Ngardok Lake, Palau's first Ramsar site

Directory of Wetlands of Palau - 2014

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1993 Palau Account Compiler: Demei O. Otobed

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1 Introduction

The Secretariat of the Pacific Regional Environment Programme is an intergovernmental organisation charged with promoting cooperation among Pacific islands countries and territories to protect and improve their environment and ensure sustainable development for present and future generations. For more information, see: www.sprep.org.

Wetlands are among the world's most productive (and threatened) ecosystems and the services that they provide to humanity are significant. In order to effectively conserve and manage wetlands, a first step is to document and understand their distribution and status through conducting detailed baseline wetland inventories. Across the Pacific region, The Directory of Wetlands in Oceania 1993 documented available information on the distribution, status and values of wetlands in Pacific Island Countries and Territories, however, much of this existing information needs updating.

A number of Pacific Island Countries are contracting parties to the Ramsar Convention on Wetlands and as such are obligated to formulate and implement national planning to promote the conservation of their Ramsar Sites and other wetlands within their jurisdiction. Such planning relies very much on the availability of comprehensive data on wetlands.

The aim of this project was to update wetland inventories for Kiribati, Palau and Vanuatu as a means of strengthening the baseline state of knowledge of wetlands in these countries. Such baseline information would be valuable for informing conservation decisions, raising awareness of the importance of wetlands, influencing public perception of wetlands, creating ongoing monitoring, revealing trends over time, identifying priority sites for conservation management (e.g. for designating Ramsar Sites or other types of Protected Areas) and as a tool for planning and implementing effective conservation interventions for wetlands, especially in light of the impacts of climate change.

This project activities to build national capacity to conduct future wetland inventory updates, as well as to be able to use information collated in the inventory process in national decision making. To facilitate this, collated data will be centralized and delivered to SPREP, which will act as the central depository and dissemination point.

Updating wetland inventories is a priority under the SPREP Regional Wetlands Action Plan 2011-2013.

Funds for the project were granted to SPREP from the Australian Government and through the Convention for the Protection of Natural Resources and the Environment of the South Pacific Region (Noumea Convention), to update wetland inventories.

SPREP contracted the team of Roger Jaensch and Doug Watkins to work with the appropriate National Government agencies on the project. Roger led the updates for Palau and Vanuatu and Doug the update for Kiribati.

2 Palau Overview

2.1 Compilers and scope of update

The introduction and overview for Palau for the 1993 edition of *A Directory of Wetlands in Oceania* (Scott 1993) were compiled by Demei Otobed. This updated version was prepared by Pua Michael and Roger Jaensch in 2014.

This update retains essential still-current information from the 1993 edition, introduces data that have become available subsequently and adds several new categories of information. Consequently, it has standalone status.

Updated accounts for important sites that were included in the 1993 edition follow this introduction and overview; references cited in the following sections or in the accounts are listed together. One new site has been added from the numerous candidates, according to available time and resources for the update. Other outstanding candidates to be considered for full documentation in the future are listed below.

For the 2014 update of the national wetland directory, the boundary of each site was defined following discussion between consultants and the national agency responsible for wetlands. It was based as far as possible on information in the original Directory (Scott 1993), which in many cases was open to wide interpretation. For some sites it was possible to expand the site to include additional wetland areas and wetland types, including marine types such as coral reefs, which were contiguous and hydrologically connected. This approach enabled ecologically integrated sites to be defined, which should assist management planning.

The site boundary shown in this update serves to define the scope of information in the site account and has no legal status except in the case of listed Ramsar Sites. It was fully intended that these site boundaries would be subject to adequate discussion through consultation with landholders and other stakeholders. As time and resources available for the 2014 update were limited, the extent to which this was achieved by the national authorities was limited. The site boundary therefore should be regarded as provisional, subject to further discussion.

2.2 Geographical summary

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 Palauan archipelago lies about 800 km north of the equator, 740 km east of the Philippine Islands (see map below) and 6,000 km south-west of Hawaii. It consists of 586 islands (Republic of Palau 2004) of which 12 are permanently inhabited. The islands include 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 and associated intertidal flats.

Area: Land, 535 km^2 including mangroves (Republic of Palau 2004; Kitalong *et al.* 2008); Economic Exclusion Zone, over 600,900 km^2 (Republic of Palau 2004).

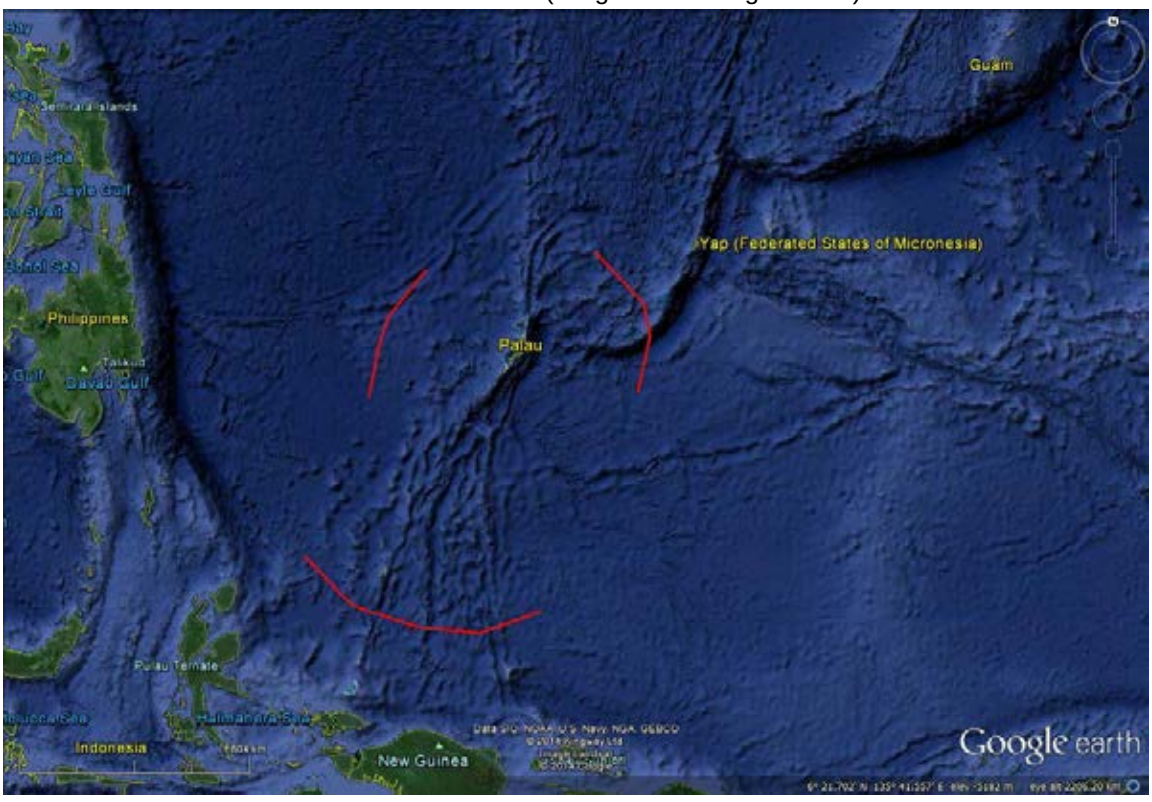
With an area of 367 km^2 and length of 45 km, Babeldaob is by far the largest island in the archipelago, comprising about three quarters of the total land mass (see map below). Neighbouring islands to the south are much smaller: Koror (9.3 km^2), Peleliu (12.7 km^2) and Angaur (8.4 km^2). Five islets and an atoll lie in the far south-west of Palau's territory, about 600 km from Babeldaob and 200 km from Indonesian territory.

Palau is divided into 16 states that are largely defined by traditional clan-chieftain areas. Ten states cover Babeldaob; Koror State covers most of the Southern Lagoon; Kayangel (north of Babeldaob), Pelelieu and Angaur islands are distinct States; and the remote south-western islets are in Sonsorol and Hatohobei States. The capital is a relatively new facility in Melekeok State, separate from the principal urban area in Koror.

2.3 Geological and geomorphic setting

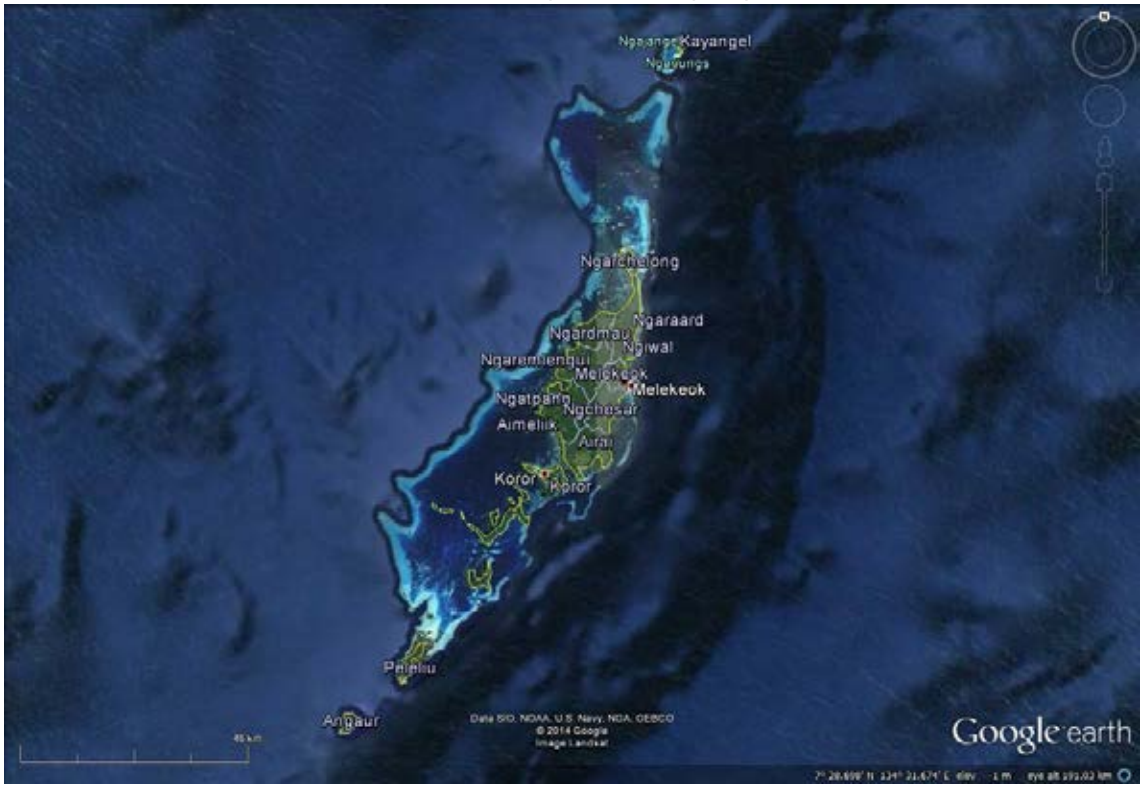
The Palau islands are near the southern end of the Palau-Kyushu submarine ridge system and lie between the Philippine and Pacific Plates. Babeldaob, parts of Koror and a few small islands in the vicinity of Koror (about 70% of the land area of Palau) are of volcanic origin, with highly acidic red soil, and are characterized by rolling, forested hills, coastal bottomlands and tidal flats. All of Palau is underlain by Eocene basalt and/or andesite and much of the eruptive activity occurred under the sea (Colin 2009). The maximum elevation on Babeldaob is 275 m. High rainfall has contributed to substantial erosion of Babeldaob forming a thick layer of soil over the island and broad alluvial beds around the coast.

Location of Palau (Image from Google Earth)



The other large islands are of more recent limestone formation; some islets are coral atolls. Peleliu and Angaur are raised coral platforms with jagged hills and level coastal areas. The famous Rock Islands of Palau, between Koror and Pelelieu, are extremely steep, coralline limestone islands, typically undercut along the water's edge; while many are very small islets, the largest islands are Ngerukdabel (19.0 km^2) and Mecherchar (8.8 km^2).

Islands and States of Palau, Angaur to Kayangel (Image from Google Earth)



Many small short rivers traverse Babeldaob and contribute significantly to Palau's wetland landscape and biodiversity, but there are no surface streams on the limestone islands. Ngerdorech River, on the east side of Babeldaob, is Palau's longest river (>10 km).

Much of Palau, from Babeldaob to Pelelieu, is surrounded by a discontinuous barrier reef that is 260 km long and encompasses a lagoon with an area of about 1,450 km^2. The barrier reef is particularly well developed on the western side, where it is up to 2.5 km in width. The lagoon is considered to have northern, central and southern sections. Deeper sea separates the northern island Kayangel, the southern island Angaur, and the distant south-western islets from this barrier-lagoon system. The Palau Trench, a deep sea feature, lies close to the east of the Palau archipelago.

2.4 Climate and natural disasters

Palau has a humid maritime tropical climate with only slight seasonal variations. The mean annual temperature on Koror, the capitol, is 27°C, with variation of about 10° C across the year and a mean diurnal range of about 6°C. The average annual rainfall in Koror is 3,810 mm; rainfall is highest on the west coasts of Palau. Rainfall varies little from month to month, although February to April are slightly drier and June to August wetter than the monthly average. The 24-hour rainfall record is 430 mm (Colin 2009). Droughts occur occasionally. The relative humidity averages about 90% at night and 75-80% during the day. Winds are dominantly from the north-east and east from November to May but from the south-west during June to September.

Although Palau lies outside the main paths of severe tropical disturbances and typhoons, such storms with high winds occasionally (five times since 1945) cross the islands during July-November. Within the last decade, two severe typhoons have impacted Palau: Typhoon Bopha in December2012, which produced storm surges up to 10 m high and damaged coral

reefs on the east coast; and Typhoon Haiyan less than a year later in November 2013, which caused extensive wind damage and saltwater intrusion on Kayangel.

Two high tides occur per day in Palau and the range between peak high and low tides is about 2 m (Colin 2009). At Malakal harbour, sea-level has risen 19 mm over the 30 years to 2000 but to put this in context, mean sea level changes in the order of 500 mm have occurred over short periods (Colin 2009). The North Equatorial Counter Current and the Mindanao Eddy affect Palau's overall biodiversity by bringing in coral and fish larvae from the Philippines, New Guinea, and Indonesia (Republic of Palau 2004).

2.5 Biogeographic regions

In terms of Freshwater Ecoregions of the World (FEOW: http://www.feow.org/; Abell *et al.* 2008), the **West Caroline Islands Freshwater Ecoregion** (http://www.feow.org/ecoregions/details/830) is the FEOW unit applicable to Palau. Yap Island, 400 km to the east-north-east in the Federated States of Micronesia, is also part of this ecoregion.

In terms of Marine Ecoregions of the World (MEOW: http://worldwildlife.org/biome-categories/marine-ecoregions; Spalding *et al.* 2007), the **West Caroline Islands Marine Ecoregion (**http://www.marineregions.org/gazetteer.php?p=details&id=21988) is the MEOW unit applicable to Palau. Yap Island is also part of this ecoregion.

2.6 Vegetation

The natural vegetation of the main islands of Palau is lowland tropical rainforest and about 75% (principally on Babeldaob) remains covered in primary or secondary rainforest. Although some clearing was traditionally practised, especially in swamp forests to create wet taro gardens, larger areas were cleared during the era of Japanese occupation (1914-44) for broader-scale farming. Such areas have subsequently reverted to 'savannah' comprising ferns, grass and shrubs or have been planted for agroforestry.

A different form of rainforest occurs on the rugged, soil-sparse limestone islands and this cover is largely intact on uninhabited islands, notably in the Rock Islands area. The flatter disturbed areas of platform islands like Angaur support extensive tree-shrub regrowth that commonly includes non-native plant species.

The flora of Palau has been well studied and Kitalong *et al.* (2008) provide detailed text and a pictorial guide to the native trees. An overview of vegetation of Palau's mangroves, freshwater marshes and swamp forests is given under the summary on wetland types (below) with further mention in applicable site accounts.

2.7 Wetlands of Palau

No systematic inventory of all wetland in Palau has been undertaken, but the wetlands 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: mangrove forests (33); lowland swamp forest (21); cultivated wetland (taro swamp) (17); riparian wetlands (8); coastal saline marshes (4); freshwater marsh (open canopy swamp) (3); and several minor types. Estimates of the areas of wetland vegetation, which gives insight to the types and extents of several wetland types, were published in 1987 (Table 1), confirming that mangrove forest and swamp forest are by far the dominant types of vegetated terrestrial wetland in Palau. These assessments do not

consider the extensive areas of marine wetland, e.g. shallow lagoons; seagrass beds; and fringing, patch and barrier reefs.

Rivers

With over three metres of annual rainfall spread through the year, Palau's streams and rivers are typically permanent. Channels are generally at most a few tens of metres wide and banks support riparian rainforest or mangroves. The relatively small catchments do not favour development of extensive floodplains although the lowest reaches of many rivers on Babeldoab support broad zones of mangrove forests (see below); this is most evident in the rivers entering Ngeremeduu Bay, some of which exhibit river meanders. Small seasonal streams occur on Koror, Malakal and Arabesang islands.

Table 1: Areas of wetland vegetation in Palau (in hectares; after Cole *et al.* (1987)

	Babeldaob	Other high islands	Coral islands	Rock islands	**Totals**
Freshwater Marsh	448	<1	27		475
Cultivated Marsh	107	2	25		134
Saline Marsh			25	<1	25
Swamp Forest	1,617	15	47	1	1,680
Mangrove Forest	4,025	205	435	43	4,708
Totals	6,197	222	559	44	7,022

Lakes

There are only two natural freshwater lakes of any size in Palau: Ngardok Lake and Ngerkall Pond. Both are on Babeldaob in remote upper catchment and are less than 10 ha in area. Ngardok Lake has an outflowing river.

Artificial lakes and ponds include a small reservoir in Airai State (a water supply for Koror); sewage treatment ponds at Malakal; water-filled bomb craters on Babeldaob; and abandoned, flooded phosphate pits on Angaur and Peleliu (Engbring and Suzuki 1988).

The 'marine lakes' of Palau are 57 lakes and inlets in karst sink-hole structures on some of the high limestone islands within the Rock Islands complex, notably Ngeruktabel and Mecherchar. They are all tidally connected and thus saline, some through open channels but most by subterranean tunnels and fissures. Some are permanently stratified from top to bottom due to density differences and lack of mechanisms to overturn the water column. The lakes support distinctive invertebrates, including a spectacular jellyfish fauna dominated by five subspecies of *Mastigias papua*, which are endemic to several of the marine lakes (Colin 2009).

Freshwater swamps

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,* the broadleaf raft-forming *Hanguana malayana,* sedges and other taller herbaceous growth. Where the water is somewhat brackish, the mangrove fern *Acrostichum aureum* may be present.

Some freshwater marsh (over 130 ha) is cultivated for taro, a staple vegetable in Palauan diets with over 100 varieties cultivated (Republic of Palau 2004), and here the edible vine

Ipomoea aquatica also may be found (Cole *et al.*1987). Taro swamp gardens ('mesei') support waterbird communities of rails, herons and ducks (Ketebengang and Gupta 2011).It has been said that the taro patch system enabled Palau's people and culture to flourish (Republic of Palau 2004).

Freshwater marsh near Ngeremeduu Bay (Photo: R. Jaensch)

Swamp forests occur where soils are inundated with fresh or slightly brackish water and the most common habitat for such forests is in low-lying areas, just inland of mangroves and above tidal influence. About 37 woody species have been listed for swamp forests in Palau (Kitalong *et al.* 2008). Species common to swamps on the landward side of mangroves and along rivers include *Horsfieldia amklaal, Cynometra ramillora, 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. Other widespread swamp forest species include *Campnosperma brevipetiolata* and *Horsfieldia irya* (Kitalong *et al.* 2008). Remnants of swamp forest on Peleliu are dominated by *Barringtonia racemosa* and *Terminalia catappa.* On Angaur, *Barringtonia racemosa, Hibiscus tiliaceus* and betelnut palm *Areca catechu* grow in a swampy area near the airstrip (Cole *et al.*1987). Swamp forests provide an important source of freshwater for mangroves during times of drought (Republic of Palau 2004).

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 plant species include *Cyperus javanicus, Derris trifoliata* (especially at the edge of mangroves), *Eleocharis geniculata, 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, western Babeldaob (Photo: R. Jaensch)

Mangroves

Extensive mangrove forest up to 1 km wide grows around 85% (125 km) of the Babeldaob coastline, 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 south-west coasts. There is a small stand of planted mangroves on Kayangel Atoll, along the shore of a saltwater pond in the interior of a small islet (Cole *et al.*1987). A zone of dark organic matter covers the sea bottom just seaward of the end of the mangrove forests (Colin 2009).

More than 29 woody species have been recorded in Palauan mangrove forests (Woodroffe 1987; Kitalong *et al.* 2008), with major 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* spp. become common.

Heritiera littoralis is found along the landward side of mangroves and upstream, while in some places *B. gymnorrhiza* has been found growing inland in totally enclosed sink-holes in limestone areas. Stands of nipa palm *Nypa fruticans* occur along the lower portions of some rivers and at their mouths (Cole *et al.*1987).

At least 17 mangrove species in Palau have traditional uses including medicines, building materials, and handicrafts (Duke 1999). Many species of reef fishes, including blacktip reef shark *Carcharhinus melanopterus*, cardinalfish *Apogon* spp., mojarras *Gerres* spp., goatfish *Parupeneus* spp. and rabbitfish *Siganus* spp. use mangroves for foraging and shelter and economically valuable mangrove crab *Scylla serrata* and mangrove clams (*Anodonita* spp., *Polymeseda* spp. and *Terebralia* spp.) are harvested from mangroves for subsistence purposes (Republic of Palau 2004).

***Sonneratia* mangrove roots, Koror** (Photo: R. Jaensch)

Seagrass beds

Substantial areas of seagrass occur in the lagoons associated with the major islands of Palau, typically on sandy fringing flats that are associated with coral reef structures. Seagrass beds are widespread along the west coast of Babeldaob (Maragos *et al.* 1994) and another notable seagrass area is on the south-east coast, about 5 km south-south-west of Koror urban area. Eight species of seagrass occur in Palau at shallow depth (Table 8.1 in Colin 2009); *Thalassia hemprichii* and *Enhalus acroides* are the most abundant and dominant species (Republic of Palau 2004). Seagrasses are the main food source for herbivorous fishes, sea turtles, and dugongs *Dugong dugon*.

Coral reef systems

Barrier, patch and fringing reefs are prominent components of the wetland estate of Palau. The barrier reef covers 355km^2(up to 3 km wide) and the total area of reefs is estimated to be 1150 km^2. The shallow reef flats are usually covered by less than 3 m of water at high tide and are exposed or very shallowly inundated at lowest spring tides (Colin 2009). They have sediments and rubble derived from calcium carbonate and may have seagrasses as well as coral heads, mostly not living, and are fringed by living reef dominated by species of *Porites*, *Montipora* and *Acropora* (Colin 2009). In the far south of the southern lagoon, near Peleliu, the flats are of carbonate sand.

