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Freshwater turtles of the Kikori Drainage, Papua New Guinea, with special reference to the pig-nosed turtle, *Carettochelys insculpta*

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Abstract. A survey of the Kikori River drainage of the Gulf Province of Papua New Guinea identified four species of freshwater turtle. The pig-nosed turtle *Carettochelys insculpta* and the southern New Guinea soft-shelled turtle *Pelochelys bibroni* are riverine species. The New Guinea spotted turtle *Elseya novaeguineae* lives primarily in the tidal freshwater creeks and streams, flooded sinkholes and swamps of the lowland rainforest. The New Guinea painted turtle *Emydura subglobosa* resides almost exclusively in forest sinkholes and swamps. *Pelochelys bibroni* was the least-common species, and is probably locally endangered. Greatest turtle diversity occurred in the Karst Plains of the Kikori sub-basin, where there is a greater diversity of habitat available to turtles. Lowest diversity occurred in the highlands, where turtles were present in very low density as introduced populations, brought in from the Kikori lowlands, Mount Bosavi and the Western Province by visiting relatives. Linguistic diversity concurred with turtle diversity of the regions in which the languages were spoken. *C. insculpta* nests both on riverine sand beaches and on coastal beaches, sand spits and isolated sand bars where the Kikori River discharges into the Gulf of Papua. Adult females and eggs of *C. insculpta* are harvested heavily by local people for local consumption.

Introduction

Diversity of Australian freshwater turtles is reasonably well known (Georges and Thomson 2006). Regions of greatest species richness and endemism are the Fitzroy-Burnett-Mary systems of east coastal Queensland (eight species, three endemics) and the coastal rivers of the Northern Territory (10 species, two endemics). Two species are endemic to the south-western corner of Western Australia. The turtle fauna of New Guinea is poorly known (Rhodin and Mittermeier 1976; Rhodin 1993, 1994; Rhodin *et al*. 1993; Iskandar 2000; Georges *et al*. 2006), but surveys suggest that the southern New Guinea lowlands are a regional hotspot for turtle diversity and endemism (10 species, six endemics) in Australasia. Species recorded for the southern lowlands of Papua New Guinea are *Elseya branderhorsti*, *Elseya novaeguineae*, *Emydura subglobosa*, *Chelodina novaeguineae*, *Chelodina parkeri*, *Chelodina pritchardi*, *Chelodina reimanni*, *Chelodina rugosa* (formerly *Chelodina siebenrocki*), *Carettochelys insculpta* and *Pelochelys bibroni*.

The Australian and New Guinea fauna are clearly interrelated, sharing a diverse array of taxa (e.g. carrion beetles (Peck 2001), freshwater rainbow fish (McGuigan *et al*. 2000), birds of paradise (Heads 2002) and elapid snakes (Keogh *et al*. 1998)). Turtles are no exception. *Carettochelys insculpta* is found in the larger rivers of southern New Guinea and Northern Australia (Georges and Rose 1993) and *Chelodina rugosa* (to include what was formerly known as *C. siebenrocki*) occupies the low-lying seasonal tea tree swamps and floodplains of both northern Australia and coastal southern New Guinea. *Chelodina novaeguineae* of New Guinea has a sister taxon in *Chelodina canni* of Australia (McCord and Thomson 2002), *Emydura subglobosa* of New Guinea and *Emydura worrelli* of northern Australia are sister taxa (perhaps one biological species; Georges and Adams 1996), and *Elseya branderhorsti* of New Guinea has close affinities with species in the *Elseya dentata* group of north-eastern Australia (Georges and Thomson 2006). These close phylogenetic relationships presumably reflect periods of interconnection and isolation of the two land masses as the sea level has risen and fallen. Streams draining the Arafura Sill and adjacent exposed regions of the Sahul shelf to the west (c. 22 000 ya) would have once provided opportunity for dispersal of obligate freshwater organisms between the two landmasses, as would the streams and wetlands of the Torres Strait land bridge (c. 8000 ya) to the east, and Lake Carpentaria present intermittently as an extensive saline, brackish and freshwater lake (Torgersen *et al*. 1983, 1985, 1988), from 40 000 to 12 000 ya (Waelbroeck *et al*. 2002).

Understanding what determines the spatial patterns of Australian tropical biodiversity clearly requires knowledge of the New Guinea fauna and the history of interconnection of New Guinea and northern Australia. We are hampered by poor knowledge of the present distribution and abundance of the New Guinea component, and poor knowledge of their

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systematics. The first objective of this paper is to report diversity of freshwater turtles in the Kikori River drainage of the Gulf Province of Papua New Guinea. This study complements an earlier study of turtle biodiversity in the lowland swamps of the Transfly region of the Western Province (Georges *et al.* 2006).

Of particular interest is the pig-nosed turtle, *Carettochelys insculpta*. It is the sole remaining species of its family (Pritchard 1979), is very distinctive (Georges and Wombey 1993), and is restricted to the southern rivers of the island of New Guinea and the major rivers of the Northern Territory in Australia. Its taxonomic distinctiveness and limited distribution have generated considerable interest from the scientific community since its discovery in 1886 in the Fly River of Papua New Guinea (Georges and Rose 1993). Unfortunately, these attributes have also engendered great interest in turtle fanciers and, more recently, the Chinese food market where large turtles of other species are becoming hard to obtain (Maturbongs 1999; Samedi and Iskandar 2000).

In Papua New Guinea, the new pressures of global trade in turtles come on top of concerns about pressures internal to the country, brought about by a changing relationship between the local people and their traditional resources. *Carettochelys* is widely and heavily exploited for its meat and eggs and is an important component of the subsistence economies in New Guinea (Pernetta and Burgin 1980; Groombridge 1982). Stereotyped nesting habits render *Carettochelys* (like sea turtles) extremely susceptible to overexploitation. Groombridge (1982) lists traditional hunting of turtles and harvesting of eggs in southern New Guinea as the principal threat to the species. Levels of exploitation in the Gulf and Western Provinces have been exacerbated in recent times by the introduction of modern technology, principally outboard motors and because, as clan warfare has decreased, people have moved from the hinterland to more convenient locations along the river banks. Populations of *Carettochelys* in New Guinea are reported to have declined sharply between 1960 and 1980 (Groombridge 1982). More recent surveys indicate that the level of harvest of nesting females and eggs remains very high (Pauza 2003). The numbers of turtles and eggs passing through the Kikori markets in 2003 (Pauza 2003) compared with 1980 (Rose 1981; Rose *et al*. 1982) indicate that the decline of this species has continued unabated. *Carettochelys* is in trouble in the Kikori, and if trends recorded over past decades continue, we could see a collapse of an important resource in the subsistence economy of the local people, and a collapse in one of a diminishing number of strongholds for *Carettochelys* within its already restricted range.

