean annual temperature of 27°C (mean maximum 32°C, mean minimum 26°C. From March to October, light east to southeast trade winds prevail.
Ecological features: Stands of mangrove dominated by *Rhizophora mucronata*, with some *Bruguiera gymnorrhiza*, *Lumnitzera racemosa* and *Sonneratia alba*.
Land tenure: Mostly native land, in small hereditary holdings.
Conservation measures taken: None.
Conservation measures proposed: The Tourism Council of the South Pacific has recommended that all mangrove areas be fully protected because of their value in preventing coastal erosion (TCSP, 1990).
Land use: The I-Kiribati are traditionally subsistence fishermen. Tarawa is the capital and administrative centre of Kiribati. The population of South Tarawa numbers nearly 20,000, making this one of the most densely populated islands in the world.
Disturbances and threats: The acute shortage of land has led to extensive reclamation of the lagoon foreshore and loss of some mangrove. Construction of solid-fill causeways between islets has disturbed circulation patterns in the lagoon, and this may have had an effect on the mangroves. Dumping of rubbish on the lagoon shore and disposal of sewage have caused some pollution, and this was responsible for an outbreak of cholera in 1977. There is extensive exploitation of the lagoon resources, and giant clams in particular have suffered from over-harvesting (UNEP/IUCN, 1988).
Hydrological and biophysical values: The value of mangroves in preventing coastal erosion is especially high in view of the fragile physical nature of the atoll islands.
Social and cultural values: No information.
Noteworthy fauna: No information is available on the mangrove fauna. The intertidal lagoon fauna is described by Bolton (1982); the coral reefs are described by UNEP/IUCN (1988).
Noteworthy flora: The stands of mangroves on Tarawa (and also Abemana and Aranuka atolls) are noteworthy for their isolation, occurring here at the extreme edge of their distribution in the

Central Pacific.
Scientific research and facilities: The Atoll Research Unit is based on Tarawa and is supported by the University of the South Pacific Institute of Marine Resources. It carries out research on the marine environment, particularly environmental problems affecting Tarawa (UNEP/IUCN, 1988).
Management authority and jurisdiction: No information.
References: Bolton (1982); Dahl (1986); UNEP/IUCN (1988).
Reasons for inclusion: 1d, 2b. One of the few areas of mangroves in Kiribati, at the limit of mangrove distribution in the Central Pacific.
Source: See references.

McKean Island Wildlife Sanctuary (2)

Location: 3°35'S, 174°02'W; the most westerly of the Phoenix Islands, about 280 km west-southwest of Kanton Island and 125 km north-northwest of Nikumaroro.
Area: 57 ha.
Altitude: Sea level to 5 m on the northern beach crest.
Overview: A low coral island with a central landlocked supersaline lagoon, of considerable interest for its diverse and relatively undisturbed plant communities and large breeding colonies of seabirds.
Physical features: McKean Island is a flat, sand and coral island approximately circular in shape, with a diameter of some 800 m. The beach is largely composed of reef rock and coral rubble, and rises sharply to a circumferential crest within which the land is concave. The interior basin has been further depressed by extensive phosphate workings during the 19th century. There is no standing surface fresh water on the island, nor any evidence of a freshwater lens. A small, shallow, landlocked and highly saline lagoon occupies the centre of the island, and fills the area of the former phosphate workings. The depth of the lagoon fluctuates with the tide, reaching a maximum depth of 60 cm at high water. The island is surrounded by a fringing reef, 100-200 m wide. The inferred mean annual rainfall is 800 mm. The prevailing winds are easterly trades.
Ecological features: The vegetation comprises stunted *Sida fallax* scrub with low herbs and grasses. Seven species have been recorded in five main vegetation types. The western part of the island is covered by an extensive mat of *Tribulus cistoides*, while inland saline flats support *Sesuvium portulacastrum*. Most of the remainder of the island supports a mixture of *Portulaca lutea* and *Boerhavia albiflora*. The highest ground is covered by *Digitaria pacifica* grass with scattered mats of *Boerhavia* and *Tribulus* on a coarse rubble substrate. *Lepturus pilgerianus* is located mostly on the west coast of the island, mixed with *Tribulus cistoides* (Garnett, 1983).
Land tenure: State owned.
Conservation measures taken: McKean Island was declared a bird sanctuary in June 1938 under the Gilbert and Ellice Island Colony Wild Birds Protection Ordinance of 1938. The island was designated a Wildlife Sanctuary in 1975 under the 1975 Wildlife Conservation Ordinance (IUCN, 1991).
Conservation measures proposed: Dahl (1980) proposed the establishment of a national or international reserve in the Phoenix Islands, including McKean, Birnie, Phoenix, Enderbury, Orona (Hull) and possibly also Manra (Sydney), with Kanton Island as the communications link and surveillance centre. Garnett (1983) has made a number of general recommendations for management of the Phoenix Islands, including erection of multi-lingual notice boards advising visitors, such as long-distance yachtsmen and fishermen from Japanese, Taiwanese and Korean fleets, of the importance of the islands for science and nature conservation. Garnett (1983) also recommended that the Wildlife Sanctuary at McKean Island be upgraded to Closed Area.
Land use: Uninhabited. The island was bonded under the 1856 American Guano Act in March 1859, and was mined for phosphate between 1839 and 1870, by which time all reserves were exhausted. A scheme to introduce coconuts was prevented by the outbreak of World War II. The

island has seldom been visited, although there is a reasonably good anchorage off the west coast.
Disturbances and threats: None known.
Hydrological and biophysical values: None known.
Social and cultural values: None known. The presence of Polynesian Rats suggests that McKean was visited by Polynesians in pre-historic times, but there is no evidence that the island was ever settled.
Noteworthy fauna: McKean is a very important breeding site for seabirds. Twenty-nine species have been recorded on the island, and 17 are known to breed. At least six of the breeding populations are considered to be of international significance. These are: 5,000 Audubon's Shearwaters (*Puffinus l'herminieri*), 1,000 White-throated Storm Petrels (*Nesofregatta (fuliginosa) albigularis*), 40,000 Lesser Frigatebirds (*Fregata ariel*), 23,400 Grey-backed Terns (*Sterna lunata*), 20,000 Brown Noddies (*Anous stolidus*) and 15,000 Blue-grey Noddies (*Procelsterna cerulea*). The colonies of White-throated Storm Petrel and Lesser Frigatebird are the largest known colonies of these species in the world. The Polynesian Rat (*Rattus exulans*) is the only mammal, and the Mourning Gecko (*Lepidodactylus lugubris*) is the only reptile. Invertebrates include the hermit crab *Coenobita perlata*, the land crab *Geograpsus grayii* and at least 15 insects (Garnett, 1983).
Noteworthy flora: The relatively diverse and undisturbed terrestrial vegetation is considered to be of international conservation importance (Garnett, 1983).
Scientific research and facilities: The island was visited by the Smithsonian Institution's Pacific Ocean Biological Survey Program in the 1960s, and has been visited by several ornithologists in recent years.
Management authority and jurisdiction: Wildlife Conservation Unit, Ministry of Line and Phoenix Development.
References: Dahl (1980, 1986); Garnett (1983); IUCN (1991); TCSP (1990).
Reasons for inclusion: 1a, 2c. The island is valued for the variety and naturalness of its terrestrial habitats and large breeding populations of seabirds, several of which are of outstanding international importance.
Source: See references.

Birnie Island Wildlife Sanctuary (3)

Location: 3°35'S, 171°33'W; 90 km east of Phoenix (Rawaki) in the Phoenix Islands.
Area: 20 ha.
Altitude: Sea level to 4 m on the eastern beach crest.
Overview: A small coral island with interesting vegetation cover, a landlocked supersaline lagoon and large breeding colonies of seabirds. The island has never been inhabited and is the least disturbed of the Phoenix Group.
Physical features: Birnie Island, the smallest of the Phoenix Islands, is a low coral sandstone island measuring only 1.2 km by 0.5 km. A shallow, landlocked supersaline lagoon occupies a depression in the southeast. Despite being stream-fed, the lagoon often dries out completely. The northern half of the island is flat and covered in uniform vegetation. The east coast is rocky and consists of coral sandstone and coral fragments, while the west coast is low and sandy. Birnie is one of the drier Phoenix Islands, with an inferred mean annual rainfall of 600-800 mm or less. The prevailing winds are easterly trades.
Ecological features: The vegetation is extremely simple. Most of the island is covered by low herbs dominated by *Portulaca lutea* and some *Boerhavia albiflora*. These occur in pure stands or in varying co-dominant mosaics. The beach, beach crest and lagoon flats have either sparse or no vegetation cover, while the lagoon shoreline has an interrupted strip of uniform *Sesuvium portulacastrum*. This also occurs in a number of shallow depressions. Scattered dwarf *Sida fallax* scrub and bunch grass, probably *Lepturus* sp., have been recorded, but have since become locally extinct

(Garnett, 1983).
Land tenure: State owned.
Conservation measures taken: Birnie Island was declared a bird sanctuary in June 1938 under the Gilbert and Ellice Island Colony Wild Birds Protection Ordinance of 1938. The island was designated a Wildlife Sanctuary in 1975 under the 1975 Wildlife Conservation Ordinance.
Conservation measures proposed: Birnie was selected by the International Biological Programme as one of the "Pacific Ocean Islands Recommended for Designation as Islands for Science" (Elliott, 1973). Dahl (1980) proposed the establishment of a national or international reserve in the Phoenix Islands, including Birnie, McKean, Phoenix, Enderbury, Orona (Hull) and possibly also Manra (Sydney), with Kanton Island as the communications link and surveillance centre. Garnett (1983) has made a number of general recommendations for management of the Phoenix Islands, including erection of multi-lingual notice boards advising visitors, such as long-distance yachtsmen and fishermen from Japanese, Taiwanese and Korean fleets, of the importance of the islands for science and nature conservation. Garnett (1983) has also recommended that the Wildlife Sanctuary be upgraded to Closed Area.
Land use: Uninhabited. The island was bonded under the 1856 American Guano Act in February 1860, and was formally placed under British protection in July 1889. The rights to exploit the island passed through a number of commercial concerns in the 19th and early 20th centuries, but no activities were undertaken. Colonization was considered in 1937, but not implemented, and an unsuccessful attempt was made to establish coconut plantations in 1939. Since then, the island has remained uninhabited, unused and seldom visited.
Disturbances and threats: None known.
Hydrological and biophysical values: None known.
Social and cultural values: None known. The presence of Polynesian Rats suggests that Birnie was visited by Polynesians in pre-historic times, but there is no evidence that the island was ever settled.
Noteworthy fauna: Birnie is an important breeding site for seabirds; 22 species have been recorded and six are known to breed. Populations of 100 Brown Boobies (*Sula leucogaster*) and 100 Blue-grey Noddies (*Procelsterna cerulea*) are considered to be nationally important, whilst 350-800 Masked Boobies (*Sula dactylatra*) may be internationally important. Polynesian Rats (*Rattus exulans*) are common on the island, and Green Turtles (*Chelonia mydas*) nest on the beaches. Invertebrates are poorly known, but include a mite and two parasitic flies (Garnett, 1983).
Noteworthy flora: The undisturbed atoll vegetation is considered to be of international significance (Garnett, 1983).
Scientific research and facilities: Few people have ever visited the island and only limited research has been undertaken.
Management authority and jurisdiction: Wildlife Conservation Unit, Ministry of Line and Phoenix Development.
References: Dahl (1980, 1986); Elliott (1973); Garnett (1983); IUCN (1991); TCSP (1990).
Reasons for inclusion: 1a, 2c. The least disturbed (most natural) of the Phoenix Islands, valued for its vegetation, supersaline lagoon, seabird colonies and turtle population.
Source: See references.

Phoenix (Rawaki) Island Wildlife Sanctuary (4)

Location: 3°42'S, 170°43'W; the most easterly of the Phoenix Islands, about 180 km southeast of Kanton and 90 km east of Birnie.
Area: 65 ha.
Altitude: Sea level to 6 m on the beach crest.
Overview: A small coral island with large breeding colonies of seabirds, a landlocked supersaline

lagoon and some small freshwater pools. The latter are the only freshwater wetlands in the Phoenix Islands.

Physical features: Phoenix (Rawaki) Island is a low coral island measuring 1.2 km (northwest to southeast) by 0.8 km, with a circumferential beach crest. Inland areas slope gently downwards to a 20 ha, landlocked, shallow supersaline lagoon which occupies much of the centre. There are also some small, permanent freshwater pools, the only freshwater wetlands in the Phoenix Group. The steep beach is fringed by a narrow platform reef, 30-100 m wide, and on the east coast there are storm ridges of broken coral. Phoenix is one of the drier islands in the Phoenix Group, with an inferred mean annual rainfall of 800 mm. The prevailing winds are easterly trades.

Ecological features: The vegetation is simple, comprising low herbs, grasses and stunted *Sida fallax*. These mainly form single species stands, although mixtures of *Lepturus pilgerianus* and *Sesuvium portulacastrum*, and *Boerhavia* sp. and *Portulaca lutea*, also occur. A broad belt of *Sesuvium* is found along the lagoon shore, and there are two large patches of *Sida* scrub near the north end of the lagoon. An endemic shrub, *Triumfetta procumbens*, has become extinct during this century. Further details of the vegetation are provided by Garnett (1983). No introduced plants are known to occur on the island.

Land tenure: State owned.

Conservation measures taken: Phoenix Island was declared a bird sanctuary under the Gilbert and Ellice Island Colony Wild Birds Protection Ordinance of 1938, and designated a Wildlife Sanctuary in 1975 under the 1975 Wildlife Conservation Ordinance.

Conservation measures proposed: Phoenix Island was selected by the International Biological Program as one of the "Pacific Ocean Islands Recommended for Designation as Islands for Science" (Elliott, 1973). Dahl (1980) proposed the establishment of a national or international reserve in the Phoenix Islands, including Phoenix, McKean, Birnie, Enderbury, Orona (Hull) and possibly also Manra (Sydney), with Kanton Island as the communications link and surveillance centre. Garnett (1983) has made a number of general recommendations for management of the Phoenix Islands, including erection of multi-lingual notice boards advising visitors, such as long-distance yachtsmen and fishermen from Japanese, Taiwanese and Korean fleets, of the importance of the islands for science and nature conservation. Garnett (1983) has also recommended that the Wildlife Sanctuary be upgraded to Closed Area.

Land use: Uninhabited. Phoenix was bonded under the 1856 American Guano Act in 1859 and 1860, and was mined for phosphate between 1862 and 1871, by which time all reserves were exhausted. Some 20,000 to 40,000 tonnes were exported during this period. In June 1889, Phoenix was annexed to Great Britain and until 1938 various commercial concerns were licensed to develop the island, although no activities were undertaken. A survey in 1937 concluded that the island was unsuitable for colonization. An unsuccessful attempt was made to establish coconut plantations in 1939 (Garnett, 1983). Since then, the island has been uninhabited and unused, except as a Wildlife Sanctuary. There is no safe anchorage, and the island is seldom visited.

Disturbances and threats: European Rabbits (*Oryctolagus cuniculus*) were introduced in the 1860s, and currently number between 100 and 1,000 individuals.

Hydrological and biophysical values: None known.

Social and cultural values: None known. There is no evidence to suggest that the island was ever visited in pre-historic times.

Noteworthy fauna: Phoenix is a very important breeding site for seabirds, supporting some of the largest populations in the Central Pacific. Twenty-six species have been recorded and 18 are known to breed. Noteworthy populations include 10,000 Wedge-tailed Shearwaters (*Puffinus pacificus*), 3,000 Christmas Island Shearwaters (*P. nativitatis*), 12,000 Audubon's Shearwaters (*P. l'herminieri*), 500 Bulwer's Petrels (*Bulweria bulwerii*), 400 White-throated Storm Petrels (*Nesofregatta (fuliginosa) albigularis*), 850 Masked Boobies (*Sula dactylatra*), 16,000-45,000 Lesser Frigatebirds (*Fregata ariel*) and 250,000 Sooty Terns (*Sterna fuscata*) (Garnett, 1983). There are no mammals other than the introduced rabbits. Small numbers of Green Turtles (*Chelonia mydas*) nest on the beaches. Insects are abundant, but exhibit low species diversity (Garnett, 1983)

Noteworthy flora: An endemic species of shrub, *Triumfetta procumbens*, apparently now extinct.

Scientific research and facilities: The island was visited by the Smithsonian Institution's Pacific Ocean Biological Survey Program in the 1960s, by the Line Islands Expedition in 1974, and by the joint Royal Society/Smithsonian Institution expeditions in 1973 and 1975.
Management authority and jurisdiction: Wildlife Conservation Unit, Ministry of Line and Phoenix Development.
References: Dahl (1980, 1986); Elliott (1973); Garnett (1983); IUCN (1991); TCSP (1990).
Reasons for inclusion: 1a, 2c. The island is valued for its outstanding breeding colonies of seabirds and naturalness of its various habitats. The small freshwater pools are unique in the Phoenix Islands.
Source: See references.

Teraina (Washington) Island (5)

Location: 4°43'N, 160°25'W; in the northern Line Islands.
Area: Total land area 1,420 ha; lake 200 ha; bogs 100 ha.
Altitude: 0-5 m.
Overview: A raised wet atoll with a very interesting closed freshwater lagoon, extensive peat bogs and some swamp forest.
Physical features: Teraina is a raised, wet coral limestone island with an average annual rainfall of 2,970 mm. A freshwater lake of 200 ha occupies the position of its former lagoon. This borders on swampy woodland rich in epiphytes and ferns and two unique peat bogs covering 100 ha. Canals have been cut through the bogs.
Ecological features: Peat bogs with *Scirpus riparius* and *Cyrtosperma chamissonis*; swampy forest of *Pandanus* and *Cocos nucifera* with a dense fern undergrowth of *Polypodium scolopendria* and *Asplenium pacificum*. Also *Pisonia* atoll forest and atoll scrub. Thirty-five species of flowering plants are known from the island.
Land tenure: Largely state owned. Some of the copra plantations are freehold.
Conservation measures taken: None.
Conservation measures proposed: Dahl (1980) recommended that the bogs and perhaps the lake, including adequate areas of habitat for the Christmas Island Warbler, should be protected, as should the main seabird breeding areas.
Land use: Coconut plantations, subsistence agriculture and fishing. Modern settlement dates from about 1860, the resident population numbering 416 in 1978. There was some limited exploitation of guano and phosphate during the second half of the 19th century.
Disturbances and threats: Feral dogs, cats and pigs pose a threat to breeding seabirds. Feral cats have doubtless contributed to the decline in numbers of terns, noddies and ground-nesting boobies, and the island has suffered in the past from the depredations of feral pigs.
Hydrological and biophysical values: No information.
Social and cultural values: No information.
Noteworthy fauna: The wetlands of Teraina are the only known locality for Coue's Gadwall (*Anas strepera couesi*). The two type specimens of this small, dark race of the Gadwall were collected on Teraina in 1874. The duck has not been found again, and is presumed to have become extinct during the early years of settlement. The island supports the largest surviving population of the Christmas Island Warbler or Bokikokiko (*Acrocephalus aequinoctialis*), which is known only from this island, Tabuaeran, Kiritimati and Baker. There is also a population of the Scarlet-breasted or Kuhl's Lorikeet (*Vini kuhlii*) numbering several hundred pairs. This species is believed to have been introduced by early Polynesian colonists. Teraina is an important seabird rookery, with about 10 breeding species, the most abundant being Red-footed Booby (*Sula sula*) and White Tern (*Gygis alba*). Polynesian Rats (*Rattus exulans*) occur on the island, and a few Green Turtles (*Chelonia mydas*) nest on the beaches.

Noteworthy flora: The peat bogs and swamp forest are unique in Kiribati.
Management authority and jurisdiction: Ministry of Line and Phoenix Development.
References: Dahl (1980, 1986); Garnett (1983); Perry (1980).
Reasons for inclusion: 1d, 2b. The only large freshwater lake and swamp forest in Kiribati, and much the largest area of peat bog.
Source: See references.

Tabuaeran (Fanning) Island (6)

Location: 3°52'N, 159°20'W; in the northern Line Islands.
Area: Land area 3,370 ha; area of lagoon unknown.
Altitude: 0-4 m.
Overview: A tidal lagoon with brackish marshes and unusual "estuarine" conditions on a "wet" atoll.
Physical features: Tabuaeran is a low-lying atoll with a narrow fringing reef and three principal islets almost encircling a marine lagoon. The lagoon is tidal, and the surrounding brackish marshes and extensive intertidal mudflats create estuarine-like conditions. There are several small islets in the lagoon and some areas of salt pans. Tabuaeran is a wet atoll, with an average annual rainfall of about 2,000 mm.
Ecological features: Guinther (1971) has described the vegetation of the lagoon. Terrestrial vegetation includes atoll scrub and atoll forest with *Pisonia grandis* and *Messerschmidia argentea* (St. John, 1974). About half the land area has been planted to coconuts.
Land tenure: Largely state owned. Some of the copra plantations are freehold.
Conservation measures taken: None.
Land use: Coconut plantations, subsistence agriculture, salt production and fishing. Modern settlement dates from 1848, the resident population numbering 434 in 1978. There was some exploitation of guano and phosphate during the second half of the 19th century.
Disturbances and threats: Feral cats and introduced Black Rats have doubtless contributed to the decline in numbers of terns, noddies and ground-nesting boobies, and the island has suffered in the past from the depredations of feral pigs. As long ago as 1925, it was noted that the disturbance to the native vegetation had been extensive enough to result in a considerable loss of traditional nesting sites for seabirds. Some breeding seabirds (*e.g.* Masked Booby *Sula dactylatra*) had already disappeared from the island by 1963.
Hydrological and biophysical values: No information.
Social and cultural values: No information.
Noteworthy fauna: Tabuaeran was formerly an important seabird rookery with 12 breeding species, but populations are now much reduced and only about six species still breed regularly: White-tailed Tropicbird (*Phaethon lepturus*), Red-footed Booby (*Sula sula*), Great Frigatebird (*Fregata minor*), Brown Noddy (*Anous stolidus*), Black Noddy (*A. minutus*) and White Tern (*Gygis alba*). There is small population of the Scarlet-breasted or Kuhl's Lorikeet (*Vini kuhlii*) on the northwestern islet. This species is believed to have been introduced by early Polynesian colonists. Tabuaeran is one of only four islands on which the Christmas Island Warbler or Bokikokiko (*Acrocephalus aequinoctialis*) is known to have occurred, but according to Perry (1980), the species has disappeared from this island since 1924. There are five species of lizards on the island.
Noteworthy flora: The 22 native plant species include two endemics.
Scientific research and facilities: Guinther (1971) has studied the ecology of the estuarine environments in the lagoon.
Management authority and jurisdiction: Ministry of Line and Phoenix Development.
References: Dahl (1980, 1986); Guinther (1971); Perry (1980); St. John (1974).
Reasons for inclusion: 1d. A tidal lagoon with unusual estuarine conditions.

Source: See references.

Kiritimati (Christmas) Island Wildlife Sanctuary (7)

Location: 2°00'N, 157°20'W; in the northern Line Islands, 285 km southwest of Tabuaeran, 2,500 km south of Honolulu in Hawaii and 2,700 km north of Tahiti in French Polynesia.
Area: Island 32,137 ha; main lagoon 16,000 ha; subsidiary lagoons 16,800 ha.
Altitude: Sea level to 13 m.
Overview: Kiritimati is the world's largest coral atoll with a total land area of 321 sq.km and an approximately equal area of lagoons. With its multi-complex system of subsidiary land-locked lagoons, the island and its several hundred islets harbour some of the world's largest concentrations of seabirds, and are of global significance both in terms of diversity and abundance. The entire island is a Wildlife Sanctuary within which there are five closed areas.
Physical features: Kiritimati has the largest land area of any coral atoll in the world, with an approximately equal area of saltwater and supersaline lagoons. The single, large, flat island consists of coral formations 30-120 m in depth overlying volcanic rocks, and has a large tidal lagoon covering 16,000 ha and opening to the northwest. At the eastern end of this lagoon, there are several hundred smaller landlocked lagoons occupying 16,800 ha and delimited by causeways and larger tracts of land. Salinities vary widely, and many of the lagoons are supersaline. These tidal and landlocked lagoons contain hundreds of islets, the three principal ones being Cook Island, Motu Tabu and Motu Upoa. There are considerable variations in water level, and extensive intertidal mudflats are present. Freshwater lenses occur, with salinities varying between 0 and 3.5 p.p.t., and with a water table generally at a depth of between 0 and 2 m. Thirteen different physical units have been described by Garnett (1983), namely: seaward reef, seaward beach, beach crest, coastal dunes, boulder ramparts, coastal plain, central ridge, inland dunes, lagoon scarp, lagoon dunes, lagoon flats, lagoon beach and lagoon reef. The island rises to 13 m in height at the top of the dunes along the north coast of the Southeast Peninsula. Soil development is poor due to the limited supply of organic matter. A reef platform extends 30-120 m from the shoreline around the whole island, being widest along the north coast. Further details are provided by Garnett (1983), UNEP/IUCN (1988) and IUCN (1991).
Kiritimati lies within the equatorial dry zone. The mean annual rainfall is 873 mm, varying widely between a minimum of 177 mm and a maximum of 2,621 mm. Rainfall is usually heaviest in March and April, and lightest in October and November. The temperature is constant, ranging diurnally between 24°C and 30°C, with little seasonal variation. The prevailing winds are easterly trades.
Ecological features: The native vegetation comprises forest, scrub, dwarf scrub, grassland and herb communities. Indigenous forest is restricted to three small groves of *Pisonia grandis* attaining a height of 10 m, at Southeast Point, Motu Tabu and near Northwest Point. The dominant scrub over most of the island is *Scaevola taccada*, in either pure stands or with *Messerschmidia argentea* and *Suriana maritima*. Lower lagoon flats are dominated by *Suriana*, growing to a maximum height of 2 m. *Messerschmidia* is found most commonly on the beach ridge, coastal plain and lagoon shores. *Sida fallax*, reaching 2 m in height, is abundant on the coastal plain to the south and on sandy soils elsewhere. *Heliotropium anomalum* forms a dwarf scrub on beach ridges and boulder ramparts, mixed with *Portulaca lutea* and *P. oleracea*. Extensive *Sida* dwarf scrub, mixed with *Heliotropium*, *Boerhavia repens*, *Portulaca*, *Cassytha filiformis* and *Lepturus repens*, is found in the Southeast Peninsula and southern coastal plains. Elsewhere, *Lepturus*-dominated grasslands cover large areas of coastal plain. The principal herbaceous community is dense *Sesuvium portulacastrum* mat which frequently covers the low-lying, waterlogged lagoon shore. Approximately 5,200 ha in the west have been planted with coconut palms (*Cocos nucifera*), and about 50 other introduced species occur, mainly around villages, abandoned military installations and other disturbed sites. Most alien species are believed to have arrived during the present century. Further details are provided by Garnett (1983) and IUCN

(1991).
Land tenure: Largely state owned.
Conservation measures taken: Kiritimati was gazetted as a bird sanctuary in December 1960, under the Gilbert and Ellice Island Colony Wild Birds Protection Ordinance of 1938. The three principal lagoon islets (Cook Island, Motu Tabu and Motu Upua) were declared reserves with restricted access. Under the 1975 Wildlife Conservation Ordinance, the entire island was re-gazetted as a Wildlife Sanctuary in May 1975, with five areas being designated as Closed Areas: Cook Island (19 ha), a long, narrow islet at the entrance to the main lagoon; Motu Tabu (3.5 ha), a small islet with planted *Pisona* woodland in the main lagoon; Motu Upua (19 ha), a larger islet with *Messerschmidia*, *Heliotropium*, *Suriana* and *Scaevola* scrub and scattered *Cocos nucifera*; Ngaontetaake (2.7 ha), an islet in the east of the central lagoon; and Northwest Point, a traditional nesting area for Sooty Terns north of the main settlement. All are important nesting areas for sea birds, Motu Upua holding the largest extant colonies of Phoenix Petrel and Christmas Island Shearwater. Entry into the Closed Areas is prohibited except under written permit.
A Wildlife Conservation Unit was established on Kiritimati in 1977 to survey and monitor seabirds populations, enforce strict wildlife conservation legislation, control feral cats and pigs, and provide a conservation education programme. The Unit is represented on the Kiritimati Development Committee and the Local Land Planning Board. Garnett (1983) proposed a five-year management plan (1983-87) involving law enforcement, education and public awareness, surveys and research, advice to government, control of introduced species and appropriate development of tourism. Many of the activities proposed in this management plan have subsequently been carried out by the Wildlife Conservation Unit. A grant has been made available by New Zealand to fund programmes for the eradication of feral cats and pigs.
Conservation measures proposed: Garnett (1983) has recommended that the island as a whole loses its wildlife sanctuary status and that a number of specific areas be gazetted as wildlife sanctuaries, namely all the islets, the central lagoons, Northwest Point, Paris Peninsula and Southeast Peninsula. Within these proposed sanctuaries, it is recommended that the following areas be declared closed areas: Cook Island, Motu Tabu, Motu Ubua, Ngaontetaake, Frigatebird Island and all Sooty Tern colonies.
Land use: Kiritimati was bonded under the 1856 American Guano Act in June 1858, after which it was sporadically exploited for phosphate. The island has been occupied more or less continuously since 1882. By 1886, some 18,000-20,000 coconut palms had been planted, and 200 tons of pearl-shell exploited. A number of commercial concerns were licensed to exploit the island in the late 19th century, and some 70,000 coconut palms were planted at the turn of the century, although only 25% survived due to severe drought. The island was uninhabited from 1905 to 1912, but then followed large-scale development of coconut plantations by Central Pacific Coconut Plantation Ltd. The island was occupied by Allied forces during World War II, and an airstrip was constructed. From 1956 to 1958, atmospheric nuclear bomb tests were conducted by the U.K. some 50 km south of the island, and up to 4,000 servicemen were present. Further bomb tests were carried out by the U.S.A. in 1962. Military interests ceased in 1969, and many of the installations were dismantled. The surviving infrastructure of roads, wharfs and airport facilities have established Kiritimati as the administrative centre for the Line Islands. The principal economic activity is copra production, the Government copra plantation covering some 5,170 ha. The population in 1989 was estimated at 2,000, the great majority of whom live in London, Banana and Poland villages in the west. Recent developments include small-scale vegetable production and the export of live crayfish and chilled reef and ocean fish. A 1971 University of Hawaii expedition investigated the possibilities for production of brine shrimp (*Artemia salina*), and brine shrimp were introduced into the lagoon, but commercial implementation of the project was abandoned in 1978. A pilot project to determine the potential for salt production has been undertaken. In recent years, there has been some tourism to the island. Further details are given in Garnett (1983) and IUCN (1991).
Disturbances and threats: Coconut plantations have replaced the natural vegetation over about a third of the land area. The indigenous Tree Heliotrope (*Messerschmidia argentea*) and other shrubs have been needlessly destroyed on several occasions in the name of agricultural projects that have

turned out to be ill-conceived (Perry, 1980). Substantial changes have occurred in the ecology of the island as a result of the introduction of alien plants. The introduced Sourbush (*Pluchea odorata*) became widely dispersed during World War II, and forms thickets eliminating open habitats in some parts of the island. The low-growing vine *Tribulus cistoides* now dominates extensive open areas, but is to some extent beneficial in that it provides increased cover for some nesting seabirds (Perry, 1980). By 1978, there were over 50 species of exotic plants on the island (Perry, 1980). It is not known if the island was adversely affected by atmospheric nuclear bomb test programmes during 1956-58 and 1962. The El Nino-Southern Oscillation of 1982-83 had a devastating effect on seabird populations, leading to 90% mortality and no reproductive success in a number of species. Both numbers of birds and reproductive activity increased in 1983, but recovery was set back by the El Nino-Southern Oscillation of 1986-87.

Feral cats have been present on the island since the 19th century and pose the most serious threat to bird life. The feral cats feed almost entirely on seabirds, and their distribution is closely correlated with that of nesting seabirds. The total number of cats on the island, although showing considerable fluctuations, may at times exceed 2,000. As a result of predation by cats, 11 of the 18 breeding seabirds now nest only on lagoon islets that are free of cats. An exceptionally dry period during the latter part of 1978 resulted in the lowering of water levels in a number of shallow lagoons, enabling cats to move across to former islets where they extirpated several previously secure colonies of Grey-backed Terns (Perry, 1980). A cat eradication programme employing night-shooting has met with only limited success. However, the recruitment of stray domestic cats into the feral population has been countered by programmes of trapping in the villages since 1981, and by a local bye-law which makes it illegal to possess a female cat until it has been neutered.

Feral pigs formerly posed a serious threat to ground-nesting terns in particular, but intensive hunting has drastically reduced the numbers of pigs on the island in recent years. The Black Rat (*Rattus rattus*) has been recorded in the past, but apparently no longer persists. Tilapia (*Oreochromis* sp.) and brine shrimp (*Artemia salina*) have been introduced into the lagoons.

Direct exploitation of seabirds for food posed a serious threat to populations of Sooty Terns, Red-tailed Tropicbirds and boobies until 1977, when the wildlife conservation laws were enforced for the first time. The large-scale collection of Sooty Tern eggs for food occasionally resulted in complete nesting failure in some colonies. Tropicbirds were frequently killed for the sake of their tail streamers and other plumage feathers which were used in making fish lures and for decorating artifacts (Perry, 1980). Poaching remains a problem. An increase in fishing activity, better roads, cheaper and improved cross-country motor-cycles and the wider availability of outboard motors have all contributed to greater accessibility to previously remote parts of the island, with consequent increased disturbance and poaching at the seabird colonies. Red-tailed Tropicbirds, Red-footed Boobies and Masked Boobies, in particular, have suffered from the increased levels of poaching. There seems to be little prospect of these populations recovering to their pre-1982/83 levels, as long as feral cats and poaching are prevalent.

Hydrological and biophysical values: No information.

Social and cultural values: Archaeological research indicates that Kiritimati was visited by early Polynesians but not settled for prolonged periods. Remains include two sites which may have been villages, and a number of stone structures.

Noteworthy fauna: Thirty-seven species of birds have been recorded on the island, and 20 of these are known to breed. Kiritimati has the greatest variety and some of the largest populations of tropical seabirds anywhere in the world. Eighteen species of seabirds breed on the island. Population estimates prior to the 1982/83 El Nino included 12,000 pairs of Phoenix Petrels (*Pterodroma alba*), 500,000 pairs of Wedge-tailed Shearwaters (*Puffinus pacificus*), 6,000 pairs of Christmas Island Shearwaters (*P. nativitatis*), 500 pairs of White-throated Storm Petrel (*Nesofregetta (fuliginosa) albigularis*), 4,000 pairs of Red-tailed Tropicbird (*Phaethon rubricauda*), 1,500 pairs of Masked Booby (*Sula dactylatra*), 6,000 pairs of Red-footed Booby (*S. sula*), 6,000 pairs of Great Frigatebird (*Fregata minor*), 4,500 pairs of Lesser Frigatebird (*F. ariel*), 3 million to 4 million pairs of Sooty Terns (*Sterna fuscata*), 3,000 pairs of Grey-backed Tern (*S. lunata*), 2,000 pairs of Blue-grey Noddy (*Procelsterna cerulea*), 10,000 pairs of Black Noddy (*Anous minutus*) and 4,000 pairs of White

Tern (*Gygis alba*) (Schreiber & Schreiber, 1984). The population of Sooty Terns, estimated at 15 million birds in the 1960s, remains the largest known population in the world despite the decline in recent years. The terns nest on five principal islets, two of which are in Closed Areas. The population of Phoenix Petrels is also the largest in the world, as is probably that of Wedge-tailed Shearwaters. Other internationally significant populations include those of the White-throated Storm Petrel, Red-tailed Tropicbird, Masked Booby, Great Frigatebird, Lesser Frigatebird, Grey-backed Tern and Blue-grey Noddy. Populations of all species declined to a greater or lesser extent following the devastating El Nino-Southern Oscillation of 1982 and 1983, and in most cases have remained below 1981 levels since then (Schreiber & Schreiber, 1984, 1989). There is only one indigenous land-bird, the Christmas Island Warbler (*Acrocephalus aequinoctialis*), which is fairly common except in the vicinity of settlements, favouring semi-open areas of native *Lepturus* grass with scattered *Messerschmidia* and *Scaevola* shrubs. The total population has been estimated at about 1,000 individuals (Garnett, 1983). The Scarlet-breasted or Kuhl's Lorikeet (*Vini kuhlii*) has been introduced to the island but remains scarce and local. Common migrants include the Pacific Golden Plover (*Pluvialis fulva*), Wandering Tattler (*Heteroscelus incanus*), Bristle-thighed Curlew (*Numenius tahitiensis*) and Ruddy Turnstone (*Arenaria interpres*). The type specimen of the Tuamotu Sandpiper (*Prosobonia cancellatus*) was collected on the island in January 1778, but the species has not been found there since.
The only mammal on the island, other than feral animals, is the Polynesian Rat (*Rattus exulans*), which is widespread and abundant. This was presumably introduced by early Polynesians. Green Turtles (*Chelonia mydas*) regularly come ashore in small numbers to nest. Mourning Geckoes (*Lepidodactylus lugubris*) and Snake-eyed Skinks (*Ablepharus boutonii*) are common, and the Stump-toed Gecko (*Gehyra mutilata*) has been recorded. Noteworthy invertebrates include Coconut Crabs (*Birgus latro*), ghost crabs (*Ocypode* spp.), land crabs (*Cardisoma carnifex* and *Geograpsus grayii*) and land hermit crabs (*Coenobita perlata*). Further details of the fauna are provided by Garnett (1983).
Noteworthy flora: The island has one endemic plant species, *Cuscuta campestris*.
Scientific research and facilities: Kiritimati has been the subject of numerous studies and surveys. A considerable amount of research has been undertaken on the breeding seabirds (*e.g.* Schreiber & Ashmole, 1970; Garnett, 1982, 1983, 1984; Schreiber & Schreiber, 1984, 1989), while Milder and Schreiber (1982, 1989) have described the nesting behaviour and vocalizations of the Christmas Island Warbler. The University of Hawaii has several projects in the Line Islands and uses Kiritimati as a base. A meteorological observatory and projects on sea level rise and water temperature are based on the island. A bibliography of studies on the flora, fauna and past and present human use is given by Garnett (1983).
Conservation education: The Wildlife Conservation Unit has developed an education and public awareness programme on the island.
Recreation and tourism: An hotel and improved air connections with Honolulu have enabled the development of small-scale tourism for sport fishing and naturalists. Specialist wildlife tours consist of six-day guided visits to reserves, reefs and the Southeast Peninsula (Garnett, 1983).
Management authority and jurisdiction: Wildlife Conservation Unit, Ministry of the Line and Phoenix Groups.
References: Anon. (1985); Chock & Hamilton (1962); Dahl (1980, 1986); Garnett (1982, 1983, 1984); IUCN (1991); Milder & Schreiber (1982, 1989); Perry (1980); Schreiber & Ashmole (1970); Schreiber & Schreiber (1984, 1989); TCSP (1990); UNEP/IUCN (1988); Wildlife Conservation Unit (1985).
Reasons for inclusion: 1a, 1d, 2a, 2b, 2c. The island is recognized as having considerable scientific and conservation importance for wildlife in the Central Pacific. It is particularly valued for the diversity and abundance of its seabird populations, with internationally significant breeding populations of 10-12 species. The large and complex system of partially and completely landlocked lagoons with hundreds of islets is unique in the Central Pacific.
Source: See references.

Malden Island Wildlife Sanctuary and Reserve (8)

Location: 4°03'S, 155°01'W; in the southern Line Islands, 676 km south-southeast of Kiritimati.
Area: 3,930 ha.
Altitude: Sea level to 8 m at the beach crest.
Overview: A dry, low-lying coral island with sparse scrub and a shallow, enclosed lagoon connected to the sea by underground fissures. Malden Island is a Wildlife Sanctuary and a Closed Area with significant populations of several species of seabirds. The island was extensively mined for phosphates between 1860 and 1927.
Physical features: Malden Island is a low, flat, coral limestone island roughly triangular in shape with a fringing reef. The island measures about 8 km from east to west and 6 km from north to south. A series of wave-like ridges of sand and coral boulders forms a circumferential beach crest. The island contains an enclosed and highly saline lagoon covering approximately 1,300 ha and occupying about one third of the total land area. The lagoon is connected to the sea by underground channels, and has numerous small islets comprised of coral rocks and slabs. The floor of the lagoon is covered in brown mud, and there are some mudflats along the shore. The soil is composed of coarse coral gravel around the margin of the island, but is finer in the interior, with more sand and mud. There is no standing fresh water on the island, but there may be a freshwater lens. The fringing reef is about 100 m wide and extends 300-400 m at its northwestern and southeastern points. Malden is an arid island, with a mean annual rainfall of 726 mm. The annual rainfall is, however, very variable, ranging from as little as 100 mm to 2,400 mm. The mean annual temperature is 29.3°C (minimum 23.8°C, maximum 37.2°C). The prevailing winds are easterly trades, and severe storms are extremely rare.
Ecological features: The general aspect of the island is that of moorland, being sparsely vegetated with stunted *Sida fallax* scrub, low herbs and grasses. *Pisonia grandis* forest formerly covered much of the island, but this was greatly reduced by indiscriminate felling and grazing during the 19th century, and only one or two clumps of *Pisonia* survive near the northeast corner of the island. Introduced weeds are particularly common around the old settlement areas. The introduced low-growing woody vine *Tribulus cistoides* now dominates extensive open areas where it provides increased cover for young Sooty Terns. Parts of the lagoon flat are completely devoid of vegetation. Sixteen species of vascular plants have been recorded, nine of which are indigenous (Garnett, 1983).
Land tenure: State owned (Government of the Republic of Kiribati).
Conservation measures taken: Malden Island was gazetted as a Wildlife Sanctuary and Closed Area in May 1975 under the 1975 Wildlife Conservation Ordinance. Practical enforcement of the regulations is, however, difficult as the Wardens are stationed on Kiritimati, some 670 km away.
Conservation measures proposed: Malden Island was selected by the International Biological Program as one of the "Pacific Ocean Islands Recommended for Designation as Islands for Science" (Elliott, 1973).
Land use: Early Polynesian settlements were abandoned when the island was discovered by Europeans in 1825. Malden was bonded in 1860 under the 1856 American Guano Act, and heavily exploited for guano and phosphate deposits from 1860 until 1927. This was the most commercially successful of the Central Pacific guano islands. The island was occupied between 1956 and 1959 by British servicemen to monitor the Christmas Island atmospheric nuclear bomb test programme, and was itself used as a target for some of the larger detonations (Garnett, 1983). An airstrip was constructed in 1958 and was in regular use until July 1979. Since then, the island has been uninhabited and unused except as a Wildlife Sanctuary. There is no anchorage, and landing is difficult and dangerous.

Possible change in land use: The U.S. mineral exploration company GEOMAREX surveyed the island in 1980, and found substantial gypsum deposits which might be worth exploiting commercially in the future (Garnett, 1983).
Disturbances and threats: Extensive exploitation of guano and phosphate deposits between 1860 and 1927 resulted in the disappearance of the Phoenix Petrel (*Pterodroma alba*), at least two other procellarids and Red-tailed Tropicbird (*Phaethon rubricauda*) as nesting species, although the tropicbird has since returned (Perry, 1980). Potholes and trenches dating back to the phosphate mining days still mar the interior of the island. Cats, pigs, goats and House Mice were introduced by the phosphate company. The last small herd of five feral pigs was eradicated by the Smithsonian Institution's Pacific Ocean Biological Survey Program in 1964, and the goats have also disappeared. Feral cats and House Mice are still present on the island. However, in 1978, the cats appeared to be present in very low numbers and were having little impact on the seabird colonies (Perry, 1980). The original vegetation cover was severely damaged by the phosphate workings, indiscriminate felling and feral pigs and goats. Most of the *Pisonia grandis* forest was destroyed, and this led to the extirpation of the Black Noddy (*Anous minutus*) as a breeding species and disappearance of many of the nesting White Terns (Perry, 1980). Fires are a potential hazard; a fire in 1977 threatened breeding seabirds (Perry, 1980). Malden Island is occasionally visited by foreign yachtsmen and fishermen, and these visits cannot be monitored from Kiritimati.
Hydrological and biophysical values: None known.
Social and cultural value: Malden Island is of considerable historical importance. Twenty-one archaeological sites with a total of over 70 ruined buildings and other stoneworks have been found, indicating that the island was settled by early Polynesian for several generations.
Noteworthy fauna: Malden is a very important breeding site for seabirds. Nineteen species have been recorded and 11 or 12 have been found breeding in recent years. Populations have been estimated as follows: 40 Red-tailed Tropicbirds (*Phaethon rubricauda*), 3,000 Masked Boobies (*Sula dactylatra*), 2,000 Brown Boobies (*S. leucogaster*), 5,000 Red-footed Boobies (*S. sula*), 3,000 Great Frigatebirds (*Fregata minor*), 7,000 Lesser Frigatebirds (*F. ariel*), 10,000 Sooty Terns (*Sterna fuscata*), 2,500 Grey-backed Terns (*S. lunata*), 200 Blue-grey Noddies (*Procelsterna cerulea*), 500 Brown Noddies (*Anous stolidus*) and 50 White Terns (*Gygis alba*) (Perry, 1980). The island supports the largest concentrations of Lesser Frigatebirds, Grey-backed Terns and probably also Masked and Brown Boobies in the Line Islands. Tidal mudflats bordering the lagoon are frequented seasonally by large numbers of Pacific Golden Plovers (*Pluvialis fulva*), Bristle-thighed Curlews (*Numenius tahitiensis*) and Wandering Tattlers (*Heteroscelus incanus*). The only mammals still present on the island are feral cats and House Mice (*Mus musculus*). Polynesian Rats (*Rattus exulans*) are known to have occurred in the past, but are now locally extinct. Small numbers of Green Turtles (*Chelonia mydas*) nest on the beaches. Two species of lizard, the Mourning Gecko (*Lepidodactylus lugubris*) and Snake-eyed Skink (*Ablepharus boutonii*) have been recorded. Invertebrates include hermit crabs (*Ceonobita* spp.) and a brown libellulid dragonfly (Garnett, 1983).
Noteworthy flora: None known.
Scientific research and facility: The island was visited by the Smithsonian Institution's Pacific Ocean Biological Survey Program on several occasions in the 1960s, and by the Line Islands Expedition in 1974. In recent years, staff of the Wildlife Conservation Unit have visited the island almost annually. No detailed research has, however, been undertaken, and there are no research facilities on the island.
Management authority and jurisdiction: Wildlife Conservation Unit, Ministry of Line and Phoenix Development.
References: Dahl (1980, 1986); Elliott (1973); Garnett (1983, 1984); IUCN (1991); Perry (1980); TCSP (1990).
Reasons for inclusion: 1a, 2c. Malden is valued for its large breeding populations of seabirds and interesting saline lagoon.
Source: Mr Aobure Teataata.

Starbuck Island Wildlife Sanctuary (9)

Location: 5°37'S, 155°56'W; in the southern Line Islands, 830 km south-southeast of Kiritimati.
Area: Land area 1,620 ha.
Altitude: Sea level to 6-8 m on a steep bank behind the reef.
Overview: A small coral island with several interesting saline lagoons, a very large breeding colony of Sooty Terns and breeding populations of at least four other seabirds. The island is protected as a Wildlife Sanctuary and is remote and seldom visited. The presence of feral cats poses a threat to the breeding seabirds.
Physical features: Starbuck is a low, dry, coral limestone island with fringing and offshore reefs. The island extends for 8.9 km from east to west and up to 3.5 km from north to south. The beach is steep and backed by a 6-8 m high bank composed of large coral fragments. This rampart drops 2.5 m to the flat interior, which is largely composed of broken, black coral pieces. There are several small, shallow and highly saline lagoons in the southeast which occasionally dry out completely. There is no free-standing fresh water on the island, although a freshwater lens may form. Soils appear to be mainly coral sand interspersed among larger areas of coral rag and broken reef rock (IUCN, 1991). Starbuck is one of the drier Line Islands with an inferred mean annual rainfall of about 800 mm. The prevailing winds are easterly trades.
Ecological features: The island is covered with an impoverished atoll scrub vegetation. With the exception of a limited number of *Cordia subcordata* bushes, the vegetation consists entirely of stunted *Sida fallax* scrub with low herbs and grasses. Five other species have been tentatively identified: a bunch grass, probably *Lepturus repens*, *Bidens pilosa*, *Portulaca lutea*, *Tribulus cistoides* and *Ipomoea* sp. *Bidens*, *Ipomoea* and *Tribulus* are all likely to have been introduced, while the other species are probably indigenous (Garnett, 1983).
Land tenure: State owned.
Conservation measures taken: Starbuck was established as a Wildlife Sanctuary and Closed Area in 1975 under the 1975 Wildlife Conservation Ordinance.
Conservation measures proposed: The elimination of feral cats would considerably enhance the nature conservation value of the island (Garnett, 1983).
Land use: The island is uninhabited. Starbuck was bonded under the 1856 American Guano Act and mined for phosphate between 1870 and 1893. The rights to exploit the island passed through a number of companies until 1920, since when no action has been taken to develop or use the island in any way. The island has seldom been visited in recent years, and there is no safe anchorage.
Disturbances and threats: Feral cats are present on the island (three were sighted in 1974), and these have probably caused a decline in the numbers of breeding terns, noddies and ground-nesting boobies (Garnett, 1983).
Hydrological and biophysical values: None known.
Social and cultural values: None known. The presence of Polynesian Rats suggests that the island may have been visited by Polynesians in pre-historic times, but there is no evidence that the island was ever inhabited.
Noteworthy fauna: Starbuck is a very important breeding site for seabirds. Fifteen species have been recorded around the island, and as many as 11 species may breed. The island is particularly important for its large colony of Sooty Terns (*Sterna fuscata*), estimated at about 1.5 million pairs (Perry, 1980; Garnett, 1983). Polynesian Rats (*Rattus exulans*) occur on the island, and Green Turtles (*Chelonia mydas*) have been recorded, although it is not known if they nest.
Noteworthy flora: None known.
Scientific research and facilities: The Line Islands Expedition visited Starbuck in 1974.
Management authority and jurisdiction: Wildlife Conservation Unit, Ministry of Line and Phoenix Development.
References: Dahl (1980, 1986); Garnett (1983); IUCN (1991); Perry (1980).
Reasons for inclusion: 1a, 2c. The island is a special value for its colony of Sooty Terns which is

thought to be of international importance.
Source: See references.

Vostok Island Wildlife Sanctuary (10)

Location: 10°06'S, 152°23'W; in the southern Line Islands; 158 km north-northwest of Flint, 230 km west of Caroline, 709 km south southeast of Malden and 1,490 km northwest of Rarotonga in the Cook Islands.
Area: 24 ha.
Altitude: 0-5 m.
Overview: Vostok Island is one of four Wildlife Sanctuaries in the Line Islands and the least disturbed island in this group. It harbours eight breeding species of seabirds, and supports a dense stand of *Pisonia* forest on deep peat deposits. The island is too small, remote and inhospitable to support any commercial undertaking.
Physical features: Vostok is a small, triangular-shaped sand and coral island with a fringing reef but no lagoon. There is no standing fresh water on the island and no evidence of a freshwater lens. However, the interior of the island is covered in peat soils up to one metre thick over phosphatic hardpan, and these peats are moist at a depth of 30 cm. In the south and west, the beaches are about 50 m wide and rise abruptly to a crest at the edge of the forested interior. In the east, the beaches are 25-35 m wide and border on a raised flat area of coral sand and rubble.
Ecological features: The vegetation is extremely simple. The central portion of the island (about 10-15 ha) is occupied by a pure stand of *Pisonia grandis* forest which reaches its maximum density and a height of 30 m at the edge of the western beach.
Boerhavia repens forms a herb mat on the sandy edges of clearings in the forest and also occurs in a belt 3-10 m wide extending from the north to the southeast end of the island. The succulent herb *Sesuvium portulacastrum* may be present (Clapp & Sibley, 1971b). Elsewhere, there are open areas of sand, and sand with coral rubble.
Land tenure: Vostok Island is wholly owned by the Government of the Republic of Kiribati. In recent years, the island was leased to a Captain Omer of Moorea, French Polynesia, but the lease terminated in 1989.
Conservation measures taken: The island was gazetted as a Wildlife Sanctuary in June 1979 under the 1975 Wildlife Conservation Ordinance. The killing of all resident and regularly occurring birds and the Green Turtle is prohibited. The island is also protected by its remoteness and inhospitable nature.
Conservation measures proposed: Vostok Island was selected by the International Biological Program as one of the "Pacific Ocean Islands Recommended for Designation as Islands for Science" (Elliott, 1973). Garnett (1983) recommended that the Wildlife Sanctuary be upgraded to Closed Area status.
Land use: The island was bonded under the 1856 American Guano Act in 1860, and a British claim was made in 1873, but it is unlikely that the phosphate deposits were ever worked. An unsuccessful attempt was made in 1922 to establish a coconut plantation (Garnett, 1983). Until 1989, this island together with Caroline and Flint were leased to a Captain Omer Darr of French Polynesia. The leaseholder did not, however, develop Vostok. Its small size and various other factors have rendered Vostok unsuitable for any form of commercial undertaking, and this has ensured that the island has remained intact since Darr's leasehold. At present, the island is uninhabited, and no use is made of it other than as a Wildlife Sanctuary.
Possible changes in land use: None is anticipated at present.
Disturbances and threats: Vostok is the least disturbed of the Line Islands, and the only island in this group not affected by introduction of alien mammals. An attempt to plant coconut seedlings in 1922 failed. Fire poses the principal threat, and could be especially hazardous on this island where

the terrain is capped by a deep layer of peat. Fortunately, a fire in 1974 caused only limited damage to breeding seabirds. Yachts occasionally cruise past the island and anchor offshore, but the level and types of disturbance which these visits cause are unknown.
Hydrological and biophysical values: None known.
Social and cultural values: There are no known archaeological sites on the island, although the presence of rats suggests that Polynesians may have visited the island in pre-historic times (Garnett, 1983).
Noteworthy fauna: Vostok Island is a very important breeding site for seabirds, especially five tree-nesting species, the Red-footed Booby (*Sula sula*), Great Frigatebird (*Fregata minor*), Lesser Frigatebird (*F. ariel*), Black Noddy (*Anous minutus*) and White Tern (*Gygis alba*) which nest in the *Pisonia* forest. Three other species breed on the island in smaller numbers, the Masked Booby (*Sula dactylatra*), Brown Booby (*S. leucogaster*) and Brown Noddy (*Anous stolidus*). The populations of Masked Booby (400), Red-footed Booby (3,000) and Great Frigatebird (4,500) are considered to be of national importance (Garnett, 1983). Several migratory shorebirds from the northern hemisphere have been recorded including the Pacific Golden Plover (*Pluvialis fulva*), Bristle-thighed Curlew (*Numenius tahitiensis*) and Wandering Tattler (*Heteroscelus incanus*). The only mammal known to occur on Vostok is the Polynesian Rat (*Rattus exulans*), which is abundant. This is a vegetarian feeding on stems and leaves of both *Pisonia* and *Boeharvia*, and does not pose a threat to nesting seabirds. One species of skink, the Azure-tailed Skink (*Emoia cyanura*), occurs on the island, and Green Turtles (*Chelonia mydas*) have been seen offshore, although there is no record of nesting. The large population of Coconut Crabs (*Birgus latro*) is nationally important.
Noteworthy flora: The undisturbed *Pisonia* forest is an excellent example of a type of atoll forest which would once have covered many atoll and coral islands in the Central Pacific before clearance by man.
Scientific research and facilities: Recent scientific visits to the island have included visits by the Pacific Ocean Biological Survey Program in June 1965, the Line Islands Expedition in September 1974, and staff of the Wildlife Conservation Unit in November 1977 and May 1991.
Management authority and jurisdiction: Wildlife Conservation Unit, Ministry of the Line and Phoenix Development.
References: Clapp & Sibley (1971b); Dahl (1980, 1986); Elliott (1973); Garnett (1983); IUCN (1991); Perry (1980); TCSP (1990).
Reasons for inclusion: 1d, 2c. Vostok is the least disturbed of the Line Islands. The excellent stand of *Pisonia* forest and the deep peat deposits are of special interest.
Source: K. Teeb'aki.

Caroline Atoll (11)

Location: 10°00'S, 150°14'W; in the southern Line Islands, 830 km west of Tahiti in French Polynesia.
Area: 227 ha.
Altitude: 0-6 m.
Overview: Caroline Atoll is one of the most unspoiled of the Line Islands. It combines features of physical and biological interest with natural scenic beauty. The atoll harbours impressive breeding populations of seabirds, while its pristine lagoon supports a rich and varied marine life with very large populations of *Tridacna* clams. Many of these features are of national and international conservation significance. The island has been a focus of potential development by foreign entrepreneurs, but its remoteness from administrative centres creates various problems for development, and it has been recommended that much of the atoll be reserved for nature conservation.
Physical features: Caroline island is a low-lying, densely vegetated crescent-shaped atoll, 9.2 km

long by 1.6 km wide. It consists of 38 small wooded islets surrounding a narrow tidal lagoon. Channels between the islets vary in width from as little as 5 m to as much as 200 m. The northernmost and southernmost islets are the largest in the group. There is no standing fresh water on the atoll. However, the vegetation is lush and dense throughout, and the accumulation of decayed plant material contributes significantly to the moist-retaining process in the soil. Freshwater lenses are said to exist on South Island and on Nake Islet in the north. In 1974, the freshwater lens on South Island was about 1.5 m below ground level. The lagoon is partly enclosed and is about 500 m wide at its widest. It is shallow and clear, about 6-10 m deep, and contains living corals. Some of the coral reefs form continuous barriers across the lagoon, and many are partly exposed at low tide.

Ecological features: The main plant formations are forests of *Pisonia grandis* and *Calophyllum* sp., forest/scrub dominated by the Beach Heliotrope *Messerschmidia argentea*, *Suriana* scrub, and dwarf scrub with *Morinda citrifolia* and *Heliotropium* sp. Fifteen of the 35 species of vascular plants recorded from the island are native. Coconut plantations exist on South Island and to a lesser extent also on Long Islet and Nake Islet in the north. Groves of coconut palms or individual palms can be found here and there on some of the other islets, but most islets are still free of this introduced species.

Land tenure: The entire atoll is owned by the Government of the Republic of Kiribati.

Conservation measures taken: None, other than the general protection afforded to seabirds and Green Turtles under the Wildlife Conservation Ordinance of 1975.

Conservation measures proposed: Various recommendations have been made with respect to the importance of Caroline Atoll and the possibility of implementing appropriate conservation measures. Dahl (1980) considered the atoll to be a candidate for reserve status, especially if existing introduced predators could be controlled. It has been suggested that the atoll should be designated as a Biosphere Reserve under the Unesco Man and the Biosphere Programme and/or as a World Heritage Site under the World Heritage Convention. Following the Kiribati Government Expedition to the atoll in 1991, personnel of the Wildlife Conservation Unit and officials of the Ministry of Line and Phoenix Development agreed that all islets in Caroline Atoll except South Island, Long Islet and Nake Islet should be made into Wildlife Sanctuaries.

Land use: There was some exploitation of guano and phosphate in the second half of the 19th century, and a small stock-raising and copra community inhabited the atoll from 1846 to the late 1930s. In recent decades, the atoll has been uninhabited, although South Island, Long Islet and Nake Islet are visited from time to time by Polynesian copra gatherers under an agreement with the Government in Tarawa, The atoll has recently been leased to a Mr Urima Felix of Moorea, French Polynesia. The lessee has proposed to develop the island for the extraction of copra, exploitation of fish, and tourism, and envisages the eventual development of a hotel complex. Nothing has yet been finalized by the developer, and the future of the leasehold is uncertain.

Possible changes in land use: It is possible that there will be some development on the three main islets, South, Long and Nake, in the future, but this remains uncertain because of the remoteness of the atoll and the various logistic problems which development would entail.

Disturbances and threats: A solid coconut plantation occupies the whole of South Island. This introduced species has taken over all of the interior of the island to the edge of the beach. Smaller plantations exist on Long and Nake islets, but these have spread only to a limited extent. Coconut palms are highly competitive, their high, dense canopies blocking out the light and inhibiting the growth of native species. An introduced parasitic vine, *Ipomoea tuba*, has successfully colonized both open and shaded areas. The recent leasing of Caroline Atoll to a French Polynesian entrepreneur has led to some poaching of Green Turtles. The leaseholder has established a homestead on Motu Ana-Ana, and has brought domestic dogs and cats with him. These now pose a serious threat to seabirds, which had already ceased to breed on Motu Ana-Ana by 1990. Caroline Atoll is regularly visited by yachts, and these presumably cause some disturbance to wildlife.

Hydrological and biophysical values: No information.

Social and cultural values: The social and cultural values of Caroline Atoll lie mainly in its conservation significance which, it is believed, could be enhanced through the development of nature-oriented tourism.

Noteworthy fauna: Caroline is a very important atoll for seabirds, with nine breeding species: Masked Booby (*Sula dactylatra*), Brown Booby (*S. leucogaster*), Red-footed Booby (*S. sula*), Great Frigatebird (*Fregata minor*), Lesser Frigatebird (*F. ariel*), Sooty Tern (*Sterna fuscata*), Brown Noddy (*Anous stolidus*), Black Noddy (*A. minutus*) and White Tern (*Gygis alba*). The most abundant species are the Great Frigatebird, estimated at 10,000 birds, and Sooty Tern, estimated at 500,000 birds (Perry, 1980). The Reef Heron (*Egretta sacra*) occurs on the island and evidently breeds, while several species of migratory shorebirds, such as the Pacific Golden Plover (*Pluvialis fulva*), Bristle-thighed Curlew (*Numenius tahitiensis*) and Wandering Tattler (*Heteroscelus incanus*), are winter visitors. The Long-tailed Cuckoo (*Eudynamis taitensis*) occurs as a regular non-breeding visitor from New Zealand. Green Turtles (*Chelonia mydas*) nest on the beaches, and there are three native species of lizards. *Tridacna* clams are abundant throughout the lagoon. Other conspicuous invertebrates include Coconut Crabs (*Birgus latro*), land crabs and hermit crabs.
Noteworthy flora: There are excellent undisturbed stands of *Pisonia* forest on many of the islets, and these provide nesting habitat for a large proportion of the breeding seabirds.
Scientific research and facilities: Several scientific visits have been made to the atoll including visits by staff of the Wildlife Conservation Unit in 1988 and 1991. Earlier visits included those by the Pacific Ocean Biological Survey Program in 1965 and Line Island Expedition in 1974.
Management authority and jurisdiction: Ministry of Line and Phoenix Development.
References: Clapp & Sibley (1971a); Dahl (1980, 1986); Garnett (1983); Perry (1980).
Reasons for inclusion: 1a, 2b, 2c. Caroline Atoll combines a variety of features of conservation importance. Virtually all of the islets except the inhabited Motu Ana-Ana support populations of seabirds. Caroline continues to support large populations of the Coconut Crab which is now rare on most inhabited atolls. The *Pisonia* forests are amongst the oldest stands of this species in the Line and Phoenix Islands, and provide habitat of exceptional importance to the wildlife. The pristine lagoon, with its rich marine life and large populations of *Tridacna* clams, is of great national and international conservation importance.
Source: Aobure Teataata.

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REPUBLIC OF THE MARSHALL ISLANDS

INTRODUCTION

Area: 181 sq.km.

Population: 40,600 (1988)

The Republic of the Marshall Islands consists of 29 coral atolls and five coral islands or "table reefs" spread over some 750,000 sq.km of ocean between latitudes 4° and 15° North and longitudes 160° and 173° East in the central Pacific. The islands lie to the east of the Caroline Archipelago and northwest of the Gilbert Islands (Kiribati). All are low-lying, with maximum elevations generally between 1.5 and 6 m, and nowhere exceeding 8 m. The islands form two parallel chains, the Ratak ("sunrise") Islands in the east and the Ralik ("sunset") Islands in the west. While some of the atolls are very small, the archipelago includes Kuwajleen (Kwajalein) which has the largest atoll lagoon in the world (2,173 sq.km). The islets or "ane", of which there are over 1,100, are composed of coral sand and gravel, cobbles and boulders, and consolidated limestone.