Whereas coral reefs were not generally considered for the 1993 edition of the Directory and resources did not permit specific inclusion in the present update, they have been included where contiguous with or adjacent to existing sites. For example, many of the sites in the 1993 edition which focus on mangrove wetlands, have adjacent fringing-reef flats, patch-reefs and enclosed or surrounding shallow marine lagoons. Where appropriate, and subject to local endorsement, the boundaries of such sites have been redefined to extend seaward and include some of these marine wetlands. This is consistent with an integrated approach to coastal zone management.

Seagrass partly exposed at low tide, Koror (Photo: R. Jaensch)

2.8 Wetland fauna

Palau has 47 freshwater fishes (Jenkins 1999; Ketebengang and Gupta 2011) dominated by gobies that complete part of their life cycle in connected marine habitats. Although there is conflicting information on endemics (nil to 4 species: e.g. Republic of Palau 2004), some freshwater fishes may prove to be endemic, e.g. the goby *Sicyopus fehlmanni* (Parenti and Maciolek 1993).

Fishes of the marine wetlands (mangroves, lagoon, reefs) are relatively well known, especially because of traditional and commercial harvest and a major dive tourism industry. Fehlman (1960) recorded 65 fishes of 25 Families in mangroves of south-west Babeldaob. Some years ago, at least 1387 fishes were known from Palau's shallow marine waters and of these 1278 were classifiable as 'reef fishes' (Myers 1999); more species have since been discovered, hence the total number may approach 1500 species. Rabbitfishes (Siganidae) comprise a large portion of the subsistence catch from seagrass beds and also use outer reef, lagoon and mangrove habitats (Colin 2009).

Formerly widespread, the estuarine crocodile *Crocodylus porosus* was almost exterminated in the Palau Islands from 1965 to 1981by large-scale bounty hunting following a human death caused by a crocodile. However, the species is now recovering under protection, although most of the individuals are small and extremely secretive; the largest recorded in a 2003 survey was about 4 m long (Brazaitis and Eberdong 2003). A relatively recent estimate of total number of individuals in Palau was 500-700 (Brazaitis *et al.* 2009) but there is a common view that numbers are increasing (Matthews 2003; Colin 2009), so an update survey is warranted. Several thousand crocodiles of undocumented species and origin were introduced to Palau for commercial farming in the 1930s but this has not compromised the genetic integrity of the original population – which might eventually be identified as a distinct management unit (i.e. an isolated population) 800-1200 km from nearest other crocodile populations (Brazaitis *et al.* 2009). Tidal freshwater creek systems and freshwater grasslands and ponds are best for breeding while nearby hypersaline creeks are important for rearing sub-adults where they can find refuge from predatory adults (Messel and King 1991; Brazaitis *et al.* 2009).

Other wetland reptiles of Palau include the sea krait *Laticauda colubrina*, adults of which often come ashore near mangroves (Colin 2009), and four marine turtles: green turtle

Chelonia mydas and hawksbill *Eretmochelys imbricata* (common and breeding);and olive Ridley *Lepidochelys olivacea* and leatherback *Dermochelys coriacea* (uncommon: Colin 2009).

Waterbirds of Palau include the Yellow Bittern *Ixobrychus sinensis* (with local-breeding and non-breeding migratory individuals: Pratt and Etpison 2008), Rufous Night-Heron *Nycticorax caledonicus,* Pacific Reef-Heron *Egretta sacra,* Grey (Pacific Black) Duck *Anas superciliosa,* White-browed Crake *Porzana cinerea,* and Common Moorhen *Gallinula chloropus.* Palau supports endemic subspecies of the Banded Rail ('Teriid') *Gallirallus philippensis pelewensis* and Purple Swamphen ('Uek') *Porphyrio porphyrio pelewensis* and the applicable population of moorhen is confined to several western Pacific islands (Wetlands International 2014). The rail and swamphen are relatively plentiful, the latter especially in taro swamps where it is persecuted by gardeners, but as non-forested freshwater wetlands are limited in Palau, most of the other freshwater species are uncommon and the Grey Duck and Common Moorhen are in danger of extinction in the islands (Engbring and Suzuki, 1988). Total numbers of waterbird species recorded in Palau include: ducks, 6 species; herons and allies, 13; rails, 7; and gulls and terns, 13 species (Pratt and Etpison 2008).

The islands of Palau are within the East Asian – Australasian Flyway and 38 species of migratory shorebird have been recorded (Pratt and Etpison 2008). The more regular and/or abundant migrants include the Pacific Golden Plover *Pluvialis fulva,* Lesser Sand Plover *Charadrius mongolus,* Common Greenshank *Tringa nebularia,* Wood Sandpiper *Tringa glareola,* Grey-tailed Tattler *Heteroscelus brevipes,* Common Sandpiper *Actitis hypoleucos,* Whimbrel *Numenius phaeopus,* Ruddy Turnstone *Arenaria interpres* and Red-necked Stint *Calidris ruficollis* (Engbring and Suzuki 1988; Pratt and Etpison 2008). The Whimbrel is the State bird of Melekeok and is depicted on flags and communal 'men's houses'. Some shorebird individuals remain in Palau through the non-breeding period but others such as Far Eastern Curlew *N. madagascariensis* travel onwards to and return from areas farther south, such as presumably Australia (Pratt and Etpison 2008).

Marine invertebrates have been well studied, notably through the ecological, taxonomic and genetic research of local coral reef institutes (see below). Palau has over 400 species of hard coral (Belau Watershed Alliance 2011) and over 300 species of soft coral. Palau is close to the global hotspot for reef biodiversity (eastern Indonesia, Philippines, New Guinea) and accordingly the reef systems of Palau are considered to be the richest in the Pacific, with the highest species diversity (UNEP/IUCN 1988).

Dugongs *Dugong dugon* inhabit the seagrass beds and associated habitats of Palau as a highly isolated population. They were formerly common but are threatened with local extinction (Marsh *et al.* 1992); a monitoring survey in 2003 recorded 27 individuals, including young (Republic of Palau 2004).

2.9 Human population

Population: 20,901 (2013 data, South Pacific Commission) augmented by substantial numbers of tourists. Population was previously higher (up to 40,000) during the Japanese Administration about a century ago (Republic of Palau 2004).
Population growth rate: 2.3 % (2000) supported by immigration of foreign workers.
Distribution: about 70% of people live in the main urban centre on Koror.
Population density: 43 per km^2 (2013 data, SPC).
Languages: Palauan; English.

The Palau Islands had been settled for nearly 2,000 years before contact with European traders and missionaries in the 17thand18thcenturies. 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 United States was given responsibility for Palau as a Trust Territory. The Republic of Palau was established with a constitutional democratic government in January 1981, and in 1994a Compact of Free Association with the United States established Palau as an independent nation.

Indigenous Palauans are of Micronesian heritage; today, significant numbers of people of Japanese, Filipino, European and Chinese heritage also reside in Palau. The people of Sonsorol and Hatohobei States in the south-west are closely related to those of the atoll-dwelling peoples of Yap and Chuuk States in the Federated States of Micronesia (Republic of Palau 2004).

Clan systems remain strong in Palau and play a significant role in administration and daily life and society is strongly matrilineal. A hierarchical system of chiefs continues to be engaged formally in State and National affairs, alongside elected representatives and administration. Each State has a number of chiefs, a primary chief and an elected administration including a Governor. At national level, a council of chiefs and High Chief advise the publicly-elected President.

Boating is a common feature of daily life in Palau (Photo: R. Jaensch)

2.10 Land tenure system

The majority of land and sea areas in Palau are under ownership of the relevant States ('public land'). Areas below high tide, including mangroves and reefs, typically are State land, not in customary ownership, and fishing is permitted within a State where the user's boat is registered. Large areas, mainly coastal, are under customary ownership ('private land'); these may be sold or leased to other owners and a land court mediates on any ownership disputes. Land developments require approval of the relevant State and States are closely involved in any decisions about declaration of the various types of protected area and nominations to international site networks.

2.11 Economy

The economy is based on tourism and fishing. Palau is a particularly desired destination for divers and snorkelers; more than 50% of visitors undertake diving and a large proportion visit the Rock Islands (Republic of Palau 2004). Tourism was worth USD 27.5 million to the Palau economy in 2004 (Cesar *et al.* 2004) and long line tuna fishery had an average gross annual value of USD 28 million (Republic of Palau 2004, citing Kitalong).

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.

2.12 Pressures and threats to wetlands

During the Japanese Administration (1914-1944), large areas in southern Babeldaob were cleared of native forest for pineapple and sugar cane fields. Starting a little earlier under the German Administration, bauxite mining in Ngardmau State, Babeldaob, destroyed native forest and mining of phosphate created numerous pits on Angaur. However, Palau's natural environments, including wetlands, overall remain in good condition, partly due to the overall low population density.

Construction of the 'Compact Road', a major highway encircling Babeldoab and opened in 2007, has been a boon for transport and communication. Negative consequences have included a dramatic increase in catchment erosion and sedimentation in rivers, mangroves and the marine lagoon, and opportunities for more development in the catchments. Forest clearing followed by burning that maintains grassland vegetation, starts the process of land degradation.

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). In recent years, less wetland taro is being grown, partly because traditionally the Palauan women worked the gardens but many are now in other employment, and this has indirectly resulted in a loss of some prime habitat for rails and other waterbirds (Engbring and Suzuki 1988)

In Palau, mangroves are typically in State land, not under customary ownership (see below), and thus are targets for development. Relatively small areas of mangrove have been cleared for infrastructure (ports, local navigation channels), housing (Koror and villages), and aquaculture (Ngatpang); however, the cumulative loss has been significant and may increase. The human impact on mangroves in Palau otherwise is mostly confined to small-scale removal of timber, firewood, food and medicinal products for local/subsistence purposes.

These days, mangrove crabs may be harvested more so than traditionally; fish was preferred in the past but the change to a cash economy means that crabs are targeted because they stay alive out of water for some days and they can be caught without boats (Colin 2009). Crocodiles are major predators of mangrove-inhabiting crabs and the protection of crocodiles is considered by some fishermen to have contributed to a decline in crab harvests (Colin 2009). Many local fishermen, and some fisheries officers, report that certain species of marine fish are less common and smaller than they used to be, which indicates that overfishing may be occurring (Republic of Palau 2004).

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.

Invasive species such as tree-smothering rope vine *Merremia* sp. are taking hold in Palauan uplands and wetland species such as water hyacinth *Eichhornia crassipes* are a potential threat. Efforts in 2004 to eradicate local populations of invasive Tilapia fish (species not advised) were relatively effective (38,000 individuals taken from four sites) but some Tilapia apparently persist (Keith *et al.* 2011). The non-native marine invertebrate *Eudendrium carneum*, a hydroid, is known to have become widespread in the channel between Koror and Babeldaob (Colin 2009).

The effects of rising sea-level due to climate change will be of concern for low-lying atolls in Palau, where scarce freshwater sources may be intruded by saline water. A severe drought hit Palau in January-May 1998 (an El Nino event) and associated high surface temperatures of seawater led to widespread coral bleaching (Colin 2009) with local losses of 90% of coral, as well as depletion of jellyfish in the marine lakes; uncontrolled fires and total failure of taro crops also occurred. Coral bleaching related to climate change is one of the greatest threats to Palau's coral reef ecosystems (Republic of Palau 2004).

2.13 Threatened wetland species

Palau does not yet have a formal list of threatened species defined in legislation, though an unofficial list is maintained by the Belau National Museum. Some globally threatened (IUCN Red List) species occur in Palau including widespread but declining marine turtles (see above), some of which nest on a few beaches. The small resident populations of Grey Duck and Common Moorhen may be close to extinction (see above); these populations also occur on other Pacific islands. Two vulnerable migratory shorebirds occur, in small numbers and mainly on passage: Far Eastern Curlew and Great Knot *Calidris tenuirostris* (Pratt and Etpison 2008; IUCN Red List).

2.14 Conservation measures

In the 20 years since the 1993 edition of the Directory, considerable progress on wetland conservation has occurred in Palau and the country is at the leading edge of many initiatives in the Pacific Islands region, which are of benefit to wetlands. Under the Micronesia Challenge, agreed at highest level among the relevant countries, targets were set of 30% of near-shore and 20% of terrestrial resources conserved by 2020: Palau has already exceeded these targets.

From the mid-1990s, initiatives on 'conservation areas' supported by SPREP, the Convention on Biological Diversity and GEF took effect. Conservation areas were not established as protected areas typical of European models; rather, they were set up in key areas of biodiversity where local land and resource owners agreed to meet conservation goals concurrent with maintaining sustainable livelihoods. National legislation prescribes the arrangements for these community-managed conservation areas in Palau and States/landholders can register them, creating controls on access and resource exploitation.

More recently, a Protected Areas Network (PAN) has been established nationally with support from The Nature Conservancy and Palau Conservation Society; this provides coordinators for participating States and access to resources to promote and manage conservation areas. To be included in PAN, a conservation area must have a registered management plan. Funding to support PAN activities is derived directly from a Green Fee

levied on visitors departing Palau. Palau is the first country to fulfil all obligations under the Convention on Biological Diversity, to establish a self-sustaining network of protected areas.

Most of Palau's important wetlands identified in the 1993 edition of the Directory (Scott 1983) are now included in or are partly covered by Conservation Areas (CAs), for example:

- Ngardok Lake Nature Reserve: covers the entire catchment of Ngardok Lake Directory site.
- Ngeremeduu Bay CA: covers this Directory site and is a little larger to seaward.
- Ngerimel Mangrove Conservation Area: covers part of the Ngerimel River site.

A National Biodiversity Strategy and Action Plan (NBSAP) has been produced for Palau (Republic of Palau 2004) and this includes numerous references to wetlands. Linked to the NBSAP process, public awareness of the importance and conservation of mangroves and freshwater wetlands has been raised in Palau over the past two decades through publication of posters, school curricula, and community events such as World Wetlands Day. These activities have been undertaken by government agencies, often on a project-funded basis, in partnership with regional and community organisations.

Environmental impact assessment is required for large-scale development projects. Palauan law requires use of silt curtains to reduce sedimentation from construction within the lagoon/reef wetlands.

2.15 Wetland area legislation

Considerable progress has occurred since 1993 in regard to enactment of legislation and in accession to international agreements, relevant to wetlands in Palau. There is no legislation relating specifically and principally to wetland conservation in Palau, but several Acts are applicable to wetlands and their biodiversity:

Protected Land Life Act on the Conservation of Birds (1982)

The Natural Heritage Reserve System Act (1991):

- Calls for both terrestrial and marine area conservation measures through the identification and implementation of reserve sites at the State level; it focuses on unique natural resources which support unique communities of flora and fauna.

The Marine Protection Act (1994):

- Promotes sustainable development of marine resources for commercial fishermen in the Republic of Palau; it specifies closed seasons and size limits for certain crustaceans and fishes.

The Forest Management Plan (1994):

- Provides direction for the long-term sustainable management of Palau's forest systems; a Mangrove Management Plan was derived from this in 1999 but has yet to be implemented for lack of resources; and a Forest Practice Act, still pending approval, identifies mangrove conservation areas throughout Palau.

Palau Natural Resources Council Act (2001):

- The Council mandate is to provide comprehensive analysis, planning, and implementation on methods of preventing soil erosion, improving water quality, and protecting other natural resources.

Protected Area Network Act (2003):

- Provides formalities for establishment of the Protected Area Network in Palau

Water Resources Management Act:

- No legislation is in place as yet to require buffer zones around streams and other wetlands but this has been discussed.

Environmental Protection and Conservation Act:

- Makes provision for EIA; also addresses registration of community conservation areas.

Interpretive sign, Ngardok Lake, Palau's first Ramsar site (Photo: R. Jaensch)

The Ngerukewid Islands Wildlife Preserve, established by legislation in 1956, is the only legally established and perennially protected natural area in Palau. Also known as the "Seventy Islands", the Ngerukewid Islands are an outlier of the "Rock Islands" comprising a cluster of 37 limestone islands in the Southern Lagoon and though there is no surface freshwater in the islands, coral reefs and two tiny patches of mangroves are present (Thomas *et al.* 1989).Access to the area is restricted.

Relevant international agreements to which Palau has formally become a Contracting Party are:

Convention on Biological Diversity (1999)
Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) (2004)
World Heritage Convention (2002):

- Rock Islands of the Southern Lagoon is Palau's first World Heritage site and this includes marine lakes, coral reef features and shallow lagoon.

UN Framework Convention on Climate Change (2000).
UNESCO Man and the Biosphere Programme:

- Ngeremeduu Bay is listed under this agreement (2005).

Ramsar Convention on Wetlands (2003):

- Lake Ngardok Nature Reserve is Palau's first Ramsar site (2003).

2.16 Organisations responsible for or otherwise involved with wetlands

a) Government of the Republic of Vanuatu

Ministry of Natural Resources, Environment and Tourism (MNRET):

The Ministry is responsible for management and administration of the country's natural environment and is the country's focal point for international environmental agreements.

Bureau of Agriculture, Forestry Division: takes responsibility for terrestrial wetlands and invasive plants and animals; maintains inventories of forests and wetlands including mangroves.

Bureau of Marine Resources: monitors commercial harvest of fish and other marine resources; oversees aquaculture.

Environmental Quality Protection Board: tests and regulates water supplies, building on earlier work by the US Geological Service; oversees environmental impact assessment.

Office of the Palau Automated Land and Resources Information System:

PALARIS maintains national geographic information systems for Palau.

Ministry of Community and Cultural Affairs:

Bureau of Arts and Culture: manages historical and heritage sites.

Bureau of Youth Sports and Recreation: responsible for recreation areas.

United States Government agencies:

The US Geological Service and the Forest and Soils divisions of the US Department of Agriculture maintain some research and management activities in Palau, building on previous work.

b) Non-governmental Organizations

Palau Conservation Society, and The Nature Conservancy, both support and implement conservation activities including site management (through PAN), community awareness, and research, throughout Palau.

Belau Watershed Alliance: a consortium that aims to promote integrated catchment management across Palau, particularly Babeldaob.

2.17 Wetland research

Detailed vegetation maps of Palau were 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 also carried out an inventory of the timber resources of Babeldaob which includes information on the mangrove and swamp forests (MacLean *et al.*1988); inventory plots are situated throughout Palau. In cooperation with supporting organisations, the Bureau of Agriculture (Forestry) has been studying sedimentation in mangroves since 2010.

Information on the extremely rich and diverse reef systems has been summarized by UNEP/IUCN (1988). The Coral Reef Research Foundation and Pacific International Coral Reef Center have conducted high level research on marine wetlands and their biodiversity. Detailed studies include work on speciation of jellyfish in the marine lakes, e.g. Dawson

(2005). Summary information on the marine environments of Palau is summarised in a major publication by Colin (2009).

The birds of Palau are well known, with field guides prepared by Engbring and Suzuki (1988) and Pratt and Etpison (2008).National surveys of birds were conducted in 1991 and 2005 by the Palau Conservation Society and US Fish and Wildlife Service (Ketebengang and Gupta 2011). More recently, the Belau National Museum has spearheaded the National Program for Monitoring Forest and Coastal Birds, an attempt to monitor environmental health through surveys of indicator bird species at over 20 stations. For coastal wetlands these species are the Rufous Night-Heron, Pacific Reef Heron and Little Pied Cormorant *Phalacrocorax melanoleucos*. A standardised protocol has been established and annual reports are being released, e.g. Olsen and Eberdong (2013).

Research has been conducted on estuarine crocodiles in Palau, including work to determine the taxonomic/genetic status (e.g. Messel and King 1991; Brazaitis and Eberdong 2003; Russello *et al.* 2006). Marsh *et al.* (1992) provided an assessment of the status of dugong in Palau.

Some research on the freshwater fishes and invertebrates of Palau has been conducted by Wetlands International (Jenkins 2009) and the National Museum of Natural History of Paris and earlier researchers (Keith *et al.* 2011).

Additional items of research on wetlands and their biodiversity in Palau may be seen in the list of References, below.

2.18 References

Abell, R., Thieme M., Revenga C. et al. 2008. Freshwater ecoregions of the world: a new map of biogeographic units for freshwater biodiversity conservation. BioScience 58, 403–414.

Belau Watershed Alliance. 2011. Belau Watershed Alliance Five Year Action Plan 2010-2015. Belau Watershed Alliance. 20 pp.

Brazaitis, P and Eberdong, J. 2003. Preliminary summary of the Palauan saltwater crocodile field study. US Fish and Wildlife Service and The Nature Conservancy, Koror, Palau.

Brazaitis, P, Eberdong, J, Brazaitis, PJ and Watkins-Colwell, GJ. 2009. Notes on the saltwater crocodile, *Crocodylus porosus*, in the Republic of Palau. Bulletin of the Peabody Museum of Natural History 50: 27-48.

Cole, G.C., Falanruw, C.F., MacLean, C.D., Whitesell, C.D. and Ambacher, A.H. 1987. Vegetation Survey of the Republic of Palau. Pacific Southwest Forest and Range Experiment Station. United States Department of Agriculture, Forest Service, U.S.A.

Colin, P. 2009. Marine Environments of Palau. Coral Reef Research Foundation, Koror, Palau. Mutual Publishing and Indo-Pacific Press, San Diego. 414 pp.

Duke, NC. 1999. The 1998 Survey of *Rhizophora* species in Micronesia. Agreement No. PSW-98-021-RJVA. USDA-Forest Service, Institute of Pacific Islands Forestry, Honolulu, Hawaii.

Engbring, J. and Suzuki, T. 1988. Field Guide to the Birds of Palau. Bureau of Education, Koror, Palau.

Fehlman, AR. 1960. Ecological distribution of fishes in a stream drainage in the Palau Islands. Ph.D. Dissertation, Stanford University 182 pp.

