ARTICLES

Editorial Introduction

The following paper on *Carettochelys insculpta* represents an initial sampling of an on-going cooperative international effort to document our current state of knowledge of the conservation biology and survival status of all freshwater turtles of the world. In 1989, at the First World Congress of Herpetology in Canterbury, the IUCN/SSC Tortoise and Freshwater Turtle Specialist Group presented the published results of a similar undertaking on the status of tortoises (*The Conservation Biology of Tortoises*, edited by Ian R. Swingland and Michael W. Klemens). At that Congress it was decided to produce a companion follow-up volume on freshwater turtles. That volume, *The Conservation Biology of Freshwater Turtles*, edited by Peter C.H. Pritchard and Anders G.J. Rhodin, has been in production since that time. Because of the large number of species (currently 220, and always changing), the vast amount of data to be gathered, and the numerous worldwide turtle specialists (currently 85) involved, the process has been a slow one. The volume is now nearing completion and public release is anticipated for sometime in the first half of 1994. The following account was written for the volume, and represents a sample of what is being produced for each freshwater turtle species. This account is particularly complete and thorough, and we felt that it warranted inclusion in this inaugural issue of *Chelonian Conservation and Biology* to serve as an example of what the Specialist Group is in the process of producing. The format of all accounts in the volume follows this one, with sections for Abstract, Taxonomy, Description, Distribution, Habitat and Ecology, Population Status, Threats to Survival, Conservation Measures Taken, Conservation Measures Proposed, Captive Husbandry, and Current Research.

Chelonian Conservation and Biology, 1993, 1(1):3-12

Conservation Biology of the Pig-Nosed Turtle, *Carettochelys insculpta*

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ABSTRACT. – ***Carettochelys insculpta* is the sole surviving member of the Carettochelyidae, a family of turtles widely distributed during the Tertiary. It is restricted to the southern rivers of New Guinea and the major rivers of the Northern Territory in Australia. *Carettochelys* is a distinctive geographic and taxonomic relict and, although locally abundant, it is rare in the sense of being geographically restricted. Populations in New Guinea are thought to be declining because of increased exploitation for meat and eggs. This exploitation has been exacerbated in recent times by the introduction of modern technology, principally outboard motors. Clan warfare has ceased and people have moved from the hinterland to more convenient locations along riverbanks. Levels of industrial activity such as mining, exploration for oil, gold and copper, logging, and fishing have increased. Any of these activities has the potential to impact wildlife populations, including those of the pig-nosed turtle. In Australia, feral water buffalo pose a major threat through trampling of nesting banks and widespread destruction of the riparian vegetation upon which the turtles depend. Other potential pressures include aggressive pastoral and agricultural practices that push the land beyond capacity in the important catchments, with resulting erosion and siltation of water courses. Mining activity in sensitive areas, such as Kakadu National Park, may also pose a threat unless strict controls are applied on containment of mine waste, fishing activities of the mine staff, draw-down of the water table, and routes taken in the transport of chemicals used for extraction of minerals. Urgent research is required to determine trends in population numbers and levels of exploitation in New Guinea. Additional research should be undertaken to determine whether management leading to sustainable exploitation of *Carettochelys* is necessary and attainable, and if it is, to make recommendations on how such sustainable utilization might be brought about. In Australia, research is required to determine the distribution of *Carettochelys*, so that the importance of the two known major populations can be adequately assessed. Wet-season habitat requirements, extent of seasonal movements, and requirements of juveniles are unknown, yet this information is needed to gauge the possible impact of proposed or potential development within catchments and to gauge the adequacy of existing reserves for protecting the species.**

Taxonomy

Carettochelys insculpta was first described as a new genus and species in 1886 by Dr. E.P. Ramsay from an incomplete specimen collected in the Strickland River, a tributary of the Fly River in Papua New Guinea. The circumstances of its collection, by Walter Froggatt and Jas H. Shaw while on an expedition with the Geographical Society of Australasia, are described by Waite (1905). The genus is

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monotypic and no subspecies are recognized.

Soon after its description, Boulenger (1887) placed *Carettochelys insculpta* in its own family, the Carettochelyidae, and included it among the suborder of side-necked turtles, the Pleurodira. He made this latter decision with some reference to morphological characters but primarily because, at the time, only side-necked turtles were known from Australia and New Guinea. Baur (1891a, 1891b) was vehemently opposed to grouping *Carettochelys* with the side-necked turtles and called upon Ramsay to release details of the articulation of the cervical vertebrae "to show at once the affinities of this peculiar genus." Unfortunately, the specimen lacked key anatomical elements, the cervical vertebrae, so the matter remained one of considerable debate (Strauch, 1890; Vaillant, 1894; Boulenger, 1898; Gadow, 1901; Ogilby, 1907; Hay, 1908) until the work of Waite (1905) became widely known. He described a more complete specimen from the island of Kiwai at the mouth of the Fly River, and examination of the cervical vertebrae established that *Carettochelys insculpta* properly belongs to the suborder Cryptodira, not the side-necked Pleurodira.

The debate on the affinities of *Carettochelys* continued sporadically, as summarized by Walther (1922), Frair (1985) and Meylan (1988). Current wisdom has it that *Carettochelys insculpta* is the sole surviving member of a family known from deposits of Cretaceous to Oligocene age of North America, Europe, and Asia (Pritchard, 1979b), with closest living relatives among the soft-shelled turtles (Trionychidae) (Chen et al., 1980; Frair, 1983, 1985). It is sufficiently distinct to warrant retention of the family Carettochelyidae and some would argue that it should be separated from the trionychids at the level of superfamily at least (Williams, 1950; Frair, 1985). Time of divergence is estimated from the molecular clock to be of the order of 40 million years (Chen et al., 1980).