The climate is tropical maritime with a mean annual temperature of 27.8°C, the mean monthly temperatures varying by only 2°C. Rainfall increases from north to south, from about 750-1,000 mm in the northernmost atolls to over 4,000 mm on Jalwoj (Jaluit) in the south. In the dry northern atolls, the heaviest rainfall occurs from September to November, whereas in the wet southern atolls it is heavy throughout the year. In the northern Marshalls, the Northeast Trades predominate throughout the year; in the south, these predominate from December to April, with east or southeast winds blowing for much of the rest of the year. Typhoons are rare, with only four reported since 1900 (UNEP/IUCN, 1988).

The islands were first settled sometime between 1500 and 1000 BC and first visited by Europeans in the early 16th Century. Following the Second World War, the United States of America took control of the islands under a United Nations Trusteeship. The independent government of the Marshall Islands was established in May 1979, and the islands became an independent state in free association with the U.S.A. in October 1986. Twenty-three of the atolls and four of the islands are inhabited, with over half of the population living on just two, Majro (Majuro, the political and economic centre) and Kuwajleen (a large military base). The economy is based on the production of copra and fishing. Tourism is limited, and the islands are still heavily dependent on foreign aid.

Small remnants of atoll forest and beach forest, mostly comprising pan-Pacific species, occur on some of the uninhabited atolls, but most of the islands have been extensively modified by man, particularly for coconut and breadfruit plantations and as a result of military activities. Bikini and Ane-wetak (Enewetak) were used as atomic test sites by the U.S.A. from 1946 to the 1960s. The 1954 Bravo test, the first and largest thermo-nuclear explosion by the U.S.A., spread fallout to several of the northern atolls and caused inestimable damage and social disruption to many reef and island communities (UNEP/IUCN, 1988). The full extent of the disruption to the atoll ecosystems has never been properly documented or evaluated. The greatest long-term threat to the ecosystems of the Marshall Islands is that posed by sea-level rise as a result of global warming. Contamination of underground freshwater supplies, loss of land and increased hurricane damage may make the country uninhabitable if worst-case scenarios are realised (Pernetta, 1988).

The Marshall Islands are important for their turtle and seabird populations. The Green Turtle

(*Chelonia mydas*) still nests in large numbers on some of the northern atolls, notably Pikaar (Bikar), Bok-ak (Taongi) and Bikini, but the Hawksbill (*Eretmochelys imbricata*) is now uncommon in the islands and under threat from continued persecution. Many of the islands support large breeding colonies of seabirds, particularly Bok-ak (Taongi), Pikaar (Bikar), Taka, Jemo, Wotho, Ujlan (Ujelang), Ujae and Kuwajleen (Hay, 1985). Bok-ak, with at least 14 breeding species, is one of the most important breeding sites for seabirds in the Pacific. There are only two resident land birds in the Marshall Islands, the Micronesian Pigeon (*Ducula oceanica*) and Purple-crowned Fruit-Dove (*Ptilinopus porphyraceus*), and one of these, the fruit-dove, is now believed to be extinct in the islands. Other native terrestrial fauna include a number of species of skinks and geckoes.

Dahl (1980 and 1986) has given a brief account of the natural ecosystems of the islands, and has reviewed their importance for nature conservation. UNEP/IUCN (1988) provide a general account of the coral reef systems and reef resources, and give further details on Arno, Bikini, Ane-wetak, Kuwajleen and Majro (Majuro) atolls. Thomas *et al.* (1989) describe the natural diversity and conservation values of six of the northern atolls (Bok-ak, Pikaar, Taka, Wotho, Rongerik and Erikub) and one coral island (Jemo).

There are currently no protected areas in the Marshall Islands. Two of the northern atolls, Bok-ak and Pikaar, were designated as reserves by Order of the District Administrator in the 1950s and 1960s, but these designations have not been recognized since independence (IUCN, 1991). Dahl (1986) recommended the reinstatement of these two reserves and establishment of additional protected areas for the conservation of seabirds, natural vegetation and coral reef systems. Thomas *et al.* (1989) confirmed the significance of Bok-ak and Pikaar, and identified several other sites of special conservation value in the northern Marshalls.

Summary of Wetland Situation

There are no natural, permanent freshwater wetlands in the Marshall Islands. Standing fresh water is a rarity, and running water is totally lacking except briefly during heavy rain storms. The only significant fresh water occurs underground in shallow Ghyben-Herzberg lenses of fresh water floating on salt water in the porous interiors of the atoll islets. These lenses are found on most islets of any real extent except in the dry northern region of the archipelago. Relatively small groundwater fluxes and continuous tidal fluctuations result in a relatively thick zone of mixing between fresh and salt water, and a relatively thin freshwater lens (Olsen, 1984; Thomas *et al.*, 1989).

There are a few very small, mostly brackish, ponds on some of the wet atolls. These have been formed as a result of the closure of a small portion of the lagoon and subsequent dilution with rainwater. One such pond, on Ellep (Lib) Island in the Ralik Chain, contains fresh water (Dahl, 1980). Wherever these wetlands occur, they are important in the local economy for the cultivation of taro. Artificial taro pits occur in the interiors of most of the larger islets in the southern, wet atolls. These pits were created by digging down to below the freshwater table and then filling with a muck consisting of decomposing vegetable matter. They are planted with *Colocasia* and *Cyrtosperma*, the principal and most edible taro genera, as well as sugar cane and a few marsh plants useful as food and medicines (Thomas *et al.*, 1989).

Mangrove vegetation has a very restricted distribution in the Marshall Islands, and only four species are native: *Bruguiera gymnorrhiza*, *Lumnitzera littorea*, *Rhizophora mucronata* and *Sonneratia alba* (Woodroffe, 1987). Poorly developed and impoverished swamps are known on Jalwoj, Arno and Aelonlaplap (Ailinglaplap) atolls in the southern and wettest parts of the archipelago. Further north, mangroves are found mostly inland, in low wet spots termed "mangrove depressions". These depressions are usually rock-bottomed, but many have organic-rich muddy or sandy sediments in them, and some may be connected to the sea by a subterranean connection. *Bruguiera gymnorrhiza* is the principal species, often growing in association with the fern *Acrostichum aureum*; *Lumnitzera littorea* is also occasionally present (Fosberg, 1975). In some cases at least, *e.g.* on Bikini Atoll, these stands of mangroves have probably been planted by the islanders, who had uses for the trees. Stands of *Rhizophora mangle* on Ane-wetak Atoll are also thought to have been introduced by man (Woodroffe, 1987).

Small areas of tidal salt marsh are found on some atolls; these comprise strand species, mainly grasses, on the coast and in depressions subject to tidal flooding (Dahl, 1980)

Sea-grasses are very rare in the Marshall Islands, only two stands of *Thalassia hemprichii* being known from shallow water in Ujlan and Aelonlaplap atolls, and one *Cymodocea rotunda* bed in Majro Atoll. This seems to be the eastern limit of *Thalassia* in the Pacific. *Halophila* sea-grass beds have recently been reported from the lagoon side of several islets in Kuwajleen Atoll (Thomas *et al.*, 1989).

The only significant wetlands, other than strictly marine systems (coral reefs, reef flats, sea-grass beds *etc.*), would appear to be as follows:

* A small tidal pond with mangrove-fringed channel in the centre of Majej (Mejit) Island, a low coral island in the Ratak Chain.
* Several small stands of mangroves on Arno Atoll (Ratak Chain).
* Mangroves in small depressions on islets in Aelonlaplap Atoll (Ralik Chain).
* Mangroves in small depressions on islets in Jalwoj Atoll (Ralik Chain).
* A small stand of *Bruguiera gymnorrhiza* in Bikini Atoll (Ralik Chain), probably introduced by man.
* A small stand of *Rhizophora mangle* in Ane-wetak Atoll (Ralik Chain), presumably introduced by man.
* A small freshwater pond in the central depression of Ellep (Lib) Island, a low coral sand island in the Ralik Chain.
* A small, enclosed saline lagoon in one of the two main islands in Namdik (Namorik) Atoll (Ralik Chain).

None of these sites is afforded any special protection. Dahl (1980) recommended the establishment of one or more reserves to protect examples of the mangrove communities, but other authors have paid scant attention to these small wetland areas.

Only one species of waterbird, the Pacific Reef Heron (*Egretta sacra*), is resident in the Marshall Islands, the complete absence of Rallidae reflecting the lack of wetland habitats. The islands are, however, relatively important for migratory shorebirds, with eight species occurring commonly on migration and in winter: Pacific Golden Plover (*Pluvialis fulva*), Wandering Tattler (*Heteroscelus incanus*), Grey-tailed Tattler (*H. brevipes*), Bristle-thighed Curlew (*Numenius tahitiensis*), Whimbrel (*N. phaeopus*), Bar-tailed Godwit (*Limosa lapponica*), Ruddy Turnstone (*Arenaria interpres*) and Sanderling (*Calidris alba*) (Amerson, 1969; Garrett & Schreiber, 1988; Pratt *et al.*, 1987). Pacific Golden Plover and Ruddy Turnstone are the commonest shorebirds, with wintering populations almost certainly numbering in the thousands. The Marshall Islands are of international importance for their substantial wintering population of Bristle-thighed Curlews. The species occurs widely throughout the islands, but appears to be most common in the northern atolls. The birds frequent reefs, beach rocks and sandy shorelines, and are generally widely scattered, seldom congregating in flocks. Thus in May 1986, Garrett and Schreiber (1988) found the species in small numbers on virtually every islet they visited in Bikini Atoll, although in total they observed only about 25 birds.

Situated at the end of the Micronesian chain and relatively close, by Pacific standards, to the continents of Asia and North America, the Marshall Islands have attracted a wide variety of migratory waterfowl as rare stragglers or vagrants. At least one species of heron, nine species of ducks and geese, one crake, thirteen shorebirds, two gulls and three terns have been recorded in the islands as vagrants.

Wetland Research

Apart from some work on the mangrove communities (Fosberg, 1975), little if any research has been carried out on the wetlands of the Marshall Islands. The marine ecosystems have, however, received a considerable amount of attention, with some atolls, notably Arno and Kuwajleen, being the subject of extensive studies. The results of much of this work have been published in the Atoll Research Bulletin. Detailed coastal resource atlases have been prepared for Majro, Arno and Kuwajleen atolls by the U.S. Army Corps of Engineers. A multi-disciplinary expedition to the northern Marshall Islands in September 1988 investigated the natural diversity and conservation values of Bok-ak, Pikaar, Taka, Jemo, Wotho, Rongerik and Erikub, and identified several sites as being specially worthy of protection (Thomas *et al.*, 1989; Thomas and Juvik, 1989). However, none of these dry atolls has any significant wetlands. The birds of the Marshall Islands have been documented by Amerson (1969) and Garrett and Schreiber (1988).

Wetland Area Legislation

Conservation legislation in the Marshall Islands has recently been summarized by Anon (1989) and IUCN (1991). The National Environmental Protection Act (1984), along with the Coastal Conservation Act (1988), charges the Marshall Islands Environmental Protection Authority with responsibility to "preserve and improve the quality of the environment". Amongst other measures, the Act makes provision for the preservation of important historical, cultural and natural aspects of the nation's heritage. A number of Trust Territory regulations, covering such topics as water supply, pesticides and sewage disposal, remain in force but will be revised in due course. There is currently no protected areas legislation, and the two protected areas established prior to independence are no longer recognized.

At international level, the Republic of the Marshall Islands is a party to the Convention for the Protection of the Natural Resources and Environment of the South Pacific (SPREP Convention), and has ratified the Convention on Biological Diversity. However, it is not as yet a party to the Convention on the Conservation of Nature in the South Pacific (Apia Convention) or any of the other international conventions that directly promote the conservation of nature (IUCN, 1991).

Wetland Area Administration

Not applicable.

Organizations involved with Wetlands

(a) Governmental

Ministry of Resources and Development
- Maritime Resources Authority
- Division of Agriculture

Environmental Protection Authority

(b) Non-governmental

Alele Museum of the Marshall Islands

WETLANDS

There do not appear to be any non-marine wetlands in the Marshall Islands which might qualify as wetlands of international importance on the basis of the Ramsar Criteria. Several atolls have been identified as being of high conservation value for their rich and diverse reef systems, for their large breeding populations of seabirds and/or turtles, or as good examples of relatively undisturbed atoll ecosystems. These are described in detail by UNEP/IUCN (1988), Thomas *et al.* (1989) and IUCN (1991).

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NAURU

INTRODUCTION

Area: Published figures range from 20.7 to 21.3 sq.km.

Population: 9,100 (1990).

The Republic of Nauru comprises a single raised coral limestone island in the west central Pacific Ocean at 0°31'S, 166°56'E, some 42 km south of the Equator. Its nearest neighbour is Banaba (Ocean) Island, 306 km to the east in the Republic of Kiribati. Nauru is one of the three great phosphatic-rock islands of the Pacific (the other two being Banaba in Kiribati and Makatea in French Polynesia). It is oval-shaped and bounded by a reef platform which is exposed at low tide. The ground rises gently from sandy beaches to a fertile coastal belt, 100-300 m wide, with soils consisting of a mixture of sand and fine corals. Inland, a coral-limestone escarpment rises to a central plateau with an average height of about 50 m and a high point at 71 m. This plateau, which covers about 75% of the island's total area, is composed largely of phosphate bearing rocks. These deposits of tricalcium diphosphate, the second richest deposits in the world (after those of neighbouring Banaba Island), occur in small isolated masses (nests) and pits, separated by walls and pinnacles of very hard dolomite limestone. The undisturbed plateau soils are classified as Lithic Haplustolls, Typic Haplustolls and Lithic Ustorthents mainly derived from phosphate materials and, to a lesser extent, dolomitic limestone (Manner and Morrison, 1991).

The climate is tropical with daily temperatures ranging between 24.4°C and 33.9°C, and average humidity between 70 and 80%. The average annual temperature is 27°C, with a seasonal variation of 1°C. Annual rainfall averages about 2,000 mm, much of it occurring during the monsoon season from November to February. However, the annual rainfall is subject to wide fluctuations, ranging from as little as 104 mm to over 4,572 mm. Droughts are not uncommon, and several lasting more than 12 months have occurred this century. Streams are non-existent. The tidal range is about 2.0 m.

Nauru was under German administration from the 1880s until 1914, and then under Australian administration (on behalf of Australia, New Zealand and the U.K.) until the 1960s. In 1966, the Nauruans were given self government, and in January 1968, full independence was achieved. Indigenous Nauruans, of mixed Polynesian, Micronesian and Melanesian descent, make up about 60% of the population, the rest being a mixture of Australians, New Zealanders, Chinese and other Pacific Islanders. There is no capital city as such, although Aiwo and Yaren Districts contain the bulk of the island's governmental and commercial structures. The inhabitants live in small settlements scattered throughout the island, but mostly in the coastal belt.

Nauru's economy is based mainly on the phosphate mining industry. Except for interruptions during World War I and World War II, the phosphate deposits have been mined continuously since 1906. Mining activities were taken over by the Nauru Phosphate Corporation in 1970, and the industry now produces in excess of two million metric tonnes per year. However, it is estimated that the phosphate deposits will be exhausted around the year 2000. The phosphate revenues bring the island one of the highest per capita incomes in the world. Since independence, over 60% of the revenue from phosphate exports has been invested in long-term trust funds, designed to provide the inhabitants with a future income when the phosphate deposits are exhausted. Agriculture is very limited, with a few fruit trees, coconuts, *Pandanus* and breadfruit planted or protected along the coastal belt and in the area around Buada Lagoon. There is also some small-scale cultivation of bananas and vegetables in the coastal belt and in the swampy area bordering Buada Lagoon.

The natural vegetation comprises mixed plateau forest, atoll forest and scrub with *Pandanus* and *Cocos* in the coastal belt, and less than two hectares of mangroves (IUCN, 1991). Only about 10% of the flora is indigenous, and only one endemic species, a species of *Phyllanthus*, has been reported (Dahl, 1986). Manner *et al.* (1984, 1985) identify two indigenous forest types which once dominated the central plateau. The first type, dominated by *Ficus prolixa*, is found on the escarpment and on limestone outcrops or eroded hill crests in the interior. The second type, which probably covered more than 90% of the plateau before mining, is dominated almost entirely by *Calophyllum inophyllum*. Stands of *Pandanus* species are occasionally interspersed amongst both forest types, but are reported to have been deliberately planted for their edible fruits.

Phosphate mining has had a drastic effect on the topography and vegetation of the plateau. Before mining can begin, the land is stripped of vegetation, and the topsoil and contaminated phosphate are scraped off, thereby exposing the phosphate deposits. By 1989, some 75% of the surface area of the island had been mined, and over 90% of the plateau forest had been destroyed, leaving less than 200 ha of forest intact (SPREP, 1989). Virtually no attempt has been made to rehabilitate any of the mined areas, and by the end of this century, an estimated 80% of the total land area (1,760 ha) will have been transformed into pitted, barren wastelands with scattered coral pinnacles (Manner *et al.*, 1984).

This destruction of the island's indigenous forest and scrub poses a serious threat to the survival of Nauru's one endemic bird species, the Nauru (or Finsch's) Reed Warbler (*Acrocephalus rehsei*). This is currently listed in the IUCN Red List of Threatened Animals in the 'Endangered' category (IUCN, 1990). Its present status is unknown, but island residents reported that it could still be found in the remaining brushy areas on the island in 1983 (Pratt *et al.*, 1987).

Dahl (1980 and 1986) has recommended that efforts be made to establish protected areas, including reefs and important cultural sites, and that any remaining forested areas be protected from further mining. However, as the phosphate deposits are the only significant resource on the island, commercial development of phosphate mining has taken priority over the conservation of the natural environment. The Republic of Nauru has made it clear that it will not consider any conservation measures in the remaining phosphate bearing areas.

Concern has recently been expressed that continuing denudation of the central plateau for phosphate mining may cause long-term micro-climatic changes, and restoration of mined land is now a key environmental issue. A Commission of Inquiry into the Rehabilitation of the Worked-Out Phosphate Lands has been established to look at the question of rehabilitation and its cost and feasibility (UNEP/IUCN, 1988). Certainly, the Republic of Nauru could chose to invest some of the capital derived from phosphate mining to rehabilitate the central plateau, through the levelling and breaking up of the pinnacles, the importation of topsoil and the planting of appropriate tree species (Manner *et al.*, 1985).

Summary of Wetland Situation

There is very little surface water on the Nauru's highly permeable terrain, much the largest permanent water body being Buada Lagoon. This is a brackish sunken lagoon, some 3-4 ha in extent, surrounded by a swampy area. It is situated near the centre of the limestone plateau, and has a salinity of 2 p.p.t. and a pH of 8. Ranoemihardjo (1981) lists one other lagoon (at Anabar), a small brackish lagoon with a salinity of 10 p.p.t., and 28 tiny fresh to slightly brackish ponds, most of which were formed in bomb craters during World War II.

Many of the ponds and the two lagoons are used for the rearing of milkfish (*Chanos chanos*). Fry are collected from the reef at low tide, acclimatized for 2-3 weeks, and then released into the ponds and lagoons. Growth rates have, however, been slow, partly because of competition with *Tilapia* and partly because of the insufficiency of natural food and overcrowding (Ranoemihardjo, 1981). *Tilapia mossambica* was introduced into the island in about 1960 to feed on mosquito larvae, and rapidly became abundant in the lagoons and ponds. At the request of the Republic of Nauru, a *Tilapia* eradication programme was implemented by FAO in 1979 and 1980. This involved poisoning the lagoons and ponds with the highly toxic fish poison rotenone (Ranoemihardjo, 1981). Both of the lagoons and most of the ponds are also used as dumping grounds for rubbish.

There are two other wetland systems of note in Nauru. The first is a series of tiny wetlands (0.25-0.33 ha in extent) along the inner edge of the reef lagoon at the base of the limestone escarpment. These are small brackish marshes which sometimes dry out completely. They are virtually unused by the islanders, and remain in an almost unspoiled condition. The second system is a small patch of mangroves, probably less than two hectares in extent, on the island's northeast coast. This very isolated stand of mangroves, of unknown origin, contains only a single species, *Bruguiera gymnorrhiza* (Woodroffe, 1987). The mangrove fruits were apparently once used as a food by the Nauruans.

The only significant water resources available for human consumption lie underground. Traditionally, the inhabitants used groundwater accessible in wells and caves in the karst. However, these supplies are dwindling, apparently as an indirect result of the mining activities (SPREP, 1989). During prolonged droughts, fresh water is shipped to the island in empty phosphate ships.

Nauru's marine systems have been described by UNEP/IUCN (1988). There is no true reef and no lagoon; rather, the island is surrounded by an intertidal reef platform, some 150-200 m wide, cut into the original limestone of the island and typified by the presence of numerous emergent coral pinnacles. The platform is dominated by large yellow-brown algae and little or no coral growth occurs on the reef flat. Coastal waters are relatively unpolluted, although there may have been one or two instances of silt accumulating on some parts of the reef flat.

Wetland Research

The only research specifically related to wetlands has focused on the development of fish culture in the island's ponds and lagoons (Ranoemihardjo, 1981). Soil surveys have been undertaken by John Morrison of the University of the South Pacific, while Manner *et al.* (1984, 1985) have studied the natural vegetation of the plateau and plant succession after phosphate mining.

Wetland Area Legislation

There is no legislation relating specifically to the inland aquatic systems, and indeed no legislation concerning the conservation of terrestrial ecosystems. No protected areas have been established, and none is proposed (IUCN, 1991). The Marine Resources Act 1978 makes provisions for the exploitation, conservation and management of fish and aquatic resources in territorial waters and the exclusive fisheries zone. In general, customary rights over the reefs restrict over-harvesting, and allow the recovery of exploited resources, especially on the reef slopes (UNEP/IUCN, 1988).

The Republic of Nauru is a member of the South Pacific Regional Environment Programme (SPREP) and has signed, but not yet ratified, the Convention for the Protection of the Natural Resources and Environment of the South Pacific (SPREP Convention) and the Convention on Biological Diversity. It is not, however, as yet a party to the World Heritage Convention, Man and the Biosphere Programme or Ramsar Convention.

Wetland Area Administration

Not applicable.

Organizations involved with Wetlands

The Department of Island Development and Industry is the government body concerned with the island's natural resources, and has been involved with the development of fish farming in the lagoons and ponds. However, no specific government entity is directly assigned to take charge of the inland aquatic habitats or the fishery which they support.

WETLANDS

Only one of Nauru's tiny wetlands would appear to be of international importance on the basis of the Ramsar criteria, namely Buada Lagoon. The following site account has been compiled from the literature.

Buada Lagoon (1)

Location: 0°32'S, 166°55'E; near the south end of the island of Nauru, approximately 1.3 km from the coast.
Area: 3-4 ha.
Altitude: Near sea level.
Overview: An enclosed brackish lagoon in the interior of a raised coral limestone island.
Physical features: A small, brackish, sunken lagoon, some 3-4 ha in extent, surrounded by a swampy area. The lagoon is situated in a depression near the southwest end of Nauru's limestone plateau, and has a salinity of 2 p.p.t. and a pH of 8 (Ranoemhardjo, 1981). The water is slightly greenish in colour. The lake is fed by local run-off, principally during the monsoon season from November to February.
The climate is tropical, with an average annual rainfall of about 2,000 mm. There are, however, wide fluctuations in rainfall from year to year, and droughts are not uncommon.
Ecological features: No information is available on the aquatic vegetation. The natural vegetation on the surrounding plateau comprises plateau forest dominated almost entirely by *Calophyllum inophyllum*. However, most of this forest has now been cleared for phosphate mining, leaving barren wastelands with scattered coral pinnacles (Manner (Manner *et al.*, 1984 & 1985).
Land tenure: Customary ownership.
Conservation measures taken: None.
Land use: The lagoon was formerly used for the rearing of milkfish (*Chanos chanos*). Fry were collected from the reef at low tide, acclimatized for 2-3 weeks, and then released into the lagoon. Growth rates were reported to be slow, partly because of competition with *Tilapia* and partly because of the insufficiency of natural food and overcrowding (Ranoemihardjo, 1981). There is some small-scale cultivation of fruit trees, *Pandanus*, breadfruit, bananas and vegetables in the swampy area bordering the lagoon.
Disturbances and threats: *Tilapia mossambica* were introduced into the lagoon in about 1960 to feed on mosquito larvae. They increased rapidly and were thought to be limiting production of milkfish through competition. At the request of the Republic of Nauru, a *Tilapia* eradication programme was implemented by FAO in 1979 and 1980. This involved poisoning the lagoon with

the highly toxic fish poison rotenone (Ranoemihardjo, 1981). The lagoon is used as dumping grounds for rubbish.
Hydrological and biophysical values: No information.
Social and cultural values: No information.
Noteworthy fauna: No information.
Noteworthy flora: No information.
Scientific research and facilities: Some work has been carried out on the development of fish culture in the lagoon (Ranoemihardjo, 1981).
Management authority and jurisdiction: No information. The Department of Island Development and Industry has been involved with fish farming in the lagoon.
References: Manner *et al.* (1984 & 1985); Ranoemhardjo (1981); SPREP (1989).
Reasons for inclusion: 1d. A very isolated and unusual brackish lagoon in the interior of a raised coral island.
Source: See references.

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NEW CALEDONIA

INTRODUCTION

by the Association pour la Sauvegarde
de la Nature Néo-Calédonienne

Area: 19,100 sq.km; including the main island of Grande Terre (16,890 sq.km), the Loyalty Islands (1,970 sq.km), the Isle of Pines (152 sq.km), the Bélep Archipelago and some other small islands (Huon, Surprise, Chesterfield, Matthew, Hunter etc).

Population: 164,173 (April 1989 census). These include 74,000 Melanesians, 55,000 Europeans, 19,000 Polynesians (Tahitians, Wallisians) and 16,000 Indonesians, Vietnamese and others.

The main island of New Caledonia (Grande Terre) lies in the South Pacific at the southern tip of the Melanesian arc, about 1,500 km from the east coast of Australia. Situated between latitudes 19°30' and 23°00' South, just north of the Tropic of Capricorn, it stretches from 163° to 168° East. Grande Terre is almost completely surrounded by a barrier reef which borders a lagoon of clear, rather shallow water covering 16,000 sq.km and varying in width from about one km to 25 km. This barrier reef is the second largest in the world, after the Australian Great Barrier Reef. Grande Terre itself is very elongate in shape, being about 400 km long (from northwest to southeast) but only 50 km wide. This elongate shape is due to the presence of a mountainous spine with an average altitude of 1,000 m. The two highest massifs reach peaks at 1,628 m in the north (Mt Panié) and 1,618 m in the south (Mt Humboldt). The island is noticeably asymmetrical in topography. The east coast is characterized by steep slopes and often by high shorelines. In the west, the central chain gives way to a zone of hills and small plains with wide swampy bays such as the Bay of Dumbéa and Bay of St Vincent.

The Loyalty Islands, which account for most of the remaining area of New Caledonia, lie about 110 km to the northeast of Grande Terre. They comprise three raised coral limestone islands, Ouvea, Lifou and Mare, and a number of tiny islets.

The climate is tropical oceanic, typically warm and rather moist, but here again with a hygrometric asymmetry between the windward east and the leeward west of the main island. As everywhere at these latitudes, the southern trades blow mainly from the east and southeast. Although mean annual temperatures vary little from north to south, ranging between 22° and 24°C, there is a warm season from December to April (average 26°C at Nouméa) and a comparatively cool season from May to October (20°C at Nouméa). Precipitation varies greatly between the east and west coasts, from roughly 2,000 mm in the east to 1,000 mm in the west, and there are large variations from one year to another. Noumea may receive as much as 1,500 mm in wet years, but only 600 mm in dry years. The south may sometimes receive more than 3,000 mm of rain. Tropical depressions and cyclones occasionally hit New Caledonia between January and the end of March.

Because of its long isolation, the variety of soil types and the diversity of climates due to its topography, New Caledonia possesses an exceptionally rich flora and varied vegetation. In this respect, New Caledonia is the most important island in the South Pacific. Some 3,250 species of vascular plants have been recorded, and about 75% of these are endemic. Of particular interest are the 44 native species of gymnosperms and 31 species of palms, all of which are endemic. Over large areas of the island, however, the native vegetation has been destroyed by burning, cultivation, livestock raising and mining. Because of these activities, native vegetation now covers only about half of New Caledonia. The native vegetation consists of moist or sclerophyllous forests, mangrove forest and scrub linked to the presence of ultrabasic or acidic rock. On some 600,000 ha, "niaouli" savannas have replaced the original forest formations which have been destroyed by repeated fires.

New Caledonia, isolated from neighbouring continents for at least 100 million years, lacks a great number of terrestrial animal species. This is particularly true of mammals, which are represented only by bats (flying foxes), of which three species are endemic. All other land mammals have been introduced by Europeans (domestic animals, livestock, feral pigs, rats etc). On the other hand, the islands do possess a number of interesting endemic species of reptiles and birds. Of the 34 species of lizards known from New Caledonia, no less than 30 are endemic, while of the 76 bird species, 21 are endemic. The most notable of the endemic birds is the Kagu (*Rhynochetos jubatus*), the only surviving member of its family, the Rhynochetidae. Also of note are a number of endemic freshwater fishes including one species, *Galaxias neocaledonicus*, which is found only in lakes near the southeastern tip of Grande Terre. This appears to be a relict of an ancient fauna that existed when the climate was much colder than it is today. In contrast to the terrestrial fauna, the marine fauna of New Caledonia's barrier reef and lagoon is extremely rich, with a wide variety of corals, fish, crustaceans, sponges etc. A summary account of the coral reefs is given in UNEP/IUCN (1988), along with a more detailed account of five of the most important reef systems.

The New Caledonian archipelago has been inhabited for over 3,000 years. The first colonists were a branch of the Austronesians originating in Southeast Asia. Polynesians arrived at a much later date, and European settlement began in the 19th century, followed by Asians (Indochinese, Javanese, and Japanese) and further Polynesians (Wallisians and Tahitians). New Caledonia was annexed by France in 1853, and became a French Overseas Territory in 1946. The principal economic activities are mining (nickel, with a ferro-nickel plant at Nouméa), livestock raising (primarily cattle) and tourism (86,000 tourists in 1990). New Caledonia is the world's third largest nickel producer, behind Canada and the former U.S.S.R., and possesses 30% of the world's reserves of nickel ore. There are also some chromium, iron, cobalt and manganese mines on the west coast. Mining provides around 90% of exports.

Livestock raising is concentrated mainly on the west coast, while coffee and copra are cultivated mainly on the east coast. Shrimp aquaculture has recently expanded and is enjoying considerable success. A large portion of the island's meat, vegetables and fruit are imported from Europe, Australia, New Zealand and the U.S.A.

Summary of Wetland Situation

The most extensive wetlands in New Caledonia are mangrove forests, which occur widely on saline and muddy soils in the intertidal zone. The total area of mangroves has been estimated at 20,250 ha (Thollot, 1987), with most of this being found on the west coast of Grande Terre where conditions are most favourable for mangrove development. Thollot (1987) estimated the linear extent of mangroves as 79% of the west coast shoreline but only 14% of the east coast. The rivers of the gently sloping northern half of the west coast are characterised by intricate mangrove-fringed deltas and tidal mudflats. Mangroves are also found in sheltered inlets and embayments, in the lee of headlands and lagoon islands, and fringing estuaries and shallow lagoon areas. Further south along the west coast, hills and promontories are common, with intervening wide bays occupied by extensive mangrove and salt marsh communities. The large rivers of the southern half of the west coast empty into intricate embayments where active delta formation allows abundant mangrove development (Holthus & Galinie, 1990). Along most of the rugged east coast, mangroves are restricted to estuarine river mouths, and have a lower species diversity than those on the west coast, because of the exposed shoreline and strong wave action. There are also a few small patches of mangroves on the Isle of Pines, the Loyalty Islands and the Béleps.

Most stands of mangrove are not very tall, and none exceeds 20 metres in height. Estimates of the number of mangrove species range from 11 to about 20, depending on definition. They include: five species of *Rhizophora*, *Bruguiera eriopetala* (syn. *sexangula*), *Ceriops tagal*, *Xylocarpus granatum*, *Lumnitzera littorea*, *L. racemosa*, *Sonneratia alba*, *Heritiera littoralis* and *Avicennia officinalis*. *Rhizophora* generally dominates along the outer edge of the mangrove forest. Behind this, a narrower band dominated by *Avicennia* is commonly found in estuaries and sheltered embayments. *Bruguiera* tends to dominate along river channels. On the landward edge of the mangrove forest, *Acanthus ilicifolius*, *Excoecaria agallocha* and the creeper *Derris trifoliata* are often present, along with the halophytic fern *Acrostichum aureum*. The highly saline soils of the upper mangrove flats support halophytic vegetation with *Suaeda* sp., *Salicornia australis* and filamentous algae (Cyanophycae), beyond which there is often a littoral forest of common Indo-Pacific species.

A considerable amount of work has been carried out on the mangroves of New Caledonia, particularly by Baltzer (1965, 1969), who has described the mangroves of the Mara embayment and Dumbea River delta in some detail. Thollot (1987) has investigated the importance of mangrove forests for the fish fauna of New Caledonia's lagoon, and lists 64 species of fish belonging to 35 families which occur in the mangrove areas.

The total area of freshwater lakes, ponds and marshes has been estimated at 4,000 ha (SPREP, 1985). Much the most important freshwater wetlands are the lakes and marshes of the Plaine des Lacs near the southeastern tip of Grande Terre. This region of impermeable sub-soils is always at least partially flooded, and contains two large lakes (Lac en Huit and Grand Lac), numerous smaller lakes and ponds, and a large zone of swamps. It is a unique and very fragile ecosystem with a natural heritage of exceptional value.

Other wetlands include limited areas of freshwater swamp forest dominated by *Melaleuca quinquenervia* and numerous rivers and mountain streams. The rivers and streams possess a distinctive fauna including 11 endemic freshwater snails, but this fauna remains poorly known (Dahl, 1980).

The waterfowl of New Caledonia appear to have received very little attention. Only about 12 species are resident, and none of these is endemic (Mayr, 1945). Seven species are fairly common and widespread: the Little Pied Cormorant (*Phalacrocorax melanoleucos*), White-faced Heron (*Ardea novaehollandiae*) Pacific Reef Heron (*Egretta sacra*), Rufous Night-Heron (*Nycticorax caledonicus*), Pacific Black Duck (*Anas superciliosa*), Banded Rail (*Rallus philippensis*) and Purple Swamphen (*Porphyrio porphyrio*). The other five species which are known or thought to be resident, Australian Dabchick (*Tachybaptus novaehollandiae*), Australian Bittern (*Botaurus poiciloptilus*), White-browed Crake (*Porzana cinerea*), Spotless Crake (*P. tabuensis*) and Beach Thick-knee (*Esacus magnirostris*), are all rare or local. Small numbers of migratory shorebirds occur on passage and during the austral summer, the commonest species being Pacific Golden Plover (*Pluvialis fulva*), Whimbrel (*Numenius phaeopus*), Bar-tailed Godwit (*Limosa lapponica*), the two tattlers (*Heteroscelus incanus* and *H. brevipes*), Ruddy Turnstone (*Arenaria interpres*) and Sharp-tailed Sandpiper (*Calidris acuminata*). The Silver Gull (*Larus novaehollandiae*) is a common winter visitor from Australia. Other birds associated with the wetlands include the Swamp Harrier (*Circus approximans*) and Osprey (*Pandion haliaetus*), both widespread residents in the Territory.

Although neither the economy nor the population density of New Caledonia is having an overwhelming effect on wetlands as yet, some degradation and loss of wetlands has occurred. Nickel mining activities in the interior highlands have had a pronounced effects on many rivers and streams. The massive dumping of waste material down the slopes below the nickel mines has resulted in huge amounts of loose material being washed into the valleys, clogging the minor stream beds and thus causing flooding in the major rivers beds and covering fertile agricultural land in the valleys. Further downstream, deltas have undergone rapid changes as a result of increase in the sediment loads carried by the affected rivers (Dupon, 1986). The effects of these changes on the aquatic flora and fauna are poorly known. Bird *et al.* (1984) report on no fewer than forty streams whose valleys, in their middle and/or lower reaches, have been modified to various extents by deposits of mining waste. In more than half of these cases, the estuaries and bays into which the streams flow have also been affected. Here, the increased deposition of red clay and sterile lateritic sub-soil has caused some degradation of the mangrove forest and associated organisms (Holthus & Galinie, 1990).

The greatest threats to mangrove forest are in the area of the capital, Nouméa. These include reclamation of mangrove swamps for the expansion of urban areas, in-filling for road construction, and industrial pollution, especially in the neighbourhood of the Doniambo nickel plant. Overall, however, the mangrove forests of New Caledonia remain in a relatively healthy condition, although in the longer term, reclamation for the development of aquaculture and associated eutrophication could pose serious threats to these systems.

Wetland Area Legislation

While the first legislative measures directed toward nature protection in New Caledonia are a half-century old, the first text generally defining areas of environmental protection and listing zones already protected is Resolution No.108 of 9 May 1980. In accordance with this text, New Caledonia has established over 30 Strict Nature Reserves (Reserves Naturelles Integrales), Territorial Parks (Parcs Territoriaux) and Special Reserves (Reserves Speciales). Special Reserves include botanical reserves, faunal reserves and marine reserves (IUCN, 1991). This protected areas system covers many of the Territory's natural ecosystems, but does not include examples of dry (sclerophyllous) forest and maquis (shrub vegetation) in the mining areas on the west coast. Provisions in Article 10 of Resolution No.108 created four protected areas which include significant tracts of wetland:

- L'Ile Pam and L'Ilot Leprédour, including their mangroves, have been designated as Special Faunal Reserves.
- Part of the periphery of the Plaine des Lacs lies within the Southern Botanical Reserve (a Strict Nature Reserve).
- A large portion of Yate Lake lies within the Haute Yate Special Faunal Reserve.

In March 1990, the Assembly of the South Province created a Special Botanical Reserve of 400 ha at Madeleine Falls (La Chute de la Madeleine). This reserve also includes a part of the Plaine des Lacs.

Protection zones can also be established under the Water Resources and Pollution Law (Deliberation No.105 of 26 August 1968), whereby activities likely to endanger water quality can be prohibited or controlled.

At international level, France has ratified the Convention on the Conservation of Nature in the South Pacific (Apia Convention), the Convention for the Protection of the Natural Resources and Environment of the South Pacific (SPREP Convention) and the World Heritage Convention, and has signed but not yet ratified the Convention on Biological Diversity. France became a party to the Convention on Wetlands of International Importance especially as Waterfowl Habitat (the Ramsar Convention) in October 1986, but its ratification does not extend to New Caledonia.

Wetland Area Administration

Article 5 of Resolution No.108 provided that all protected areas be placed under the control of the Service des Eaux et Forets du Territoire. Since decentralization of administration and jurisdiction in 1990, environmental matters and the management of parks and reserves have been placed under the jurisdiction of the provinces. Thus in South Province, the agency responsible for the environment, parks and reserves (Service de l'Environnement, de la Gestion des Parcs et Reserves) comes under the Provincial Directorate of Rural Development.

Organizations involved with Wetlands

At governmental level, the Service de l'Environnement, de la Gestion des Parcs et Reserves, the Service de la Protection Vegetale et des Forets and the Department of Maritime Affairs have jurisdiction in matters relating to the terrestrial and marine environments. The National Gendarmerie verifies infractions and seizes equipment used by offenders (Articles 6 and 7 of Resolution No.108).

ORSTOM (French Institute of Scientific Research for Development in Cooperation), a governmental agency with an office in Nouméa, employs teams of research botanists and zoologists, some of whom have studied wetlands, particularly mangroves, in the Territory.

Two non-governmental organizations, the Association pour la Sauvegarde de la Nature Neo-Caledonienne (ASNNC) and the Caledonian Ornithological Society, direct their activities toward a better understanding of the natural world and better protection of the environment.

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WETLANDS

Site descriptions compiled by the Association pour la Sauvegarde de la Nature Néo-Calédonienne.

Embouchure du Diahot (1)

Location: 20°20'S, 164°20'E; downstream from the town of Ouega, near the northwest tip of Grande Terre.
Area: Approximately 2,000 ha.
Altitude: Sea level to about 10 m.
Overview: A large area of mangrove forest, *Melaleuca* swamp forest and marshy savannah in the estuary and delta of the Diahot River, with a small mangrove-fringed island offshore.
Physical features: The Diahot River is New Caledonia's longest river. It empties into a gulf where a large delta of silt and sand is covered by extensive mangrove forests. Inland, a complex of fresh to

brackish water lakes and marshes borders the lower reaches of the river, the entire area being about 15 km long and up to 2 km wide. Pam Island (460 ha) at the mouth of the river is surrounded by mangroves and reefs; it is steep-sided and rises to a peak at 166 m. The tides are semi-diurnal with a range of 0.1-1.8 m. The climate is tropical oceanic, with a mean annual precipitation of 1,200-1,300 mm, and a mean annual temperature of 24°C.
Ecological features: Mangrove forest in brackish and saline areas, closed stands of *Melaleuca* forest in areas permanently flooded with fresh water, and swampy *Melaleuca* savannah (niaouli). The closed stands of *Melaleuca* include trees 30 metres tall and lack an understorey. Pam Island is covered in secondary vegetation.
Land tenure: Partly public maritime waters of the French Government and partly Territorial. Pam Island is under public ownership. There are a few private properties in surrounding areas.
Conservation measures taken: None at the wetland. Pam Island was declared a Special Faunal Reserve (Reserve Speciale de Faune de l'Ile de Pam) by Resolution No.108 of the Territorial Assembly in May 1980. Entry into the reserve and hunting are prohibited.
Conservation measures proposed: It has been recommended that a Special Faunal and Floral Reserve be established at the mouth of the Diahot.
Land use: There is probably some harvesting of mangrove crabs (*Scylla serrata*) and mangrove oysters (*Crassostrea cucullata turberculata*) and limited extraction of firewood. Pam Island is uninhabited.
Disturbances and threats: No information.
Hydrological and biophysical values: No information.
Social and cultural values: No information.
Noteworthy fauna: Dugongs (*Dugong dugon*) are present in the Diahot estuary.
Noteworthy flora: It is believed that the mangroves of the Diahot estuary include all of the mangrove species occurring on both the east and west coasts of Grande Terre. Such a convergence of species is known to occur in the Bélep Islands. The closed stands of *Melaleuca* forest in the perennial freshwater marshes are unusual in New Caledonia and merit protection.
Management authority and jurisdiction: Service des Domaines,
Direction Territoriale des Services Fiscaux.
References: Holthus & Galinie (1990); IUCN (1991).
Reasons for inclusion: 1a, 1d, 2b, 2c. The site possesses closed stands of *Melaleuca* swamp forest, a rare habitat type in New Caledonia, and probably also an unusually diverse mangrove forest.
Source: Association pour la Sauvegarde de la Nature Néo-Calédonienne.

Leprédour Islet (2)

Location: 21°59'S, 165°59'E; in West Lagoon, just off the west coast of Grande Terre about 15 km south of the Commune of Bouloupari.
Area: About 200 ha of mangroves.
Altitude: Sea level.
Overview: An unusual stand of mangrove forest on the southwestern shore of Lepredour Islet in West Lagoon.
Physical features: Lepredour Islet is a small limestone and sandstone island, 760 ha in area, with steep slopes rising to a peak at 225 m. The islet is composed of volcanic and sedimentary formations of Tertiary origin. The extensive intertidal zone in the southwestern part of the island is entirely covered by mangrove forest. The tides are semi-diurnal with a range of 0.1-1.8 m. The climate is tropical oceanic, with an annual rainfall of between 800 and 1,000 mm and a mean annual temperature of 22.5°C.
Ecological features: Mangrove forest and some *Melaleuca* savannah (niaouli).
Land tenure: Property of the French Government, placed at the disposal of the High

Commissioner.
Conservation measures taken: Leprédour Islet, including its mangroves, was created as the governor's hunting reserve in September 1941, and was designated as a Special Faunal Reserve by Territorial Resolution No.108 of May 1980 (Reserve Speciale de Faune de l'Ilot Lepredour). Article A 1322-2 of the Code de la Protection de la Nature et de l'Environnement prohibits disembarkation or approach on the seaward side within 100 m. All hunting is prohibited throughout the year, except with permission of the Service de l'Environnement et Gestion des Parcs et Reserves and the High Commissioner.
Land use: A little hunting. There was a settlement on the island in former times, but it is now uninhabited.
Disturbances and threats: Deer have been introduced onto the island, and the mangrove forest and *Melaleuca* savannah are reported to be very disturbed (IUCN, 1991).
Hydrological and biophysical values: The commercial and artisanal harvest of fishes in West Lagoon is to a large extent dependent on the mangrove ecosystem.
Social and cultural values: No information.
Noteworthy fauna: No information.
Noteworthy flora: The mangrove is thought to be a fossil mangrove swamp, a relic of pre-transgression times, before the post-glacial rise of the general ocean level.
Management authority and jurisdiction: The Service de l'Environnement et Gestion des Parcs et Reserves is responsible for the management of the reserve; the Service des Domaines, Direction Territoriale des Services Fiscaux, has territorial jurisdiction.
References: IUCN (1991).
Reasons for inclusion: 1a, 2b, 2c. The mangrove swamp is of particular interest as it is the most extensive mangrove swamp on any islet in the lagoon, and is the only example of a mangrove swamp facing the prevailing wind and thus with no protection from wave action and ocean swell.
Source: Association pour la Sauvegarde de la Nature Néo-Calédonienne.

Dumbea and Karikouie Mangroves (3)

Location: 22°12'S, 166°24'E; west from the outskirts of Nouméa for about 20 km, Grande Terre.
Area: About 1,000 ha.
Altitude: Sea level.
Overview: A large area of coastal and estuarine mangroves in the deltas of the Dumbéa and Karikouié Rivers in the Baie de Dumbea. There is evidence that the mangroves were formerly much more extensive.
Physical features: Extensive mangrove forests occur in the intertidal zone in the deltaic and estuarine systems of the Dumbea and Karikouie Rivers which enter the Baie de Dumbea to the west of the city of Noumea. In the Dumbea delta, mangroves occur widely on river levees, on mud and sand banks, along tidal channels and in marginal depressions. Inland, the mangrove swamps give way to salt marshes and then brackish and freshwater swamps. The maximum tidal range in the bay is 1.7 m.
The climate is tropical oceanic, with an average annual rainfall of about 1,000 mm and a mean annual temperature of about 22°C. The temperature of the sea varies from a minimum of 19°C to a maximum of 28°C.
Ecological features: Several vegetation zones have been identified in the Dumbea River delta, and these have been related to the frequency of tidal inundation (Baltzer, 1969; Chapman, 1976). The lowest zone, on the seaward fringe of the mangroves, is dominated by *Rhizophora mucronata* which occurs down to 1.1 m below the high equinoctial spring tide level. *R. mucronata* and *Bruguiera eriopetala* occur together in an intermediate zone around the level of the high neap tides. Where conditions become brackish, *Rhizophora* decreases and *Acrostichum aureum* and Cyperaceae are

associated with *Bruguiera*. At higher and drier levels, *Avicennia officinalis* becomes mixed with *Bruguiera*, or else forms a pure community of its own. Eventually it borders onto a *Salicornia australis* sward. Beyond the *Salicornia* belt, with further rise in land level up to extreme high water mark, there is a belt of *Lumnitzera racemosa*.

Land tenure: Public maritime waters of the French government. Surrounding areas are partly owned by the Communes of Nouméa and Mount Dore, and partly private properties.

Conservation measures taken: The remaining mangrove areas around Noumea have been given protected status in the Urban Development Plan (Plan d'Urbanisme) in zones where no clearing, filling or construction is allowed. The entire coastal zone of Nouméa and its environs is part of a protected area within which all mining activity is regulated.

Conservation measures proposed: Holthus and Galinie (1990) suggested that mangrove areas could be developed as natural parks, with walkways to provide access, to offset the decrease in open wooded areas around Noumea.

Land use: Some mangrove crabs (*Scylla serrata*) and mangrove oysters (*Crassostrea cucullata turberculata*) are harvested, and there is a little extraction of firewood. The only products harvested in substantial amounts from the mangroves here, as elsewhere in New Caledonia, are fish.

Possible changes in land use: A proposal to develop commercial shrimping at the mouth of the Dumbéa River is under consideration.

Disturbances and threats: The principal threat to the mangroves in the Noumea area has been, and still is, clearing and filling for waterfront, industrial and residential development. In the early 1900s, the waterfront area of Noumea (Baie de la Moselle) was cleared of mangrove and filled with material removed during the levelling of adjacent hills. All four of the principal stands of mangroves in the Noumea area are either in the process of being cleared for urban development, or are under threat of being cleared (Holthus & Galinie, 1990). The construction of solid-fill causeways for a highway through riverine mangrove along the Dumbea River has resulted in mangrove die-off due to waterlogging on the inland side of the causeway (Bird *et al.*, 1984). In spite of the protected status of the mangroves, clearing and filling continue to be authorized by the Territorial Government and building permits are granted by the Municipal Government (Holthus & Galinie, 1990). There is also a considerable amount of pollution in the mangroves in the vicinity of the Doniambo nickel plant.

Hydrological and biophysical values: The mangrove forests play a valuable role in dampening the effects of flood waters and trapping much of the river-borne sediment, preventing it from being discharged into adjacent coral reefs and recreational waters. The mangroves may also play a valuable role as a natural tertiary treatment system for secondarily treated waste water (Holthus & Galinie, 1990). The commercial and artisanal harvest of fishes in West Lagoon is to a large extent dependent on the mangroves.

Social and cultural values: No information.

Noteworthy fauna: No information.

Noteworthy flora: No information.

Scientific research and facilities: Baltzer (1969) carried out a detailed survey of the plant communities, sediments and tidal phenomena in the Dumbea River delta, and various studies have been undertaken by ORSTOM researchers, *e.g.* a study of the importance of the mangroves for the fish fauna of the lagoon by P. Thollot (1987).

Management authority and jurisdiction: Service des Domaines,
Direction Territoriale des Services Fiscaux.

References: Baltzer (1969); Bird *et al.* (1984); Chapman (1976); Holthus & Galinie (1990); Thollot (1987).

Reasons for inclusion: 1a, 2b, 2c. One of the largest areas of mangrove vegetation in New Caledonia, close to a large urban centre.

Source: Association pour la Sauvegarde de la Nature Néo-Calédonienne.

Yate Lake and Riviere Bleue (4)

Location: 22°08'S, 166°49'E; west of Yate, near the southeastern tip of Grande Terre,
Area: Unknown.
Altitude: Lake Yate at 156 m; catchment area to 1,250 m at the summit of Mt Dzumac.
Overview: A large water storage reservoir, built for hydro-electric purposes, and two of the principal tributary rivers, the Riviere Bleue and Riviere Blanche, in protected catchment areas to the west.
Physical features: Lake Yate is much the largest artificial lake in New Caledonia and probably the largest in the insular Pacific. It was created by a hydro-electric scheme in 1959, and flooded large areas of forested valleys bottoms. Two of the largest rivers entering the lake, the Riviere Bleue and the Riviere Blanche, rise in the Massif du Dzumac to the west, and are wholly within a protected catchment area. Although there has been some logging in the past, much of the forest in the catchment areas of these two rivers remains relatively intact, and as a consequence, the rivers have remained in an almost pristine condition. Freshwater marshes occur along the lower reaches of the Riviere Blanche and near the southwest corner of the lake (Ouenarou). The lake itself is subject to wide fluctuations in water level and supports little emergent aquatic vegetation. Geologically, the area forms part of the ultrabasic southern massif, with significant alluvial deposits in the valley bottoms. The climate is tropical oceanic with an average annual rainfall exceeding 3,000 mm.
Ecological features: Clear fast-flowing rivers and streams, and freshwater marshes with some *Melaleuca*. The Territorial Park protects the most important remnant of the once extensive southern forest, and includes 6,000 ha of dense rainforest. The area was logged in the 1930s and includes secondary growth. The main plant communities are described by IUCN (1991).
Land tenure: Public. The area is under relatively little pressure from Melanesian land claims.
Conservation measures taken: The western end of the lake and its watershed are included within the Haute Yate Special Faunal Reserve (Reserve Speciale de Faune de la Haute Yate), a reserve of 15,900 ha created in 1960 and confirmed by Resolution No.108 of May 1980. An area of 9,054 ha within the faunal reserve, including the whole of the Riviere Bleue, its mouth in Lake Yate and a small section of the lake shore, was designated as a Territorial Park (Parc Territorial de la Riviere Bleue) in May 1980. Under Article A 1321-4 of the Code de la Protection de la Nature et de l'Environnement, entry into the Faunal Reserve is regulated, and only holders of titles for forestry or mining and staff of La Societe d'Energie Electrique are permitted to visit the area regularly (IUCN, 1991). Hunting and fishing are prohibited in the reserve, but the legal protection does not prohibit prospecting for minerals, exploitation of minerals or forestry. The Territorial Park enjoys total legal protection, including prohibition of prospecting and mining.
Land use: Research, outdoor recreation and tourism in the Territorial Park and Faunal Reserve. There is no permanent habitation in the reserve, and there are no villages in the immediate vicinity.
Disturbances and threats: Mineral prospecting and fires have degraded parts of the Faunal Reserve. There has been some forestry exploitation in the past, but this ceased in what is now the Territorial Park in 1975, and the forest is regenerating. The Kagu and other native wildlife is threatened by introduced dogs, cats, pigs and rats. Black Bass have been introduced into the lake.
Hydrological and biophysical values: No information.
Social and cultural values: No information.
Noteworthy fauna: Little Pied Cormorants (*Phalacrocorax melanoleucos*), White-faced Herons (*Ardea novaehollandiae*) and Pacific Black Ducks (*Anas superciliosa*) occur around the lake. No other information is available on the aquatic fauna of the lake or rivers. The forests of Riviere Bleue Territorial Park contain all of the endemic bird species of New Caledonia which are still known to survive. The park is particularly important for its large population of the endemic flightless Kagu (*Rhynochetos jubatus*), estimated at 200 individuals in 1989. The park also supports the largest remaining population of the Crow Honeyeater (*Gymnomyza aubryana*) and a large population of the Notou or Giant Pigeon (*Ducula goliath*).
Noteworthy flora: No information is available on the aquatic vegetation. Over 400 species of

plants have been recorded in the Territorial Park, about 80% of which are endemic to New Caledonia. Rare species such as *Libocedrus yateensis* and the parasitic gymnosperm *Parasitaxis ustus* are of particular interest (IUCN, 1991).
Scientific research and facilities: The fauna and flora of the Territorial Park has been well documented, and research on the Kagu has been on-going since 1980. However, little if any work seems to have been carried out on the fauna and flora of the rivers or the lake.
Recreation and tourism: About 20,000 people visited the Territorial Park in 1991. Various camping and picnicking facilities are available in the park, and a network of trails, including 60 km suitable for motor vehicles, provides easy access.
Management authority and jurisdiction: Management of the Faunal Reserve and Territorial Park is the responsibility of the Service de l'Environnement et Gestion des Parcs et Reserves.
References: IUCN (1991).
Reasons for inclusion: 1a, 2b. Lake Yate is the largest freshwater body in New Caledonia, and Riviere Bleue and Riviere Blanche are two of the least disturbed rivers.
Source: Association pour la Sauvegarde de la Nature Néo-Calédonienne.

Plaine des Lacs (5)

Location: 22°15'S, 166°55'E; about 50 km east of Nouméa and 10 km south of the Nouméa-Yaté road, Yaté Commune, near the southeastern tip of Grande Terre,
Area: About 5,000 ha.
Altitude: 200-260 m.
Overview: A group of permanent freshwater lakes and marshes in depressions on a large plain surrounded by hills near the southeastern tip of Grande Terre. The area is of exceptional botanical and zoological interest, and supports many endemic species.
Physical features: The Plaine des Lacs is a slightly undulating plain about 10 km long by 5 km wide, with altitudes varying between 260 and 240 m. The numerous depressions are occupied by permanent freshwater lakes, ponds and marshes, the largest lakes being Lac en Huit and Grand Lac. The plain is drained by the Riviere des Lacs, a tributary of the Yate, from its source in Lac en Huit across the northern edge of the plain. After the 10 m drop of Madeleine Falls (La Chute de la Madeleine), the river enters Yate Lake beyond its confluence with Pernod Creek which drains the exterior of the northwest slopes of the Plaine des Lacs. A narrow alluvial zone 1-5 m wide along the banks of the Riviere des Lacs is subject to flooding during high water. The geological substrate comprises peridotitic rocks which make up much of southern Grande Terre; the soils are ultrabasic ferric latosols and very poor in chemical elements except magnesium, iron and chromium. The deep horizons have concentrations of nickel and manganese that are higher than normal. In the lowest, central portions of the plain, the soils are more or less peaty.
The soils show a clear tendency toward induration in the form of fine ferruginous gravel, boulders of laterite or even solid laterite crusts several metres thick and completely impermeable.
The climate is tropical oceanic with an average annual rainfall of 2,500-3,000 mm and a mean annual temperature of between 22° and 23°C.
Ecological features: Freshwater marshes throughout the Plaine des Lacs are dominated by *Xyris pancheri* (Xyridaceae) and *Schoenus brevifolius* (Cyperaceae) (Dahl, 1980). In the Madeleine Falls area, the aquatic vegetation is poor in species, but includes a carnivorous species of *Utricularia*, a relatively rare aquatic fern *Blechnum francii*, and a species of *Eriocaulon* endemic to the south of Grande Terre (Jaffre, 1988). The narrow alluvial zone along the Riviere des Lacs supports a distinctive community dominated by the two gymnosperms *Nageia (Decussocarpus) minor* and *Dacrydium guillauminii* in a shrub layer 3-5 m high. *D. guillauminii* is known only from the banks of the Riviere des Lacs. A low discontinuous shrub layer in this alluvial zone comprises *Melaleuca brongnartii*, *Xanthostermon aurantiacum*, *Homalium kanaliense*, *Pancheria communis* and *Cloezia aquarium*. The herbaceous layer,

which is absent on gravelly soil but continuous on alluvial soil, comprises the Cyperaceae *Costularia xyridiodes*, *Schoenus brevifolius*, *Chorizandra cymbaria* and *Tricostularia guillauminii*, and the Xyridaceae *Xyris pancheri* and *X. neocaledonica* (Jaffre, 1988). The dominant vegetation of drier ground is a semi-wet woody/herbaceous scrub with two endemic species of gymnosperms, an endemic fern and numerous lichens. Plant communities in the Madeleine Falls area have been described by Jaffre (1988) and are summarized in IUCN (1991).

Land tenure: Owned by the French Government and the Territory. Concessions for mineral exploration have been granted, but no mining was in progress in 1991.

Conservation measures taken: A Special Botanical Reserve of about 400 ha (Reserve Speciale Botanique de la Chute de la Madeleine) was created along the Riviere des Lacs in 1990 (Resolution No.39-90/APS of 28 March 1990). This is located on the north-northwest edge of the Plaine des Lacs and is bordered in part by the Riviere des Lacs. Legislation prohibits the collection, removal, displacement or harvesting of any mineral or vegetation. Seven small protected areas, totalling 4,466 ha, have been established in the vicinity of the Plaine des Lacs. Together these constitute the Southern Special Botanical Reserve (Reserve Speciale Botanique du Sud), established by Resolution No.108 in May 1980. All mining activity is prohibited in these reserves (Order No.72-395/CG of 17 August 1972).

Conservation measures proposed: Dahl (1980) recommended the establishment of a reserve on the Plaine des Lacs to protect the lake fauna and marsh flora. More recently, it has been recommended that a Special Faunal and Floral Reserve be created to protect the entire plain.

Land use: No information.

Disturbances and threats: The growing numbers of visitors to the region have caused considerable damage; trees have been burned and broken, and rubbish has been dumped in the area. In the medium or long term, the principal threat comes from mining development (nickel, iron, chromium etc.) because of the potential mineral value of the region. Some mining activities began in the area in 1992.

Hydrological and biophysical values: No information.

Social and cultural values: The wetlands have some potential for tourism and conservation education. The region is of great interest to scientists and is becoming the object of intensive scientific study.

Noteworthy fauna: An endemic species of fish, *Galaxias neocaledonicus*, is known only from the Plaine des Lacs. It has been found in Lac en Huit and may also occur in the Madeleine Falls Special Botanical Reserve. This nocturnal species is believed to be a "living fossil" with Gondwanian affinities with New Zealand. Other aquatic species of scientific interest include two genera and three endemic species of freshwater snails, two species of shrimps, which are possibly endemic to the lakes, and a sponge. No information is available on the waterfowl.

Noteworthy flora: The Madeleine Falls area is exceptional for the diversity of its flora, the high concentration of gymnosperms and the presence of many rare species such as the aquatic fern *Blechnum francii* and an endemic carnivorous bladderwort (*Utricularia* sp.). Jaffre (1988) lists 168 species of phanerogam and ferns belonging to 53 families. About 95% of these are endemic to New Caledonia, and about 20% are endemic to the south of Grande Terre. The area is rich in lichens, many of which are apparently undescribed.

Scientific research and facilities: Botanists from the Botanical Laboratory at ORSTOM carried out a survey of the vegetation and detailed inventory of the flora of the Madeleine Falls area in 1988 (Jaffre, 1988).

Conservation education: The wetland is situated close to the small town of Yate, and could have some potential for conservation education.

Management authority and jurisdiction: Service des Forêts et du Patrimonie Naturel (SFPN), Direction du Développement Rurale Province Sud. Responsibility for management of the Madeleine Falls Special Botanical Reserve rests with the Service de l'Environnement et Gestion des Parcs et Reserves.

References: Dahl (1980); IUCN (1991); Jaffre (1988).

Reasons for inclusion: 1a, 2a, 2b, 2d. A unique wetland; much the largest area of freshwater lakes

and marshes in New Caledonia, with many endemic species.
Source: Association pour la Sauvegarde de la Nature Néo-Calédonienne.

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NIUE

INTRODUCTION

Area: 259 sq.km.

Population: 2,270 (1989).

Niue is an isolated island at 19°05'S, 169°50'W, approximately 480 km northeast of Tonga and 560 km southeast of Western Samoa. It is a raised atoll of coralline limestone about 62 m high, with prominent coastal terraces about 20-28 m above sea level. The karst topography is rich in deep fissures and limestone caves. The interior of the island is slightly depressed, representing the "lagoon" of the original atoll. The soils are generally poor, highly leached coral residues with an admixture of volcanic ash or debris, some better soils occurring in pockets of organic accumulation. The island has an unusually high natural radioactivity (UNEP/IUCN, 1988).

The climate is subtropical with a mean annual temperature of 24.7°C (mean maximum 27.0°C, mean minimum 24.3°C.). The annual rainfall averages about 2,000 mm and is evenly distributed throughout the year; the mean humidity is 79.7%. The island lies on the edge of the hurricane belt, and is occasionally subjected to severe hurricanes.

Niue is a self-governing state in free association with New Zealand, which still maintains responsibility for defence and foreign affairs. The population consists almost entirely of Niueans, with a small Tongan minority and some New Zealanders. The population is declining at about 2.6% per annum as a result of emigration to New Zealand, and there are now about twice as many Niueans living in New Zealand as in Niue. The economy is based on copra, fruit and vegetable exports, tourism and budgetary support from Wellington.

Marine systems have recently been described by UNEP/IUCN (1988). The principal terrestrial ecosystems are lowland rain forest on raised coral substrate (limestone forest), coastal forest on terraces, secondary forest and fern-scrub barrens. Of the 629 plant taxa recorded on the island, 175 are indigenous (Dahl, 1986). Endemic animals include a species of charopid snail and a subspecies of the Polynesian Triller *Lalage maculosa whitmeei* (Pearsall, 1991). Coastal areas are of considerable scenic, cultural, geological and ecological value (TCSP, 1990).

Much of the terrestrial vegetation has been heavily disturbed and degraded by past and present shifting agriculture and logging. The abandoned land develops into a fern-scrub community with very poor recovery potential (Pearsall, 1991). This now covers approximately 12.4% of the island, while secondary growth and regenerating forest account for a further 46.2% (IUCN, 1991). Overgrazing is also reported to be a severe problem. However, a patch of 150 ha of limestone forest in the Huvalu Tapu area has been protected under customary law since pre-European times. The forest remains in pristine condition, and contains many of the island's indigenous species. Further forest reserves would, however, be desirable for the conservation of the triller (Hay, 1985).