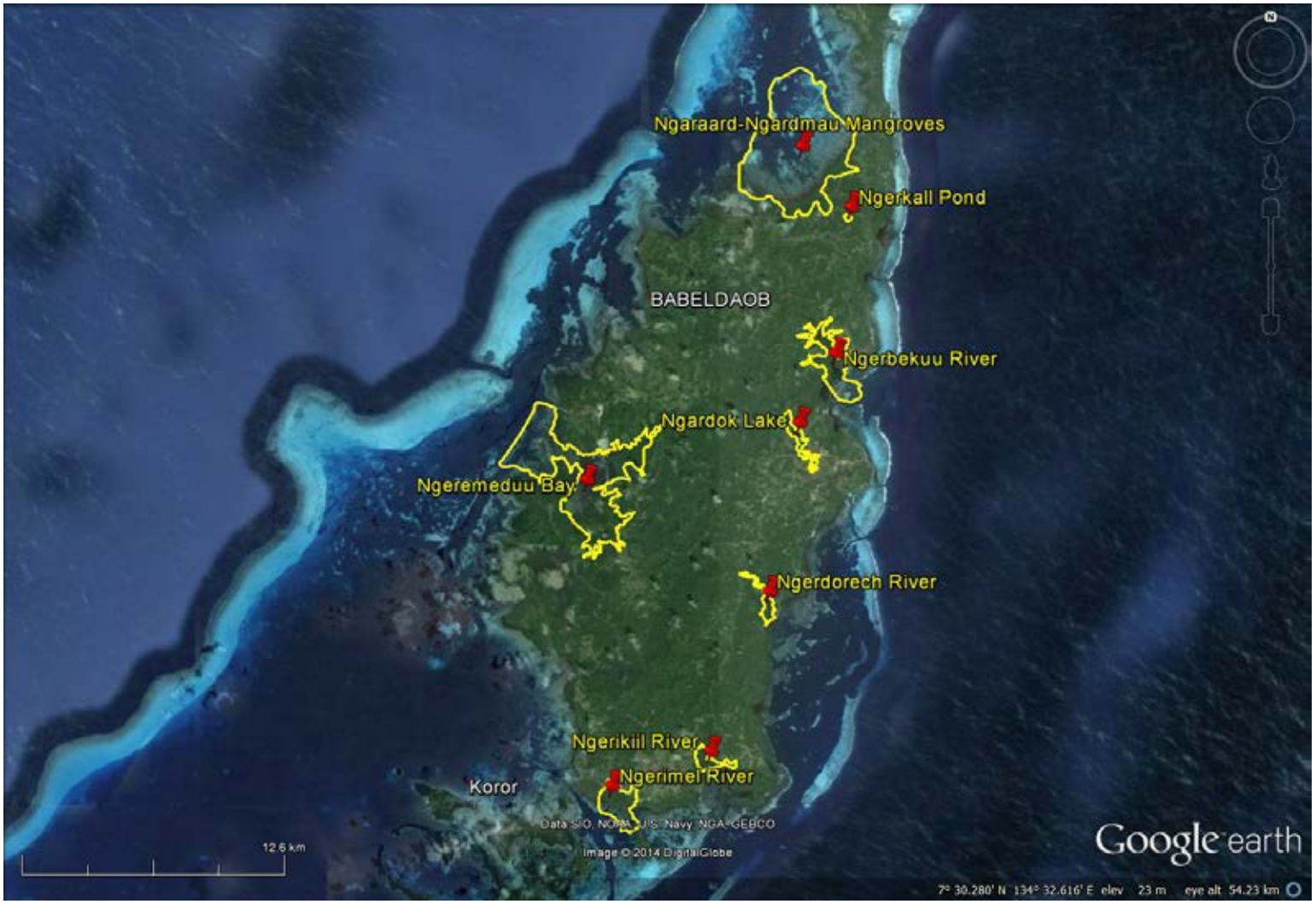
Jenkins, AP. 1999. A preliminary investigation of the freshwater ichthyofauna of the Ngardok Lake and Ngeremeduu Bay watersheds, Palau. Wetlands International – Oceania, 9 pp.

Jenkins AP., Jupiter SD, Qauqua, I. and Atherton, J. 2009. The importance of ecosystem-based management for conserving aquatic migratory pathways on tropical high

islands: a case study from Fiji. Aquatic Conservation: Marine and Freshwater Ecosystems 20: 224-238.
Keith, P, Gerbeaux, P, Marquet, G, Taillebois, L and Castelin, M. 2011. Freshwater survey of Babeldaob, Palau. National Museum of Natural History of Paris, 32 pp.
Ketebengang, H and Gupta, A. 2011. State of Palau's Birds 2010. A conservation guide for communities and policymakers. Palau Conservation Society. 23 pp.
Kitalong, AH, DeMeo, RA and Holm, T. 2008. A Field Guide to Native Trees of Palau. 236 pp.
MacLean, CD., Cole, T.G., Whitesell, C.D. and McDuMe, K.E. 1988. Timber Resources of Babelthuap, Republic of Palau. Pacific Southwest Forest and Range Experiment Station. United States Department of Agriculture, Forest Service, U.S.A.
Marsh, H, Rathburn, G, O'Shea, T and Preen, T. 1992. An assessment of the status of dugongs in Palau including comments on sea turtles. Report to Ministry of Natural Resources, Government of Palau, 20 pp.
Matthews, E. 2003. Local knowledge about crocodiles in Palau. Palau Conservation Society. 19 pp.
Messel, H and King, FW. 1991. Survey of the crocodile populations of the Republic of Palau, Caroline Islands, Pacific Ocean, 8-24 June 1991. Report to the Government of Palau.
Myers, RF. 1999. Micronesian reef fishes (3rd ed.). Coral Graphics, Guam, 330 pp.
Olsen, AR and Eberdong, M (eds.) 2013. State of Palau's Birds 2012. Belau National Museum, Koror. 22 pp.
Parenti, LR and Maciolek. 1993. New sycydiine gobies from Ponape and Palau, Micronesia, with comments on systematics of the subfamily Sicydiinae (Teleostei: Gobidae). Bulletin of Marine Science 53: 945-972.
Pratt, HD and Etpison, MT. 2008. Birds and Bats of Palau. Mutual Publishing, Honolulu, 290 pp.
Republic of Palau. 2004. National Biodiversity Strategy and Action Plan, 96 pp.
Russello, MA, Brazaitis, P, Gratten, J, Watkins-Colwell, GJ and Caccone, A. 2006. Molecular assessment of the genetic integrity, distinctiveness and phylogeographic context of the saltwater crocodile (*Crocodylus porosus*) on Palau. Conservation Genetics [some details missing].
Scott DA, Asian Wetland Bureau, International Waterfowl and Wetlands Research Bureau. 1993. A Directory of Wetlands in Oceania. Slimbridge, U.K. : Kuala Lumpur : International Waterfowl and Wetlands Research Bureau ; Asian Wetland Bureau
Spalding M.D., Fox H.E., Allen G.R., Davidson N., Ferdaña Z.A., Finlayson M., Halpern B.S., Jorge M.A., Lombana A., Lourie S.A., Martin K.D., McManus E., Molnar J., Recchia C.A., Robertson J. 2007. Marine Ecoregions of the World: a bioregionalization of coast and shelf areas. BioScience 57: 573-583.
Stemmermann, L. and Proby, F. 1978. Inventory of Wetland Vegetation in the Caroline Islands. Vol.I: Wetland Vegetation Types. Vol.II: Wetland Plants. Bishop Museum, Honolulu, Hawaii.
Thomas, P.E.J., Holthus, P.F. and Idechong, N. 1989. Ngerukewid Islands Wildlife Preserve Management Plan. South Pacific Regional Environment Programme. South Pacific Commission, Noumea, New Caledonia.
Woodroffe, C.D. 1987. Pacific Island Mangroves: Distribution and Environmental Settings. Pacific Science 41(1-4): 166-185.
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.

2.19 Location maps of the inventoried wetland sites of Palau

Location of inventoried wetland sites in Babeldaob (Source: Google Earth)



Location of inventoried wetland sites in southern Palau (Image from Google Earth)

3 Wetland Accounts

3.1 Ngaraard-Ngardmau Mangroves

A. Overview:

A coastal wetland complex comprising a large area of mangrove forest and adjoining freshwater swamp forest, inflowing river, fringing flats and lagoons with coral reefs, on the north-west coast of Babeldaob Island. The forest is rich in tree species and the wetlands provide important nursery and other habitat for marine and freshwater animals.

B. Area, boundary and dimensions:

Area: 2,430 ha (polygon area using Google Earth Pro).
Boundary: The site comprises coastal mangroves on either side of the line dividing Ngardmau and Ngarraard States, and contiguous freshwater swamp forest to the landward side, up to the high water mark, from a point about 1.0 km N of Ngetbong village (Ngardmau) east and north to a point 1.2 km west-north-west of Galap village near the access to the north-western marine lagoon. The boundary runs seaward of these two limit points to follow the outer edge of the inner fringing flats and reefs. The site also include the lower reaches of the Ngerchokl River, Ngaraard State, which enters the middle south-east side of the site.
Dimensions: about 7 km (4.3 miles) north-south, by 5 km (3.1 miles) east-west.

C. Location:

Coordinates: 7°38'N, 134°36'E (Site limits: 7°36'-40'N, 134°34'-37'E).
On the north-west coast of Babeldaob Island, 35 km (21.7 miles) north of Koror urban area.
States: Ngaraard and Ngardmau.

D. Site maps: See below.

The site boundary shown in this update serves to define the scope of information in the site account and has no legal status. It is provisional and subject to further discussion.

E. Ramsar Wetland Types:

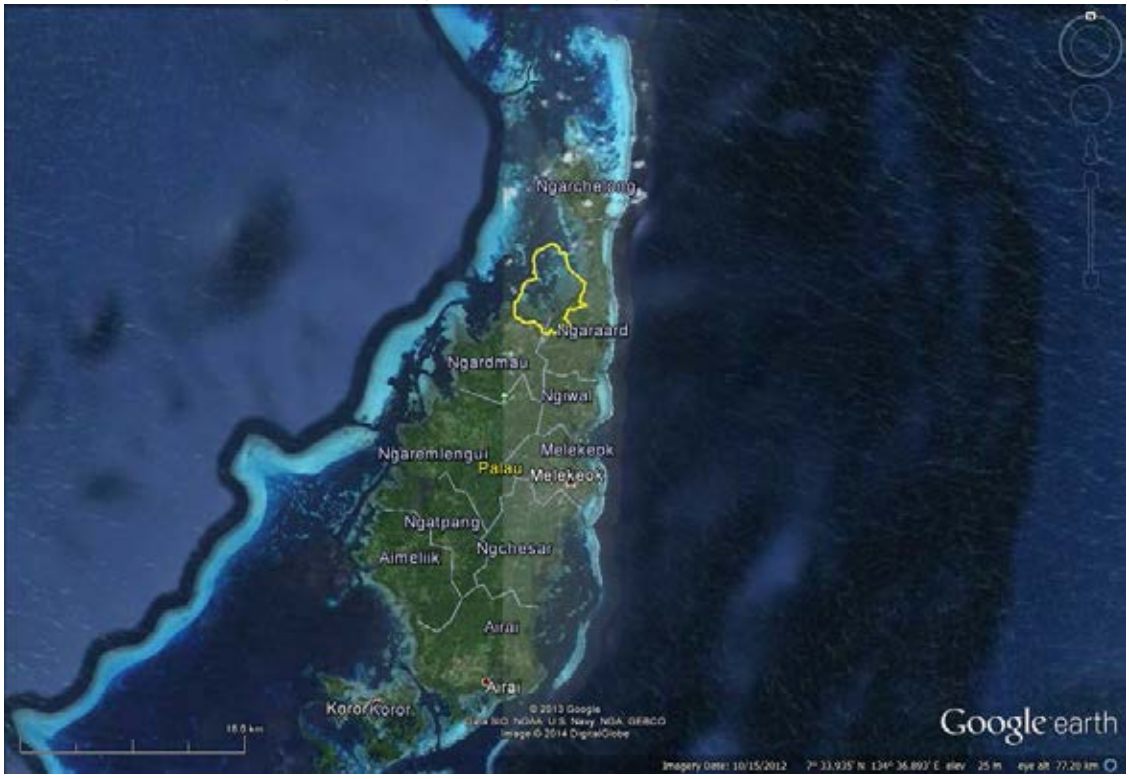
Dominant types:

- A: Permanent shallow marine waters in most cases less than six metres deep at low tide.
- B: Marine subtidal aquatic beds (sea-grass beds).
- C: Coral reefs.
- I: Intertidal forested wetlands (mangrove swamps, tidal freshwater swamp forests).
- M: Permanent river.
- Xf: Freshwater, tree-dominated wetlands (includes freshwater swamp forests, on inorganic soils).

Types also present:

- F: Estuarine waters (permanent water of estuaries).
- G: Intertidal mud flats.

Location of Ngaraard-Ngardmau Mangroves (Image from Google Earth)



Ngaraard-Ngardmau Mangroves: suggested site boundary (for discussion)
(Image from Google Earth)

Ngaraard-Ngardmau Mangroves: suggested site boundary (for discussion)

(Image from Google Earth)

F. Geomorphic setting:

Elevation: From sea level to a little above sea level.
Geology: of volcanic origin. The site comprises gently-sloped and level coastal landforms including a broad fringing reef flat that has numerous closed and semi-enclosed basins (holes) and some channels associated with inflowing freshwater streams.

G. Biogeographic region:

West Caroline Islands Marine Ecoregion (Spalding *et al.* 2007).

H. Climate:

Palau's climate is humid subtropical with annual rainfall averaging 3810 mm (152 inches) per year (Ketebengang and Gupta 2011); rainfall is relatively even across the months. Palau historically has experienced direct typhoon impacts once every 20 years; however, destructive typhoons occurred both in 2012 (Bopha) and 2013 (Haiyan). Rainfall and thus water levels may be lower during drought which occurs occasionally under El Nino conditions.

I. Soil:

The soils are of volcanic origin over most of the site (USDA 1983). Sand on fringing flats may include material of coralline origin.

J. Water regime:

Estuarine environments are the dominant regime for the site and the offshore areas are fully exposed to marine influence. The mangrove forests and fringing flats are affected by the tides (range: approx. 2.0 m). Freshwater enters the site via at least one stream (Ngerchokl River).

K. Water chemistry: No information.

L. Biota:

The area contains a well-developed stand of mangrove forest; characteristic species are *Sonneratia alba*, *Rhizophora mucronata* and *Bruguiera gymnorrhiza* (Kerradel Planning Team 2011, citing Kitalong 1990) but most of the mangrove tree species known from the Caroline Islands are present in the area. Substantial areas of pristine swamp forest dominated by *Horsfieldia irya* and with scattered *Calophyllum pelewense* lie landward of the mangroves (Kerradel Planning Team 2011, citing Costion and Kitalong 2006).

The estuarine crocodile *Crocodylus porosus* and the dog-faced snake *Cerberus rhyncops* occur in the mangroves, also the Palau fruit bat *Pteropus pelewensis*. A variety of forest birds forage in the mangroves. The seagrass beds on the north-west side of Babeldaob may be the most important feeding area for dugong *Dugong dugon* in Palau (Marsh et al. 1992).

Invertebrates in the site include the mangrove crab *Scylla serrata*, various other crabs, various bi-valves, gastropods and some tunicates. Keith et al. (2011) recorded three fishes (*Anguilla marmorata*, *Sicyopus fehlmanni* and *Stiphodon percnopterygionus*) and seven crustaceans (mainly *Atyoida* and *Caridina* spp.) from the lower Ngerchokl River.

M. Land use:

Land uses within the site include cutting of mangroves for timber, fishing, harvesting of mangrove crabs and bi-valves, hunting of fruit bats and wild pigs, and recreation/tourism. Fishes caught for subsistence and commercial purposes in the site include parrotfishes, surgeonfishes, rabbitfishes, groupers, mullets, wrasses and snappers (Kerradel Planning Team 2011). Ngerchokl River is zoned for education and ecotourism (Kerradel Planning Team 2011).

N. Pressures and trends:

This is a relatively undisturbed area but the site was almost certainly affected by increased sedimentation arising from construction of the round-island Compact Road in upper catchment of the site, since the 1993 Directory site account was compiled. Excessive cutting of mangrove vegetation and landfill for development may pose threats in the future.

O. Land tenure and administrative authority:

Land tenure: Owned by the two States and local chiefs. Adjacent land is owned partly by the government and partly by local landowners. Reef-flat and lagoon areas are owned by the States.

Administrative authority: The States of Ngaraard and Ngardmau.

P. Ramsar listed? No.

Q. Ramsar Criteria met:

Criterion 1. Contains a representative, rare, or unique example of a natural or near-natural wetland type found within the appropriate biogeographic region.

Criterion 3. Supports populations of plant and/or animal species important for maintaining the biological diversity of a particular biogeographic region.

Criterion 4. Supports plant and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions.

Criterion 8: The streams, mangroves, lagoons and reefs of the site provide substantial stocks of fish and other marine resources on which local people depend.

R. Justification for Ramsar Criteria met:

Criterion 1: The site includes good representative examples of several wetland types characteristic of the West Caroline Islands Marine Ecoregion: notably, mangroves (Type I), fringing flats with coral reefs (Types A, C) and freshwater swamp forests (Type Xf). These wetlands are some distance from Koror urban area and are still relatively undisturbed.

Criterion 3: Most of the mangrove tree species known from the West Caroline Islands Marine Ecoregion are present in the area. The site is important for maintaining crocodilians (estuarine crocodile *Crocodylus porosus*) in the bioregion.

Criterion 4: The streams, mangroves, lagoons and reefs of the site provide a substantial area of nursery habitat for many species of fish, crustaceans and other estuarine/marine organisms.

Criterion 8: The streams, mangroves, lagoons and reefs of the site provide substantial stocks of fish and other marine resources on which local people depend.

S. Conservation and management status of the wetland:

The Ngaraard Mangrove Conservation Area, established in 1994, covers a substantial area in the centre of the site. As mapped by PALARIS, the Conservation Area primarily includes fringing flats, reefs and lagoon but the intent was inclusion of the adjacent mangrove forest along the Ngaraard coast (Kerradel Planning Team 2011). One source cites its area as 1.42 km2 (Republic of Palau 2010). Ngaraard State's management plan for this area zones the northern parts of the mangroves for subsistence fishing, with a closed zone in the south (Kerradel Planning Team 2011).

Lower reaches of Ngerchokl River are within the Diong Era Ngerchokl Conservation Area, established in 2008; some swamp forest is within this Conservation Area.

T. Ecosystem services:

Food supply: The site supports a diverse community of marine organisms (e.g. fishes, crabs and bi-valves) many of which provide protein for local people.
Fuel wood: The mangrove forest plays an important role in the lives of the local people by providing an important source of fuel wood.
Medicinal products: Some traditional medicines are obtained from the mangrove forests.
Maintaining water quality: The mangrove and swamp forests filter silt from run-off entering from the land, thereby protecting the reefs from being smothered by silt.
Coastal protection: The mangrove forest prevents coastal erosion and provides protection against tropical storms.
Carbon sink: the forests of the site store large quantities of carbon.
Cultural values: A registered historical site along the Ngerchokl River is associated with a traditional legend about a "Fountain of Youth", though it is not yet a major tourist attraction.

U. Current recreation and tourism:

There is no organised eco-tourism in the site at present.

V. Existing scientific research:

Forestry research (Kerradel Planning Team 2011, citing Kitalong 1990 and Costion and Kitalong 2006).
Freshwater surveys (Keith *et al.* 2011).

W. Management plans and monitoring programs:

All Conservation Areas are required to have a management plan before they are formally established (Protected Area Network Act 2003). The Kerradel Conservation Network addresses implementation of conservation area management in this part of Palau. The Kerradel Conservation Network Management Plan 2011-2016 (Kerradel Planning Team 2011) applies to the two protected areas in the site and prescribes permitted activities in each land-use zone and a detailed work plan for implementation by Ngaraard State.

X. Current communication and public education programs:

The legend of the Fountain of Youth River is taught in elementary school in Palau.

Y. References cited:

Keith, P, Gerbeaux, P, Marquet, G, Taillebois, L and Castelin, M. 2011. Freshwater survey of Babeldaob, Palau. National Museum of Natural History of Paris, 32 pp.

Kerradel Planning Team. 2011. Kerradel Conservation Network Management Plan 2011-2016. Kerradel Planning Team and Palau Conservation Society. 65 pp.

Ketebengang, H and Gupta, A. 2011. State of Palau's Birds 2010. A conservation guide for communities and policymakers. Palau Conservation Society. 23 pp.

Marsh, H, Rathburn, G, O'Shea, T and Preen, T. 1992. An assessment of the status of dugongs in Palau including comments on sea turtles. Report to Ministry of Natural Resources, Government of Palau, 20 pp.

Republic of Palau. 2010. Mauritius +5 (Small Island Developing States) Status Report.

Spalding M.D., Fox H.E., Allen G.R., Davidson N., Ferdaña Z.A., Finlayson M., Halpern B.S., Jorge M.A., Lombana A., Lourie S.A., Martin K.D., McManus E., Molnar J., Recchia C.A., Robertson J. 2007. Marine Ecoregions of the World: a bioregionalization of coast and shelf areas. BioScience 57: 573-583.

USDA. 1983. Soil survey of islands of Palau, Republic of Palau. USDA Soil Conservation Service.

Z. Compilers:

Original compilers (for 1993 edition): Demei O. Otobed.
Updated by: Pua Michael and Roger Jaensch, May 2014.

3.2 Ngerkall Pond

A. Overview:

A small pond, largely covered with aquatic vegetation, in the uplands of northern Babeldaob. Ngerkall Pond is one of only two natural freshwater ponds of substantial size in Palau.

B. Area, boundary and dimensions:

Area: 7.5 ha (polygon area using Google Earth Pro).
Boundary: the high water mark of the pond, to which is added a buffer zone of 100 m (328 feet).
Dimensions: The pond is about 60 metres long by 45 metres wide (197 feet by 148 feet).

C. Location:

Coordinates: 7°36.31'N, 134°37.55'E
Location is in northern Babeldaob Island, 33 km (20.5 miles) north of Koror urban area and 2 km (1.2 miles) north-west of Ngkeklau village.
State: Ngarraard.

D. Site Maps: See below.

The site boundary shown in this update serves to define the scope of information in the site account and has no legal status. It is provisional and subject to further discussion.

E. Ramsar Wetland Types:

Tp: Permanent freshwater marshes/pools; ponds (below 8 ha), marshes and swamps on inorganic soils; with emergent vegetation water-logged for at least most of the growing season.

Note: If deposits of peat (partly-decomposed organic matter) form a significant part of the substrate to the wetland, a different and additional wetland type (U: Non-forested peatlands) may be applicable.

F. Geomorphic setting:

Elevation: About 50 m.

The pond is on volcanic geology (USDA 1983). The pond was created as a result of a landslide.

G. Biogeographic region:

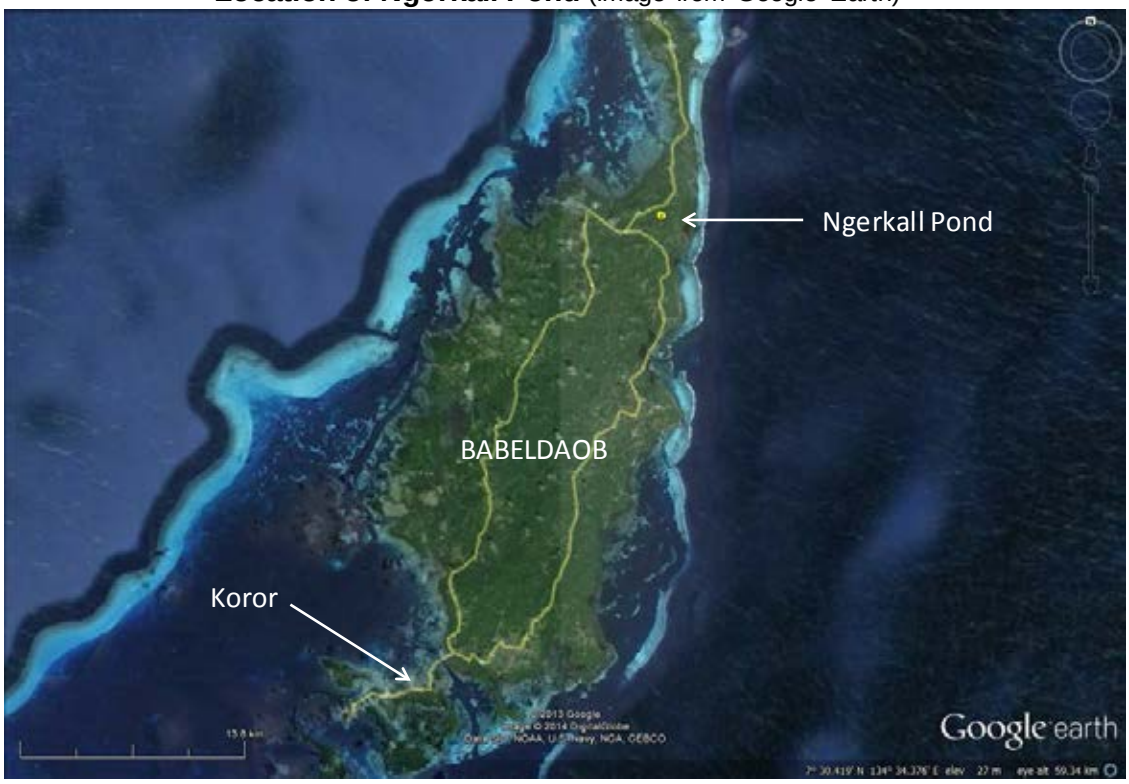
West Caroline Islands Freshwater Ecoregion (Abell *et al.* 2008).