The second objective of this paper is to provide fundamental information on the distribution, nesting and habitat of this high-profile species in the Kikori region. We provide data to confirm anecdotal reports (Rhodin and Rhodin 1977) that *Carettochelys insculpta* nests on open coastal beaches and sand bars in addition to riverine sand beaches.

Materials and methods

Study area

The Kikori drainage basin extends from the alpine grasslands of Doma Peaks of the Southern Highlands Province to the extensive mangrove wetlands of the Gulf Province. It comprises three sub-basins. The Tagari-Hegigio sub-basin includes the Hegigio River and its major tributaries, the Tegari and Bakari. The Lake Kutubu-Digimu-Mubi sub-basin includes a large perched barrage lake in the vicinity of Moro, Lake Kutubu, its outflow the Soro-Digimu River, and the Mubi River, which ultimately joins the Hegigio River to form the Kikori River proper. The Kikori sub-basin extends from this junction to include its passage through the Karst Plains to the extensive coastal delta. The Kikori drainage basin is connected to the Purari drainage basin to the east and the Omati drainage basin to the west – their freshwater delta regions interconnect during both wet and dry seasons.

A summary of the geomorphology of the Kikori basin has been prepared as part of the Environmental Impact Statement of the Papua New Guinea Gas Project (Enesar 2005). Limestone is the dominant surface geological feature in the region and, coupled with exceptionally high rainfall, erosion by solution (karstification) has been a major influence in the development of the present landforms. These eroded surfaces often lack defined stream patterns, and much runoff is vertical, filtering down through cracks in the limestone into cave systems, aquifers and underground streams that can emerge as surface streams at long distances from their sources. Landforms of this system have been classified by Löffler (1977) but his classification is too detailed for the purposes of the present study. We draw from his paper to recognise the following regions of importance in determining the distribution and abundance of freshwater turtles in the Kikori region.

The 'Highlands' refer to those lands above major waterfalls (e.g. Wassi Falls) or above fast-flowing waters likely to be a barrier to turtle dispersal. Here the karst forms a rugged terrain of mountains, cones, pinnacles, towers, hogbacks and strike ridges, dolines and hummocks, caves, and underground rivers. At the headwaters, there are volcanic landforms associated with Mounts Bosavi, Sisa and Dorma.

The 'Karst Plains' have formed where the base level of karst erosion has been reached, and they occupy the central part of the Kikori basin at ~40–100 m elevation. The river system is highly confined within its limestone bed, and meanders and oxbows are absent. The Karst Plains provide the most diverse opportunities for freshwater turtles, comprising the main river channel (much of it tidal), numerous small tidal creeks and swamps, small creeks emerging from small limestone caverns, and numerous water-filled circular depressions between 20 and 100 m in diameter scattered through the forest. Sand banks suitable for turtle nesting are common. We only had the opportunity to visit the tidal reaches (downstream of Kaiam Ferry).

The 'Kikori Delta' is a large alluvial plain below 40 m elevation, dissected by a distributary system of river channels, and formed where thick layers of soils, principally soft silts and clays, have been deposited over the underlying limestone plain. There are few sand banks in the delta proper – two only were observed by us, in the vicinity of Vieru and Doibo. The mangrove and swamp forest of the Kikori Delta is one of the most extensive stands of mangroves in Papua New Guinea.

The 'Kikori Coast' comprises the delta islands exposed to the Gulf of Papua, including the islands of Goarabari, Banana and Ibibubari. Wind and wave action creates coastal beaches, sand bars and sand islands (e.g. Turivio Island) in what is a very dynamic system. These beaches and sand bars are used by both marine and freshwater turtles for nesting.

The climate is wet tropical. Temperatures at Kopi range from a minimum of 18°C to a maximum of 37°C, with a mean daily minimum of 22.0°C and a mean daily maximum of 33.5°C. Mean daily temperature is 27.7°C (Enesar 2005). Mean relative humidity is high, at between 82% (1500 hours) and 92% (0900 hours). Annual rainfall in the Kikori lowlands is very high by global standards. The annual mean rainfall at Kopi for the years 1991–2006 was 5667 mm (range 4400 mm in 2004 to 8432 mm in 1999). It typically rains in all months of the year, with a peak in the monthly average of 732 mm (range 124–1730 mm) for June and a minimum monthly average of 275 mm (range 0–536 mm) in December. The period of November to January is regarded as the 'dry' season, when river levels are low, forests are not flooded and water clarity is greatest. December is the only month in which zero rainfall has been recorded. Not only is rain likely in every month, including those of the dry season, but rainfall is highly variable as are associated river flows. In November for example, monthly rainfall can be as low as 41 mm and as high as 880 mm. To put this in context, rainfall of 285 mm in a period of 7 days in November of 2006 was sufficient to inundate all nesting banks above the delta region for several days and destroy the entire upland production of eggs by *Carettochelys* for the season up to that time. In December, monthly rainfall can be as low as zero and as high as 536 mm.

Lowland regions of the Kikori are predominantly affected by the north-west monsoon, with variable north-west or west winds accompanied by thunderstorms and rain. At other times, the trade winds blow predominantly from the south-east and also bring copious quantities of rain.

Methods

Our approach was to work within the networks of Oil Search and the Worldwide Fund for Nature (WWF) to provide appropriate liaison and advance warning of our visit. As part of this liaison, villagers were requested to retain turtles for our examination before they were killed and consumed. Villages and fishing camps in each of the three subdrainages of the Kikori, representing each of the broad landforms (Table 1), are shown in Fig. 1.