Summary of Wetland Situation

There are no significant freshwater wetlands in the interior of the island and no mangroves in the coastal zone. No wet soils are identified in a recent soil map of Niue (Leslie, 1986). However, six of the 27 scenic and historic features identified by Dahl (1980) and the Tourism Council of the South

Pacific (TCSP, 1990) as being worthy of special protection contain small springs, streams or pools. These are as follows:

- Anapala: a chasm with freshwater pool;
- Avaiki: a cave with pools (a fish breeding area);
- Matapa Chasm: a scenic deep cleft in rock with a freshwater stream;
- Togo: beach caves and a freshwater pool;
- Vaikona: a chasm and cave with series of deep brackish pools;
- Vaitafe: a broad reef with pool and freshwater spring.

Wetland Research

Various studies have been carried out on the hydrology, hydrogeology and groundwater resources of the island (Jacobson and Hill, 1980; Schofield, 1959 and 1969; Waterhouse, 1981), and a detailed soil survey has been undertaken (Leslie, 1986).

Wetland Area Legislation

There is an almost total lack of environmental legislation in the fields of protected areas and species, pollution control or environmental impact assessment (TCSP, 1990). An Environmental Protection Ordinance with conservation provisions was proposed in 1975, but no progress seems to have been made with this since then (Dahl, 1980; UNEP/IUCN, 1988). The Wildlife Ordinance (1972) protects listed birds and the fruit bat *Pteropus tonganus*, and there is a Fish Protection Ordinance (1965). No protected areas have been formally designated, but one area (Huvalu Forest) is well protected under customary law, and customary restrictions are applied from time to time in temporary marine "reserves" to allow the recovery of exploited resources (IUCN, 1991).

Niue is a member of the South Pacific Regional Environment Programme (SPREP). However, it has not as yet signed or ratified either the Convention for the Protection of the Natural Resources and Environment of the South Pacific (SPREP Convention), the Convention on the Conservation of Nature in the South Pacific (Apia Convention) or the Convention on Biological Diversity, nor is it a party to the World Heritage Convention, Man and the Biosphere Programme or Ramsar Convention (IUCN, 1991).

Wetland Area Administration

Not applicable.

Organizations involved with Wetlands

The Department of Agriculture, Forestry and Fisheries is the Government body with responsibility for the natural environment.

WETLANDS

None of Niue's tiny wetlands would appear to be of international importance on the basis of the Ramsar Criteria.

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COMMONWEALTH OF THE NORTHERN MARIANA ISLANDS

INTRODUCTION

by Derek W. Stinson

Area: 478 sq.km.

Population: 43,000 in 1990.

The Commonwealth of the Northern Mariana Islands (CNMI) comprises 14 of the 15 Mariana Islands, an archipelago in Micronesia situated between latitudes 14°10' and 20°31' North. Guam, the southernmost of the Mariana Islands, is presently a U.S. Territory and politically separate. Saipan, the capital of the CNMI, lies approximately 2,400 km south of Tokyo and 2,600 km east of Manila. Two geologically different island arcs make up the CNMI. The five southernmost islands are geologically oldest, and primarily consist of uplifted limestone. The remaining nine northern islands are entirely volcanic material, and some exhibit sporadic volcanic activity. Pagan, the largest of the northern islands, has several cones and older collapsed calderas. Two major eruptions have occurred on Pagan this century, and about half of the island is relatively barren cinder fields and lava flows. Saipan, the largest island (120 sq.km), has a rugged limestone ridge running along its northern two-thirds, the highest point of which is 436 m. Saipan has extensive sand beaches on its western side, protected by a barrier reef and lagoon. Tinian (100 sq.km) is mostly relatively flat and consists of level limestone terraces with three high sections, the highest point of which is 178 m. Tinian's coastline is mostly rocky and unprotected from wave action.

The climate is warm and humid with little seasonal or daily variation in temperature, the temperatures generally remaining between 25 and 30°C. Most of the 2,000-2,500 mm of annual rain falls in the rainy season, from June to November. The CNMI is in an area of typhoon formation, and tropical storms are common in the rainy season and early part of the dry season. Northeast trade winds generally blow during the dry season, from December to May. As is typical of small oceanic islands, the terrestrial fauna is relatively depauperate, but with a high degree of endemism. In recent years, a subsistence economy has become a rapidly expanding tourist economy.

Summary of Wetland Situation

Lake Susupe and the large contiguous reed marsh and swamp on the western coastal plain of Saipan comprise over 60% of the freshwater wetlands in the CNMI. Smaller marshes on Saipan, the Pagan lakes, and Lake Hagoi and a swamp on Tinian make up most of the remainder. There are a few small stands of mangroves (*Bruguiera gymnorrhiza*) on Saipan which may have been much more extensive in the past.

In addition to loss of wetlands through filling during this century, wetlands were affected by cultivation of sugar cane and rice during the Japanese period (1914-1944). Waste water from a sugar mill drained into Lake Susupe and probably deposited large quantities of organic matter in the lake. Little wetland agriculture is practised now, and most wetlands are covered with thick stands of reeds (*Phragmites karka*). In addition to agriculture and development impacts to wetlands, the exotic mosquito fish (*Gambusia affinis*) and tilapia (*Sarotheradon mossambicus*) were introduced, and probably greatly altered the aquatic ecosystems. *Gambusia* was probably introduced by the U.S. military for mosquito control during World War II (Eldredge, 1988; Maciolek, 1984). Tilapia were introduced for small-scale aquaculture during the 1950s. Both fishes have become notorious for the ecological havoc they cause where they have been introduced (Courtenay & Robins, 1989; Myers, 1965). The high level of infestation of tilapia and circumstantial evidence suggest that tilapia have played a role in the decline of the Mariana Common Moorhen (*Gallinula chloropus guami*) and the extinction of the Marianas Mallard (*Anas oustaleti*) (Stinson *et al.*, 1991b). Poaching and egg collection also played a major role in the extinction of the Mallard.

Except for a small amount of agriculture, wetlands are subject to little use. In the near future, portions of publicly owned marsh may be used for taro cultivation in an experimental moorhen habitat improvement programme administered by the CNMI Department of Natural Resources. Although subject to little economic activity, the value of the wetlands for flood control and groundwater recharge should not be underestimated. Underground sources for public water supply are limited; the wetlands are sites of groundwater recharge and help to reduce salt water intrusion. While allowing recharge, the wetland store great quantities of storm run-off during heavy rains. The marshes also filter out large quantities of eroded material that might otherwise increase siltation of the coastal lagoon and reef resulting in coral die-off.

The freshwater wetlands of Saipan and Tinian are essential to the survival of the Mariana Common Moorhen, a U.S. and CNMI Endangered Species. The Nightingale Reed-warbler (*Acrocephalus luscinia luscinia*) on Saipan, also listed as an Endangered Species, uses reedy marshes and wetland edges, but is not restricted to wetland habitats. The Guam population, which seems to have been primarily restricted to wetland habitats, is now extinct (Reichel *et al.*, 1992). The wetlands of the CNMI are also used by a great variety of migrants.

The greatest threats to wetlands are development and drawdown for water use. At present, wetlands are effectively protected by both federal and local laws. Wetlands would almost certainly be subject to greater development pressures should any political changes reduce the involvement of federal agencies. There is reportedly an investigation being conducted to determine the feasibility of using the waters of Lake Susupe for public water supply. Such use would undoubtedly result in: (a) a reduction in the size of the Susupe wetlands, (b) a decrease in the depth and therefore the amount of open water at Lake Susupe due to encroachment by emergent aquatic plants, and (c) the seasonal persistence of flooding throughout the marsh. This has been a problem on Tinian, where wells adjacent to Makpo Swamp have been pumping water since the 1930s. Makpo is described in historical literature as open water with a variety of waterfowl, but it is now a shallow swamp (Barratt, 1988; Northern Islands Company, 1989). An additional threat is the potential use of wetlands for aquaculture, which would render portions of the wetlands unsuitable for the Mariana Moorhen.

Wetland Research

There is currently little wetland research being conducted, with the exception of an ecological study of the Mariana Moorhen and an attempt to create artificial wetland as mitigation for loss of wetland habitat as a result of filling (Dames and Moore, 1990). Past research has involved descriptive inventories and engineering studies for flood control proposals (Tenorio and Associates, 1979; Moore *et al.*, 1977; Best and Davidson, 1981; ERC, 1990). The most intensive research activity occurred for the environmental impact analysis for two flood control project proposals (U.S. Army Corps of Engineers, 1986a & 1986b). These projects seem to be on hold because of marginal cost/benefit analyses and lack of local funding, but will probably be revived in the event of future flood damage. These projects could probably be designed to improve habitat conditions for Mariana Moorhens, and may provide the funding and impetus for much needed but costly habitat improvement activities. These needs include an increase in open water habitat and the eradication of tilapia, if feasible.

Wetland Area Legislation

(a) Federal Laws

- Rivers and Harbors Act of 1899 - Authorizes the Army Corps of Engineers to regulate dredging of 'navigable' waters.
- Fish and Wildlife Coordination Act of 1958 - Includes a requirement that other federal agencies consult with the U.S. Fish and Wildlife Service about proposals that have an impact on wetlands.
- Land and Water Conservation Fund Act of 1965 - Authorizes a fund from which money can be used for acquisition of land for conservation purposes.
- Coastal Zone Management Act of 1972 - Requires that all federal actions be consistent with an approved management programme, and provides a framework for providing funding to state coastal resource management programmes, including the CNMI Coastal Resources Management Office.
- Endangered Species Act of 1973 - Section 2 directs federal agencies to cooperate with state and local agencies to resolve water resource issues in concert with the conservation of endangered species. Section 7 directs federal agencies to consult with the U.S. Fish and Wildlife Service about any action, including issuance of permits, that will impact endangered species.
- Clean Water Act of 1977 - In addition to water quality provisions in this law, Section 404 authorizes the Army Corps of Engineers to regulate the discharge of fill into wetlands through a permit system.
- Emergency Wetlands Resources Act of 1986 - Authorizes the use of money from the Land and Water Conservation Fund for the acquisition of important wetland habitat. The Act directs the Department of the Interior to develop a plan for identifying priority sites for acquisition. National and Regional Wetlands Priority Conservation Plans have been prepared by the U.S. Fish and Wildlife Service (U.S. Fish & Wildlife Service, 1989a & 1990).

(b) Commonwealth Laws

- Coastal Resources Management Act (PL 3-47) - Established the Coastal Resources Management Office (CRMO) and contains regulations and standards for activities permitted in 'Wetland and Shoreline Areas of Particular Concern' (APCs). The established policy for impacts to APCs is sequential consideration of avoidance, minimization and mitigation. Regulations affecting APCs include the prohibition of adverse impacts on drainage patterns, destruction of important habitat, discharge of toxic substances and degrading of water quality and flow. Regulations also protect mangroves and critical wetland habitat of rare and endangered species and maintenance of public landholdings within and adjacent to wetland and mangrove APCs. One limitation encountered has been that these regulations are locked into APCs as outlined on maps that fail to delineate the wetlands adequately. This has limited the ability of CRMO to protect wetlands not so identified. This problem is currently being corrected.
- Fish, Game and Endangered Species Act (PL 2-51) - Authorizes the designation of endangered species and critical habitat. The Act established the Division of Fish and Wildlife, and contains fish and wildlife regulations. One shortcoming is the lack of specific powers and protections in the critical habitat designation.
- Environmental Protection Act (PL 3-23) - Established the Division of Environmental

Quality, and includes regulations for water quality certification, waste water discharge and earth-moving permit systems.

- Public Land Exchange Act (PL 5-33) - Includes the framework for acquisition of land for public purposes, including wetland protection, through exchange for public land. The Act makes no provision for prioritizing wetland acquisitions.

Wetland Area Administration

One wetland on Saipan (not otherwise described in this Directory) is part of American Memorial Park, a U.S. National Park administered by the National Park Service. This wetland is primarily swamp and was impacted by filling and waste oil in the past. Most of the mangroves on Saipan are found in the Park, either in this wetland or adjacent to the Puerto Rico mudflats. The mudflats are not part of the National Park, and are therefore not adequately protected. The Park wetland is used by a small number of Mariana Moorhens. No other wetlands are formally protected. However, privately owned wetlands are being acquired through exchange for other public land to protect wetlands and relieve private individuals of land which cannot be filled for development. The supply of public land available for exchange may, however, be exhausted before all wetlands are acquired. The Mariana Public Land Corporation that administers public lands has verbally expressed the willingness to turn management of the acquired wetlands over to the CNMI Department of Natural Resources.

Organizations involved with Wetlands

a) CNMI Government

- Mariana Public Land Corporation (MPLC)
  Leases public land for development, homesteads, agriculture and grazing, and administers land acquisition through land exchanges.
- Coastal Resources Management Office (CRMO)
  The primary permitting agency for physical development, including activities within the coastal and wetland 'Areas of Particular Concern'.
- Division of Environmental Quality (DEQ)
  Regulates water quality and contaminants. The DEQ is the permitting agency for pollution control, sewage disposal and earth-moving activities. It monitors water quality and administers most of the federal clean water laws.
- Department of Natural Resources (DNR)
  Responsible for the management and disposition of submerged lands. The Director is authorized to designate 'Critical Habitat' for endangered species.
- Division of Fish and Wildlife (DFW)
  Conducts research on native fauna including the Moorhen. The DFW reviews land use proposals and makes recommendations to CRMO, DEQ, DNR and federal agencies concerning permit issuance and conditions.

b) U.S. Government

- U.S. Army Corps of Engineers (ACOE)
  Mandated by Section 404 of the Clean Water Act to regulate the discharge of fill into wetlands through a permit system. The ACOE also regulates dredging of

navigable waters through the Rivers and Harbors Act.

- U.S. Fish and Wildlife Service (USFWS)

  Mandated to ensure the survival of Endangered Species. This includes review of project proposals that will affect Endangered Species including Section 404 permit applications to ACOE for the discharge of fill into wetlands. The USFWS consults with other federal agencies regarding permit applications and proposals. The USFWS Refuge Section may become involved in formal protection of important CNMI wetlands by the establishment of a wildlife refuge, and is authorized to expedite protection through easements or acquisition when necessary.

- Environmental Protection Agency (EPA)

  Evaluates permit applications to ACOE under EPA's 404 (b) (1) 'Guidelines for impacts that can be avoided and may require public participation and a detailed alternative analysis'.

WETLANDS

Site descriptions compiled by Derek W. Stinson of the Division of Fish and Wildlife, CNMI Government.

Pagan Lakes (1)

Location: Inner (Sanhalom) Lake 18°09'52"N, 145°46'39"E; Lagona Lake 18°08'19"N, 145°46'03"E; on the island of Pagan, 375 km north of Saipan. Both lakes are on the main northern part of the island. Lagona Lake is near the west coast and Inner Lake is at the western foot of Mount Pagan.
Area: Lagona Lake 17 ha; Inner Lake 15 ha.
Altitude: Lagona Lake 0.15 m; Inner Lake 1.3 m.
Overview: The two Pagan lakes are the only significant wetlands on the islands north of Saipan. Both lakes are geologically rather young and have not developed marshes. The emergent vegetation that was present was recently destroyed by both feral ungulates and a volcanic eruption that deposited large amounts of cinders on the lake shores.
Physical features: Pagan is a volcanic island of 46 sq.km. The most recent major eruption was in 1981. According to Corwin *et al.* (1957), Inner Lake has a nearly flat muddy bottom with a maximum depth of 23 m. Recent accumulation of cinders may have decreased the size and depth somewhat. Warm springs emptied into the lake near the southeast shore, but these may also have been affected by the eruption in 1981. The lake waters are oligosaline, with an average chloride content of 2.5 p.p.t.
Lagona Lake has, or had, a maximum depth of 20 m (Corwin *et al.*, 1957). The bottom of fine grained alluvium is covered by organic debris. A cinder beach 10 m in height and a minimum of 85 m in width separates the western shore of the lake from the ocean. The beach isolates the lake sufficiently to make tidal influence of the lake very small. During storms, waves sometimes wash over the beach and raise the level of the lake. The lake water is mesosaline, with an average chloride content of 7 p.p.t.
The climate of Pagan is similar to that of Saipan but with slightly less annual rainfall (approximately 1,730 mm) and slightly cooler temperatures (average 27-29°C).

Ecological features: The lakes have been heavily impacted by man and volcanic activity. Earlier this century, the lakes supported a fringe of water fern (*Acrostichum aureum*) which was used by Mariana Common Moorhens (*Gallinula chloropus guami*) and an endemic form of the Nightingale Reed-warbler (*Acrocephalus luscinia yamashinae*). However, much of this vegetation was destroyed by feral animals in the 1960s and 1970s. In 1981, Mount Pagan erupted and buried any remaining emergent vegetation under ash deposits. Another factor that has had a serious impact on the ecology of the lakes has been the introduction of tilapia (*Sarotheradon mossambicus*) in the 1950s (Stinson *et al.*, 1991b). Although Inner Lake had a thick layer of cinders floating on its surface for months after the recent eruptions, the tilapia survived, and both lakes are heavily infested with this pest species.
The vegetation surrounding Lagona Lake is primarily trees, particularly *Cocos nucifera*, *Casuarina equisetifolia* and *Hibiscus tiliaceus*. Small patches of sedges (*Cyperus* spp.) and grasses have colonized the northern shore. Inner Lake has had much of the surrounding vegetation buried by ash deposits, but the west shore has a stand of *Casuarina* and there are a few *Cocos* palms.
Land tenure: Public/Commonwealth.
Conservation measures taken: In an effort to allow emergent aquatic plants to become re-established on the shore of Lagona Lake, a solar electric fence has been erected by the Division of Fish and Wildlife and Soil Conservation Service to exclude feral ungulates.
Conservation measures proposed: If emergent vegetation becomes re-established and if tilapia could be eradicated, Mariana Common Moorhens might be re-introduced.
Land use: None; the island is uninhabited.
Possible changes in land use: None expected in the immediate future because of sporadic volcanic activity. However, if the volcano becomes quiescent, the island may be re-inhabited and receive consideration for development. Pagan is the largest Mariana island north of Saipan, and has the safest anchorage and most extensive beaches.
Disturbances and threats: Lagona Lake was formerly the site of a village, and during World War II, the island's population reached 8,000. However, the most obvious disturbances have been due to thick deposits of volcanic ash and cinders. The introduction of tilapia and mosquito fish (*Gambusia* spp.) has also had a serious impact on the aquatic ecosystem. There seems to be no additional threats to these lakes at present, unless resort developments are proposed. Intense grazing by domestic animals destroyed much of the wetland vegetation and apparently caused the extinction of the endemic subspecies of Nightingale Reed-warbler in the 1960s (Reichel *et al.*, 1992).
Hydrological and biophysical values: The lakes retain large quantities of silt that would otherwise have an impact on the fringing reef.
Social and cultural values: Pagan is no longer inhabited, but the lakes were used for fishing and recreation when the island was inhabited. Lagona Lake was the site of a village during the Japanese administration (1914-1944).
Noteworthy fauna: The wetland vegetation formerly supported a population of about 75 Mariana Common Moorhens (*Gallinula chloropus guami*) and an endemic subspecies of the endangered Nightingale Reed-warbler (*Acrocephalus luscinia yamashinae*). No Reed-warblers could be found in 1979, and this subspecies is now believed to be extinct (Tenorio and Associates, 1979). The Moorhen is also now extinct on Pagan, although it survives elsewhere in the Mariana Islands (Stinson *et al.*, 1991b). The introduction of tilapia in the 1950s may have affected the Moorhen and led to its decline prior to the volcanic eruption of 1981 which finally eradicated this population (Stinson *et al.*, 1991b).
The lakes are often used by migrant and vagrant waterbirds. Species reported include: *Phalacrocorax carbo*, *P. melanoleucos*, *Nycticorax nycticorax*, *N. caledonicus*, *Bubulcus ibis*, *Egretta sacra*, *E. garzetta*, *Anas penelope*, *A. crecca*, *A. platyrhynchos*, *Pandion haliaetus*, *Tringa nebularia*, *T. glareola*, *Xenus cinereus*, *Actitis hypoleucos*, *Heteroscelus brevipes* and *H. incanus*.
Noteworthy flora: None.
Recreation and tourism: The lakes provide recreational swimming and are an interesting place to explore for visiting scientists and transient sailing boats.
Management authority and jurisdiction: Coastal Resources Management (Susupe, Saipan) and

U.S. Army Corps of Engineers (Agana, Guam).
References: Corwin *et al.* (1957); Glass *et al.* (1990); Reichel *et al.* (1992); Stinson *et al.* (1991a, 1991b); Tenorio and Associates (1979).
Reasons for inclusion: 1d, 2b; formerly 2a, 2d. These lakes are the only significant wetlands in the archipelago north of Saipan, and are two of only four lakes in the CNMI. They formerly supported a population of the endangered Mariana Common Moorhen (*Gallinula chloropus guami*) and an endemic subspecies of the endangered Nightingale Reed-warbler (*Acrocephalus luscinia yamashinae*). Moorhens may be re-introduced in the future if the habitat can be rehabilitated.
Source: Derek W. Stinson.

Puerto Rico Mudflats (2)

Location: 15°13'03"N, 145°43'33"E; 1.5 km north of Garapan, Saipan.
Area: 17 ha.
Altitude: Sea level.
Overview: Tidal mudflats bounded by a narrow strip of national park and a landfill. The site has a broken fringe of mangroves. It is the only intertidal mud-bottomed area in the CNMI, and is an important feeding area for migratory waterbirds.
Physical features: A mudflat that is irregularly exposed at low tide. The mudflats contain several rusting hulks of pontoons, remnants from the American invasion of 1944. The site is bounded on the northeast by a landfill built up on coral fill. A narrow fringe of mangrove and strand vegetation along the southeast shoreline is backed by a busy primary road. The southwest is bounded by an artificial breakwater protecting a boat basin.
Ecological features: The southeast boundary comprises a broken fringe of mangroves (*Bruguiera gymnorrhiza*) and other strand trees (*Pandanus* spp. and *Thespesia populnea*). The mudflats are partly vegetated with sea-grasses (*Enhalus acoroides* and *Halodule uninervis*). This area may have been partly filled at one time during construction of the coastal road.
Land tenure: The southeast shore down to the mean high tide mark is part of American Memorial Park, administered by the U.S. National Park Service. Land below the mean high tide mark is public land.
Conservation measures taken: None.
Conservation measures proposed: Acquisition of the mudflats as part of American Memorial Park was recently considered, but was not pursued because of the political risk that this would result in or accelerate consideration of alternative development proposals.
Land use: Recreation and subsistence fishing.
Possible changes in land use: There is reportedly a proposal to close and cap the existing landfill on the northeast boundary of the site, and to use it for commercial docking facilities. This would presumably require the dredging of the northern part of the mudflats to accommodate large ships.
Disturbances and threats: The mangroves may have been much more extensive at one time, but were filled during construction of the coastal road. The main island landfill at the northern boundary may be leaching poisons into the mudflats and tidal waters. No study has been carried out to evaluate or quantify this problem. An abundance of trash and garbage floats or blows onto the shore from the dump, or is deliberately dumped there. Closure of the dump will stop this, but dump closure may be followed by dredging of a portion of the site for commercial or private port facilities.
Hydrological and biophysical values: The mangroves help to protect the shoreline from typhoon damage and perhaps saltwater intrusion.
Social and cultural values: Primarily in preserving native and migrant birds, and conserving opportunities for traditional harvest of shellfish, although possible contamination of the stocks needs to be investigated.

Noteworthy fauna: The sea-grass beds provide important habitat for juvenile fishes, while the mudflats support an abundance of fiddler crabs (*Uca* spp.) and molluscs. When exposed at low tide, the mudflats are heavily used by resident and migratory waterbirds for feeding. When the flats are not exposed, the pontoons are used as loafing sites by waterbirds. Native breeding birds often seen at the site include *Ixobrychus sinensis*, *Egretta sacra*, *Halcyon chloris* and *Myzomela rubrata*. Migrants that commonly use the area include: *Pluvialis (dominica) fulva*, *Charadrius mongolus*, *Numenius phaeopus*, *Tringa nebularia*, *Actitis hypoleucos*, *Heteroscelus brevipes*, *H. incanus* and *Arenaria interpres*. Additional species recorded at the site include: *Butorides striatus*, *Ardea cinerea*, *Pluvialis squatarola*, *Charadrius leschenaultii*, *Limosa lapponica*, *Numenius arquata*, *N. madagascariensis*, *Xenus cinereus*, *Calidris tenuirostris*, *C. ruficollis* and *C. temminckii*.
Noteworthy flora: Mangroves are extremely limited in extent in the CNMI, and are considered to be an endangered habitat. Three small stands on Saipan are the only mangroves in the CNMI.
Scientific research and facilities: The site is used for surveys of migratory birds.
Conservation education: The site has potential for school field trips.
Recreation and tourism: The site is immediately adjacent to a National Park and shoreline bike trail. It is one of the best bird-watching localities in the Marianas, and is the site of numerous first records for the archipelago (Glass *et al.*, 1990; Stinson *et al.*, 1991a).
Management authority and jurisdiction: Coastal Resources Management (Susupe, Saipan), Department of Natural Resources (Capitol Hill, Saipan), U.S. Army Corps of Engineers (Agana, Guam) and U.S. National Park Service.
References: Duenas and Swavely, Inc. (no date); Glass *et al.* (1990); Reichel *et al.* (1992); Stinson *et al.* (1991a).
Reasons for inclusion: 1d, 2b, 3b. Perhaps the only mudflat habitat in the CNMI and an important feeding site for migratory shorebirds. The opportunities for migratory shorebirds to stop over during periods of inclement weather are limited in Oceania.
Source: Derek W. Stinson.

Kagman North (3)

Location: 15°10'35"N, 145°46'05"E; approximately 6.6 km ESE of Garapan on the Kagman Peninsula, Saipan.
Area: Approximately 1 ha.
Altitude: 60 m.
Overview: A small, permanently flooded man-made pond and adjacent seasonally flooded field consistently used by relatively high numbers of the endangered Mariana Common Moorhen (*Gallinula chloropus guami*).
Physical features: A 0.5 ha excavated pond with a surrounding berm. A small field outside the berm is seasonally flooded. The pond has a slope of approximately 20% and a maximum depth of 7 m. It was originally excavated as part of an irrigation project in 1971, but apparently was never used. Soil at the site (Chacha Clay) typically has a dark yellowish-brown clay surface layer of approximately 17 cm. The subsoil is mottled, strong brown clay to 100 cm. The substratum is mixed strong brown, dark red and light grey clay to more than 150 cm (Young, 1989).
Ecological features: The pond is partly covered with a mat of swamp morning glory (*Ipomoea aquatica*) and has some *Lemna* spp. floating on the water surface. The surrounding vegetation is primarily tall grass (*Pennisetum purpureum*) and the small tree tangentangen (*Leucaena leucophala*). The vegetation of the adjacent seasonal wetland is typical of disturbed sites, and includes *Mimosa invisa* and *Ludwigia octovalvis*.
Land tenure: Public/Commonwealth.
Conservation measures taken: The pond is currently under the jurisdiction of the Department of Natural Resources.

Land use: The wetland is little used, except for harvest of *Ipomoea aquatica* by nearby residents. The pond also functions in flood control. The adjacent area is a homestead project, and local residents are building homes there.
Possible changes in land use: None expected.
Disturbances and threats: During 1990, much of the surrounding vegetation was mowed down, and apparently the pond was intended to be used as a ponding basin for the new surrounding homestead area. After some inter-agency correspondence, this plan was changed so that the pond will not be further physically impacted. As more homes are built in the adjacent homestead area, there may be increasing disturbance from humans and pets. An additional threat is the potential for introduction of tilapia (*Serotheradon mossambicus*), an aggressive, exotic fish that has seriously impacted the ecology of other wetlands on Saipan.
Hydrological and biophysical values: Kagman North is probably the only permanent freshwater pond on Saipan. Most other wetlands are at least slightly brackish. The pond has an important function in flood control.
Social and cultural values: Primarily preservation of an Endangered Species that was formerly abundant and commonly subject to subsistence hunting.
Noteworthy fauna: The pond supports up to 10% of the Saipan population of the endangered Mariana Common Moorhen (*Gallinula chloropus guami*), and is frequently used by migratory waterbirds including the herons *Bubulcus ibis* and *Egretta intermedia* and the ducks *Anas strepera*, *A. crecca*, *A. acuta* and *A. querquedula*. The pond is noteworthy for the absence of tilapia.
Noteworthy flora: None known.
Scientific research and facilities: The wetland will probably become a primary study site for research on the Mariana Common Moorhen. It offers a contrast to other Saipan wetlands that are largely choked with reeds (*Phragmites karka*) and infested with tilapia.
Conservation education: The site has potential for use by small school groups, but access would have to be limited to avoid disturbance to nesting Moorhens.
Recreation and tourism: The wetland is visited by bird-watchers, including occasional tour groups and Audubon field trips.
Management authority and jurisdiction: Department of Natural Resources (Capitol Hill, Saipan) and U.S. Army Corps of Engineers (Agana, Guam).
References: Dames and Moore (1990); Stinson *et al.* (1991b); Young (1989).
Reasons for inclusion: 2a, 3c. The site consistently supports up to 10% of the Saipan population of the Mariana Common Moorhen and up to 5% of the world population of this endangered subspecies.
Source: Derek W. Stinson.

Susupe Wetland (4)

Location: 15°09'10"N, 145°42'40"E; east of Susupe village, Saipan. The site includes Susupe Lake and the surrounding marsh from Chalan Kiya to Chalan Kanoa and Chalan Paio.
Area: 202 ha.
Altitude: 0.8 m.
Overview: A slightly brackish marsh containing a 17 ha lake and about 17 small ponds. This wetland is essential habitat for the endangered Mariana Common Moorhen (*Gallinula chloropus guami*), and is used by the endangered Nightingale Reed-warbler (*Acrocephalus luscinia*). The lake and marsh constitute the largest area of waterbird habitat in the CNMI.
Physical features: Susupe Wetland encompasses a major portion of the western coastal plain of Saipan between the villages of Oleai and San Antonio. The wetland was probably once a coastal

lagoon, but was formed when coastal lime sand blocked off the low-lying area from the sea (U.S. Army Corps of Engineers, 1986b). The wetland receives run-off from a watershed of about 1,120 ha. During the rainy season, the entire marsh retains standing water, reaching a depth of 1.8 m in the small pothole ponds. During the dry season, much of the standing water disappears, but most of the soil remains saturated and the potholes normally retain water. The potholes have been reported to dry up in extremely dry years (U.S. Army Corps of Engineers, 1986b). The limestone rocks and sandy soils that underlie much of the area possess a great capacity for absorption, and allow rainwater to percolate. There is very little surface flow of water in channels.

Lake Susupe is the central and lowest point within the wetland. The lake and nearby ponds may be sink holes in the underlying limestone. The lake is perennial and has no surface outlet to the sea. Lake water contains high concentrations of alkaline earths derived from the drainage through limestone. Susupe is a closed mixohaline lake with reported salinities of 0.5-11 p.p.t., and is contiguous with basal groundwater. Periodic changes in water level occur, but are not caused by tidal action. The lake shows very little stratification in temperature, salinity and pH (7.2-8.4). Surface waters are saturated with dissolved oxygen during the day. Bottom sediments consist of black, gelatinous sedimentary peat composed of decaying vegetation and plankton, terrigenous silts and clays. Organic and inorganic nitrogen levels in Lake Susupe are high, but phosphate seems to be scarce. Lake water examined in a glass appears faint yellowish-brown in colour. pH data suggest that the colour is due to suspended particulates rather than to humic acid discoloration (U.S. Army Corps of Engineers, 1986b).

The small pothole ponds to the east and south of the lake show more pronounced thermal stratification and rapid extinction of dissolved oxygen below the surface. The lack of mixing in these ponds and the high oxygen demand from decomposing vegetation create a stagnant, highly reducing environment. Salinity measurements have ranged from about 0.5 to 5.8 p.p.t. (U.S. Army Corps of Engineers, 1986b). pH measurements taken in December 1978 at the potholes ranged from 4.5 to 8.3 (U.S. Army Corps of Engineers, 1986b). The soil of the marsh, Mesei Variant muck, typically has a black muck surface layer of 20 cm. Below this to 60 cm is 'very dark grey gravelly mucky clay loam and olive grey gravelly mucky sandy loam'. The substratum is 'grey very gravelly sandy loam' (Young, 1989). Parts of the wetland, particularly on the west side, were filled with limestone gravel and debris previous to and during World War II.

The climate is warm and humid, the temperature almost always remaining between 25 and 30°C. The annual rainfall, most of which falls in the rainy season from July to December, is 2,000-2,500 mm. The CNMI is in or near an area of typhoon formation, and is subject to occasional periods of heavy rain.

Ecological features: The original plant communities in the wetland are unknown because they were cleared for extensive cultivation of rice and sugar cane during the 30 years of the Japanese mandate (1914-1944). Lake Susupe has a relatively narrow fringe of bulrush (*Scirpus littoralis* var. *thermalis*). Surrounding the bulrush is a broken band of water fern (*Acrostichum aureum*) which grows to over two metres tall and in water up to one metre in depth. Ironwoods or Australian pines (*Casuarina equisetifolia*) form a broken line around the lake and patchy stands with an understorey of *Acrostichum* in the pothole area east of the lake. Most of the marshland beyond this fringe is choked with dense, monospecific stands of reeds (*Phragmites karka*) broken only at the potholes and by a few stands of bamboo (*Bambusa vulgaris*). Floating mats of salt grass (*Paspalum distichum*) are found at most of the potholes. Around the outer boundaries of the marsh and west of the lake are dense stands of the small tree *Hibiscus tiliaceus* forming seasonally flooded swamps.

Land tenure: The wetland is part public (Commonwealth) land and part private land. Lake Susupe is publicly owned, but a small portion of the lake shore is privately owned.

Conservation measures taken: No official refuges have been specifically designated, but all wetlands are regulated by local and U.S. Federal statutes. The most effective protection for local wetlands is Section 404 of the U.S. Clean Water Act. This Section requires that any discharge of fill into a wetland must have a permit issued by the U.S. Army Corps of Engineers. The listing of the Mariana Common Moorhen (*Gallinula chloropus guami*) as a U.S. Endangered Species in 1984 resulted in the additional requirement that the U.S. Army Corps of Engineers cannot issue a permit to fill Saipan wetlands without first consulting with the U.S. Fish and Wildlife Service. Privately owned portions of the wetland are being acquired through the exchange of public land when landowners express an interest in this action. The Commonwealth is thus acquiring wetland for conservation purposes. This process has been relatively free of political considerations, but public land available for exchange may be exhausted before all the wetland is acquired.

Conservation measures proposed: No official proposals to make the wetland into a refuge have been made. The U.S. Fish and Wildlife Service has tentative plans to help acquire easements and acquisition to expedite the establishment of a Commonwealth wildlife refuge. The wetland is on the list for priority acquisition for federal funds when available (U.S. Fish and Wildlife Service, 1990).

Land use: Very little of the wetland is used. There is a private home on the west shore of the lake and a small vehicle repair shop. There is also a small amount of cultivation of taro on private land on the fringes of the wetland. A very small amount of recreational fishing takes place at the lake. The villages of Susupe and Chalan Kanoa lie to the west and southwest of the wetland. These areas are densely populated suburban neighbourhoods.

Possible changes in land use: No changes in land use are anticipated, but land adjacent to the wetlands will be heavily developed for housing and small businesses. A major flood control project was proposed for the area, but was never implemented, perhaps because of lack of local financial commitment (U.S. Army Corps of Engineers, 1986b). This proposal may resurface after the next episode of severe flooding. If this project were properly designed and maintained, it might improve the wetland as Moorhen habitat. There have been proposals in the past to use the lake water for irrigation, aquaculture or public water supply, but none is being considered seriously at present.

Disturbances and threats: The wetland ecosystem has been seriously impacted by past activities. During the Japanese mandate, many dikes and irrigation canals, still visible today, were constructed throughout the marsh. The present effect on drainage is unknown. The lake was also connected to the sea by a drainage ditch, but this was blocked by road construction in 1944. Lake water was used for irrigation and for industrial wash water for a nearby sugar mill. The mill's effluent, containing soil, cane waste and perhaps pesticides, drained back into the lake through a ditch. The lake was probably also affected by fertilizers from adjacent wetland farming. These disturbances probably caused whole-scale reduction in species diversity of the aquatic plant and animal community. Also of importance was the introduction of exotic mosquito fish (*Gambusia affinis*) and tilapia (*Sarotheradon mossambicus*). *Gambusia* was probably introduced by the U.S. military during World War II for mosquito control. Tilapia were introduced in 1955 for aquaculture. Both species are hardy, tolerant omnivores, and have been implicated in the reduction and extirpation of native fishes and crustaceans elsewhere (Courtenay & Robins, 1989; Maciolek, 1984; Myers, 1965). These exotic species, coupled with the degradation of the lake environment, may have had a severe impact on aquatic food organisms and may have contributed to the extinction of the Marianas Mallard (*Anas oustaleti*) and the decline of the Mariana Common Moorhen (Stinson *et al.*, 1991b). The most recent threat to the wetland is a proposal, currently under study, to use lake water as a source of public water.

Hydrological and biophysical values: The role of Susupe wetland in groundwater recharge and flood control is extremely important. The lake and marsh hold great amounts of storm water after storms, and allow infiltration to the groundwater. The sediment trapping function of the wetland is crucial to the health of the lagoon and reef less than one km from the western edge of the wetland. Sediment load and coastal erosion would be much worse if the wetland did not stop and hold storm water during typhoons.

Social and cultural values: The wetland is one of the characteristic features of Saipan for residents and visitors alike. Recreational fishing, the hunting of waterbirds (now prohibited) and exploring the fringes of the wetland are important memories to many long-time residents. The wetland is critical habitat to endemic bird species that are unique to the Marianas, including the Mariana Common Moorhen (locally called 'Pulattat'), the Nightingale Reed-warbler ('Gaga kariso') and formerly the Marianas Mallard, now extinct. These species are part of the threatened heritage of the CNMI. The lake and marsh are not very important in fish production. Tilapia are little used, and access to the lake is very limited as the marshes are covered with impenetrable reed thickets. As more and more of Saipan's natural areas are lost to development and the proliferation of resorts and golf courses, these marshes are likely to be amongst the last fragments of wild areas and important wildlife habitat remaining on the island.

Noteworthy fauna: Susupe wetland constitutes 77% of the remaining habitat for the Mariana Common Moorhen (*Gallinula chloropus guami*) in the CNMI (excluding Guam). This endemic subspecies of Moorhen was listed as Endangered by the U.S. Fish and Wildlife Service in 1984. Only about 300-400 survive on the islands of Guam, Saipan and Tinian. Estimates of the number occupying the Susupe wetland have included 36 (Stinson *et al.*, 1991b), 90-120 (U.S. Army Corps of Engineers, 1986b) and 60-100 (Tenorio and Associates, 1979). Although the quality of the wetland is reduced, it supports a large percentage of the Moorhens remaining on Saipan and perhaps nearby Tinian. It is also a dry season refuge for Moorhens when many other smaller wetlands have dried up. The Moorhen shared habitats with the Marianas Mallard (*Anas oustaleti*), which is now extinct, partly as a result of over-hunting and partly as a result of wetland loss and degradation.

The wetland is also used by the endangered Nightingale Reed-warbler (*Acrocephalus luscinia*). This species has become extinct on Pagan, Aguijan and Guam for various reasons. It remains relatively widespread on Saipan, but its habitat is rapidly decreasing as a result of development.

In addition to the Moorhen, Reed-warbler and common resident breeding birds such as the Yellow Bittern (*Ixobrychus sinensis*), the wetland is used by a variety of migratory and vagrant species. These have included: *Nycticorax nycticorax*, *Bubulcus ibis*, *Egretta sacra*, *E. garzetta*, *E. intermedia*, *E. alba* (*Casmerodius albus*), *Ardea cinerea*, *Anas penelope*, *A. falcata*, *A. strepera*, *A. crecca*, *A. acuta*, *A. querquedula*, *A. clypeata*, *Aythya ferina*, *A. fuligula*, *A. marila*, *Larus ridibundus*, *Chlidonias hybrida* and *Sterna bergii*.

A species of prawn has been described from Susupe Lake, but apparently is now rare or extinct (Gurney, 1939).

Noteworthy flora: The wetland includes the largest reed marsh remaining in the Marianas and a large percentage of the swamp habitat.

Scientific research and facilities: Research on the Mariana Common Moorhen is being conducted at the wetland.

Conservation education: If the lake and surrounding marsh can be secured through land exchange, easements and outright purchase, the potential exists for some interpretive development. The U.S. Fish and Wildlife Service has tentative plans to help establish a Commonwealth Wildlife Refuge at the wetland. The possibility exists for an interpretive board-walk nature trail.

Recreation and tourism: The lake is stagnant, has a very muddy bottom and is rather shallow. The potential for recreation is low except for nature trails. An interpretive nature trail and visitor centre would probably be heavily used by tourists. However, the best location for such a facility, on the western shore of the lake, is privately owned.

Management authority and jurisdiction: Commonwealth agencies: Division of Fish and Wildlife (Saipan), Coastal Resources Management (Susupe, Saipan) and Mariana Public Land Corporation (Capitol Hill, Saipan). Federal agencies: U.S. Fish and Wildlife Service (Honolulu, Hawaii) and U.S. Army Corps of Engineers (Agana, Guam and Fort Shafter, Hawaii).

References: Courtenay & Robins (1989); Gurney (1939); Maciolek (1984); Myers (1965); Stinson *et al.* (1991b); Tenorio and Associates (1979); U.S. Army Corps of Engineers (1986b); U.S. Fish and Wildlife Service (1989b & 1990); Young (1989).

Reasons for inclusion: 1a, 2a, 2b, 2d, 3c. Susupe wetland supports a minimum of 10% of the world population of the Mariana Common Moorhen (*Gallinula chloropus guami*). It should be considered critical to the survival of this endangered subspecies.

Source: Derek W. Stinson.

Flores Pond (5)

Location: 15°08'23"N, 145°42'50"E; 2 km north of Saipan International Airport, Saipan.

Area: 1 ha.
Altitude: 40 m.
Overview: A small, seasonally flooded pond that is consistently used by relatively high numbers of Mariana Common Moorhens (*Gallinula chloropus guami*).
Physical features: Flores Pond lies in the lowest point of a depression of approximately 5 ha. The soil is primarily Inarajan Clay, a deep, somewhat poorly drained soil formed in mixed alluvium from volcanic and limestone uplands. The surface layer is dark clay about 18 cm thick over mixed very dark grey or grey-brown clay and a substratum of brown clay to 150 cm (Young, 1989). The area generally retains ponded rainwater during the rainy season, but dries up during the early dry season. The area that remains flooded for the longest period has a mud bottom, but is colonized by grasses and forbs during the dry season.
The climate is warm and humid, the temperature nearly always remaining between 25 and 30°C. The annual rainfall of approximately 2,000-2,500 mm falls primarily during the rainy season, which lasts from July to December. The month with the highest rainfall is usually September. The CNMI lies in or near an area of typhoon formation, and is subject to occasional periods of heavy rainfall and flooding.
Ecological features: The vegetation is typical of abandoned agricultural sites, and the original vegetation is unknown. The vegetation at the pond includes grasses, forbs (*Ludwigia octovalvis*) and shrubs (*Sesbania cannabina*). Areas of mud become exposed at low water levels. The surrounding vegetation is part forested (with some *Hibiscus tiliaceus*) and part pasture and agricultural fields.
Land tenure: Privately owned.
Conservation measures taken: Identified as a Priority Wetland Acquisition Site in the Regional Wetlands Concept Plan under the Emergency Wetland Resources Act (U.S. Fish & Wildlife Service, 1990).
Conservation measures proposed: Potential exists for public acquisition through land exchange.
Land use: The site receives some light grazing during the dry season. It appears to have been used for agriculture in the past.
Possible changes in land use: The drainage pattern could easily be disrupted by nearby development if this were to prevent storm water from reaching the pond.
Disturbances and threats: The area is used for some light grazing during the dry season, but this does not seem to have any negative effects. Introduced tilapia (*Sarotheradon mossambicus*) entered the wetland in storm waters in 1990, but died off when the pond dried up. Part of the wetland appears to have had some top-soil removed, and this is a potential problem in the future. Renewed agricultural activity is possible, but if this were limited in extent, it would probably not have serious impacts. Possible development of adjacent lands may reduce the available cover and affect use of the wetland by birds.
Hydrological and biophysical values: The pond retains large amounts of storm water and allows it to infiltrate or evaporate slowly. It also retains eroded soil that would otherwise impact the lagoon and offshore reefs. The pond also probably recharges groundwater to some extent.
Social and cultural values: Primarily in preserving endangered endemic bird species and functioning as a site for educational field trips.
Noteworthy fauna: Relatively large numbers (maximum 16) of the endangered Mariana Common Moorhen (*Gallinula chloropus guami*) use the wetland when it is flooded, and the endangered Nightingale Reed-warbler (*Acrocephalus luscinia*) has been recorded there. Areas of shallow water and mud are heavily used by the Moorhens and also by a variety of migrant and vagrant waterbirds which have included: *Phalacrocorax melanoleucos*, *Nycticorax nycticorax*, *Bubulcus ibis*, *Egretta garzetta*, *Anas crecca*, *A. acuta*, *A. querquedula*, *A. clypeata*, *Aythya ferina*, *Pluvialis (dominica) fulva*, *Tringa stagnatilis*, *T. nebularia*, *T. ochropus*, *T. glareola*, *Actitis hypoleucos*, *Gallinago hardwickii*, *G. gallinago*, *Calidris temminckii*, *C. acuminata*, *C. alpina*, *Philomachus pugnax* and the wagtail *Motacilla alba lugens* (Glass *et al.*, 1990; Stinson *et al.*, 1991a).
Noteworthy flora: None known.
Scientific research and facilities: The pond will probably become an important study site for the Mariana Common Moorhen.

Conservation education: The site is used by the Marianas Audubon Society during field trips, and has been used by the Soil Conservation Service during its field trips. The wetland will continue to be used for recreational and educational activities as long as the landowners are willing to allow access.
Recreation and tourism: The wetland is used by small groups of resident bird-watchers and bird tours, but as the site is small, seasonal and privately owned, the potential is limited.
Management authority and jurisdiction: Mr Donald Flores (owner) and U.S. Army Corps of Engineers (Agana, Guam).
References: Glass *et al.* (1990); Stinson *et al.* (1991a, 1991b); U.S. Fish & Wildlife Service (1990); Young (1989).
Reasons for inclusion: 1a, 2a, 3c. The site seasonally supports up to 10% of the Saipan population and 5% of the world population of the endangered Mariana Common Moorhen. It is also an important stop-over site for a variety of migrant and vagrant waterbirds.
Source: Derek W. Stinson.

Lake Hagoi (6)

Location: 15°04'00"N, 145°43'33"E; west of North Field near the northern end of Tinian.
Area: 17 ha.
Altitude: 5 m.
Overview: Lake Hagoi is a mesohaline marshy pond with less than one ha of open water. Although Lake Hagoi dries up during droughts, it occasionally supports the highest concentrations of Mariana Common Moorhens (*Gallinula chloropus guami*) reported at any site.
Physical features: A marshy pond occupying the lowest part of a basin of 17 ha on a raised limestone terrace. There is generally less than one ha of open water, and the lake dries out completely during prolonged droughts. The wetland soil, Mesei Variant Muck, typically has a black muck surface layer of 20 cm. Below this to 60 cm there is 'very dark grey gravelly mucky clay loam and olive grey gravelly mucky sandy loam', and the substrate is a gravelly loam (Young, 1989). The soil of the surrounding area is Chinen Clay Loam, a shallow, well-drained soil of limestone plateaus. The climate of Tinian is very similar to that of Saipan, being warm and humid, and subject to heavy rains during tropical storms.
Ecological features: The small area of open water is surrounded by about two ha of marsh vegetation dominated by *Scirpus littoralis*. There are also patches of water fern (*Acrostichum aureum*) near the open water and in the surrounding marsh. Most of the rest of the wetland is vegetated with thick stands of *Phragmites karka*. Near the perimeter of the wetland are patches of *Hibiscus tiliaceus* and bamboo (*Bambusa vulgaris*).
Land tenure: Commonwealth land under lease to the U.S. Navy.
Conservation measures taken: None.
Conservation measures proposed: Lake Hagoi is listed as a potential acquisition site (U.S. Fish & Wildlife Service, 1990). The open water is slowly silting in and becoming increasingly choked with vegetation. Some dredging may be required in the future to maintain open water and increase its permanence through the dry season.
Land use: None. The wetland was formerly used for agriculture.
Possible changes in land use: The U.S. Navy has proposed to lease land back to the local government or individuals for agriculture and grazing, but this would probably not affect the lake.
Disturbances and threats: In former times, a farm was located adjacent to the lake, and shallow wells were dug for irrigation water. Mosquito fish (*Gambusia affinis*) are reported from the lake, and are known to be notoriously destructive to native fauna. The fish was probably introduced by the U.S. military during World War II for mosquito control. Introduced monitor lizards and rats probably also have an impact on nesting birds. The possible introduction of tilapia (*Sarotheradon*

mossambicus) may represent the greatest threat to the Mariana Common Moorhen at the wetland. Another potential threat is a proposal to locate a radar installation on Tinian in the direct flight path between Lake Hagoi and Lake Susupe on Saipan. The wide variation in numbers of Moorhens observed at Lake Hagoi suggests that Moorhens fly between Hagoi and wetlands on Saipan seasonally, if not regularly. The proposed radar installation could therefore pose a collision hazard for Moorhens.

Hydrological and biophysical values: Groundwater recharge, although the groundwater is not presently being exploited.

Social and cultural values: Primarily in preserving the endangered Mariana Common Moorhen.

Noteworthy fauna: The extinct Marianas Mallard (*Anas oustaleti*) was last reliably reported from Lake Hagoi in 1974 (Shallenberger, 1979). The largest concentrations of Mariana Common Moorhens (*Gallinula chloropus guami*) ever reported have been at this lake. In 1982, Engbring *et al.* (1986) observed 100 Moorhens and estimated that an additional 25 were present. The highest numbers are generally reported during the dry season, apparently because other wetlands have dried up (Stinson *et al.*, 1991b). The commonest resident bird at the lake is the Yellow Bittern (*Ixobrychus sinensis*). The lake is also frequently used by migratory waterbirds including: *Nycticorax nycticorax*, *Bubulcus ibis*, *Egretta sacra*, *E. intermedia*, *Anas penelope*, *A. strepera*, *A. crecca*, *A. acuta*, *A. querquedula*, *A. clypeata*, *Aythya fuligula* and *Fulica atra*.

Other species reported from the site include a lymnaeid snail (*Galba viridis*) and introduced mosquito fish (*Gambusia affinis*), monitor lizards (*Varanus indicus*) and rats (*Rattus* spp.) (Best & Davidson, 1981).

Noteworthy flora: None known.

Scientific research and facilities: Lake Hagoi will probably be included as a study site in future studies of the Mariana Common Moorhen.

Conservation education: Lake Hagoi is one of only two wetlands of any size on Tinian and could be used for educational field trips, although access is relatively difficult because of the dense vegetation and mud.

Recreation and tourism: The site has only limited potential for recreation and tourism, and these should not be recommended because the development required to improve access would be likely to increase the problems of feral animals and may encourage poaching.

Management authority and jurisdiction: Coastal Resources Management (Susupe, Saipan), U.S. Army Corps of Engineers (Agana, Guam) and Department of the Navy, Pacific Division (Pearl Harbor, Hawaii).

References: Best and Davidson (1981); Engbring *et al.* (1986); Glass *et al.* (1990); Shallenberger (1979); Stinson *et al.* (1991b); Tenorio and Associates (1979); U.S. Fish & Wildlife Service (1988 & 1990); Young (1989).

Reasons for inclusion: 1a, 2a, 3c. Lake Hagoi occasionally supports higher numbers of the endangered Mariana Common Moorhen than any other site, involving 50% of the CNMI population and perhaps 30% of the entire world population.

Source: Derek W. Stinson.

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REPUBLIC OF PALAU

INTRODUCTION

Area: 492 sq.km.

Population: 13,873 (1986 census); 14,106 (1988 estimate).

The Republic of Palau, situated between latitudes 6°53' and 8°12'N and longitudes 134°08' and 134°44'E, is located at the extreme western edge of the Caroline Islands. The archipelago lies about 800 km north of the equator, 740 km east of the Philippine Islands and 6,000 km southwest of Hawaii. It consists of approximately 350 islands including several high islands formed by Eocene volcanic activity and numerous low and raised coral and coralline limestone islands and islets. The islands are encircled by barrier, fringing and patch reefs with inner and outer reef flats. The barrier is some 450 km in length and encompasses a lagoon with an area of about 1,450 sq.km. The barrier reef is particularly well developed on the western side, where it is up to 2.5 km in width. The reef systems of the Palau Islands are considered to be the richest in the Pacific, with the highest species diversity (UNEP/IUCN, 1988).

With an area of 367 sq.km, Babeldaob is by far the largest island in the archipelago, comprising about three quarters of the total land mass. This island, parts of neighbouring Koror (9.3 sq.km) and a few small islands in the vicinity of Koror are of volcanic origin, and are characterized by rolling, forested hills, coastal bottomlands and tidal flats with mangrove forest. The maximum elevation on Babeldaob is about 240 m. All other islands are of more recent limestone formation. Two large islands in the south, Peleliu (12.7 sq.km) and Angaur (8.4 sq.km), are raised coral platforms with jagged hills and level coastal areas. The famous Rock Islands of Palau are extremely steep, coralline limestone islands, typically undercut along the water's edge. They occupy the area from Koror south to Peleliu, and include the large islands of Ngerukdabel (19.0 sq.km) and Mecherchar (8.8 sq.km).

Palau has a humid maritime tropical climate with only slight seasonal variations. The mean annual temperature on Koror, the capitol, is 27°C, with a mean diurnal range of about 7°C. The average annual rainfall is 3,730 mm. Rainfall varies little from month to month, although February, March and April are slightly drier than the average. The relative humidity averages about 90% at night and 75-80% during the day. Although Palau lies outside the main paths of severe tropical disturbances and typhoons, such storms with high winds occasionally hit the islands.

The Palau Islands had been settled for nearly 2,000 years before contact with European traders and missionaries in the 17th and 18th centuries. Spain claimed sovereignty over the Caroline Islands, including Palau, in 1885, but maintained only loose reign until 1899, when the islands were sold to Germany. Germany lost its Micronesian possessions after World War I, when Japan was entrusted with a mandate over Palau. Following World War II, the U.S. was given responsibility for Palau as a Trust Territory. The Republic of Palau was established as a constitutional democratic government in January 1981, and in February 1986, Palau and US Government representatives formally signed a Compact of Free Association. However, this has yet to be approved, and Palau remains a remnant of the former Trust Territory of the Pacific (IUCN, 1991).

There is relatively little agriculture in Palau, and this is primarily for subsistence purposes. Major crops include cassava, taro, sweet potatoes, bananas, papayas, coconuts and a variety of vegetables. The economy is based on fishing, tourism and aid.

Although the Palauan islands at one time may have been completely covered with native forest, they are now only 75% forest (Cole *et al.*, 1987). Most of the remaining land is classed as grassland, agro-forest or secondary vegetation. Almost all of the agro-forest and secondary vegetation was once forested land, but the origins of the grasslands are less certain. During the Japanese Administration (1914-1945), large areas in southern Babeldaob were cleared of native forest for pineapple and sugar cane fields. During the same period, bauxite mining in Ngardmau State on the northwest coast destroyed native forest.

Summary of Wetland Situation

The wetlands of the Republic of Palau have been described in some detail by Stemmermann and Proby (1978). These authors identified 84 wetlands, and suggested that there may be more, as they were unable to survey most of the rock islands. The 84 sites included the following:

-	mangrove forests	33
-	coastal saline marshes	4
-	lowland swamp forest with high canopy	11
-	lowland swamp forest with low canopy	10
-	freshwater marsh/open canopy swamp	1
-	savannah wetland/upland marsh	2
-	cultivated wetland (taro swamp)	17
-	flooded bomb craters	1
-	reservoir	1
-	riparian wetlands	8
-	ruderal wetlands (roadside ditches)	5

Stemmermann and Proby (1978) considered two sites to be of great interest and worthy of special protection: an area of mangrove forest and swamp forest in Ngeremeduu (Ngatpang) Bay on Babeldaob; and a unique stand of *Bruguiera* in a depression on Mecherchar Island.

Lakes and Marshes

Lakes and marshes are limited in Palau. There are only two natural freshwater lakes of any size; Ngardok and Ngerkall. Both are on Babeldaob and are relatively small and remote. The "marine lakes" of Palau are mostly land-locked, saltwater lakes on some of the high limestone islands, with a distinctive but very limited fauna. Artificial lakes and ponds include one reservoir (a water supply for Koror), water-filled bomb craters on Babeldaob and abandoned, flooded phosphate pits on Angaur and Peleliu (Engbring & Suzuki, 1988).

Freshwater marshes occur in areas just slightly above sea level and surrounded by mangroves, along most of the larger perennial streams and in depressions in upland areas. The vegetation of these marshes includes tall reeds, especially *Phragmites karka*, sedges and other taller herbaceous growth. Where the water is somewhat brackish, the fern *Acrostichum aureum* may be present. Over 130 ha of freshwater marsh are cultivated for taro, and here the edible vine *Ipomoea aquatica* may be found (Cole *et al.*, 1987).

Saline marshes generally occur along the coast near mangroves or in depressions in sand or mud flats. Most areas of saline marsh are tiny, although there is one patch of 0.4 ha on Ngebad Island. Common species include *Cyperus javanicus*, *Derris trifoliata* (especially at the edge of mangroves), *Eleocharis geniculata*, *Fimbristylis cymosa*, *Lippia nodiflora*, *Paspalum distichum* and *Vigna marina*. A number of woody species characteristic of coastal sand dunes, swamp forests and mangroves may surround or be sparsely scattered in the marshes (Cole *et al.*, 1987).

Swamp Forest

Swamp forests occur where soils are inundated with fresh or slightly brackish water. The most common habitat for such forests is in low-lying areas, just inland of mangroves and above tidal influence. The coastal lowland swamps of Palau are generally quite disturbed, with *Hibiscus tiliaceus* being a common component after disturbance. Taro cultivation is a common competing land use for these swamp areas, and is probably the main reason for the clearing of swamp forest (Cole *et al.*, 1987).

Species common to swamps on the landward side of mangroves and along rivers include *Horsfieldia amklaal*, *Cynometra ramiflora*, *Calophyllum soulattri*, *Barringtonia racemosa*, *Heritiera littoralis*, *Samadera indica* and, in its understorey, *Stemonurus ammui*. The climbing vine *Derris trifoliata* is commonly found growing on trees. A swamp forest association typical of low areas with impeded drainage is the *Horsfieldia amklaal*, *Barringtonia racemosa* and *Donax canniformis* type. This type of swamp forest occurs in coastal areas and also quite commonly along streams in the interior hills of Babeldaob. Remnants of swamp forest on Peleliu are dominated by *Barringtonia racemosa* and *Terminalia catappa*. On Angaur, *Barringtonia racemosa*, *Hibiscus tiliaceus* and *Areca catechu* (betelnut) grow in a swampy area near the airstrip (Cole *et al.*, 1987).

Mangrove Forest

Extensive mangrove forest grows around much of Babeldaob, and to a lesser extent around Koror, Peleliu and some of the smaller offshore islands. The mangroves of Babeldaob Island are well developed, especially on the south and southwest coasts, and all but 32 km of the island's 157 km of coastline are bounded by mangroves. Ten species of mangrove have been recorded (Woodroffe, 1987), with well developed stands reaching 15-20 m in height. *Sonneratia alba* and *Rhizophora mucronata* are dominant on the seaward side of the mangroves (Stemmermann and Proby, 1978). At the mouths of larger rivers and around bays, *Rhizophora mucronata* and *R. apiculata* grow in pure stands or mixed with *Sonneratia* and some *Bruguiera gymnorrhiza*, while on the landward side of the mangroves, the species mix may include *Lumnitzera littorea* and *Xylocarpus granatum*. In the upper parts of estuaries, *Rhizophora* spp. are rare; *Sonneratia* remains common and *Bruguiera*, *Xylocarpus* and *Lumnitzera* become common. *Heritiera littoralis* is found along the landward side of mangroves and upstream, while *B. gymnorrhiza* has been found growing inland in totally enclosed sink-holes in limestone areas. Stands of *Nypa fruticans* occur along the lower portions of some rivers and at their mouths (Cole *et al.*, 1987).

There is a small stand of mangroves in Kayangel Atoll, along the shore of a saltwater pond in the interior of a small islet adjacent to Kayangel Island proper. This stand of *Bruguiera* and *Rhizophora* trees was planted by the Palau Department of Agriculture and Forestry in the mid 1970s (Cole *et al.*, 1987).

Table 1: Area of Wetland Vegetation in the Republic of Palau

	Babeldaob islands	Other high islands	Coral islands	Rock	Total
Freshwater Marsh	448	<1	27	0	475

Cultivated Marsh	107	2	25	0	134
Saline Marsh	0	0	25	<1	25
Swamp Forest	1,617	15	47	1	1,680
Mangrove Forest	4,025	205	435	43	4,708
Total	6,197	222	559	44	7,022

After Cole *et al.* (1987).

Wetland Fauna

Wetland birds include the Yellow Bittern (*Ixobrychus sinensis*), Rufous Night-Heron (*Nycticorax caledonicus*), Cattle Egret (*Bubulcus ibis*), Pacific Reef-Heron (*Egretta sacra*), Grey Duck (*Anas superciliosa*), Banded Rail (*Rallus philippensis*), Slaty-legged Crake (*Rallina eurizonoides*), White-browed Crake (*Porzana cinerea*), Purple Swamphen (*Porphyrio porphyrio*) and Common Moorhen (*Gallinula chloropus*). As freshwater habitats are limited, most of the freshwater species are uncommon, and the Grey Duck and Common Moorhen are in danger of extinction in the islands (Engbring & Suzuki, 1988).

Situated only 740 km from the east coast of Mindanao in the Philippines, the islands of Palau are easily reached by migrant shorebirds in the East Asian/Australasian flyway, and many species using this flyway have been recorded during the migration seasons. The commoner migrants include Pacific Golden Plover (*Pluvialis fulva*), Wood Sandpiper (*Tringa glareola*), Grey-tailed Tattler (*Heteroscelus brevipes*), Common Sandpiper (*Actitis hypoleucos*), Whimbrel (*Numenius phaeopus*), Ruddy Turnstone (*Arenaria interpres*) and Rufous-necked Stint (*Calidris ruficollis*) (Engbring & Suzuki, 1988).

Formerly widespread, the Estuarine Crocodile (*Crocodylus porosus*) was almost exterminated in the Palau Islands by Australian hunters following an incident in which a tourist was injured. However, the species is now recovering under protection, although most of the individuals are small and extremely secretive. Amphibians include an endemic species of ranid frog (Dahl, 1986) and the introduced toad *Bufo marinus*.

In general, Palau's natural environments, including wetlands, remain in good condition, partly due to the low population density. In recent years, less wetland taro is being grown, and this has resulted in a loss of some prime habitat for rails and other waterbirds (Engbring & Suzuki, 1988). Unplanned development on the island of Koror is also a cause for concern. Nearly all birds are fully protected by local law, but with an increase in guns and speed boats and the simultaneous decline in the authority of the chiefs, illegal hunting is becoming more common and could pose a threat to some species of waterbirds.

Wetland Research

Detailed vegetation maps of Palau have been prepared by the Forest Service, U.S. Department of Agriculture, in cooperation with the Government of Palau (Cole *et al.*, 1987), and these provide information on the extent and composition of the mangrove forests, freshwater swamp forests, freshwater marshes and saline marshes. The Forest Service has also carried out an inventory of the timber resources of Babeldaob which includes information on the mangrove and swamp forests (MacLean *et al.*, 1988). Information on the extremely rich and diverse reef systems has recently been summarized by UNEP/IUCN (1988). The birds of Palau are relatively well known, and an excellent field guide has been prepared by Engbring and Suzuki (1988).

There are two scientific laboratories in the Republic of Palau: one for marine scientists and the other shared by the Office of Conservation Management and the Entomological Office.

