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 more sby. 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.sq.) draining the central highlands, and is the third largest river in Papua New Guinea, discharging

2,607 cubic metres per 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, Campnospenna, 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 *Tirnonius* 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 javanka* 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.*

Lower montane zone

- 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*, *V accinium* 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 more sby (Osborne, unpublished). It is also threatening Port more sby'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; LOffier, 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 more sby. 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 fakinellus, 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 titnorensis,* which occurs in large numbers in the seasonally-flooded trans-Fly area, and in lesser numbers in wetland areas near Port more sby. 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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