As standard procedure, villagers were asked for the name of their language group and the names they gave to turtles. Part of the questioning was to determine whether any of the names were generic (for any turtle) or whether any two names referred to a single species of turtle, perhaps because of joint use of names from a neighbouring language group, or whether different names were given to different morphotypes (juvenile *v.* adult) of the same species. Once a set of names was obtained, we matched these

Table 1. Villages and fishing camps visited between 22 November and 13 December 2006 in the Kikori drainage basin

Latitude and longitudes were taken with a global positioning system set to WGS-84 projection. ×, evidence found in the form of live specimens or shells; +, reliably reported to be present; CI, *Carettochelys insculpta*; EN, *Elseya novaeguineae*; ES, *Emydura subglobosa*; PB, *Pelochelys bibroni*. The animals reported for the highlands are reputedly introduced. Clearly, highest turtle diversity occurs in the Karst Plains

Village/camp	Location	CI	PB	EN	ES
Highlands: Kutubu-Digimu-Mubi sub-basin					
Soro	6°22′39″S, 143°15′7″E				
Kapoi	6°22′19″S, 143°16′41″E			+	
Wasami Is	6°22′45″S, 143°17′44″E			+	
Tugiri	6°23′24″S, 143°20′45″E				
Kese	6°26′31″S, 143°22′0″E				
Yakerebo	6°26′46″S, 143°22′27″E				
Highlands: Tagari-Hegigio sub-basin					
Wairo	6°31′52″S, 143°11′5″E			+	
Hebaya	6°32′45″S, 143°13′49″E				
Karst Plains: Kikori sub-basin					
Kaiam	7°5′50″S, 143°59′34″E	×	×	×	+
Lalau-Ario	7°13′37″S, 144°13′36″E	×	+	×	
Waira	7°15′48″S, 144°11′37″E	×		×	
APC Logging Camp	7°7′56″S, 144°19′43″E	×			
Kopi	7°18′30″S, 144°10′54″E	×	+	×	×
Ogamabu	7°44′19″S, 144°14′59″E	×		×	+
Kikori Delta: Kikori sub-basin					
Kikori	7°24′20″S, 144°14′59″E	×			
Apeawa	7°33′27″S, 144°18′12″E	×	+		
Ero[A]	7°26′54″S, 144°21′55″E	×			
Veiru	7°28′16″S, 144°15′9″E				
Kikori Coast					
Ibubabari Island	7°47′5″S, 144°28′19″E	×			
Banana Island	7°46′0″S, 144°24′45″E	×			
Turivio Island	7°47′42″S, 144°26′24″E	×			

[A]Ero was not visited, but villagers were interviewed and eggs sighted.

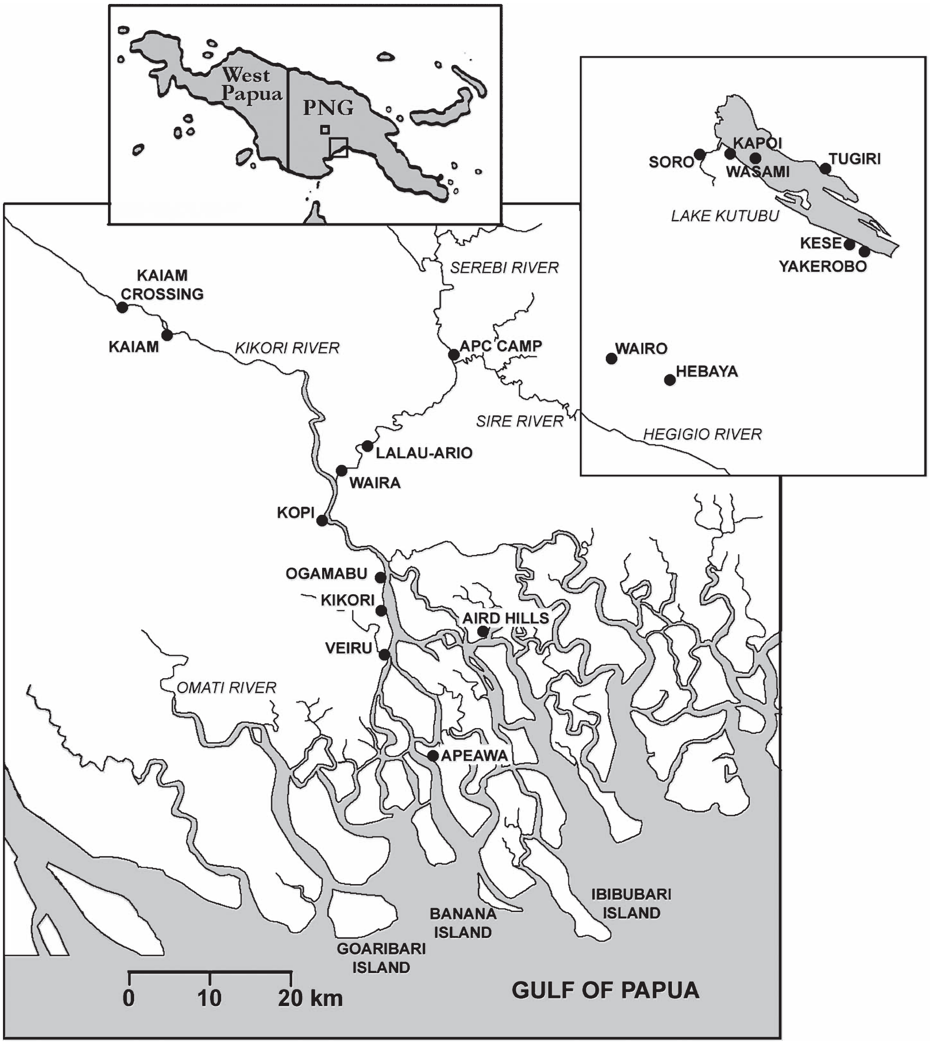

Fig. 1. A map of the Kikori region showing the extensive delta and the villages visited during this study. Lake Kutubu (inset) drains into the Mubi tributary of the Kikori drainage, and is in the southern highlands.

against species, by identifying diagnostic features (without leading) or with the aid of photographs (Georges *et al*. 2006). The names were confirmed when live specimens came to hand. By this method, we could identify which species were harvested regularly in the local area, regardless of which species were passed to us for examination. For each specimen, we obtained details of its exact location of capture and the method of capture. Villagers were paid 2 kina (AU$0.85) for each turtle from which tissue was taken, and a further 3 kina (AU$1.25) for allowing examination of gonads. We supplemented the turtles examined by trapping using standard baited traps (after Legler 1960) fitted with breathing tubes. Catfish and forest fruits were used as bait. We trapped in small tidal creeks, limestone caverns, water-filled sinkholes and small swamps.