Wetland Area Legislation

Prior to 1981, some United States federal legislation and Trust Territory legislation was applicable. This included the Trust Territory Endangered Species Act (1975) which protects listed species and allows for the acquisition of land or water for the purpose of conserving threatened species. Other Trust Territory Acts and US legislation relevant to nature conservation and the environment in Palau have been summarized by IUCN (1991).

The Palau National Code makes various provisions for the protection of species and establishment of protected areas. Section 202 of the Code protects most bird species and their eggs, section 203 protects Dugongs (*Dugong dugon*) and section 206 creates a Fish and Game Commission (Dahl, 1980). Sections 3001 to 3004 provide for the creation, prohibitions, penalties and regulations relating to Ngerukewid Islands Wildlife Preserve. This preserve, established by District Order in 1956, is the only legally established and perennially protected natural area in the Republic of Palau. Also known as the "Seventy Islands", the Ngerukewid Islands are an outlier of the "Rock Islands" comprising a cluster of 37 limestone islands, islets and rock pinnacles which rise steeply from the surrounding lagoon waters. The total area of the preserve is 1,200 ha of which the islands comprise only 90 ha (Thomas *et al.*, 1989). There is no surface freshwater in the islands, and the only wetlands are two tiny patches of mangroves.

Other sections in the Palau Code provide for the protection of Ngerumekaol Channel as a spawning ground for groupers from April 1 to July 31 every year. There are also a number of State Ordinances which provide for the establishment of *Trochus* sanctuaries, some 21 of which have been established by the various states (IUCN, 1991).

The Republic of Palau has signed but not yet ratified the Convention for the Protection of the Natural Resources and Environment of the South Pacific (the SPREP Convention). Palau is not, however, as yet a party to the Unesco Man and the Biosphere Programme, Ramsar Convention or World Heritage Convention, nor has it signed or ratified the Convention on the Conservation of Nature in the South Pacific or the Convention on Biological Diversity.

Wetland Area Administration

Management of recreation areas and historical sites falls under the Bureau of Community Services in the Ministry of Social Services, while that of conservation areas such as the Ngerukewid Islands Wildlife Preserve falls under the Bureau of Resources and Development in the Ministry of National Resources. Enforcement of the laws pertaining to these areas remains with the Bureau of Public Safety in the Ministry of Justice (Bureau of Resources and Development, 1989). A Division of Conservation and Entomology has been created within the Bureau of Resources and Development, with a broad remit to prepare conservation programmes and pest control and entomological activities (IUCN, 1991). This agency has not, however, as yet been involved directly with wetlands.

Organizations involved with Wetlands

Bureau of Resources and Development, Ministry of National Resources.

WETLANDS

Site descriptions compiled by Demei O. Otobed of the Division of Conservation and Entomology, Bureau of Resources and Development. The eight sites described below are the principal wetlands on the main island of Babeldaob. Many other smaller wetlands exist in the islands, and further study may reveal a number of these to be of international importance.

Ngaraard-Ngardmau Mangroves (1)

Location: 7°37'N, 134°36'E; on the northwest coast of Babeldaob Island, between Ngardmau Point and Kloualtaoch; Ngaraard and Ngardmau States.
Area: 160 ha.
Altitude: Sea level to just over one metre above sea level.
Overview: A large area of mangrove forest and coastal swamps on the northwest coast of Babeldaob Island. The mangrove forest is rich in tree species, and serves to protect the immature stages of numerous marine organisms. The wetland provides important habitat for fruit bats, birds, crocodiles, fishes and crustaceans.
Physical features: An area of mangrove forest subject to tidal inundation. Several streams carry fresh water into the wetland, which adjoins very rich inner reef flats. In some places, especially near the mouths of the streams, the water is brackish. The substratum is dark and rich in organic matter.
Ecological features: Coastal mangrove forest with some freshwater swamps inland. Most of the mangrove tree species known from the Caroline Islands are present in the area.
Land tenure: Owned by the States and local chiefs. Adjacent land is owned partly by the government and partly by local landowners.
Conservation measures taken: None.
Land use: The cutting of mangrove for timber, fishing, harvesting of mangrove crabs and bi-valves, and hunting of fruit bats and wild pigs.
Possible changes in land use: Road construction through the area.
Disturbances and threats: Excessive cutting of mangrove vegetation and landfill for development may pose threats in the future.
Hydrological and biophysical values: The mangrove forest filters silt from run-off entering from the land, thereby protecting the reefs from siltation. The forest also prevents coastal erosion and provides protection against tropical storms. The ecosystem supports a diverse community of marine organisms many of which are important to the local people.
Social and cultural values: The mangrove forest plays an important role in the lives of the local people by providing an important source of timber, foods such as mangrove crabs and bi-valves, and some medicines.
Noteworthy fauna: The Palau Fruit Bat *Pteropus pelewensis*, the Estuarine Crocodile *Crocodylus porosus* and the Dog-faced Snake (*Cerberus rhyncops*) occur in the mangroves. A variety of forest birds forage in the mangroves, and some waterbirds use the area for nesting. Invertebrates include the mangrove crab *Scylla serrata*, various other crabs, various bi-valves, gastropods and some tunicates.
Noteworthy flora: The area contains a well developed stand of mangrove vegetation containing most of the mangrove species occurring in the Caroline Islands.
Management authority and jurisdiction: The States of Ngaraard and Ngardmau.
Reasons for inclusion: 1a, 2b, 2c. One of the best examples of mangrove forest on the west coast

of Babeldaob, far from the capitol, Koror and still relatively undisturbed.
Source: Demei O. Otobed.

Ngerkall Pond (2)

Location: 7°36'N, 134°37'E; near the northern tip of Babeldaob Island, 2 km northwest of Ngkeklau village, Ngarrard State.
Area: 1.3 ha.
Altitude: About 50 m.
Overview: A small pond, largely overgrown with aquatic vegetation, in the uplands of northern Babeldaob. The pond is 60 metres long, 45 metres wide and 60-90 cm deep. Ngerkall Pond is one of only two natural freshwater ponds of any size in Palau.
Physical features: A freshwater pond created as a result of a landslide. The pond is fed by run-off from the adjacent hillsides and has a small catchment area.
Ecological features: The aquatic vegetation consists of graminoids, sedges and *Hanguana malayana*. The wetland remains in an almost pristine condition.
Land tenure: The State Government and local Chiefs.
Conservation measures taken: None.
Land use: None; the wetland is undisturbed and there is no cultivation on the surrounding hillsides.
Disturbances and threats: There is some burning and hunting in the general area.
Hydrological and biophysical values: The pond traps sediments, acts as a natural water storage reservoir, and may assist in the recharge of groundwater.
Social and cultural values: Local people occasionally use the pond as a source of drinking water, and the aquatic vegetation may have provided a source of sedges for weaving materials in the past.
Noteworthy fauna: The wetland probably still supports small numbers of the locally endangered Grey Duck (*Anas superciliosa*) as well as Purple Swamphen (*Porphyrio porphyrio*). Migratory waterbirds occasionally visit the area.
Noteworthy flora: The wetland supports a variety of freshwater aquatic plants with very restricted distribution in Palau.
Recreation and tourism: A few school children visit the area during hiking trips.
Management authority and jurisdiction: State of Ngaraard.
References: Anon (1956).
Reasons for inclusion: 1d, 2b. One of only two significant freshwater ponds in Palau, with rich aquatic vegetation still in an almost undisturbed condition.
Source: Demei O. Otobed.

Ngerbekuu River (3)

Location: 7°33'N, 134°37'E; on the east coast of Babeldaob Island, 2 km southwest of Ngermechau village, Ngiwal State.
Area: 122 ha.
Altitude: A few metres above sea level.
Overview: An area of freshwater swamps, lowland swamp forest with high canopy and adjacent mangrove forests along the Ngerbekuu River.

Physical features: A large area of mangrove forest, swamp forest and freshwater swamp in the estuary of the Ngerbekuu River. The mangrove area is influenced by the tides and some parts of the area are brackish.
Ecological features: The wetland incorporates fresh, brackish and saline ecosystems, and supports a wide diversity of mangrove and swamp forest species.
Land tenure: The State of Ngiwal and local chiefs hold title to the mangrove forests and freshwater swamps. There is some privately owned land along the Ngerbekuu River.
Conservation measures taken: None.
Land use: Some of the freshwater swamps are used for taro patches, and parts of the swamp forest are used for agro-forestry. Some mangrove trees are harvested for timber. The estuary is also a fishing ground for fin fish, crabs and bivalves.
Possible changes in land use: There is a proposal to build a causeway across the wetland to link the states of Melekeok and Ngiwal.
Disturbances and threats: Landfill, excessive cutting of timber and possible construction of a causeway.
Hydrological and biophysical values: The wetland protects the adjacent reef flats from siltation by trapping sediments carried down by the river. It is a highly productive ecosystem, with a rich and diverse fauna and flora still relatively intact.
Social and cultural values: Parts of the wetland are important for the cultivation of taro. The forests provide a valuable source of timber, and the estuary is an important fishing ground. There are some ancient dwellings of archaeological interest in the area.
Noteworthy fauna: The wetland supports populations of the Estuarine Crocodile (*Crocodylus porosus*) and the Palau Fruit Bat (*Pteropus pelewensis*). The mangrove crab (*Scylla serrata*) is common.
Noteworthy flora: All of the mangrove species occurring in Palau are present, as well as a wide variety of the swamp forest and freshwater swamp species.
Management authority and jurisdiction: State of Ngiwal.
References: Smith (1983); Stemmermann & Proby (1978).
Reasons for inclusion: 1a, 2b, 2c. The wetland serves as a refuge for a wide variety of marine and terrestrial organisms.
Source: Demei O. Otobed.

Ngardok Lake (4)

Location: 7°31'N, 134°36'E; about 4 km northwest of Melekeok town, Melekeok State, on the eastern side of Babeldaob Island.
Area: 3.4 ha.
Altitude: 20 m.
Overview: A small, natural, freshwater lake with some swamp vegetation. This is the largest perennial body of fresh water in Palau.
Physical features: Ngardok Lake is 720 m long, 180 m wide and 2.7 m deep, and has a volume of 15,000,000 gallons. It is situated in the largest water catchment area in Palau, and receives water from several rivers rising in Melekeok and Ngchesar states. Deltaic deposits at the mouths of these rivers support swamp vegetation.
Ecological features: The natural swamp vegetation is composed of sedges, grasses and various herbaceous species.
Land tenure: Owned by the Government of Melekeok State and local Chiefs.
Conservation measures taken: None.
Conservation measures proposed: It has been proposed that Ngardok Lake and surrounding areas be designated as a protected area.
Land use: None; the lake and surrounding areas remain in a natural condition, and there is no

cultivation in the area.
Possible changes in land use: There is a proposal to dam the area for a hydro-electrical project for the State of Melekeok.
Disturbances and threats: There is some hunting in the vicinity of the lake, and nearby areas are occasionally subject to burning during the dry season.
Hydrological and biophysical values: The Ngardok Lake catchment area supplies water to a large part of the eastern side of Babeldaob, including the States of Ngchesar and Melekeok. The lake plays a role in natural flood control and maintenance of water quality in the area. The whole area provides important habitat for a wide variety of native animals and plants.
Social and cultural values: The Ngardok catchment is a very important source of freshwater. During periods of severe drought in the past, people from all over Babeldaob came to Ngardok Lake for drinking water.
Noteworthy fauna: The lake supports a small population of Estuarine Crocodiles (*Crocodylus porosus*), as well as various waterbirds, freshwater eels, several species of fish, gastropods and other freshwater invertebrates.
Noteworthy flora: The lake supports a variety of freshwater aquatic plants with very restricted distribution in Palau.
Conservation education: The lake is frequently visited by students and other individuals wishing to study its flora and fauna, and thus has considerable value for conservation education.
Management authority and jurisdiction: Melekeok State Government.
References: Anon (1956); Stemmermann & Proby (1978).
Reasons for inclusion: 1d, 2b. Ngardok Lake is the only natural freshwater lake in Palau, and remains in a pristine condition.
Source: Demei O. Otobed.

Ngerdorech (Ngetkebau) River (5)

Location: 7°26'N, 134°35'E; on the east coast of Babeldaob Island, east of Ngersuul village, Ngchesar State.
Area: 100 ha.
Altitude: A few metres above sea level.
Overview: An area of freshwater swamps, lowland swamp forest and mangrove forest along the lower reaches and in the estuary of the Ngerdorech (Ngetkebau) River.
Physical features: The Ngerdorech River is one of the largest rivers in Palau. It originates at Ngardok Lake (Site 4) and empties onto the inner reef flats on the east coast of Babeldaob. Along its lower course, it supports a complex of freshwater swamps, swamp forest and mangrove forest.
Ecological features: Freshwater swamps, swamp forest and mangrove forest.
Land tenure: Taro patches in the freshwater swamps are privately owned. The mangrove forest and other parts of the swamp are owned by Ngchesar State and the local Chief.
Conservation measures taken: None.
Land use: Parts of the freshwater swamp are utilized for the cultivation of taro. Other activities include the cutting of timber, hunting, fishing and the gathering of medicines and edible plants. The river is an important source of water for Ngersuul village.
Disturbances and threats: Increased siltation in the freshwater swamps and mangroves; excessive removal of aquatic vegetation; possible re-routing of the watercourse; road construction; increased farming activities; over-exploitation of timber; excessive hunting.
Hydrological and biophysical values: The wetland protects the adjacent reef flats from siltation by trapping sediments carried down by the river. It is a highly productive ecosystem, with a rich and diverse fauna and flora.
Social and cultural values: An important area for the cultivation of taro, cutting of timber,

harvesting of natural medicines, and hunting and fishing. The river is navigable for some distance inland, and is important for transportation.
Noteworthy fauna: Palau Fruit Bats (*Pteropus pelewensis*), Estuarine Crocodiles (*Crocodylus porosus*) and Dog-faced Snake (*Cerberus rhyncops*). The wetland also supports a wide variety of forest birds, waterbirds, fishes, crabs and bivalves.
Noteworthy flora: The site supports a diverse wetland flora including many of Palau's endemic species and most of the mangrove species occurring in the Caroline Islands.
Conservation education: The site has considerable potential for conservation education.
Management authority and jurisdiction: State of Ngchesar, Ngersuul Hamlet.
References: Stemmermann & Proby (1978).
Reasons for inclusion: 1a, 2b, 2c. The wetland serves as a refuge for a wide variety of marine and terrestrial organisms.
Source: Demei O. Otobed.

Ngerikiil River (6)

Location: 7°22'30"N, 134°33'30"E; at the south end of Babeldaob Island, east of the international airport, Airai State.
Area: 130 ha.
Altitude: Sea level to about 5 m.
Overview: An area of freshwater swamps, lowland swamp forest with high canopy and mangrove forests along the lower reaches and in the estuary of the Ngerikiil River.
Physical features: The site comprises the lower portion of the Ngerikill River and its estuarine system in Airai Bay. The river is perennial, and supports freshwater swamps and swamp forest; mangrove forest occurs in the intertidal zone. Some of the swamps along the river are used for the cultivation of taro and gardening.
Ecological features: Freshwater swamps, swamp forest and mangrove forest.
Land tenure: The Airai State Government and local Chiefs hold title to most of the area.
Conservation measures taken: None.
Land use: Cultivation of taro, hunting and fishing, the cutting of timber, and the gathering of natural medicines. This wetland lies close to Palau International Airport.
Disturbances and threats: Parts of the wetland have been reclaimed for agriculture, and some degradation occurred as a result of the construction of the airport. Burning, disturbance from farming activities and road construction have also caused some problems.
Hydrological and biophysical values: The wetland protects the adjacent reef flats from siltation by trapping sediments carried down by the river. It is a highly productive ecosystem, with a rich and diverse flora and fauna.
Social and cultural values: An important area for the cultivation of taro, harvesting of natural medicines, hunting and fishing. The river is an important source of fresh water for Airai State. There are some sites of archaeological interest in the wetland.
Noteworthy fauna: Palau Fruit Bats (*Pteropus pelewensis*), Estuarine Crocodiles (*Crocodylus porosus*) and Dog-faced Snake (*Cerberus rhyncops*). The wetland also supports a wide variety of forest birds, waterbirds, fishes, crabs and bivalves.
Noteworthy flora: The site supports a diverse wetland flora including many of Palau's endemic species and most of the mangrove species occurring in the Caroline Islands.
Conservation education: The site has considerable potential for conservation education as it is located close to Koror and can be approached by land transportation.
Recreation and tourism: Because of its proximity to Koror, the site receives more visits from tourists than most other wetlands in Palau.
Management authority and jurisdiction: Airai State.

References: Anon (1956); Smith (1983); Stemmermann & Proby (1978).
Reasons for inclusion: 1a, 2b, 2c. Although somewhat disturbed as a result of a major development project (airport construction), the site continues to support a rich and diverse flora and fauna.
Source: Demei O. Otobed.

Ngerimel River (7)

Location: 7°21'30"N, 134°31'30"E; at the south end of Babeldaob Island near Ngeruluobel village, west of the international airport, Airai State.
Area: 5 ha.
Altitude: Sea level to about 5 m.
Overview: A small area of freshwater swamp along the lower reaches of the Ngerimel River, and a larger area of mangrove forest at the mouth of the river.
Physical features: The site comprises freshwater swamps and mangrove forest along the Ngerimel River downstream of the Airai water storage reservoir. The wetland is natural but has been affected by the construction of the Airai Reservoir upstream. There is a water pumping station downstream of the dam, and many people live around the mouth of the river. A main highway cuts across the wetland.
Ecological features: Freshwater swamps and mangrove forest somewhat disturbed by human activities.
Land tenure: Mainly Ngeruluobel Hamlet, Airai State, with some private ownership.
Conservation measures taken: None.
Land use: Parts of the freshwater swamp are utilized for the cultivation of taro. Mangrove trees are cut for timber, and there is some hunting and fishing. Surrounding areas are under cultivation or used for human settlement.
Disturbances and threats: There is a considerable amount of disturbance to the area from farming activities, burning, oil spills, siltation, cutting of vegetation and landfill for house construction and other development.
Hydrological and biophysical: The wetland protects the adjacent reef flats from siltation by trapping sediments carried down by the river.
Social and cultural values: Many people live around the wetland and utilize its resources. The freshwater swamps are especially important for taro cultivation. Airai Reservoir provides water for Airai State and the whole of Koror State.
Noteworthy fauna: Palau Fruit Bats (*Pteropus pelewensis*), Estuarine Crocodiles (*Crocodylus porosus*) and Dog-faced Snake (*Cerberus rhyncops*). The wetland also supports a wide variety of forest birds, waterbirds, fishes, crabs and bivalves.
Noteworthy flora: Despite the disturbance from human activities, the site continues to supports a diverse wetland flora including many of Palau's endemic species and most of the mangrove species occurring in the Caroline Islands.
Conservation education: The wetland has considerable potential for conservation education because of its proximity to densely populated areas. The site could be used to educate the local people about the effects of human activities on natural wetland ecosystems.
Management authority and jurisdiction: Ngeruluobel Hamlet, Airai State.
References: Anon (1956); Smith (1983); Stemmermann & Proby (1978).
Reasons for inclusion: 1a, 2b, 2d. An interesting freshwater swamp with a diverse flora rich in endemic species.
Source: Demei O. Otobed.

Ngeremeduu Bay (8)

Location: 7°29'N, 134°31'E; on the west coast of Babeldaob Island in Ngeremlengui, Ngatpang and Aimeliik States.
Area: About 1,500 ha.
Altitude: Sea level to about 10 m.
Overview: A large area of riverine marshes, swamp forest and mangrove forest around Ngeremeduu Bay, the largest indentation on the western side of Babeldaob.
Physical features: Ngeremeduu Bay is a large, tidal sea bay with a relatively narrow opening to the sea in the northwest corner and extensive mangrove swamps. Four large rivers, the Ngeremeskang, Ngkebeduul, Ngatpang and Ngimet, empty into the bay, providing an abundant supply of fresh water which creates brackish conditions in much of the bay. There are large areas of freshwater swamp and swamp forest along the lower reaches of the rivers and well developed mangrove forests, particularly in the estuary of the Ngeremeskang River in the northeast and around the island of Ngerasech in the south. The bay contains the most extensive area of mudflats in Palau.
Ecological features: Mangrove forest, swamp forest and freshwater swamps. Most of the mangrove tree species known from the Caroline Islands are present in the area. The freshwater swamps are the most diverse in Palau.
Land tenure: The bay is owned by the three State governments and local chiefs. Parts of the freshwater swamp and adjacent dry land are privately owned.
Conservation measures taken: None.
Conservation measures proposed: Stemmermann and Proby (1978) identified Ngatpang Bay as a wetland of great interest and worthy of special protection.
Land use: Cultivation of taro; hunting; fishing; collection of edible plants and medicines; cutting of timber; navigation and transportation.
Possible changes in land use: There is a proposal to construct a large international airport capable of handling jumbo jets near the bay.
Disturbances and threats: Landfill for housing and road construction; increased gardening and farming activities; over-exploitation of timber; overfishing and excessive hunting.
Hydrological and biophysical values: The mangrove forest filters silt from run-off entering from the land, thereby protecting the reefs from siltation. The forest also prevents coastal erosion and provides protection against tropical storms. The ecosystem supports a diverse community of marine organisms many of which are important to the local people.
Social and cultural values: A large number of people living around the bay are dependent on its natural resources for their livelihood. The bay is one of the best sources of crabs, sting-rays and many other economically important marine species on Babeldaob Island. The freshwater swamps are important for the cultivation of taro, while the mangrove and swamp forests provide a source of timber and natural medicines. There are many sites of historical importance in the area.
Noteworthy fauna: Estuarine Crocodile (*Crocodylus porosus*), Dog-faced Snake (*Cerberus rhyncops*) and a wide variety of land birds and waterbirds, fishes, crabs and other estuarine and marine invertebrates. Dugongs (*Dugong dugon*) occur in the bay.
Noteworthy flora: The site includes the largest and most diverse freshwater swamp communities in Palau, as well as large, well developed stands of mangrove with all the Palauan species present.
Scientific research and facilities: Some marine studies have been carried out on the inner reef flats at Ngatpang and Ngermetengel in Ngeremlengui State.
Management authority and jurisdiction: Ngeremlengui, Ngatpang and Aimeliik States.
References: Anon (1956); Cole *et al.* (1987); Stemmermann & Proby (1978).
Reasons for inclusion: 1a, 2b, 2c. The largest wetland in Palau, with the most extensive freshwater swamps and mangrove forests.
Source: Demei O. Otobed.

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PAPUA NEW GUINEA

This contribution, covering the political entity of Papua New Guinea including its offshore islands, is an update of the inventory produced for *A Directory of Asian Wetlands* (Scott, 1989). Since 1987, when the contribution for the Asian wetlands directory was written, further information regarding impacts on wetlands of mining and climate change (particularly sea level rise), the introduction of further fish species and the spread and control of exotic aquatic weeds has become available. This information is reviewed in the Introduction. The bibliography lists references mentioned in the text and relevant articles and papers produced following the publication of the earlier Directory.

INTRODUCTION

by Patrick L. Osborne

Area: 462,000 sq.km.

Population: 3,006,800 (1980 census).

Papua New Guinea is situated between the stable land mass of Australia and the deep ocean basin of the Pacific. The island of New Guinea, the second largest island in the world, is divided politically into Irian Jaya (Indonesia) and Papua New Guinea. Papua New Guinea is administered as nineteen provinces and the National Capital District around Port Moresby. Although the population of just over three million is small in relation to the land area (462,000 sq.km) the population is estimated to be growing at a rate of 2.1%, and 48% of the population is under 15 years of age. Over 95% of the land is held under customary tenure, and most of the rural people rely to some degree on natural resources for their livelihood.

Papua New Guinea experiences relatively high annual rainfall of 2,500-3,500 mm. Some lowland areas are drier, but annual rainfall of less than 1,000 mm is restricted to a small area surrounding the National Capital District. Large areas of the highlands receive in excess of 4,000 mm per year and in some places over 10,000 mm per year has been recorded. Air temperatures are high throughout the year with little seasonal variation. Daily mean maximum temperatures on the coast are around 30-32°C, with minima around 23°C. With increasing altitude, the absolute average temperatures decrease and seasonal variation tends to equal or exceed the daily temperature range. Above 2,200 m altitude, frosts occur but only rarely. Frosts are more common at over 3,000 m altitude, and snow occasionally falls on the higher mountains. The combination of high rainfall and temperature results in high humidity, cloudiness and only moderate rates of evaporation. For further information on the climate of Papua New Guinea, see McAlpine *et al.* (1983).

The relief of Papua New Guinea is dominated by a broad central cordillera that runs through the middle of the country. On the border with Irian Jaya, the main mountain range is about 100 km wide, but it increases in width in the central highlands region to 300 km. From there, the cordillera narrows towards Milne Bay. These highlands are a complex system of ranges and valleys. The highest peaks are Mt Wilhelm (4,509 m), Mt Giluwe (4,368 m), Mt Albert Edward (3,990 m) and Mt Victoria (4,035 m).

North of the central cordillera is a depression which is occupied by the Sepik River in the west and by the Ramu River to the east. A discontinuous mountain chain separates the Sepik-Ramu wetland from the north coast. The Torricelli Mountains, rising to 1,200 m, form the western part of this chain, and at the eastern end the Adelbert, Finisterre and Saruwaged Ranges rise to almost 4,000 metres. The Sepik and Ramu Rivers discharge to the Bismarck Sea in a wide gap between the Torricelli and Adelbert Ranges. The Markham River occupies the eastern part of this great northern depression, and is an unusual river for Papua New Guinea being a braided stream for most of its length. To the south, in the western part of Papua New Guinea, is a huge tract of low-lying land drained by the Fly and Strickland Rivers. The Purari River has a large catchment area (33,670 km^2) draining the central highlands, and is the third largest river in Papua New Guinea, discharging 2,607 m^3/second into the sea. A detailed study of this river is reported in Petr (1983). The area east of the Purari River consists of the coastal plains of Gulf and Central Provinces. These coastal plains are swampy areas traversed by meandering rivers with associated oxbow lakes. The lower reaches of the rivers have extensive floodplains that may be seasonally inundated giving rise to vast swamps. Small wetlands are found in the highlands and on the islands.

Given the high rainfall and generally rugged topography, rivers are usually fast-flowing with very high discharges. Consequently, except in the broader, lowland areas, most rivers in Papua New Guinea have a poorly developed aquatic fauna and flora.

Chambers (1987) recorded a total of 5,383 lakes with a surface area greater than 0.1 ha. Over 80% of the lakes in Papua New Guinea lie below 40 m altitude, and only 4% are over 2,000 m in altitude. More than half the lakes (3,003) are equal to or less than 2 ha, and only 22 lakes are larger than 1,000 ha. The total surface area of all the lakes was estimated to be 229,600 ha. Over 75% of these are in the Western and East Sepik Provinces. The lakes of Western Province fall into two categories: tributary lakes and oxbow lakes. Tributary lakes are formed by the blocking of a tributary by a river, and are usually shallow (*e.g.* Boset Lagoon and Lake Daviumbu). Oxbow lakes are of variable depth depending on age. The largest lake in Papua New Guinea, Lake Murray (surface area 650 sq.km) lies in a shallow depression (maximum depth 10 m) between the Strickland and Fly Rivers. Most of the lakes associated with the Sepik River are oxbows, although the second largest in the country (Chambri Lake) fills a shallow depression.

The flora of Papua New Guinea is one of the richest in the world. This is probably due to the country's great diversity of habitats from lowlands with tropical rainforest, monsoon woodlands, savanna, grasslands and freshwater swamps and mangroves to high mountains with frequent frosts and occasional snow falls.

Mangrove swamps occupy large parts of the coastal areas in Papua New Guinea. They are normally found along protected bays and near the mouths of rivers. The largest areas of mangroves occur in the south, especially in the Gulf of Papua into which several large rivers flow (*e.g.* the Fly, Kikori and Purari). The north coast is not as rich in mangroves as the south coast, but *Avicennia alba* and *Sonneratia caseolaris* have been recorded there and not on the south coast. Conversely, *Avicennia officinalis* has only been found on the south coast. Cragg (1987) describes the biological and ecological characteristics of mangrove forests in Papua New Guinea, and reviews their exploitation and management.

It is estimated that the mangrove forests in the Gulf of Papua occupy an area of between 162,000 and 200,000 ha (including nipa palm stands), Rhizophoraceae dominate with 121,500 ha (56%), while species of *Bruguiera* and *Camptostemon* comprise 18% and 14% respectively. In the Purai Delta, there are about 134,000 ha of mangroves. The Central Province, including the National Capital District, has an estimated 57,770 ha of mangrove swamps.

Mangroves in Papua New Guinea provide food, building materials, energy (firewood) and medicine (Rau, 1984). While large areas of mangroves in remote regions are untouched, those near urban areas and in proximity to development schemes are subject to various degrees of degradation. Some of the developments that have resulted in indiscriminate felling of mangroves include oil and gas exploration in the Gulf of Papua, various timber projects and port developments. The felling of mangroves for firewood in urban areas is also now causing concern. No conservation areas have been established exclusively for mangroves, but mangroves in Wildlife Management Areas are protected (*e.g.* Maza in the Western Province and N'Drolowa in Manus Province) are protected.

Paijmans (1976) recognised four major categories of wetland vegetation, and sub-divisions within these are summarized below.

Saline and brackish swamps

- Mangrove scrub: A dense scrubby vegetation of pioneering mangroves found on the seaward side of muddy shores. The dominant species are *Avicennia marina*, *Sonneratia caseolaris* and *Ceriops tagal*.

- Low mangrove forest: Dense even-aged, one-layered forest of *Rhizophora* pioneers in sheltered positions or develops after *Rhizophora* has invaded colonizing stands of *Avicennia* and *Sonneratia*.

- Mature mangrove forest: Mangrove forest inland with a more open canopy allowing the development of an understorey. Species of *Bruguiera* and *Rhizophora* dominate.

- *Avicennia* scrub and woodland: In areas with low and markedly seasonal rainfall, *Avicennia marina* is the most common mangrove species. It forms scrub and woodland on both the seaward and landward side of mangrove vegetation.

- *Excoecaria* scrub and woodland: *Excoecaria agallocha* is characteristic of brackish fluctuating swamps on the inner side of mangrove vegetation in low rainfall areas.

- Nipa palm woodland: Woodland consisting of *Nypa fruticans* covers extensive low-lying areas in estuaries subject to daily brackish flooding, and also lines tidal creeks where fresh and salt water meet and mix.

Lowland freshwater swamps

- Aquatic vegetation: This type consists of free-floating, floating-leaved and submerged plants. These either form a mixture or are arranged in concentric zones. They occupy the shallow margins between open water and grass swamp, and in places cover entire lakes that have a uniform depth.

- Herbaceous swamp vegetation: Herbaceous communities consisting of sedges, herbs and ferns are characteristic of stagnant, permanent, relatively deep swamps. Common species include *Thoracostachyum sumatranum*, *Scleria* sp., *Hanguana malayana* and the fern *Cyclosorus* sp. *Phragmites karka* often dominates along gently sloping swamp margins whereas *Pseudoraphis spinescens* and *Ischaemum polystachyum* form narrow bands along more steeply sloping, wet-dry margins.

- *Leersia* grass swamp: Grasses such as *Leersia hexandra*, *Echinochloa stagnina*, *Oryza* spp., *Panicum* sp. and *Hymenachne amplexicaulis* occupy permanently swampy plains that may be under three metres of water in the flood season. Herbs such as *Polygonum* spp., *Ludwigia* spp. and *Ipomoea aquatica* may be anchored in the grass mat and reach out over open water.

- *Saccharum-Phragmites* grass swamp: Tall swamp grasses, mainly *Saccharum robustum* and *Phragmites karka*, grow in swamps that are shallower than those described above and may be intermittently dry.

- *Pseudoraphis* grass swamp: *Pseudoraphis spinescens* is a low creeping swamp grass that is most extensive in southwestern Papua New Guinea. Here it forms dense, almost pure stands on floodplains that are seasonally dry. These grasses are heavily grazed by deer and wallabies.

- Mixed swamp savanna: This is a transitional vegetation type between purely herbaceous swamps and swamp woodland: it occurs in permanent, stagnant swamps. In addition to an herbaceous cover, there is an open layer of trees such as *Nauclea*, *Campnosperma*, *Syzygium* and *Melaleuca.*

- *Melaleuca* swamp savanna: *Melaleuca* swamp savanna is characteristic of the fluctuating backswamps of the middle Fly and Strickland Rivers, and also occurs along parts of the monsoonal south and southwest coasts. *Melaleuca* trees form an open, almost pure, canopy. In the wet season, *Melaleuca* swamp savanna is inundated and colonized by aquatic plants.

- Mixed swamp woodland: In permanent swamps, the tree storey of mixed swamp woodland is generally open and ranges from low to tall. Common trees are *Campnosperma* spp., *Nauclea coadunata*, *Mitragyna ciliata* and *Timonius* sp. Palms and pandans fill in much of the space below the trees and *Hanguana malayana*, sedges and *Cyclosorus interruptus* form a dense ground cover.

- Sago swamp woodland: The sago palm *Metroxylon sagu* is a widespread tall shrub that grows in more or less permanent swampy woodland. All gradations occur from stands of pure sago to woodland with a dense layer of trees and an open lower tier of sago. The palm grows best where there is a regular influx of fresh water.

- Pandan swamp woodland: Swamp pandans occupy a habitat similar to that of sago palm but have a wider range. They form open to quite dense, pure stands in shallow, fresh to brackish, stagnant to frequently flooded swamps.

- Mixed swamp forest: This is the most common type of swamp forest. It generally has an open but occasionally dense canopy. Some of the commoner trees include *Campnosperma* spp., *Terminalia canaliculata*, *Nauclea coadunata*, *Syzygium* sp., *Alstonia scholaris*, *Biscofia javanica* and *Palaquium* sp.

- *Campnosperma* swamp forest: The densest stands of *Campnosperma* (*C. brevipetiolata* and *C. coriace*) are found in permanently flooded backswamps. Sago may form a dense understorey.

- *Terminalia* swamp forest: This type is mainly found in North Solomons Province, where *Terminalia brassii* grows together with *Campnosperma* spp. and locally dominates in the canopy of open swamp forest. It is found in low-lying, frequently flooded, bouldery and sandy rivers and peat swamps with flowing waters.

- *Melaleuca* swamp forest: *Melaleuca* swamp forest is mainly confined to monsoonal southwestern Papua New Guinea, where it occurs in narrow bands in seasonally dry swamps along rivers. The main species is *Melaleuca cajuputi.*

<u>Lower montane zone</u>

- Sedge grass swamp: Communities dominated by sedges and grasses occur above about

1,800 m in swamps occupying intermontane basins, local depressions in valley floors and seepage slopes. Many different sedges are present, and they commonly make up most of the ground cover. Characteristic grasses are *Arundinella furva*, *Isachne* spp. and *Dimeria* spp.

- *Phragmites* grass swamp: *Phragmites karka* commonly forms pure stands in seepage areas on slopes and on flat valley floors to over 2,500 m. *P. karka* also occurs associated with *Miscanthus floridulus* along river banks and swamp margins.

- Swamp forest: Lower montane swamp forest grows in small patches fringing intermontane basins. The forest has a low and open canopy over a dense layer of small trees and shrubs and sparse herbaceous ground cover. Common trees include *Syzygium*, *Garcinia* and locally *Nothofagus perryi*.

Upper montane zone

- Herbaceous swamp vegetation: Herbaceous communities consisting of a mixture of low herbs, sedges, grasses and mosses occupy depressions, fringe open water and, in the higher parts of the zone, also occur on slopes. Common grasses include: *Anthoxanthum angustum*, *Agrostis reinwardtii* and *Monostachya oreoboloides*. The sedge *Carpha alpina* and the fern *Gleichenia vulcanica* locally form pure stands. Common shrubs include *Leucopogon*, *Drapetes*, *Vaccinium* and *Trochocarpa*.

Salvinia molesta and the spread of *Eichhornia crassipes* (Water Hyacinth)

Salvinia molesta formerly covered large areas of the lakes in the middle and lower Sepik Valley but biological control measures have been remarkably successful (see Room & Thomas, 1985; Thomas & Room, 1986; Creagh, 1991). Water hyacinth (*Eichhornia crassipes*) has spread up the Sepik River as far as Ambunti and D. Coates, (pers. comm.) predicts that it will be a significant problem in the near future. The weed has also been found growing in Mount Hagen, and has infested Waigani Lake near Port Moresby (Osborne, unpublished). It is also threatening Port Moresby's major water supply reservoir (Creagh, 1991). Warnings regarding the spread of this weed (Mitchell, 1978/1979; Osborne & Leach, 1984: Coates, pers. comm.) have, until recently, been ignored by Government. However, Creagh (1991) has indicated that the Division of Entomology, CSIRO, Australia and the PNG Government Department of Agriculture and Livestock are currently seeking resources to begin a water hyacinth control programme. Creagh (1991) reports that water hyacinth was initially found only around Madang, and that it spread from there to the lakes in the lower Sepik. However, an earlier infestation (and probably the initial one) was in the gold-mining dredge ponds at Bulolo. Water hyacinth spread from there to Lae and Madang in the early 1980s (see Mitchell, 1978/1979, and Osborne & Leach, 1984). In Australia, considerable success in the biological control of water hyacinth has been achieved using the weevil, *Neochetina bruchi*, and this success offers some hope in controlling the infestations in Papua New Guinea.

Wetland Fauna

No systematic or comprehensive surveys have been made of the fauna of any wetland in Papua New Guinea. The vertebrate fauna is relatively well known, but there is very little information on the distribution and habitat requirements of invertebrates. It is, however, pertinent to note that the very lack of such information reflects the present state of knowledge of the majority of wildlife species in Papua New Guinea. A systematic programme of research is not yet underway, although growing concern is resulting in activity through programmes such as the Tropical Forest Action Plan and the Biodiversity Support Programme.

Twelve zooplankton species have been recorded from the lakes on Mount Wilhelm (Bayly & Morton, 1980; Löffler, 1973; McKenzie, 1971). Low species diversity was attributed to the youthfulness of these lakes compared with the diversity of zooplankton in older, higher altitude, tropical lakes. Chambers (1988) recorded 51 zooplankton species from three lakes adjacent to the middle Fly River. Taxonomic works on freshwater invertebrates include Holthuis (1974, 1982) (Decapoda); Richardson (1977) (leeches); Robertson (1983) (*Macrobrachium*); Benthen-Jutting (1963) (Mollusca); McKenzie (1956) (mussels); McMichael & Hiscock (1958) (mussels).

The freshwater fish fauna of New Guinea consists of 329 species (Allen 1991). Of this total, 13 species are introduced forms and about 102 species are fishes that are believed to have a marine larval stage and are relatively widespread outside New Guinea. In general, the fish fauna of New Guinea is closely related to that of northern Australia. Nearly all the families, most genera, and numerous species are shared between these two areas; two closely related families, Rainbowfishes (Melanotaeniidae) and Blue-eyes (Pseudomugilidae) are unique to the combined region. The freshwater fishes are mainly derived from marine ancestors belonging to the orders Pristiformes, Clupeiformes, Siluroidiformes, Beloniformes, Syngnathiformes, Mugiliformes, Perciformes and Pleuronectiformes. The country completely lacks fish belonging to the true freshwater fishes of Southeast Asia, the saltwater barrier demarcated by Wallace's line forming an insurmountable obstacle to their eastward progress (Munro, 1967; Allen, 1991). Further details of the origin and zoogeography of the New Guinea fish fauna is provided by Allen (1991).

At least 22 species of fish have been introduced into Papua New Guinea, representing 19 genera, 11 families and all six continents. Most introductions have been unsuccessful or were never released into the wild. Of the successful introductions, most have had a negligible impact as either food fishes or in the control of mosquitoes (Allen, 1991). Tilapia (*Oreochromis mossambica*) is an exception as it now provides the major subsistence source of protein to villagers living along the Sepik River, and is the basis of a thriving commercial fishery on Waigani Lake near Port Moresby. The Common Carp is well-established and abundant in the highlands, and also constitutes a significant component of catches from the Sepik River system. *Tilapia rendalli* has recently been introduced to the Sepik and Ramu Rivers, but it is still too early to say whether it has been successful (D. Coates, pers. comm.). Approval has also been given for the introduction of the Java Carp (*Puntius gonionotus*) to the highlands streams in the Sepik catchment (D. Coates, pers. comm.). Allen (1991) regards most of the earlier introductions as having had a negative impact through competition for space and limited food resources, or by feeding on the native species. Even the popular *Oreochromis mossambica* has adversely affected the environment, creating turbid conditions in formerly clean lakes and over-crowding the indigenous fauna due to its prolific breeding. On the positive side, the number of established introductions is relatively few, and the Fly River seems to be free of introductions. Allen (1991) states that the uniqueness of New Guinea's fish fauna sets it apart from the Indonesian Archipelago lying west of "Weber's Line". He regards it as "particularly sad to witness the introduction of fishes from the Indonesian side of the Line." He recommends that the Government of Papua New Guinea should seriously consider the imposition of a ban on further introductions. Lake Kutubu is the home of eleven endemic fishes; no other mountain Lake in New Guinea has such a wealth of species, and Allen (1991) makes the following plea:

> "At present the lake remains in a pristine condition, but its future is clouded. Oil deposits were discovered nearby, and now the exotic calls of birds of paradise, parrots and hornbills compete with the drone of helicopters. There are no roads in the area, therefore these aircraft are used to ferry personnel and supplies to the drilling site. A proposal to link Lake Kutubu by road with Mendi and the Highlands Highway network is presently being considered. There is also a proposition to establish a township of 2,000 people on the

> shores of the lake to provide manpower and support facilities for the drilling operation. This development would be disastrous to the lake's delicate ecosystem. Hopefully the Papua New Guinea Government will take steps to protect this important wildlife refuge."

Osborne and Totome (1991 and in press) have carried out a limnological study of Lake Kubutu including observations of a mixing event within this oligomictic lake.

Of the three orders of amphibians, neither caecilians nor salamanders occur in Papua New Guinea. Frogs (Anura: five families) are well represented, with over 200 species described at present and new species being recognised as current research proceeds. The five families are Bufonidae (one introduced species), Hylidae (about 70 species), Leptodactylidae (about 5-10 species), Microhylidae (about 90 species) and Ranidae (about 10-15 species). Not all species are aquatic: a large number are forest dwellers which burrow beneath the surface or live beneath leaf litter. The majority of species are endemic to either Papua New Guinea or the island of New Guinea. A southern group having its origins in Australia can be recognised, as can a group of species originating from the Solomon Islands to the southeast. The surrounding islands have, in general, a depauperate amphibian fauna in comparison with the adjacent mainland.

Reptiles are represented by two species of crocodiles, 150-200 species of lizards, 90-95 species of snakes and 11 species of tortoises and turtles. The two species of crocodile are the New Guinea or Freshwater Crocodile *Crocodylus novaeguineae* and the Estuarine or Saltwater Crocodile *Crocodylus porosus*. Both species are still found in relatively large numbers and are heavily exploited for hides and meat. The endemic Freshwater Crocodile is the commoner species, though less widespread. It is restricted to the mainland whereas the Estuarine Crocodile is also found on most of the surrounding islands. The Freshwater Crocodile prefers a freshwater environment but is occasionally found in brackish waters such as the Fly delta. It is more often found in sluggish, shallow water rather than fast-flowing or deeper areas (Burgin, 1980a). The Estuarine Crocodile characteristically occurs in brackish areas such as estuaries and mangroves. Although once thought to be restricted to the coastal tidal areas, the species is now known to occur well inland. The inland populations are generally associated with freshwater pools and deep rivers, but the species has been recorded from fast-flowing rocky streams up to 1,000 km inland (Burgin, 1981). *C. porosus* is relatively easy to hunt as its nests are easy to locate, and as a consequence, it is now rare in the large mangrove areas of Gulf and Western Provinces and also in East and West Sepik Provinces where it was once apparently common.

Numbers of both species declined during the late 1950s and 1960s through indiscriminate hunting. In 1969, the Crocodile Trade (Protection) Act (Chapter 213) was implemented, placing a ban on trade in skins greater than 51 cm belly width. This halted further decline in crocodile numbers, as indicated by a steady level of export during the 1970s. In 1981, a ban was placed on trade in skins smaller than seven inches. This ban was established because Papua New Guinea was in a position to ranch crocodiles on a large scale (Bolton, 1978; Bolton & Laufa, 1979; Burgin, 1980b). By 1984, although the number of skins exported was the same as in previous years, 30% were from ranched animals and consequently were of higher grade and greater size. In 1982, extensive monitoring of both species commenced especially in the Ambunti District of the East Sepik Province. Between 1982 and 1985, the number of *C. porosus* nests virtually doubled in this area, indicating the effectiveness of the management policy.

Of the 150-200 species of lizard belonging to five families, only certain members of the dragon lizards (Agamidae) and Monitors (Varanidae) are habitually associated with water. The Water Monitor *Varanus indicus* and Gould's Monitor *V. gouldii* appear to be equally at home in freshwater or on land, although their food habits show them to be primarily land animals.

Of the six families of snakes recorded from Papua New Guinea, three are typically aquatic and can be expected in the still and slow-flowing waters of the lowlands. The file-snakes (Acrochordidae) include one or two genera with two or three species according to taxonomic opinion. The water-snakes of the family Colubridae (genera *Amphiesma*, *Cerberus*, *Enhydris*, *Fordonia* and *Myron*) are regular inhabitants of wetlands, although the family also includes many species restricted to land. Sea-snakes (Hydrophiidae) are represented by just over 20 species in eight genera. These are all marine, although *Enhydris* and *Schistosa* have been recorded in some northern rivers away from the sea. Several species are frequently seen in shallow water over reefs and presumably occur in mangrove waters.

There are six species of marine turtles in the seas around Papua New Guinea and two species of freshwater turtles, the Pit-shelled Turtle, *Carettochelys insculpta,* and the Soft-shelled Turtle *Pelochelys bibroni*. Both the freshwater turtles are found in fresh waters south of central cordillera; *C. insculpta* is almost totally restricted in distribution to southern Papua New Guinea, while *P. bibroni* is found also in the fresh waters of the Sepik wetlands and occurs west through Indonesia to India. Five species of tortoises (Chelidae) occur in the freshwater wetlands of Papua New Guinea (Goode, 1967). Four of these are found only south of the central cordillera, and are inhabitants mainly of still or slow-flowing water bodies. *Elseya novaeguineae* and *Chelodina siebenrocki* are endemic to New Guinea, and *Chelodina parkeri* is endemic to the Fly River Basin and coastal areas.

The avifauna of Papua New Guinea is relatively well documented, *e.g.* Beehler and Finch (1985) and Beehler *et al.* (1986). Of the 708 species of birds listed for New Guinea, some 115 are waterfowl, and all but three of these occur in Papua New Guinea. Seven species are endemic to the New Guinea region: the Forest Bittern *Zonerodius heliosylus*, Salvadori's Duck *Anas waiguiensis*, four mountain forest rails of the genus *Rallina* (*R. rubra*, *R. leucospila*, *R. forbesi* and *R. mayri*) and the New Guinea Flightless Rail *Megacrex inepta*. All are present in Papua New Guinea except for *R. leucospila*, which is confined to the mountains of the Vogelkop peninsula in Irian Jaya. About 52 species of waterfowl are breeding residents; the remainder are either passage migrants and winter visitors from Asia (over 40 species) or dry season visitors from Australia (about 20 species).

The breeding waterfowl include two grebes, two cormorants, *Anhinga novaehollandiae*, about 12 species of herons and egrets, *Ephippiorhynchus asiaticus*, *Anseranas semipalmata*, nine species of ducks, 15 species of Rallidae, *Grus rubicunda*, *Irediparra gallinacea* and six species of shorebirds (including the Rufous Woodcock *Scolopax saturata*). The great majority of passage migrants and winter visitors from Asia are shorebirds (30 regular species and seven vagrants). Several of these occur in very large numbers *en route* to and from the wintering areas in Australia. Other northern migrants occurring in significant numbers include *Ixobrychus sinensis*, *Anas querquedula*, *Chlidonias leucoptera*, *Sterna hirundo* and *S. albifrons*. Regular migrants from Australia include *Pelecanus conspicillatus*, several herons and egrets, *Threskiornis molucca*, *Carphibis spinicollis*, *Plegadis falcinellus*, *Platalea regia*, *Haematopus longirostris*, *Stiltia isabella*, *Charadrius cinctus*, *Larus novaehollandiae*, *Chlidonias hybrida* and *Hydroprogne caspia*. In addition, several species which breed in Papua New Guinea also occur as common dry season visitors from Australia.

There are no less than 22 species of kingfishers (Alcedinidae) in New Guinea, but many of these are birds of forest or savanna, and not particularly associated with water.

Of the 190-200 species of mammals occurring in Papua New Guinea, only four can be clearly tied to the presence of water; two species of lowland water-rat, *Hydromys chrysogaster* and *H. neobrittanicus,* and two upland species, *Crossomys moncktoni* and *Hydromys habbema*. These occur in slow flowing and fast flowing rivers, particularly with clear water, but are not common elements of the wetland fauna. Mention should also be made of the introduced deer, the Javan Rusa, *Cervus timorensis*, which occurs in large numbers in the seasonally-flooded trans-Fly area, and in lesser numbers in wetland areas near Port Moresby. These populations are typically swamp-dwellers, and frequently graze with their head submerged.

Wetlands and Climate Change

Significant work has been carried out recently to predict the implications of climate change in the South Pacific, and a number of papers describe the likely effects on wetlands in Papua New Guinea (Bualia, 1990; Chappell, 1990; Hughes & Bualia, 1990; Pernetta & Osborne, 1990). Physical consequences include shoreline retreat, increased flooding and enhanced salt water intrusion. The mangrove habitats fringing the Gulf of Papua are likely to undergo substantial reduction in area, with compression of existing zones as a result of sea-level rise. It is likely that the reduction in nursery areas for penaeid prawns may have significant impacts on the size of this commercial resource, and the fish community will possibly decrease in both diversity and abundance. It is likely that following a rise in sea-level, flooding of the low-lying land along the Fly River will be more frequent and of longer duration. Pernetta and Osborne (1990) recommend that a detailed study of how sediment deposition in Lake Murray and the lakes of the middle Fly region, particularly with regard to mercury and heavy metals, may change with higher river levels.

Wetlands and Mine Waste Disposal

The Ok Tedi mine, located in the upper catchment of the Ok Tedi, a tributary of the Fly River, is one of the largest open-cut copper and gold mines in the world. Waste rock and tailings are currently dumped into the Ok Tedi, and Pickup *et al.* (1981) identified increased sediment loads leading to increased siltation and enhanced heavy metal concentrations in the water and sediments as two potential, detrimental effects on the middle Fly wetlands. Natural Systems Research (1988) indicated that the principal environmental threat from the Porgera copper and silver mine in Enga Province is through disposal of mine waste into the Laiagap-Strickland River system. This mine started production in 1990. Environmental consequences similar to those identified for the Ok Tedi mine are listed by Natural Systems Research (1988), with the additional complication that the Porgera mine tailings are higher in mercury than the natural suspended sediment load of the Strickland River. High levels of mercury in fish of the Fly-Strickland River systems have been known for some time (Lamb, 1977; Kyle & Ghani, 1982a, 1984). Furthermore, Kyle and Ghani (1982b) recorded elevated concentrations of mercury in the hair of the people living round Lake Murray. The Herbert River, which drains Lake Murray into the Strickland, has been shown to reverse flow on occasions, a result of the flatness of the topography and marked seasonal fluctuations in the water level of Lake Murray and the Strickland River (Natural Systems Research 1988; Osborne *et al.*, 1987). This discovery indicated a pathway by which mine wastes could accumulate in Lake Murray.

Mowbray (1988a, 1988b) predicted that the effects of tailings from the Ok Tedi mine would probably be confined to the upper reaches of the Ok Tedi but that chronic effects could extend down the Fly River. Even the mining company projected that the impact on the Middle Fly would be fewer fish species in reduced numbers (Townsend, 1988). Osborne *et al.* (1988) showed that sediments transported by the Fly River are deposited in Lake Daviumbu, a backswamp of the Middle Fly region. This contrasts with the environmental impact assessment which predicted that little river-borne sediment was expected to reach these backswamps (Maunsell & Partners, 1982). So far, apart from a number of critical incidents in the construction and operation of the Ok Tedi mine (see Townsend, 1988), it has not been possible to show that either of these mines is having or will have long term effects on the Middle Fly region, but the threat is real. They will, however, have major impacts on the upper reaches of these large river systems, but the distance downstream that these effects may extend is unknown.

Wetland Area Legislation

There is no specific environmental legislation directed primarily towards the conservation of wetlands. Protection is afforded however under a number of Acts.

The Conservation Areas Act 1978 allows for the establishment of "Conservation Areas", these being areas of land deemed worthy of legal protection for a variety of reasons. Assent for, and control of, each Conservation Area is the responsibility of the landowners.

The Fauna (Protection and Control) Act 1974-1982 allows for the systematic management, use and conservation of the fauna of Papua New Guinea. Wildlife Management Areas may be established under this Act. These are similar to Conservation Areas, but their purpose is restricted to the management of wildlife resources, whereas a Conservation Area may be established for its scenic, aesthetic or historic values. The establishment of Wildlife Management Areas throughout Papua New Guinea has led to the publication of a set of rules for the management of each area. As each area is established for a different purpose, each set of rules differs from all others.

The National Parks Act of 1982 allows for the establishment, on state-owned or long-leased land, of a series of National Parks protecting areas of outstanding scenic and scientific value.

The Crocodile Trade (Protection) Act 1974-1982 allows for the control of the crocodile industry on a systematic basis and provides regulations promoting the conservation of crocodiles on a sustained yield basis. There are thirteen regulations under this Act, dealing with control over buying, exporting, farming and licensing. The responsibility for enforcing these regulations lies with Rangers. For the purpose of this Act, any person appointed as a Ranger under the Fauna Protection Act is also a Ranger under the Crocodile Trade (Protection) Act.

The International Trade of Endangered Species of Fauna and Flora Act 1979 allows for the control, on a co-operative basis, of the export and import of certain wildlife species among countries which are signatories to the international agreement (CITES).

The Dumping of Wastes at Sea Act 1981 allows for the control of pollution of the seas surrounding Papua New Guinea. Dumping of Wastes at Sea Regulations 1980 deal principally with permits and fees; they also designate as Enforcement Officers the Principal Environmental Contaminants Officer, Department of Environment and Conservation, and the Marine Officer (Search and Rescue), Department of Transport and Civil Aviation.

The Environmental Contaminants Act 1978 allows for the control of a wide range of pollutants (including noise) which could be detrimental to the environment. Regulations are currently being drafted for gazetting under this Act.

The Environmental Planning Act 1978 allows for control over exploitation of environmental resources, and requires the preparation of an Environmental Impact Statement for projects which may have massive and long-term effects upon the quality of the environment after the project has finished. There are no regulations gazetted under this Act. A detailed set of guidelines for developers has, however, been prepared by the Department of Environment and Conservation.

The Water Resources Act can regulate land drainage, river/stream channels (diversion and damming) and the disposal of wastes to land, swamps and water courses and bodies. It encompasses both fresh and saline waters to the territorial boundaries of Papua New Guinea. It is empowered to declare Water Control Districts which are specifically designed for the protection of public water supply but could also be used to include environmental conservation.

Papua New Guinea is a signatory to the following international agreements with environment-conservation implications:

- International Plant Protection Convention, Rome 1951.
- International Convention for the Prevention of Pollution of the Sea by Oil, London 1954.
- Plant Protection Agreement for the South East Asia and Pacific Region, Rome 1956.
- International Convention on Civil Liability for Oil Pollution Damage, Brussels 1969.
- International Convention on the Prevention of Marine Pollution by Dumping of Wastes and other Matter, London, Mexico City, Moscow 1972.
- International Convention on International Trade in Endangered Species of Wild Fauna and Flora, Washington 1973 (CITES Treaty).
- International Convention on the Conservation of Nature in the South Pacific, Apia 1976.
- International Convention on the Prohibition of Military or any other Hostile Use of Environmental Modification Techniques, New York 1976.
- United Nations Convention on the Law of the Sea, Montego Bay 1982.
- International Convention for the Protection of the Natural Resources and Environment of the South Pacific, 1986 (SPREP Convention).
- International Convention on Biological Diversity, Rio de Janeiro 1992.

Wetland Area Administration

The Department of Environment and Conservation is charged with the responsibility of protecting the natural habitats and conserving the wildlife of Papua New Guinea. However, as most land is traditionally owned, the acquisition of land for conservation is difficult. The Department of Forests is responsible for the timber resources including mangrove forests, and the Department of Fisheries and Marine Resources is responsible for all fish resources.

Organizations involved with Wetlands

a) Governmental Organizations

- Department of Environment and Conservation
  Includes the Division of Water Resources, Division of Nature Conservation and Division of Environment.
- Department of Forestry
  Includes the Forest Products Research Centre in the National Capital District and the Forestry Research Institute in Lae.
- Department of Fisheries and Marine Resources
  Includes the Fisheries Research Institute in Kanudi.
- Department of Agriculture and Livestock.
  Includes the Aquatic Weed Control Unit in Wewak.
- Department of Lands and Physical Training
  Includes the National Mapping Bureau.

b) Statutory Authorities

- University of Papua New Guinea

Particularly the Biology Department and Motupore Island Research Department.

c) Non-Governmental Organizations

- Papua New Guinea Bird Society
  Based in the National Capital District.
- Christensen Research Institute
  Based in Madang.
- Wau Ecology Institute
  Based in Wau.

WETLANDS

The 33 wetlands listed below are described in *A Directory of Asian Wetlands*. The site accounts were taken from a *Draft Inventory of Wetlands in Papua New Guinea* compiled by Patrick L. Osborne for the Department of Environment and Conservation (Osborne, 1987).

1. Sepik and Ramu Floodplains, West Sepik, East Sepik and Madang Provinces: 1,200,000 ha
2. Lake Wisdom, Madang Province: 8,592 ha
3. Markham Floodplain, Morobe Province: 196,400 ha
4. Lake Wanum, Morobe Province: 404 ha
5. Red Hill Swamp, Morobe Province: 320 ha
6. Lake Yanamugi, Morobe Province: 350 ha
7. Mambare Wetland, Northern Province: 344,100 ha
8. Musa Wetland, Northern Province: 179,700 ha
9. Lake Lavu, Milne Bay Province: 264 ha
10. Sawataetae Wildlife Management Area, Milne Bay Province: 700 ha
11. Rakua Wetland, Milne Bay Province: 59,000 ha
12. Mullins Harbour Wetland, Milne Bay Province: 127,700 ha
13. Wetlands of Central Province: 1,240,000 ha
    Includes:
    - Waigani Swamp: 120 ha
    - Lea Lea Salt Flats: area unknown
    - Lake Iaraguma: 200 ha
    - Kanosia Lagoon: 30 ha
    - Aroa Lagoon: 150 ha
    - Hisiu Lagoon: 50 ha
14. Kikori Wetlands and Purari River, Gulf Province: 1,331,300 ha
15. Fly River Floodplain, Western Province: 4,500,000 ha
    Includes:
    - Lake Murray: 64,700 ha
    - Boset Lagoon: 1,680 ha
    - Lake Daviumbu: 1,168 ha
16. Bensbach River and Tonda Wildlife Management Area, Western Province: 590,000 ha
17. Lake Birip, Enga Province: 2.9 ha
18. Lake Ipea and Sirunki Basin, Enga Province: 2,900 ha
19. Lake Onim, Southern Highlands Province: 16 ha
20. Lake Papapli, Enga Province: 120 ha
21. Lake Parago, Enga Province: 36 ha
22. Lake Kutubu, Southern Highlands Province: 4,924 ha

23. Lake Wololo, Southern Highlands Province: 4 ha
24. Lake Wongabi, Southern Highlands Province: 4 ha
25. Lake Kopiago, Southern Highlands Province: 150 ha
26. Malai Wetland, Manus Province: 14,700 ha
27. Kelaua Wetland, Manus Province: 10,000 ha
28. Namo Wetland and Lake Namo, West New Britain Province: 100,000 ha
29. Lake Dakataua, West New Britain Province: 4,920 ha
30. Lake Hargy, West and East New Britain Provinces: 930 ha
31. Toriu Wetland, East New Britain Province: 81,300 ha
32. Empress Augusta Bay Wetland, North Solomons Province: 90,100 ha
33. Abia Wetland and Lahala Lake, North Solomons Province: 29,700 ha

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PITCAIRN ISLANDS

INTRODUCTION

Area: 43 sq.km.

Population: 66 in January 1992.

The Pitcairn Islands are a group of four small islands situated between latitudes 23° and 26° South and longitudes 124° and 131° West in the South Pacific, about 2,000 km southeast of Tahiti and 1,900 km west of Easter Island. The group comprises Pitcairn Island (25°04'S, 130°06'W) and three uninhabited islands: Oeno (120 km northwest of Pitcairn), Henderson (200 km east-northeast of Pitcairn) and Ducie (472 km east of Pitcairn). Pitcairn itself is a high volcanic island of 450 ha with lava cliffs and rugged hills rising to a peak at 335 m. Henderson, the largest island in the group with an area of 3,700 ha, is a raised limestone atoll which rises to 33 m. Oeno (65 ha) and Ducie (70 ha) are both low coral atolls with maximum elevations of about 4 metres.

The climate is subtropical, with an average annual rainfall of about 2,000 mm spread evenly throughout the year. Henderson is somewhat drier than Pitcairn, with 1,620 mm of rainfall in 1991/92 compared with 2,170 mm on Pitcairn in the same period. Mean monthly temperatures range from 24°C in January to 19°C in July. The Southeast Trades predominate.

The Pitcairn Islands are a British Crown Colony, with the British High Commissioner to New Zealand holding the position of Governor. Most of the 66 inhabitants are direct descendants of the mutineers from H.M.S. Bounty and their Polynesian consorts, who reached the islands in 1790. In 1856, the 194 inhabitants were moved to Norfolk Island, off the east coast of Australia, but by 1864, 43 of the islanders had returned, and Pitcairn has been permanently settled since then. The local economy is based on subsistence agriculture, the fertile volcanic soils of Pitcairn producing a wide variety of tropical and subtropical crops. Some fruit, vegetables and handicrafts are sold to passing ships running between New Zealand and Panama. A re-afforestation scheme was introduced in 1963 with emphasis on the planting of miro trees (*Thespesia populnea*) which provide the wood used in making handicrafts.

The islands are of particular conservation importance for their endemic plants and invertebrates, endemic land-birds (four on Henderson Island), globally significant breeding populations of seabirds (especially gadfly petrels *Pterodroma* spp.), and non-breeding populations of the threatened Bristle-thighed Curlew (*Numenius tahitiensis*). The main interest in the coral reefs is their isolated and undisturbed location at the geographical limit of reef growth. The breeding population of Green Turtles (*Chelonia mydas*) at East Beach on Henderson Island may also be of international importance.

Summary of Wetland Situation

The Pitcairn Islands have very few freshwater habitats. Pitcairn itself has some permanent streams as well as a number of intermittent streams, but there do not appear to be any permanent freshwater ponds or marshy habitats. No fresh water is known to occur on the other three islands except for cave drips on Henderson and freshwater lenses on Oeno. The only other wetland habitats in the islands are coral reefs, reef flats and beaches. Coral reefs are well developed on Oeno and Ducie and surround most of Henderson, but are poorly developed around Pitcairn (Hepburn *et al.*, 1992). There are three large discrete coral sand beaches on Henderson.

Only seven species of waterbirds are known from the islands. The Pacific Reef-Heron (*Egretta sacra*) has been recorded on Henderson and Oeno. The flightless Henderson Island Crake (*Porzana (Nesophylax) atra*) is confined to Henderson where it remains common, and the Spotless Crake (*Porzana tabuensis*) has been reported from Oeno. Wandering Tattlers (*Heteroscelus incanus*) and Bristle-thighed Curlews (*Numenius tahitiensis*) are fairly common non-breeding visitors to the beaches and reef flats during the austral summer, and the Pacific Golden Plover (*Pluvialis fulva*) and Sanderling (*Calidris alba*) have been recorded (Williams, 1960; Pratt *et al.*, 1987; M. de L. Brooke, pers. comm.). The relatively large numbers of Bristle-thighed Curlews (a threatened species) on Henderson and Oeno are of international significance. Green Turtles (*Chelonia mydas*) nest on the largest beach on Henderson.