H. Climate:

Palau's climate is humid subtropical with annual rainfall averaging 3810 mm (152 inches) per year (Ketebengang and Gupta 2011); rainfall is relatively even across the months. Palau historically has experienced direct typhoon impacts once every 20 years; however, destructive typhoons occurred both in 2012 (Bopha) and 2013 (Haiyan). Rainfall and thus

water levels may be lower during drought which occurs occasionally under El Nino conditions.

Location of Ngerkall Pond (Image from Google Earth)



Ngerkall Pond: suggested site boundary (for discussion)
(Image from Google Earth)

Ngerkall Pond: suggested site boundary (for discussion) (Image from Google Earth)

I. Soil:

Of volcanic origin: classed as "Ngardok silt loam" (Kerradel Planning Team 2011). Additionally, given the aquatic vegetation of the wetland, peat (partly-decomposed organic matter) may form a significant part of the substrate: to be investigated.

J. Water regime:

The pond is fed by run-off from the adjacent hillsides and has a small catchment area. Apparently there is no inflow stream (Bright 1979); it is not known if there is an outflow stream. The pond is mostly 60-90 cm (2-3 feet) deep with a maximum depth earlier recorded as 2.0 m (6.4 feet; Bright 1979). Volume of water has been recorded as 300,000 to 400,000 gallons (Bright 1979).

K. Water chemistry:

The water is fresh and is acidic due to the high organic content; it is naturally low in productivity (Bright 1979).

L. Biota:

Aquatic vegetation in the pond consists of grasses, sedges and the broad-leaved emergent plant *Hanguana malayana*; the latter has been recorded as occupying a 5-10 m (16-33 feet) wide margin (Bright 1979). The wetland remains in an almost pristine condition. Without specifying examples, the original 1993 Directory states that the pond supports a variety of freshwater aquatic plants with very restricted distribution in Palau.

The wetland possibly still supports small numbers of the Pacific Black (Grey) Duck Anas superciliosa pelewensis, which is widespread in the south-west Pacific but is nearing extinction in Palau, as well as Purple Swamphen *Porphyrio porphyrio pelewensis*, which is a subspecies endemic to Palau (Ketebengang and Gupta 2011). Migratory waterbirds from Asia occasionally visit the area, presumably including Yellow Bittern *Ixobrychus sinensis* which would inhabit the Hanguana.

There is one report, without details, of crocodiles occurring in the site (Kerradel Planning Team 2011). A fish *Misgurnus anguillicaudatus* has been listed for the pond (Bright 1979).

M. Land use:

The wetland is undisturbed and there is no cultivation on the surrounding hillsides that lie in catchment outside the site boundary.

N. Pressures and trends:

Some burning and hunting previously occurred in the catchment of the site but presumably has reduced or ceased since declaration of the Conservation Area.

O. Land tenure and administrative authority:

Land tenure: The State Government and local Chiefs.
Administrative authority: State of Ngaraard.

P. Ramsar listed? No.

Q. Ramsar Criteria met:

Criterion 1. Contains a representative, rare, or unique example of a natural or near-natural wetland type found within the appropriate biogeographic region.
Criterion 3. Supports populations of plant and/or animal species important for maintaining the biological diversity of a particular biogeographic region.

R. Justification for Ramsar Criteria met:

Criterion 1: The site is a good representative example of a wetland type (freshwater ponds: Type Tp) that is rare in the West Caroline Islands Freshwater Ecoregion. It is one of only two significant freshwater ponds in Palau (the other being Ngardok Lake), with rich aquatic vegetation still in an almost undisturbed condition.
Criterion 3: The site supports a variety of freshwater aquatic plants such as *Hanguana malayana* with very restricted distribution in Palau, and thus the whole West Caroline Islands Freshwater Ecoregion. The site supports a subspecies of Purple Swamphen *Porphyrio porphyrio pelewensis*, which is endemic to Palau (Ketebengang and Gupta 2011). Comparison of the list of wetland plants at Ngerkall Pond with a list of wetland plant species for the bioregion may potentially provide additional justification for Criterion 3.

S. Conservation and management status of the wetland:

The pond is within the Ngerkall Lake and Metmellasech Watershed Conservation Area, which covers much, if not all, of its catchment (watershed). This is a “no entry, no take” zone (Kerradel Planning Team 2011).

T. Ecosystem services:

Water quality improvement: The pond and its vegetation trap sediment.
Water supply: The pond acts as a natural water storage reservoir. Local people occasionally use the pond as a source of drinking water.
Groundwater recharge: The pond may assist in the recharge of groundwater.
Materials supply: The aquatic vegetation may have provided a source of sedges for weaving materials in the past.

U. Current recreation and tourism:

No regular organised visitations. A few school children visit the area during hiking trips.

V. Existing scientific research: No information.

W. Management plans and monitoring programs:

All Conservation Areas in Palau must have a management plan before they are established (Protected Area Network Act 2003). The Kerradel Conservation Network addresses implementation of conservation area management in this part of Palau. The plan for Ngerkall Pond is part of the Kerradel Conservation Network Management Plan 2011-2016 (Kerradel Planning Team 2011).

X. Current communication and public education programs: None at present.

Y. References cited:

Abell, R., Thieme M., Revenga C. et al. 2008. Freshwater ecoregions of the world: a new map of biogeographic units for freshwater biodiversity conservation. BioScience 58, 403–414.

Bright, GR. 1979. The inland waters of Palau, Caroline Islands. Office of the Chief Conservationist, TTPI, Koror, Palau, Unpublished Manuscript.

Ketebengang, H and Gupta, A. 2011. State of Palau's Birds 2010. A conservation guide for communities and policymakers. Palau Conservation Society. 23 pp.

Kerradel Planning Team. 2011. Kerradel Conservation Network Management Plan 2011-2016. Kerradel Planning Team and Palau Conservation Society. 65 pp.

USDA. 1983. Soil survey of islands of Palau, Republic of Palau. USDA Soil Conservation Service.

Z. Compilers:

Original compilers (for 1993 edition): Demei O. Otobed
Updated by: Pua Michael and Roger Jaensch, May 2014

3.3 Ngerbekuu River

A. Overview:

An area of freshwater swamps, lowland swamp forest with high canopy, and adjacent mangrove forests along the Ngerbekuu River; also, adjoining fringing flat, coral reef and intervening lagoon, immediately beyond the river mouth.

B. Area, boundary and dimensions:

Area: 427 ha (polygon area using Google Earth Pro).
The site boundary includes the lower (tidal) reaches of Ngerbekuu River and all surrounding contiguous mangrove and swamp forest to the high water mark; also, fringing flat seaward of the river mouth within the Ngemai Conservation Area boundary. Part of a small mangrove-covered island traversed by the coastal road is included. The southernmost part of the site boundary stops at the State border. Much of Imekang Bay and Imolch Bay is included in the site.
Note: an alternative site boundary could follow the boundaries of the two Conservation Areas relevant to the site (see below); this would add some dry-land areas in the upper catchment (watershed) and may exclude or include some areas of swamp forest and shallow bay.

C. Location:

Coordinates: 7°32'N, 134°37'E
On the east coast of Babeldaob Island, 27 km (16.7 miles) north of the Koror urban area and 2.3 km (1.4 miles) south-west of Ngermechau village.
State: Ngiwal

D. Site Maps: See below.

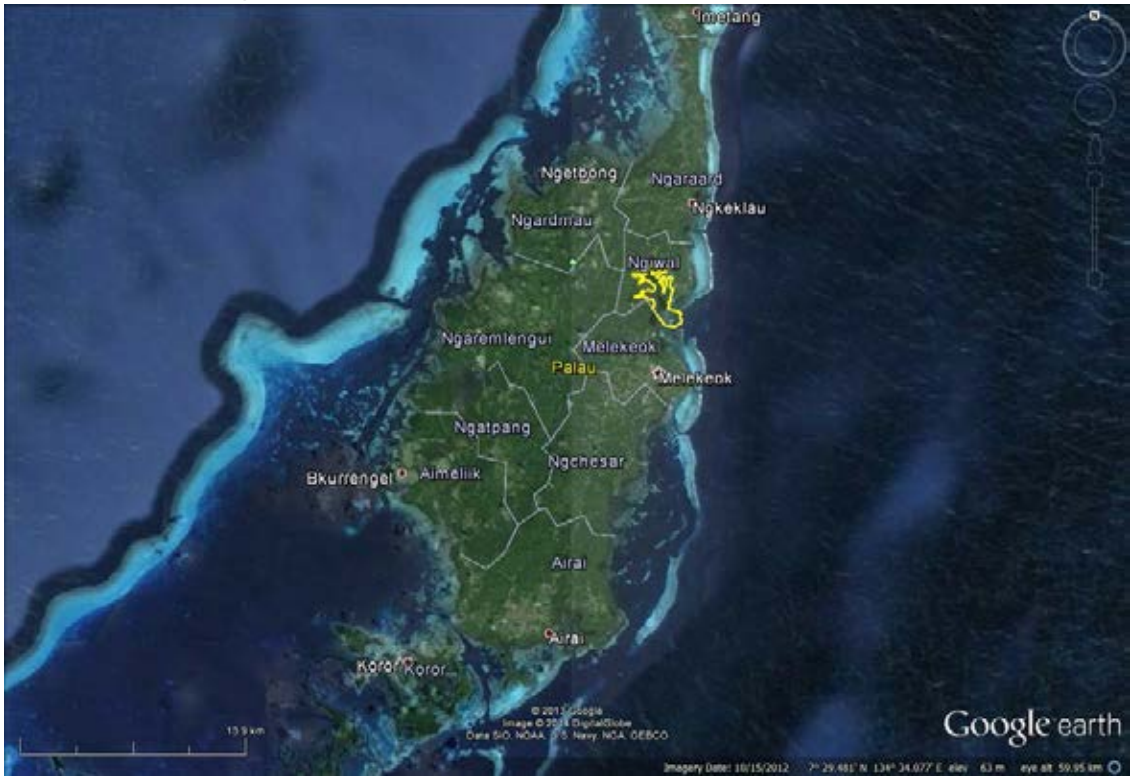
The site boundary shown in this update serves to define the scope of information in the site account and has no legal status. It is provisional and subject to further discussion.

E. Ramsar Wetland Types:

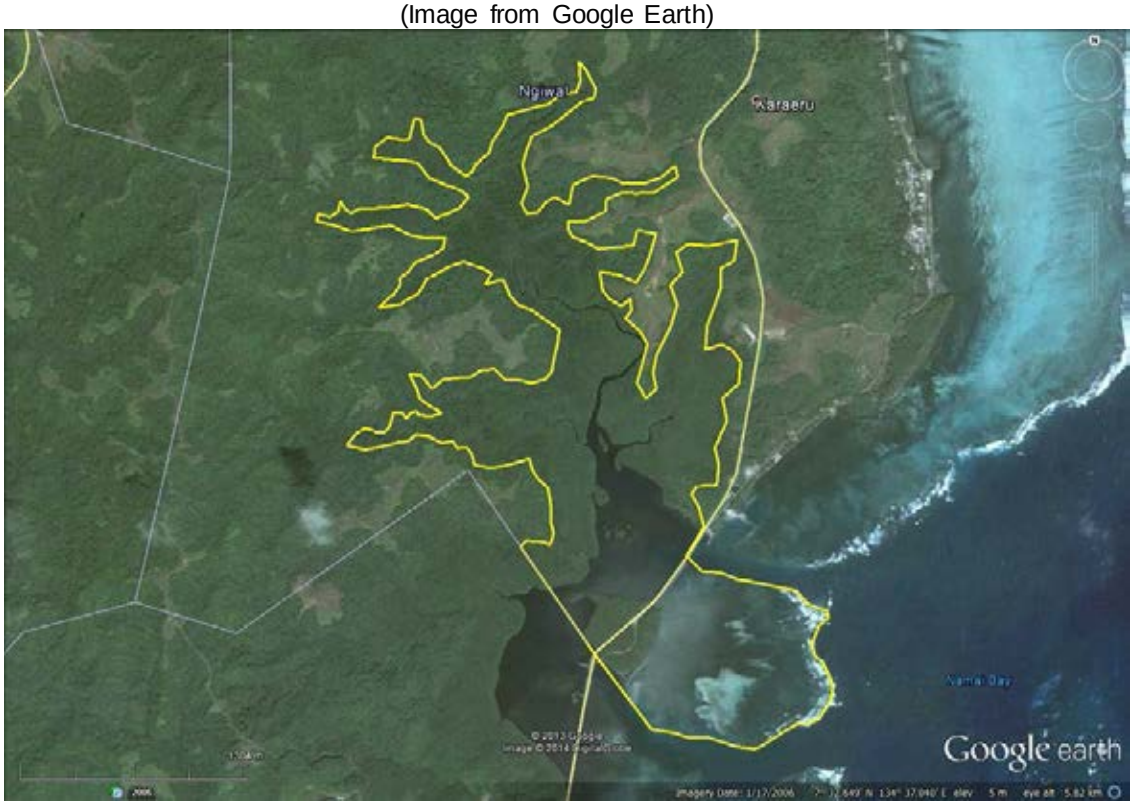
Dominant wetland types:
- A: Permanent shallow marine waters in most cases less than 6 metres deep at low tide.
- B: Marine subtidal aquatic beds (sea-grass beds).
- F: Estuarine waters (permanent water of estuaries).
- G: Intertidal mud flats.
- I: Intertidal forested wetlands (mangrove swamps, tidal freshwater swamp forests).
- Xf: Freshwater, tree-dominated wetlands (includes freshwater swamp forests, on inorganic soils).

Other types present in the site:
- C: Coral reefs.
- M: Permanent rivers/streams/creeks (includes waterfalls).
- Human-made wetland Type 3: Irrigated land (taro swamp-gardens).

Ngerbekuu River: location (Image from Google Earth)

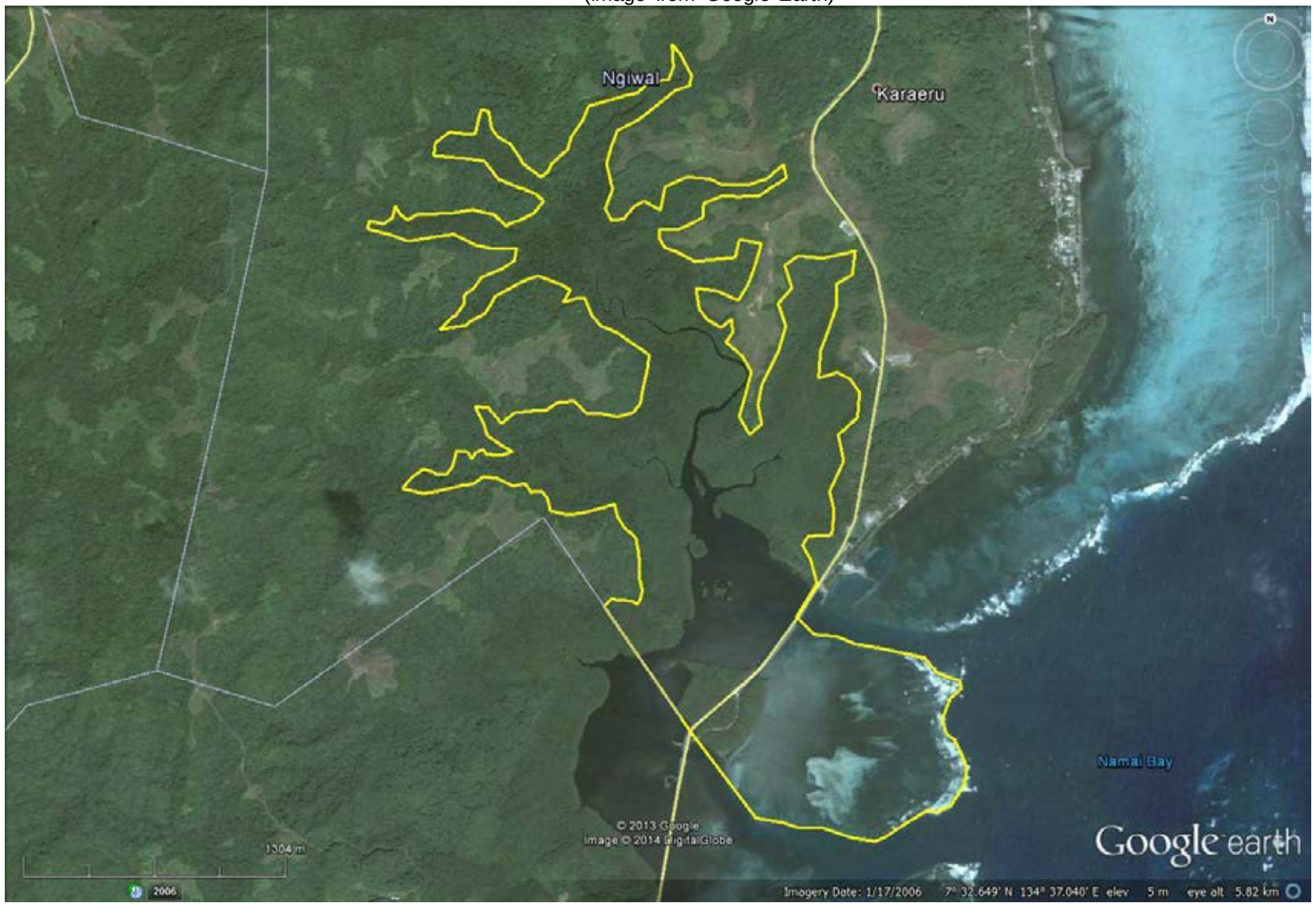


Ngerbekuu River: suggested site boundary (for discussion)
(Image from Google Earth)



Ngerbekuu River: suggested site boundary (for discussion)

(Image from Google Earth)



Fringing flat, seagrass, mangrove: Ngemai CA (Photo: R. Jaensch)

F. Geomorphic setting:

Elevation: From sea-level to a few metres above sea level.

Geology is mostly of volcanic origin but the island is on limestone (USDA 1983). The site includes: lowland traversed by lower reaches of the river; an estuary with small islands; a larger island within the bay; and a fringing flat, with substantial sediment deposit and coral reef at the edges, extending seaward from the island.

G. Biogeographic region:

West Caroline Islands Marine Ecoregion (Spalding *et al.* 2007).

H. Climate:

Palau's climate is humid subtropical with annual rainfall averaging 3810 mm per year (Ketebengang and Gupta 2011); rainfall is relatively even across the months. Palau historically has experienced direct typhoon impacts once every 20 years; however, destructive typhoons occurred both in 2012 (Bopha) and 2013 (Haiyan). Rainfall and thus water levels may be lower during drought which occurs occasionally under El Nino conditions.

I. Soil:

The soils are of volcanic origin over most of the site but are associated with limestone on the island (USDA 1983). Sand and coral fragments would be included in sediments on the fringing flat.

J. Water regime:

The site includes freshwater, through tidal, to marine regimes. Estuarine environments are the dominant regime for central parts of the site and the offshore areas are fully exposed to marine influence. The mangrove forests are affected by the tides which have a range of about 2.0 m (6.5 feet). At lowest spring tides, almost all of the bay and estuary landward of the causeway is exposed mud (Colin 2009). A waterfall is situated in the

upper reaches of the river. The Ngerbekuu River catchment (Watershed) covers 1.056 million m2 (BWA 2010).

K. Water chemistry: Some parts of the site are brackish.

L. Biota:

The wetland incorporates fresh, brackish and saline ecosystems, and supports a wide diversity of mangrove and swamp forest tree/plant species. All of the mangrove species (16) occurring in Palau are present, as well as a wide variety of the swamp forest and freshwater swamp species. Seagrass is common in sediments on the fringing flat, extending up to 1.5 km (0.9 miles) offshore.

Imekang Bay: crocodiles inhabit the estuary and mangrove

(Photo: R. Jaensch)

The wetland supports populations of the estuarine crocodile *Crocodylus porosus*; crocodiles were reported to nest in the freshwater marshes behind the mangroves (more than 10 years ago: MNRET officers). The mangroves have suitable refuge habitat for sub-adult crocodiles (Messel and King 1991). Three crocodiles were seen in the river in recent years and crocodiles are sometimes seen resting beside the causeway (MNRET officers). Dugong *Dugong dugon* occur on the reef flat over the sea grass beds. Mangrove crabs *Scylla serrata* are common. The Palau fruit bat *Pteropus pelewensis* occurs in the wetland forests.

Waterbirds using the fringing flats include Rufous Night-Heron *Nycticorax caledonicus*, Pacific Reef Heron (Eastern Reef Egret) *Egretta sacra*, Crested (Swift) *Tern bergii* and the migratory Whimbrel *Numenius phaeopus*.

M. Land use:

The estuary is a subsistence fishing ground for fin fish, crabs and bivalves. Some of the freshwater swamps are used for taro gardens, and parts of the swamp forest are used for agro-forestry. Some mangrove trees are harvested for timber for local use.

N. Pressures and trends:

The causeway across the bay, through the large island, was built in the Japanese period then modified and widened as part of building the Compact Road (Colin 2009), about 10 years ago. This has had some impact on water circulation and sedimentation in the vicinity despite inclusion of two bridges, but the detailed impacts are not known. Storm surge associated with Cyclone Bopha caused some damage to east coastal areas of Babeldaob in 2012. Excessive cutting of timber from the wetland forests is a potential threat to the site.

O. Land tenure and administrative authority:

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.
Administrative authority: State of Ngiwal.

P. Ramsar listed? No.

Q. Ramsar Criteria met:

Criterion 1. Contains a representative, rare, or unique example of a natural or near-natural wetland type found within the appropriate biogeographic region.
Criterion 3. Supports populations of plant and/or animal species important for maintaining the biological diversity of a particular biogeographic region.
Criterion 4. Supports plant and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions.
Criterion 8: The streams, mangroves, lagoons and reefs of the site provide substantial stocks of fish and other marine resources on which local people depend.