Turtles were identified with the aid of the key provided by Georges *et al*. (2006). Sex of adults was determined using external dimorphic characters, particularly those of the tail, which is much longer in mature males in these species. Each turtle was measured (maximum carapace length, midline plastron length) with vernier calipers ($\pm$0.1 mm) or from photographs taken from directly above and below and a scale included. Mass of *Carettochelys* was determined from the relationship between carapace length (CL, in cm) and body mass (kg) established for the species in Australia (Georges and Kennett 1989): adult mass = $1.63\ CL^{2.88} \times 10^{-4}$ ($R^2 = 0.997$, $n = 48$). A small sliver of tissue was taken from the clawless digit of the rear foot and preserved in 75% ethanol for DNA analysis.

When a specimen was to be killed for immediate consumption, we requested permission to examine its gonads to determine reproductive status (mature, immature) and reproductive condition. Oviducal eggs, pre-ovulatory follicles, additional developing follicles and fresh corpora lutea on the ovary were counted when present. Special attention was paid to determining if there were two or more sets of corpora lutea present, as an indication of multiple clutching (Georges 1983). Males were examined to determine if the testes were enlarged, pink and vascularised as an indication of spermatogenesis or spermiogenesis or if they were small, compact, yellow and lacking vascularisation indicating quiescence (Georges 1983). Epididymides were examined to see if they were straight and translucent (an indication of immaturity), coiled and translucent (an indication of pending maturity), or coiled and white (an indication of maturity).

Nests of *Carettochelys* were located by surveying the banks of the Kikori from Kopi to Kaiam, Waira to APC Camp, and coastal beaches by boat. Intact nests of *Carettochelys insculpta* were excavated carefully and the depth to first egg and chamber depth measured. Distance from water and height above water were also recorded. The eggs were counted, as were the number of eggs that had not patched (presumed infertile), and the eggs were photographed with a standard scale for later measurement. Egg mass was estimated from egg diameter assuming isometry. Eggs obtained from villagers or in other ways were treated similarly.

Trial nest surveys were undertaken as to establish 'proof of concept'. Four transects were selected as representative of the nesting regions: (1) Kopi to Kaiam Crossing; (2) the junction of the Sebiri and Kikori rivers to the logging camp now residing at the former Australian Petroleum Corporation (APC) exploration site at Victoria Junction; (3) from Ogamabu to Apeawa; and (4) the coastal beaches of Banana Island, Turivio Island and Ibubibari Island (Fig. 1). The trial surveys were undertaken in a 23′ fibreglass boat driven by a 75 hp outboard motor on the falling tide in the morning. Nesting tracks of *Carettochelys* were clearly evident on the sand bars and sandy loam banks where the turtles had left the water on the falling tide to seek nesting opportunities or to nest. Both banks were surveyed. A second trial survey from helicopter (Eurocopter BK-117) was undertaken on the morning falling tide between Kopi and Kaiam Crossing. Flying height was 75′ and traversing speed was 50 kn. Only banks on the left side of the river were surveyed.

Details of harvest for trade were gained opportunistically. We visited the Kikori Markets on five separate days, and the APC Logging Camp Market once. We recorded information on the species traded, the component of the turtle that was traded (live animal, meat, eggs, plastron), the buyer, and the amount received for the purchase.

Where indicated, our data were combined with those from a similar 2003 survey undertaken as part of WWF activities (Pauza 2003).

Results

Turtle diversity

We obtained four species of freshwater turtle as part of our survey (Table 1). The pig-nosed turtle *Carettochelys insculpta* and the southern New Guinea soft-shelled turtle *Pelochelys bibroni* are riverine species. Both were reported from throughout the lowland regions of the Kikori drainage, in the main channels of the delta, the Kikori and the Serebi Rivers. *Carettochelys insculpta* was the most conspicuous species, and probably the most abundant, in the Kikori River basin. We found evidence of it throughout the tidal reaches of the Kikori, in the form of adult specimens, nests and distinctive signs of nesting activity (Fig. 2). *Pelochelys bibroni* was the least common, and is probably locally endangered. The New Guinea spotted turtle *Elseya novaeguineae* is caught occasionally in the main river channels, but lives primarily in the tidal freshwater creeks and streams that dissect the lowland rainforest of the karst plains and in flooded sinkholes and associated swamps. The New Guinea painted turtle *Emydura subglobosa* was uncommon in the Kikori, and resides almost exclusively in forest sinkholes and swamps. During the dry season (November to January), the turtles aestivate in undercut banks and tunnels.

Questioning on specific names in a local language, followed by matching those names with species, is considered a robust, albeit indirect, method of ascertaining the number of species in a region. The peoples of the Kikori region recognised three (occasionally four) types of freshwater turtle in their language (Table 2). The two species of chelid turtle of the delta were grouped by most people under a single name – Kehoko (Rumu), Kaso bubal (Ikobi), Ketori/Ketoko (Porome) or Koimo (Kerewo). The name Kehoko refers to the black carapace of both species, and Kaso bubal refers to their common small size compared with the larger river turtles *Carettochelys* and *Pelochelys*. Those who regularly hunted turtles in the swamps, sinkholes and small creeks distinguished two types in their vocabulary, Kehoko for *Emydura subglobosa* and Purapati (variation Kurapati) for small salmon-coloured *Elseya novaeguineae*. Despite considerable effort, we could not ascertain with certainty which name applied to the adults of *Elseya novaeguineae*.

Carettochelys insculpta was recognised in all languages as a distinct species, referred to variously as Piku (Rumu), Uwo (Ikobi, Kerewo), Watemu/Watemui (Porome) or Buguama (Foroba). *Pelochelys bibroni* was also recognised as a distinct species, referred to variously as Mimiri (Ikobi, Rumu, Foroba), Kauri/Dabeuri (Porome), Kiomo (Urama) or Unawaya (Kerewo). In the Rumu language, *Pelochelys* is also commonly referred to as Otohehe, which literally means soft wings, a reference to the soft margins of the shell of this turtle.

Peoples of the southern highlands within the Kikori drainage recognised only *Elseya novaeguineae*, and believed it to have been introduced to the area from the lowlands in the 1980s. The names Baregwarabo (Foi) and Eketaiyā (Fasu) are probably generic names for turtle.