No protected areas have been established in the islands, but the extreme isolation of Henderson, Oeno and Ducie affords these uninhabited islands a considerable degree of protection. Henderson Island was inscribed as a World Heritage Site under the Unesco World Heritage Convention in 1988. Hepburn *et al.* (1992) have recently discussed the application of the Convention on Wetlands of International Importance especially as Waterfowl Habitat (the Ramsar Convention) to the Pitcairn Islands, and have concluded that the two low-lying coral atolls of Oeno and Duce and the beaches and inshore reefs of Henderson would be suitable for designation as Wetlands of International Importance under the terms of the Convention.

Wetland Research

Despite a substantial number of visits by scientists and naturalists to one or more of the Pitcairn Islands in the last century, the islands remain relatively poorly known. A major independent multi-disciplinary expedition, based on Henderson Island from January 1991 to March 1992, has gathered a considerable amount of information on the current and historical ecology of Henderson and on the other islands in the group. Thirty-four individuals from seven countries participated in this expedition. Much of the information has yet to be analyzed and presented, but early results from the expedition (Brooke *et al.*, 1991; Weisler *et al.*, 1991) provide a substantially improved basis for assessing the conservation value of the islands' biota (Hepburn *et al.*, 1992). One of the objectives of the Pitcairn Islands Scientific Expedition was to assess the potential for designation of Oeno and Ducie atolls as Wetlands of International Importance under the terms of the Ramsar Convention.

Wetland Area Legislation

Conservation legislation in the Pitcairn Islands has recently been reviewed by Hepburn *et al.* (1992). There is no specific conservation policy for the islands, and there appears to be no specific legislation covering the protection of sites for conservation purposes. The Ordinances (Local Government Regulations, 1971) cover wildlife protection and fisheries management. The legislation generally prohibits the killing of wild birds or taking of their eggs, or, subject to the authority of the Wild Bird Protection Committee, controls the extent to which certain prescribed species may be exploited. An amendment in 1982 adds species which are protected (three whales, three seabirds and two turtles), and sets conditions under which they may be captured, killed or harassed. This amendment also extends protection to migratory species as a means of implementing the Convention on the Conservation of Migratory Species of Wild Animals (the Bonn Convention) within the Pitcairn Islands.

The Pitcairn Islands are included in the UK ratification of the Ramsar Convention.

Wetland Area Administration

The Pitcairn Islands Council has ultimate responsibility for the implementation of any management decisions which might affect natural ecosystems including wetlands.

Organizations involved with Wetlands

Pitcairn Islands Council
- Wild Bird Protection Committee

WETLANDS

Site descriptions compiled from information provided by J.R. Setterfield (Office of the Governor of Pitcairn Island), M. de L. Brooke and I. Hepburn.

Oeno Atoll (1)

Location: 23°56'S, 130°44'W; in the central South Pacific, 120 km northwest of Pitcairn.
Area: Land area, 65 ha; land, reef and lagoon, 1,600 ha.
Altitude: Sea level to 3.6 m.
Overview: A seldom visited, ecologically undisturbed atoll with a significant wintering population of Bristle-thighed Curlews (*Numenius tahitiensis*) and large breeding populations of seabirds.
Physical features: A low coral atoll comprising a central islet surrounded by a lagoon, mostly 3-6 m in depth, which in turn is surrounded by a fringing reef within which there are many smaller reefs. An interesting northward shift of the islet, the result of erosion and deposition under the influence of the prevailing Southeast Trades, has taken place in the last 150 years.
Ecological features: *Montipora* is the dominant coral genus, with *Acropora* also common. Other genera recorded are *Pocillopora*, *Psammocora*, *Pavona*, *Porites*, *Cyphastrea*, *Plesiastrea* and *Montastrea*. The terrestrial vegetation is atoll forest and scrub with a few coconuts.
Land tenure: State owned (Crown Land).
Conservation measures taken: None. Considerable protection is afforded by the extreme remoteness of the island.
Conservation measures proposed: Oeno was proposed for listing as an "Island for Science" in 1969 (Elliot, 1973). Hepburn *et al.* (1992) have recommended that the entire atoll be designated as a Ramsar Site. Hepburn (in prep) recommends that the island be made rat-free to provide a secure nesting site for seabirds, especially gadfly petrels (*Pterodroma* spp.) which are heavily predated by Polynesian Rats on Henderson.
Land use: Uninhabited, but usually visited once a year (and sometimes more) by about 30 Pitcairn islanders for a fishing holiday. Occasionally visited by the crews of passing yachts (about five a year).
Possible changes in land use: Various persons in Mangareva (Gambier Islands, French Polynesia) have expressed interest in the establishment of black pearl oyster farms in the lagoon.
Disturbances and threats: Introduced Polynesian Rats (*Rattus exulans*) are present. The disturbance associated with the proposed establishment of oyster farms might be detrimental to the seabird populations, especially if the latter were harvested. Fishing in the lagoon and the harvesting of shells could also be damaging to the lagoon ecosystem. The Pitcairn islanders have recently

expressed a desire to plant coconuts and other exotic species on the island.
Hydrological and biophysical values: None known.
Social and cultural values: A "holiday resort" for Pitcairn islanders.
Noteworthy fauna: The island supports a significant wintering population of Bristle-thighed Curlews (*Numenius tahitiensis*) (about 100 individuals), and a large breeding population of seabirds, including about 8,000-10,000 pairs of Murphy's Petrels (*Pterodroma ultima*), 250 pairs of Red-footed Boobies (*Sula sula*), 250 pairs of Masked Boobies (*S. dactylatra*) and 100 pairs of Great Frigatebirds (*Fregata minor*). Coconut Crabs (*Birgus latro*) occur on the island, and the undisturbed lagoon supports prolific fish populations.
Noteworthy flora: There are no endemic species of plants on the island, but this constitutes the extreme southeastern limit for several species (*e.g. Hedyotis romanzoffiensis*). *Tournefortia argentea* grows to the exceptional height of 8 m.
Scientific research and facilities: The island was briefly visited by a Smithsonian Expedition in 1987. Scientists from the Pitcairn Islands Scientific Expedition (based on Henderson) visited the island at approximately three-monthly intervals during 1991 and early 1992.
Recreation and tourism: Roughly once a year, the island is visited by about 30 Pitcairn islanders for a holiday of one week.
Management authority and jurisdiction: Pitcairn Islands Council in conjunction with the British Consulate-General in Auckland (New Zealand).
References: Dahl (1980, 1986); Elliot (1973); Hepburn (in prep); Hepburn *et al.* (1992); Philipson & St. John (1960); UNEP/IUCN (1988); Williams (1960).
Reasons for inclusion: 1a, 2a, 2c. One of the least disturbed atolls in southeastern Polynesia, with an internationally important wintering population of Bristle-thighed Curlews.
Source: M. de L. Brooke.

Henderson Island (2)

Location: 24°22'S, 128°20'W; in the central South Pacific, 200 km ENE of Pitcairn Island.
Area: Land area, 3,700 ha; area of beaches and reef flats unknown.
Altitude: Sea level to 33 m.
Overview: One of the least disturbed raised coral atolls in the world, with its terrestrial ecosystems virtually intact. The island supports a large breeding population of seabirds, and has four endemic land-birds, one of which is a flightless rail. The beaches and reef flats are important for wintering Bristle-thighed Curlews (*Numenius tahitiensis*).
Physical features: A raised coral atoll composed of coralline limestone, with a slight depression in the centre considered to be an uplifted lagoon. The island is arid, with no surface fresh water except for some drippings in caves, a few very small fresh to brackish pools at the South End (which appear to be rain-fed and become increasingly saline through evaporation and salt-spray), and small amounts of rainwater trapped in vegetation, such as at the base of *Asplenium* leaves. Fresh or brackish springs have been located below high tide level at North Beach and Northwest Beach. No readily available source of groundwater has yet been located. The surface of the island is largely reef rubble, with some areas of dissected limestone, especially around the periphery. The island is surrounded by steep cliffs of bare limestone. There is a fringing reef averaging 50-100 m in width around most of the island except in the extreme south and west. In three places, North Beach, Northwest Beach and East Beach, the reef extends up to 200 m offshore, and is backed by a wide, gently shelving coral sand beach over bedrock which is partly exposed. The reef off the East Beach has a poorly developed lagoon; those off the North and Northwest beaches are seawardly sloping reef platforms without a well-defined reef crest. There are two narrow channels through the reef on the north and northwest coasts. Tides are semi-diurnal, with a tidal range at spring tides of about one metre.

The island lies in the Southeast Trades, and probably has a mean annual rainfall of about 1,500 mm. The recorded rainfall during the period February 1991 to January 1992 was 1,620 mm.
Ecological features: Coral cover on the fringing reef is about 5%, dominated by *Pocillopora* with *Millepora* becoming dominant at depths greater than 7 m. The top of the island is densely vegetated with tangled scrub and scrub forest, 5-10 m tall, except in the central part of the depression, which is more sparsely vegetated. The tallest trees are screwpine *Pandanus tectorius*; other trees include the endemic sandalwood *Santalum hendersonense*, *Myrsine hoskae*, *Celtis paniculata* var. *viridis*, and two shrubby endemic varieties of *Bidens hendersonensis*. Some coconuts have been planted near the main landing sites, close to which the Pitcairners harvest hardwoods. Otherwise the vegetation is largely undisturbed.
Land tenure: State owned (Crown Land).
Conservation measures taken: Henderson Island has not been declared a protected area as such, although it receives *de facto* protection from its isolation and various restrictions on possession, occupation and transference of land applied under the Lands and Administration of Estates Ordinance (IUCN, 1991). Access to the island requires a licence issued by the Governor following approval by the Pitcairn Islands Council. Henderson Island was inscribed as a World Heritage Site under the Unesco World Heritage Convention in 1988, but no formal management of the site has yet been undertaken. The UK Joint Nature Conservation Committee has recently commissioned the production of a draft management plan for the World Heritage Site.
Conservation measures proposed: Henderson was proposed for listing as an "Island for Science" in 1969 (Elliot, 1973), and recommended as a reserve by the IUCN Threatened Plants Committee (Dahl, 1980). It has also been suggested that the island be declared a Biosphere Reserve under Unesco's Man and the Biosphere Programme. The draft management plan (Hepburn, in prep) recommends that Local Government Regulations be amended to provide appropriate protection to the World Heritage Site. Hepburn *et al.* (1992) have recommended that the coastal and inshore marine zones of the island be designated as a Ramsar Site.
Land use: Henderson was apparently colonized by Polynesians between about 800 and 1600 AD, but has remained uninhabited in modern times. Pitcairn islanders visit the island roughly once a year, normally for one day, to cut and remove timber (*Cordia subcordata* and *Thespesia populnea*) from the woodlands behind the beach. The wood is used for carving handicrafts for sale to visitors. The island is occasionally visited by passing yachts and natural history cruise ships.
Disturbances and threats: Goats and pigs were introduced to the island in the early part of this century but did not survive. Introduced Polynesian Rats (*Rattus exulans*) are, however, still present, and cause devastating predation on the chicks of three species of gadfly petrel, *Pterodroma neglecta*, *P. heraldica* and *P. ultima*. The terrestrial vegetation is still largely pristine, with very few exotics, although there are two substantial coconut groves at the principal landing sites. A proposal in 1982/83 by an American millionaire to settle on Henderson was given serious consideration by the British authorities. The development would have included clearance of forest in order to graze cattle, the building of an airfield, and the introduction of other farm stock. The proposal was finally rejected on environmental and technical grounds. There has been some anchor damage to the coral reefs. Reef blasting to improve the landing passage would be detrimental, as would the introduction of any alien plants or animals.
Hydrological and biophysical values: None known.
Social and cultural values: Miro trees (*Thespesia populnea*) and Toa (*Cordia subcordata*) are of value to the Pitcairn islanders as a source of wood for carving.
Noteworthy fauna: The beaches and reef flats are used by a wintering population of some 40-50 Bristle-thighed Curlews (*Numenius tahitiensis*), most of which arrive in early September and depart in April. Small numbers of Wandering Tattlers (*Heteroscelus incanus*) and Sanderlings (*Calidris alba*) also occur on the beaches. The island is very important for its large breeding population of seabirds, estimated at 50,000-80,000 pairs. These include 10,000-20,000 pairs of Kermadec Petrels (*Pterodroma neglecta*), 30,000 pairs of Herald Petrels (*P. heraldica*), several thousand pairs of Murphy's Petrels (*P. ultima*), 200-300 pairs of Red-tailed Tropicbirds (*Phaethon rubricauda*), 50-60 pairs of Masked Boobies (*Sula dactylatra*), a few hundred pairs of Red-footed Boobies (*S. sula*), 100 pairs of

Great Frigatebirds (*Fregata minor*), 100 pairs of Brown Noddies (*Anous stolidus*), small numbers of Black Noddies (*A. minutus*), possibly ten pairs of Blue-grey Noddies (*Procelsterna cerulea*) and very large numbers of Fairy Terns (*Gygis alba*) (Hepburn, in prep). The island has three endemic species of land-birds, the Henderson Island Rail (*Porzana (Nesophylax) atra*), Henderson Island Fruit-Dove (*Ptilinopus insularis*) and Stephen's Lorikeet (*Vini stepheni*), as well as an endemic subspecies of the Pitcairn Reed Warbler (*Acrocephalus vaughani taiti*). The rail is primarily a forest bird, foraging in the leaf litter for insects and molluscs. Although still common, this flightless and tame species would be at considerable risk from introduced predators and is therefore listed as threatened in the IUCN Red Data Book (Collar & Andrew, 1988). The total population was estimated at about 4,700 pairs in 1991/92 (Hepburn, in prep). The lorikeet appears to be rather uncommon, and is also listed as threatened.

The only mammal present is the introduced Polynesian Rat (*Rattus exulans*). Green Turtles (*Chelonia mydas*) nest on East Beach, where up to 30 scrapes were reported in 1991/92. There is one species of skink (*Emoia cyanura*), which appears to be abundant throughout the island, and two species of gecko, one of which (as yet unidentified) may be endemic. Coconut Crabs (*Birgus latro*) are present. Possibly all of the island's 14 or so species of land snail and about 30% of the island's 170 species of insect are endemic. The proportion of endemic species in some other invertebrate groups is given by Hepburn (in prep). The coral reefs support a diverse marine fauna, although fish species are relatively few (UNEP/IUCN, 1988).

Noteworthy flora: Henderson supports a rich and almost undisturbed terrestrial flora, with 72 species of vascular plants, ten of which are endemic to the island. The two endemic varieties of the shrub *Bidens hendersonense* are of particular botanical interest.

Scientific research and facilities: A number of scientific expeditions have visited the island, including the Whitney South Sea Expedition in 1922 and the Mangarevan Expedition in 1934. A multi-disciplinary scientific expedition (the Pitcairn Islands Scientific Expedition) was based on the island from January 1991 to March 1992. The major results of this expedition are likely to be available in 1994.

Recreation and tourism: The island is occasionally visited by passengers from cruise ships, with groups of up to 100 people landing at a time.

Management authority and jurisdiction: Pitcairn Islands Council in conjunction with the British Consulate-General in Auckland (New Zealand).

References: Collar & Andrew (1988); Dahl (1980, 1986); Elliot (1973); Hay (1985); Hepburn (in prep); Hepburn *et al.* (1992); IUCN (1991); St. John & Philipson (1962); UNEP/IUCN (1988).

Reasons for inclusion: 1a, 2a, 2b, 2c, 2d. Henderson is of outstanding value as the world's best remaining example of a raised coral atoll ecosystem. The reef flats and beaches support an internationally significant wintering population of Bristle-thighed Curlews.

Source: J.R. Setterfield, I. Hepburn and references.

Ducie Atoll (3)

Location: 24°40'S, 124°47'W; in the central South Pacific, 472 km east of Pitcairn Island and 1,336 km WNW of Easter Island.

Area: Land area, 70 ha; land, reef and lagoon, 320 ha.

Altitude: Sea level to 4 m.

Overview: A seldom visited, exceptionally undisturbed atoll; the easternmost atoll in the Indo-Pacific biogeographic region, possessing a pure, though impoverished, Polynesian biota.

Physical features: A small coral atoll comprising a main island (Acadia) and three smaller islets or "motu" (Edwards, Pandora and Westward) encircling a lagoon approximately 1.5 km in diameter. The islands are composed of coral rubble, echinoid remains and dead shells. Acadia is largely surrounded by reef flats, the reef to the northwest consisting for the most part of a somewhat uneven reef pavement flat. Small channels between the lagoon and the ocean are found at the northernmost extension of Westward and western end of Acadia, but these have little influence on water exchange within the lagoon. The greatest seaward extension of the reef is at the southwest, where the shelf extends 270 m offshore to a depth of 30 m. There is a regular semi-diurnal tide. Salinity in the lagoon is about 38 p.p.t., and water temperature averages 26.5°C.

Ecological features: The reef flats are generally covered by a thin layer of sand and fine algal growth. There is a fair amount of coral cover in the lagoon, the dominant genera being *Montipora* and *Astreopora*. The lagoon floor between the patch reefs consists of fine white sand. The outer reef has fairly good coral cover, with very high cover (as much as 50%) recorded in deeper water. Corals of the genera *Acropora* and *Montipora* dominate. Terrestrial vegetation is confined to Acadia, and comprises an impoverished atoll scrub dominated by *Tournefortia*. There is also one *Pemphis* bush.

Land tenure: State owned (Crown Land).

Conservation measures taken: None. Considerable protection is afforded by the extreme remoteness of the island.

Conservation measures proposed: Ducie was proposed for listing as an "Island for Science" in 1969 (Elliot, 1973). Hepburn *et al.* (1992) have recommended that the entire atoll be designated as a Ramsar Site.

Land use: The atoll is visited very infrequently (less than five times a year) by passing yachts and cruise ships, but because of the difficulty in landing, few people set foot on the islands.

Disturbances and threats: Polynesian Rats (*Rattus exulans*) are present, but apparently cause relatively little predation on nesting sea-birds. There is a possibility that the crews of passing fishing boats occasionally land on the islands to harvest seabirds. In 1970, there was evidence of a relatively recent mass mortality of corals, the cause of which was not identified, although a sudden drop in water temperature was postulated. Some recovery seemed to have occurred by 1987 (UNEP/IUCN, 1988).

Hydrological and biophysical values: None known.

Social and cultural values: Limited value for tourism.

Noteworthy fauna: Ducie Atoll is particularly important for its large breeding populations of sea-birds. The island supports probably the world's largest breeding colony of Murphy's Petrels (*Pterodroma ultima*), with around 250,000 pairs, as well as about 20,000 pairs of Kermadec Petrels (*P. neglecta*) and 20,000 pairs of Herald Petrels (*P. heraldica*). Other breeding seabirds include Christmas Shearwater (*Puffinus nativitatis*), Red-tailed Tropicbird (*Phaethon rubricauda*), boobies (*Sula* spp.), Great Frigatebird (*Fregata minor*), Sooty Tern (*Sterna fuscata*), Brown Noddy (*Anous stolidus*), Blue-grey Noddy (*Procelsterna cerulea*) and Fairy Tern (*Gygis alba*). Three species of migrant shorebirds have been reported, Wandering Tattler (*Heteroscelus incanus*), Bristle-thighed Curlew (*Numenius tahitiensis*) and Sanderling (*Calidris alba*), but numbers are generally low (less than 20). There are no land-birds, and the only mammal present is the Polynesian Rat (*Rattus exulans*). Two species of land hermit crab (*Coenobita* spp.) have been recorded. The fish fauna is considered to be impoverished; only 138 species were recorded by Rehder and Randall (1975), with 15 of these being confined to southeastern Oceania. However, the island has a reputation for its large shark population. Insects, crustaceans, echinoderms and corals are listed by Rehder and Randall (1975).

Noteworthy flora: The island is exceptional for the paucity of its flora; only two species of vascular plants are known.

Scientific research and facilities: The island was visited by the Whitney South Sea Expedition in 1922, by the 1970-71 National Geographic Society-Oceanic Institute Expedition to Southeast Oceania, and by Operation Raleigh in 1987. Scientists from the Pitcairn Islands Scientific Expedition (based on Henderson) visited the island at approximately three-monthly intervals during 1991.

Recreation and tourism: The island has some value for "high-quality" tourism, *e.g.* for passengers from Society Expeditions cruise ships.

Management authority and jurisdiction: Pitcairn Islands Council in conjunction with the British Consulate-General in Auckland (New Zealand).

References: Dahl (1980, 1986); Elliot (1973); Hepburn *et al.* (1992); Rehder & Randall (1975);

UNEP/IUCN (1988).
Reasons for inclusion: 1a, 2a, 2c. An exceptionally undisturbed atoll ecosystem and one that, by virtue of its geographical location, is likely to remain so.
Source: M. de L. Brooke and references.

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SOLOMON ISLANDS

INTRODUCTION

by Tanya Leary

Area: 28,450 sq.km

Population: 285,176 (1986 census); 328,695 (1991 estimate).

Solomon Islands is an independent island nation. The archipelago extends over approximately 860 km of the Southwest Pacific, in a northwest, southeast direction roughly between latitudes 5°S and 12°S and longitudes 152°E and 170°E. Continuing the island chain to the northwest is the island of Bougainville which is politically a part of Papua New Guinea, and offset to the southeast is the nation of Vanuatu. The Australian mainland lies some 1,600 km to the southwest.

The Solomon Islands consist of a double chain of six major islands with approximately 992 smaller islands, atolls, and reefs peripheral to and intermingled with them. The islands range from large, rugged and mountainous islands clothed with luxuriant primary rainforest (the largest being Guadalcanal with an area of 5,310 sq.km), to small, bare sand and coralline atolls. The Solomon Islands form part of the Pacific "Ring of Fire", and there is hence constant seismic activity including earthquakes and volcanoes. The larger islands are almost entirely of volcanic origin and consist of a range of lavas. Because of their recent emergence, most islands are surrounded by uplifted coral terraces. The larger islands are characterized by extreme ruggedness as ridge-valley landscapes predominate with moderately high to very high relief. Undulating rolling landscapes have a limited distribution and extensive fluvial plains are exceptional.

The proximity of the Solomon Islands to the equator give them a typically tropical climate with relatively high and uniform temperature, high humidity and abundant rainfall. The mean annual rainfall ranges from 3,000 to 5,000 mm, the wide variation depending on topography, latitude and orientation of the islands to prevailing winds. From May to October, the southeast trade winds blow, and during this time the southeast coasts of the larger islands experience peak rainfall, while the northwest coasts experience a dry season. From November to April, the wind is predominantly from the northwest, bringing heavy rains and cyclones. Very strong winds are associated with some cyclones, and entire swathes of forests can be defoliated and villages destroyed (Hansell & Wall, 1976).

The Solomon Islands has a population growth of 3.5%, and much of the population is concentrated in the coastal zone. The subsistence nature of the economy is reflected in the small proportion of salary earners - around 8.3% (Stats. Bull., 1990). Fish and fish products, logs and timber are the principal export earners for the Solomon Islands.

Summary of Wetland Situation

There has been very little scientific work carried out on the wetlands of the Solomon Islands. The last national map coverage of vegetation types was by Hansell and Wall (1976), and this is now very much out of date due to land clearing for subsistence agriculture and for commercial logging operations. A National Forest Resources Inventory is currently underway, and information on vegetation types (including wetlands) will be updated.

Table 1 lists the major wetland vegetation communities mapped by Hansell and Wall (1976).

Table 1: Wetland Vegetation Communities

SALINE SWAMP FOREST	
Low mangrove forest	80 km²
Tall mangrove forest	562 km²
FRESHWATER SWAMP FOREST	
Casuarina swamp forest	16 km²
Reed swamp (*Phragmites*)	47 km²
Herbaceous swamp	4 km²
Campnosperma swamp forest	51 km²
Mixed species swamp forest	631 km²
Pandanus swamp	83 km²
Sago palm swamp	19 km²
Terminalia swamp forest	288 km²

Mangroves are the most extensive wetland type in the Solomon Islands. Hansell and Wall (1976) found mangroves on most islands and covering large coastal areas on Isabel, New Georgia and Malaita. On Makira and Guadalcanal, mangroves are more or less confined to the eastern extremities at Star Harbour and Marau Sound respectively. The mangrove communities are characteristically species-poor by South East Asian standards, but rich by Australian standards. Woodroffe (1987) lists 19 species for the Solomon Islands. The most widespread genera are *Rhizophora* (four species) and *Bruguiera* (three species), while *Avicennia* (three species) occurs locally but not in large stands. Other mangrove species include two species of *Sonneratia* and single species of *Ceriops*, *Aegiceras*, *Xylocarpus*, *Lumnitzera*, *Osbornia*, *Scyphiphora* and *Nypa*.

Ten types of wetland vegetation are mapped by Hansell and Wall (1976), as follows:

Low Mangrove forest: Low (2-5 m) and sometimes stunted mangrove forests occur along the seaward margins of coastal swamps or locally in backswamp areas.

Tall Mangrove forest: This type is tall (up to 25 m) and occurs inland of low mangrove forest along river estuaries and around lagoons. It covers extensive areas on Isabel, on New Georgia and in the Maramasike Passage on Malaita. It is of mixed species composition.

Casuarina swamp forest: This type of swamp forest is found adjacent to ultramafic areas, and occurs only on San Jorge and Isabel on both sides of the Ortega Channel. The forest is medium to tall (up to 25 m), and is dominated by *Casuarina papuana*.

Reed Swamp: Small areas commonly dominated by *Phragmites karka* occur on most islands, often close to large rivers where they fill abandoned meanders. The ground cover largely consists of scattered small trees with a low cover of grasses, sedges or reeds.

Herbaceous swamp: This type is of limited occurrence. It has been identified at lakes on Makira, at lakes on San Jorge and at Lauvi Lagoon on Guadalcanal. It is generally found as a floating mat over deep water and grading into open water or sago swamp.

Campnosperma swamp forest: This forms widespread almost pure stands on Isabel and New Georgia, and is dominated by *C. brevipetiolatum*. It occurs in most swamps except on Guadalcanal and Makira where it has not been recorded.

Mixed species swamp forest: This is the most widespread of the swamp forest types and is found on all islands. The canopy contains a range of tree species with composition varying in different areas. Some of the common species are *Inocarpus fagiferus*, *Eugenia tierneyana*, *Intsia bijua*, *Barringtonia* spp., *Calophyllum vexans* and *Pterocarpus indicus*.

Pandanus swamp: Extensive areas of swamp forest with *Pandanus* species dominating a shrub layer up to seven metres in height occur on all the larger islands. On Guadalcanal, only small areas were noted at Lauvi Lagoon. The canopy is low and often broken, and may in places take a rather open appearance revealing a low herbaceous covering.

Sago Palm swamp: This forest type is dominated by the Sago palm *Metroxylon* sp. On Guadalcanal, some of the larger swamps contain almost pure stands of *Metroxylon sagu*. In other areas, scattered individual emergents of *Eugenia tierneyana*, *Inocarpus fagiferus*, *Erythrina orientalis* and *Pandanus* sp. are commonly associated with sago. Because of its importance in the economic life of village communities, sago has been distributed and planted around the islands so that many stands can be considered to be cultivated.

Terminalia swamp forest: This often occurs as almost pure stands of *Terminalia brassii* in freshwater swamps or scattered along water courses.

There are a number of small lakes or brackish lagoons throughout the Solomon Islands, but the two most notable are Lake Te-Nggano on Rennell and Lauvi Lagoon on Guadalcanal. Due to its isolation, the island of Rennell has a high proportion of endemic species. Lake Te-Nggano is most notable for an endemic species of sea krait (*Laticauda crockeri*) which is found nowhere else (McCoy, 1980). Lauvi Lagoon supports the largest single population of Estuarine Crocodiles (*Crocodylus porosus*) in the Solomon Islands. A national survey in 1989 (Messell & King, 1989) found that crocodile population was severely depleted. Messell and King estimated that the total population was only about 1,000 individuals, and concluded that the species was now threatened with extinction throughout the islands. Only a few scattered localities appeared to support viable populations.

The fauna of the Solomon Islands is of considerable international importance. With the exception of Papua New Guinea, the Solomon Islands have a greater diversity of animal species and higher level of endemism than any other Pacific island nation (Leary, 1991). Little is known of the ecology and habitat preferences of most animal species. However, at least some appear to be wetland dependent. For example, there is an endemic subspecies of the Mangrove Monitor *Varanus indicus spinulosus* which appears to occur only in the San Jorge and Thousand Ship Bay area, on both sides of the Ortega Channel. This area supports a distinctive vegetation community (*Casuarina* swamp forest), found nowhere else in the islands. Further taxonomic examination may reveal that *spinulosus* is in fact a distinct species. The preferred habitat of an endemic giant rat (*Uromys ponceleti*) is believed, by local residents, to be *Terminalia brassii* swamp forest. This giant rat is found only on Choiseul.

There are approximately 50 species of waterfowl and seabirds in the Solomon Islands (Mayr, 1945).

Of these only Becks' Petrel (*Pterodroma becki*) and Solomon's Sea Eagle (*Haliaeetus sanfordi*) are listed as globally threatened species (Collar and Andrews, 1989). However, Diamond (1987) also states that the Grey Teal (*Anas gibberifrons*) has not been recorded in the Solomon Islands since 1928, and this may now be extinct in the archipelago.

Freshwater wetlands and mangroves are of economic importance to the largely subsistence economy of Solomon Islanders. The leaf of the Sago Palm, in particular, is an important building material, and is also extensively used in traditional weaving. Mangroves and other types of swamp forest also supply important building materials and food resources ranging from the fruits of mangroves to a large variety of shells, crustaceans and fish. There is little information on the fish of the mangroves of Solomon Islands, but Blaber and Milton (1990) sampled 13 estuaries and found 136 species, although no estuary contained more than 50 species.

The relatively sparsely populated nature of the Solomon Islands has resulted in few threats to freshwater wetlands and mangrove areas. To date, mangroves have not been exploited on an industrial scale, and are protected under the Forest Resources and Timber Utilization Act. However, there is some exploitation of mangroves by customary landowners for fuel wood for fish smoking, especially in the vicinity of the Noro fish cannery. Some degradation of mangrove resources is occurring through clearing for new settlements and expansion of old settlements, cutting for firewood (especially for drying copra and bech-de-mer), siltation from on-shore soil erosion from agriculture and forestry activities, and landfill for coastal "reclamation", especially by using mangroves for dump sites. The latter is restricted to the vicinity of provincial capitals and is not widespread.

The industrial base of the Solomon Islands is still very small and is restricted to Honiara, Tulagi and Noro. Industrial pollution of mangroves and freshwater wetlands has not been documented, and it is unlikely that it is of significance. The only area where industrial pollution may be impacting on mangroves is in the vicinity of the Noro fish cannery.

Use of DDT, Malathion and Fenitrothion for anti-malarial spraying campaigns has been widespread in the past, and there has been little or no assessment of the impact on the environment. It is likely that there are residual high levels of DDT in the environment. High levels of DDT have been detected in some freshwater animals sampled from rivers on Guadalcanal (Anon, 1990). Agriculture pesticides, herbicides and chemical fertilisers are not actively encouraged by the Ministry of Agriculture and Lands. However, they have been used in large-scale coconut and oil palm plantations on Guadalcanal and Russells.

In general, the existing direct threats to wetlands appear to be minor. The magnitude of indirect threats to wetlands from logging in adjacent areas is unknown, and is in need of investigation as large-scale logging is occurring on the majority of the larger islands.

Wetland Research

There has been very little research on either freshwater or saline wetlands in the Solomon Islands, and there is no recent information on the extent or status of the nation's wetland resources. However, a National Forest Resources Inventory commissioned by the Forestry Division commenced in 1991, and is due to be completed in 1993. Although wetlands are not the main emphasis of the inventory, more up-to-date information on wetlands should be provided through it. The only recent wetland related research is that of Blaber and Milton (1990), who sampled fish in 13 estuaries in the Solomon Islands.

Wetland Area Legislation

There is no specific wetland legislation or policy. With the exception of the Queen Elizabeth II National Park Act (which is no longer operating), there is no national Protected Area legislation. Both Guadalcanal Province and Temotu Province have ordinances which have provisions that would enable wetlands to be protected under them, but to date no areas have been established. An antiquated Wild Birds Protection Act (1914, amended 1930) protects a number of wetland birds including herons, egrets, cranes, plovers and the Purple Swamphen (*Porphyrio porphyrio*). It also provides for a closed season on hunting of wild duck from 1 May to 31 July. It also has provisions for the declaration of bird sanctuaries. No sanctuaries have been declared in wetland areas, and the legislation itself has never been enforced. Mangroves are protected from commercial logging and export under the Forest Resources and Timber Utilisation Act. A National Environment Management Strategy has recently been completed and endorsed by Cabinet (SPREP, 1992). This, to some extent, addresses wetlands and associated environmental issues. The South Pacific Regional Environment Programme (SPREP) and World Conservation Union (IUCN) have recently assisted the Solomon Islands in preparing a new Environment Act (or Bill). This has been endorsed by the Solomon Islands Cabinet but not yet passed.

Solomon Islands has ratified the Convention for the Protection of the Natural Resources and Environment of the South Pacific (the SPREP Convention) and has signed but not yet ratified the Convention on Biological Diversity. It is not, however, as yet a party to the Unesco Man and the Biosphere Programme, Ramsar Convention or World Heritage Convention, nor has it signed or ratified the Convention on the Conservation of Nature in the South Pacific

Wetland Area Administration

The Environment and Conservation Division within the Ministry of Natural Resources is responsible for conservation, but as there are no protected areas or protected area legislation, the Division is not involved in any wetland area administration. Discussions are currently being held concerning accession to the World Heritage Convention and nomination of the island of Rennell (which includes Lake Te-Nggano and extensive wetlands) as a World Heritage site. This however, is only at a very preliminary stage.

Organizations involved with Wetlands

There are no government or non-governmental organizations which specifically deal with wetlands. The Forestry Division administers the Forest Resources and Timber Utilisation Act, and the Environment and Conservation Division administers the Wild Birds Protection Act.

WETLANDS

Insufficient information is available on the wetlands of the Solomon Islands to present a comprehensive list of wetlands of international importance. Very few sites have been studied in any detail, and in general very little attention has been given to wetland ecosystems by wildlife biologists, ecologists or conservationists. The distribution of mangrove vegetation and the other main wetland vegetation types was well documented by Hansell and Wall (1976), but this information is now very much out of date, and the conservation value of most of the wetland areas remains unknown. In view of the high degree of endemism amongst several faunal groups in the archipelago, it seems probable that there are many even quite small wetlands, especially in the outlying islands, which are of unique importance for their endemic amphibians, freshwater fishes or aquatic invertebrates.

The following preliminary list of important wetlands in the Solomon Islands is based on a provisional list compiled by Tanya Leary of the Environment and Conservation Division and the literature. A recent report on a proposed protected forests system for the Solomon Islands, prepared by Annette Lees, Martin Garnett and Shane Wright on behalf of the Australian National Parks and Wildlife Service, has been particularly valuable (Lees *et al.*, 1991). Only nine wetlands, all clearly of international significance, are sufficiently well documented to merit full site accounts. A further 24 wetland areas which are known or thought to be of special conservation value are described in brief after the main site accounts. All of these may, on further study, prove to be of international significance, along with many other wetlands the conservation values of which have not yet been recognized.

Wetlands of Eastern Choiseul and Rob Roy Island (1)

Location: 7°17'-7°26'S, 157°06'-157°39'E; at the eastern tip of Choiseul Island and around neighbouring Rob Roy Island, Choiseul Province.
Area: Unknown.
Altitude: Sea level.
Overview: The drowned coastline of southeastern Choiseul and Rob Roy Island with many rivers and sheltered lagoons, large areas of swamp forest and extensive mangrove forests, especially on either side of Rob Roy passage between Choiseul and Rob Roy Island.
Physical features: The drowned coastline of southeastern Choiseul is characterized by extensive swamps, low hills and many small islands. Rob Roy Island, a low-lying island almost covered with coconut plantations, lies very close to the southeastern end of Choiseul, and is separated from it by a narrow sea passage which is broadly fringed with mangrove forest. The island is almost completely encircled with mangrove forest. There is a particularly extensive mangrove forest near the entrance of Rob Roy passage into Pisuka Bay.
Ecological features: Tall mangrove forest dominated by *Rhizophora* spp., but with *Bruguiera* sp. locally common. The seaward side of the mangrove forest is dominated by *Rhizophora apiculata*, and then in sequence to the landward side are found *R. stylosa*, *Lumnitzera littorea* and *Xylocarpus granatum*. At river mouths, *Bruguiera* sp. appears with the *R. apiculata*, and on the landward side of the mangrove swamps, the forest grades into *Pterocarpus indicus*, *Ficus hombroniana*, *Barringtonia asiatica* and *Pandanus*. Beach forest is present in patches on some of the southern islets (Lees *et al.*, 1991). There are some stands of *Terminalia brassii* with a closed, even canopy on Rob Roy Island. Dryland forests are described by Lees *et al.* (1991).
Land tenure: Customary ownership.
Conservation measures taken: None.
Conservation measures proposed: Lees *et al.* (1991) have proposed the establishment of a large protected area encompassing the whole of southeastern Choiseul east of Oaka Harbour as well as Rob Roy Island and associated islets. This would include all of the important wetland areas.
Land use: The region is sparsely populated, with people living in small scattered villages along the coast. The principal activities are fishing, hunting, subsistence gardening and cultivation of coconut palms.
Disturbances and threats: Crocodile habitat is disappearing quickly as more and more gardens are planted along waterways (Messel & King, 1989).
Hydrological and biophysical values: No information.
Social and cultural values: No information.
Noteworthy fauna: Dugong (*Dugong dugon*) are reported to be plentiful in the area. Two Estuarine Crocodiles (*Crocodylus porosus*) were observed in Oaka Harbour by Messel and King in 1989, but these authors concluded that the species was on the verge of disappearing from Choiseul. Birds

recorded by Lees *et al.* (1991) during a survey in early 1990 included Pacific Reef Heron (*Egretta sacra*), Pacific Black Duck (*Anas superciliosa*) and Solomons Sea Eagle (*Haliaeetus sanfordi*). There are significant nesting beaches for sea turtles at Komboro Point at the eastern end of Choiseul (Lees *et al.*, 1991).
Noteworthy flora: No information.
Management authority and jurisdiction: No information.
References: Hansell and Wall (1976); Lees *et al.* (1991); Messel & King (1989).
Reasons for inclusion: 1a, 2a, 2b, 2c. Extensive stands of mangrove forest; threatened species.
Source: Tanya Leary and references.

Marovo Lagoon (2)

Location: 8°02'-8°45'S, 157°35'-158°13'E; New Georgia, Vangunu and Nggatokae Islands, Western Province.
Area: 70,000 ha.
Altitude: Sea level.
Overview: Marovo Lagoon is one of the largest lagoons in the world and has the best-defined double barrier reef. It contains over 300 islands including sand cays, mangrove islets, raised reefs and small volcanic cones, and is bordered along its southern edge by extensive mangrove forests and freshwater swamp forests. The region is one of great ecological diversity, supporting a wide variety of forest and reef communities.
Physical features: Marovo Lagoon is a complex reef and lagoon system extending for 100 km from the northern end of New Georgia southeast along the northeastern coast of that island and around the north end of Vangunu Island to Nggatokae Island in the extreme east. New Georgia, Vangunu and Nggatokae are volcanic in origin, their peaks rising to 820, 1,040 and 840 m respectively in a complex of extinct volcanic cones. Numerous rivers and streams have carried sediments off the volcanic slopes of all three islands and created a swampy coastal plain with many mangrove-lined estuaries and deltas which comprises the southwestern shore of the lagoon. The lagoon is bounded to the north and east by a string of narrow barrier islands which follow the entire coastline from the north end of New Georgia island southeast to Nggatokae. These barrier islands are formed from elevated reefs which have risen up to 15 metres above sea level in the north and up to 25 metres in the south. In the south, the islands form a double barrier with the two chains of islands separated by water up to 80 metres deep.
Marovo Lagoon encloses an area of 700 sq.km within which there are over 300 small islands of varied geomorphology: sand cays, mangrove islets, raised reef islands and small islands of volcanic origin. The lagoon is deepest and widest around the island of Vangunu, where distances from the main islands to the barrier islands can exceed eight km. Its narrowest points are in the north (about 2.5 km) where it is also at its shallowest. Baines (1985) describes three major habitats in the lagoon: sand cay complexes such as Mindeminde and Tinge, comprising groups of numerous small vegetated sand islets on patch reefs with a thin mangrove fringe; estuarine complexes such as Ghoe River/Nono Lagoon, Kolo River and Kele Bay, which have shallow water, muddy bottoms rich in organic detritus, varying salinity and freshwater inputs rich in organic material from freshwater swamps and mangroves; and barrier islands such as Uipi, which are long narrow islets with marked environmental contrast between ocean-facing fringing reefs and lagoon-side fringing reefs.
The climate is humid tropical, with an average annual rainfall of 3,000-4,000 mm.
Ecological features: Mangrove forest occurs in the lower reaches of the rivers and larger streams such as the lower Kolo River on New Georgia. There are also important stands near Patutiva on Vangunu and along the northern coast of Nggatokae. Mangroves also form fringe vegetation around many of the islets and the barrier islands in North Marovo. The mangrove forest is typically dominated by species of *Rhizophora* with local concentrations of *Lumnitzera littorea*, *Heritiera littoralis*,

Dolichandrone spathacea, *Xylocarpus granatum* and *Bruguiera* sp. *Pandanus* may be common in the understorey at the landward margin of the mangroves (Lees *et al.*, 1991).

The swampy and fertile soils along the larger rivers and low-lying margins of the lagoon support a distinctive type of swamp forest dominated by *Terminalia brassii*, *Campnospermum brevipetiolatum*, *Eugenia tierneyana* and *Ficus* sp. This forest type is particularly common along the northwestern and southeastern coasts of Vangunu and along the coast of New Georgia in northern Marovo (Lees *et al.*, 1991).

Many of the small islands inside the lagoon and most of the barrier islands are still covered in their original forest. Tall forest on the exposed windward side of the barrier islands is dominated by large figs. On the more sheltered leeward side of the barrier islands, *Eugenia tierneyana* occurs on the lowest and wettest surfaces. *Pometia pinnata* and *Vitex cofassus* grow on the higher portions of the barrier islands and on some of the higher islands in the lagoon, while the highest islands, such as Bulo (with a peak at 233 metres), support some hill forest. Beach forest fringes the lagoon and barrier islands, and includes *Instia bijuga*, *Barringtonia asiatica*, *Calophyllum inophyllum*, *Diospyros* sp. and *Cordia subcordata* as conspicuous species. The lowest islands, consisting of detrital wash and sand cays, support a woodland of tall *Casuarina equisetifolia*, *Cocos nucifera* and *Pandanus* (Lees *et al.*, 1991).

Land tenure: Land areas are almost entirely under customary ownership.

Conservation measures taken: Most of the coastal lands and all of the submerged lands of the lagoon are subject to traditional law (Baines, 1985). Throughout the area, there is a uniform system of reef-lagoon tenure which is largely traditional, although there have been some adaptations. A Marovo Lagoon Resource Management Project was set up by two local men in 1982 to promote the wise use of the lagoon's natural resources. In 1984, the Marovo Area Council called for assistance from the Western Provincial Government in assessing the marine and terrestrial resources and environment of the area and determining effective forms of management for these. Shortly after, a proposal for an investigation of the lagoon's resources and preparation of appropriate management plans was prepared by the Commonwealth Science Council as part of its South Pacific Coastal Zone Management Programme (SOPACOAST), and Marovo was accepted as a pilot project for high islands of the South Pacific region. The principal objective of this project is to involve local communities in the documentation and study of their resources in order to promote their management and conservation (Commonwealth Science Council, 1986).

Conservation measures proposed: Various authors have recommended that all or parts of Marovo Lagoon be afforded some protection (Dahl, 1980; SPREP, 1985; TCSP, 1990), and the lagoon has been under consideration for World Heritage status since 1987. The Marovo Lagoon Resource Management Project has been instrumental in the promotion of the lagoon for World Heritage status, a concept which has won the approval of the Western Provincial Government and Solomon Islands Cabinet. The New Zealand Government, through its development cooperation programme, is providing funding to investigate the possibility of World Heritage designation. Lees *et al.* (1991) have recommended that the whole of Marovo Lagoon from its northernmost point at Kolombaghea south to Bulo Island be afforded protection status to prevent large-scale, destructive land-use operations from taking place in the future. For the lagoon to be adequately protected, it is essential that adjoining lands on New Georgia are not developed in any way that would give rise to appreciable erosion or other forms of major pollution. Ideally, therefore, all bordering watersheds should be included in the protected area, as recommended by Lees *et al.* (1991). The forests would, however, have to be categorized to allow for areas of continued sustainable use by their owners.

Land use: About 20 of the islands in the lagoon are inhabited. A census in 1986 indicated that 6,600 people were living around the lagoon and on its weather coasts in over 50 villages. The annual population growth rate is between 3.5 and 4.7% (Lees *et al.*, 1991). These people are principally subsistence gardeners and fishermen, clearing forest for shifting agriculture and harvesting fish, shells and other marine products from the lagoon. In addition, there are groves of ngali nuts (*Canarium* sp.), coconuts and sago palms (used mainly for thatching), and there is some exploitation of mangroves for firewood and timber for construction. Commercial fishing in the lagoon is a part-time activity, and is based on small units using gill nets and lines, taking mainly reef fish. The catch is iced and shipped to Honiara. The lagoon is also an important source of baitfish for the skipjack tuna industry (Commonwealth Science Council, 1986).

Disturbances and threats: Mangroves around the lagoon have been felled, partly as a result of a mistaken belief that they inhibit the growth of coconut plantations. There is some dynamite fishing in the lagoon by a small number of local individuals, and there are increasing pressures for commercial fishing, due to an increasing population and growing prospects of inadequate agricultural land. Pollution from trading and passenger ships passing through the lagoon could become a problem in the near future, as could the uncontrolled growth of tourism and increased number of yachts. There is also considerable mineral prospecting activity, mainly for epithermal gold deposits (UNEP/IUCN, 1988). In general, however, the lagoon's forested catchments have been little disturbed. Hurricanes are infrequent and of low intensity, and human impact has been limited to some forest clearance for gardening and a little timber removal on Vangunu and Nggatokae (Lees *et al.*, 1991).

Hydrological and biophysical values: No information.

Social and cultural values: The lagoon is of great importance to the islanders of New Georgia, Vangunu and Nggatokae as a basis for their way of life. The rich local cultures are intimately linked with the region's ecological diversity, and are dependent on the continuing health of the natural resources of the lagoon and adjacent forests.

Noteworthy fauna: A crocodile survey in 1989 found only small numbers of Estuarine Crocodiles (*Crocodylus porosus*) in Western Province in general, and the species may no longer occur in Marovo Lagoon (Messel and King, 1989). Local people report low numbers of Dugongs (*Dugong dugon*) in the northern part of the lagoon (Lees *et al.*, 1991). Waterbirds recorded during a survey in early 1990 included Green Heron (*Butorides striatus*), Pacific Reef Heron (*Egretta sacra*), Pacific Black Duck (*Anas superciliosa*), Solomons' Sea Eagle (*Haliaeetus sanfordi*), Osprey (*Pandion haliaetus*), Pacific Golden Plover (*Pluvialis fulva*), Whimbrel (*Numenius phaeopus*), Common Sandpiper (*Actitis hypoleucos*), Beach Stone Curlew (*Esacus magnirostris*), Common Tern (*Sterna hirundo*) and Black-naped Tern (*S. sumatrana*) (Lees *et al.*, 1991).

A survey of Mt Javi in 1990 by the Environment and Conservation Division and the Australian Museum discovered a new endemic species of large monkey-faced flying fox (*Pteralopex* sp.). Subsequent work by the Australian Museum has found this as yet undescribed species to be common in the New Georgia and Vangunu areas. Other mammal surveys of New Georgia and Vangunu by the Environment and Conservation Division and Australian Museum have revealed that these islands support a diverse fauna of megachiropteran and microchiropteran bats.

Noteworthy flora: No information.

Scientific research and facilities: Various studies have been carried out as part of a coastal zone management project under the auspices of the Commonwealth Science Council and more recently as part of a WWF project at Marovo Lagoon.

Conservation education: Education and training are important elements of the Marovo Lagoon Resource Management Project. A community awareness workshop is held annually to inform the local communities of the results of project investigations and to facilitate community review and direction of the project.

Recreation and tourism: The lagoon has considerable potential for tourism. The area has significant archaeological and anthropological interest, the scenery is spectacular and the reefs and sand cays in sheltered waters have great recreational value. Numerous yachts visit the lagoon, stopping at villages to buy handicrafts, and SCUBA diving is a popular tourist activity. There is a small Australian-owned tourist resort on the island of Uipi (UNEP/IUCN, 1988). In recent years there have been a number of landowner initiatives to develop small-scale, low-impact tourism ventures in Marovo Lagoon. One such project, now well-advanced, is the development of tourist accommodation at Matakuri Island.

Management authority and jurisdiction: Customary jurisdiction. The Western Provincial Government has some jurisdictional right over parts of the lagoon.

References: Baines (1985); Commonwealth Science Council (1986); Dahl (1980, 1986); Hansell and Wall (1976); Lees *et al.* (1991); Messel & King (1989); Pearsall (1991); SPREP (1985); TCSP (1990).

Reasons for inclusion: 1a, 1c, 2a, 2b, 2c. Marovo Lagoon is regarded as the best-defined double barrier reef in the world, and is one of the world's largest island-enclosed lagoons. It is an area of exceptional ecological diversity, with most of its natural ecosystems still almost intact.
Source: Tanya Leary and references.

Western Isabel and the Arnarvon Islands (3)

Location: 7°20'-7°42'S, 157°57'-158°44'E; from the western end of Isabel Island west to the Arnarvon Islands, Isabel Province.
Area: Area of wetlands unknown. Total area 43,200 ha; Arnarvon Islands Wildlife Sanctuary 1,000 ha.
Altitude: Sea level.
Overview: An archipelago of forested high islands, smaller low-lying islands and islets that flank and extend the northwestern peninsula of Isabel Island. The extensive mangrove swamps, reefs, shoals and sand bars are important for turtles, crocodiles and migratory waterfowl.
Physical features: An archipelago of more than 100 islands of varying sizes at the northwest end of Isabel, extending from Austria Sound in the east to the tiny Arnarvon Islands in the Manning Strait (which separates Isabel from Choiseul). The two large islands of Barora Ite (south of Kia) and Barora Fa (west of Kia) are surrounded by many smaller islands, islets, reefs, shoals and sand bars. Most of the islands are low-lying and some are swampy. Mangrove forest occurs widely in the sheltered arms of the archipelago and fringes many of the islands, in places extending up to one kilometre from the shore. Much of the mangrove forest has developed on mud and peat that has settled over old coral platforms (Lees *et al.*, 1991. The Arnarvon Islands comprise three slightly-raised coral reefs: Sikopo, Kerehikapa and Arnarvon. There is evidence that these islands have sunk slightly in recent years, and are occasionally completely flooded (IUCN, 1991).
The climate is humid tropical with an average annual rainfall of 3,000 mm and mean temperatures varying between 24°C and 29°C. The wettest period is January to April, with 1,270-1,500 mm of rainfall. The prevailing winds are the southeast trades.
Ecological features: The mangrove communities include tall mangrove forest dominated by *Rhizophora* spp. with *Bruguiera* sp. and *Dolichandrone* sp. locally common, and low stunted forest dominated by *Rhizophora*. There are some areas of swampy grassland, mainly *Phragmites karka* with scattered low shrubs (Hansell and Wall, 1976). The islands support lowland rainforest dominated by species such as *Campnosperma brevipetiolata*, *Pometia pinnata*, *Vitex cofassus*, *Canarium salomonense* and *Celtis latifolia*. The smaller trees include *Aglaia* sp., *Neoscortechinia forbesii*, *Celtis philippinensis*, *Myristica* sp., palms and *Pandanus*. Patches of beach forest contain *Terminalia catappa*, *Heritiera littoralis*, *Barringtonia asiatica* and *Calophyllum inophyllum* (Lees *et al.*, 1991). The vegetation of the Arnarvon Islands comprises mainly trees and bushes of the genera *Pisonia*, *Casuarina*, *Pandanus*, *Calophyllum* and *Cordia*, as well as coconut palms (*Cocos nucifera*) and at least three species of grasses and sedges (IUCN, 1991).
Land tenure: Customary ownership.
Conservation measures taken: In 1975, the Ministry of Natural Resources designated the Arnarvon Islands as "off-limits" under a trespass law, and in 1979, these islands were included within a provincial Protected Lands Bye-law. In April 1980, a wildlife sanctuary of 1,000 ha was established in the Arnarvon Islands under a Local Government Ordinance, principally to protect the nesting grounds of Hawksbill and Green Turtles. However, the reserve was subsequently abandoned because of disputes over the ownership of the islands. There has recently been renewed interest by both Government and landowners in reviving a protected area for the Arnarvon Islands and surrounding marine areas. Negotiations concerning a Marine Reserve are now at a preliminary stage.
Conservation measures proposed: Hansell and Wall (1976) recommended that all of the islands

be declared a protected nature reserve, while Dahl (1980) suggested the establishment of a reef reserve in the Manning Strait and mangrove forest reserves in the general area. The Solomon Islands National Environment Management Strategy supports the re-establishment of the Arnarvon Islands Turtle Sanctuary (SPREP, 1992). Lees *et al.* (1991) have proposed the establishment of a protected area encompassing the entire western peninsula of Isabel (west of the Rakata River) and archipelago west to the Arnarvon Islands.
Land use: The inhabitants of Kia (population 1,000) and other smaller settlements on the northwestern tip of Isabel are dependent principally on subsistence gardening and fishing. None of the islands is permanently inhabited, but the archipelago is used for fishing and the harvesting of turtles, clams and megapode eggs.
Disturbances and threats: Natural threats include cyclones, earthquakes and rising sea levels (IUCN, 1991). Estuarine Crocodiles were exterminated in the Arnarvon Islands as a result of intensive hunting for skins in the 1960s and early 1970s (Vaughan, 1981). Disputes over land ownership have led to the abandonment of the Arnarvon Island Wildlife Sanctuary, and this area is now subject to heavy exploitation (Leary, 1990).
Hydrological and biophysical values: No information.
Social and cultural values: No information.
Noteworthy fauna: An important area for Estuarine Crocodiles (*Crocodylus porosus*), sea turtles, migratory shorebirds and other waterbirds. Fifteen crocodiles were observed at Ghahirahobo Island Lagoon in the southwestern sector of the archipelago during a crocodile survey in 1989 (Messel and King, 1989). The area is also reported to contain about 65% of the feeding and nesting sites for Hawksbill Turtles (*Eretmochelys imbricata*) and Green Turtles (*Chelonia mydas*) in the Solomon Islands. The Arnarvon Islands are especially important for Hawksbill Turtles, and may be the most heavily used nesting site for this species in the Pacific, after Campbell and Long Islands in Australia. Some 656 Hawksbill Turtle nests and 53 Green Turtle nests were recorded in the wildlife sanctuary between May 1979 and December 1980 (Vaughan, 1981). However, survey work conducted by the Environment and Conservation Division and the Fisheries Division in 1991 and 1992 indicated that the nesting population of turtles had declined considerably.
The Solomons Sea Eagle (*Haliaeetus sanfordi*), Osprey (*Pandion haliaetus*) and Common Megapode (*Megapodius freycinet*) occur in the islands, and many migratory shorebirds use the islands and tidal flats as feeding and resting areas during the austral summer. Whimbrel (*Numenius phaeopus*) and Common Sandpiper (*Actitis hypoleucos*) have been recorded. A report of Long-billed Curlew (*Numenius americanus*) in Vaughan (1981), repeated in IUCN (1991) and Lees *et al.* (1991), is clearly erroneous, and presumably relates to Far Eastern Curlew (*N. madagascariensis*). A few islets in the extreme northwest support high numbers of breeding pigeons.
Noteworthy flora: No information.
Scientific research and facilities: The Solomon Islands Turtle Project was initiated in 1975, with much of the work being carried out in the Arnarvon Islands. Some research facilities were constructed on Arnarvon Island, but these were destroyed in 1981 by a section of a Choiseul island group which claimed a customary right of ownership of the islands. No attempt has been made to re-establish these facilities (IUCN, 1991). The Environment and Conservation Division and the Fisheries Division carried out tagging and monitoring of nesting turtles during the peak nesting season from June to August in 1991 and 1992, as part of the Regional Marine Turtle Conservation Programme coordinated by SPREP.
Management authority and jurisdiction: Customary jurisdiction. Administrative responsibility for the Arnarvon Islands Wildlife Sanctuary is held by the Ministry of Natural Resources and Isabel Province.
References: Dahl (1980); Hansell & Wall (1976); IUCN (1991); Leary (1990); Lees *et al.* (1991); SPREP (1992); Vaughan (1981).
Reasons for inclusion: 1a, 2a, 2b, 2c. An outstanding archipelago, still in a more or less undisturbed condition; important for crocodiles, turtles and migratory waterfowl.
Source: Tanya Leary and references.

Ortega Passage (4)

Location: 8°23'S, 159°37'E; between the islands of Isabel and San Jorge, Isabel Province.
Area: Total area of wetlands unknown; *Casuarina* swamp forest 1,600 ha.
Altitude: Sea level.
Overview: A large area of freshwater swamps, principally *Casuarina* swamp forest, on either side of the Ortega Passage, and mangrove forests on the shores of Thousand Ships Bay to the east.
Physical features: Ortega Passage is a narrow sea channel between San Jorge island and Isabel. The channel has a broad fringe of *Casuarina* swamp forest which, with the adjacent herbaceous swamps on San Jorge island, comprises the largest area of freshwater swamp in Isabel Province. The swamps are composed largely of alluvium from the ultrabasic rock exposed on San Jorge island. There is at least one small freshwater lake in the swamps on San Jorge. Thousand Ships Bay, at the east end of Ortega Passage, has a broad fringe of mangrove forest.
Ecological features: Swamp forest dominated by *Casuarina papuana* up to 25 m tall, with some *Dacrydium xanthandrum*, *Calophyllum vexans*, *C. vitiense* and *Fagraea gracilipes*. Also herbaceous swamps and sago swamps on San Jorge, and mangrove forests in Thousand Ships Bay.
Land tenure: Customary ownership.
Conservation measures taken: None.
Conservation measures proposed: Dahl (1980), SPREP (1985), the Tourism Council of the South Pacific (1990) and Lees *et al.* (1991) have recommended that a protected area be established to conserve the unique *Casuarina* swamp forests.
Land use: Drop-net towers have been built out over the water in Ortega Passage for fishing. Thousand Ships Bay provides good anchorage for local fishing boats and trading vessels.
Disturbances and threats: None known in the *Casuarina* swamp forest, which apparently remains intact. However, the ultrabasic vegetation on San Jorge island has largely been destroyed by fire, and large areas of fern and scrub savanna have become established (Lees *et al.*, 1991). Nickel deposits have been located on San Jorge, Jejevo and Takata (southern Isabel), although at the moment only the Jejevo and Takata areas are subject to prospecting licences. Any future mining is likely to result in some disturbance to the area.
Hydrological and biophysical values: No information.
Social and cultural values: No information.
Noteworthy fauna: An endemic subspecies of the Mangrove Monitor *Varanus indicus spinulosus* appears to be confined to the mangrove and swamp forests on either side of the Ortega Passage. Estuarine Crocodiles (*Crocodylus porosus*) are said to occur. An endemic species of giant rat, *Solomys sapientsis*, is known to occur in the hinterlands on the Isabel side of the Ortega Passage.
Noteworthy flora: The *Casuarina* swamp forest of the Ortega Passage is a unique swamp forest community, unknown elsewhere in the Solomon Islands.
Management authority and jurisdiction: No information.
References: Dahl (1980); Hansell and Wall (1976); Lees *et al.* (1991); SPREP (1985); TCSP (1990).
Reasons for inclusion: 1d, 2b, 2d. The site includes the only swamp forest of its type in the Solomon Islands.
Source: Tanya Leary and references.

Lake Te-Nggano (5)

Location: 11°46'S, 160°27'E; at the east end of Rennell Island, Central Province.
Area: 15,500 ha.
Altitude: Sea level.
Overview: A large brackish lagoon on a raised atoll; one of the two largest lakes in the Solomon Islands and reportedly the largest brackish-water lake in the insular Pacific. The fauna and flora include an endemic sea snake and an endemic orchid. The lake supports large numbers of waterbirds including four subspecies endemic to Rennell and a further subspecies endemic to Rennell and nearby Bellona.
Physical features: Rennell Island (840 sq.km) is a raised coral atoll with coastal limestone cliffs up to 150 m high, a central depression representing the old lagoon floor and karstic topography. It is probably the finest example of a raised coral atoll in the world, and reportedly also the largest and highest. The southeastern end of the former lagoon remains flooded in the form of Lake Te-Nggano. This lake comprises about one quarter of the island; it is approximately 27 km long by nine km wide, and is surrounded by limestone cliffs. There are about 200 small islands in the lake, including the Atualanganga and Gakahuta groups near the western end. These provide breeding habitat for a number of species of seabirds and waterbirds. The water is slightly saline and faintly sulphurous. There is believed to be an underground channel approximately one kilometre in length at the east end of the lake which connects the lake with the sea. This channel is thought to allow the migration of elvers into the lake and adult eels to the sea. Wave action along the north coast of the island can be detected over one kilometre inland on the lake, and coral fish have been collected in the lake, both further proving the connection (Lees *et al.*, 1991). The bottom of the lake, which rarely exceeds 40 m in depth, is a nearly unbroken plain. The age of the lake as a body of almost fresh water is unknown, although it seems probable that the lagoon was cut off from the sea not long after the uplifting of Rennell began in the Pleistocene (Lees *et al.*, 1991).
The climate is humid tropical, with an average annual rainfall of 4,250 mm. January to March are the driest months.
Ecological features: There are some small swamps around the margins of the lake, many of which are under cultivation for taro. Most of the islands and a narrow strip of land around the lake are covered in largely undisturbed forest, although some of the islands have been cleared for coconuts. Lowland rainforest covers about 90% of the rest of the island. This is dominated by species of *Ficus*, *Terminalia sepicana*, *Elaeocarpus sphaericus*, *Endospermum molaccanum*, *Sterculia parkinsonii*, *Burckella obovata* and *Palaquium amboinense*. Palms are not conspicuous, except for the climbing rattan (*Calamus* spp.) which is abundant. Some 90% of the forest cover is undisturbed (Lees *et al.*, 1991).
Land tenure: Customary ownership.
Conservation measures taken: None.
Conservation measures proposed: Dahl (1980) identified Rennell Island as an island of exceptionally high conservation importance, and various authors have recommended that parts or all of the island be protected (Diamond, 1976; Hansell & Wall, 1976; SPREP, 1985; TCSP, 1990). In 1989, the Solomon Islands' Cabinet gave approval for investigations relating to the proposed designation of Rennell Island as a World Heritage Site, and the New Zealand Government subsequently agreed to fund a detailed study of the island for this purpose. The Solomon Islands National Environment Management Strategy adds its support to this proposal (SPREP, 1992). Lees *et al.* (1991) similarly recommended that the forests of Rennell and Lake Te-Nggano be afforded protection, but stressed that any protection measures would have to include planning for future gardening, hunting and timber removal in "exclusion zones".
Land use: About 1,200 people of Polynesian origin live on the island. The principal activities are subsistence gardening, hunting and fishing. There are four small villages on the shores of the lake. The introduced Tilapia constitute a major source of food for the inhabitants of these villages. Parts of the swamp are used for taro cultivation, and elsewhere, small tracts of forest have been cleared for the cultivation of fruit and vegetables.
Disturbances and threats: *Tilapia* have been introduced into the lake. There have been proposals to mine bauxite on the island and to develop a major logging operation, but neither of these proposals has been taken any further. Perhaps the greatest potential threat to the endemic fauna is

the deliberate or accidental introduction of mammalian predators. Polynesian Rats (*Rattus exulans*) have already been introduced onto the island, and Black Rats (*Rattus rattus*) may also be present.
Hydrological and biophysical values: No information.
Social and cultural values: No information.
Noteworthy fauna: Due to its isolation, Rennell Island has a high proportion of endemic species and subspecies amongst its fauna. Of the 37 breeding land-birds and waterbirds, five are endemic species, nine are endemic subspecies, and six are subspecies endemic to Rennell and the neighbouring island of Bellona. Of the ten species of bats known from the island, three are endemic subspecies. The aquatic fauna of Lake Te-Nggano has been well studied and is summarized in Wolff (1970). Seventy-seven species have been recorded from the lake, including two sea snakes, two indigenous fishes, six gastropods, 22 crustaceans, 40 insects, one water mite, two annelid worms and two nematodes. One of the sea snakes, the sea krait *Laticauda crockeri*, is known only from this lake. Tilapia (*Tilapia* sp.) has recently been introduced, and is now abundant.
The lake supports large numbers of waterbirds including endemic subspecies of the Australian Little Grebe (*Tachybaptus novaehollandiae rennellianus*), Little Pied Cormorant (*Phalacrocorax melanoleucos brevicauda*), Black Bittern (*Dupetor flavicollis pallidior*) and Grey Teal (*Anas gibberifrons remissa*). The first three of these remain common, but the Grey Teal has not been reported since 1928, and may now be extinct (Diamond, 1987). Other resident waterfowl include a small subspecies of the Australian White Ibis (*Threskiornis molucca pygmaeus*) endemic to Rennell and Bellona, Pacific Reef Heron (*Egretta sacra*), Pacific Black Duck (*Anas superciliosa*), Sooty Rail (*Porzana tabuensis*) and Purple Swamphen (*Porphyrio porphyrio*) (Mayr, 1945). The Royal Spoonbill (*Platalea regia*) has been recorded as a non-breeding visitor. Diamond (1976) reported small numbers of Great Cormorants (*Phalacrocorax carbo*), and Lees *et al.* (1991) observed at least 100 individuals in early 1990. This species may have been a recent colonist to the island (from Australia), as it is not listed for the Solomon Islands by Mayr (1945). Other birds associated with the wetland include Osprey (*Pandion haliaetus*), Black-naped Tern (*Sterna sumatrana*) and an endemic subspecies of the Collared Kingfisher (*Halcyon chloris amoena*). Pacific Golden Plover (*Pluvialis fulva*) and one of the tattlers (*Heteroscelus incanus* or *H. brevipes*) have been observed on migration.
Noteworthy flora: A rare endemic orchid, *Dendrobium rennellii*, occurs on the small islands in Lake Te-Nggano. The forest community of Rennell Island is very unusual in that most of the common canopy species found in the rest of the Solomon Islands are absent, presumably because of the extreme isolation of the island (Lees *et al.*, 1991).
Scientific research and facilities: The fauna and flora of Rennell Island have been very well studied, culminating in a seven volume work, "The Natural History of Rennell Island", edited by Torben Wolff (1970).
Recreation and tourism: In recent years, an interest has been expressed by some Rennellese in developing a tourist industry based on the outstanding natural features of the island. A small rest house has already been established on the edge of the lake near Te-Nggano village, and this has been designed to attract "eco-tourists" to the island. An airstrip in East Rennell and a road connecting the existing airstrip in West Rennell to the lake are currently under construction. This improved access will greatly enhance the accessibility of the lake to tourists.
Management authority and jurisdiction: Customary jurisdiction.
References: Dahl (1980, 1986); Diamond (1976, 1987); Hansell & Wall (1976); Lees *et al.* (1991); Mayr (1945); Pearsall (1991); SPREP (1985, 1992); TCSP (1990); Wolff (1970).
Reasons for inclusion: 1a, 2a, 2b, 2d, 3b. Te-Nggano Lake is of outstanding importance for its unique fauna and flora, including an endemic species of sea-snake, four endemic subspecies of waterfowl and an endemic orchid. Rennell Island is considered by some to be the world's finest raised coral atoll, and for its size, is probably the least environmentally disturbed island in the South Pacific.
Source: Tanya Leary and references.

