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 Nivas (including Nivafo'ou and Nivatoputapu) 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 watermelons 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 Nivafo'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 Nivatoputapu 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 (*ulnas 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. Pemetta (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 kinke 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 Nivafo'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.

Wetland Name: Fanga'uta and Fangakakau Lagoon
1
Country: Tonga
Coordinates: 21°10'S, 175°10'W
Location: 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 sylosa* 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 citnfolia, 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 teciorius* 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: la, 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.

Wetland Name: Sopu Flats
Country: Tonga
Coordinates: 21°07'S, 175°18'W
Location: 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 Tumstone (*Arenaria interpres*) and a species of curlew (*Numenius* sp.). Resident species include Pacific Reef Heron (*Egretta sacra*), Pacific Black Duck (*Arras 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: la, 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.

Wetland Name: Nomuka Lagoon

Country: Tonga

Coordinates: 20^{0}15'S, 174°48'W

Location: 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: ld. The only significant "marine lake" in Tonga, with interesting non-tidal mangrove and salt marsh vegetation.

Source: See references.

Wetland Name: Tofua Crater Lake

Country: Tonga
Coordinates: 19°45'S, 175°04'W
Location: 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: Ia. A large undisturbed crater lake; the second largest lake in Tonga.
Source: See references.

Wetland Name: Kao Crater Lake
Country: Tonga
Coordinates: 19°40'S, 175°02'W
Location: 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: la. A very isolated and undisturbed crater lake surrounded by moss forest near the summit of the highest peak in Tonga.
Source: See references.

Wetland Name: Lake Ano and Ngofe Marsh
Country: Tonga
Coordinates: 18°39'S, 174°03'W
Location: 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: la, 2b. An interesting brackish lake and the largest freshwater swamp in Tonga.
Source: See references.

Wetland Name: Nivafo'ou Crater Lake
Country: Tonga
Coordinates: 15°36'S, 175°38'W
Location: on the island of Nivafo'ou in the Nivas, 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 Nivafo'ou Island. The island is of special interest for its endemic megapode, *Megapodius pritchardii.*
Physical features: Nivafo'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: Nivafo'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 Nivafo'ou Megapode (*Megapodius pritchardit*) 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: la, ld, 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.

REFERENCES

Anon. (1985). Tonga. *In:* Thomas, P.E.J. (ed.), Report of the Third South Pacific National Parks and Reserves Conference. Volume III. Country Reviews. South Pacific Commission, Noumea, New Caledonia.

Anon. (1989). Tonga Country Review. Report presented at the Fourth South Pacific Conference on Nature Conservation and Protected Areas, Port Vila, Vanuatu, September 1989. SPREP/IUCN.

Chesher, R.H. (1984). Pollution Sources Survey of the Kingdom of Tonga. SPREP Topic Review No. 19. South Pacific Commission, Noumea. 110 pp.

Collar, N.J. & Andrew, P. (1988). Birds to Watch: The ICBP World Checklist of Threatened Birds. ICBP Technical Publication No. 8. ICBP, Cambridge, U.K.

Dahl, A.L. (1980). Regional Ecosystems Survey of the South Pacific Area. SPC Technical Paper No. 179. South Pacific Commission, Noumea, New Caledonia.

Dahl, A.L. (1986). Review of the Protected Areas System in Oceania. UNEP & IUCN Commission on National Parks and Protected Areas, Gland, Switzerland.

Eaton, P. (1985). Land Tenure and Conservation: Protected Areas in the South Pacific. SPREP Topic Review No. 17. South Pacific Commission, Noumea. 103 pp.

Ellison, J.C. (1988). Holocene sea level record of Tongatapu, Kingdom of Tonga, from pollen analysis of mangrove sediments. M.Sc. thesis, Simon Fraser University, Canada. 94 pp.

Ellison, J.C. (1989). Pollen analysis of mangrove sediments as a sea-level indicator: Assessment from Tongatapu, Tonga. Palaeogeography, Palaeoclimatology, Palaeoecology 74: 327-341.

Ellison, J.C. (in press). The Pacific palaeogeography of *Rhizophora mangle* L. Botanical Journal of the Linnean Society.

Ellison, J.C. & Stoddart, D.R. (1991). Mangrove ecosystem collapse during predicted sea-level rise: Holocene analogues and implications. Journal of Coastal Research 7(1): 1-15.

Hay, R. (1985). Bird Conservation in the Pacific Islands. SPREP Topic Review No. 25 (ICBP Study Report No. 7). South Pacific Commission, Noumea, New Caledonia. (ICBP, Cambridge, U.K).

Interdepartmental Environment Committee (1990). Environmental Management Plan for the Kingdom of Tonga. Economic and Social Committee for Asia and the Pacific (ESCAP). Bangkok, Thailand. 197 pp.

IUCN (1991). IUCN Directory of Protected Areas in Oceania. Prepared by the World Conservation Monitoring Centre. IUCN, Gland, Switzerland and Cambridge, U.K.

Koloi, F.F. (1984). Tonga Island. *In:* Water Resources of Small Islands, Water and Mineral Resources Programme: 218-221. Technical Proceedings (Part 3) from the Workshop of Water Resources of Small Islands, Suva, Fiji, July 1984. Commonwealth Science Council Technical Publication Series No. 182. Commonwealth Secretariat, London.

Pearsall, S.H. (1991). Tonga. *In: a* series of country and island databases prepared for The Nature Conservancy's South Pacific Regional Biodiversity Assessment. The Nature Conservancy, Honolulu, Hawaii.

Pernetta, J.C. (1988). Projected climate change and sea level rise: a relative impact rating for countries of the South Pacific Basin. *In:* Proc. MEDU Joint Meeting of the Task Team on the Implications of Climatic Change in the Mediterranean. Split, Yugoslavia, 3-7 October 1988.

Pratt, HD., Bruner, P.L. & Berrett, D.G. (1987). A Field Guide to the Birds of Hawaii and the Tropical Pacific. Princeton University Press, Princeton, U.S.A.

Rinke, D. (1986). The Status of Wildlife in Tonga. Oryx 20(3): 146-151.

TCSP (1990). Guidelines for the Integration of Tourism Development and Environmental Protection in the South Pacific. Tourism Council of the South Pacific, Suva, Fiji.

UNEP/IUCN (1988). Coral Reefs of the World. Volume 3: Central and Western Pacific. UNEP Regional Seas Directories and Bibliographies. IUCN, Gland, Switzerland and Cambridge, U.K./UNEP, Nairobi, Kenya.

Vodonaivalu, S. (1982). A Botanical Survey of the Tidal Forest (Mangal) of Fiji, Tonga, and Western Samoa. University of the South Pacific, Institute of Marine Resources, Suva, Fiji.

Watling, D. & Talbot-Kelly, C. (1982). Birds of Fiji, Tonga, and Samoa. Milwood Press, Wellington, New Zealand. 176 pp.

Woodroffe, C.D. (1987). Pacific Island Mangroves: Distribution and Environmental Settings. Pacific Science 41(1-4): 166-185.

Zann, L.P., Kimmerer, W.P. & Brock, R.E. (1984). The Ecology of Fangu'ata Lagoon, Tongatapu, Tonga. University of Hawaii, Sea Grant Program. UNIHISEAGRANT-CR 84-4, Honolulu, Hawaii. 102 pp.