Nesting

Carettochelys insculpta nested on sand bars on the main river channel that form on bends in the river, behind debris, or where small creeks enter the main stream (e.g. Fig. 3). They nested only at night and predominantly on the high tide or falling tide. This is presumably so that they can assess the quality of prospective nesting sites, particularly in relation to the tides, as they only nested above the high water mark. All of the nests we located in the river region had been harvested by local villagers. *Carettochelys* also nested on coastal beaches of islands in the delta (Fig. 2). Again, they nest at high tide or on the falling tide at night above the high-water mark. Almost all nests were harvested by local villagers, but we also located fresh nests on Turivio Island that had not been harvested, and nests well into incubation that had survived harvesting. Many of these nests had been inundated by high tides, but had survived these brief periods of inundation. The attributes of the nests and eggs are reported in Table 3. There was very little nesting activity in the delta region proper (Fig. 2), owing largely to the lack of suitable nesting banks.

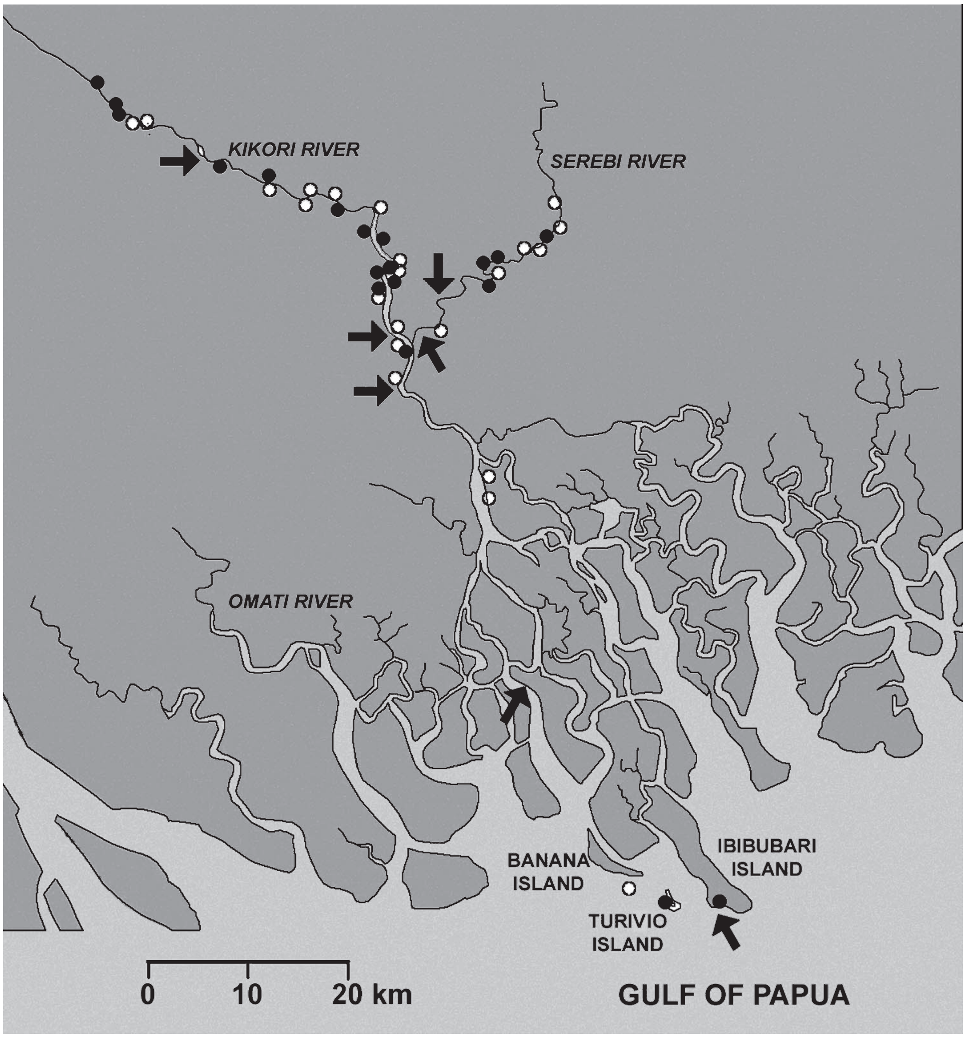

Fig. 2. Locations of nesting activity of the pig-nosed turtle (*Carettochelys insculpta*) in the Kikori drainage. Closed circles indicate actual nesting, open circles indicate presence of nesting tracks only, arrows indicate where we examined adult and subadult turtles caught locally. The one in the delta proper was a juvenile. The remainder were adult females.

One female that was examined before consumption had laid 14 eggs immediately before capture, had 12 more in her oviducts, 15 enlarged vitellogenic follicles and two sets of corpora lutea. This suggests that three nests were to be deposited in the season, had she survived. She also had fruits and two *Carettochelys* eggs in her stomach. The latter were probably obtained from nests destroyed by high river levels and flows in the days before our arrival.

The eggs of *Elseya novaeguineae* and *Emydura subglobosa* are laid in the soil of the forest floor, often near the base of trees, and are harvested and eaten when encountered. None were encountered during our study. None of the 11 female *Elseya novaeguineae* examined by us were gravid. The one female dissected before consumption had nine corpora lutea indicating that a clutch had been laid, seven preovulatory follicles and 21 developing follicles suggesting a clutch size of seven to nine and multiple clutching. The two males had testes that were enlarged and flaccid suggesting a postspermatogenic condition. As they had not yet regressed, spermiation was likely to be continuing, and the epididymides were white and distended with sperm. Stomach contents contained a combination of aquatic plant material, fruits, crustacea and terrestrial beetles. *Elseya novaeguineae* is clearly omnivorous and opportunistic in its diet.

Harvest

Freshwater turtles and their eggs were harvested regularly for food by people of all villages in the tidal reaches of the Kikori drainage basin that we visited. *Carettochelys* and *Pelochelys bibroni* are favoured by virtue of their large size and the quantity of meat that can be obtained; *Elseya novaeguineae* and *Emydura subglobosa* are favoured for their superior taste (greasy).