Lauvi Lagoon (6)

Location: 9°53'S, 160°26'E; on the southeast coast of Guadalcanal, Guadalcanal Province.
Area: 200 ha.
Altitude: Sea level.
Overview: A freshwater lagoon with extensive swamp vegetation on the southeast coast of Guadalcanal; the second largest lake in the Solomon Islands and the most important site for the Estuarine Crocodile.
Physical features: Lauvi Lagoon is a freshwater lake on a coastal strip of flat land on the weather (southern) coast of Guadalcanal. The lagoon is roughly triangular in shape, and is separated from the sea on two of its sides by bush-covered gravel dunes. Its third side backs on to steep ridges covered in tropical rainforest. The triangular shape suggests that the lagoon has been formed by the meeting of two opposing currents depositing gravel at their meeting point (Lees *et al.*, 1991). The lagoon is between 2.5 and 4.0 metres deep; pH values of 5.6-6.9 have been reported (Gray, 1972). The lagoon is fed by a number of streams and several springs which run off the base of the basalt rocks of Guadalcanal's eastern highlands. The level of the lagoon rises during the peak of the rainy season (July and August) until the pressure of water causes a break in the beach, creating an outfall.
Ecological features: The surface of the lagoon supports extensive floating mats of sedges (Cyperaceae) and the ferns *Acrostichum aureum* and *Marsilea* sp. Common aquatic plants include species of *Vallisneria*, *Nitella*, *Fontinalis*, *Ceratopteris* and *Ceratophyllum* (Gray, 1974). A rare type of freshwater swamp dominated almost completely by pandans (*Pandanus* sp.) occurs on submerged islands in the lagoon and around its shallow margins. The vegetation along the beach side of the lagoon is dominated by *Barringtonia asiatica*, with *Hibiscus tiliaceus*, *Morinda citrifolia*, *Calophyllum inophyllum*, *Ochrusia oppositifolia*, *Macaranga* spp., *Terminalia catappa* and strangling figs also present. The exposed beach side of the forest features a zone of the shrub *Scaevola taccada*, while *Ipomoea pes-caprae* grows on the gravel dunes. *Casuarina equisetifolia* also occurs in the strand vegetation. The northwestern corner of the lagoon supports tall swamp forest dominated by *Terminalia brassii*, while the drier northern shore supports more typical lowland forest where *Pometia pinnata* and figs become common (Lees *et al.*, 1991).
Land tenure: Customary ownership.
Conservation measures taken: None.
Conservation measures proposed: Various authors have proposed that Lauvi Lagoon should be given some form of protection (Dahl, 1980; SPREP, 1985; TCSP, 1990), and the Solomon Islands National Environment Management Strategy identifies the lagoon as a priority site for the development of a "nature site" (SPREP, 1992). Lees *et al.* (1991) have proposed the establishment of a large protected area in southeastern Guadalcanal to protect Lauvi Lagoon and its forest catchments and thereby safeguard the crocodile population and other wildlife. The proposed reserve would also protect and enhance the tourism values of the region by reserving the catchments of a forested walking track through the mountains. The proposed protected area also includes Lee's Lake, a small freshwater lake in the highlands of the interior (see Site 26).
Land use: Fishing, principally for *Chanos chanos*, *Caranx ignobilis* and *Megalops cyprinoides*. The fish were formerly caught with hand lines, but gill/tangle nets are now widely used (Gray, 1972). There are coconut plantations and an agricultural experimental field station near the lagoon.
Disturbances and threats: None known.
Hydrological and biophysical values: No information.
Social and cultural values: Fishing in Lauvi Lagoon provides an important source of food for the inhabitants of nearby villages.
Noteworthy fauna: Lauvi Lagoon is important habitat for the Estuarine Crocodile (*Crocodylus porosus*), and now supports the largest single population of this species in the Solomon Islands. A survey in 1989 located 92 crocodiles in the lagoon (Messel & King, 1989), and the population has recently been estimated at about 200 individuals, representing 20% of the total population in the Solomons. Leatherback Turtles (*Dermochelys coriacea*) nest on a black sand beach near the lagoon.

Fish species reported by Gray (1972) include *Amphitherapon caudavittatus*, *Apogon hyalosoma*, *Chanos chanos*, *Caranx ignoblis*, *Megalops cyprinoides*, *Lutjanus argentimaculatus* and *Anguilla marmorata*.
The lagoon supports a variety of waterbirds including Little Pied Cormorant (*Phalacrocorax melanoleucos*), Little Heron (*Butorides striatus*), Pacific Reef Heron (*Egretta sacra*), Black Bittern (*Dupetor flavicollis*), Pacific Black Duck (*Anas superciliosa*), Osprey (*Pandion haliaetus*) and Purple Swamphen (*Porphyrio porphyrio*). A pair of Australian Little Grebes (*Tachybaptus novaehollandiae*) was observed during a survey in early 1990, the first record of this species on Guadalcanal (Lees *et al.*, 1991).
Noteworthy flora: The lagoon supports a rare type of swamp forest dominated almost completely by *Pandanus* sp.
Scientific research and facilities: Preliminary studies have been carried out on the aquatic vegetation (Gray, 1974), fishes (Gray, 1972) and crocodiles (Messel & King, 1989).
Recreation and tourism: The Tourism Council of the South Pacific (1990) and the Solomon Islands National Environment Management Strategy have identified Lauvi Lagoon and its environs as being of prime potential for the development of nature tourism.
Management authority and jurisdiction: Customary jurisdiction.
References: Dahl (1980); Gray (1972, 1974); Lees *et al.* (1991); Messell & King (1989); Pearsall (1991); SPREP (1985, 1992); TCSP (1990).
Reasons for inclusion: 1a, 2a, 2b. One of the largest freshwater lakes in the Solomon Islands, supporting the largest single population of Estuarine Crocodiles and a diverse wetland plant community rare elsewhere in the Solomon Islands.
Source: Tanya Leary and references.

Are'Are Lagoon and Maramasike Passage (7)

Location: 9°20'-9°38'S, 161°03'-161°24'E; along the southwestern coast of Malaita, and between Malaita and Maramasike, Malaita Province.
Area: Unknown.
Altitude: Sea level.
Overview: A long narrow coastal lagoon with many barrier islands and fringing mangroves (Are'Are Lagoon), and extensive mangrove forests along a narrow channel (Maramasike Passage) between Malaita and Maramasike islands.
Physical features: Are'Are Lagoon stretches for 26 km along the southwest coast of Malaita Island. The lagoon is about one km wide, and is sheltered from the open sea by a chain of barrier islands. Much of the lagoon is fringed with mangroves, and there are numerous saline and freshwater swamps along its very indented coastline. Maramasike Passage, to the east, is a 20 km long passage between Malaita and Maramasike islands. In places, the passage is less than 400 m wide and only about 4 m deep. Raroi Su'u Lagoon at the north end of the passage is a sheltered bay with a broad fringe of mangroves.
Ecological features: Tall mangrove forest dominated by species of *Rhizophora* and *Bruguiera*; tall alluvial forests, particularly at the northern end of Maramasike Passage, with *Calophyllum kajewskii*, *C. vitiense*, *Pometia pinnata*, *Vitex cofassus*, *Dillenia* spp., *Terminalia brassii*, *T. copelandii*, *Archidendron oblongum*, *Alstonia scholaris*, *Endospermum medullosum* and *Pterocarpus indicus* (Lees *et al.*, 1991).
Land tenure: Customary ownership.
Conservation measures taken: None.
Conservation measures proposed: Lees *et al.* (1991) have proposed the establishment of a protected area encompassing the southern end of Malaita island and the western part of Maramasike island "to protect a representative example of forest communities on a large expanse of lowland rolling hills and alluvial surface, and an outstanding landscape feature, the narrow Maramasike Passage and its environs". The proposed protected area would include the whole of Are'Are Lagoon and Maramasike Passage as well as their catchments.

Land use: There are numerous fishing villages around Are'Are Lagoon and several villages along Maramasike Passage, mostly in the north.
Disturbances and threats: The forests of the Are'Are area were badly damaged by Cyclone Namu in 1986, and in addition, large areas have been cleared for subsistence agriculture (Lees *et al.*, 1991).
Hydrological and biophysical values: No information.
Social and cultural values: No information.
Noteworthy fauna: The Estuarine Crocodile (*Crocodylus porosus*) may still occur in the area. Messel and King (1989) considered that Taha River and Taramata Creek near the northern end of the passage provided excellent habitat for crocodiles although none was encountered during their survey. Birds recorded by Paul Scofield (in Lees *et al.*, 1991) in the vicinity in January 1990 included Pacific Reef Egret (*Egretta sacra*), Rufous Night-Heron (*Nycticorax caledonicus*), Black Bittern (*Dupetor flavicollis*), Pacific Black Duck (*Anas superciliosa*), Solomons Sea Eagle (*Haliaeetus sanfordi*), Osprey (*Pandion haliaetus*), Banded Rail (*Rallus philippensis*) and Bush-hen (*Amaurornis olivaceus*).
Noteworthy flora: No information.
Management authority and jurisdiction: No information.
References: Hansell and Wall (1976); Lees *et al.* (1991); Messel & King (1989).
Reasons for inclusion: 1a, 2b, 2c. Are'Are Lagoon is the least disturbed of Malaita's three principal lagoon communities.
Source: Tanya Leary and references.

Makira Swamps (8)

Location: 10°25'S, 161°33'E; in the interior of west-central Makira, Makira Province.
Area: Unknown.
Altitude: Near sea level to 80 m.
Overview: A number of extensive freshwater swamps in broad river valleys in the lowlands and foothills of western Makira, the most extensive swamps of this type in the Solomon Islands.
Physical features: Makira Island has a greater area of inland swamps than any other island in the Solomons. These swamps are mainly present in the western lowlands where broad valleys containing swamps have developed on the basement basalt rocks. Some of the swamps are as high as 80 metres above sea level. They occur both in the headwaters and along the middle courses of rivers, and generally have a sinuous shape. Most are 500-1,000 metres wide, up to five kilometres in length, and fill the whole width of the valley floor. In some cases, the swamps contain small freshwater lakes. They are believed to have been created when the northern coast of Makira was uplifted, with an associated drowning of the southern coastline. These events affected a decrease in river gradients and an infilling of the valleys by braided streams. The swamps extend in interrupted segments across most of western Makira, and are separated by incised valley sections (Hansell & Wall, 1976; Lees *et al.*, 1991). The upper reaches of the Wainaraha and Waitaa Rivers in western Makira are believed to contain the greatest diversity of swamp communities (Lees *et al.*, 1991).
Ecological features: In the wetter parts of the swamps, *Pandanus*, bamboos and ferns form a complete cover one to three metres high. Occasional emergent *Pandanus* can reach 15 metres in height, and are often covered by scrambling ferns. A tall mixed swamp forest with *Terminalia brassii* and *Eugenia tierneyana* occurs at the edges of the wetlands (Hansell & Wall, 1976; Lees *et al.*, 1991). Other wetland vegetation includes sago swamp dominated by the sago palm *Metroxylon salomonense* and swampy grassland with *Phragmites karka* and low shrubs.
Land tenure: Customary ownership.
Conservation measures taken: None.
Conservation measures proposed: Lees *et al.* (1991) have recommended that a representative and intact example of these unique swamps be protected along with hill and ridge forest to complete the vegetated community transition. The protected area would need to be large, and would have to

include all upper catchment sectors of the swamps within the reserve. It was suggested that the upper reaches of the Wainaraha and Waitaa Rivers would be particularly suitable for reserve status.
Land use: No information.
Disturbances and threats: No information.
Hydrological and biophysical values: No information.
Social and cultural values: No information.
Noteworthy fauna: No information.
Noteworthy flora: No information.
Management authority and jurisdiction: Customary jurisdiction.
References: Hansell & Wall (1976); Lees *et al.* (1991).
Reasons for inclusion: 1d, 2b. Large inland swamps of the type found on Makira are almost unknown elsewhere in the Solomon Islands.
Source: Tanya Leary and references.

Te Roto Crater Lake (9)

Location: 12°16'S, 168°49'E; on the island of Tikopia in the Santa Cruz Islands, Temotu Province.
Area: 100 ha.
Altitude: Sea level.
Overview: A slightly brackish volcanic crater lake on the small island of Tikopia.
Physical features: Tikopia island (5 sq.km) is the visible remains of an extinct single-cone volcano with a large crater lake at its centre. The lake is brackish, and has a maximum depth of about 60-80 m. It lies at sea level, and has been cut off from the sea in recent times. In 1606, is was an open sea bay, and in 1828 there remained a broad connection with the sea. The narrow sandspit which now separates the lake from the sea is partly artificial and reinforced with stone blocks. In most years, a channel is opened after the heavy monsoonal rains to allow excess lake water to flow out. The crater rim reaches a maximum elevation of 374 m at the summit of Mount Reani to the northeast. The climate is humid tropical, with an average annual rainfall of 4,000 mm and mean temperatures of 25-29°C. The heaviest rainfall occurs from October to March.
Ecological features: There are some swampy areas around the lake margins, parts of which are under cultivation for taro.
Land tenure: Customary ownership.
Conservation measures taken: None.
Land use: Fishing for native species and introduced *Tilapia*. Marshy areas around the lake shore are cultivated for taro. The island's 1,100 inhabitants are of Polynesian origin.
Disturbances and threats: *Tilapia* has recently been introduced into the lake.
Hydrological and biophysical values: No information.
Social and cultural values: No information.
Noteworthy fauna: Mayr (1945) lists Little Pied Cormorant (*Phalacrocorax melanoleucos*), Pacific Reef Heron (*Egretta sacra*), Pacific Black Duck (*Anas superciliosa*) and Purple Swamphen (*Porphyrio porphyrio*) for the island.
Noteworthy flora: No information.
Management authority and jurisdiction: No information.
References: Dahl (1986); Pearsall (1991).
Reasons for inclusion: 1a.
Source: Tanya Leary and references.

OTHER IMPORTANT WETLANDS

Wetlands of Shortland Island (10)

Location: 7°04'S, 155°52'E; around Shortland Island in the Shortland Group, Western Province.
Area: Unknown.
Altitude: Sea level.
Overview: Mangrove swamps on the southeast coast of Shortland Island and around neighbouring Pirumeri Island.
Conservation measures taken: None.
Noteworthy fauna: No information.
Noteworthy flora: No information.
Source: Hansell and Wall (1976).

Mangroves of Western Choiseul (11)

Location: 6°42'S, 156°24'E; at the western end of Choiseul Island, Choiseul Province.
Area: Unknown.
Altitude: Sea level.
Overview: Mangrove swamps at the western end of Choiseul Island, especially around Choiseul Bay. Choiseul Bay is the proposed site for the provincial capital of the newly created Choiseul Province, and some disturbance to the wetlands is likely.
Conservation measures taken: None.
Noteworthy fauna: No information.
Noteworthy flora: No information.
Source: Hansell and Wall (1976).

Choiseul *Terminalia* Forest (12)

Location: 6°45'S, 156°35'E; Choiseul Island, Choiseul Province.
Area: Unknown.
Altitude: Near sea level.
Overview: *Terminalia brassii* swamp forest in the interior of Choiseul Island.
Conservation measures taken: None.
Noteworthy fauna: Apparently the preferred habitat of the endemic Giant Rat *Uromys ponceleti*.
Noteworthy flora: Swamp forest dominated by *T. brassii*.
Source: Dahl (1980).

Wetlands of Wagina Island (13)

Location: 7°25'S, 157°46'E; on Wagina Island, off the eastern tip of Choiseul, Choiseul Province.
Area: Unknown.
Altitude: Sea level.

Overview: Freshwater swamps and mangrove forest on Wagina Island, principally on the north and east coastal plains.
Conservation measures taken: None.
Noteworthy fauna: No information.
Noteworthy flora: No information.
Source: Hansell and Wall (1976).

Wetlands of Vella Lavella (14)

Location: 7°40'S, 156°35'E; around the northern half of Vella Lavella Island, Western Province.
Area: Unknown.
Altitude: Sea level.
Overview: Freshwater swamps, mangrove forest and thermal wetlands on the island of Vella Lavella.
Conservation measures taken: None.
Noteworthy fauna: No information.
Noteworthy flora: No information.
Source: Hansell and Wall (1976).

Lake Ove (15)

Location: 8°17'S, 156°31'E; near the southern end of Simbo Island, south of Ranongga, Western Province.
Area: Unknown.
Altitude: Unknown.
Overview: A hot crater lake on Mount Matindingi (335 m). The yellow-green sulphurous water is close to boiling point.
Conservation measures taken: None.
Noteworthy fauna: The megapode *Megapodius freycinet* lays its eggs in the warm volcanic soils around the lake.
Noteworthy flora: No information.
Source: Dahl (1986).

Wetlands of Southern Kolombangara (16)

Location: 8°07'S, 157°07'E; round the southern end of Kolombangara Island, Western Province.
Area: Unknown.
Altitude: Sea level.
Overview: Freshwater swamps, swamp forest and mangrove forest along the south coast of Kolombangara Island.
Conservation measures taken: None.
Conservation measures proposed: Several authors have proposed that a protected area be established on Kolombangara to conserve the remaining unlogged lowland forest as well as all the remaining montane forest on the island.

Noteworthy fauna: No information.
Noteworthy flora: No information.
Source: Dahl (1980); Diamond (1976); Hansell and Wall (1976); Lees *et al.* (1991); SPREP (1985).

Mbaeroko Bay (17)

Location: 8°12'S, 157°16'E; at the west end of New Georgia Island, Western Province.
Area: Unknown.
Altitude: Sea level.
Overview: Freshwater swamps, swamp forest and mangrove forest around Mbaeroko Bay at the west end of New Georgia.
Conservation measures taken: None.
Noteworthy fauna: No information.
Noteworthy flora: No information.
Source: Hansell and Wall (1976).

Roviana Lagoon (18)

Location: 8°20'S, 157°30'E; on the southwest coast of New Georgia Island, Western Province.
Area: Unknown.
Altitude: Sea level.
Overview: Freshwater swamps, swamp forest and mangrove forest around Roviana Lagoon on the southwest coast of New Georgia.
Conservation measures taken: None.
Noteworthy fauna: No information.
Noteworthy flora: No information.
Source: Hansell and Wall (1976).

Lake Rano and Renard Cove (19)

Location: 8°41'S, 157°19'E; on Rendova Island, Western Province.
Area: Unknown.
Altitude: Near sea level.
Overview: A sheltered sea bay with fringing mangroves on the east coast of Rendova Island (Renard Cove), and a small lake near the south end of the island (Lake Rano).
Conservation measures taken: None.
Noteworthy fauna: Important habitat for the Estuarine Crocodile (*Crocodylus porosus*). A crocodile survey in 1989 located a total of 11 crocodiles in Renard Cove.
Noteworthy flora: No information.
Source: Lees *et al.* (1991); Messel & King (1989).

Wetlands of Tetepare (20)

Location: 8°45'S, 157°32'E; on the island of Tetepare, southeast of Rendova, Western Province.
Area: Unknown.
Altitude: Sea level.
Overview: An area of undisturbed beach forest and mangrove forest along the southern and eastern shores of Tetepare Island, and a small lake at Tavara on Waugh Bay at the west end of the island. Tetepare is a raised coral island with fringing reef (area 120 sq.km; maximum elevation 357 m). The island is very sparsely populated, with fewer than fifty people living in a single settlement at the western tip.
Conservation measures taken: None.
Conservation measures proposed: The entire island, excepting the present copra plantation, has been proposed as a protected area to protect habitat of the endemic white-eye *Zosterops tetiparia*.
Noteworthy fauna: Messel and King (1989) suggested that the small lake at Tavara would be an excellent place for restocking Estuarine Crocodiles (*Crocodylus porosus*).
Noteworthy flora: No information.
Source: Dahl (1980); Diamond (1976); Hansell and Wall (1976); Lees *et al.* (1991); Messel & King (1989); SPREP (1985).

Mangroves of Northern Isabel (21)

Location: 7°55'S, 159°15'E; on the north coast of Isabel Island, Isabel Province.
Area: Unknown.
Altitude: Sea level.
Overview: Extensive tracts of mangrove forest along the north-central coast of Isabel Island.
Conservation measures taken: None.
Noteworthy fauna: No information.
Noteworthy flora: No information.
Source: Dahl (1986); Hansell and Wall (1976).

Huali Bay (22)

Location: 8°25'S, 159°50'E; at the east end of Isabel Island, Isabel Province.
Area: Unknown.
Altitude: Sea level.
Overview: Mangrove forest around Huali Bay at the east end of Isabel Island.
Conservation measures taken: None.
Noteworthy fauna: No information.
Noteworthy flora: No information.
Source: Hansell and Wall (1976).

Wetlands of the Russell Islands (23)

Location: 9°00'S, 159°10'E; in the Russell Islands, Central Province.

Area: Unknown.
Altitude: Sea level.
Overview: Mangrove forest on the north coast of the main island in the Russell group.
Conservation measures taken: None.
Noteworthy fauna: No information.
Noteworthy flora: No information.
Source: Hansell and Wall (1976).

Wetlands of Nggela (24)

Location: 9°00'S, 160°13'E; around Nggela Island, Central Province.
Area: Unknown.
Altitude: Sea level.
Overview: Mangrove forest in the Nggela Islands, particularly in the Mboli Passage between Nggela Sule and Nggela Pile.
Conservation measures taken: None.
Noteworthy fauna: No information.
Noteworthy flora: No information.
Source: Hansell and Wall (1976).

Sago Swamp Forests of Guadalcanal (25)

Location: 9°33'S, 160°34'E; on the northeast coast of Guadalcanal Island, Guadalcanal Province.
Area: Unknown.
Altitude: Near sea level.
Overview: A large area of sago swamp forest dominated by the sago palm *Metroxylon salomonense* on the north coastal plain of eastern Guadalcanal.
Conservation measures taken: None.
Noteworthy fauna: No information.
Noteworthy flora: One of the best stands of sago swamp forest in the Solomon Islands.
Source: Dahl (1980); SPREP (1985); TCSP (1990).

Lee's Lake (26)

Location: 9°42'S, 160°23'E; in the east-central highlands of Guadalcanal, Guadalcanal Province.
Area: Unknown.
Altitude: c.600 m.
Overview: A small freshwater lake approximately two km long and 250-500 m wide in the highlands of Guadalcanal; apparently the only freshwater montane lake of any size in the Solomon Islands.
Conservation measures taken: None.
Conservation measures proposed: Proposed for protection by the Tourism Council of the South Pacific (TCSP, 1990), and included within the proposed Lauvi protected area (Lees *et al.*, 1991).
Noteworthy fauna: No information.

Noteworthy flora: No information.
Source: Lees *et al.* (1991); SPREP (1985); TCSP (1990).

Marau Sound (27)

Location: 9°50'S, 160°50'E; at the east end of Guadalcanal, Guadalcanal Province.
Area: Unknown.
Altitude: Sea level.
Overview: Mangrove forest in Marau Sound at the east end of Guadalcanal Island.
Conservation measures taken: None.
Noteworthy fauna: No information.
Noteworthy flora: No information.
Source: Hansell and Wall (1976).

Mangroves of Northern Malaita (28)

Location: 8°08'-8°53'S, 160°55'E; on the northeast coast of Malaita Island, Malaita Province.
Area: Unknown.
Altitude: Sea level.
Overview: Extensive mangrove forests along the northeast coast of Malaita Island.
Conservation measures taken: None.
Noteworthy fauna: No information.
Noteworthy flora: No information.
Source: Hansell and Wall (1976).

Mangroves of Western Malaita (29)

Location: 8°44'-9°02'S, 160°44'E; on the west coast of Malaita Island, Malaita Province.
Area: Unknown.
Altitude: Sea level.
Overview: Extensive mangrove forests along the west coast of Malaita.
Conservation measures taken: None.
Noteworthy fauna: No information.
Noteworthy flora: No information.
Source: Hansell and Wall (1976).

Three Sisters Islands (30)

Location: 10°07'-10°16'S, 161°58'E; off the north coast of Makira Island, 19-31 km north of Kirakira, Makira Province.
Area: Unknown.

Altitude: Sea level.
Overview: A group of three low-lying coral islands, Malaupaina, Malaulalo and Ali'ite, with some fringing mangroves.
Conservation measures taken: None.
Noteworthy fauna: The islands support one of the three largest populations of Estuarine Crocodile (*Crocodylus porosus*) surviving in the Solomon Islands. There are also many large monitor lizards (*Varanus* sp.).
Noteworthy flora: No information.
Source: Dahl (1986); Messel & King (1989); TCSP (1990).

Star Harbour (31)

Location: 10°48'S, 162°18'E; at the east end of Makira Island, Makira Province.
Area: Unknown.
Altitude: Sea level.
Overview: Extensive mangrove forests in Star Harbour at the east end of Makira Island.
Conservation measures taken: None.
Noteworthy fauna: No information.
Noteworthy flora: No information.
Source: Hansell and Wall (1976).

Lake Wairata (32)

Location: 10°50'S, 162°28'E; on Santa Ana Island, east of Makira Island, Makira Province.
Area: Unknown.
Altitude: Near sea level.
Overview: A small brackish lake near the north end of Santa Ana Island (a raised coral atoll).
Conservation measures taken: None.
Noteworthy fauna: No information.
Noteworthy flora: No information.
Source: Dahl (1986).

Wetlands of Nendo (33)

Location: 10°50'S, 165°50'E; on the south coast of Nendo Island in the Santa Cruz Islands, Temotu Province.
Area: Unknown.
Altitude: Sea level.
Overview: A system of lagoons with extensive mangrove forest and mudflats on the southeast coast of Nendo Island and nearby Nibanga Noi island. The site includes Tepiai Lagoon and Blamoli Lagoon on Nendo; Matimi Lagoon on Nibanga Noi, and the mangroves of Matimi Inlet between these two islands.
Conservation measures taken: None.
Noteworthy fauna: Important habitat for the Estuarine Crocodile (*Crocodylus porosus*). There are

some Hawksbill Turtle (*Eretmochelys imbricata*) and Green Turtle (*Chelonia mydas*) nesting beaches on islands in the vicinity.
Noteworthy flora: No information.
Source: Hansell and Wall (1976); Messel & King (1989).

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TOKELAU

INTRODUCTION

Area: 12.25 sq.km.

Population: 1,700 (1988).

Tokelau, formerly the Union Islands, is an island territory under New Zealand administration. It comprises three small atolls, Atafu (3.5 sq.km), Nukunonu (4.7 sq.km) and Fakaofo (4.0 sq.km), each consisting of a number of low-lying, scrub-covered islets surrounded by reefs and encircling a large central lagoon up to 400 fathoms in depth. The islands are situated between latitudes 8° and 10° South and longitudes 171° and 173° West, some 480 km north of Western Samoa. The central atoll, Nukunonu, lies 92 km from Atafu and 56 km from Fakaofo. The islets are made up of coral rubble and sand mixed with a thin layer of humus, and are of generally low fertility. At no point do they rise more than 5 m above sea level.

The climate is humid tropical, tempered by trade winds. The average annual temperature is 28°C, with little seasonal variation. Rainfall is irregular but heavy, averaging about 2,500 mm per year. Tokelau is at the north edge of the main hurricane belt, and hurricanes are rare, although stormy weather is not uncommon between November and March.

The islands became a British Protectorate in 1877, and were formally annexed in 1916 and included within the Gilbert and Ellice Islands Colony. The islands were separated from the Gilbert and Ellice group in 1925, and administrative control was transferred to New Zealand. The 1948 Tokelau Islands Act included Tokelau within the boundaries of New Zealand. The islands are governed from the Office of Tokelau Affairs in Apia, Western Samoa. The inhabitants, who are now citizens of New Zealand, are Polynesian, with close links with Tuvaluans and Western Samoans. The resident population of about 1,700 is evenly distributed between the three atolls, but there are at least another 3,000 Tokelauans living in New Zealand. The principal activity is fishing. Agriculture is limited, because of the low fertility of the soil, the main crops being coconuts, pulaka, breadfruit, pawpaw, pandanus and bananas. The principal revenue earners are copra, postage stamps, souvenir coins and handicrafts, and the economy is dependent to a large extend on subsidies from New Zealand and remittances from Tokelauans working in New Zealand. There are no harbour or airport facilities in the islands.

The marine ecosystems have been described by UNEP/IUCN (1988). The principal terrestrial ecosystems are beach scrub and coconuts, but there are remnants of atoll forest, with species of *Cordia*, *Pisonia* and *Guerttarda*, on Tokelau and Long islets in Nukunonu Atoll (Dahl, 1986; Parham, 1971). Mangroves are absent. Some 67 vascular plants have been recorded, including 16 adventive weeds and grasses and 13 cultivated plants (Anon, 1989). There are no major breeding colonies of sea-birds, but small colonies of most of the common species of terns, noddies and boobies are to be found on relatively undisturbed islets. The investigation of suitable islets for sea-bird protection was identified as a priority by Hay (1985). Only one land-bird, the Pacific Pigeon (*Ducula pacifica*), breeds on the islands. Sea-birds and the pigeon are taken for food by the local population, and are at present on the decline (Anon, 1989). Three species of turtle, the Green Turtle (*Chelonia mydas*), Hawksbill (*Eretmochelys imbricata*) and Loggerhead (*Caretta caretta*), nest on the islands, but all are now rare (UNEP/IUCN, 1988).

In general, the vegetation has not been greatly modified, and apart from the over-exploitation of giant clams and turtles, there is no evidence of depletion of marine resources (IUCN, 1991; UNEP/IUCN, 1988). The potentially most threatening environmental hazard is that posed by increasing sea level due to global warming. Even a small rise in sea level could make the islands uninhabitable because of the greatly increased damage that would be caused by hurricanes.

Because of the dependence of a dense population on a very limited area of land, most of Tokelau's conservation policies relate to protection of the human environment. Conservation of Tokelau's natural resources has so far been achieved through traditional practices (SPREP, 1985). The traditional "lafu" system, which prohibits the harvesting and disturbance of a particular land or marine resource, is still practised. This system is imposed and policed by the Council of Elders who are the traditional authority on each atoll (Anon, 1989). An Agriculture and Fisheries Committee was established in 1984 to supplement and complement the work of the Council of Elders in resource management. This Committee has imposed various restrictions on the harvesting of giant clams (*Tridacna squamosa* and *T. maxima*) and taking of turtle eggs. The Department of Agriculture and Fisheries has facilitated resource surveys and provided scientific information to support conservation and resource management (Anon, 1989). Recently, however, there have been difficulties with the traditional system, largely as a result of a general reduction in the authority of the Council of Elders (Toloa & Gillett, 1989).

The preparation of a National Conservation Strategy was identified as a priority in the Action Strategy for Nature Conservation in the South Pacific Region (SPREP/IUCN, 1989), as was the establishment of national parks on each of the three atolls. It has recently been reported that some 47 ha of land on Nukunonu Atoll has been designated a protected area by the local Council of Elders, with adjoining reef areas to be added at a later date (IUCN, 1991).

Summary of Wetland Situation

There is no surface fresh water on any of the atolls, the inhabitants relying on roof catchments, small tanks and galleries for their water supply. There are some tiny brackish pools on two of the atolls, but no mangroves or closed lagoons, and the only other wetlands are reef flats exposed at low tide. These are important feeding areas for Pacific Reef-Herons (*Egretta sacra*) and migratory shorebirds.

Wetland Research

A hydrogeological study of Tokelau was undertaken by Kammar (1981).

Wetland Area Legislation

There is no legislation in Tokelau concerning either the conservation of habitats and species or the establishment of protected areas. Instead, there is a long-standing system of resource management based on traditional custom (IUCN, 1991).

New Zealand acts for Tokelau in international agreements. The Government of New Zealand is party to the Ramsar Convention, World Heritage Convention and Convention for the Protection of the Natural Resources and Environment of the South Pacific Region (SPREP Convention), but it is not clear if this places any obligations upon Tokelau itself (IUCN, 1991).

Wetland Area Administration

All land is under customary ownership.

Organizations involved with Wetlands

The Department of Agriculture and Fisheries is the government body responsible for natural resources.

WETLANDS

Tokelau has no significant wetlands in the conventional sense. Information on the most important area of reef flats has been provided by Kirifi Kirifi, Extension Officer, Fakaofo.

Teahagaloa (1)

Location: 9°19'-9°24'S, 171°12'-171°16'W; on the island of Fakaofo.
Area: 10 ha.
Altitude: Sea level.
Overview: An area of reef flat, almost exposed at low tide, with deposits of sand and coral limestone, scattered coral heads and boulders of sedimentary rock.
Physical features: A large area of reef flats separating the deep central lagoon of Fakaofo Atoll from the open ocean. About 10% of the area comprises a continuous plate of sedimentary rock which underlies the entire atoll. Sand dunes on this plate are normally submerged at high tide. There are also many large boulders of sedimentary rocks scattered about the surface of the plate. On the lagoon side, there are extensive coral reefs at depths of two to five metres. Water flows over the plate during rising and falling tides as it enters and drains out of the lagoon. The water depth varies from place to place but is generally between 30 cm and 5 metres during low tide.
The climate is humid tropical, tempered by trade winds. The average annual temperature is 28°C, with little seasonal variation. Rainfall is irregular but heavy, and can exceed 2,500 mm per year.
Ecological features: The flats support some small patches of marine algae. The marine fauna is dominated by a great variety of reef fish, with lesser numbers of shellfish, echinoderms and sea cucumbers.
Land tenure: Customary ownership. The reef flat is owned by the whole community, with everyone on the island having equal rights to fish on it at any time, except under very special circumstances when specific localities may be privately claimed following their initial discovery.
Conservation measures taken: The island Council of Elders occasionally imposes regulations to control fishing activities and to resolve social disputes.
Land use: About 900 people live in the area. They are highly dependent on marine life as their primary source of protein. Fishing is the principal activity, the fishing occurring either with traditional stone traps, with nets, by rod-and-line, with spears or by hand (harvesting of clams). The use of stone traps is normally seasonal. In 1986, the Fisheries Department imported *Trochus niloticus* from Fiji, and released these onto the reef on a trial basis. Preliminary results suggest that this introduction has been successful.
Disturbances and threats: The area remains relatively undisturbed by man's activities, and the only serious problem is overfishing. The excessive use of fishing nets with small mesh-size poses a major threat to fish populations, especially parrotfish, while a rapid decline in the clam population is forecast as a result of the over-exploitation of immature clams.
Hydrological and biophysical values: The reef flat is the principal gap through which water flows between the lagoon and the open ocean. It plays a vital role in removing pollutants, including

oil, from the waters of the lagoon, and thereby protects the adjacent reefs from excessive pollution. These reefs support the largest marine biomass in the atoll, including many economically important species such as the clams *Tridacna maxima* and *T. squamosa* and many reef fish species. Huge numbers of juvenile fish find shelter around the coral reefs.
Social and cultural values: The area constitutes a major fishing ground for the islanders. Traditional stone traps are still used for fishing, and until recently, were the main method of fishing, catching enough fish to support the whole community. However, with the introduction of modern fishing techniques, there is a fear that this traditional activity, with strong cultural links, will gradually disappear.
Noteworthy fauna: The marine fauna of the coral reefs and reef flats has been summarized by UNEP/IUCN (1988). This rich marine fauna provides abundant food for a variety of fish-eating birds such as Pacific Reef-Heron (*Egretta sacra*), Wandering Tattler (*Heteroscelus incanus*), Black-naped Tern (*Sterna sumatrana*), Black Noddy (*Anous minutus*) and Fairy Tern (*Gygis alba*).
Noteworthy flora: None known.
Management authority and jurisdiction: The Fakaofo Council of Elders is responsible for the management of the site.
References: UNEP/IUCN (1988).
Reasons for inclusion: 1a, 2b, 2c. An important fishing ground for the inhabitants of Fakaofo Atoll, and an important feeding area for a variety of waterfowl and sea-birds.
Source: Kirifi Kirifi.

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KINGDOM OF TONGA

INTRODUCTION

Area: 699 sq.km.

Population: 101,000 (1990).

The Kingdom of Tonga comprises 171 islands in the southwest Pacific, 2,250 km northeast of New Zealand and 640 km east of Fiji. The islands are distributed in a north-south line stretching over about 900 km of ocean between latitudes 15°30' and 22°20' South and longitudes 173°00' and 176°15' West. The islands are mainly elevated coral reefs which cap the peaks of two parallel submarine ridges, although some are volcanic. The region is geologically active, with earthquakes and volcanic eruptions in recent times. The islands are arranged in three main groups: Vava'u (143 sq.km) in the north, Ha'apai (119 sq.km) in the centre and Tongatapu (265 sq.km) in the south. The Tongatapu and Ha'apai groups are low-lying coral limestone islands. Tofua and Kao, to the west of the Ha'apai Group, the islands of the Vava'u Group and the isolated Niuas (including Niuafo'ou and Niuatoputapu) in the far north, are mountainous volcanic islands with low cones (some still active), between 500 and 1,000 m high. The extinct volcano of Kao, rising to 1,046 m, is the highest point in the Kingdom.

The climate is tropical maritime, with a mean annual temperature of 21.0°C (range 15°-27°C) on Tongatapu and 23.5°C on Vava'u, and a mean annual rainfall of 1,771 mm on Tongatapu and 2,342 mm on Vava'u. December to April is the hot, rainy season, with especially high humidity from January to March. The prevailing winds are the Southeast Trades. Tonga gets an average of two tropical cyclones per year, usually between November and March.

Polynesians first reached Tonga from Fiji over 3,000 years ago. The islands became a British Protectorate in 1899, although they remained under their own monarchy. Tonga became a fully independent country in June 1970, and is the last remaining hereditary monarchy in the South Pacific. Only 37 islands are inhabited, the remainder being too small, isolated and/or with insufficient water to support permanent populations. Many of these uninhabited islands are visited by fishermen and turtle and shellfish collectors. Over 70,000 people (about 68% of the population) live on the main island of Tongatapu, the site of the capital, Nuku'alofa. Most of the remainder live on the Ha'apai Group and 'Uta Vava'u (the main island in the Vava'u Group).

The economy is largely based on agriculture. Copra, coconuts, bananas, vanilla and water-melons are the chief exports. Other crops grown for local consumption include yams, taro, cassava, groundnuts, rice, maize, sugar cane and citrus fruits. The processing of coconuts into copra and desiccated coconut is the only significant industry. Tourism and cottage handicrafts are small but growing industries. Fisheries, especially inshore, are important, although demand exceeds supply, and Tonga is a net importer of fish and fish products.

Although most of the larger islands are raised coral limestone islands, much of the soil is volcanic, having been deposited as ash and cinders from the chain of volcanoes to the west. The original vegetation on limestone islands comprised lowland rain forest dominated by *Calophyllum*. However, virtually all of the primary forest on the flat islands was cleared for agriculture many years ago, and there are now large areas of secondary vegetation with *Lantana* and *Psidium* scrub, and *Sorghum* and *Panicum* grasslands, particularly on the islands of Tongatapu, 'Eua and 'Uta Vava'u. Coastal scrub with *Barringtonia* and *Scaevola* occurs on most islands, and *Casuarina* woodlands are found on recent lava flows. The crater zone of most volcanic islands has a distinct but sparse herbaceous flora, and there is moss (cloud) forest on the summit of Kao and on Tafahi, to the north of the Vava'u Group. About 770 species of vascular plants have been recorded, including 70 ferns (three endemic species), three gymnosperms (one endemic species) and 698 angiosperms (nine endemic species) (Dahl, 1986).

The terrestrial fauna includes 12 reptiles (including one endemic species of skink which is probably extinct), 18 birds (two endemic species) and two bats, the only native mammals on the islands (Dahl, 1986). Sea turtles breed on many of the islands, and there are several large seabird colonies, the most important including those on 'Ata and Nuku (Hay, 1985).

Dahl (1980 & 1986) has given a brief account of the natural ecosystems of the islands, and has reviewed their importance for nature conservation. UNEP/IUCN (1988) provide a general account of the coral reef systems and reef resources, and give further details on five of the most important reef systems.

The principal threats to the natural ecosystems include soil destruction, deforestation, overgrazing and mining of sand and coral. Logging is now a growing problem on some of the high islands. The rats *Rattus rattus*, *R. exulans* and *R. norvegicus*, the mongoose *Herpestes auropunctatus*, and feral dogs, cats, goats and pigs have been introduced onto most of the larger islands. Pollution is also a serious problem locally. The unwise use of pesticides in agriculture and household and urban pest control, illegal poisoning and bombing of fish, and inadequate disposal of various pollutants, including sewage, solid waste and soluble toxins, are resulting in environmental damage on the more densely populated islands (Pearsall, 1991).

Summary of Wetland Situation

There are three main types of wetlands in Tonga: partially enclosed tidal lagoons with mangrove forest; totally enclosed brackish to saline lagoons with saltwater marshes and/or mangroves, and freshwater crater lakes. Several of the wetlands are very large by Pacific island standards, and the total area of lakes and internal waters amounts to over 2,963 ha. There are, however, very few streams of any significance, and no permanent streams on any of the low-lying limestone islands.

The principal wetlands are as follows:

- a large, partially enclosed double lagoon system with extensive mangrove swamps near Nuku'alofa on Tongatapu;
- volcanic crater lakes on Niuafo'ou, Tofua, Kao and possibly also Late;
- enclosed brackish lagoons on Nomuka and 'Uta Vava'u;
- a freshwater marsh near Tu'anuku on 'Uta Vava'u.

Mangrove swamps, dominated by species of *Rhizophora*, are well developed in the lagoon system on Tongatapu, in parts of the Vava'u Group, and around the totally enclosed lagoon on Nomuka in the Ha'apai Group. Seven species of mangrove have been reported from Tonga: three species of *Rhizophora*, two species of *Xylocarpus*, *Bruguiera gymnorrhiza* and *Lumnitzera littorea* (Woodroffe, 1987). The total area of mangroves has been estimated at 1,000 ha.

On several islands, large areas of reef flat are exposed at low tide. These are particularly extensive along the northwest shore of Tongatapu (Sopu Flats), along the channels between the many islands in the southern part of the Vava'u Group, and at the west end of Niuatoputapu in the extreme north. Extensive seagrass beds occur around Tongatapu (dominated by *Halodule uninervis*), in the Vava'u Group (dominated by *Syringodium isoetifolium*) and at Nomuka in the Ha'apai Group (*H. uninervis* and *S. isoetifolium*).

Very little information is available on the wetland fauna. Rather few species of waterbirds occur in the islands, and only five species are resident: the Pacific Reef Heron (*Egretta sacra*), Pacific Black Duck (*Anas superciliosa*), Banded Rail (*Rallus philippensis*), Spotless Crake (*Porzana tabuensis*) and Purple Swamphen (*Porphyrio porphyrio*). Six species of shorebirds occur on migration and during the austral summer: Pacific Golden Plover (*Pluvialis fulva*), Wandering Tattler (*Heteroscelus incanus*), Bristle-thighed Curlew (*Numenius tahitiensis*), Whimbrel (*N. phaeopus*), Bar-tailed Godwit (*Limosa lapponica*) and Ruddy Turnstone (*Arenaria interpres*), but only the plover and tattler would appear to be common (Pratt *et al.*, 1987; Watling and Talbot-Kelly, 1982). The Great Crested Tern (*Sterna bergii*) is a common resident in inshore waters, frequently feeding and resting on the reef flats. Land birds which occasionally visit the wetlands include the Swamp Harrier (*Circus approximans*), which is confined to the Ha'apai Group, and the widespread Collared Kingfisher (*Halcyon chloris*).

The wetlands are under threat from a variety of sources. Some wetland habitat has been reclaimed for urban development, especially around the big lagoons on Tongatapu. The discharge of sewage from tourist facilities and destructive fishing techniques have been identified as the most acute environmental hazards in coastal wetlands and reef systems (Chesher, 1984). Other hazards include the use of lead in paints used for water catchment systems, increasing use of pesticides, siltation of harbour environments, and construction of causeways without ducts for water circulation. Pernetta (1988) suggests that climatic change and sea-level rise could have severe impacts on the coastal systems in the islands, and could possibly lead to economic and social disruption, inter-island movement of populations, and emigration.

Little attention has been given to the conservation of wetlands in Tonga, except on the island of Tongatapu, where a large reserve of 2,835 ha has been established to protect the Fanga'uta and Fangakakau lagoons. There are prohibitions on the dumping of any effluents, on the cutting of any mangroves, on commercial fishing and on certain forms of subsistence fishing in the lagoons. This reserve, which was established under the provisions of the Birds and Fish Preservation Act, is the only protected area in the Kingdom which contains significant wetland habitat. All other existing protected areas were established to protect small islands, reefs systems and sites of cultural interest (IUCN, 1991).

A comprehensive Environmental Management Plan (Interdepartmental Environment Committee, 1990) has recently been prepared in a cooperative effort between the United Nations Economic and Social Commission for Asia and the Pacific (UN/ESCAP) and the Government of Tonga. The objectives of the Environmental Management Plan are: to examine the existing state of the environment in Tonga and summarize the relevant existing information in a single document; to determine the environmental participants in the Kingdom and their resource needs; to discover environmental resource needs that are not being met and identify these as problems; and to recommend a plan of action to deal with existing and projected environmental problems. The plan makes a series of recommendations relevant to the conservation of wetlands and water resources, and identifies a number of opportunities for further protected areas, several of which would contain wetlands. The plan also makes a series of recommendations aimed at increasing public involvement in environmental issues, monitoring and research (IUCN, 1991).

Wetland Research

Very little research has been carried out on the wetlands of Tonga, and most of this has concerned the lagoon system on Tongatapu. Vodonaivalu (1982) conducted a botanical survey of the mangrove forests of Tonga. Zann *et al.* (1984) studied the ecology of Fangu'ata Lagoon, and Ellison (1988) carried out research on the mangrove swamps of this lagoon for her M.Sc thesis. Dr Dieter Rinke of the Brehm Fund South Seas Expedition has recently been studying the birds of Tonga, especially the threatened species.

Wetland Area Legislation

There is no legislation which relates specifically to wetlands. However, the Birds and Fish Preservation Act (1915, amended in 1974), the Forest Act (1961), the Parks and Reserves Act (1976) and the Public Health Act all have a bearing on the conservation of wetlands. The Birds and Fish Preservation Act limits or prohibits the catching or injuring of 11 species of birds, all species of sea turtles and certain species of fish. Protected birds include the Niuafo'ou Megapode (*Megapodius pritchardii*) and the Sooty Rail (*Porzana tabuensis*). However, implementation of the Act is reported to be inadequate, and it is acknowledged that the Act requires updating (IUCN, 1991).

The Parks and Reserves Act of 1976 provides "for the establishment of a Parks and Reserves Authority and for the establishment, preservation and administration of Parks and Reserves". It states that every park "shall be administered for the benefit and enjoyment of the people of Tonga and there shall be freedom of entry and recreation therein by all persons". In the case of reserves, there shall be closer controls to enable the protection and preservation of the habitat and wildlife concerned. Tonga is fortunate in that its political and legal system enable parks and reserves to be established with less opposition than in many other South Pacific countries. However, this process is now hampered because of the considerable pressure of population on land resources (Eaton, 1985).

Pollution control is achieved mainly through the Public Health Act, administered by the Environmental Health Section of the Department of Health. All development projects are subject to environmental impact surveys supervised by the Office for National Parks and Reserves and the Department of Lands and Surveys.

At international level, the Kingdom of Tonga is not yet a party to the Convention on the Conservation of Nature in the South Pacific (the Apia Convention), the Convention for the Protection of the Natural Resources and Environment of the South Pacific (SPREP Convention) or any of the other international conventions that directly promote the conservation of nature.

Wetland Area Administration

No government agency has specific responsibility for the administration of wetland areas. The Ministry of Lands, Survey and Natural Resources has primary responsibility for matters relating to the conservation of natural resources, including wetlands. Under the provisions of the Parks and Reserves Act of 1976, a Parks and Reserves Authority was established in 1989 within this Ministry to protect, manage and develop natural areas in the Kingdom. In addition to the general administration of parks and reserves, this authority is also responsible for environmental impact assessment of all physical developments, physical planning and environmental education. Park management is hampered by shortage of funds and personnel, and there has been only limited development of protected areas (IUCN, 1991).

Organizations involved with Wetlands

Ministry of Lands, Survey and Natural Resources
- Parks and Reserves Authority

WETLANDS

Site descriptions based on information provided by Joanna C. Ellison and Dieter Rinke and on the literature.

Fanga'uta and Fangakakau Lagoon (1)

Location: 21°10'S, 175°10'W; in the centre of Tongatapu Island, on either side of the capital, Nuku'alofa.
Area: 2,835 ha (Folaha Mangrove Swamp 50 ha).
Altitude: Sea level.
Overview: A shallow, tidal, double lagoon complex on the northern coast of Tongatapu with fringing mangrove forest, some salt marsh vegetation, and only a narrow outlet to the sea. An important fish breeding area, but now degraded by pollution and overfishing.
Physical features: The lagoon comprises a shallow, almost enclosed estuarine embayment with two main branches separated from each other and from the ocean by a complex system of reefs and channels. The westernmost part, Fanga'uta Lagoon, is made up of a sinuous channel, the Folaha Sector, approximately 0.5 km wide, and a broad shallow basin, the Pe'a Sector, surrounding Kanatea Island and roughly two km in diameter. Fangakakau Lagoon in the east connects directly to the sea through a narrow channel, and can be subdivided into a shallow southerly basin, the Vaini Sector, and the deeper Mu'a Sector. The lagoon is generally shallow, reaching depths of only 1-2 m in the Pe'a and Vaini sectors, 3 m in the Folaha Sector and 6 m in the Mu'a Sector. Tidal circulation is constrained by the geometry of the reef flats and channels, with a range of 0.13 m compared to an open sea range of 1.06 m. A mean residence time of 23 days has been calculated, whilst tidal mixing is about 12% efficient. The salinity in the Fanga'uta section is 25.7 p.p.t. Freshwater input to the lagoon occurs entirely from the groundwater lens except during heavy rains. The groundwater is rich in nutrients, and provides essentially the entire nutrient supply to the lagoon. There are several islands, notably Nukunuku Motu, Kanatea, Talakite, Mata'aho and Mo'ungatapu (Zann *et al*., 1984).
Of the total 58 km of shoreline, 44.5 km are covered by tidal mangrove forest. Mangroves are most extensive in the Fanga'uta section, especially in the Folaha Sector where there is a single stand of about 50 ha of forest, 0.5-1.5 km southwest of Folaha village. This is the oldest mangrove forest known for the Holocene in the Pacific. The forest is natural in origin, and is believed to have been established about 7,000 years ago when sea level stabilized. The underlying sediments of peat and marine silt on limestone are four metres deep. The mangrove forest extends from the mainland into the lagoon, providing a tombolo linkage between the mainland and Nukunuku Motu across which a causeway has been built for agricultural access.
The climate is tropical maritime, with an average annual rainfall of 2,050 mm (range 838 to 2,655 mm since 1947) and mean monthly temperatures ranging from 21.2°C in August to 26.1°C in February. The prevailing winds are the Southeast Trades.
Ecological features: The ecology of Fangu'ata and Fangakakau lagoon has been described by Zann *et al.* (1984). Where the wind influence is strong and water is shallow, as in the Pe'a Sector, the water is turbid and the bottom has only slight seagrass cover. Here and in deeper parts of the lagoon, plankton dominate. In shallow areas protected from the wind, as in the Vaini Sector, a dense mat of sea-grass has developed. The principal seagrass species are *Halophila ovalis* and *Halodule pinifoliosa*. Algae include *Caulerpa serratula*, *C. racemosa*, *C. ashmeadii*, *Cladophora* sp., *Chorodesmis* sp., *Halimeda discoidea* and *Gracilaria* sp. (Zann *et al*., 1984).
The Folaha mangrove forest has been described by Ellison (1988), who recognizes five main vegetation zones:

- The lowest zone consists of almost pure *Rhizophora mangle (samoensis)* with a few individuals of *Rhizophora stylosa* mixed in and some *Lumnitzera littorea* along the upper boundary. The epiphyte *Taeniophyllum fasciola* grows on the stems of *R. mangle*.

- A zone of *Bruguiera gymnorrhiza*, with occasional *Lumnitzera littorea* on its lower margins. Common understorey species are *Polypodium scolopendria*, *Acrostichum aureum* and occasional *Davallia solida* and *Derris trifoliata*.
- Above 0.75 m elevation, *B. gymnorrhiza* becomes interdispersed with *Excoecaria agallocha*, and there is a more diverse assemblage of understorey species including *Clerodendron inerme*, *Hoya australis*, *Asplenium nidus* and *Dalbergia candenatensis*.
- Just above the level of mean high tides, *B. gymnorrhiza* and *E. agallocha* become interdispersed with *Hibiscus tiliaceus*, and additional species appear in the understorey, *e.g.* the epiphyte *Stenochlena palustris*, *Xylocarpus granatum*, *Pandanus tectorius*, *Lantana camara* and *Mariscus javanicus*.
- *Bruguiera*, *Excoecaria* and *Hibiscus* remain as co-dominants in the upper edge of the mangrove forest, but many other tree species are present, *e.g. Pandanus tectorius*, *Pittosporum arborescens*, *Xylocarpus granatum*, *Morinda citrifolia*, *Syzygium clusiifolium* and *Geniostoma insulere*, and the understorey is even richer.

The upper edge of the mangrove forest gives way to wet grassland with *Cyperus alternifolius*, *Paspalum vaginatum*, *Panicum maximum*, weeds and herbs. In the Mu'a Sector of the lagoon, the shoreline is raised limestone and there is very little mangrove. Some *Rhizophora mangle (samoensis)* is found in shallower shoreline areas, but elsewhere, *Hibiscus tiliaceus*, *Pandanus tectorius* and *Acrostichum aureum* dominate the shoreline. Inland, the native vegetation is a dry littoral woodland with species such as *Cocos nucifera*, *Rhus taitensis*, *Leucaena leucocephala*, *Psidium guajava* and *Mangifera indica*. Only small remnants of this woodland survive, most of the terrestrial vegetation of Tongatapu having been cleared for agriculture, principally coconut plantations.

Land tenure: State owned. Folaha mangrove swamp has been allocated as agricultural lots. Adjacent land is under private ownership in agricultural lots.

Conservation measures taken: The entire lagoon system, including all mangroves and foreshore (an area of 2,835 ha), was declared a protected area in 1974 under Act 24 amending the Birds and Fish Preservation Act of 1915. All commercial fishing, trawling and setting of fish-fences or traps, discharge of effluents into the lagoon, drilling, dredging, construction of any building works, harbours, wharfs, piers or jetties, and cutting or damaging mangrove trees is prohibited. The prohibition on fishing has apparently never been completely observed or enforced. However, a motion by the Legislative Assembly to repeal it in September 1981 was not ratified, and it thus remains in force (UNEP/IUCN, 1988).

Conservation measures proposed: Zann *et al.* (1984) have made a number of recommendations including the continued prohibition of commercial fishing and dredging, and the development of aquaculture of prawns, shellfish, mullet, milkfish and baitfish.

Land use: With a population of over 70,000, Tongatapu is one of the most densely populated islands in the South Pacific. A number of settlements border on the lagoon, including a suburb of Nuku'alofa. The local populace has historically exploited the lagoon resources. However, the introduction of synthetic monofilament gill nets, arrowhead fish-fences, commercial trawling, and the effects of pollution led to a rapid decline in reported catches during the late 1960s. A commercial trawling operation for penaeid prawns began in 1974, but because large numbers of juvenile fish were caught and the fishery for mullet, milkfish and bonefish continued to decline, the lagoon was gazetted for protection. Some subsistence fishing is still allowed in the lagoon, but there are controls on the methods used; fish-fences cannot be constructed and the minimum size for the mesh of nets is 2.5 inches (Eaton, 1985). Despite a ban on the cutting of mangrove trees, mangroves continue to be cut for fuel, timber and access. The bark is stripped from *Bruguiera gymnorrhiza* for making tapa dye. The principal land use in adjacent areas is mixed subsistence and cash agriculture, mainly *Cocos nucifera*, vanilla, root crops and bananas.

Possible changes in land use: In 1981, plans were put forward to dredge for building aggregate and landfill in Fanga'uta Lagoon, although all drilling and dredging in the lagoon are supposedly banned. There are plans to build a bridge and causeway across the entrance to the lagoon complex when funds are available (UNEP/IUCN, 1988). The Folaha mangrove swamp is likely to be completely cleared for agriculture, as population pressure increases on Tongatapu.

Disturbances and threats: The lagoon has been overfished, with a consequent gradual decline in mullet yields. The location of numerous arrowhead fish-fences around the entrance channel and the subsistence fishery within the lagoon have prevented fish stocks from recovering (Zann *et al.*, 1984). Land reclamation and the dumping of rubbish have caused localized disturbances. The entire system is now reported to be at least moderately polluted and degraded. Although it is prohibited to release pollutants into the lagoon, this prohibition is poorly enforced. Effluents are discharged directly into the lagoon from several sources, and there is considerable inflow of contaminated groundwater (TCSP, 1990). Mangrove cutting, although theoretically banned in the lagoon, still occurs, and there are now large areas of secondary growth dominated by the mangrove fern *Acrostichum aureum*. The entire Folaha mangrove swamp has been designated for clearance for agricultural purposes. The swamp was surveyed in 1986 for allocation into agricultural lots, but was still largely unfelled in early 1988.

Hydrological and biophysical values: Folaha mangrove swamp acts as a sediment trap for the polluted waters of the lagoon, and thereby plays an important role in maintaining water quality.

Social and cultural values: The lagoon is an important nursery ground for many reef and other food fishes which are the mainstay of the local subsistence fishery. The lagoon is an important breeding area for snappers (*Lethrinus* sp.) and supports juvenile populations of Grey Mullet (*Mugil cephalus*) and several species of penaeid prawn. The mangrove forest supports a crab fishery, and provides a variety of plant products utilised by the local people.

Noteworthy fauna: The fish and invertebrate fauna of the lagoon have been described by Zann *et al.* (1984). A total of 96 fish species is present in the lagoon, with the greatest diversity occurring near the entrance. Invertebrate species with a wide distribution in the lagoon include the alpheid shrimp *Alpheus mackayi*, the mantis shrimps *Squilla* sp. and *Lysiosquilla* sp., the commercially important prawns *Metapenaeus ensis* and *Penaeus semisulcatus*, and various crabs, notably *Scylla serrata*, *Thalamita prymna*, *Calappa hepatica* and several species of Xanthidae. *Holothuria atra* is common in parts of the lagoon, and several other species of holothurians occur near the lagoon entrance. Common bivalves include several small tellinids and *Grafrarium tunidum*. The jellyfish *Cassiopea* sp. is very common in the western part of the lagoon and is harvested for consumption. Crabs (*Sesarma* sp.) and molluscs (*Littorina* sp.) are common in the mangroves. Corals are virtually absent owing to the low salinity, soft substrate and high turbidity, but were more widespread in the recent past, as attested by the presence of large beds of dead *Acropora* and dead *Porites* "microatolls". This change is ascribed to an uplift at some time between 40 and 200 years ago, probably in 1914, resulting in conditions within the lagoon becoming unsuitable for coral growth (UNEP/IUCN, 1988).

Resident waterbirds associated with the lagoon include the Pacific Reef Heron (*Egretta sacra*), Pacific Black Duck (*Anas superciliosa*) and Great Crested Tern (*Sterna bergii*). Migrants include the Pacific Golden Plover (*Pluvialis fulva*), Wandering Tattler (*Heteroscelus incanus*) and Bar-tailed Godwit (*Limosa lapponica*). The Wattled Honeyeater (*Foulehaio carunculata*) occurs in the mangrove forest. The Banded Sea-snake *Laticauda colubrina* has been recorded in the lagoon.

Noteworthy flora: Folaha mangrove swamp is the largest mangrove swamp in Tonga. It exhibits high species diversity, and has intrinsic scientific interest as the earliest known Holocene peat-forming mangrove forest in the Pacific, about 7,000 years in age.

Scientific research and facilities: A study was made of Fanga'uta and Fangakakau Lagoon in 1981 by the Institute of Marine Resources of the University of the South Pacific, the Hawaii Institute of Marine Biology and the Tonga Fisheries Division (Zann *et al.*, 1984). J.C. Ellison carried out a detailed study of the present ecology and palaeoecology of the Folaha Mangrove Swamp between May 1987 and January 1988. There is an Agricultural Research Farm at Vaini, where the herbarium collection is held.

Conservation education: The lagoon is situated on Tongatapu, where most of Tonga's high schools and its two universities are located. The wetland thus has considerable potential for use for education purposes, although it appears that no plans exist at present.