R. Justification for Ramsar Criteria met:

Criterion 1: The site includes good representative examples of several wetland types that are characteristic of the West Caroline Islands Marine Ecoregion: notably, mangrove swamps (Type I), fringing flats with seagrass beds (A, B), and estuarine waters (F). Ngerbekuu River is the only major stream in Palau that has not been affected by upriver sedimentation from construction of the Compact Road, because the road does not pass through its catchment (watershed).
Criterion 3: The site is important for maintaining crocodilians as a component of biodiversity in the West Caroline Islands Marine Ecoregion.
Criterion 4: Crocodiles nest in the site's marshes and the site therefore is important for the viability of crocodile populations in Palau. The mangroves, shallow lagoon and coral reefs in the site are important nursery areas for fishes, crustaceans and other marine organisms.
Criterion 8: The site supports substantial fish stocks that are harvested by local people; harvested species that breed in the mangroves and are harvested in the reefs include rabbitfish *Siganus fuscescens* and *S. lineatus*.

S. Conservation and management status of the wetland:

The Ngemai Conservation Area covers the fringing/reef flat and eastern parts of the mangrove island within the site. The main channel of Ngerbekuu River and a buffer about 100 metres (328 feet) either side lie within the Olselkesol Conservation Area.

T. Ecosystem services:

Food supply: The estuary is an important subsistence fishing ground. Some parts of the wetland are important for the cultivation of taro for local consumers.
Wood supply: The mangrove forests provide a valuable source of timber for local people.
Biochemical products: traditional medicines are obtained from the wetland forests.
Hazard reduction: the mangroves and fringing flat protect the coast from damage by severe storms.
Maintaining water quality: The mangrove and swamp forests filter silt from run-off entering from the land, thereby protecting the reefs from being smothered by silt.
Cultural heritage: There are some ancient dwellings of archaeological interest in the area.
Carbon sink: the forests of the site store large quantities of carbon.

U. Current recreation and tourism:

No major activity at present but the management plan for the conservation area includes plans for (potential) kayaking up the river.

V. Existing scientific research:

A bird monitoring site for the National Program for Monitoring Forest and Coastal Birds is situated in Ngemai Conservation Area (Olsen and Eberdong 2013).

W. Management plans and monitoring programs:

A management plan is in existence for all Conservation Areas in Palau (Protected Area Network Act 2003). The Ngiwal State Protected Areas and Natural Resources Management Plan 2010-2015 includes the site in its prescriptions (BWA 2010). The Ngemai Conservation Area was closed to fishing and other resource harvesting from 1997, then reopened in 2002; the benefits have been uncertain (Colin 2009).

X. Current communication and public education programs:

An interpretive sign and map of the two Conservation Areas is situated on the roadside on the large island, at the edge of Ngemai Conservation Area.

Y. References cited:

Babeldaob Watershed Alliance. 2010. Ngiwal State Protected Areas and Natural Resources Management Plan 2010-2015. The Nature Conservancy and Babeldaob Watershed Alliance.

Colin, P. 2009. Marine Environments of Palau. Coral Reef Research Foundation, Koror, Palau. Mutual Publishing and Indo-Pacific Press, San Diego. 414 pp.

Ketebengang, H and Gupta, A. 2011. State of Palau's Birds 2010. A conservation guide for communities and policymakers. Palau Conservation Society. 23 pp.

Messel, H and King, FW. 1991. Survey of the crocodile populations of the Republic of Palau, Caroline Islands, Pacific Ocean, 8-24 June 1991. Report to the Government of Palau.

Olsen, AR and Eberdong, M (eds.) 2013. State of Palau's Birds 2012. Belau National Museum, Koror. 22 pp.

Spalding M.D., Fox H.E., Allen G.R., Davidson N., Ferdaña Z.A., Finlayson M., Halpern B.S., Jorge M.A., Lombana A., Lourie S.A., Martin K.D., McManus E., Molnar J., Recchia C.A., Robertson J. 2007. Marine Ecoregions of the World: a bioregionalization of coast and shelf areas. BioScience 57: 573-583.

USDA. 1983. Soil survey of islands of Palau, Republic of Palau. USDA Soil Conservation Service.

Z. Compilers:

Original compilers (for 1993 edition): Demei O. Otobed
Updated by: Pua Michael and Roger Jaensch, May 2014

3.4 Ngardok Lake

Consistent with the approach taken across Palau and following the model set by the original 1993 Directory, this site account update focuses on the actual wetland ecosystems (the lake and connected swamp wetlands). The Ramsar Information Sheet for the Ramsar site in this area (Lake Ngardok Nature Reserve) refers to the reserve boundary and thus includes large areas of non-wetland in the upper catchment, which are not included in this wetland inventory site (Republic of Palau 2012). Hence, there are differences in site boundary and area: compare the map below with the RIS map.

A. Overview:

Ngardok Lake is a small, natural, freshwater lake and associated freshwater marshes, swamp forest and outflow stream. It is the largest, natural permanent body of fresh water in Palau and all of Micronesia and it supports breeding crocodiles. It is within Palau's first Ramsar site.

B. Area, boundary and dimensions:

Area: 102 ha, of which the lake occupies 3.4 ha (polygon area using Google Earth Pro).
The site boundary follows the lake's high water mark, extended outwards by a buffer zone of 100 m (328 feet). Also included are: the Ngerdoch River downstream from the lake to the present lower boundary of the Lake Ngardok Nature Reserve (i.e. at the Compact Road); swamps and swamp forest associated with this section of the River; and swamp forest immediately upstream of the lake. Note: An alternative boundary could be the entire nature reserve (conservation area), which includes large areas of dry land in the upper catchment.
Ngardok Lake is 750 m (2,460 feet) long, up to 150 m (492 feet) wide and 2.7 m (8.9 feet) deep, and has a volume of 56.8 million litres (15 million gallons).

C. Location:

Coordinates: 7°30'N, 134°36'E (Site limits: 7°29'-31'N, 134°35'-36'E.)
On the eastern side of Babeldaob Island, 23 km (14.3 miles) north of Koror urban area and about 2.7 km north-west of the Palau Capitol,
State: Melekeok.

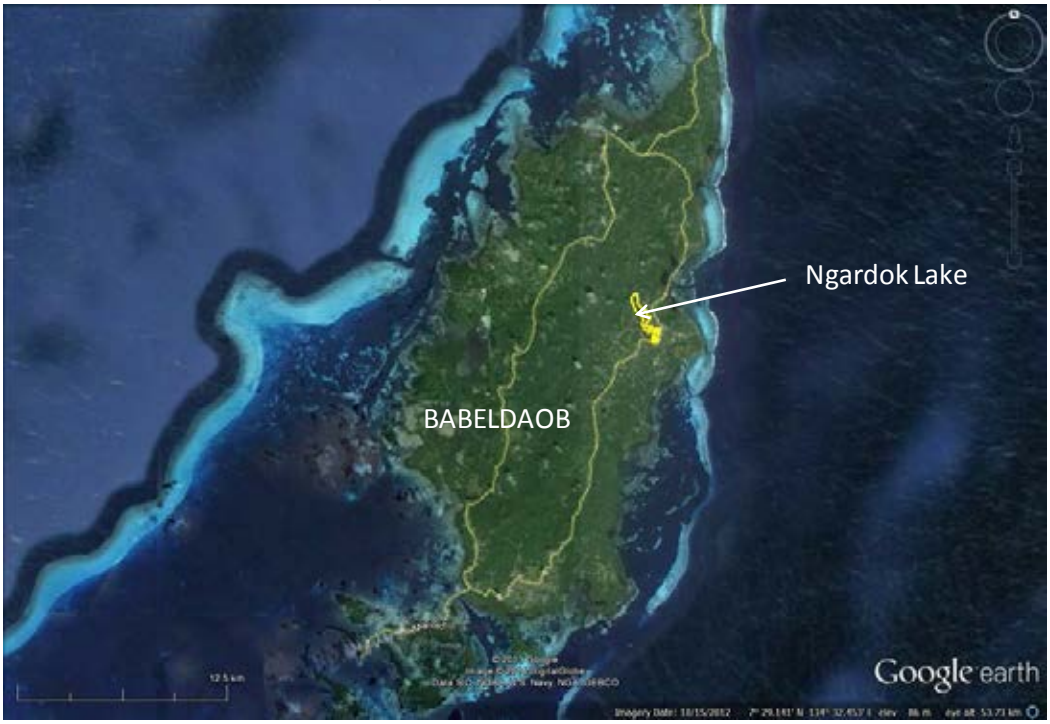
D. Site Maps: See below

The site boundary shown in this update serves to define the scope of information in the site account and has no legal status. It is provisional and subject to further discussion.

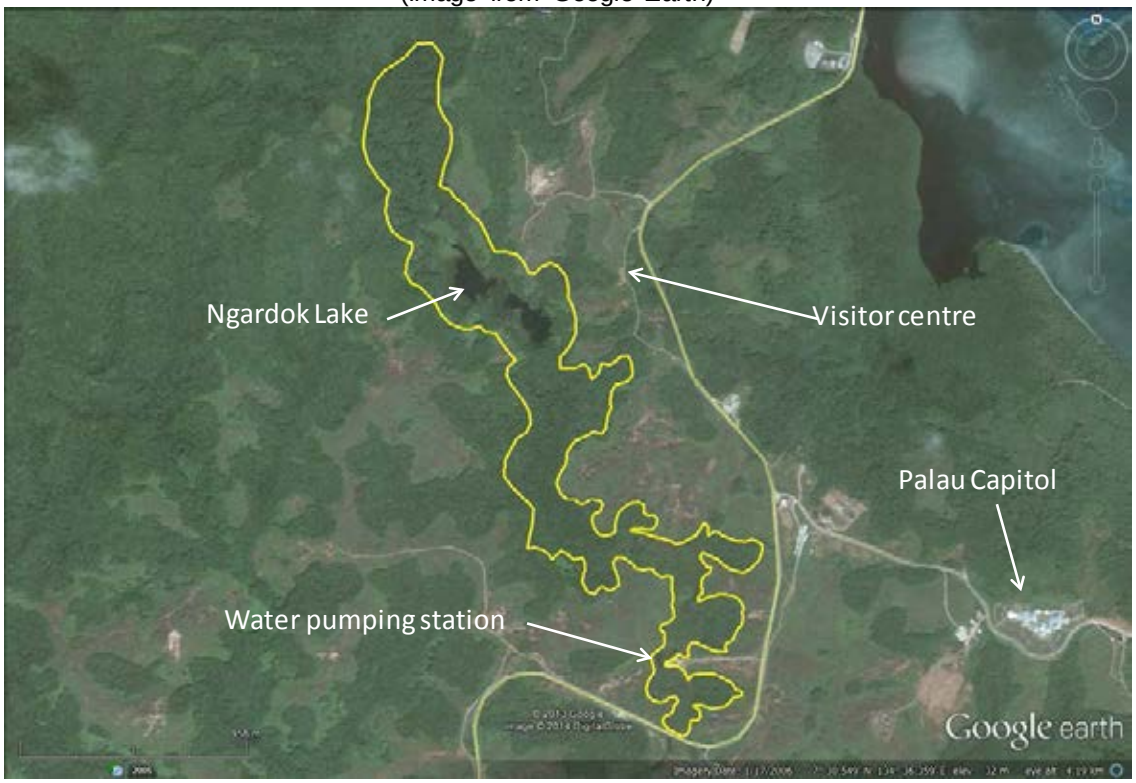
E. Ramsar Wetland Types:

Tp: Permanent freshwater marshes/pools; ponds (below 8 ha), marshes and swamps on inorganic soils; with emergent vegetation water-logged for at least most of the growing season.
Xf: Freshwater swamp forest.
M: Permanent river/stream.

Location of Ngardok Lake (Image from Google Earth)



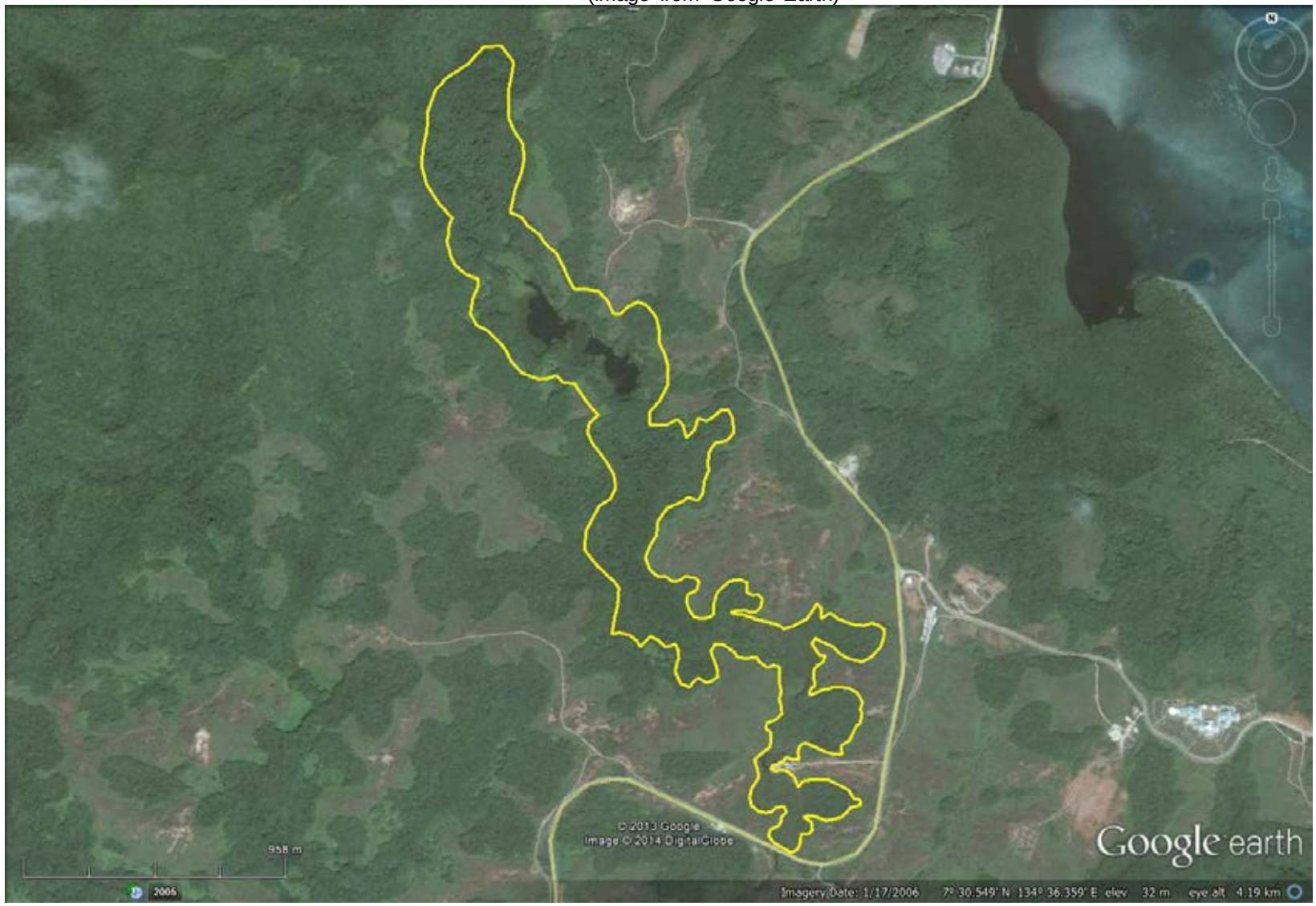
Ngardok Lake: suggested boundary (for discussion) of the inventory site
(Image from Google Earth)



Note: The outer edge of the swamps is difficult to determine from the Google Earth image; vegetation maps may help define some parts of the site boundary more accurately.

Ngardok Lake: suggested site boundary (for discussion). Note that this differs from the boundary of the Nature Reserve.

(Image from Google Earth)



Note: Type Tp applies to both the pond/lake water, and the marshes around it (sedges and *Hanguana malayana*). Also, if deposits of peat (partly-decomposed organic matter) form a significant part of the substrate to the wetlands, one or more different and additional wetland types (U: Non-forested peatlands; Xp: peat-swamp forests) may also be applicable.

Aerial view of Ngardok Lake (Photo: P. Colin, CRRF – from signboard)

Freshwater marsh with *Pandanus*, downstream of Ngardok Lake
(Photo: R. Jaensch)

F. Geomorphic setting:

Elevation: The lake is at 30 m (96 feet) above sea level.

The site is on volcanic geology (USDA 1983). The lake is situated in undulating upland, within a small river valley of variable width. There is a suggestion that Lake Ngardok was originally created by a natural dam formed by deposits of clay eroded during heavy rains (Republic of Palau 2012).

G. Biogeographic region:

West Caroline Islands Freshwater Ecoregion (Abell *et al.* 2008).

H. Climate:

Palau's climate is humid subtropical with annual rainfall averaging 3810 mm per year (Ketebengang and Gupta 2011); rainfall is relatively even across the months. Mean daily temperature is 27oC (80oF). Rainfall and thus water levels may be lower during drought which occurs occasionally under El Nino conditions. Palau historically has experienced direct typhoon impacts once every 20 years; however, destructive typhoons occurred both in 2012 (Bopha) and 2013 (Haiyan).

I. Soil:

Soils are deep, poorly drained and from highly weathered volcanic material. When washed into the water, they remain suspended, making the water cloudy. Also, it is possible that deposits of peat (partly-decomposed organic matter) form a significant part of the substrate to the wetland.

J. Water regime:

The lake 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 in the lake area. Water is permanent and normally is about 7.5 metres (25 feet) deep though some sources advised a depth of only 15 feet. The level can rise by 0.5-1.0 metres (about 2-3 feet) for short periods after heavy rain. Water outflows from the southern end of the lake via Ngerdorch River to the sea, a distance of about 12 km (7.4 miles); in August 1999, Jenkins (1999) recorded flow rates of 0.16 to 0.30 m/s in the river. Water in swamps in the southern part of the site is 1 to 3 m (3 to 10 feet) deep (Bright 1979).

Water quality testing has been performed by the Palau Environmental Quality Protection Board, but the USGS study in 1996 is the most comprehensive water quality study available. This study estimated the lake's volume to be about 34 million gallons (128,000 cubic meters) although other studies estimated the volume to be smaller (e.g. US Army 1956). Also through this study, rainfall and lake-elevation data collected from April 1996 to March 1998 indicated that lake levels correlated to rainfall values with lake elevation rising rapidly in response to heavy rainfall and then returning to normal levels within a few days.

K. Water chemistry:

The lake holds fresh water. In August 1999, Jenkins (1999) recorded pH in the outflow river of 7.6 to 7.7 and water temperature of 26.5 to 27.1 C; Brazaitis et al. (2009) recorded pH of 6.5 at the lake mouth. Temperature and dissolved oxygen measurements indicated that Lake Ngardok is stratified (Yeung and Wong 1999). Given that air temperature on Palau exhibits little seasonal variation, it is likely that this pattern of stratification is persistent. As a result, complete mixing of the lake is probably rare. Near

anaerobic conditions exist at the lake bottom and low dissolved oxygen (3.2 milligrams per L) was measured at the outflow (Yeung and Wong 1999). The USGS water quality monitoring equipment is no longer functioning and is beyond repair (Booth, 2007).

L. Biota:

The lake supports a variety of freshwater aquatic plants with very restricted distribution in Palau. The natural marsh vegetation is composed of sedges, notably *Sceleria laevis*, the broad-leaved aquatic plant *Hanguana malayana*, grasses and other sedges (Republic of Palau 2012). The *Hanguana* forms broad floating mats on the lake surface, which occupy the greater part of some embayments.

Floating beds of *Hanguana*, Ngardok Lake (Photo: R. Jaensch)

Swamp forest is dominated by *Campnostemon* and *Pandanus* species; small specimens of these are encroaching into marsh areas, presumably as part of the natural succession in these wetlands. Some areas of upland forest, up to 20 m (70 feet) high, occur beside the lake. Costion (2008) described the Reserve as a “hotspot” for native vegetation in Micronesia with a native vascular plant species count of approximately 724 species with high orchid diversity, important *Pandanus* marsh and the presence of the uncommon endemic *Rauvolfia insularis* tree (Kitalong and Holm 2004).

The lake supports a small breeding population of estuarine crocodile *Crocodylus porosus*; females reputedly use Ngerdorch River to access the sea whereas males may travel overland by the relatively short (1.5 km = 0.9 miles) and most direct route (Brazaitis 1998; Reserve Manager, pers. com.). Nests have not been found recently but evidence of eggs has been noted near the lake edge (Reserve Manager, pers. com., 2014). Brazaitis (1998) reported that the peak breeding, reproduction, and dispersal season was during the rainy months from June to September. In a 1991 survey, 17 crocodiles were recorded in the lake (Messel and King 1991) but only three were found in a 2003 survey, all in the 1.2 m class, and capacity to support large crocodiles was determined to be limited (Brazaitis et al. 2009). Site managers consider that only one or two large crocodiles inhabit the lake.

Waterbirds known to occur in the lake include the Common Moorhen *Gallinula chloropus* (Caroline-Marianas population), which is vulnerable to extinction in Palau on account of its small numbers and scarce habitat; more than 50 occur in the lake, which is the largest sub-population in Palau and breeding possibly still occurs (Pratt and Etpison 2008). Others include the Asian migrant Yellow Bittern *Ixobrychus sinensis* and the resident White-browed Crake *Porzana cinerea*. Some Purple Swamphen *Porphyrio porphyrio pelewensis* presumably also occur; this population is endemic to Palau. The Pacific Black (Grey) Duck *Anas superciliosa pelewensis* may have occurred at the lake in the past.

Fishes recorded from the site include *Ophisternon bengalense*, two gobies *Redigobius* sp. and *Sicyopterus* sp., *Kuhlia rupestris* and *Puntius seali*; also the introduced poeciliid *Xiphophorous maculatus* which was introduced during the Japanese occupation (1914-1944) for mosquito control (Jenkins 1999). According to Nature Reserve staff, freshwater eels apparently also occur in the lake.

Bright (1979) gives a list of insects, water mites, crustaceans and molluscs found in the lake.

M. Land use:

Apart from some 'savannah' areas (ferns, grass, small shrubs) created by past clearing for cultivation, the lake and surrounding areas remain in a near-natural condition, and there is no ongoing cultivation in the area. This is ensured by the existence of the nature reserve (Conservation Area).

Water is pumped from the outflow river at a site 2.6 km (1.6 miles) downstream of the lake and 0.5 km (0.3 miles) upstream of the Compact Road, to supply Melekeok and Ngchesar States. Water levels at the pumping site have become low during droughts.

N. Pressures and trends:

Nearby areas are occasionally subject to burning during the dry season. Some invasive plants species (e.g. Singapore daisy *Sphagneticola trilobata*, and the legume *Leucaena leucocephala*) occur around the entrance road to the site and managers need to prevent them entering the wetland area and its buffer zone. Water hyacinth *Eichhornia crassipes* and Tilapia are present elsewhere in Palau and would have devastating impacts if allowed to enter the Ngardok Lake system.

A study of the changes in the extent of *Hanguana malayana* in 2003 indicated that the extent had increased between 1992 and 2003, reducing the surface area of the lake (Ongalibang, 2003). It is unclear by how much the surface area of the lake has been reduced but USGS (1999) estimated that *Hanguana* covered about 58 per cent of the surface area of the lake (Yeung and Wong 1999). The cause of its spread is not currently known.