Adult and juvenile *Elseya novaeguineae* were harvested on fishing lines baited with forest fruits, by diving with a mask, muddling with the feet and hands through shallow water, probing

Table 2. Names for freshwater turtles from the eight language groups we encountered during the study

Dialects are given in square brackets, villages are in parentheses. Language groups were confirmed by reference to the Ethnologue (Gordon 2005), the Pacific Language Mapping Project (Blundell 2006) and other reports (Wurm and Hattori 1981). Spelling of names was confirmed with native speakers and others well versed in particular languages (Saruso Kirawa (Kasere), Robbie Petterson (Rumu), Martin Steer (Porome), May and Loeweke (1981; Fasu)). These names complement those published by Rhodin *et al.* (1980). ’ = glottal stop

Turtle	Language								
	Ikobi [Kasere] (Kaiam)	Foroba (Omo, Kuru)	Rumu (Kopi, Ogamabu, Irimuku, Lalau, Ario, Waira)	Porome [Kibiri] (Veiru, Doibo)	Porome [Porome] (Ero, Wowou)	Kerewo [Goaribari] (Apeawa, Samoa)	Kiwai NE [Urama] (Veraibari)	Foi (Soro, Wasami, Tugiri, Kese, Kapoi)	Fasu (Wairo, Hebaya)
Emydura subglobosa	Kaso bubal	Kinisuga	Kehoko	Ketori	Ketoko	–	Koimo	–	–
Elseya novaeguineae	Kaso bubal	Kesoga	Kehoko, Purapati	Ketori	Ketoko	Koimo[B]	Koimo	Baregwarabo	Eketaiyā
Carettochelys insculpta	Kaso Uwo	Buguama	Piku	Watemui	Watemu	Uwo[B]	Va’ema[A]	–	–
Pelochelys bibroni	Kaso Mimiri	Mimiri	Mimiri, Otohehe	Kauri	Dabeuri	Unawaya	Goava’ema	–	–
Marine turtle	–	–	–	–	–	Mirimiri, Gamo[C]	Mia Mia	–	–

[A]Ma’ema has been recorded for Gope dialect, Kiwai NE language by Robert Petterson.
[B]Confirmed for Samoa Village, Aird Hills by Martin Steer.
[C]Name provided by Martin Steer for Samoa Village (Kerewo), Aird Hills.

Fig. 3. A typical riverine nesting beach for *Carettochelys insculpta*. The tracks (inset) are readily distinguishable from those of other species and clearly visible from helicopter.

the numerous small limestone caverns from which water emerges with a bush knife or limb and hooking the turtles out. During the dry season, up to 15 turtles can be found wedged in, aestivating in a single cavern. The turtles are also harvested by drugging them with the sap of a local liana vine, a practice widespread in the Pacific (Barrau 1955). The vine stem is pulverised to release the milky sap (active ingredient Soponin), which is collected and used to poison fish in small, confined water bodies, such as creek pools and sinkholes, during the dry season. The fish float to the surface, but turtles are affected also. They sink and become disoriented and eventually move to the edges of the water where they can be captured readily. Men occasionally spear the turtles through the shell or limb. Animals examined by us were caught with a spear, by muddling, by diving with a mask, on a baited line, and in our hoop traps baited with catfish and forest fruits.

When active, *Emydura subglobosa* are harvested in the forest sinkholes and associated swamps using similar techniques to those used for *Elseya novaeguineae*. During the dry season (November to January), the turtles aestivate in undercut banks and tunnels. The origin of the tunnels is not clear, but the local people believe that the turtles dig them. The aestivating turtles are pulled from their retreat either through the opening or by digging down some metres from the water’s edge. Of the two animals examined by us, one was caught on a line and the other migrating overland between water bodies.

Adult *Carettochelys* are harvested primarily during the nesting season by patrolling nesting banks, intercepting nesting females and turning them on their backs. Females who have completed the nesting chamber and are in the process of depositing their eggs enter a ‘trance’ characteristic of marine turtles, which facilitates their capture. The turtles are sometimes caught by diving on them after they have entered the water after nesting. Only females are targeted by these methods. Other methods of capture include diving for the turtles with the aid of a mask (glass) in the headwaters of the Seribi and Sire tributaries, or in the tidal regions when the water levels are low and the water is relatively clear. The turtles are occasionally caught throughout the year on lines with hooks baited with prawn, sago grubs or fruits. Animals examined by us were caught during nesting at night, or diving with a mask, or on fishing lines baited with prawn. The sole *Pelochelys bibroni* examined by us was caught on a line.

The eggs of both large river species are harvested intensively, though the relative level of harvest of the two species is difficult to determine without direct observation. The local people often take hard-shelled *Carettochelys* eggs that are smaller than usual to be those of *Pelochelys*. *Pelochelys* lays smaller eggs, but they are soft-shelled. *Carettochelys* nests on sand banks that are visited regularly by local villagers during the nesting season, and the tracks left by the nesting female facilitate location of the nests. A bush knife is used to probe the sand, with the nest chamber

Table 3. Nest and egg attributes for the pig-nosed turtle (*Carettochelys insculpta*) from the Kikori region
Comparable data for the Daly River (Doody *et al.* 2003) and the Alligator Rivers region of the Northern Territory, Australia (Georges and Kennett 1989), are included for comparison. Infertility rates are based on the frequency of eggs that did not patch, and may include eggs in which the embryos died very early. Egg measurements are the mean values of the mean for each clutch. Means are given with their standard errors, ranges (in parentheses) and sample sizes. A dash indicates that no data are available