Management authority and jurisdiction: The Birds and Fish Preservation Act places principal

responsibility for management of the lagoon on the Fisheries Division in the Ministry of Lands, Survey and Natural Resources. The lagoons are under the jurisdiction of the Crown.
References: Dahl (1980, 1986); Eaton (1985); Ellison (1988, 1989, in press); Ellison & Stoddart (1991); IUCN (1991); TCSP (1990); UNEP/IUCN (1988); Zann *et al.* (1984).
Reasons for inclusion: 1a, 2b, 2c. Much the largest enclosed lagoon system in Tonga, important as a breeding area and nursery grounds for various commercially important fish and shrimps, and supporting a rich and diverse mangrove forest of considerable scientific interest.
Source: Joanna C. Ellison and references.

Sopu Flats (2)

Location: 21°07'S, 175°18'W; on the northwest coast of Tongatapu, west of Nuku'alofa.
Area: 3,000-4,000 ha.
Altitude: Sea level.
Overview: A large area of intertidal reef flats, important for waterbirds, especially migratory shorebirds. Also an important fishing ground for local people.
Physical features: A large area of reef flats on the northwest shore of Tongatapu with extensive mudflats exposed at low tide and a narrow mangrove fringe. The flats extend west from Nuku'alofa for about 8 km to the western tip of Tongatapu and north to the small island of 'Atata.
Ecological features: The mangrove fringe is dominated by species of *Rhizophora*.
Land tenure: Property of the Crown. Adjacent land above high water mark is in private ownership.
Conservation measures taken: None.
Land use: Fishing and harvesting of shellfish and other marine products.
Disturbances and threats: Fishing activities at low tide cause a considerable amount of disturbance to wildlife, and there is over-exploitation of the marine resources.
Hydrological and biophysical values: No information.
Social and cultural values: The reef flats are a rich source of shellfish and other edible marine products for the local people.
Noteworthy fauna: An important site for waterbirds, especially shorebirds such as the Pacific Golden Plover (*Pluvialis fulva*), Wandering Tattler (*Heteroscelus incanus*), Ruddy Turnstone (*Arenaria interpres*) and a species of curlew (*Numenius* sp.). Resident species include Pacific Reef Heron (*Egretta sacra*), Pacific Black Duck (*Anas superciliosa*) and Purple Swamphen (*Porphyrio porphyrio*). The White-faced Heron (*Ardea novaehollandiae*) and Striated Heron (*Butorides striatus*), formerly rare stragglers to Tonga, have been recorded with increasing frequency in recent years and may be in the process of colonizing the islands.
Noteworthy flora: No information.
Management authority and jurisdiction: No information.
Reasons for inclusion: 1a, 2b, 3b. The large size of the area and the isolation of Tonga make this an important wintering site for migratory shorebirds.
Source: Dieter Rinke.

Nomuka Lagoon (3)

Location: 20°15'S, 174°48'W; in the Ha'apai Group, 105 km NNE of Tongatapu.
Area: 180 ha.
Altitude: Sea level.

Overview: An enclosed brackish to saline lagoon with a fringe of mangroves and salt marsh vegetation.
Physical features: Nomuka is a small raised coral limestone island of 534 ha, rising to a peak at 51 m and with a narrow fringing reef. The island contains a totally enclosed salt water lagoon 1.2-1.5 m deep with well-developed stands of mangroves and fringing salt marsh vegetation.
Ecological features: Mangrove swamp dominated by species of *Rhizophora*; non-tidal salt marsh with *Cyperus* sp.
Land tenure: No information.
Conservation measures taken: None.
Land use: No information. Most of the island is under cultivation for coconuts.
Disturbances and threats: No information.
Hydrological and biophysical values: No information.
Social and cultural values: No information.
Noteworthy fauna: No information.
Noteworthy flora: The non-tidal mangrove swamp and salt marsh vegetation are of conservation interest.
Management authority and jurisdiction: No information.
References: Dahl (1980, 1986); Pearsall (1991); Woodroffe (1988).
Reasons for inclusion: 1d. The only significant "marine lake" in Tonga, with interesting non-tidal mangrove and salt marsh vegetation.
Source: See references.

Tofua Crater Lake (4)

Location: 19°45'S, 175°04'W; to the west of the main Ha'apai Group, 155 km north of Tongatapu.
Area: 815 ha.
Altitude: About 20 m above sea level.
Overview: A large undisturbed crater lake in the centre of a high volcanic island.
Physical features: Tofua is a high volcanic island of 55.6 sq.km, rising to peaks at 507 m and 501 m on the north and south rims, respectively, of the central crater. This steep-sided, 4 km wide caldera is occupied by a large crater lake. The volcano is still active, with steam and gases issuing from a cone on the north side of the lake. The steep slopes to the south and southwest of the lake are forested; extensive lava flows cover the slopes to the north.
Ecological features: No information.
Land tenure: No information.
Conservation measures taken: None.
Conservation measures proposed: The Tourism Council of the South Pacific (TCSP, 1990) has recommended that the island be protected as a forest and geological or scenic protected area.
Land use: Formerly inhabited, the island was evacuated in 1854 because of the risk of eruptions. Some people have since returned to the island, and there are now two small settlements.
Disturbances and threats: Feral pigs are present.
Hydrological and biophysical values: No information.
Social and cultural values: No information.
Noteworthy fauna: Tofua is one of only two islands in Tonga where the Swamp Harrier (*Circus approximans*) is known to occur.
Noteworthy flora: No information.
Management authority and jurisdiction: No information.
References: Dahl (1980, 1986); Pearsall (1991); TCSP (1990).
Reasons for inclusion: 1a. A large undisturbed crater lake; the second largest lake in Tonga.
Source: See references.

Kao Crater Lake (5)

Location: 19°40'S, 175°02'W; to the west of the main Ha'apai Group, 5 km northeast of Tofua and 160 km north of Tongatapu.
Area: Less than 50 ha.
Altitude: Unknown; summit of island at 1,046 m.
Overview: A small freshwater crater lake surrounded by moss forest near the summit of Kao volcano.
Physical features: Kao Island is a high volcanic island with a peak at 1,046 m (the highest point in Tonga) and a small crater containing a freshwater lake. The volcano is active, and there are extensive lava flows around the summit. The shore of the lake is black lava. The summit area is covered in moss (cloud) forest; the lower slopes support lowland rain forest.
Ecological features: No information.
Land tenure: No information.
Conservation measures taken: None.
Conservation measures proposed: Dahl (1980) recommended the establishment of a reserve to protect the moss forest and lake habitats. The Tourism Council of the South Pacific (TCSP, 1990) has recommended that the island be protected as a forest and geological or scenic protected area.
Land use: Probably none at the lake. The island is comparatively isolated, and supports only a small population in a single settlement at the south end.
Disturbances and threats: None known.
Hydrological and biophysical values: No information.
Social and cultural values: No information.
Noteworthy fauna: No information.
Noteworthy flora: No information.
Management authority and jurisdiction: No information.
References: Dahl (1980, 1986); Pearsall (1991); TCSP (1990).
Reasons for inclusion: 1a. A very isolated and undisturbed crater lake surrounded by moss forest near the summit of the highest peak in Tonga.
Source: See references.

Lake Ano and Ngofe Marsh (6)

Location: 18°39'S, 174°03'W; near Tu'anuku village at the west end of 'Uta Vava'u Island in the Vava'u Group, 300 km north-northeast of Tongatapu.
Area: Approximately 500 ha.
Altitude: Sea level.
Overview: A large brackish lake and small freshwater swamp on a coral limestone island.
Physical features: 'Uta Vava'u, the main island in the Vava'u Group, is a raised coral platform with cliffs along the north coast and a low-lying southern coastline with an intricate network of channels and inlets creating one of the most sheltered harbours in the Pacific. Lake Ano (Lake Ono) is a large enclosed brackish lake near the west end of the island. Ngofe Marsh is a small freshwater swamp in a depression to the south the lake. The swamp covers about 25 ha, and is completely overgrown with reeds.
Ecological features: Freshwater swamp dominated by "reeds", presumably *Cyperus* sp.
Land tenure: No information.
Conservation measures taken: None.

Conservation measures proposed: Dahl (1980) recommended the establishment of a reserve to protect the swamp and lake habitats.
Land use: No information. 'Uta Vava'u is a densely populated island, with most people engaged in fishing and agriculture. The many protected anchorages in the bays along the south coast of 'Uta Vava'u make this a popular destination for cruising yachts.
Possible changes in land use: Recent decisions by the Government of Tonga have targeted Vava'u for rapid development for agricultural and tourist activities, with additional roads, causeways, resorts and harbours planned (UNEP/IUCN, 1988).
Disturbances and threats: No information.
Hydrological and biophysical values: No information.
Social and cultural values: No information.
Noteworthy fauna: No information.
Noteworthy flora: The freshwater swamp vegetation at Ngofe Marsh is of conservation interest.
Management authority and jurisdiction: No information.
References: Dahl (1980, 1986); Pearsall (1990); UNEP/IUCN (1988).
Reasons for inclusion: 1a, 2b. An interesting brackish lake and the largest freshwater swamp in Tonga.
Source: See references.

Niuafo'ou Crater Lake (7)

Location: 15°36'S, 175°38'W; on the island of Niuafo'ou in the Niuas, 610 km north of Tongatapu and 385 km southwest of Savai'i in Western Samoa.
Area: 1,450 ha.
Altitude: Near sea level.
Overview: A large crater lake and several smaller lakes with associated hot springs and reed swamps, in the centre of Niuafo'ou Island. The island is of special interest for its endemic megapode, *Megapodius pritchardii*.
Physical features: Niuafo'ou Island (34.7 sq.km) is a collapsed volcanic cone, once 1,300 m high, but now reaching a peak at 205 m on the northern rim of the central crater. The centre of the island is occupied by a large crater lake, Vai Lahi, nearly 5 km wide and 84 m deep, a smaller lake, Vai Si'i, in the northeast, and several tiny lakes, ponds and hot springs in the northeast and south. During periods of heavy rainfall, these lakes and ponds combine to form one large lake. There are three small secondary cone islands in the main lake, the highest of which, Motu Molemole, has its own crater lake ("a lake within an island within a lake within an island"). The volcano is active; the last major eruptions were in 1929 and 1946.
Ecological features: There is some *Cyperus* swamp around the lakes. There appears to have been a change in the ecology of the lakes in recent years, possibly as a result of an increase in sulphur. The island remains largely forested, although parts of the south and west sides are covered by bare black lava fields.
Land tenure: No information.
Conservation measures taken: None.
Conservation measures proposed: Dahl (1980), Hay (1985) and the Tourism Council of the South Pacific (1990) have recommended the establishment of a reserve to protect the forest, lake and marsh habitats and the endemic megapode. D. Rinke has recommended that all of the island inside the crater be given reserve status to protect the lake systems, the indigenous forests and the endemic megapode.
Land use: Niuafo'ou is a remote and sparsely populated island. There is no permanent wharf and only one anchorage on the west side. The island was evacuated after an eruption in 1946, and the 1,300 inhabitants moved to Eua Island. Some 200 returned in 1958, and the population had

increased to 678 by 1976. The principal activity is subsistence agriculture.
Possible changes in land use: The Government of Tonga is reportedly negotiating with the Government of the Islamic Republic of Iran to convert the island's crater into an oil storage container. This would involve draining the lakes and lining the crater with concrete before filling it with oil (Pearsall, 1991).
Disturbances and threats: The lake ecosystems have been greatly disturbed by the introduction of tilapia (*Oreochromis* sp.) in the main lake and all associated lakes. There was a boom in fish populations in the early years after introduction. The original green colour caused by algae disappeared, and duck numbers fell markedly in the five years after fish introduction. However, there is some evidence that the tilapia are now dying out. The principal threat to the endemic megapode is from predation by feral cats and harvesting of eggs by the local people. Although the species is protected by law, there is no enforcement, and more than 100 eggs can be collected at each breeding site in one year (Collar and Andrew, 1988).
Hydrological and biophysical values: No information.
Social and cultural values: No information.
Noteworthy fauna: The Pacific Black Duck (*Anas superciliosa*) still occurs in small numbers. The Niuafo'ou Megapode (*Megapodius pritchardii*) is confined to the island, where it uses hot volcanic ash to incubate its eggs, a habit which concentrates its nesting sites to areas of loose soil close to vents, either in forest or in open ash. A survey in 1976 suggested that there were between 200 and 400 birds on the island (Collar and Andrew, 1988). The forests also support the last remaining Tongan population of the Blue-crowned Lorikeet (*Vini australis*).
Noteworthy flora: No information.
Management authority and jurisdiction: No information.
References: Collar & Andrew (1988); Dahl (1980, 1986); Hay (1985); Pearsall (1991); TCSP (1990); Watling & Talbot-Kelly (1982).
Reasons for inclusion: 1a, 1d, 2b, 2d. The lake system, hot springs and reed swamps are of great conservation value, and the surrounding forests are home to an endemic megapode.
Source: Dieter Rinke and references.

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TUVALU

INTRODUCTION

Area: 25.11 sq.km.

Population: 8,600 (1987).

Tuvalu, formerly the Ellice Islands, comprises a 570 km chain of nine atoll systems and raised coral islands in the southwest Pacific between 5^{o} and 11^{o}S and 176^{o} and 180^{o}E. The islands lie about 1,050 km north of Fiji. Funafuti (254 ha), Nukufetau (307 ha), Nukulaelae (166 ha), Nanumea (361 ha) and Nui (337 ha) are atolls, generally with narrow strips of land in the east and reefs with scattered islets in the west. Niutao (226 ha), Nanumanga (310 ha) and Niulakita (41 ha) are limestone islands with enclosed brackish to saline lagoons. Vaitupu (509 ha) is intermediate in type, with two virtually land-locked internal lagoons. The maximum elevation is about 4 m above sea level.

The climate is humid tropical, with no marked seasonal variations. Temperatures average about 28^{o}C. The average annual rainfall varies from about 2,800 mm to 3,600 mm, depending on the island. Trade winds from the east moderate conditions for much of the year. The islands are occasionally affected by hurricanes, the hurricane season being from October to March.

Tuvalu is one of the smallest sovereign countries in the world. The islands were declared a British protectorate in 1892, and administered as a colony jointly with the Gilbert Islands (now Kiribati) from 1915. Separate constitutions for the Ellice Islands, renamed Tuvalu, and the Gilbert Islands came into force in 1975, and in October 1978 Tuvalu became a fully independent nation. The inhabitants are almost entirely of Polynesian origin, and have close ties with the Samoans and Tokelauans to the south and east. The population density is very high (340 persons per sq.km in 1987), as is the growth rate (2.8% per annum in 1987). About 25% of the population live on Funafuti, the capital island, and there are villages on all eight of the outlying islands. The principal activity is fishing. Agriculture is very limited because of the poor quality of the soil which is composed largely of coral sand and rock fragments. The main food crops are coconuts, pulaka, pandanus fruits, bananas and pawpaws. Copra is the only natural resource exported. The chief source of income is remittances from Tuvaluans working abroad (chiefly in Nauru), and the economy is heavily dependent on British and Australian aid. About a quarter of Government revenue comes from the sale of postage stamps to collectors.

The marine systems have recently been described by UNEP/IUCN (1988). The dominant terrestrial vegetation is atoll/beach scrub, and there is no forest on the islands. Small stands of mangrove occur on at least five of the islands. Some 86 vascular plants have been recorded, of which 44 are indigenous, but none is endemic. One endemic species of endodontid snail and four endemic species of charopid snail have been described, but their present status is unknown (Pearsall, 1991). Sea-birds have traditionally been harvested for food, and as a consequence, populations are rather low. However, there are colonies of most of the common species of terns, noddies and boobies on relatively undisturbed islets. The investigation of suitable islets for sea-bird protection has been identified as a priority (Hay, 1985; TCSP, 1990).

Most of the natural vegetation has been cleared for coconuts and gardens, and virtually all land suitable for agriculture is now under cultivation. Overgrazing is a serious problem on some of the islands, and there have been recent signs of over-fishing on Funafuti and Vaitupu (Dahl, 1986;

UNEP/IUCN, 1988). No protected areas have been established, and because of the very high population density and scarcity of undisturbed terrestrial vegetation, there is now limited scope for creation of reserves. Nevertheless, remaining areas of atoll scrub should be considered for protection, perhaps in association with sea-bird or turtle areas (TCSP, 1990).

An ESCAP Environmental Mission in 1988 identified the major environmental problems as coastal erosion, environmental impacts of land reclamation activities, degradation of fishery resources, inefficient land use practices, pollution from the absence of a sewerage system and inadequate garbage disposal, and uncontrolled exploitation of flora and fauna, especially turtles and coconut crabs (ESCAP, 1988).

The islands are subjected to occasional cyclones which have caused extensive damage to reefs in the past. Cyclones, together with rising sea levels, put the continued future existence of Tuvalu as a viable entity in some doubt (TCSP, 1990). Rising sea level has already resulted in increased saline intrusion into the groundwater, contaminating a part of the nation's very limited freshwater supplies, and in recent years, there has been increased flooding in parts of Funafuti during the high tides of February and September. In the event of severe sea level rise, the loss of freshwater resources, erosion and increased episodic destruction through hurricanes may force the evacuation of the country (Pernetta, 1988).

Summary of Wetland Situation

There are no permanent, natural freshwater bodies on the islands. However, small ponds have been constructed on some of the limestone islands for the cultivation of taro. Groundwater is present on all but two of the islands, and this, together with rainfall, provides the inhabitants with the bulk of their freshwater supply (CSC, 1984).

There are enclosed brackish to saline lagoons on Niutao, Nanumanga and Niulakita, and two small brackish tidal lagoons on Vaitupu, connected to the sea by narrow channels. Mangroves occur on three of the limestone islands (Vaitupu, Nanumanga and Niutao) and two of the atolls (Funafuti and Nui). Two species are present, *Rhizophora stylosa* and *Lumnitzera littorea*, often in association with the shrub *Pemphis acidula* (Woodroffe, 1987). On Funafuti, a shingle barrier has totally impounded the mangroves on the main islet, forming an inland mangrove swamp. Inland mangroves also occur around the land-locked lagoons on Niutao and Nanumanga. On the latter island, the lagoon is surrounded by an extensive woodland of *Rhizophora* covering about 28.5 ha. On Vaitupu, mangroves occur on the shores of both lagoons, and are almost entirely cut off from the sea. These mangroves reach about six metres in height and cover about six ha. Small stands of mangrove occur in sheltered bays on three of the islets in Nui Atoll, in total covering only about 1.7 ha (Woodroffe, 1987). The mangroves of Tuvalu were listed as a threatened ecosystem by Dahl (1986).

Wetland Research

Some studies have been carried out on the mangrove communities (Woodroffe, 1985 & 1987; Woodroffe & Moss, 1984).

Wetland Area Legislation

The Ordinance to Provide for the Conservation of Wildlife (1975, revised 1978) gives full protection to 32 species of birds, and protection to six migratory species during certain months of the year. The Ordinance also provides for the declaration of wildlife sanctuaries, but no reserves have as yet been gazetted (TCSP, 1990; IUCN, 1991). The Fisheries Ordinance (1978) controls fishing methods and seasons, and allows for designation of areas where fishing is prohibited. However, the Ordinance does not provide guidelines as to management or development of such areas, and is thus inadequate for establishing and developing marine reserves (TCSP, 1990). Recent legislation also covers pollution, regulation of sand and coral removal, and waste disposal, but implementation and enforcement are reported to be poor (UNEP/IUCN, 1988).

The Fourth Development Plan 1987-1991 contained a chapter entitled Land Management, Environment and Conservation, which stated that the Government's general aim was to bring about improved "environmental control through better utilisation of the country's very meagre land and environmental resources" (IUCN, 1991). There is as yet no environmental impact assessment legislation in Tuvalu, although this has been recommended (IUCN, 1991).

Tuvalu is a member of the South Pacific Regional Environment Programme (SPREP). It has signed the Convention for the Protection of the Natural Resources and Environment of the South Pacific (SPREP Convention) and the Convention on Biological Diversity, but neither of these has been ratified. Tuvalu has not as yet joined the Convention on the Conservation of Nature in the South Pacific (the Apia Convention), World Heritage Convention, Man and the Biosphere Programme or Ramsar Convention.

Wetland Area Administration

Not applicable.

Organizations involved with Wetlands

The Ministry of Commerce and Natural Resources is the government body responsible for natural resources.

WETLANDS

Tuvalu has very few wetlands, and only the small, isolated stands of mangrove (here treated as a single site) would appear to be of international importance on the basis of the Ramsar Criteria. The following site account has been compiled from the literature.

Tuvalu Mangroves (1)

Location: 6°05'-8°45'S, 176°15'-179°10'E; on the islands of Nanumanga, Niutao, Funafuti, Nui and Vaitupu.
Area: Over 40 ha.
Altitude: Sea level.
Overview: Small stands of mangrove on five of the Tuvalu islands, including inland mangroves around enclosed saline lagoons.
Physical features: Small stands of mangrove occur on at least five of the nine islands in the Tuvalu group: Nanumanga, Niutao, Funafuti, Nui and Vaitupu. Niutao (226 ha) and Nanumanga (310 ha) are limestone islands with enclosed brackish to saline lagoons. Mangroves occur as fringes around these lagoons, and are entirely cut off from the sea. On Nanumanga, the lagoon is

surrounded by an extensive woodland of *Rhizophora* covering about 28.5 ha. Funafuti (254 ha) and Nui (337 ha) are atolls, with a number of small islets scattered around a large, marine lagoon. Small patches of mangrove (covering 1.7 ha) occur in sheltered bays on three of the islets in Nui Atoll, while in Funafuti Atoll, there is an inland mangrove swamp on the main islet, cut off from the sea by a shingle barrier. Vaitupu (509 ha) is intermediate in type, with two virtually land-locked lagoons connected to the sea by narrow channels. Mangroves occur on the shores of both lagoons, and in total cover about 6.0 ha (Woodroffe, 1987).
The climate is humid tropical, with an average annual rainfall of about 2,800 to 3,600 mm, depending on the island. The islands are occasionally affected by hurricanes between October and March.
Ecological features: Mangrove communities with two species of mangrove: *Rhizophora stylosa* and *Lumnitzera littorea*. In some areas, the shrub *Pemphis acidula* grows in association with the mangroves (Woodroffe, 1987). On Vaitupu, the mangroves grow to a height of about six metres. The dominant terrestrial vegetation in adjacent areas is atoll/beach scrub and coconut palms.
Land tenure: Customary ownership.
Conservation measures taken: None.
Land use: No information is available on the utilization, if any, of the mangroves. All of the islands are inhabited, with fishing being the principal activity.
Disturbances and threats: The mangroves of Tuvalu were listed as a threatened ecosystem by Dahl (1986). Major environmental problems in the islands include coastal erosion, degradation of fishery resources, pollution from the absence of a sewerage system and uncontrolled garbage disposal (ESCAP, 1988), but the extent to which these affect the mangrove communities is unknown. The principal long-term threat is possible sea level rise as a result of global warming (Pernetta, 1988).
Hydrological and biophysical values: No information.
Social and cultural values: No information.
Noteworthy fauna: No information.
Noteworthy flora: These very isolated stands of mangroves, and especially the inland mangrove swamps on Nanumanga, Niutao and Funafuti, are of considerable botanical interest.
Scientific research and facilities: Some studies have been carried out on the mangrove communities (Woodroffe, 1985 & 1987; Woodroffe & Moss, 1984).
Management authority and jurisdiction: Ministry of Commerce and Natural Resources.
References: Dahl (1986); ESCAP (1988); Pernetta (1988); Woodroffe (1985 & 1987); Woodroffe & Moss (1984).
Reasons for inclusion: 1d, 2b. The mangroves are of considerable interest because of their isolation.
Source: See references.

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UNITED STATES OF AMERICA - OUTLYING ISLANDS

INTRODUCTION

Area: Midway 5.18 sq.km; Johnston 2.52 sq.km; Wake 7.4 sq.km; Palmyra 6.56 sq.km; Kingman Reef 0.03 sq.km; Jarvis 4.45 sq.km; Howland 1.62 sq.km; Baker 1.24 sq.km.

Population: Midway 2,300 (1981); Johnston 1,000 (1981); Wake 1,600 (1981). Palmyra, Kingman Reef, Jarvis, Howland and Baker are uninhabited.

Three isolated islands in the North Pacific (Midway, Johnston and Wake), three of the Line Islands (Palmyra, Kingman Reef and Jarvis) straddling the Equator, and two islands at the northern end of the Phoenix Islands (Howland and Baker), almost on the Equator, are unincorporated U.S. possessions.

Midway Atoll (28°15'N, 177°20'W), the northwesternmost atoll in the Hawaiian chain, comprises a circular coral atoll with two low sandy islands, Sand Island and Eastern Island, approximately 1,850 km northwest of Oahu. The atoll was discovered in 1859 and annexed by the U.S.A. in 1867. It has been used as a commercial aircraft stopover since 1935, and has been an important military airbase since 1941 under the jurisdiction of the U.S. Navy (UNEP/IUCN, 1988).

Johnston Atoll (16°,45'N, 169°32'E) comprises a coral atoll with two natural islands, Johnston and Sand, and two artificial islets, North (Akau) and East (Hikina), created by construction work in 1963-64. The atoll is situated approximately 1,320 km southwest of Oahu. It was discovered in 1796, claimed by Hawaii in 1858, and taken over by the U.S. Navy in 1934. Guano was exported by the U.S.A. during the second half of the 19th century, and an airforce base was established in the 1940s. The islands are now under the jurisdiction of the U.S. Department of Defence and are used by the Defense Nuclear Agency as a store for chemical munitions. Considerable controversy surrounded the recent construction of an incinerator on the island for the destruction of nerve gas and other chemical weapons (IUCN, 1991; UNEP/IUCN, 1988).

Wake Atoll (19°18'N, 166°35'E) comprises a coral atoll with three small islands, Wilkes, Wake and Peal, approximately 1,200 km north of Kwajalein in the Marshall Islands. The islands were discovered in 1841, and annexed by the U.S.A. in 1898. A seaplane base opened in 1935, and the islands became important as a stopover for trans-Pacific flights. Wake has been administered by the U.S. Air Force since 1972, and is an important airforce base (UNEP/IUCN, 1988).

Palmyra (5°52'N, 162°05'W) is an uninhabited atoll with a number of small, low islets around a lagoon complex on a platform reef. It lies near the western end of the Line Islands, approximately 1,600 km south of Oahu. The atoll was discovered in 1802, claimed by Hawaii in 1862 and annexed by the U.S.A. in 1912. It has been privately owned since about 1900, but is now unoccupied. However, it was an important air transport base during World War II, and the U.S. Air Force continued to use the landing strip until 1961. Originally there were 52 small islets in the atoll, but many of these were linked together during the war and there are now only 39. A proposal to use Palmyra for storage of nuclear waste in 1979 was rejected (Dahl, 1986; UNEP/IUCN, 1988).

Kingman Reef (c.6°32'N, 162°17'W) is a triangular reef with one tiny coral islet, about 75 km north-northwest of Palmyra. According to some reports, in heavy seas the entire island is submerged. The reef was used as a seaplane station in 1937 and 1938, but has otherwise been undisturbed (Dahl, 1986; North, 1990).

Jarvis Island (0°23'S, 160°01'W) is a low, flat coral island surrounded by a fringing reef in the Line Islands, approximately 2,100 km south of Oahu. The island was occupied during World War II, but is now uninhabited (Dahl, 1986; IUCN, 1991; UNEP/IUCN, 1988).

Howland Island (0°48'N, 176°38'W) is a low, flat coral island surrounded by a fringing reef at the northern end of the Phoenix Islands, approximately 1,150 km east of Tarawa in Kiribati. The island was annexed by the U.S.A. in 1856 and was an important source of guano between 1859 and 1878. An airstrip and lighthouse were built in 1937 and the island was occupied during World War II, but is now uninhabited (Dahl, 1986; IUCN, 1991; UNEP/IUCN, 1988).

Baker Island (0°12'N, 176°29'W) is a small coral island surrounded by a fringing reef, approximately 58 km southeast of Howland. Guano was mined in the late 19th century, and the island was occupied during World War II, but it has been uninhabited since then (Dahl, 1986; IUCN, 1991; UNEP/IUCN, 1988).

The legal status of seven of these islands is currently under dispute, with the State of Hawaii seeking to extend its boundaries to include Midway, Howland, Baker, Jarvis, Kingman Reef and Palmyra, and the State of Guam seeking to add Wake (locally known as Enenkio) to its territory (North, 1990). The Marshall Islands have joined the dispute by renewing their claim to Wake Island.

Midway, Johnston, Wake, Jarvis, Howland and Baker are all arid atolls, with very low rainfall (average annual rainfall on Johnston, 663 mm). The islands are covered with low grasses and sparse shrubs, and lack fresh water. Palmyra has a wet climate, with an average annual rainfall of about 5,100 mm per year, and is the only "wet" atoll under U.S. jurisdiction. The vegetation is very lush, with coconut palms, several species of ferns and two species of trees, but the islands lack permanent fresh water. Midway, Johnston, Wake, Jarvis, Howland, Baker and Palmyra all support large breeding colonies of sea-birds. Green Turtles (*Chelonia mydas*) nest in large numbers on Midway, and occur regularly in the seas around the other islands. The Hawaiian Monk Seal (*Monachus schauinslandi*) remains common on Midway, and is an occasional visitor to Johnston Atoll (IUCN, 1991; UNEP/IUCN, 1988).

Midway Atoll was notified as a National Wildlife Refuge in 1988 (IUCN, 1991). Prior to that, the U.S. Fish and Wildlife Service had assisted in the management of wildlife under a memorandum of agreement with the U.S. Navy. Johnston was declared a bird refuge in 1926 under Presidential Executive Order, and later upgraded to National Wildlife Refuge. At Wake Atoll, Air Force regulations have designated important sea-bird nesting areas as refuges. Jarvis, Howland and Baker were declared National Wildlife Refuges in 1974, and are under the jurisdiction of the U.S. Fish and Wildlife Service. The refuges are administered by the Hawaiian Islands and Pacific Islands National Wildlife Refuge Complex in Honolulu (IUCN, 1991; UNEP/IUCN, 1988). Kingman Reef and Palmyra are unprotected. Hay (1985) has suggested that Palmyra would be a suitable site for a reserve, perhaps under a non-governmental organization such as The Nature Conservancy.

Summary of Wetland Situation

There is no natural fresh water on any of the islands, and it seems that there are no true wetlands.

WETLANDS

None.

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REPUBLIC OF VANUATU

INTRODUCTION

by Ernest Bani and David Esrom

Area: 12,189 sq.km. (14,763 sq.km.)

Population: 142,630 (1989 National Census).

The Republic of Vanuatu (formerly the Anglo-French Condominium of the New Hebrides) is an archipelago of about 80 islands located near the eastern limits of the Indo-West Pacific region between latitudes 13° and 21° South and longitudes 166° and 170° East. The islands are oceanic, formed by uplift and accumulation of volcanic and carbonate deposits, mainly during the Quaternary Period. Lying at the end of the Melanesian arc which includes New Guinea and the Solomon Islands to the northwest, they form a distinct geographic and biogeographic unit separated by deep ocean trenches from neighbouring land masses.

The climate varies from hot, very wet and humid with little seasonality in the north, to a warm, less humid and more seasonal climate in the south. Rainfall decreases from about 4,200 mm in the north to about 1,500 mm in the south. The mean daily temperatures at sea level fluctuate only slightly around 25°C throughout the year. Vanuatu lies in the cyclone belt, and cyclones may occur anywhere in the islands between November and April. Over the last 40 years, the islands have been struck by an average of 2.6 cyclones per year.

Some 85% of the population are dependent on traditional subsistence agriculture (slash-and-burn farming) for their livelihood, although this is often supplemented by reef fishing and occasionally also freshwater fishing. The remainder of the population live in the urban centres of Port Vila on Efate and Luganville on Espiritu Santo. Most of the population lives along the coast, and the interiors of many islands, particularly the larger, are virtually uninhabited. Thus although the overall population density is low, densities along the coast are often quite high. On some islands, this has resulted in problems of soil erosion associated with reduced fallow periods in the slash and burn cycle.

The characteristic vegetation is evergreen rainforest which covers about 75% of the country. On the larger mountainous islands, three major categories of vegetation can be readily identified: (a) evergreen tropical forests on lowland, wet, windward slopes; (b) semi-deciduous forests and fire-induced savannahs and grasslands on lowland, drier, leeward slopes; and (c) evergreen forests of upland and summit areas where the cooler, wetter and more humid climate results in a forest of smaller trees rich in epiphytes (Chambers, 1992). There are about 900 species of flowering plants in Vanuatu, a comparatively low number compared with neighbouring island groups, and only 135 (15%) are endemic. The fern flora, by contrast, is comparatively rich, with about 250 species known to occur (Chambers, 1992).

Vanuatu is rich in natural resources but generally poorly developed. About 5,000 sq.km (41%) of Vanuatu's total land area are suitable for cultivation, but only about 30% of this area is currently under cultivation. Conditions of climate and soil support the cultivation of copra, cocoa, coffee and a variety of other agricultural crops such as tubers, spices and fruits, as well as the development of livestock husbandry. There is considerable potential for forestry development, particularly in areas where agricultural development is limited. Significant potential also exists for the development of coastal and deep-sea fisheries. Mineral resources have been located on many islands, and there is potential for the exploitation of zinc, manganese, gold and raised coral limestone, as well as geothermal energy.

The country's main export is copra, although coffee, beef and cocoa exports are gaining in importance. Tourism is the main foreign exchange earner.

Summary of Wetland Situation

Dahl (1980 & 1986) lists the following wetland habitats as occurring in Vanuatu:

- permanent lake (Ambae, Ambrym, Efate, Epi, Espiritu Santo, Gaua, Maewo, Malekula, Tanna and Thion);
- hot springs with algae (Efate);
- freshwater swamp and marsh (Anatom, Efate, Epi, Erromango, Espiritu Santo, Gaua, Maewo, Tanna and Thion);
- mountain streams (common);
- lowland rivers (common);
- riverine forest on alluvial soils;
- swamp forest (Efate, Malekula and Espiritu Santo);
- non-tidal salt marsh (Loh);
- closed lagoon (Efate);
- mangrove forest (mostly on Malekula);
- sea-grass beds (common in coastal areas).

There are about 25-30 natural freshwater lakes in Vanuatu. Several of these are crater lakes, some within active volcanoes. Much the largest is Lake Letas (1,900 ha), the largest freshwater lake in the island Pacific outside of New Guinea. This lake lies within the occasionally active Mount Garet on Gaua Island. The caldera lakes of Ambae's active volcano Waivundolue, at over 1,300 m elevation, are the highest lakes in the South Pacific. Many of the other freshwater lakes occur in lowland areas and usually support marsh vegetation. Most are very small, and some are seasonal. There are also a few brackish and saline lagoons in the coastal zone of some islands, *e.g.* on north Efate and south Espiritu Santo. The largest of the brackish lagoons is Lake Nalema on east Epi. Vanuatu's largest closed saline lagoon, Ekasuvat Lagoon near Port Vila on Efate, is now much disturbed by urban development.

Rivers and streams are abundant in the islands, the largest occurring on Espiritu Santo and Malekula. Although of no great length, these rivers may carry large amounts of water during rainy periods. Most of the rivers are characterized by their large and rapid fluctuations in flow regime coupled with generally steep gradients. Many, such as the Teouma River on Efate and the Matenoi River on south Malakula, flow through spectacular and almost inaccessible gorges for much of their length. The only extensive floodplain area in the country is formed by the rivers which drain the Tabwemasana Range of central Espiritu Santo and flow north into Big Bay. Some rivers, particularly in areas made up largely of raised reefs, *e.g.* eastern Espiritu Santo, coastal Efate and the Torres Islands, flow only at times of heavy rainfall. On some islands, there is little or no surface water for all or much of the year because of the porous nature of the uplifted coral substrates.

Freshwater swamps and swamp forests are generally small and few in number. They occur as fringing areas around lakes on Efate and Thion Island, in depressions on plateaux *e.g.* on Efate, Epi, Maewo and Gaua, in extinct volcanoes such as Vanua Lava, or on floodplains such as those of the rivers entering Big Bay on Espiritu Santo (Chambers, 1992). Patches of swamp forest on Efate are dominated by species of *Barringtonia* and *Pandanus*, while those on Malekula are dominated by species of *Hibiscus* and *Metroxylon*. The largest area of swamp forest in Vanuatu occurs on the floodplains south of Big Bay on Espiritu Santo. These floodplains receive most of the rivers that drain the island's high mountain massif, and support a particularly rich and diverse swamp forest community dominated by species of *Hibiscus* and *Erythrina*.

Mangroves constitute the most extensive wetland vegetation in Vanuatu. There are estimated to be between 2,500 and 3,000 ha of mangrove forest in the islands, of which almost 2,000 ha occur on Malekula. Two large areas of mangrove along the east coast of Malekula account for over 1,800 ha of this total; elsewhere mangroves occur as small stands or narrow belts along lagoon perimeters, sea shores and estuaries. Sizeable stands of mangrove occur on only nine of the 80 islands in the archipelago: Malekula (1,915 ha), Hiu (210 ha), Efate (100 ha), Emae (70 ha), Epi (60 ha), Vanua Lava (35 ha), Ureparapara (30 ha), Mota Lava (25 ha) and Aniwa (15 ha) (Lal & Esrom, 1990). Thirteen species of mangrove tree have been recorded (Macnae, 1968). Typically, there are four recognizable zones: a landward fringe now generally cleared by human activity, thickets of *Ceriops tagal* with the mangrove fern *Acrostichum aureum*, a *Rhizophora* forest zone, and a seaward zone of *Avicennia marina*, occasionally with scattered *Sonneratia caeseolaris* and *Bruguiera*. In some localities, the stands of *Sonneratia* and *Bruguiera* comprise a further recognizable zone (Chambers, 1988).

The human impact on mangroves in Vanuatu still appears to be slight, and is mainly limited to subsistence activities. Mangrove wood is harvested to meet the energy needs of rural populations, and mangroves are occasionally cleared for easier access to the sea. However, conversion of mangroves to other uses has not as yet occurred to any significant extent. In some localities, the landward fringe has been converted to agricultural use such as coconut plantations, while in other areas, notably the Maskelyne Islands, some mangroves have been cleared to allow for village construction. In the Port Vila area, tourist developments have involved the removal of 10 ha of mangroves (Chambers, 1988; Lal & Esrom, 1990).

Although the exploitation of mangroves on a traditional subsistence basis is allowed, there is a total ban on commercial logging in mangroves. Occasionally requests for logging permits have been received by the Forestry Department, but to date these have always been rejected (Chambers, 1988). There is some community based management of aquatic resources of the mangroves and adjacent coral reefs. This is based on the traditional land and sea tenure system. On special occasions, a partial or complete ban may be imposed on the harvesting of certain resources, *e.g.* in the Port Stanley area, local community chiefs often collectively ban the harvest of *Cardiosoma* crabs for commercial sales during the crab's breeding season, while continuing to allow subsistence use (Lal & Esrom, 1990).

The seagrass communities of Vanuatu have recently been described by Chambers *et al.* (1990). These authors surveyed sixty sites from Aneityum in the south to Ureparapara in the north, and found seagrass beds in 39 of these. Nine species of seagrass were recorded, six of which were new records for Vanuatu. The most widespread species were *Thalassia hemprichii*, *Cymodocea rotundata*, *Halodule inermis*, *Enhalus acoroides* and *Halophylla ovalis*. Dense stands of seagrasses were located at sixteen sites in shallow lagoons, bays and intertidal areas, in all instances where sand was the major or only substrate component. Most of the sites were rather small, but extensive seagrass beds were located on the comparatively wide intertidal areas around the Maskelyne Islands and along the southeast coast of Malakula.

Coral reefs occur throughout the archipelago, encircling some islands, but discontinuous around recently active land masses such as Espiritu Santo, Malekula and Ambrym. These have recently been described in some detail in an inventory of the coral reefs of the world (UNEP/IUCN, 1988).

Threatened taxa associated with the wetlands of Vanuatu include the Black Flying-Fox *Pteropus tonganus* and endemic White Flying-Fox *P. anetianus*, which often roost in mangroves, the Estuarine

Crocodile *Crocodylus porosus*, now confined to a single site on Vanua Lava island in the Banks Islands, and the Dugong *Dugong dugon*, which occurs throughout the islands and remains relatively common. For both the Estuarine Crocodile and the Dugong, Vanuatu is the easternmost limit of their extensive distributions in southern Asia and the Pacific. Little is known about marine turtles in Vanuatu, although the Green Turtle (*Chelonia mydas*), Hawksbill (*Eretmochelys imbricata*), Loggerhead (*Caretta caretta*) and Leatherback (*Dermochelys coriacea*) occur and nest in the islands. However, as there are few large sandy beaches, breeding populations may be small (Chambers, 1992). Other species of conservation interest include three species of freshwater mollusc.

Dahl (1980) recommended that reserves be established to protect examples of all major natural ecosystems in Vanuatu including lakes, freshwater swamps, swamp forests and mangroves. At present, however, there are only five small reserves and recreation parks in Vanuatu (IUCN, 1991). The largest of these, President Coolidge and Million Dollar Point, is a marine reserve covering 100 ha off the coast of Espiritu Santo. Lake Emaotul (commonly known as Duck Lake) on Efate has been proposed as a freshwater reserve (Dahl, 1980; TCSP, 1990), but no further action has been taken. Undoubtedly there are many lakes and rivers in Vanuatu which, on account of their interesting features and often spectacular locations, merit consideration for protected area status.

Although the freshwater wetlands are currently little disturbed by human activity, they are likely to come under increasing pressure as populations increase and the development of mining, forestry and agriculture proceeds. Because of their limited extent, swamp forests in particular are likely to come under threat. Agricultural pressures are already high on some islands, and with a population growth rate of about 3.3% per annum, these pressures are likely to increase considerably in the coming decades. There are, as yet, no records of environmental damage from pesticide use, but the inadequate disposal of various pollutants, including sewage and solid waste, is resulting in some contamination of coastal wetlands.

Wetland Research

The freshwater wetlands of Vanuatu have never been adequately studied, and there are only some scattered references to these wetlands in the literature (Baker, 1929; Balfour-Browne, 1939; Bregulla, 1992; Jenkin, 1929; Kimmins, 1936; Lowndes, 1928 & 1931; Mosely, 1932; Salem, 1959). The freshwater fauna has been little studied and is virtually unknown. Data are lacking on the composition and type of freshwater communities, their distribution and variation within the country, and their chemical, physical and morphometric characteristics. Some limited chemical analyses have been carried out by government agencies in the past, but these have never been published. As a consequence, there is insufficient information available to plan development in such a way that the freshwater resources and human dependence upon these resources can be adequately safeguarded.

The mangrove resources of Vanuatu have received rather more attention. Marshall and Medway (1976) have described the mangrove community in Vanuatu, and scientists from the ORSTOM Mission on Efate have carried out a variety of studies, including some inventory work using SPOT satellite imagery. Lal and Esrom (1990) conducted a study on the economics of mangrove utilization and management in Vanuatu, while Chambers (1988) reported on the mangroves of Vanuatu for the UNDP/UNESCO Working Group Meeting on Mangroves in Apia in 1988. The Action Strategy for Nature Conservation in the South Pacific Region (SPREP/IUCN, 1989) recommends that a thorough survey and inventory of the mangrove areas of Malekula be undertaken as a national priority.

Wetland Area Legislation

There is no legislation relating specifically to wetland conservation in Vanuatu, although a draft Water Resources Act was submitted to the Government in 1986. This draft act, which seeks to promote the coordinated management of water resources and watershed areas at a national level, is still under consideration by the Government. Two major provisions of the draft act call for an inventory of water resources and the production of a National Water Development Plan, respectively. No progress has as yet been made on either of these two basic requirements for the management of water resources.

The 'Public Health Bill', also still in draft form, includes a separate provision for the protection of water supplies. This would penalize persons who 'drop, deposit or throw any refuse or other matter or thing into any channel, drain, lake, reservoir, river, stream or watercourse or upon the bank of any of the same or in any part of the sea abutting on the foreshore'. Provision is also made for a specific offence which consists of defiling or polluting, or permitting drainage or refuse from land to flow into or be deposited in, any watercourse, stream, lake, pond or reservoir forming part of the water supply.

The Forestry Act 1982 provides for the restriction of clearing operations using heavy machines (bulldozers, graders) or similar machines on any land within 15-20 metres of any stream without first obtaining approval from the Director concerned. It provides for the protection of land from erosion and disruption of stream flow, the conservation of land as an area or part of an area of particular scenic, cultural, historical or national interest, and the preservation of land for use by the public for recreation.

The principal statute governing the management of fisheries is the Fisheries Act 1982. This Act requires the Director of Fisheries to prepare and keep under review plans for the management and development of fisheries in Vanuatu waters. The Act prohibits all fishing for marine mammals in Vanuatu waters, and also prohibits the use of explosives and poisons for fishing. It also provides that the Minister may declare 'any area of Vanuatu waters and the seabed underlying such waters to be a marine reserve'.

The principal piece of legislation dealing with wildlife protection is the Wild Bird Protection Regulation 1962. This regulation makes it unlawful to kill, wound, capture or take the eggs of a number of named species of wild birds unless a permit to do so has been granted by the Department of Agriculture. These regulations also impose a close season for Pacific Black Duck (*Anas superciliosa pelewensis*) and for some ten other species including other ducks, doves and the Incubator Bird *Megapodius freycinet*.

Vanuatu is not yet a party to any of the international conventions or programmes that directly promote the conservation of natural areas, namely the World Heritage Convention, the UNESCO Man and the Biosphere Programme and the Convention on Wetlands of International Importance especially as Waterfowl Habitat (Ramsar Convention). However, Vanuatu has recently become a party to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). An International Trade (Fauna and Flora) Act 1989 was drafted, and has now been approved by the national parliament and gazetted. This provides the responsible government institution with powers to restrict the capture or killing of wetland species listed under CITES. Vanuatu has also signed but not yet ratified the Convention on Biological Diversity.

Wetland Area Administration

Vanuatu has no wetland reserves, and the total area covered by wetlands is unknown. There is a need for research to be carried out on the wetlands of Vanuatu to assess their wildlife values and requirements for conservation. It has recently been proposed that a Freshwater Resources Survey be implemented on a collaborative basis between the relevant government agencies and competent regional authorities.

Organizations involved with Wetlands

a) Government of the Republic of Vanuatu

- Department of Agriculture, Livestock and Horticulture
  Responsible for the management and administration of the Wild Bird Protection Regulation.
- Department of Fisheries
  Responsible for the management and development of marine resources as spelt out under the Fisheries Act 1982.
- Department of Forestry
  Responsible for the management and development of the country's forest resources.
- Department of Geology, Mines, Minerals and Water Supply
  Responsible for water protection, management and development to meet the needs of the people.
- Department of Physical Planning and Environment
  Responsible for planning in urban areas, assessment of potential protected areas, and management and administration of the country's natural environment. The Department is the country's focal point for local, regional and international environmental organizations, and is the agency responsible for CITES.

b) Non-governmental Organizations

- Institut Francais de Recherche Scientifique pour le Developpement en Cooperation (ORSTOM)
  Conducts research on mangroves and fisheries, the latter in collaboration with the Department of Fisheries.
- Vanuatu Natural Science Society (VNSS)
  Organizes meetings relevant to wildlife protection, and conducts surveys on the wild fauna and flora of Vanuatu. The Chairman of VNSS is the International Council for Bird Preservation (ICBP) Representative for Vanuatu. The Society publishes the newsletter 'Naika'.

WETLANDS

Site descriptions compiled by Ernest Bani and David K. Esrom of the Environment Section, Department of Physical Planning and Environment.

Alligator River (1)

Location: 13°49'S, 167°32'E; on the east coast of Vanua Lava Island in the Banks Islands, northern Vanuatu.
Area: 200 ha.
Altitude: Sea level.

Overview: A tidal inlet in mangrove forest.
Physical features: The Alligator River is a tidal inlet which meanders for some 500-700 metres through a patch of mangrove forest before coming to an abrupt halt at a steep bank. Some fresh water trickles down this bank, but there is no river or stream as such entering the inlet. The main channel is generally about 10 metres wide, but widens to about 50 metres near its mouth. There are a few short side channels.
The climate is humid tropical with an average annual rainfall of 4,000 mm and a mean temperature of 30°C. The wet season (also the cyclone season) extends from November to April.
Ecological features: Mangrove forest with a canopy at about 15-20 m.
Land tenure: Customary ownership.
Conservation measures taken: None.
Conservation measures proposed: The Environment Section in the Department of Physical Planning and Environment has recommended that the site be protected as a Crocodile Reserve.
Land use: Some subsistence fishing; subsistence agriculture in adjacent areas.
Disturbances and threats: Severe cyclones are known to have caused a decline in the crocodile population in the past, and may do so again.
Hydrological and biophysical values: No information.
Social and cultural values: None known.
Noteworthy fauna: The Alligator River still supports a tiny population of the Estuarine Crocodile *Crocodylus porosus*. Recent studies have shown that very few crocodiles remain, and breeding has apparently ceased (Chambers and Esrom, 1989). This decline appears to have been caused by mortality from cyclones and hunting. The Estuarine Crocodile occurs in Vanuatu at the easternmost extremity of its enormous range.
Noteworthy flora: The site includes an interesting stand of mangrove forest.
Scientific research and facilities: The Environment Section in the Department of Physical Planning and Environment carried out a preliminary survey of the area in 1989 (Chambers and Esrom, 1989).
Management authority and jurisdiction: The sites is under the jurisdiction of the Department of Lands.
References: Armstrong (1900); Chambers & Esrom (1989); Dickson (1981); Fox (1958); Groombridge (1982); Luders (1983).
Reasons for inclusion: 1b, 2a. This is the only site in Vanuatu in which crocodiles have been sighted in recent years.
Source: E. Bani and D.K. Esrom.

Nagpen (Selva) River (2)

Location: 13°49'-13°51'S, 167°32'E; near the southern end of Vanua Lava Island in the Banks Islands, northern Vanuatu.
Area: 10 km of river.
Altitude: Sea level to 200 m.
Overview: An unusually sterile river draining a large area of sulphur springs.
Physical features: A small river, 10 km in length, draining some 500 ha of hot sulphur springs in the interior of Vanua Lava. The river water has a very bitter taste, is highly acidic and appears to be almost sterile. It is a dark, peaty brown in colour and quite clear, except along the lower reaches of the river where there is a yellowish/brownish substance in suspension. This may be produced as a result of a chemical reaction occurring when fresh and saline waters mix near the river mouth.
The climate is humid tropical with an average annual rainfall of 4,000 mm and a mean temperature of 30°C. The island lies in the cyclone belt, and has been severely affected by cyclones on several occasions during the 1970s and 1980s.

Ecological features: There are no aquatic plants in the river. The vegetation along the banks of the lower reaches is dominated by the screw palm (*Pandanus* sp.) and tamanu (*Calophyllum* sp.). *Hibiscus tiliaceus* also occurs here and becomes progressively commoner nearer the river mouth where it is the dominant species. Along the tidal reaches of the river, *Pandanus* stems are stained an orange colour, presumably from sulphur precipitated out of the water.
Land tenure: Customary ownership.
Conservation measures taken: None.
Land use: None; subsistence agriculture in adjacent areas.
Disturbances and threats: None known.
Hydrological and biophysical values: No information.
Social and cultural values: None.
Noteworthy fauna: There are no fish in the river and very few invertebrates. Only a few insect larvae were observed during a brief survey of the river in 1989.
Noteworthy flora: None known.
Management authority and jurisdiction: No information.
References: Chambers & Esrom (1989); TCSP (1990).
Reasons for inclusion: 1d. This is the largest area of hot springs in Vanuatu.
Source: E. Bani and D.K. Esrom.

Lake Letas (3)

Location: 14°13'-14°16'S, 167°29'-167°33'E; in the centre of Gaua (Santa Maria) Island in the Banks Islands, northern Vanuatu.
Area: 1,900 ha.
Altitude: 418 m.
Overview: A deep freshwater lake and associated marsh in a volcanic crater.
Physical features: A freshwater lake, 360 m deep, and associated marshy area in a crater in the caldera of Mount Garet. The caldera is about seven to ten km in diameter. The lake has an active volcanic cone emerging at one side and hot springs on the inner crater wall.
The climate is humid tropical with an average annual rainfall of over 4,000 mm and a dry season from May to October.
Ecological features: No information is available on the aquatic vegetation. The lake is surrounded by dense equatorial cloud forest rich in epiphytes and *Hibiscus tiliaceus*.
Land tenure: Customary ownership.
Conservation measures taken: None.
Conservation measures proposed: The Tourism Council of the South Pacific has identified Lake Letas as a suitable site for inclusion in Vanuatu's protected area system (TCSP, 1990), and the Department of Physical Planning and Environment is currently considering the site as a potential protected area.
Land use: None.
Disturbances and threats: In the 1980s, it was suggested that the lake could be used as a source of water for power generation to supply industrial developments proposed for the island.
Hydrological and biophysical values: No information.
Social and cultural values: No information.
Noteworthy fauna: No information.
Noteworthy flora: No information.
Management authority and jurisdiction: The Department of Lands has jurisdiction over the area.
References: Mallick (1973); Quantin (1982); TCSP (1990).
Reasons for inclusion: 1b. Lake Letas is the largest lake in Vanuatu, and the largest freshwater

lake in the island Pacific outside of New Guinea.
Source: E. Bani and D.K. Esrom.

Jordan River Floodplains (4)

Location: 15°12'S, 166°49'-166°55'E; south of Big Bay, in north-central Espiritu Santo.
Area: Over 1,000 ha.
Altitude: Near sea level to 300 m.
Overview: A large area of freshwater marshes and swamp forest on the floodplain of several rivers entering Big Bay.
Physical features: A low-lying area of freshwater marshes and swamp forest on the floodplain of the Jordan River and several other rivers and streams debouching into Big Bay on the north coast of Espiritu Santo Island. The rivers rise in the densely forested Tabwemasana Range to the south, which includes Vanuatu's highest mountain, Mount Tabwemasana (1,869 m).
The climate is humid tropical with an average annual rainfall of 2,000 mm and a mean temperature of 29°C.
Ecological features: Swamp forest dominated by species of *Hibiscus* and *Erythrina*. Undisturbed humid tropical forest and cloud forest in the catchment area to the south.
Land tenure: Customary ownership.
Conservation measures taken: None.
Conservation measures proposed: The floodplains of the Jordan River and forested slopes of the Tabwemasana Range to the south have been identified as a priority area for the establishment of some form of protected area.
Land use: Fishing. Livestock grazing and subsistence agriculture in some areas.
Disturbances and threats: None known.
Hydrological and biophysical values: The rivers and their floodplains support a rich fishery. The region is an important water catchment area for settlements around Big Bay.
Social and cultural values: The fishery resources have traditionally provided an important source of food for the local people.
Noteworthy fauna: Little information is available on the wetland fauna, although the rivers are known to support a variety of freshwater fish species and the swamp forests are reported to be rich in bird life. The montane forests in the catchment area support the rare endemic Santo Mountain Starling (*Aplonis santovestris*), thought to be on the verge of extinction but rediscovered in this area in September 1991.
Noteworthy flora: No information.
Management authority and jurisdiction: No information.
References: Chambers *et al.* (1989); Dahl (1980, 1986); Quantin (1982).
Reasons for inclusion: 1d, 2b, 2d. The only extensive floodplain in Vanuatu, with the largest area of swamp forest. The region remains in a relatively pristine condition.
Source: E. Bani.

Lake Wai Memea (5)

Location: 15°15'S, 167°59'E; at the extreme northeast tip of Ambae (Aoba) Island.

Area: 6 ha.
Altitude: 100 m.
Overview: A small freshwater crater lake with some swamp vegetation.
Physical features: A permanent freshwater lake formed in one of the eight interlocking craters near the northeastern tip of Ambae Island, and surrounded by human settlements and subsistence gardens. The crater is considered by Bullard (1962) to be a typical example of a phreatic cone where explosions resulting from the contact of hot lava with cold water have resulted in the accumulation of a rampart of cinders and ash in a wide ring round a large explosion crater.
The climate is generally humid tropical with mean temperatures of around 30°C and a mean annual rainfall in the range 1,500-2,000 mm.
Ecological features: Areas of open water are bordered by swamp vegetation with *Hibiscus tiliaceus* and sago palm *Metroxylon* sp. There are stands of *Nypa fruticans* to the north of the lake.
Land tenure: Customary ownership.
Conservation measures taken: None.
Land use: Water supply, hunting and fishing; subsistence farming in surrounding areas.
Possible changes in land use: There are plans to extend the water supply from the lake to communities some 10-15 km away.
Disturbances and threats: There is a considerable amount of hunting in the area, which may threaten local wildlife populations. A proposal to increase utilization of the lake for water supply may lead to problems of over-use.
Hydrological and biophysical values: A source of good quality water, unaffected by any siltation problems.
Social and cultural values: The lake constitutes a water supply for the surrounding communities, schools, a hospital and the local government centre. It is also popular for recreational fishing.
Noteworthy fauna: An important wetland for the Australasian Dabchick *Tachybaptus novaehollandiae*, the Incubator Bird *Megapodius freycinet* and mud crabs. The lake supports a large population of fish introduced in the 1960s.
Noteworthy flora: No information.
Recreation and tourism: The site has considerable potential for outdoor recreation.
Management authority and jurisdiction: The lake is under the control of the Local Government Council.
References: Bullard (1962); Ward (1970.
Reasons for inclusion: 1b. A good example of a freshwater crater lake in a phreatic cone.
Source: E. Bani and D.K. Esrom.

Lake Wai Lembutaga (6)

Location: 15°15'S, 167°58'E; near the northeast tip of Ambae (Aoba) Island.
Area: 10 ha.
Altitude: 2 m.
Overview: A freshwater crater lake with extensive beds of papyrus.
Physical features: A permanent freshwater lake formed in a phreatic explosion crater at the eastern end of Ambae Island. The cone or tuff ring contains a crater about 914 metres in diameter with steep walls up to 91 metres in height. This type of structure is considered by Bullard (1962) to be typical of phreatic cones where explosions resulting from a contact of hot lava with cold water have resulted in the accumulation of a rampart of cinders and ash in a wide ring round a large explosion crater. The lake is situated in one of the eight interlocking craters of this type at the eastern end of the island (Bullard, 1962; Ward, 1970).
The climate is humid tropical, with an average annual rainfall of 1,500 mm and a dry season from May to October.

Ecological features: Large portions of the lake are covered with papyrus (*Cyperus papyrus*). The vegetation around the lake is secondary with various species of trees and shrubs.
Land tenure: Customary ownership. Adjacent areas are leased to Vureas High School (a Government school).
Conservation measures taken: None.
Land use: Some hunting and fishing; subsistence agriculture, forestry plantation and cattle ranching in surrounding areas. The lake is a source of water supply for a nearby Junior Secondary School.
Disturbances and threats: Excessive use of water for domestic supply and road construction along the escarpment towards the coast. Native forests nearby have been cleared for forestry plantations.
Hydrological and biophysical values: Public water supply.
Social and cultural values: The lake has some cultural significance to the local people.
Noteworthy fauna: The lake supports a large fish population and is important for the Australasian Dabchick *Tachybaptus novaehollandiae*. Other resident birds include *Circus approximans*, *Falco peregrinus*, *Megapodius freycinet*, *Rallus philippensis* and *Halcyon chloris*. Black Flying-Fox *Pteropus tonganus* and White Flying-Fox *P. anetianus* also occur in the area.
Noteworthy flora: No information.
Management authority and jurisdiction: Local Government Council.
References: Bullard (1962); Ward (1970).
Reasons for inclusion: 1a, 2b. A good example of a freshwater crater lake in a phreatic cone, with an interesting papyrus swamp.
Source: E. Bani and D.K. Esrom.

Ambae Caldera Lakes (7)

Location: Lake Manaro Ngoru 15°24'S, 167°48'E; Lake Vui 15°24'S, 167°49'E; Lake Manaro Lakua 15°24'S, 167°51'E; in the centre of Ambae (Aoba) Island in northern Vanuatu.
Area: Lake Manaro Ngoru, 15 ha; Lake Vui, 150 ha; Lake Manaro Lakua, 170 ha. Total area of volcanic craters 500-600 ha.
Altitude: Lake Manaro Ngoru, 1,391 m; Lake Vui, 1,340 m; Lake Manaro Lakua, 1,397 m. Summit of crater rim at 1,496 m.
Overview: A caldera lake and two crater lakes surrounded by dense virgin forests at high altitude within the active volcano of Ambae Island.
Physical features: Lake Vui and Lake Manaro Ngoru are situated in young craters formed within the inner caldera. It is not certain if Lake Vui, the larger of the two, was formed within the summit crater of a broad cone filling the centre of the inner caldera or in a third and smaller caldera (Ward, 1979). The Manaro Ngoru crater has a floor one kilometre in diameter, which at times is covered by a temporary lake surrounded by a low rampart of pyroclastics abutting against the caldera wall along its western margin. It probably represents an explosion crater.
Lake Manaro Lakua lies in a third crater, to the east of Lake Vui. The presence of well-sorted, bedded, commonly cross-bedded tuffs deposited in or reworked by Lake Manaro Lakua indicates that the water once stood 100-150 metres above its present level. The tuffs occur in islands and along the crater walls. Conversely, a fringe of partly submerged trees along the western edge of the lake shows that it recently stood at a lower level (Ward, 1970).
Thermal areas exist on the southeast side of Lake Manaro Lakua and on the bed of Lake Vui. These include hot springs, geysers and fumaroles. The water of Lake Vui has a bitter taste and a distinctive green colour. Similar discolouration is often seen in the sea around Vanuatu where fumaroles occur on the summits of submarine volcanoes.
The area generally has a humid tropical climate with little seasonal variation. Mean temperatures are

around 30°C along the coast and drop slightly in the caldera to a low of 23°C. The mean annual rainfall is in the range 2,500-3,500 mm. The wet season (also the cyclone season) extends from November to April.
Ecological features: The lakes are surrounded by dense, pristine montane rain forest with endemic orchids and a very rich flora. This gives way to moss forest above 1,350 m. No information is available on the aquatic vegetation.
Land tenure: The lakes and surrounding areas are under customary ownership.
Conservation measures taken: None.
Conservation measures proposed: Government, local government centres and customary land owners are discussing the possibility of declaring the area Public Land and establishing a protected area. The lakes were identified as a site suitable for protection by the Tourism Council of the South Pacific (TCSP, 1990).
Land use: None; the area is remote and uninhabited.
Disturbances and threats: None known.
Hydrological and biophysical values: The lakes are the source of a number of rivers and streams.
Social and cultural values: The lakes are of considerable cultural importance to the people of Ambae who believe that the spirits of the dead reside there.
Noteworthy fauna: Lake Manaro Lakua is an important site for the Australasian Dabchick *Tachybaptus novaehollandiae* and green frogs. There are no fish in the lakes.
Noteworthy flora: The forests around the caldera are rich in orchids. A recent investigation discovered three new species of orchids for Vanuatu, *Agrostophyllum* cf. *torricellense*, *Dendrobium kietaense* and *Bulbophyllum microrhombos*, and a species of *Peristylus* unknown to science (Wheatley, 1989).
Scientific research and facilities: The lakes were surveyed by the Department of Mines, Minerals and Rural Water Supply in 1969, and by the Department of Physical Planning and Environment in 1988.
Recreation and tourism: The area has some potential for tourism.
Management authority and jurisdiction: The lakes are currently under the jurisdiction of the Ambae/Maewo Local Government Council. The proposed protected area would be managed by the Island Regional Council, with advice from the Department of Physical Planning and Environment.
References: TCSP (1990); Ward (1970); Wheatley (in press).
Reasons for inclusion: 1d. Three interesting crater lakes in a region of thermal activity; the highest lakes in the island Pacific outside of New Guinea.
Source: E. Bani and D.K. Esrom.

Port Stanley, Bushman Bay and Crab Bay (8)

Location: 16°04'-16°11'S, 167°24'-167°32'E; on the northeast coast of Malekula Island, 1-15 km southeast of Lakatoro.
Area: 1,000 ha, including 963 ha of mangrove forest.
Altitude: Sea level.
Overview: A complex of mangrove forests, tidal lagoons and associated salt marshes and mudflats along the northeast coast of Malekula Island.
Physical features: One of the two largest areas of mangrove in Vanuatu, comprising several large patches of mangrove forest and associated tidal lagoons, salt marshes, mudflats, rivers, streams and sandy beaches. The Port Stanley-Crab Bay area is a coraline reef platform. The largest contiguous stand of mangroves (560 ha) occurs in the Port Stanley embayment and along the shores of the adjoining Botun Bay. There are a further 32 ha of mangroves on the coast near Lakatoro to the

northwest, 72 ha on the island of Uri and 24 ha on the island of Taikata, at the entrance to Port Stanley bay. Further southeast along the coast, there is a large patch of mangroves totalling 275 ha along the northeast coast of Bushman Bay (25 ha) and along the entire coast of the adjoining Crab Bay (250 ha).