The Lake catchment is vulnerable to erosion, and there are several areas where erosion is a major concern. Severely eroded areas do not allow native plants to grow and when soils are disturbed, rain washes silt into the lake, the river below and out to the sea. This compromises the quality of the water for human consumption and will gradually fill in the lake and reduce its capacity to store water.

O. Land tenure and administrative authority:

Land tenure: Owned by the Government of Melekeok State and local Chiefs.
Administrative authority: Melekeok State Government.

P. Ramsar listed?

Yes: Lake Ngardok Nature Reserve was designated in 2003 as Palau's first Ramsar site. The Ramsar listed area covers 500 ha (Republic of Palau 2012). The inventory site is mostly (if not totally) within the Ramsar site boundary.

Q. Ramsar Criteria met:

Criterion 1. Contains a representative, rare, or unique example of a natural or near-natural wetland type found within the appropriate biogeographic region.
Criterion 3. Supports populations of plant and/or animal species important for maintaining the biological diversity of a particular biogeographic region.
Criterion 4. Supports plant and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions.

R. Justification for Ramsar Criteria met:

The following information applies to the site as defined and mapped for the inventory.

Criterion 1: The site is a good representative example of a wetland type (freshwater ponds: Type Tp) that is rare in the West Caroline Islands Freshwater Ecoregion; it also includes good representative examples of freshwater swamp forest (Type Xf). It is one of only two significant, natural freshwater ponds in Palau (the other being Ngerkall Pond), with rich aquatic vegetation still in an almost undisturbed condition. The site's integrity is enhanced by the protection of its catchment in a nature reserve.
Criterion 3: The site supports a variety of freshwater aquatic plants such as *Hanguana malayana* with very restricted distribution in Palau, and thus the whole West Caroline Islands Freshwater Ecoregion. *Pandanus kanehirae* is threatened by swamp conversion in Palau and substantial stands occur in the site, especially downstream of the lake (A. Kitalong pers.com.). The site supports a subspecies of Purple Swamphen *Porphyrio porphyrio pelewensis*, which is endemic to Palau (Pratt and Etpison 2008) and thus to the bioregion. The site is important to maintaining the viability of crocodilians as a component of the biota of the bioregion (West Caroline Islands Freshwater Ecoregion and West Caroline Islands Marine Ecoregion).
Criterion 4: The site supports breeding by the estuarine crocodile and thus is important for viability of the species in Palau and thus the bioregion. The outflow river is in the site and this is a vital migration corridor for crocodiles and fishes between the lake and the sea, enabling them to complete their life cycles.

S. Conservation and management status of the wetland:

The Lake Ngardok Nature Reserve was established in 1997; this was an offset/mitigation measure for construction of the Compact Road. Now a Conservation Area, it protects the lake's catchment (watershed) and most of the downstream areas upriver of the Compact Road. The site is in a no-take zone where no products may be harvested. Ngardok is Palau's first Ramsar Site.

T. Ecosystem services:

Water supply: The Ngardok Lake catchment area supplies water to a large part of the eastern side of Babeldaob, including the States of Ngchesar and Melekeok. During periods of severe drought in the past, people from all over Babeldaob came to Ngardok Lake for drinking water. Water is pumped from a deep hole in the downstream part of the site, upstream of the Compact Road.

Water quality: the lake and its swamp vegetation trap sediments that might otherwise continue downstream.

Flood control: The lake plays a role in natural flood control in the Ngerdorech valley.

Groundwater recharge: The lake may assist in the recharge of groundwater.

Recreation / Tourism: A nature trail runs through the site, maintained by the State. Interpretive signs are installed. A shelter is situated beside the lake.

Cultural values: Lake Ngardok has a long history of importance to the people of Melekeok and the neighbouring States. Legends about the lake's creation and stories about its use date back many generations. It could well have been used for water supply during times of extreme drought for as long as people have lived in Babeldaob. Some people have said that the name *Ngardok* originally came from the words *ngar* (living) and *dok* (a spring); hence, the name *ngardok* means "living spring".

Carbon sink: the forests of the site trap carbon.

U. Current recreation and tourism:

There is a visitor reception area and an interpretive sign and a nature trail runs through the site; some of these were established in 2008. A shelter and floating platform have been built on the edge of the lake and there are plans to clear *Hanguana* in front of the shelter, build more walkways and add more interpretive signs. Visitor numbers presently are fairly low but there is insufficient capacity to manage larger numbers.

The scenic qualities of Ngardok Lake attract visitors (Photo: R. Jaensch)

V. Existing scientific research:

A study was conducted on the spread of *Hanguana* in the lake (Ongalibang 2003).

W. Management plans and monitoring programs:

Even before Ramsar-listing, the people of Melekeok State were involved in managing the lake (A. Kitalong pers. com.). There is now a management plan, which is overseen by the State of Melekeok; the current version covers 2011 to 2016. Any major change to the plan requires a public meeting.

Melekeok State Public Law (MSPL) 4-21 establishing the Ngardok Nature Reserve (amended in 1999 to MSPL 4-32) prohibits entry without a permit, hunting, fires, camping and littering within the reserve. There is a site manager and a team of about 13 staff – mainly local people – involved in site management including revegetation of eroded areas. Hunters are prohibited and burning of the savannah is controlled. Some *Hanguana* was removed from the lake by cutting and dragging it out. Visitors pay an entrance fee which helps with the management budget; the national tourist Green Fee also contributes. Ngardok Lake is a site in the National Program for Monitoring Forest and Coastal Birds (Olsen and Eberdong 2013).

X. Current communication and public education programs:

A factsheet was produced by Palau Conservation Society for the site. The lake is visited by students and other individuals wishing to study its flora and fauna, and thus has considerable value for conservation education.

Y. References cited:

Abell, R., Thieme M., Revenga C. et al. 2008. Freshwater ecoregions of the world: a new map of biogeographic units for freshwater biodiversity conservation. BioScience 58, 403–414.

Booth, S. 2007. EU-SOPAC (EDF9) Project Report 82: Reducing Vulnerability of Pacific ACP States; Republic of Palau Technical Mission Report; KRA 2 (Water) Mission Report.

Brazaitis, P. 1998. Investigations and recommendations for the development and implementation of a safe access corridor for the dispersal of saltwater crocodiles, *Crocodylus porosus*, between nesting habitats at the Lake Ngardok conservation area and coastal mangrove habitats. Report to the US Fish and Wildlife Service.

Brazaitis, P, Eberdong, J, Brazaitis, PJ and Watkins-Colwell, GJ. 2009. Notes on the saltwater crocodile, *Crocodylus porosus*, in the Republic of Palau. Bulletin of the Peabody Museum of Natural History 50: 27-48.

Bright, GR. 1979. The inland waters of Palau, Caroline Islands. Office of the Chief Conservationist, TTPI, Koror, Palau, Unpublished Manuscript.

Costion, C. 2008. Appendix 3: Locally important forest sites and Protected Area Network considerations. Unpublished thesis draft.

Jenkins, AP. 1999. A preliminary investigation of the freshwater ichthyofauna of the Ngardok Lake and Ngeremeduu Bay watersheds, Palau. Wetlands International – Oceania, 9 pp.

Ketebengang, H and Gupta, A. 2011. State of Palau's Birds 2010. A conservation guide for communities and policymakers. Palau Conservation Society. 23 pp.

Kitalong and Holm. 2004. [details not available]

Messel, H and King, FW. 1991. Survey of the crocodile populations of the Republic of Palau, Caroline Islands, Pacific Ocean, 8-24 June 1991. Report to the Government of Palau.

Olsen, AR and Eberdong, M (eds.) 2013. State of Palau's Birds 2012. Belau National Museum, Koror. 22 pp.

Ongalibang, O. 2003. Internship experience report on Ngardok Lake Project, Republic of Palau, June 08-August 12, 2003. Report to the Micronesian and American Samoa Student Internship Program and Institute of Pacific Island Forestry in Hawaii.

Pratt, HD and Etpison, MT. 2008. Birds and Bats of Palau. Mutual Publishing, Honolulu, 290 pp.

Republic of Palau. 2012: Lake Ngardok Nature Reserve. Downloaded October 2014: https://rsis.ramsar.org/RISapp/files/RISrep/PW1232RIS.pdf

Spalding M.D., Fox H.E., Allen G.R., Davidson N., Ferdaña Z.A., Finlayson M., Halpern B.S., Jorge M.A., Lombana A., Lourie S.A., Martin K.D., McManus E., Molnar J., Recchia C.A., Robertson J. 2007. Marine Ecoregions of the World: a bioregionalization of coast and shelf areas. BioScience 57: 573-583.

United States Army. 1956. Military Geology of Palau Islands, Caroline Islands. [May also refer to Anon (1956) and Corwin et al. (1956).]

USDA. 1983. Soil survey of islands of Palau, Republic of Palau. USDA Soil Conservation Service.

Yeung, CW and Wong, MF. 1999. Storage Capacity and Water Quality of Ngerdok Lake, Babeldaob Island, Republic of Palau, 1996-1998. US Geological Survey.

Z. Compilers:

Original compilers (for 1993 edition): Demei O. Otobed
Updated by: Pua Michael and Roger Jaensch, May 2014

3.5 Ngerdorech (Ngetkebau) River

A. Overview:

The lower reaches of the Ngerdorech (Ngetkebau) River, connected freshwater swamps and lowland swamp forest, and associated mangrove forest in the estuary.

B. Area, boundary and dimensions:

Area: 82.6 ha (polygon area using Google Earth Pro).
The site extends from the sea mouth of Ngerdorech River, upriver about 4.5 km (2.8 miles) to the Compact Road bridge. It includes mangrove forests and associated swamps and swamp forests on either side, to their high water marks. Upriver of where the swamps end, a buffer of about 50 m (164 feet) has been added either side of the river channel. Open marine areas are not included in this site. The site is about 5.5 km (3.4 miles) south-south-west of the southern end of the Ngardok Lake site.
Dimensions: the site is roughly 2.7 km (3.3 miles) long, in a straight line, and varies from 100 m (328 feet) wide in the upper reaches to 450 m (1476 feet) wide at the sea edge.

C. Location:

Coordinates: 7°26'N, 134°35'E (Limits of site: 7°25'-27'N, 134°34'-35'E.)
On the east coast of Babeldaob Island, 16 km (9.9 miles) north-east of the Koror urban area, and south-west of Galakasan village.
State: Ngchesar State.

D. Site Maps: See below.

The site boundary shown in this update serves to define the scope of information in the site account and has no legal status. It is provisional and subject to further discussion.

E. Ramsar Wetland Types:

Dominant wetland types:
- F: Estuarine waters (permanent water of estuaries).
- I: Intertidal forested wetlands (mangrove swamps, tidal freshwater swamp forests).
- M: Permanent rivers/streams/creeks (includes waterfalls).
- Xf: Freshwater, tree-dominated wetlands (includes freshwater swamp forests, on inorganic soils).

Other types present:
- Human-made Type 3: Irrigated land (taro swamps).

Note: The site may include marshy, non-forested freshwater swamps (marshes: wetland Type Ts) as well as forested swamps. Perhaps the only non-forested swamps are taro gardens, but these have their own Type (Human-made 3); this issue may also apply to some other sites in Palau.

Location of Ngerdorech (Ngetkebau) River (Image from Google Earth)

Ngerdorech (Ngetkebau) River: suggested site boundary (for discussion)
(Image from Google Earth)

Ngerdorech (Ngetkebau) River: suggested site boundary (for discussion) (Image from Google Earth)

F. Geomorphic setting:

Elevation: From sea-level to a few metres above sea level.
Geology: of volcanic origin. The site lies in undulating topography that becomes flatter as the river nears its sea mouth.

G. Biogeographic region:

West Caroline Islands Marine Ecoregion (Spalding *et al.* 2007).

H. Climate:

Palau's climate is humid subtropical with annual rainfall averaging 3810 mm per year (Ketebengang and Gupta 2011); rainfall is relatively even across the months. Palau historically has experienced direct typhoon impacts once every 20 years; however, destructive typhoons occurred both in 2012 (Bopha) and 2013 (Haiyan). Rainfall and thus water levels may be lower during drought which occurs occasionally under El Nino conditions.

I. Soil: The soils are of volcanic origin (USDA 1983).

J. Water regime:

The Ngerdorech River is one of the largest rivers in Palau. It originates at Ngardok Lake and empties on to the inner reef flats on the east coast of Babeldaob. The site includes freshwater through to tidal regimes. The mangrove forests are affected by tides, which have a range of about 2.0 m (6.5 feet).

K. Water chemistry: Some parts of the area are brackish.

L. Biota:

The site supports a diverse wetland flora including many of Palau's endemic species and most of the mangrove plant species occurring in the Western Caroline Islands.

Estuarine crocodiles *Crocodylus porosus* and dog-faced snake *Cerberus rhyncops* occur in the site; also Palau fruit bats *Pteropus pelewensis*.

The wetland also supports a wide variety of forest birds, waterbirds, fishes, crabs and bivalves.

M. Land use:

Parts of the freshwater swamp wetlands are utilized for the cultivation of taro. Other activities include the cutting of timber, hunting, fishing and the gathering of medicines and edible plants.

Small farms occur near (but outside) the margins of some of the upper reaches of the river in this site.

N. Pressures and trends:

During the construction of the Compact Road, this river would have been impacted in several ways, especially by greatly increased sedimentation. Other present or potential

impacts in or surrounding the site are increased farming activities; over-exploitation of timber and excessive hunting.

O. Land tenure and administrative authority:

Land tenure: The mangrove forest and other parts of the swamp are owned by Ngchesar State and the local Chief. Taro patches in the freshwater swamps are privately owned.
Administrative authority: Ngeschar State.

P. Ramsar listed? No.

Q. Ramsar Criteria met:

Criterion 1. Contains a representative, rare, or unique example of a natural or near-natural wetland type found within the appropriate biogeographic region.
Criterion 3. Supports populations of plant and/or animal species important for maintaining the biological diversity of a particular biogeographic region.
Criterion 4. Supports plant and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions.
Criterion 8: The streams, mangroves, lagoons and reefs of the site provide substantial stocks of fish and other marine resources on which local people depend.

R. Justification for Ramsar Criteria met:

Criterion 1: The site includes good representative examples of several wetland types that are characteristic of the West Caroline Islands Freshwater Ecoregion: notably, mangrove swamps (Type I), and estuarine waters (F).
Criterion 3: The site is important for maintaining crocodilians as a component of biodiversity in the West Caroline Islands Freshwater Ecoregion.
Criterion 4: The site is part of a migration pathway for crocodiles, eels and other fishes between the sea and Ngardok Lake, a Ramsar site. The mangroves are important nursery areas for fishes, crustaceans and other marine organisms.
Criterion 8: The site is a source of fish and crustacean stocks upon which local people depend for their subsistence. Harvested species that breed in the mangroves and are harvested in the reefs include rabbitfish *Siganus fuscescens* and *S. lineatus*.

S. Conservation and management status of the wetland:

No conservation designations apply to the site at present.

T. Ecosystem services:

Water supply: The river is an important source of water for Ngersuul village.
Sediment removal: The wetland system protects the adjacent reef flats from siltation by trapping sediments carried down by the river.
Timber supply: The mangrove forests provide a valuable source of timber to local people.
Food supply: The estuary is an important fishing ground for local people and parts of the wetland system are important for the cultivation of taro.
Biochemical products: traditional medicines are obtained from the wetland forests.
Hazard reduction: the mangroves protect the shoreline from damage from storm surges.
Recreation and tourism: commercial boat tours for tourists operate in the river, with feeding of wild crocodiles.

Transport route: The river is navigable for some distance inland (at east as far as the Compact Road), and thus is important for transportation.
Carbon sink: the forests of the site store large quantities of carbon.

U. Current recreation and tourism:

Jungle River Boat Tours operates commercial boat tours for tourists in the river, including feeding of wild crocodiles. The boats enter the river near the Compact Road and travel all the way to the bay and back.

V. Existing scientific research: None at present.

W. Management plans and monitoring programs: None at present.

X. Current communication and public education programs:

The site has considerable potential for conservation education.

Y. References cited:

Ketebengang, H and Gupta, A. 2011. State of Palau's Birds 2010. A conservation guide for communities and policymakers. Palau Conservation Society. 23 pp.
Spalding M.D., Fox H.E., Allen G.R., Davidson N., Ferdaña Z.A., Finlayson M., Halpern B.S., Jorge M.A., Lombana A., Lourie S.A., Martin K.D., McManus E., Molnar J., Recchia C.A., Robertson J. 2007. Marine Ecoregions of the World: a bioregionalization of coast and shelf areas. BioScience 57: 573-583.
USDA. 1983. Soil survey of islands of Palau, Republic of Palau. USDA Soil Conservation Service.

Z. Compilers:

Original compilers (for 1993 edition): Demei O. Otobed
Updated by: Pua Michael and Roger Jaensch, May 2014

3.6 Ngerikiil River

A. Overview:

The estuary and lower reaches of the Ngerikiil River, together with associated, high-canopy swamp forest, freshwater swamps and mangrove forests.

B. Area, boundary and dimensions:

Area: 102 ha (polygon area using Google Earth Pro).
The site comprises the channel of the Ngerikiil River from its sea mouth upriver to the Compact Road; a distance of about 2.1 km (1.3 miles). It also includes swamp forests, freshwater swamps and mangroves associated with the river, to the high water mark. The site extends fully across the northern shores of Airai Bay into which the river empties. There is a buffer of about 50 m (164 feet) either side of the channel upstream of the limit of fringing swamps.
Direct distance between the extremities of the site is about 2.5 km (1.6 miles).

C. Location:

Coordinates: 7°22'N, 134°33'E
At the south end of Babeldaob Island, 10 km (6.2 miles) north-east of the Koror urban area. The south-west corner of the site is about 1.0 km (0.6 miles) east of the eastern end of the runway of the international airport.
State: Airai.

D. Site Maps: See below

The site boundary shown in this update serves to define the scope of information in the site account and has no legal status. It is provisional and subject to further discussion.

E. Ramsar Wetland Types:

Dominant wetland types:
- F: Estuarine waters (permanent water of estuaries).
- I: Intertidal forested wetlands (mangrove swamps, tidal freshwater swamp forests).
- M: Permanent rivers/streams/creeks (includes waterfalls).
- Xf: Freshwater, tree-dominated wetlands (includes freshwater swamp forests, on inorganic soils).

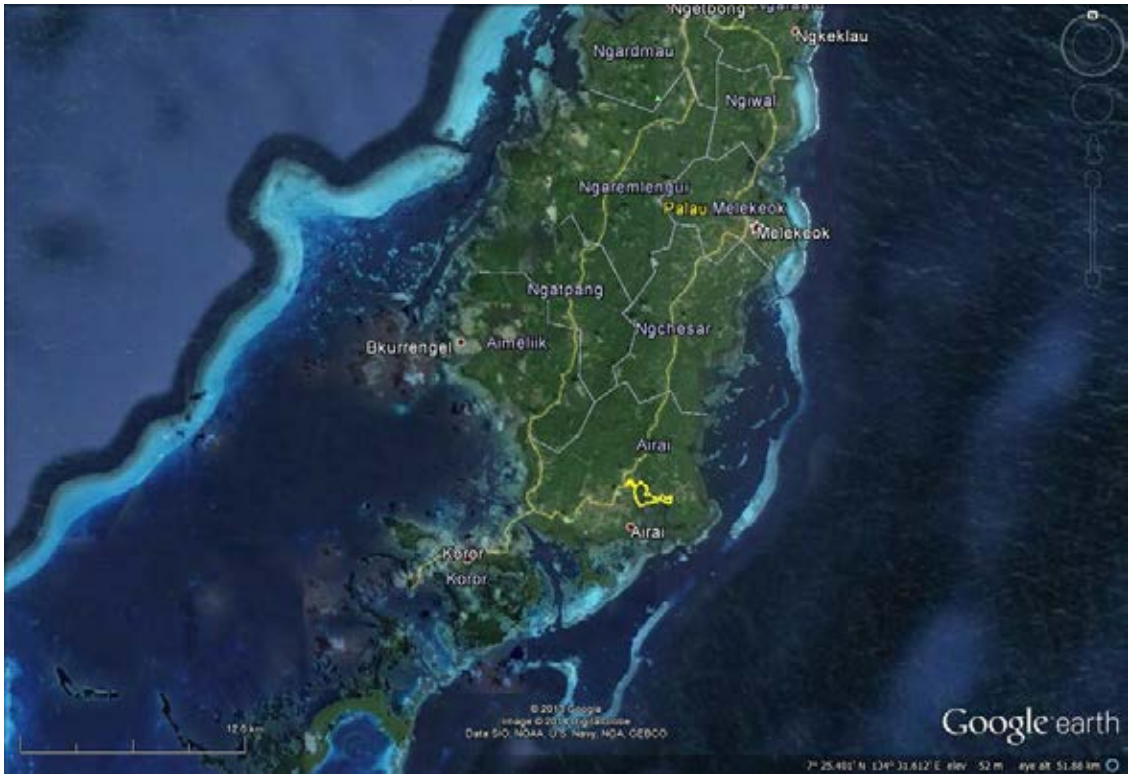
Other types present:
- Human-made Type 3: Irrigated land (taro swamps).

Note: The site may include marshy, non-forested freshwater swamps (marshes: wetland Type Ts) as well as forested swamps. Perhaps the only non-forested swamps are taro gardens, but these have their own Type (Human-made 3); this issue may also apply to some other sites in Palau.

F. Geomorphic setting:

Elevation: Sea level to slightly above sea level.
Geology: of volcanic origin. The site is situated in mostly-flat lowlands.

Location of Ngerikiil River (Image from Google Earth)



Ngerikiil River: suggested site boundary (for discussion)

(Image from Google Earth)

Ngerikiil River: suggested site boundary (for discussion)

(Image from Google Earth)

G. Biogeographic region:

West Caroline Islands Marine Ecoregion (Spalding *et al.* 2007).

H. Climate:

Palau's climate is humid subtropical with annual rainfall averaging 3810 mm per year (Ketebengang and Gupta 2011); rainfall is relatively even across the months. Palau historically has experienced direct typhoon impacts once every 20 years; however, destructive typhoons occurred both in 2012 (Bopha) and 2013 (Haiyan). Rainfall and thus water levels may be lower during drought which occurs occasionally under El Nino conditions.

I. Soil: The soils are of volcanic origin (USDA 1983).

J. Water regime:

The site comprises the lower portion of the Ngerikill River and its estuarine system in Airai Bay. The river is permanent and the site includes freshwater, through tidal, to marine regimes; the mangrove forests are affected by the tides (range: 2.0 m).

K. Water chemistry: Some parts of the area are brackish.

L. Biota:

The site supports a diverse wetland flora including many of Palau's endemic species and most of the mangrove plant species occurring in the Western Caroline Islands.

Estuarine crocodiles *Crocodylus porosus* and dog-faced snake *Cerberus rhyncops* occur in the site; also Palau fruit bats *Pteropus pelewensis*.