Parameter	Kikori River 2003	Kikori River 2006	Daly River	Alligator Rivers
Elevation above water (m)	–	0.8 $n = 1$	0.97 ± 0.033 (0.35–2.88) $n = 178$	0.59 ± 0.04 (0.4–0.7) $n = 8$
Distance from water (m)	11.9 ± 0.59 (1.5–25.5) $n = 58$	11.8 ± 2.87 (1–17) $n = 5$	2.45 ± 0.094 (0.59–9.10) $n = 180$	2.16 ± 0.28 (1.1–3.7) $n = 8$
Depth to first egg (mm)	–	7.9 ± 2.14 (3.2–13.5) $n = 5$	14.1 ± 0.50 (6.5–21.0) $n = 36$	12.5 (12–13) $n = 2$
Chamber depth (mm)	24.8 ± 0.75 (10–35)	20.4 ± 2.16 (15–26) $n = 5$	21.47 ± 0.138 (14.6–26.2) $n = 166$	19.5 (18.0–21.0) $n = 2$
Clutch size	24.6 ± 0.77 (13–37) $n = 58$	23.6 ± 1.16 (19–29) $n = 10$	10.4 ± 0.193 (4–19) $n = 164$	15.0 ± 1.0 (14–16) $n = 2$
Clutch frequency	2	3[A]	2	2
Interbreeding period (years)	–	–	2	–
Infertility (%)	–	1.0 ± 0.65 (0.0–5.3) $n = 10$	24.8 ± 3.88 (0.0–85.7) $n = 38$	0.0 $n = 2$
Egg diameter (mm)	43.1 ± 0.59 (40.2–53.1) $n = 20$	40.9 ± 0.52 (38.0–45.1) $n = 14$	39.6 ± 0.21 $n = 156$	41.8 $n = 1$
Egg mass (g)	48.0 ± 1.29 (39.3–66.6) $n = 20$	36.4 ± 0.46[B] (33.8–40.1) $n = 14$	35.2 ± 0.20 $n = 153$	40.2 $n = 1$
Clutch mass (g)	1131.3 (308–1669) $n = 20$	858.0 (797.2–946.1) $n = 14$	360.9 ± 0.632 $n = 152$	603 (562.8–643.2) $n = 2$

[A]M. Rose, unpubl. data.
[B]Egg mass estimated from egg diameter, assuming isometry.

affording reduced resistance to its penetration. The presence of eggs is confirmed by the 'chink' made when the knife contacts an egg. All the eggs are taken, except in a few cases where the hatchlings were well developed. For these nests, no eggs were removed and the nest chamber was refilled with sand. Of the nests located in the present study, most were harvested, but where possible we recorded egg and nest characteristics (Table 3). Nests of *Pelochelys bibroni* are also harvested, but this species nests less frequently and individually rather than in groups, and its eggs are harder to locate. None were found during the period of our study.

Female *Carettochelys* harvested during our visit had a carapace length on average of 47.7 ± 0.88 cm (40.4–52.0 cm, $n = 12$), which yielded estimated masses of 11.2 ± 0.56 kg (6.9–14.3 kg, $n = 12$). The single male captured had a carapace length of 34.4 cm and an estimated mass of 4.3 kg. A juvenile caught by Apeowa Villagers had a carapace length of 24.9 cm and an estimated mass of 1.7 kg. The average carapace length of females caught while nesting in 2003 was significantly larger at 52.6 ± 0.92 cm (42–65 cm, $n = 31$) with measured masses averaging 14.3 ± 0.49 kg (10.1–25.3 kg, $n = 31$).

Typically, the plastron is removed as one piece to gain access to the meat and entrails. The gut is removed, cleared of contents and cut into pieces. The gut, liver, heart and meat of the body, limbs, head and neck are boiled, often with yams and other vegetables. The eggs are used in a large variety of ways. They are boiled and eaten as part of a meal or as a snack, added to and cooked with sago or rice, or used in the preparation of biscuits and cakes.

By far the majority of turtles and turtle eggs collected during our study were consumed locally by the villagers who had collected them. Five visits to the Kikori markets failed to locate any turtles, eggs or turtle products. Seven clutches of *Carettochelys* eggs were on sale at the APC Forest Logging Camp market and had been collected by people from Aird Hills. Adult pig-nosed turtles are valued highly and attract a price of 50–100 kina (AU$20–40) in the Kikori markets, and the eggs sell for 20–50 toia (AU$0.08–0.20).

Discussion

Although diversity of freshwater turtles in the southern lowlands of New Guinea is the highest for Australasia, our study indicates that this diversity is not consistently high throughout this region. Diversity in the Kikori drainage basin (four species) is half that of the Fly drainage to the west (eight species) (Georges *et al.* 2006), with *Chelodina* species unrepresented and *Emydura subglobosa*, abundant in the Fly River lowlands, rare. Presumably this low diversity arises because the river channel is highly confined within its limestone bed, and because the rates of vertical infiltration are high. Both limit the development of more complex wetlands such as the oxbows and extensive open swamps characteristic of the Fly delta and associated tributaries. A well-developed overstorey in riverine and seasonally flooded areas may also contribute to a poorly developed freshwater turtle fauna. There are no extensive tracts of open savannah and ephemeral swamps to support *Chelodina novaeguineae*, no extensive permanent open swamps to support *Emydura subglobosa* and *Chelodina parkeri*, and no coastal Melaleuca swamps to support *Chelodina rugosa*. The reason for the absence of the New Guinea snapping turtle *Elseya branderhorsti* from the Kikori system is unknown. Perhaps the extensive span of habitat poorly suited to the species abundant in the Fly but absent in the Kikori have provided a barrier to the eastward extension of the ranges of some species, particularly *Chelodina rugosa* and *Elseya branderhorsti*. This may have limited the influence of Australian connection, via the Torres Strait land bridge and Lake Carpentaria, on turtle biodiversity to the east.

Greatest turtle diversity of freshwater turtles occurs in the Karst Plains of the Kikori sub-basin, where there is a greater diversity of habitat available to turtles. Lowest diversity occurs in the highlands, where turtles are present in very low density as introduced populations, brought in from the Kikori lowlands, Mount Bosavi and the Western Province. *Carettochelys* is the most common species, but thought to have undergone severe declines principally as a result of sustained heavy harvest pressure on the turtles and their eggs over many decades. *Pelochelys bibroni* is rare, and probably critically endangered locally, though historical abundances that could form a baseline for comparison are not known. The New Guinea painted turtle *Emydura subglobosa* and the New Guinea spotted turtle *Elseya novaeguineae* are chelid turtles, residing in the side streams, flooded sinkholes and swamps of the forest. *Elseya novaeguineae* is abundant, whereas *Emydura subglobosa* is very uncommon, but neither appear to be under threat.