The climate is humid tropical with an average annual rainfall of 1,638 mm at Port Stanley.

Ecological features: Three zones have been identified in the mangrove vegetation: an inner zone of *Ceriops tagal* thickets, a *Rhizophora* forest zone dominated by *R. mucronata* and *R. stylosa*, and a seaward zone of *Avicennia marina* with a few scattered *Sonneratia caeseolaris*. Sago palms (*Metroxylon* sp.) occur in the coconut plantations behind the mangroves.

Land tenure: Customary ownership. Some areas are leased, especially in Crab Bay.

Conservation measures taken: No special protection measures have been taken. Mangrove forests are protected from commercial exploitation by the Government. Local community chiefs can apply closures on hunting and fishing in the mangroves if considered appropriate.

Conservation measures proposed: The Environment Section of the Department of Physical Planning and Environment has proposed that a marine reserve be established in the area and that this incorporate the mangrove forests. Responsibility for management would be given to the local landowners.

Land use: Subsistence fishing and harvesting of mangroves for building materials and fuelwood; coconut plantations and subsistence agriculture in adjacent areas.

Possible changes in land use: A proposal, currently with the government, for logging in the upper catchment area could have an impact on the wetlands.

Disturbances and threats: There is some disturbance from the small human settlements scattered throughout the area. A commercial wharf was built in the area in 1987 for inter-island trading vessels. This involved the building of a causeway through the mangroves in Port Stanley bay and clearing of two or three hectares.

Hydrological and biophysical values: The mangrove fringe provides protection against coastal erosion and reduces storm damage during the frequent cyclones which affect this area. The mangroves provide a source of nutrients for a diversity of food chains, and serve as vital nursery and feeding grounds for a variety of inshore and marine invertebrates and fishes important in the commercial and subsistence fisheries.

Social and cultural values: The mangroves and their fisheries resources have traditionally provided an important source of fuelwood and food for the local people, and continue to do so.

Noteworthy fauna: The mangroves support a diverse invertebrate and fish fauna including numerous species of molluscs, crustaceans, polychaetes and finfish. Of the 20 or so crustaceans recorded from the area, only the crabs *Cardiosoma hirtipes* and *Scylla serrata* are regularly harvested for local consumption and export to Port Vila. A species of flying fox (*Pteropus* sp.) occurs in the mangroves, and there is still an apparently healthy population of Dugong (*Dugong dugon*) in the area. No information is available on the birds and reptiles.

Noteworthy flora: The site contains one of the two largest stands of mangroves in Vanuatu.

Scientific research and facilities: Several surveys and studies have been carried out in the area, particularly with respect to the species composition of the mangroves and utilization of mangrove resources.

Management authority and jurisdiction: The mangroves fall under the jurisdiction of the Department of Fisheries in collaboration with the Department of Lands and the Department of Physical Planning and the Environment.

References: Chambers (1988); Chambers *et al.* (1989); David (1985, 1987 & 1988); David & Cillaurren (1988); Lal & Esrom (1990); Macnae (1968); Marshall & Medway (1976); Quantin (1982); Woodroffe (1987).

Reasons for inclusion: 1a, 2b, 2c. One of the two largest areas of mangroves in Vanuatu.

Source: E. Bani and D.K. Esrom.

Port Sandwich and the Maskelyne Islands (9)

Location: 16°25'-16°35'S, 167°47'-167°51'E; at the southeastern tip of Malekula Island.
Area: 1,000 ha.
Altitude: Sea level.
Overview: A complex of mangrove forests, tidal lagoons and associated salt marshes and mudflats at the southeast end of Malekula Island and in the nearby Maskelyne Islands.
Physical features: A complex of mangrove forests and associated mudflats, tidal lagoons, salt marshes, rivers, streams and sandy beaches along the southeastern shores of Malekula Island and around the Maskelyne Islands a few kilometres offshore. There are three main areas of mangrove: Port Sandwich (175 ha), the coast south of Lamap (262 ha) and the Maskelyne Islands (420 ha). In the Port Sandwich area, there are 25 ha of mangroves at the mouth of the Lasopenamor River on the west side of the bay, 35 ha in the southwest corner of the bay, and 120 ha in the estuary of the Sandwich River. The area south of Lamap includes 130 ha of mangroves along the coast from Lamap to Doucere Point, 32 ha in the innermost portion of Cook Bay, and 100 ha along the coast opposite Lembong and Awi in the Maskelyne Islands. The Maskelynes are a group of small coral islands and reef platforms with extensive mangrove forests on most of the islands.
The climate is humid tropical, with an average annual rainfall of 1,987 mm and a mean temperature of 26.1°C.
Ecological features: Mangrove forest with three recognizable zones: an inner *Ceriops tagal* zone, a *Rhizophora* forest zone dominated by *R. mucronata* and *R. stylosa*, and a seaward zone of *Avicennia marina* with some *Sonneratia caeseolaris*. The sago palm (*Metroxylon* sp.) occurs amongst the coconut plantations along the landward edge of the mangroves.
Land tenure: Customary ownership.
Conservation measures taken: No special protection measures have been taken. As elsewhere in Vanuatu, mangrove forests are protected from commercial exploitation by the Government. Local community chiefs can apply closures to the exploitation of the mangrove resources if considered appropriate.
Conservation measures proposed: The Environment Unit in the Department of Physical Planning and Environment has recommended that a marine reserve be established in the area, incorporating the principal mangrove forests.
Land use: Subsistence fishing and harvesting of mangroves for building materials and fuelwood.
Disturbances and threats: In the Maskelyne Islands, villages are located within the mangrove forests. The population of the largest island, Koulivou, is about 1,000 (1989 National Census estimates), giving a population density of 313 people per sq.km. This is one of the largest population densities in Vanuatu and some 20 times the national average. As the population continues to grow, more and more mangrove is being cleared for residential areas.
Hydrological and biophysical values: The mangrove fringe provides protection against coastal erosion and reduces storm damage during the frequent cyclones which affect this area. The mangroves provide a source of nutrients for a diversity of food chains, and serve as vital nursery and feeding grounds for a variety of inshore and marine invertebrates and fishes important in the commercial and subsistence fisheries.
Social and cultural values: The mangroves and their fisheries resources constitute an important source of fuelwood and food for the local people, and are vitally important in maintaining the livelihood of the inhabitants of the Maskelyne Islands.
Noteworthy fauna: The mangroves support a rich invertebrate fauna dominated by molluscs, crustaceans and polychaetes. Of the 20 or so crustaceans, only the crabs *Cardiosoma hirtipes* and *Scylla serrata* are regularly harvested. In the Maskelyne Islands, 66 species of finfish belonging to 32 families are regularly caught in the mangrove areas, and 29 of these are found exclusively within the mangroves. Common species include mullets (Mugilidae), rabbit fish (Siganidae) and goat fish (Mullidae). Two species of flying fox, *Pteropus tonganus* and *P. anetianus*, occur in the mangroves, and there is still an apparently healthy population of Dugong (*Dugong dugon*) in the area. The region is

known to be rich in birds and reptiles, but no details are available.
Noteworthy flora: The site contains one of the two largest stands of mangroves in Vanuatu.
Scientific research and facilities: Several surveys and studies have been carried out in the area, particularly with respect to the species composition of the mangroves and utilization of mangrove resources.
Management authority and jurisdiction: The mangroves fall under the jurisdiction of the Department of Fisheries in collaboration with the Department of Lands and the Department of Physical Planning and the Environment.
References: Chambers (1988); Chambers *et al.* (1989); David (1985, 1987 & 1988); David & Cillaurren (1988); Lal & Esrom (1990); Macnae (1968); Marshall & Medway (1976); Quantin (1982).
Reasons for inclusion: 1a, 2b, 2c. One of the two largest areas of mangroves in Vanuatu.
Source: E. Bani and D.K. Esrom.

Southwest Bay Lagoon (10)

Location: 16°29'-16°32'S, 167°25'-167°27'E; on the southwest coast of Malekula Island.
Area: 72 ha.
Altitude: Sea level.
Overview: A small patch of mangrove forest.
Physical features: A stand of mangrove forest around Southwest Bay Lagoon, the only significant stand of mangroves on the west coast of Malekula Island.
The climate is humid tropical with an average annual rainfall of 1,900 mm and a mean temperature of 28°C.
Ecological features: Mangrove vegetation dominated by *Rhizophora mucronata*, *R. stylosa*, *Sonneratia caeseolaris* and *Avicennia marina*.
Land tenure: Customary ownership.
Conservation measures taken: None.
Land use: Subsistence fishing and the harvesting of mangroves for building materials and fuelwood.
Disturbances and threats: None known.
Hydrological and biophysical values: The mangrove fringe acts as a barrier to coastal erosion and reduces storm damage during the frequent cyclones which affect this area. The mangroves provide a source of nutrients for a diversity of food chains, and constitute vital breeding and nursery grounds for a variety of inshore and marine invertebrates and fishes.
Social and cultural values: The mangroves and their fisheries resources constitute an important source of timber, fuelwood and food for the local people.
Noteworthy fauna: The mangroves support a rich invertebrate fauna dominated by molluscs, crustaceans and polychaetes, as well as numerous fishes such as mullet (Mugilidae). Dugong (*Dugong dugon*) occur in the bay (Chambers *et al.*, 1989). No information is available on the birds and reptiles.
Noteworthy flora: No information.
Management authority and jurisdiction: No information.
References: Chambers *et al.* (1989); David (1988); Lal & Esrom (1990); Quantin (1982).
Reasons for inclusion: 1d, 2c. An important mangrove area.
Source: E. Bani and D.K. Esrom.

Duck Lake (Emaotul) (11)

Location: 17°44'S, 168°25'E; 8 km east of Port Vila on the island of Efate.
Area: 30 ha.
Altitude: 119 m.
Overview: A small freshwater lake with associated swamp vegetation and some swamp forest, surrounded by degraded lowland tropical rain forest.
Physical features: A small, permanent, freshwater lake with freshwater swamp and some swamp forest, in a region of lowland tropical rain forest on a raised limestone plateau above the Teouma Valley. The lake is situated between the Teouma and Rentapao rivers, but there is no surface inflow or outflow.
The climate is humid tropical with an average annual rainfall of 2,270 mm. There is little seasonal variation in rainfall, although November to April are slightly wetter than the other months.
Ecological features: Most of the lake is open water. There are grassy swamps at the east and west ends, and some swamp forest with *Barringtonia* sp. The wetland is surrounded by degraded lowland tropical forest and shrubbery, and there is an area of sago palms (*Metroxylon* spp.) and *Phragmites* reeds nearby.
Land tenure: The lake is under customary ownership, although there is considerable dispute amongst local families as to who the rightful owners are. Surrounding areas are leased for logging, subsistence farming and cattle grazing.
Conservation measures taken: None.
Conservation measures proposed: Dahl (1980) proposed the establishment of a reserve at Duck Lake and Rentapao Valley to protect the lake, freshwater swamp, swamp forest and surrounding lowland rain forest. The Tourism Council of the South Pacific has also identified the lake as a suitable site for protection (TCSP, 1990). Duck Lake is now one of the priority areas proposed for protection by the Environment Section of the Department of Physical Planning and Environment.
Land use: None at the wetland. Subsistence farming, cattle grazing and small-scale selective logging in surrounding areas.
Possible changes in land use: There have been several proposals to expand cattle grazing in the area. Proposals to establish a pig farm and a poultry farm near the lake have been rejected by the Government.
Disturbances and threats: The surrounding forest has recently been much affected by logging. The logging operations cause some disturbance to wildlife, and provide easy access, encouraging increased land clearance for agriculture.
Hydrological and biophysical values: The lake plays an important role in maintaining water supplies in the Teouma and Rentapao rivers during the dry season.
Social and cultural values: An important water supply for the local people.
Noteworthy fauna: The avifauna includes Pacific Black Duck *Anas superciliosa*, Swamp Harrier *Circus approximans* and Barn Owl *Tyto alba*. Surrounding forests are rich in bird life.
Noteworthy flora: *Barringtonia* swamp forest is a threatened ecosystem in Vanuatu.
Recreation and tourism: The lake has considerable potential for outdoor recreation and tourism because of its easy access and close proximity to Port Vila.
Management authority and jurisdiction: No information.
References: Dahl (1980); Quantin (1982); TCSP (1990).
Reasons for inclusion: 1d, 2b. Probably the best example of a non-volcanic freshwater lake in Vanuatu, with one of the country's few patches of swamp forest.
Source: E. Bani and D.K. Esrom.

Emaotfer Swamp (12)

Location: 17°48'S, 168°25'E; southeast of Port Vila on the island of Efate.

Area: 60 ha.
Altitude: 20 m.
Overview: A small freshwater swamp in the southern lowlands of Efate.
Physical features: An area of freshwater swamp consisting of tall emergent sedges and rushes, with scattered trees and pandanus around its edge. The water level fluctuates according to the wet and dry seasons.
The climate is humid tropical with an average annual rainfall of over 1,000 mm. The wet season extends from November to April.
Ecological features: The swamp vegetation includes *Cyperus diformis* and *Lepironia articulata*. Scattered *Pandanus* and lowland forest occur in surrounding areas.
Land tenure: Customary ownership.
Conservation measures taken: None.
Land use: None.
Disturbances and threats: None known.
Hydrological and biophysical values: No information.
Social and cultural values: No information.
Noteworthy fauna: No information.
Noteworthy flora: No information.
Management authority and jurisdiction: No information.
References: Quantin (1982).
Reasons for inclusion: 1d, 2b. A good example of a permanent freshwater swamp, a scarce habitat type in Vanuatu.
Source: E. Bani.

Lake Isiwi (13)

Location: 19°31'S, 169°26'E; at the foot of Yasur Volcano on the island of Tanna in southern Vanuatu.
Area: 225 ha.
Altitude: 60 m.
Overview: A freshwater volcanic lake with some marsh vegetation, at the base of Yasur Volcano.
Physical features: A shallow, freshwater lake located in a picturesque setting at the foot of Yasur Volcano, an active volcano with a summit at 1,084 m. To the north of the lake, there is an area of volcanic sand; to the northeast, an area of grassland and shrubs; and to the east, an area of sandy beaches and volcanic ash. The lake became shallower after a severe cyclone in 1987 (Cyclone Uma). The cyclone caused landslides on the slopes of Yasur, and as a result, the lake was partially filled with debris and silt.
The climate is tropical. Temperatures and rainfall are lower than in central and northern Vanuatu, and seasonality is much more pronounced.
Ecological features: Stands of *Phragmites karka* occur along the northern and western margins of the lake, and there are scattered pandanus (*Pandanus* spp.), ferns and shrubs along the northwest and southwest shores. Elsewhere the shoreline consists of sandy beaches and volcanic ash.
Land tenure: Customary ownership.
Conservation measures taken: No legal measures have been taken. However, no-one is allowed to visit the area, especially the volcano, without first obtaining permission from the customary landowners. The Tourism Council of the South Pacific has recommended that the area be brought under Government control and given protected status (TCSP, 1990).
Land use: The lake is regularly visited by foreign tourists. There are small settlements and subsistence farms in surrounding areas.
Disturbances and threats: None, other than natural disasters such as Cyclone Uma.

Social and cultural values: The customary landowners obtain some revenue from the collection of fees from tourists visiting the area to see the active volcano. The site is a sacred place for the local people of Tanna.
Noteworthy fauna: The lake supports a variety of waterfowl including Little Green Heron *Butorides striatus* and Pacific Black Duck *Anas superciliosa*.
Noteworthy flora: None known.
Recreation and tourism: The lake is a popular spot for foreign tourists coming to see Yasur Volcano, one of the most famous tourist attractions in Vanuatu at the present time. However, tourists frequently complain of the rather exorbitant costs charged by the local custodians, and little or none of the money collected from the tourists goes into providing facilities for them (TCSP, 1990).
Management authority and jurisdiction: The site is under the control of the customary landowners.
References: Mallick (1973); TCSP (1990).
Reasons for inclusion: 1a. An interesting freshwater lake of volcanic origin, noted for its scenic attraction.
Source: E. Bani and D.K. Esrom.

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WALLIS AND FUTUNA

INTRODUCTION

Area: Published figures range from 210 to 274 sq.km.

Population: 13,600 (1990).

The Territory of the Wallis and Futuna Islands is a French Overseas Territory comprising two groups of islands, the Wallis Islands (159 sq.km) and the Hoorn Islands (115 sq.km). The two island groups lie 230 km apart, and are about 600 km north of Fiji and 300 km west of Samoa. Wallis has a central island, Uvea (96 sq.km), surrounded by a barrier reef 3-4 km offshore with 19 low coral or small volcanic islets. Uvea is a low island where basaltic volcanism, active until quite recent times, has given rise to an inconspicuous relief (maximum elevation 149 m at Mt Lulu). The Hoorn Islands, comprising Futuna (80 sq.km) and Alofi (35 sq.km), are by contrast mountainous with maximum elevations of 524 m at Mt Puke on Futuna and 416 m on Alofi. They have no barrier reef and are the result of a Tertiary, much more ancient volcanic activity. The steep slopes of Futuna are interrupted by a series of uplifted coral tiers also evident on Alofi. Futuna is surrounded by a narrow fringing (apron) reef, up to 100 m wide, and there is a small patch of fringing reef on the northwest coast of Alofi. Neither Uvea nor Alofi have any permanent streams, unlike Futuna which has many small creeks flowing down the hills in deep gorges (SPREP, 1986).

The climate is tropical, with an average annual rainfall of over 2,500 mm on Futuna and over 3,000 mm on Uvea. Very heavy rains sometimes occur in association with cyclonic depressions during the hurricane season from November to March. During the dry season, the islands are cooled by the Southeast Trades.

The islands became a French Protectorate in 1842, and an Overseas Territory of France in 1961. The resident population of about 14,000 is confined to Uvea (8,000) and Futuna (6,000). However, another 12,000 people from the two islands live and work in New Caledonia, Vanuatu and France. Alofi was inhabited until around 1840, but was abandoned because of a shortage of water. Crops are, however, still grown there by the inhabitants of the eastern part of Futuna, only two km away. The inhabitants of Wallis and Futuna are almost entirely Polynesian, the Wallisians being descended from Tongans and the Futunans from Samoans. Subsistence agriculture, especially slash-and-burn farming, and fishing are the main activities. Copra and *Trochus* shells are the only significant exports, and the economy depends to a large extent on subsidies from France.

The marine ecosystems have recently been described by UNEP/IUCN (1988). Terrestrial ecosystems include pockets of lowland rain forest, montane rain forest (above 400 m on Futuna), secondary forest and scrub, grasslands, fernlands, and *Casuarina* and *Pandanus* (Dahl, 1986). Forest cover in 1986 was estimated at 15% on Uvea, 30% on Futuna and 70% on Alofi (SPREP, 1986). Over 400 vascular plants have been recorded, of which 250 are indigenous and five are endemic (Dahl, 1986). Futuna Island supports endemic subspecies of the Collared Kingfisher (*Halcyon chloris regina*), Polynesian Triller (*Lalage maculosa futunae*) and Fiji Shrikebill (*Clytorhynchus vitiensis futunae*) (Hay, 1985).

There is great pressure on land and resources from the rapidly growing human population (growth rate estimated at 4.0% per annum in 1983). Much of the forest on Uvea and the lower slopes of Futuna has been cleared for subsistence agriculture, while Alofi, until recently one of the least disturbed high islands in Western Polynesia, is now subject to increasing clearing and burning by returned migrants (Dahl, 1986). The reduction in forest cover and replacement by gardens, secondary bush and "toafa", a poor scrubby formation with only ferns, *Pandanus* and a few shrubs, has been documented by SPREP (1986).

Dahl (1980) recommended that reserves be established to protect appropriate forest, lake and coral reef areas, while Hay (1985) has suggested that the uninhabited island of Alofi be protected as a reserve for the rare Blue-crowned Lorikeet *Vini australis* and other forest birds.

Summary of Wetland Situation

There are few freshwater wetlands in Wallis and Futuna, and no mangroves. Uvea has several small lakes of volcanic origin as well as a few springs along the coast, but there are no permanent rivers, streams or swamps. Futuna has no lakes or swamps, but possesses many springs and permanent and intermittent streams. Alofi apparently has no wetlands at all. There are some small taro fields on Uvea as well as on Futuna, where the taro is grown in terraced flooded gardens at the mouths of streams.

There are at least seven freshwater crater lakes on Uvea, the largest being Kikila (17.9 ha), Lalolalo (15.2 ha), Lanutavake (4.6 ha) and Lanutuli (2.2 ha). Uvea was an important American military base from 1942 to 1944, and when the Americans left, they dumped their war equipment into these lakes. Lac Lalolalo, on the west side of Uvea, is a spectacular crater lake with vertical walls some 30 m high. Approximately 30 ha of forest surrounding the lake are afforded some protection as "Vao-Tapu" (Sacred or Forbidden Forest). Special measures are taken to protect the forest from bush fires, and the hunting of pigeons and flying foxes (*Pteropus tonganus*) is restricted. Part of the forest was cleared "illegally" in 1980, and since then, tighter controls have been exercised (SPREP, 1985). The groundwater table from which the inhabitants of Uvea derive their drinking water supply is also regarded as a protected area. Some measures are apparently being taken to prevent waste materials, pesticides, fertilizers and other chemical products from entering the groundwater through run-off and infiltration (SPREP, 1985).

Wetland Research

A variety of geological, botanical and archaeological studies have been undertaken by scientists from ORSTOM, and detailed soil maps have been produced (Fromaget & Beaudou, 1986), but no studies appear to have been carried out on the wetlands.

Wetland Area Legislation

Wallis and Futuna have no specific conservation legislation, and there are no formally designated protected areas. Several areas are protected by customary taboos, but it seems that these traditional restraints on the exploitation of natural resources are no longer sufficient to prevent over-exploitation (IUCN, 1991). The Long-term Economic and Social Development Plan, passed by the Territorial Assembly in 1979, includes a chapter on the protection of the natural heritage of the islands. Two of the priorities listed are protection of the coastal zone and protection of natural sites. Supplementary legislation is, however, desirable in respect of the protection of wooded areas, the water table, water catchments and the coastal zone (IUCN, 1991).

At the international level, France is party to the World Heritage Convention, Ramsar Convention, Convention on the Conservation of Nature in the South Pacific (Apia Convention) and Convention for the Protection of the Natural Resources and Environment of the South Pacific (SPREP Convention). It has also signed but not yet ratified the Convention on Biological Diversity.

Wetland Area Administration

Not applicable.

Organizations involved with Wetlands

No department has specific responsibility for activities relating to the natural environment.

WETLANDS

The Territory of Wallis and Futuna Islands has very few wetlands, and only the crater lakes on Uvea (here treated as a single site) would appear to be of international importance on the basis of the Ramsar Criteria. The following site account has been compiled from the literature.

Uvea Crater Lakes (1)

Location: 13°16'-13°19'S, 176°08'-176°12'W; on the island of Uvea in the Wallis Islands.
Area: 43.1 ha.
Altitude: 3-97 m.
Overview: Seven small, freshwater lakes of volcanic origin on the island of Uvea in the Wallis Islands.
Physical features: There are at least seven freshwater lakes in dormant volcanic craters on Uvea: Kikila (17.9 ha), Lalolalo (15.2 ha), Lanutavake (4.6 ha), Lanutuli (2.2 ha), Alofival (1.3 ha), Lano (1.1 ha) and Lanumaha (0.8 ha). Lac Lalolalo, on the west side of Uvea, is a spectacular crater lake with vertical walls some 30 m high.
The climate is tropical, with an average annual rainfall of over 3,000 mm.
Ecological features: No information is available on the aquatic vegetation. The vegetation in surrounding areas was originally dominated by lowland rain forest, but most of this has been cleared for shifting agriculture and has been replaced by gardens, secondary scrub, grassland and "toafa", a scrubby formation with only ferns, *Pandanus* and a few shrubs. By 1986, the forest cover on Uvea had been reduced to only about 15% (SPREP, 1986).
Land tenure: Customary ownership.
Conservation measures taken: Approximately 30 ha of forest surrounding Lac Lalolalo are afforded some protection as "Vao-Tapu" (Sacred or Forbidden Forest). Special measures are taken to protect the forest from bush fires, and the hunting of pigeons and flying foxes (*Pteropus tonganus*) is restricted (SPREP, 1985).
Conservation measures proposed: Dahl (1980) recommended that reserves be established to protect appropriate lake areas.
Land use: No information. Subsistence agriculture, especially slash-and-burn farming, in surrounding areas.
Disturbances and threats: Uvea was an important American military base from 1942 to 1944, and when the Americans left, they dumped their war equipment into the lakes. Part of the "Tapu" forest around Lac Lalolalo was cleared "illegally" in 1980 (SPREP, 1985).
Hydrological and biophysical values: No information.
Social and cultural values: No information.
Noteworthy fauna: There are reported to be "blind snakes" in Lac Lalolalo, and the flying fox *Pteropus tonganus* occurs in the surrounding forest.

Noteworthy flora: No information.
Recreation and tourism: Lake Lalolalo and Lac Lanutavake are occasionally visited by tourists, the former for its scenery and the latter for swimming.
Management authority and jurisdiction: No information.
References: Dahl (1980); Fromaget & Beaudou (1986); SPREP (1985 & 1986).
Reasons for inclusion: 1a, 2b. A group of very isolated freshwater lakes; the only significant wetlands in Wallis and Futuna.
Source: See references.

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WESTERN SAMOA

INTRODUCTION

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Area: 2,935 sq.km.

Population: 170,000.

Western Samoa is an independent state in the South Pacific situated between latitudes 13° and 14°30' South and longitudes 171° and 173° West, approximately 1,000 km northeast of Fiji. The state comprises two main inhabited islands, Savai'i (1,820 sq.km) and Upolu (1,105 sq.km), and seven islets, two of which are inhabited.

Western Samoa is an oceanic volcanic archipelago that originated in the Pliocene. The islands were formed in a westerly direction with the oldest eruption, the Fagaloa volcanics, on the eastern side. The islands are still volcanically active, with the last two eruptions being in 1760 and 1905-11 respectively. Much of the country is mountainous, with Mount Silisili (1,858 m) on Savai'i being the highest point.

Western Samoa has a wet tropical climate with temperatures ranging between 17°C and 34°C and an average temperature of 26.5°C. The temperature difference between the rainy season (November to March) and the dry season (May to October) is only 2°C. Rainfall is heavy, with a minimum of 2,000 mm in all places. The islands are strongly influenced by the trade winds, with the Southeast Trades blowing 82% of the time from April to October and 54% of the time from May to November. The closeness of Western Samoa to the cyclone belt means that is it frequently affected by cyclones, with the two worst cyclones in recorded history occurring in 1990 and 1991.

Western Samoa has been independent since 1962. The majority of the population, which is Polynesian in origin, live on the island of Upolu. The most densely populated area is the capital city of Apia, where the population density is approximately 75 persons per sq.km. By contrast, Savai'i and rural Upolu are sparsely populated. Agriculture, mainly subsistence agriculture using traditional farming methods, forms the basis of the economy, with the principal subsistence crops being taro, bananas, breadfruit and pawpaws. The four principal cash crops, and main exports, are coconuts, taro, cocoa and bananas. Tourism has grown rapidly in importance in recent years.

The natural vegetation consists primarily of lowland and montane rain forest with additional small areas of cloud, riverine, swamp, mangrove and beach forest. Extensive deforestation has occurred as a result of commercial timber operations and the clearance of land for agriculture. Most of the lowland forest on Savai'i and Upolu has now been cleared or highly modified, but the montane forests are less disturbed and still contain a rich endemic flora and fauna. The terrestrial ecosystems have recently been described by Pearsall and Whistler (1991), while UNEP/IUCN (1988) provide a general account of the coral reef systems and reef resources.

A major survey of potential protected areas was carried out in 1975 by the United Nations Development Advisory Team for the South Pacific (Holloway and Floyd, 1975). This recommended the creation of six national parks, 24 nature reserves, 13 historical/legendary sites and seven archaeological sites, but only one of the national parks (O Le Pupu Pu'e) and one of the nature reserves (Palolo Deep) were subsequently declared, in 1978 and 1979 respectively. A number of studies of the ecosystems and wildlife of Western Samoa have been carried out since then (Dahl, 1980; KRTA Limited, 1988; TCSP, 1990; Pearsall and Whistler, 1991) and these have generally endorsed the proposals of Holloway and Floyd, but no new protected areas have been established, primarily because most of the land proposed for protection is under customary ownership.

Summary of Wetland Situation

There are six main wetland communities in Western Samoa, distinguished from each other by floristic, physiognomic and geographical differences. Three of these communities, coastal marsh, montane marsh and montane bog, are dominated by herbaceous species; the other three, mangrove scrub, mangrove forest and swamp forest, are dominated by woody trees. Of the two main islands of Western Samoa, Upolu is the older and possesses the most wetland areas, especially herbaceous marshes in low-lying coastal basins which are separated from the sea by a sand barrier and lack a stream outlet. This absence of a stream outlet restricts the growth of mangroves in these areas.

The characteristic species of herbaceous marshes and bogs are *Acrostichum aureum*, *Carex graeffeana*, *Cyclosorus interruptus*, *Eleocharis dulcis*, *Paspalum orbiculare* and *Rhynchospora corymbosa*. The separation of coastal marsh from montane marsh is somewhat artificial, since both are dominated by the same species, *Eleocharis dulcis*. However, two species found in coastal marsh (*Acrostichum* and *Cyclosorus*) are rare or absent in montane marsh. Montane bog, dominated by species of *Carex* and *Paspalum*, is known only from elevations of over 1,500 metres on Savai'i.

Of the wetlands with woody vegetation, swamp forest occurs in sites where the soil is saturated with fresh water, typically inland and even in montane areas. Characteristic species include *Barringtonia samoensis*, *Erythrina fusca*, *Hibiscus tiliaceus*, *Inocarpus fagifer*, *Kleinhovia hospita*, *Palaquium stehlinii*, *Pandanus turritus* and *Terminalia richii*. *Pandanus turritus* is generally the dominant species in the swamp forest in montane craters. In eastern Upolu, there is an unusual type of mixed upland swamp forest in which lowland rain forest species and swamp forest species grow side by side.

Mangroves are confined to the two large islands, generally occurring in small stands along tidal inlets, at river mouths or as a narrow fringe along muddy and sandy shores where there is some offshore protection from extreme wave action. Two main communities are recognized; mangrove forest consisting of almost pure stands of *Bruguiera gymnorrhiza*, and mangrove scrub (rarely more than 5 m high) consisting of a mixture of both *Rhizophora (mangle) samoensis* and *Bruguiera*. There is also a single small stand (less than 1 ha) of *Xylocarpus moluccensis* on white sand substrate at a stream mouth near Sala'ilua on Savai'i.

Almost all of the wetlands in Western Samoa have been disturbed to some extent either directly by human activities or through the introduction of pests, the only exceptions being some of the higher altitude montane marshes and the montane bog on Savai'i. The cutting and in-filling of mangroves has been largely uncontrolled (Bell, 1985), and much of Western Samoa's mangrove vegetation is now badly degraded. The severe cyclones of 1990 and 1991 affected many of the wetland areas, especially herbaceous marshes along northern and eastern shores which were damaged by salt water incursions.

In their survey of the terrestrial ecosystems of Western Samoa, Pearsall and Whistler (1991) recognized a total of eight wetland ecosystems as follows: *Bruguiera* mangrove; *Rhizophora* mangrove; *Xylocarpus* mangrove; freshwater lake; herbaceous marsh; mixed lowland species swamp forest; mixed upland species swamp forest; and *Pandanus turritus* swamp forest. All eight were considered to be high priorities for conservation based on rarity and threats in Western Samoa, and four (herbaceous marsh, mixed lowland species swamp forest, mixed upland species swamp forest and

Pandanus turritus swamp forest) were considered to be of global importance because of their rarity, endangered status or presence of endemic species.

The principal wetlands of Western Samoa are as follows:

Coastal Marsh

* Falealili Marsh, Upolu
  A series of small herbaceous marshes on the south coast of Upolu, degraded by human impact. The small marsh at Malaemalu was identified as a priority site for conservation by Pearsall and Whistler (1991), but this site is now very degraded and is no longer considered to be a priority.
* Apolimafou Marsh, Upolu
  A small herbaceous marsh at the west end of Upolu, the least disturbed of any coastal marsh in Western Samoa. (See Site Accounts).
* Pu'apu'a Marsh, Savai'i
  A small marsh near the east end of Savai'i, degraded by human settlement and not considered to be a priority area for protection.
* Faga Marsh, Savai'i
  A small marsh near the east end of Savai'i, degraded by human settlement and not considered to be a priority area for protection.
* Falealupo Marshes (Cape Mulinu'u), Savai'i
  Two areas of coastal marsh at the extreme western end of Savai'i, degraded by past exploitation and human settlement, and severely damaged by Hurricane Ofa in 1990. The preservation of the village forest under a covenant agreement has in the last few years increased awareness of the conservation importance of this area. The southern marsh (Tofutafoe) was recommended for designation as a Nature Reserve by Holloway and Floyd (1975), and identified as a priority site for conservation by Pearsall and Whistler (1991).
* Satoalepai Marsh, Savai'i
  A large degraded marsh near Matautu Bay at the northern tip of Savai'i. The cyclones of 1990 and 1991 opened up an outlet to the sea, and sea water now flows freely into the marsh.

Montane Marsh

* Lakes and marshes of the Aleipata Uplands, Upolu
  A series of small lakes and herbaceous marshes in a chain of volcanic craters in the Aleipata Uplands of eastern Upolu. (See Site Accounts).
* Mount Le Pu'e Lake and Marsh, Upolu
  A small lake and marsh in a volcanic crater, protected in the O Le Pupu Pu'e National Park (2,857 ha; established 1978).
* Lake Lanoto'o, Lake Lanoata'ata and Lake Lanoanea, Upolu
  Three small lakes with fringing marshes in volcanic craters in the central highlands of Upolu. Lake Lanoto'o is the largest freshwater lake in Western Samoa. (See Site Accounts).
* Olo Manu Uta Marsh (Maugaloa Marsh), Savai'i
  A large herbaceous marsh in the eastern highlands of Savai'i. (See Site Accounts).
* Lake Mafane and Lake Mautalano, Savai'i
  Two small lakes with fringing marshes in volcanic craters in the eastern highlands of Savai'i. (See Site Accounts).

Montane Bog

* Mount Silisili Bog, Savai'i
  A small montane bog near the summit of Mount Silisili (1,858 m); the only significant montane bog in Western Samoa. (See Site Accounts).

Mangrove Scrub

* Vaovai Mangroves, Upolu
  A small area of mangrove scrub along a tidal channel near Nu'usafe'e on the south coast of Upolu. Identified as a priority site for conservation by Pearsall and Whistler (1991), but now degraded and no longer considered to be a priority.
* Vaie'e Mangroves (Fusi/Tafitoala), Upolu
  An area of mangrove scrub lining a creek on the east side of Safata Bay. The mangrove remains in a fairly healthy state, but is threatened by increasing encroachment from nearby villages. Recommended for designation as a Nature Reserve by Holloway and Floyd (1975).
* Apia Mangroves, Upolu
  A narrow strip of mangrove scrub along the north coast of Upolu, west of Apia harbour. The largest area of mangroves in Western Samoa, but degraded because of its location in the main urban area. The site is still of some importance, and is being considered for rehabilitation by the Division of Environment and Conservation.

* Moata'a Mangroves, Upolu
  A small patch of mangrove scrub just east of Apia harbour, now largely reclaimed for settlement and developments such as a sports park and hotel.
* Aleipata Mangroves, Upolu
  A small patch of mangrove scrub at the east end of Upolu, degraded by human settlement.
* Lano Mangroves, Savai'i
  A tiny patch of mangrove scrub near the east end of Savai'i, degraded by human settlement.
* Lalomalava Mangroves, Savai'i
  A small patch of mangrove scrub at the east end of Savai'i, degraded by human settlement.

Mangrove Forest

* Sa'anapu-Sataoa Mangrove Forest, Upolu
  A large stand of mangrove forest on the west side of Safata Bay; the least disturbed stand of mangrove forest in Western Samoa. (See Site Accounts).
* Falelatai Mangroves (Pata), Upolu
  A small patch of mangrove forest on a scenic tidal inlet on the southwest coast of Upolu, degraded by human activities. Recommended for designation as a Nature Reserve by Holloway and Floyd (1975) and identified as a priority site for conservation by Pearsall and Whistler (1991).
* Fasitootai Mangroves, Upolu
  A tiny patch of mangrove forest on the northwest coast of Upolu, degraded by human activities.

Swamp Forest

* Lalomauga Swamp Forest, Upolu

A small patch of degraded swamp forest near the northeast coast of Upolu. Most of the original swamp is covered with village plantations, and there is an electricity power plant in the swamp which supplies the eastern coast of the island.

* Vaipu Swamp Forest (Fusiluaga), Upolu

A large area of swamp forest in the uplands of eastern Upolu, with an unusual mixture of lowland rain forest and swamp forest species. (See Site Accounts).

No conservation areas have as yet been established specifically to protect wetlands, although the O Le Pupu Pu'e National Park (2,857 ha) contains a small crater lake and marsh (Mount Le Pu'e Lake) and a small area of coastal marsh. Parks (1992) identified the most pristine mangrove area in Western Samoa (Sa'anapu-Sataoa) as a Grade 1 Site for conservation, and this mangrove forest has recently been proposed as a Conservation Area to be established with Global Environment Facility funding under the guidance of the South Pacific Regional Environment Programme (SPREP). In addition, several water catchment areas are currently being proposed under the new Water Catchment Protection Regulation proposal to Government.

Of the 21 terrestrial ecosystems described by Pearsall and Whistler (1991), "Mixed Upland Species Swamp Forest" was identified as the highest priority for conservation in Western Samoa. Only three examples of this forest type were known, and the conservation of the largest and least disturbed of these (Punataemo'o Swamp Forest near Afulilo Falls on Upolu) was considered to be the top priority. Unfortunately, this swamp forest has since been cleared for a hydro-electric dam. The second largest example of mixed upland species swamp forest (Vaipu Swamp Forest) is safe for the moment, but could be affected in the future by an expansion of the hydro-electric project.

Very little information is available on the wetland fauna of Western Samoa. Rather few species of waterbirds occur in the islands, and only six species are resident, the Pacific Reef Heron (*Egretta sacra*), Pacific Black Duck (*Anas superciliosa*), Banded Rail (*Rallus philippensis*), White-browed Crake (*Porzana cinerea*), Spotless Crake (*Porzana tabuensis*) and Purple Swamphen (*Porphyrio porphyrio*). Eight species of shorebirds have been recorded on migration and during the austral summer, but only four, the Pacific Golden Plover (*Pluvialis fulva*), Wandering Tattler (*Heteroscelus incanus*), Bristle-thighed Curlew (*Numenius tahitiensis*) and Ruddy Turnstone (*Arenaria interpres*) are regular (Mayr, 1945; Pratt *et al.*, 1987; Watling and Talbot-Kelly, 1982). The apparently flightless Samoan Woodhen (*Gallinula (Pareudiastes) pacifica*) is known only from the forests of Savai'i and may have frequented the montane wetlands on this island. Although there is no conclusive evidence of its having been found since 1873, there have been unconfirmed reports this century from wetlands in Aleipata District.

Wetland Research

No research relating specifically to wetlands has been carried out in Western Samoa, and most of the information that is available has been derived from general surveys of the terrestrial ecosystems (*e.g.* Ollier *et al.*, 1979; Dahl, 1980; KRTA Limited, 1988; Pearsall and Whistler, 1991; Parks, 1992) and marine ecosystems (*e.g.* Bell, 1985; Andrews and Holthus, 1989; Zann, 1991). Whistler (1992) and Parks (1992) provide the most comprehensive accounts of the flora of Western Samoa's wetlands, while Vodonaivalu (1982) and Sua (1988) summarize information on the mangrove communities. Scientists from ORSTOM are currently conducting a study of fisheries in mangrove areas.

Wetland Area Legislation

Western Samoa

There is no specific legislation concerning wetland conservation in Western Samoa, although areas with potential for conservation come under the auspices of the Lands and Environment Act (1989) and National Parks and Reserves Act (1974). Policy and legislation relating to the establishment and administration of protected areas have recently been summarized by IUCN (1991).

The Forestry Act (1967) controls the conservation of water catchment areas under the Regulation on Water Catchment Protection (1992). The exploitation of marine resources is regulated through the Fisheries Protection Act (1972) and the Exclusive Economic Zone Act (1977). The Fish Dynamiting Act (1972) prohibits all use of dynamite for fishing.

The Protection of Wild Birds Regulation, imposed in 1981 under the Animal Ordinance of 1910 and amended in 1989, gives total protection to 15 species of birds and partial protection to three types of pigeon for which there are open seasons. Three resident waterbirds are covered by the schedule, namely the Pacific Black Duck (*Anas superciliosa*), White-browed Crake (*Porzana cinerea*) and Spotless Crake (*Porzana tabuensis*).

At international level, Western Samoa has ratified the Convention on the Conservation of Nature in the South Pacific (Apia Convention) and the Convention for the Protection of the Natural Resources and Environment of the South Pacific (SPREP Convention), and has also signed but not yet ratified the Convention on Biological Diversity. However, it is not yet a party to the World Heritage Convention, Unesco Man and the Biosphere Programme or Convention on Wetlands of International Importance especially as Waterfowl Habitat (Ramsar Convention).

Wetland Area Administration

With over 75% of Western Samoa's land under customary ownership, the majority of wetlands are administered by village councils and individuals. The Lands and Environment Act (1989) gives the right to the Government to take customary land for conservation purposes if there is a need to protect specific sites, but this right has not yet been used for wetland conservation. The two small wetlands in O Le Pupu Pu'e National Park are administered by the Division of Environment and Conservation, Department of Lands and Environment.

A new system for the protection of biodiversity is being developed whereby villages manage and monitor the conservation of their customary land with Government assistance instead of setting up National Parks. Four villages are already involved in this new method of conservation.

Organizations involved with Wetlands

(a) Western Samoan Government

Department of Lands and Environment

- Division of Environment and Conservation
  Responsible for administration of the Lands and Environment Act (1989), National Parks and Reserves Act (1974) and all matters concerning the protection and conservation of the environment.

(b) Non-governmental Organizations

O Le Siosiomaga Society
South Pacific Regional Environment Programme (SPREP)

WETLANDS

Site descriptions based on a report prepared by Cedric Schuster of the Division of Environment and Conservation, Department of Lands and Environment.

Lakes and Marshes of the Aleipata Uplands (1)

Location: 14°00'S, 171°27-171°33'W; in the eastern highlands of Upolu.
Area: Unknown.
Altitude: 210-550 m.
Overview: A series of small lakes and herbaceous marshes in a chain of volcanic craters in the Aleipata Uplands of eastern Upolu, mostly protected from human impact because of their high altitude.
Physical features: The Aleipata uplands of eastern Upolu comprise a long broad ridge covered with lowland rain forest. There are ten small volcanic craters along the ridge crest, at least seven of which contain interesting wetlands. Olomaga, Lanoto and Savai'i craters contain freshwater lakes with a narrow fringe of herbaceous marsh and patches of *Pandanus turritus* swamp forest; Seuga, Tiatala and Olomauga craters contain patches of *Pandanus turritus* swamp forest; and Latalua crater contains a small herbaceous marsh.
Ecological features: Herbaceous marsh with *Eleocharis dulcis*; swamp forest dominated by *Pandanus turritus*.
Land tenure: Customary ownership.
Conservation measures taken: None.
Conservation measures proposed: The central and eastern portions of the Aleipata Uplands were recommended for designation as a national park by Holloway and Floyd (1975), Dahl (1980), Anon (1985) and KRTA Limited (1988), and were identified as a priority site for conservation by Pearsall and Whistler (1991). The proposed national park (Lake Olomaga National Park) covers 1,300 ha and includes all the main wetlands.
Land use: None at the wetlands.
Disturbances and threats: There is little if any disturbance at the wetlands. The lowland rain forest in this area was severely damaged by Hurricane Ofa in 1990 and again by Hurricane Val in 1991, and the vegetation now consists mainly of weeds and secondary growth.
Hydrological and biophysical values: No information.
Social and cultural values: No information.
Noteworthy fauna: No information is available on the wetland fauna. The surrounding forests are reputed to support a particularly rich and varied bird life.
Noteworthy flora: *Pandanus turritus* swamp forest.
Management authority and jurisdiction: No information.
References: Anon (1985); Dahl (1980); Holloway & Floyd (1975); KRTA Limited (1988); Pearsall & Whistler (1991).
Reasons for inclusion: 1a, 1d, 2b. The site contains several good examples of montane marsh and important stands of *Pandanus turritus* swamp forest.
Source: Cedric Schuster.

Vaipu Swamp Forest (2)

Location: 13°58'S, 171°36'W; in the northern uplands of eastern Upolu, 24 km southeast of Apia.
Area: Approximately 520 ha.
Altitude: 240 m.

Overview: An area of mixed upland species swamp forest in a water-logged basin in the hills of eastern Upolu; the last significant wetland of this type in Samoa.
Physical features: A large patch of swamp forest in a poorly drained basin on one of the main tributaries of the Salani River. The swamp is fed by Afulilo Falls and stream, and lies below the site of the former Punataemo'o swamp forest which was recently submerged by a hydro-electric scheme. The basic alluvium and basic colluvium soils in the central part of the basin are saturated with fresh water, and there is some open water in the northeast.
Ecological features: The forest comprises a mixture of typical swamp forest species and lowland rain forest species, with *Barringtonia samoensis*, *Calophyllum neo-ebudicum*, *Cananga odorata*, *C. harveyi*, *Canthium merrillii*, *Clidemia hirta*, *Cyathea* spp., *Dysoxylum samoense*, *Elaeocarpus tonganus*, *Fagraea berteroana*, *Ficus tinctoria*, *Hernandia moerenhoutiana*, *Hibiscus tiliaceus*, *Macaranga stipulosa*, *Myristica fatua*, *M. hypargyraea*, *Neonauclea forsteri*, *Pisonia* sp., *Planchonella torricellensis*, *Pometia pinnata*, *Rhus taitensis*, *Scirpodendron ghaeri*, *Syzygium samarangense* and *Terminalia richii* (Pearsall & Whistler, 1991). The screwpine *Pandanus turritus* and various endemic woody trees such as *Aglaia samoense*, *Clintostigma samoense* and *Sterculia fanaiho* have also been recorded. The swamp forest lies adjacent to disturbed lowland rain forest and secondary forest.
Land tenure: The wetland and surrounding areas are entirely under customary ownership.
Conservation measures taken: None.
Conservation measures proposed: Holloway and Floyd (1975) recommended that the site be protected as a nature reserve, and this was supported by Dahl (1980). The site has been recognized as one of the highest priorities for conservation in Western Samoa, and was listed as the third highest priority by Pearsall and Whistler (1991) in their "Terrestrial Ecosystem Mapping for Western Samoa". The wetland has recently been proposed as a National Conservation Area.
Land use: None at the wetland. A hydro-electric power scheme has recently been developed in the catchment area.
Disturbances and threats: The wetland is threatened by development of plantations and expansion of the road network in the area. Pigeon hunting causes some disturbance, and there may be a small amount of logging. The cyclones of 1990 and 1991 caused only limited damage to the forest. Development of the Afulilo Hydro-electric Power Project in the water catchment area resulted in the destruction of the neighbouring Punataemo'o Swamp Forest; any further expansion of this project could have a detrimental effect on Vaipu Swamp Forest.
Hydrological and biophysical values: The swamp forest is a very important water catchment area for the Salani river system.
Social and cultural values: The area is of some archaeological significance, with old Samoan settlements at both ends of the wetland. These are believed to have been occupied by the Paramount Chiefs for generations.
Noteworthy fauna: Wildlife recorded at the site includes Pacific Boa (*Candoia bibroni*), two species of flying fox (*Pteropus* sp.), Pacific Black Duck (*Anas superciliosa*), Mao (*Gymnomyza samoensis*) and possibly Spotless Crake (*Porzana tabuensis*). The endangered Tooth-billed Pigeon (*Didunculus strigirostris*) is known to occur in the area.
Noteworthy flora: The site contains a rare type of swamp forest (mixed upland species swamp forest) with a number of endemic tree species.
Scientific research and facilities: The area has never been properly surveyed and is in urgent need of detailed study.
Recreation and tourism: The area has great potential for eco-tourism, although at present it is seldom visited except by pigeon hunters.
Management authority and jurisdiction: The Division of Environment and Conservation has responsibility for management; jurisdiction lies with the Department of Lands and Environment.
References: Anon (1985); Dahl (1980); Holloway & Floyd (1975); Parks (1992); Parks *et al.* (1992); Pearsall & Whistler (1991); Whistler (1992).
Reasons for inclusion: 1d, 2b, 2d. The last example of this type of mixed swamp forest surviving in Western Samoa and reportedly also in the entire South Pacific. Vaipu Swamp Forest may be the only Samoan wetland free of introduced exotic freshwater species. There is a high degree of

endemism in the flora and fauna, and the wetland remains in almost pristine condition apart from some recent cyclone damage.
Source: Cedric Schuster.

Lanoto'o, Lanoata'ata and Lanoanea Lakes (3)

Location: 13°54'S, 171°50'W; in the central highlands of Upolu, about 6 km south of Apia.
Area: Lake Lanoto'o 60 ha; area of other lakes unknown.
Altitude: Lake Lanoto'o at 762 m.
Overview: A group of three small crater lakes with fringing herbaceous marsh and *Pandanus turritus* swamp forest, in the central highlands of Upolu.
Physical features: Lake Lanoto'o, Lake Lanoata'ata and Lake Lanoanea are small freshwater lakes inside steep-sided volcanic craters. The open water areas are surrounded by a narrow fringe of herbaceous swamp and *Pandanus* swamp forest. Lake Lanoto'o is the largest lake in Western Samoa.
Ecological features: Herbaceous swamp dominated by *Eleocharis dulcis*, and upland swamp forest dominated by *Pandanus turritus*. Montane rain forest around the lakes includes species such as *Dysoxylum huntii*, *Cyathea* spp., *Hibiscus tiliaceus*, *Pometia pinnata* and *Syzygium* spp.
Land tenure: Half of Lake Lanoto'o is Government Land and half is Customary Land. Surrounding areas are partly Government Land, partly Customary Land and partly private (freehold).
Conservation measures taken: None.
Conservation measures proposed: Holloway and Floyd (1975) proposed the establishment of a national park of about 1,050 ha to protect all three lakes and the surrounding forests, and this was supported by Dahl (1980) and KRTA Limited (1988). Pearsall and Whistler (1991) also identified the three lakes and their surrounding forests as a priority site for conservation. The Department of Lands and Environment has requested the Land Board to set aside Lake Lanoto'o and its environs as a Conservation Area. The Government has been urged to declare its half of the lake as a Conservation Area as soon as possible, and to start negotiating with the customary owners for the remainder.
Land use: None at the wetlands.
Disturbances and threats: Goldfish (*Carassius auratus*) were introduced into Lake Lanoto'o in about 1900 and are thriving. The surrounding forests are being cleared for shifting agriculture and plantations, particularly in the northwest around Lake Lanoata'ata and Lake Lanoanea, and the entire area was badly affected by Hurricane Ofa in 1990 and Hurricane Val in 1991.
Hydrological and biophysical values: The region is an important water catchment area, and includes the headwaters of the Fulu-asou river system which flows north to Apia.
Social and cultural values: Eco-tourism and outdoor recreation activities, if controlled, could generate income for the local people and help to maintain the ecosystem in its natural condition.
Noteworthy fauna: An important area for the Pacific Black Duck (*Anas superciliosa*) and Spotless Crake (*Porzana tabuensis*). The forests contain most of Western Samoa's endemic bird species, notably the endangered Tooth-billed Pigeon (*Didunculus strigirostris*), Samoan Triller (*Lalage sharpei*) and Mao (*Gymnomyza samoensis*).
Noteworthy flora: Swamp forest dominated by the screwpine *Pandanus turritus*.
Conservation education: School field-trips occasionally visit the lakes, and boy-scouts and girl-guides sometimes camp in the area.
Recreation and tourism: The lakes are occasionally visited by tourists (mainly naturalists), and have good potential for tourism. KRTA Limited (1988) has made various recommendations concerning tourist development in the area, including the provision of nature trails.
Management authority and jurisdiction: The Division of Environment and Conservation has responsibility for management; jurisdiction lies with the Department of Lands and Environment.

References: Anon (1976); Anon (1985); Dahl (1980); Eaton (1985); Holloway & Floyd (1975); KRTA Limited (1988); Parks (1992); Parks *et al.* (1992); Pearsall & Whistler (1991).
Reasons for inclusion: 1a, 2b. Although now very disturbed by encroaching agriculture, the area remains important for wildlife. The site includes the largest lake in Western Samoa.
Source: Cedric Schuster.

Sa'anapu-Sataoa Mangrove Forest (4)

Location: 13°59'S, 171°52'W; on the west side of Safata Bay on the south coast of Upolu.
Area: 90 ha.
Altitude: Sea level.
Overview: An area of estuarine mangrove forest, important as a nursery ground for mullet. The village that owns the site is eager to preserve it in its natural state.
Physical features: A large stand of mangrove forest bordering the tidal estuary of the Leaf River. In 1990, Hurricane Ofa deposited a fair amount of sand in the estuary mouth, but otherwise the ecosystem remains in good condition. One of Western Samoa's finest stands of coastal forest is found across the estuary from the mangrove forest.
Ecological features: Mangrove forest dominated by *Bruguiera gymnorrhiza* with some *Rhizophora (mangle) samoensis*. Other species present include the ferns *Acrostichum aureum* and *Humata heterophylla*, and *Barringtonia asiatica*. The nearby coastal forest is dominated by *Diospyros elliptica*, *D. samoensis* and *Syzygium* spp.
Land tenure: The wetland and surrounding areas are entirely under customary ownership.
Conservation measures taken: The inhabitants of Sa'anapu village, in collaboration with the Division of Environment and Conservation, have banned dynamiting and fish poisoning in the wetland, and have established quota for crab catchers. Fishermen from neighbouring villages are prohibited from fishing in the mangroves.
Conservation measures proposed: Holloway and Floyd (1975) recommended that the site be protected as a nature reserve, and this was supported by Dahl (1980). Pearsall and Whistler (1991) listed the Sa'anapu-Sataoa Mangrove Forest along with nearby coastal rain forest in their top ten priority sites for conservation in Western Samoa, and Parks (1992) identified the mangrove forest as a Grade 1 Site for conservation. The forest has recently been proposed as a Conservation Area to be established with funding from the Global Environment Facility under the guidance of the South Pacific Regional Environment Programme (SPREP).
Land use: Fishing; harvesting of crabs. Villages and plantations in surrounding areas.
Disturbances and threats: The site is threatened by forest clearance and landfill for human settlement, and pollution. Feral pigs cause some damage to the mangroves.
Hydrological and biophysical values: The mangrove forest is an important nursery ground for a wide variety of fish species including mullet (*Mugil* spp.).
Social and cultural values: No information.
Noteworthy fauna: Birds recorded at the site include Pacific Reef Heron (*Egretta sacra*), Pacific Black Duck (*Anas superciliosa*), Pacific Golden Plover (*Pluvialis fulva*), Purple-capped Fruit-Dove (*Ptilinopus porphyraceus*), Samoan Whistler (*Lalage sharpei*), Samoan Broadbill (*Myiagra albiventris*) and Cardinal Honeyeater (*Myzomela cardinalis*). Flying foxes (*Pteropus* sp.) also occur in the mangroves. Common invertebrates include the mangrove crab *Scylla paramamosian* and crabs of the genus *Uca*.
Noteworthy flora: *Trichomanes* spp. are endemic to the forest, and the high density of epiphytes is of special interest.
Scientific research and facilities: The Division of Environment and Conservation is currently investigating the possibilities for sustainable utilization of the mangrove forest as a way of promoting its conservation.
Conservation education: Conservation of mangroves has become an important environmental

issue in Western Samoa. Because of its relatively undisturbed condition, the Sa'anapu-Sataoa Mangrove Forest will be used as an example of how a healthy mangrove forest should be.
Recreation and tourism: There is some potential for eco-tourism along the river into the mangrove forest.
Management authority and jurisdiction: The Division of Environment and Conservation has responsibility for management; jurisdiction lies with the Department of Lands and Environment.
References: Dahl (1980); Holloway & Floyd (1975); Parks (1992); Parks *et al.* (1992); Pearsall & Whistler (1991); Sua (1988); Zann (1991).
Reasons for inclusion: 1a, 2b, 2c. The largest and least disturbed stand of mangrove forest in Western Samoa; an important fish breeding area.
Source: Cedric Schuster.

Apolimafou Marsh (5)

Location: 13°52'S, 172°04'W; near the extreme western tip of Upolu.
Area: Approximately 50 ha.
Altitude: Near sea level.
Overview: An area of herbaceous marsh at the west end of Upolu; the least disturbed of any coastal marsh in Western Samoa.
Physical features: A small area of freshwater marsh on the coastal lowlands at the west end of Upolu. The site lies adjacent to coconut plantations.
Ecological features: Herbaceous marsh with *Eleocharis dulcis* and *Cyclosorus interruptus*. *Erythrina fusca* and *Pandanus tectorius* are found in isolated clumps along the edges of the marsh. *Ludwigia octovalvis* dominates in areas of disturbed vegetation along the roads bordering and crossing the wetland.
Land tenure: Customary ownership.
Conservation measures taken: None.
Conservation measures proposed: Recommended for designation as a nature reserve by Holloway and Floyd (1975), and identified as a priority site for conservation by Dahl (1980) and Pearsall and Whistler (1991). Parks (1992) identified the marsh as a Grade 2 site.
Land use: No information.
Disturbances and threats: The marsh is situated directly behind a village and is threatened by further expansion of the village. Some reduction in water supply may have occurred as a result of agricultural activities in the surrounding area. There has been some disturbance to the marsh vegetation along a road which crosses the marsh.
Hydrological and biophysical values: No information.
Social and cultural values: No information.
Noteworthy fauna: The Pacific Black Duck (*Anas superciliosa*) and Purple Swamphen (*Porphyrio porphyrio*) occur in the marsh.
Noteworthy flora: An excellent example of a lowland herbaceous marsh.
Management authority and jurisdiction: No information.
References: Anon (1985); Dahl (1980); Holloway & Floyd (1975); Parks (1992); Pearsall & Whistler (1991).
Reasons for inclusion: 1a. Probably the best remaining example of lowland herbaceous swamp in Western Samoa, still in relatively good condition.
Source: Cedric Schuster.

Lake Mafane, Lake Mautalano and Olo Manu Uta Marsh (6)

Location: 13°39'S, 172°20'W; in the eastern highlands of Savai'i.
Area: Unknown.
Altitude: 600-1,000 m.
Overview: Two crater lakes with fringing marshes and a large area of herbaceous marsh in the eastern highlands of Savai'i, still in a healthy, relatively undisturbed condition and well protected from human disturbance because of their isolated location.
Physical features: Lake Mafane (approximately 50 ha) and Lake Mautalano (a few ha) are small freshwater lakes with fringing herbaceous marshes, situated in steep-sided volcanic craters about 4 km apart. The crater rims rise to peaks at 1,000 and 716 m respectively. Olo Manu Uta Marsh (Maugaloa Marsh) is a large herbaceous marsh situated at 625 m above sea level on the southwestern slopes of Mount Olo Manu Uta, east of Mount Maugaloa. Other small volcanic craters further west along the crest of Savai'i contain smaller and as yet unmapped wetlands.
Ecological features: Herbaceous marsh with *Eleocharis dulcis* and *Rhynchospora corymbosa*. The surrounding highlands are covered in montane rain forest and cloud forest.
Land tenure: Lake Mafane and Lake Mautalano are partly on public land and partly under customary ownership; Olo Manu Uta Marsh is situated entirely on public land.
Conservation measures taken: None.
Conservation measures proposed: Lake Mafane and Olo Manu Uta Marsh were recommended for designation as nature reserves by Holloway and Floyd (1975), while Lake Mautalano was recommended for designation as a strict nature reserve, closed to the general public. All three sites were identified as priority areas for conservation by Dahl (1980). KRTA Limited (1988) recommended extending the boundaries of the proposed Mount Silisili National Park to include the three wetlands. It was suggested that the wetlands be grouped within a buffer zone and incorporated into the National Park, together with a corridor about 2,000 m in width linking them to the Silisili highlands. Pearsall and Whistler (1991) also recommended that the wetlands be included with the Silisili highlands in a single large protected area.
Land use: None. The surrounding forests are scarcely if ever used by their customary owners.
Disturbances and threats: None known at the wetlands. The upland forests on northern exposures were severely damaged by Hurricane Ofa in 1990 and Hurricane Val in 1991.
Hydrological and biophysical values: No information.
Social and cultural values: No information.
Noteworthy fauna: No information.
Noteworthy flora: No information.
Management authority and jurisdiction: No information.
References: Anon (1985); Dahl (1980); Holloway & Floyd (1975); KRTA Limited (1988); Pearsall & Whistler (1991).
Reasons for inclusion: 1a. Excellent examples of upland lakes and marshes, still in a pristine condition and surrounded by almost undisturbed primary rain forest.
Source: Cedric Schuster.

Mount Silisili Bog (7)

Location: 13°37'S, 172°29'W; in the central highlands of Savai'i.
Area: Unknown.
Altitude: Over 1,500 m.
Overview: A montane bog dominated by species of *Carex*; the only bog of this type in Western Samoa.
Physical features: A small montane bog surrounded by cloud forest near the summit of Mount Silisili (1,858 m).

Ecological features: The bog vegetation is dominated by species of *Carex*.
Land tenure: The wetland and surrounding areas are almost entirely under customary ownership.
Conservation measures taken: None.
Conservation measures proposed: The central highlands of Savai'i have frequently been recommended for reserve status, but no action has been taken because the majority of the land is under customary ownership. Holloway and Floyd (1975) recommended the establishment of a large national park (8,900 ha) and this was supported by Dahl (1980) and Hay (1985). KRTA Limited (1988) endorsed the view that the establishment of the proposed Silisili National Park was of the highest priority, and proposed extending the boundaries to include Lake Mafane, Lake Mautalano and Olo Manu Uta Marsh to the east. Pearsall and Whistler (1991) similarly recommend the establishment of a large reserve encompassing all of the central highlands of Savai'i as well as a corridor of forest extending almost down to the south coast.
Land use: None. There is no human habitation in the area.
Disturbances and threats: None known.
Hydrological and biophysical values: No information.
Social and cultural values: No information.
Noteworthy fauna: The White-browed Crake (*Porzana cinerea*) and Spotless Crake (*Porzana tabuensis*) are known to occur in the area. There is a slight possibility that the endemic Samoan Woodhen (*Gallinula (Pareudiastes) pacifica*) could still survive in the moist montane forests and bogs of central Savai'i, although there are no confirmed reports since 1873. The montane forests of Savai'i (above 900 m) are also home to the endemic Samoan White-eye (*Zosterops samoensis*), known only from this island. Other interesting birds of the cloud forest include the endangered Tooth-billed Pigeon (*Didunculus strigirostris*), the Friendly Ground-Dove (*Gallicolumba stairii*), the Island Thrush (*Turdus poliocephalus*), the rare Mao (*Gymnomyza samoensis*) and an endemic subspecies of the Red-headed Parrot-finch (*Erythrura cyaneovirens gaughrani*).
Noteworthy flora: A unique wetland plant community in Western Samoa. The surrounding cloud forests are very rich in endemic species, with approximately 53% of species endemic compared to 25-33% for the islands as a whole.
Management authority and jurisdiction: No information.
References: Anon (1985); Dahl (1980); Hay (1985); Holloway & Floyd (1975); KRTA Limited (1988); Parks *et al.* (1992); Pearsall & Whistler (1991); Whistler (1992).
Reasons for inclusion: 1d, 2b, 2d. The only significant montane bog in Western Samoa.
Source: Cedric Schuster.

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