The wetland also supports a wide variety of forest birds, waterbirds, fishes, crabs and bivalves. Birds recorded here include Rufous Night-Heron *Nyctixorax caledonicus* and Purple Swamphen *Porphyrio porphyrio pelewensis* (Olsen and Eberdong 2013).

M. Land use:

Land use within the site includes cultivation of taro, hunting and fishing, the cutting of timber, and the gathering of natural medicines.

Much of the surrounding area has been developed for farming and an international airport is close by. Water for supply to Airai State is pumped from the river upstream of the Compact Road bridge, outside the site.

N. Pressures and trends:

Parts of the wetland have been reclaimed for agriculture (taro gardens), 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 impacts. Mangroves have grown outwards from the mouth of the river over the 54 years to year 2000, probably due to increased sedimentation, which has formed a mud delta in the bay (Colin 2009). This has also eliminated living corals from the northern part of Airai Bay (Colin 2009).

O. Land tenure and administrative authority:

Land tenure: The Airai State Government and local Chiefs hold title to most of the area.
Administrative authority: Airai State.

P. Ramsar listed? No.

Q. Ramsar Criteria met:

Criterion 1. Contains a representative, rare, or unique example of a natural or near-natural wetland type found within the appropriate biogeographic region.
Criterion 3. Supports populations of plant and/or animal species important for maintaining the biological diversity of a particular biogeographic region.
Criterion 4. Supports plant and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions.
Criterion 8: The streams, mangroves, lagoons and reefs of the site provide substantial stocks of fish and other marine resources on which local people depend.

R. Justification for Ramsar Criteria met:

Criterion 1: The site includes good representative examples of several wetland types that are characteristic of the West Caroline Islands Freshwater Ecoregion: notably, mangrove swamps (Type I), and estuarine waters (F).
Criterion 3: The site is important for maintaining crocodilians as a component of biodiversity in the West Caroline Islands Freshwater Ecoregion. The site apparently supports Purple Swamphen *Porphyrio porphyrio pelewensis* which is endemic to Palau.
Criterion 4: The mangroves are important nursery areas for fishes, crustaceans and other marine organisms.
Criterion 8: The site supports fish and crustacean stocks on which local people depend for their subsistence. Harvested species that breed in the mangroves and are harvested in the reefs include rabbitfish *Siganus fuscescens* and *S. lineatus*.

S. Conservation and management status of the wetland:

Much of the mangrove forest east of the river mouth is within the Oikull Mangrove Conservation Area (0.78 km2), established in 2002; it is zoned for traditional and educational purposes (Colin 2009).

T. Ecosystem services:

Food supply: The estuary is an important fishing ground for local people and parts of the wetland are important for the cultivation of taro.
Biochemical products: traditional medicines from mangroves and swamp forest.
Hazard reduction: the mangroves protect the shoreline from storm surge.
Maintaining water quality: The mangrove and swamp forests trap silt carried down by the river, thereby protecting the adjacent lagoon and reefs.
Coastal protection: The mangrove forest prevents coastal erosion and provides protection against tropical storms.
Cultural heritage: There are some sites of archaeological interest in the wetland.
Carbon sink: the forests of the site store large quantities of carbon.

U. Current recreation and tourism: No recent information.

V. Existing scientific research: See item W below.

W. Management plans and monitoring programs:

A management plan presumably exists for the Oikull Conservation Area (required for designation of the CA under the Protected Area Network Act 2003).

A monitoring site for birds is in or near the lower reaches of Ngerikiil River, as part of the National Program for Monitoring Forest and Coastal Birds (Olsen and Eberdong 2013). Such sites, also one in the upper reaches, were established in the first instance as part of the UNDP Integrated Water Resources Initiative to monitor water quality in catchment for the water supply of Airai and Koror States (Olsen and Eberdong 2013).

X. Current communication and public education programs:

None at present. The site has considerable potential for conservation education as it is located close to Koror and can be approached by land transportation.

Y. References cited:

Colin, P. 2009. Marine Environments of Palau. Coral Reef Research Foundation, Koror, Palau. Mutual Publishing and Indo-Pacific Press, San Diego. 414 pp.

Ketebengang, H and Gupta, A. 2011. State of Palau's Birds 2010. A conservation guide for communities and policymakers. Palau Conservation Society. 23 pp.

Olsen, AR and Eberdong, M (eds.) 2013. State of Palau's Birds 2012. Belau National Museum, Koror. 22 pp.

Pratt, HD and Etpison, MT. 2008. Birds and Bats of Palau. Mutual Publishing, Honolulu, 290 pp.

Spalding M.D., Fox H.E., Allen G.R., Davidson N., Ferdaña Z.A., Finlayson M., Halpern B.S., Jorge M.A., Lombana A., Lourie S.A., Martin K.D., McManus E., Molnar J., Recchia C.A., Robertson J. 2007. Marine Ecoregions of the World: a bioregionalization of coast and shelf areas. BioScience 57: 573-583.

USDA. 1983. Soil survey of islands of Palau, Republic of Palau. USDA Soil Conservation Service.

Z. Compilers:

Original compilers (for 1993 edition): Demei O. Otobed
Updated by: Pua Michael and Roger Jaensch, May 2014

3.7 Ngerimel River

A. Overview:

The estuarine reaches of the Ngerimel River, and a larger area of associated mangrove forest and adjoining fringing flat, coral reef and lagoon, as well as adjoining freshwater swamps that are cultivated as taro gardens.

B. Area, boundary and dimensions:

Area: 281 ha (polygon area using Google Earth Pro).

The site is based on the estuarine reaches of the Ngerimel River, downstream of the road bridge, and its associated wetlands. From the bridge, the site boundary follows the high water mark to a point 830 m (2720 feet) south-west of the bridge, then runs due south to the edge of the bay; then the boundary follows the outer edge of the fringing flat east and south to the southernmost point of the Ngerimel Mangrove Conservation Area (part way along the prominent limestone ridge that is enclosed by the site); from that point the site boundary follows the Conservation Area boundary east and north, past a tidal creek mouth, to a minor road that traverses the mangroves, near Yelch village; the site boundary returns westwards along the high water mark to the starting point (the bridge), except where it extends northwards up to 600 m (1970 feet) to include an extensive area of taro swamp gardens between the Airai road and the airport's western end. The site closely relates to the area shown in the photograph in Figure 17.6 of Colin (2009).

Dimensions: up to 2.7 km long and 2.1 km wide (1.7 by 1.3 miles).

C. Location:

Coordinates: 7°21'N, 134°31'E

At the south end of Babeldaob Island, 5 km (3.1 miles) east of Koror urban area; near Ngeruluobel village, south-west of the international airport, between Airai village and the road bridge to Koror.

State: Airai.

D. Site Maps: See below

The site boundary shown in this update serves to define the scope of information in the site account and has no legal status. It is provisional and subject to further discussion.

E. Ramsar Wetland Types:

Dominant wetland types:

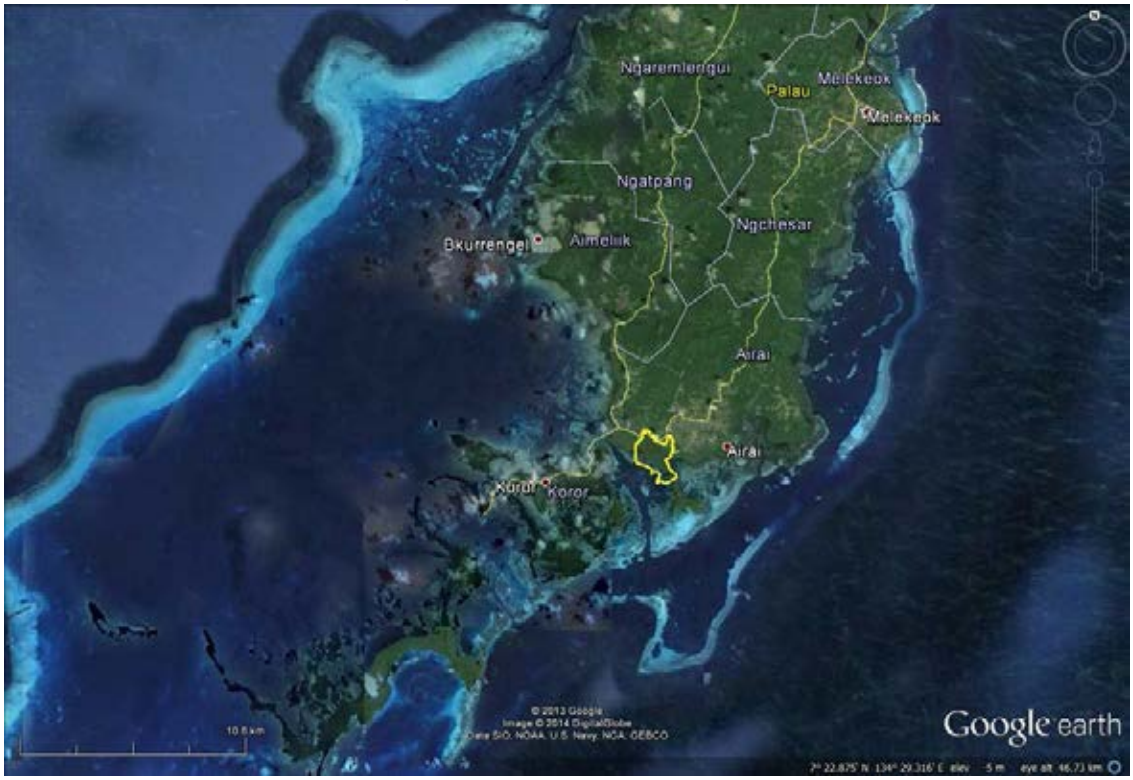
- A: Permanent shallow marine waters in most cases less than six metres deep at low tide.
- C: Coral reefs.
- F: Estuarine waters (permanent water of estuaries).
- I: Intertidal forested wetlands (mangrove swamps, tidal freshwater swamp forests).

Other types present:

- G: intertidal mud flats.
- Human-made Type 3: irrigated ponds (taro swamps).

Note: the site possibly also includes some seagrass beds (Type B), or swamp forest (Type Xf): to be investigated.

Location of Ngerimel River (Image from Google Earth)



Ngerimel River: suggested site boundary (for discussion)

(Image from Google Earth)

Ngerimel River: suggested site boundary (for discussion) (Image from Google Earth)

F. Geomorphic setting:

Elevation: Sea-level to slightly above sea-level.
Geology: probably of volcanic origin at the inland edges but dominated by limestone inside the site. Mostly flat lowland but a narrow high ridge (island) of limestone, with many small outcrops, runs along the interior of the site.

G. Biogeographic region:

West Caroline Islands Marine Ecoregion (Spalding *et al.* 2007).

H. Climate:

Palau's climate is humid subtropical with annual rainfall averaging 3810 mm per year (Ketebengang and Gupta 2011); rainfall is relatively even across the months. Palau historically has experienced direct typhoon impacts once every 20 years; however, destructive typhoons occurred both in 2012 (Bopha) and 2013 (Haiyan). Rainfall and thus water levels may be lower during drought which occurs occasionally under El Nino conditions.

I. Soil:

The soils are of limestone and volcanic origin (USDA 1983). Sediment derived from marine areas (coral fragments) lies on the fringing flat and mud derived from inland (volcanic) geology occurs at the river/creek mouths.

J. Water regime: Estuarine and nearshore marine. Tidal range is up to 1.7 m.

K. Water chemistry: Some estuarine parts of the area are brackish.

L. Biota:

The site supports a diverse wetland flora including many of Palau's endemic species and most of the mangrove plant species occurring in the Western Caroline Islands.

Estuarine crocodiles *Crocodylus porosus* and dog-faced snake *Cerberus rhyncops* occur in the site; also Palau fruit bats *Pteropus pelewensis*.

The taro swamp gardens of the site are renowned for supporting Purple Swamphen *Porphyrio porphyrio*, Buff-banded Rail *Gallirallus philippensis* and migratory shorebirds such as Swinhoe's Snipe *Gallinago megala* (Pratt and Etpison 2008).

The wetland also supports a wide variety of forest birds, other waterbirds, fishes, crabs and bivalves.

M. Land use:

All of the freshwater swamp in the north-east of the site is utilized, under a rotation system, for the cultivation of taro. Mangrove trees in the site are cut for timber and there is some hunting and fishing.

Surrounding areas are under cultivation or used for human settlement and infrastructure including highways.

Taro swamp gardens, Palau (Photo: R. Jaensch)

N. Pressures and trends:

The freshwater swamps (mostly converted to taro swamp gardens) and mangrove forest have been somewhat disturbed by human activities. The wetland site's hydrology has been affected by the construction of the Airai Reservoir upstream on Ngerimel River and there is a water pumping station downstream of the dam but also outside of the site. 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. An extensive mud delta has formed beyond the mouth of the creek entering the bay at the east side of the site and is presumed to be due to upland erosion from farming and urban development (Colin 2009). Some people live around the mouth of the river and a highway runs near the northern side of the wetland.

Note: some of the above pressures may have changed since completion of construction of the Compact Road.

O. Land tenure and administrative authority:

Land tenure: Mainly Ngeruluobel Hamlet, Airai State, with some private ownership. Marine areas are under State tenure.
Administrative authority: Airai State.

P. Ramsar listed? No.

Q. Ramsar Criteria met:

Criterion 1. Contains a representative, rare, or unique example of a natural or near-natural wetland type found within the appropriate biogeographic region.
Criterion 3. Supports populations of plant and/or animal species important for maintaining the biological diversity of a particular biogeographic region.
Criterion 4. Supports plant and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions.
Criterion 8: The streams, mangroves, lagoons and reefs of the site provide substantial stocks of fish and other marine resources on which local people depend.

R. Justification for Ramsar Criteria met:

Criterion 1: The site includes good representative examples of several wetland types that are characteristic of the West Caroline Islands Marine Ecoregion: notably, mangrove swamps (Type I) and fringing flats with coral (Types A, C).
Criterion 3: The site is important for maintaining crocodilians as a component of biodiversity in the West Caroline Islands Marine Ecoregion. The site includes an interesting freshwater swamp with a diverse flora rich in endemic species. The Purple Swamphen *Porphyrio porphyrio pelewensis* and Buff-banded Rail *Gallirallus philippensis pelewensis* are both subspecies that are endemic to Palau and thus the bioregion. Swamphens in Palau mainly occur in taro swamps, including the aggregation of taro swamps in the site (Pratt and Etpison 2008), which is one of the largest such aggregations in the country.
Criterion 4: The mangroves are important nursery areas for fishes, crustaceans and other marine organisms.
Criterion 8: The site supports stocks of fish and crustaceans that are harvested by local people. Harvested species that breed in the mangroves and are harvested in the reefs include rabbitfish *Siganus fuscescens* and *S. lineatus*.

S. Conservation and management status of the wetland:

The site encloses and is mostly covered by the Ngerimel Mangrove Conservation Area. This was set aside as an offset (mitigation) area for the development of a marina and commercial area on the north side of the Koror-Babeldaob bridge (Colin 2009).

Note: It has been assumed that Ngerimel Mangrove Conservation Area and Airai Mangrove Conservation Area are the same place.

T. Ecosystem services:

Food supply: The estuary is an important fishing ground for local people; many people live around the wetland and utilize its resources. The freshwater swamps are especially important for taro cultivation.
Materials supply: mangrove trees are used locally for timber.
Biochemical products: traditional medicines from the mangroves.
Maintaining water quality: The mangrove forest filters silt from run-off entering from the land, thereby protecting the reefs from being smothered by silt.
Coastal protection: The mangrove forest prevents coastal erosion and provides protection against tropical storms.
Carbon sink: the forests of the site store large quantities of carbon.

U. Current recreation and tourism: No information.

V. Existing scientific research: No information.

W. Management plans and monitoring programs:

All Conservation Areas are required to have a management plan before they are formally established (Protected Area Network Act 2003); status of the management plan for the Ngerimel Mangrove Conservation Area is not known.

X. Current communication and public education programs:

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.

Y. References cited:

Colin, P. 2009. Marine Environments of Palau. Coral Reef Research Foundation, Koror, Palau. Mutual Publishing and Indo-Pacific Press, San Diego. 414 pp.

Ketebengang, H and Gupta, A. 2011. State of Palau's Birds 2010. A conservation guide for communities and policymakers. Palau Conservation Society. 23 pp.

Pratt, HD and Etpison, MT. 2008. Birds and Bats of Palau. Mutual Publishing, Honolulu, 290 pp.

Spalding M.D., Fox H.E., Allen G.R., Davidson N., Ferdaña Z.A., Finlayson M., Halpern B.S., Jorge M.A., Lombana A., Lourie S.A., Martin K.D., McManus E., Molnar J., Recchia C.A., Robertson J. 2007. Marine Ecoregions of the World: a bioregionalization of coast and shelf areas. BioScience 57: 573-583.

USDA. 1983. Soil survey of islands of Palau, Republic of Palau. USDA Soil Conservation Service.

Z. Compilers:

Original compilers (for 1993 edition): Demei O. Otobed
Updated by: Pua Michael and Roger Jaensch, May 2014

3.8 Ngeremeduu Bay

A. Overview:

The Ngeremeduu Bay site is the largest inlet on the western side of Babeldaob. The site includes a large area of associated mangrove forest, swamp forest and riverine marshes, and contiguous inner fringing flat and lagoon immediately seaward of the bay mouth.

B. Area, boundary and dimensions:

Area: 1,752 ha (polygon area using Google Earth Pro). The enclosed inner bay comprises about 400 ha of open water.

The site comprises the entire interior of Ngeremeduu Bay, to the limits of tidal influence in the inflowing rivers and the high water mark of associated mangroves and swamp forests; extending also through the narrow gap to the marine lagoon and along the coast to Bkulangriil village in the north and Ngatpang village in the south; then seaward to beyond the outer edge of the fringing flat, to also include a parallel line of narrow reef flats (the seaward boundary of the site is thus about 1.0 km (0.6 miles) seaward of each village).

This site boundary matches the boundary of Ngeremeduu Conservation Area except that its extent in the marine lagoon is limited to just the inner fringing/reef flats.

The site is about 8 km (5 miles) wide and long.

C. Location:

Coordinates: 7°29'N, 134°30'E (Limits of site: 7°27'-31'N, 134°28'-32'E.)

On the west coast of Babeldaob Island, 17 km (10.6 miles) north of Koror urban area; between Bkulangriil and Ngatpang villages and reaching the Compact Road on the landward side.

States: Ngeremlengui, Ngatpang and Aimeliik.

D. Site Maps: See below.

The site boundary shown in this update serves to define the scope of information in the site account and has no legal status. It is provisional and subject to further discussion.

E. Ramsar Wetland Types:

Dominant wetland types:

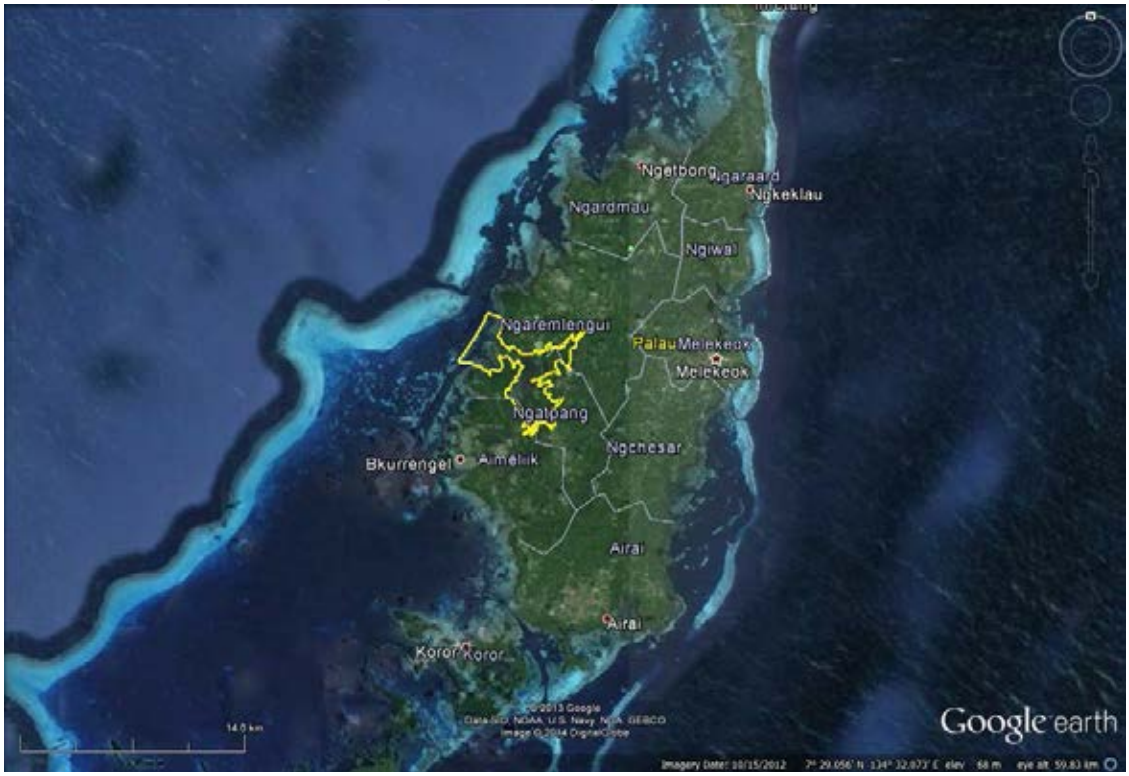
- A: Permanent shallow marine waters in most cases less than six metres deep at low tide (includes sea bays).
- B: Marine subtidal aquatic beds (includes sea-grass beds, tropical marine meadows).
- C: Coral reefs.
- F: Estuarine waters (permanent water of estuaries).
- G: Intertidal mud flats.
- I: Intertidal forested wetlands (mangrove swamps, tidal freshwater swamp forests).
- J: Coastal brackish/saline lagoons; brackish to saline lagoons with at least one relatively narrow connection to the sea.
- Xf: Freshwater, tree-dominated wetlands (includes freshwater swamp forests, on inorganic soils).

Other types present:

- Human-made 3: irrigated ponds (taro swamp gardens).

Note that Ngeremeduu Bay itself is Type J, whereas marine lagoons and deeper fringing flats outside the sea mouth but included in the site refer to Type A.

Location of Ngeremeduu Bay (Image from Google Earth)



Ngeremeduu Bay: suggested site boundary (for discussion)
(Image from Google Earth)

Ngeremeduu Bay: suggested site boundary (for discussion) (Image from Google Earth)

F. Geomorphic setting:

Elevation: From sea-level to slightly above sea level.

The site's geology is of volcanic origin (USDA 1983) and the bay is a former caldera (Colin 2009). The bay is at the seaward side of a broad area of lowland that lies between the central uplands of Babeldaob Island and a line of coastal hills, some of which are steep-sided, along the west coast. It has a relatively narrow opening to the sea in the north-west corner. The adjacent marine part of the site is dominated by a fringing (reef) flat with deeper sections including a channel parallel to the coast. Several small islands occur in the site: in the bay and outside its sea mouth.

View of Ngeremeduu Bay from the south (Photo: R. Jaensch)

G. Biogeographic region:

West Caroline Islands Marine Ecoregion (Spalding *et al.* 2007).