Linguistic diversity concurred with turtle diversity of the regions in which the languages were spoken. Greatest linguistic diversity occurred in the Rumu language spoken across lands that encompassed the tidal reaches of the Kikori drainage above the delta (the Karst Plains). Their lands are characterised by the major river channel, numerous small creeks (many of which are spring fed or emerge from limestone caverns) and water-filled limestone sinkholes. All four species are found within their lands. Least linguistic diversity in turtle names (one name, generic) occurred in the highland regions of the Kikori, where only a single species is found (*Elseya novaeguineae*), probably introduced to the area in the early 1980s. This connection between linguistic diversity and turtle diversity, and the utility of linguistic clues in determining the turtle species present in a region, was reported in a similar study in the Transfly (Georges *et al.* 2006). In contrast to the names applied to turtles of the Transfly, names applied in the Kikori region did not concur with the species recognised by science, but instead were based on common attributes of size, colour of carapace, the habitat in which they are found, and flavour when eaten. The people of the tidal Kikori upstream of the delta regularly encountered both *Emydura subglobosa* and *Elseya novaeguineae*, and were aware of what they regarded as subtle differences between them, but the general populace did not distinguish the two in their language. Both are small, have dark carapaces, red suffusion of the plastra and lower limbs, and are good eating. The relatively low frequency of encounter, the dramatic difference between them and both riverine turtles, their similar habitat preferences, and their common utility has led to a single name applied to them by all but those who hunt them frequently.

Chelonians are often classified conveniently into terrestrial, freshwater and marine species, but the boundaries between these categories are far from distinct. It is well known that freshwater turtles vary greatly in their reliance on terrestrial habitat (Roe and Georges 2007). Less well studied are turtles that occupy the boundary between marine and freshwater environments. Diamondback terrapins (*Malaclemys terrapin*) occur in coastal brackish tidal creeks, salt marshes, estuaries, lagoons and mangroves from Massachusetts, south along the Atlantic Coast, around the Florida peninsula, and west across the Gulf of Mexico to the vicinity of Corpus Christi, Texas (Ernst *et al*. 1994). They have a range of specific adaptations for tolerating salinity (Bentley *et al*. 1967; Gilles-Baillien 1970, 1973), including salt glands (Dunson 1976), but also rely on freshwater when it is available to replenish body fluids (Robinson and Dunson 1976; Davenport and Macedo 1990). *Malaclemys terrapin* is highly specialised, but several other species can be found regularly in brackish or saline waters of coastal areas (Dunson and Moll 1980; Dunson and Seidel 1986; Kinneary 1993; Rhodin *et al*. 1993; Taskavak *et al*. 1999). Our present study confirms anecdotal reports of the regular occurrence of *Carettochelys insculpta* in saline coastal areas of southern New Guinea. Furthermore, we observed the species nesting in large numbers on coastal beaches and isolated sand bars of the Gulf of Papua, at the mouth of the Kikori River. Coastal nesting of freshwater turtles has been observed previously in *Trachemys scripta venusta* of the Tortuguero region of Costa Rica (Pritchard and Trebbau 1984; Moll 1994), in *Callagur borneoensis* from Malaysia (Dunson and Moll 1980), in *Pelochelys bibroni* from Orissa, India (Vijaya 1982; Rhodin *et al*. 1993; Hussain 2003), in *Trionyx triunguis* from the Mediterranean (Atatür 1979; Carr and Carr 1985) and in *Podocnemis expansa* from the Amazon delta (Portal *et al*. 2005).

What is unusual about the nesting patterns of *Carettochelys insculpta* in the Kikori is the dichotomy in nesting opportunity and behaviour. Because there are few nesting opportunities between the coast and the upstream limits of the distributary delta, gravid female turtles are presented with a choice. Do they head or remain upstream to nest, or head downstream to the coast? The mangrove terrapin, *Batagur baska*, may respond to a similar dichotomy of opportunity. There are reports also of this species nesting in coastal areas in Burma (Maxwell 1911; Smith 1931), whereas in other parts of their range they more typically migrate upstream to nest on sand bars on river banks (Dunson and Moll 1980; Moll 1980; Holloway 2003). Both species are riverine and tropical. Coastal nesting of *Carettochelys insculpta* is unknown in Australia, and the reason for their more diverse nesting patterns in New Guinea may lie in differences in rainfall patterns, flooding regimes, distribution of waters of varying salinities at the coast, and associated risks of adult, nest and hatchling mortality between these two regions. Greater interannual variability in these risks in New Guinea may have maintained variability in female choice of where to nest. These ideas require further investigation.

The sand beaches chosen for nesting are of extremely low relief, some on unvegetated sand bars in the open Gulf waters, and the nests are inundated periodically by high tides. This preliminary study thus opens up several interesting questions for future research on the tolerance of nests to periodic inundation, salinity tolerance in the adults, hatchlings and eggs, and navigational cues used by hatchlings to migrate to freshwaters.

Fig. 4. Pig-nosed turtles (*Carettochelys insculpta*) captured in the Kikori region are often held in cages constructed beneath houses awaiting slaughter or sale. (Photo: Matt Pauza.)

The frequency with which turtles are harvested and the large size of *Carettochelys* and *Pelochelys* indicate that turtles are an important source of protein to complement agricultural produce, together with pig (*Sus scrofa* and *Sus celebensis*), fish, crabs, monitor lizards, cuscus, cassowary (*Casuarius casuarius*) and waterfowl. Our study confirms that the female adults and eggs of *Carettochelys insculpta* are heavily harvested, and the question arises as to whether this level of harvest is sustainable. Many villages have cages for housing *Carettochelys* awaiting slaughter or sale (Fig. 4). Only three turtles were held in this way at the time of our visits. The near absence of turtle and turtle eggs from the markets, contrary to observations in other reports (Rose 1981; Rose *et al*. 1982; Georges and Rose 1993), may have resulted from the interruption of harvest activity in the 3 weeks before our arrival, when heavy continuous rain flooded the Kikori and covered all nesting banks in the delta and upstream reaches.

We found no evidence of trade in turtles, eggs or turtle products with markets outside the Kikori region. In the temporary fishing camps, turtle shells were discarded in the bushes a few metres from camp, whereas in the more permanent settlements they were thrown into the river. There was no evidence of the plastra being retained for sale for the production of medicinals via the Asian trade as was common in the Transfly (Georges *et al*. 2006). We received an anecdotal report of live *Carettochelys* being shipped out of the region on logging boats for sale in the Asian market, but were unable to verify this.

Our data are suggestive of trends in the size of breeding females, and in nest and egg attributes between 2003 and 2006. There is an urgent need to undertake more systematic assessments of trends in these parameters, and trends in nesting activity generally, to provide a foundation for assessment of trends in population numbers and the need for management intervention.

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