H. Climate:

Palau's climate is humid subtropical with annual rainfall averaging 3810 mm per year (Ketebengang and Gupta 2011); rainfall is relatively even across the months. Palau historically has experienced direct typhoon impacts once every 20 years; however, destructive typhoons occurred both in 2012 (Bopha) and 2013 (Haiyan). Rainfall and thus water levels may be lower during drought which occurs occasionally under El Nino conditions.

I. Soil:

The soils are of volcanic origin (USDA 1983). Mud deltas of volcanic sediments occur at the river mouths and sand on fringing flats includes coralline fragments.

J. Water regime:

Ngeremeduu Bay is a large, shallow tidal bay; depths across the bay are several metres and mostly less than 8 m (26 feet) but increase to more than 10 m in a deeper channel through the narrowest part of the gap entering the marine lagoon. Four large rivers

(Ngeremeskang, Ngatpang, Tabecheding and Ngimet) empty into the eastern side of the bay; in August 1999, Jenkins (1999) recorded flow of 0.10 m/s in Ngeremeskang River near Ngeremeduu Bay. Estuarine environments are the dominant regime for central parts of the site and the offshore areas are fully exposed to marine influence. The mangrove forests are affected by the tides (about 2.0 m). There is no sill to hold back sediments at the bay mouth and outflow to the sea is more or less direct via a channel that cuts through the outer/barrier reef.

K. Water chemistry:

The large rivers provide an abundant supply of fresh water which creates brackish conditions in much of the bay; salinities would be lowest during the months (April to July) with heaviest rainfall. The buy is turbid and this ensures it is poor in coral communities (Colin 2009). Near the bay mouth, the muddy bay water overlies a lens of clearer salt water below (Colin 2009). In August 1999, Jenkins (1999) recorded pH of 7.2 to 7.6 and temperature of 27.5 C in two of the site's rivers.

L. Biota:

Mangrove forests are particularly extensive in the estuary of the Ngeremeskang River in the north-east and around the island of Ngerasech in the south. Mangroves extend for 3 km (1.9 miles) up Ngatpang River (Colin 2009). 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.

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 occur. Brazaitis et al. (2009) indicate there is a high concentration of crocodiles in the bay and its creeks, mangroves and swamps. Dugongs *Dugong dugon* occur in the bay.

Jenkins (1999) recorded 16 freshwater fishes in the site's rivers: for example, the eel *Anguilla marmorata*, a goby *Stiphodon pelewensis* and an eleotrid *Ophieleotris aporos*. Keith *et al.* (2011) recorded three gobies including Sicyopus fehlmanni; also four species of crustacean.

M. Land use:

Cultivation of taro, hunting, fishing, collection of edible plants and medicines, cutting of timber, and navigation and transportation occur within the site. There are two boat landings near Ibobang village on the east side of the site.

Surrounding areas are extensively forested but there are also farms, villages and a highway. An aquaculture complex is situated in former mangrove forest at Ngatpang, immediately outside the site boundary.

N. Pressures and trends:

Pressures on the site include landfill for housing and road construction; increased gardening and farming activities; over-exploitation of timber; overfishing; and excessive hunting. In the past, heavy hunting of crocodiles occurred in the bay.

O. Land tenure and administrative authority:

Land tenure: The bay is owned by the three State governments and local chiefs. Parts of the freshwater swamps and adjacent dry land are privately owned.
Administrative authority: Ngeremlengui, Ngatpang and Aimeliik States.

P. Ramsar listed? No.

Q. Ramsar Criteria met:

Criterion 1. Contains a representative, rare, or unique example of a natural or near-natural wetland type found within the appropriate biogeographic region.
Criterion 3. Supports populations of plant and/or animal species important for maintaining the biological diversity of a particular biogeographic region.
Criterion 4. Supports plant and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions.
Criterion 8: The streams, mangroves, lagoons and reefs of the site provide substantial stocks of fish and other marine resources on which local people depend.

R. Justification for Ramsar Criteria met:

Criterion 1: The site includes good representative examples of several wetland types that are characteristic of the West Caroline Islands Marine Ecoregion, notably: coastal lagoon with narrow connection to the sea (Type J: rare in the bioregion); freshwater swamp forest (Xf); mangrove swamps (I); coral reefs (C); and estuarine waters (F). This is the largest complex of estuarine-marine wetlands in Palau, with the most extensive freshwater swamps and mangrove forests, and the bay contains the most extensive area of mudflats in Palau. The whole site may be considered the largest estuary in all of Micronesia (Colin 2009).
Criterion 3: The site is important for maintaining crocodilians as a component of biodiversity in the West Caroline Islands Marine Ecoregion. Reputedly, all of the wetland tree species of Palau are present in the site: this requires confirmation and comparison with a list for the bioregion.
Criterion 4: The mangroves, shallow lagoon and reef flats are important nursery areas for fishes, crustaceans and other marine organisms.
Criterion 8: The site supports stocks of fish and crustaceans that local people harvest for subsistence. Harvested species that breed in the mangroves and are harvested in the reefs include rabbitfish *Siganus fuscescens*. *S. lineatus*.

S. Conservation and management status of the wetland:

The site is entirely within the Ngeremeduu Bay Conservation Area; this CA was set aside as part of the offset/mitigation for construction of the Compact Road (Colin 2009). Stemmermann and Proby (1978) identified 'Ngatpang Bay' as a wetland of great interest and worthy of special protection. The site was subject to substantial conservation investment in the 1990s. It has been declared as a UNESCO Biosphere Reserve.

T. Ecosystem services:

Food supply: A large number of people living around the bay are dependent on its natural resources for their livelihood. The estuary is an important fishing ground. Parts of the wetland are important for the cultivation of taro.

Commercial fisheries: The bay is one of the best sources of crabs, sting-rays and many other economically important marine species on Babeldaob Island; 50% of Palau's mangrove crabs came from the bay at one period in time (Kitalong 1992).
Timber supply: The mangrove forests are a valuable source of timber for local people.
Biochemical products: traditional medicines from mangroves and swamp forest.
Maintaining water quality: The mangrove forest filters silt from run-off entering from the land, thereby protecting the reefs from being smothered by silt.
Coastal protection: The mangrove forests prevent coastal erosion and provide protection of inner bay communities against tropical storms.
Cultural heritage: There are many sites of historical importance in the area.
Carbon sink: the forests of the site store large quantities of carbon.

U. Current recreation and tourism:

Proposals have been put forward for kayaking tours in the Bay's waterways.

V. Existing scientific research:

Some marine studies have been carried out on the inner reef flats at Ngatpang and Ngermetengel in Ngeremlengui State. Surveys of fishes have been conducted in the inflowing rivers (Jenkins 1999, Keith *et al.* 2011) and the commercial fishery has been researched (Kitalong 1992).

W. Management plans and monitoring programs:

All Conservation Areas are required to have a management plan before they are formally established (Protected Area Network Act 2003); the status of the management plan for this site is not known.

X. Current communication and public education programs: No information.

Y. References cited:

Brazaitis, P, Eberdong, J, Brazaitis, PJ and Watkins-Colwell, GJ. 2009. Notes on the saltwater crocodile, *Crocodylus porosus*, in the Republic of Palau. Bulletin of the Peabody Museum of Natural History 50: 27-48.
Colin, P. 2009. Marine Environments of Palau. Coral Reef Research Foundation, Koror, Palau. Mutual Publishing and Indo-Pacific Press, San Diego. 414 pp.
Jenkins, AP. 1999. A preliminary investigation of the freshwater ichthyofauna of the Ngardok Lake and Ngeremeduu Bay watersheds, Palau. Wetlands International – Oceania, 9 pp.
Keith, P, Gerbeaux, P, Marquet, G, Taillebois, L and Castelin, M. 2011. Freshwater survey of Babeldaob, Palau. National Museum of Natural History of Paris, 32 pp.
Ketebengang, H and Gupta, A. 2011. State of Palau's Birds 2010. A conservation guide for communities and policymakers. Palau Conservation Society. 23 pp.
Kitalong, AH. 1992. Commercial fisheries of Ngeremdiu Bay. Unpublished report, Division of Marine Resources, 8 pp.
Spalding M.D., Fox H.E., Allen G.R., Davidson N., Ferdaña Z.A., Finlayson M., Halpern B.S., Jorge M.A., Lombana A., Lourie S.A., Martin K.D., McManus E., Molnar J., Recchia C.A., Robertson J. 2007. Marine Ecoregions of the World: a bioregionalization of coast and shelf areas. BioScience 57: 573-583.
Stemmermann, L. and Proby, F. 1978. Inventory of Wetland Vegetation in the Caroline Islands. Vol.I: Wetland Vegetation Types. Vol.II: Wetland Plants. Bishop Museum, Honolulu, Hawaii.

USDA. 1983. Soil survey of islands of Palau, Republic of Palau. USDA Soil Conservation Service.

Z. Compilers:

Original compilers (for 1993 edition): Demei O. Otobed
Updated by: Pua Michael and Roger Jaensch, May 2014

3.9 Angaur Mining Ponds

This is a **new** site; it was not included in the original 1993 Directory.

A. Overview:

A series of small human-made ponds, in abandoned mining pits, some open but others largely covered with aquatic vegetation, on the island of Angaur, southern Palau.

B. Area, boundary and dimensions:

Area: 47 ha (polygon area using Google Earth Pro).
The site boundary includes the northern ponds (deeper, open water bodies) that are prominent on satellite imagery, and most of the vegetated ponds for about a kilometre (0.6 miles) to the south-east. Individual ponds are typically around 50 m (165 feet) wide and up to 100 m (330 feet) long; some vegetated areas that seem to be wetlands, are 300 m (985 feet) long.
Note: the site boundary possibly could include additional ponds on other parts of the island, such as south-west of the airstrip.

C. Location:

Coordinates: 6°54'N, 134°8'E
Location is in the north-western sector of Angaur Island, 61 km (37.9 miles) south-west of Koror urban area; north of Angaur village and north-west of the airfield.
State: Angaur.

D. Site Maps: See below.

The site boundary shown in this update serves to define the scope of information in the site account and has no legal status. It is provisional and subject to further discussion.

E. Ramsar Wetland Types:

Human-made Type 7: Excavations; gravel/brick/clay pits; borrow pits, mining pools.

F. Geomorphic setting:

Elevation: From a few meters to about 15 m (49 feet) above sea level.

Angaur Island is a limestone platform (Colin 2009) that has resulted from uplift of former coral reefs. The ponds are former mining pits that were started in the early 1900s (Colin 2009), for extraction of phosphates.

G. Biogeographic region:

West Caroline Islands Freshwater Ecoregion (Abell *et al.* 2008).

H. Climate:

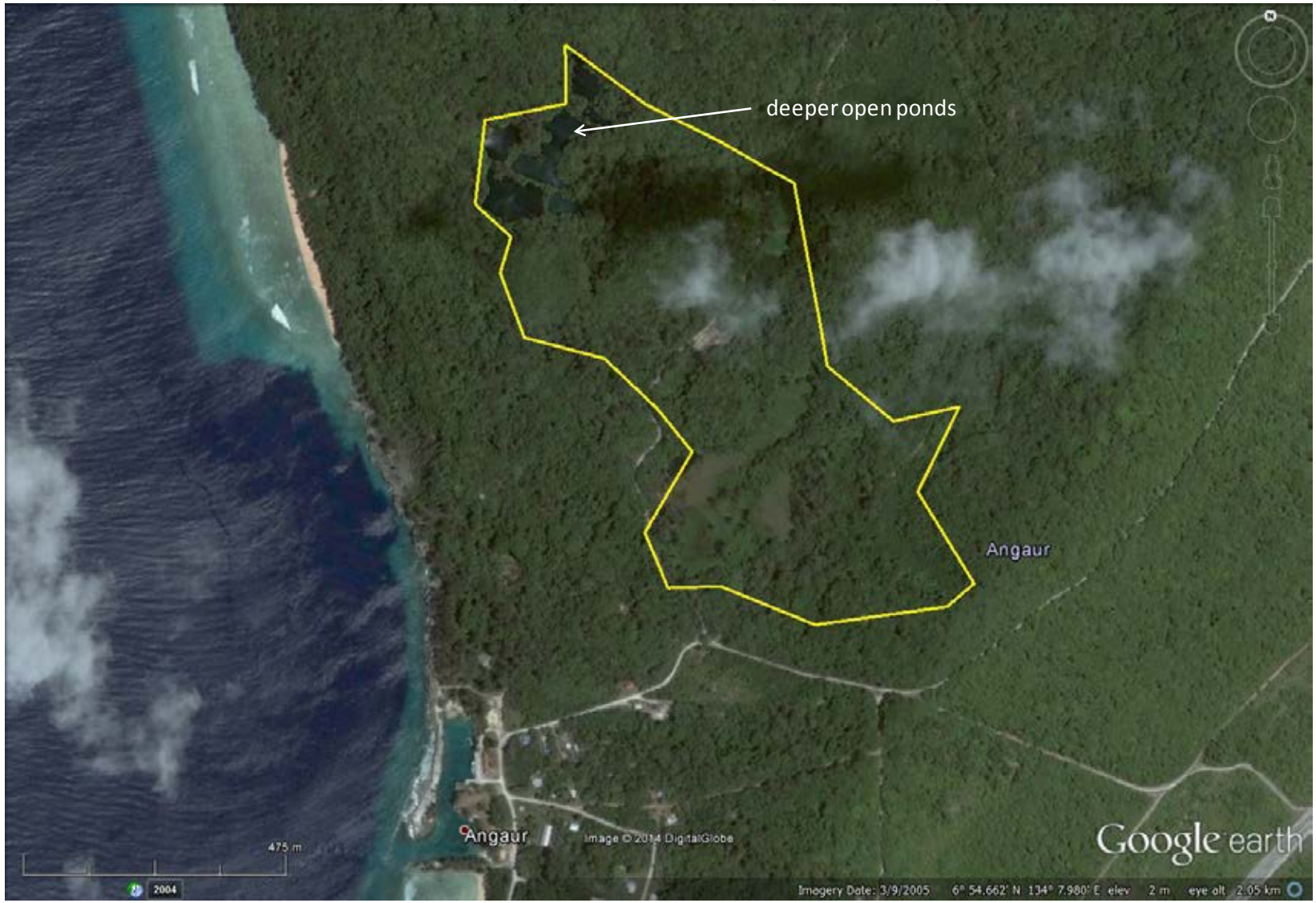
Palau's climate is humid subtropical with annual rainfall averaging 3810 mm (152 inches) per year (Ketebengang and Gupta 2011); rainfall is relatively even across the months. Palau historically has experienced direct typhoon impacts once every 20 years; however, destructive typhoons occurred both in 2012 (Bopha) and 2013 (Haiyan). Rainfall and thus

water levels may be lower during drought which occurs occasionally under El Nino conditions. Typhoon Bopha had substantial impact on Angaur (A. Kitalong pers. com.).

Location of Angaur Mining Ponds (Image from Google Earth)

Angaur Mining Ponds: suggested site boundary (for discussion)
(Image from Google Earth)

Angaur Mining Ponds: suggested site boundary (for discussion) (Image from Google Earth)



I. Soil:

The soils on Angaur are derived from coralline limestone (Kitalong *et al.* 2008).

J. Water regime:

The pits were dug to about 2.0 m (6.5 feet) below sea level and subsequently filled with fresh water. As there are no inflow or outflow streams, levels of water in the ponds presumably vary with season and during drought.

K. Water chemistry: Fresh water.

L. Biota:

Vegetation in the ponds: no information.

Common Moorhens *Gallinula chloropus orientalis* (Caroline-Marianas population) inhabit the mining ponds of Angaur; the island supports less than 20 birds but this is one of the few places in Palau where this species still occurs (Pratt and Etpison 2008). The ponds are one of the last places in Palau where the Pacific Black (Grey) Duck *Anas superciliosa pelewensis*, has been seen; though widespread in the south-west Pacific, this species is nearing extinction in Palau. Buff-banded Rail *Gallirallus philippensis pelewensis*, a subspecies endemic to Palau, is common in this area and the endemic population of Purple Swamphen *Porphyrio porphyrio pelewensis*, also occurs on Angaur though presumably it favours taro gardens (Ketebengang and Gupta 2011, Pratt and Etpison 2008). Migratory waterbirds from Asia such as Yellow Bittern *Ixobrychus sinensis* probably also occur.

Estuarine crocodiles *Crocodylus porosus* occur in the site (Pratt and Etpison 2008).

M. Land use:

Phosphate was extracted during the Japanese period and for a short time after World War 2 and there has been some recent investigation as to viability of resuming extraction (Colin 2009).

N. Pressures and trends:

Predation of bird eggs by introduced Indian monitor lizards and monkeys (long-tailed macaques) (Pratt and Etpison 2008) may impact nesting waterbirds in the site.

O. Land tenure and administrative authority:

Land tenure: The State Government and local Chiefs.
Administrative authority: State of Angaur.

P. Ramsar listed? No.

Q. Ramsar Criteria met:

Criterion 2. Supports vulnerable, endangered, or critically endangered species or threatened ecological communities.
Criterion 3. Supports populations of plant and/or animal species important for maintaining the biological diversity of a particular biogeographic region.

R. Justification for Ramsar Criteria met:

Criterion 2: Though not officially listed as threatened, the Common Moorhen *Gallinula chloropus orientalis* and Pacific Black (Grey) Duck *Anas superciliosa pelewensis* are both vulnerable to extinction in the bioregion due to scarcity of habitat and human disturbance. The site provides a remnant of habitat used by small numbers of these species. (Note: neither population is endemic to Palau.) Under the circumstances, there is a special case for Criterion 2 being met by this site.

Criterion 3: Angaur supports two waterbirds that are endemic to Palau (West Caroline Islands Freshwater Ecoregion): a subspecies of Purple Swamphen *Porphyrio porphyrio pelewensis*, and a subspecies of Buff-banded Rail *Gallirallus philippensis pelewensis*. Both occur in freshwater wetlands, the majority of which (in Angaur) are included in the site.

S. Conservation and management status of the wetland:

No conservation measures taken.

T. Ecosystem services: None identified.

U. Current recreation and tourism: No information.

V. Existing scientific research: No information.

W. Management plans and monitoring programs: No information.

X. Current communication and public education programs: No information.

Y. References cited:

Abell, R., Thieme M., Revenga C. et al. 2008. Freshwater ecoregions of the world: a new map of biogeographic units for freshwater biodiversity conservation. BioScience 58, 403–414.

Colin, P. 2009. Marine Environments of Palau. Coral Reef Research Foundation, Koror, Palau. Mutual Publishing and Indo-Pacific Press, San Diego. 414 pp.

Ketebengang, H and Gupta, A. 2011. State of Palau's Birds 2010. A conservation guide for communities and policymakers. Palau Conservation Society. 23 pp.

Kitalong, AH, DeMeo, RA and Holm, T. 2008. A Field Guide to Native Trees of Palau. 236 pp.

Pratt, HD and Etpison, MT. 2008. Birds and Bats of Palau. Mutual Publishing, Honolulu, 290 pp.

Z. Compilers:

Compiled by: Pua Michael and Roger Jaensch, May 2014

4 Candidate new sites

During the process of conducting the 2014 update, several candidate new sites were identified through literature searches and consultations. Time and resources did not allow preparation of full site accounts nor review or consultation on drafts for these sites. However, to guide future updates these sites are listed below, with brief notes on their importance.

Marine Lakes of the Rock Islands (Southern Lagoon)

Coordinates: approximate centre of site = 7° 15' N, 134 ° 24' E.
'Jellyfish Lake' (OTM Lake): 7° 9.657' N, 134 ° 22.570' E.
Wetland types: marine karst wetlands; lagoons with narrow sea openings (J, Zk(a)).
Importance (preliminary assessment): meets Ramsar Criteria 1, 3, 9.
Threats: This extraordinary site attracts large numbers of international tourists annually; tourism pressure is closely managed. Sea-level rise may impact the fine balanced process of seawater exchange between lakes and open lagoon.
Conservation measures: Within a World Heritage Area (WHA).
Comments: 57 mapped and documented marine lakes occur, in tidally-connected sink-holes and other karst depressions on several limestone islands with complex coastlines (Colin 2009). Some of the marine lakes support endemic jellyfish taxa and other marine fauna communities. A unique stand of *Bruguiera* mangrove occurs in a depression on Mecherchar Island (Stemmermann and Proby 1978). Separate site descriptions should be prepared for other components of the Rock Islands WHA.

South-eastern seagrass beds of the Rock Islands (Southern Lagoon)

Coordinates: 7° 17' N, 134 ° 28' E.
Wetland types: seagrass beds; coral reefs; shallow marine bay/lagoon (A, B, C).
Importance (preliminary assessment): meets Ramsar Criteria 1, 2, 4, 8.
Threats: None identified.
Conservation measures: Within a World Heritage Area (WHA).
Comments: supports one of the largest sea grass beds and the largest documented aggregation of dugong, in Palau.

Northern reef flats of Peleliu Island

Coordinates: 7° 2' N, 134 ° 16' E.
Wetland types: intertidal sand flats; coral reefs(C, G).
Importance (preliminary assessment): meets Ramsar Criteria 1, 4.
Threats: None identified.
Conservation measures: To be determined.
Comments: supports the largest aggregation of migratory shorebirds in Palau; presumably important as an isolated but strategic, migration stopover site in the flyway.

Ngermeskang Bird Sanctuary

Coordinates: 7° 31.2' N, 134 ° 32.7' E (position uncertain: to be confirmed).
Wetland types: freshwater swamp forest on inorganic soil (Xf, Ts).
Importance (preliminary assessment): meets Ramsar Criterion 1.
Threats: None identified.
Conservation measures: The site is a Bird Sanctuary and Conservation Area.
Comments: a well-studied and high quality area of swamp forest on Babeldaob, relatively accessible and popular for bird-watching eco-tourism.

Ngermeskang swamp forest (Photo: R. Jaensch)

Helen Reef

Coordinates: 2°54' N, 131 °47' E.
Wetland types: coral reefs (atoll), sandy island (C, E).
Importance (preliminary assessment): meets Ramsar Criteria 1, 2, 3, 4, 5?, 6? (BirdLife International has developed a draft Ramsar Information Sheet focussed on the seabird values of this reef.)
Threats: Sea-level rise could reduce the area of the island.
Conservation measures: To be determined.
Comments: supports the largest aggregation (40,000 to 100,000) of breeding seabirds in Palau, including large colonies of Sooty Tern *Sterna fuscata*, Crested (Swift) Tern *S. bergii*, and Brown Booby *Sula leucogaster*; also breeding by green turtles *Chelonia mydas* (threatened, IUCN Red List). It has one of the highest known diversities of hard coral among Pacific atolls, and is culturally and economically important to the people of Hatohobei State.

References:

Colin, P. 2009. Marine Environments of Palau. Coral Reef Research Foundation, Koror, Palau. Mutual Publishing and Indo-Pacific Press, San Diego. 414 pp.

Stemmermann, L. and Proby, F. 1978. Inventory of Wetland Vegetation in the Caroline Islands. Vol.I: Wetland Vegetation Types. Vol.II: Wetland Plants. Bishop Museum, Honolulu, Hawaii.