Description

Original detailed descriptions of the morphology of *Carettochelys insculpta* are provided by Ramsay (1886), Waite (1905), and Walther (1922) and are summarized by Cogger (1975) and Pritchard (1979a). *Carettochelys insculpta* is a heavy bodied turtle, up to 22.5 kg in weight and 56.3 cm in carapace length (M.R. Rose, unpublished data). Coloration is rich gray, olive-gray or gray-brown above, and white, cream, or yellowish below. The jaws are cream and there is a pale streak behind the eye. The species is cryptodirous; that is, the vertebral column in its neck flexes in the vertical plane when the head is withdrawn, and several of the cervical vertebrae have laterally doubled articular surfaces (Williams, 1950). There are no epidermal scutes overlying the shell, which is covered instead with a continuous skin. The carapace is relatively deep, with a median keel toward the rear. The peripheral bones are complete and well-developed (although not rigidly attached to the costal bones), so there is no flexible shell margin. The plastron is somewhat reduced but forms a continuous plate without even a median fontanelle, although several of the plastral elements are not rigidly ossified together, but rather have fibrous connections that allow a certain amount of flexibility both longitudinally (midline and bridges) and transversely (anterior plastral lobe). The limbs are paddle-shaped, like those of sea turtles,

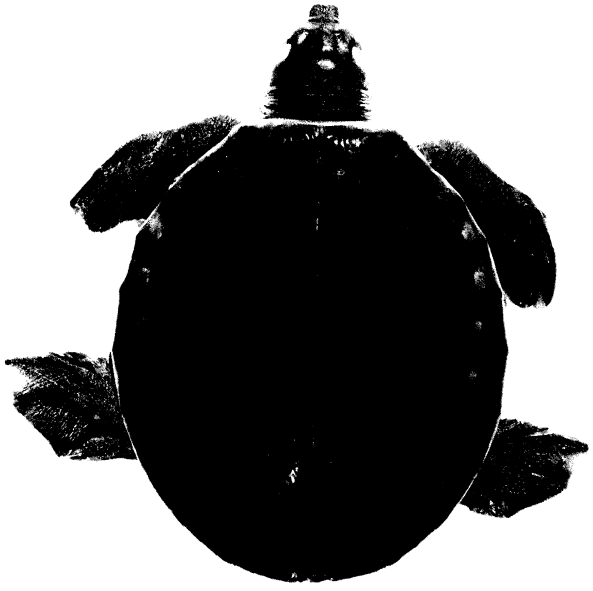

Figure 1. *Carettochelys insculpta* from Australia.

Figure 2. *Carettochelys insculpta* from Australia.

Figure 3. *Carettochelys insculpta* from Australia.

each with two claws. The dorsal surface of the tail is covered with a single line of crescent-shaped scales that decrease in size from the base to the tip. Prominent folds of skin extend laterally on each side from the undersurface of the tail across the thigh region and down the hind limbs. The nostrils are at the end of a prominent fleshy proboscis. Mature males can be distinguished from females of the same size by the tail, which is larger in males to enable successful copulation.

On emergence, hatchlings have well formed strong limbs but an extremely soft plastron and carapace. The plastron has a deep crease where folding of the body occurred during incubation. The periphery of the shell comprises loose flaps of skin, which become firm after about one week to form a strongly serrated margin. Hatchlings also have a tuberculate median keel; a poorly defined and transient polygonal outline around each of these tubercules may or may not be homologous to the scute seams of other turtles (Zangerl, 1959; Pritchard, 1979a). The tubercules are lost as the turtle grows and the median keel is present only on the posterior quarter of the carapace by the time the turtle matures.

Hatchlings from New Guinea weigh 29.6 ± 0.32 g on average and have an average carapace length of 53 ± 0.25 mm (M. R. Rose, unpublished data), whereas the equivalent data for the South Alligator River are 24.7 ± 0.84 g and 56.1 ± 0.91 mm (Georges and Kennett, 1989) and for the Daly River are 20.5 g and 41.1 ± 1.22 mm (Webb et al., 1986). They exhibit the full range of shell color variation shown in the adults, even within single clutches, and the pale streak behind the eye is already present. There may be small light patches on the carapace radiating to the peripherals, and these are more prominent toward the rear of the carapace.

Distribution

The discovery and description of this peculiar species (Ramsay, 1886) generated great interest in Europe (Walther, 1922), and the species was often specifically sought by explorers and travelers visiting Papua New Guinea and Irian Jaya (Boulenger, 1914; De Rooij, 1915, 1922; Wermuth, 1963; Schultze-Westrum, 1963; Cann, 1974). The species was soon recorded from the Strickland (Ramsay, 1886; Waite, 1905), Fly (Boulenger, 1898; Waite, 1905), Morehead (Longman, 1913), Aramia and Omati (Slater, 1961), Binaturi (Rhodin and Rhodin, 1977), Purari (Pernetta and Burgin, 1980) and Kikori rivers (Rose, 1981) of Papua New Guinea. It is known in Irian Jaya from the Setekwa (Boulenger, 1914), Heron (De Rooij, 1922), and other southern flowing rivers (Cann, 1974, 1978, 1980). It was also reported from Lake Jamur (De Rooij, 1915), but the specimen consisted of fragments of shell and may have been carried there by natives (De Rooij, 1922). Brongersma (1958) reported that *Carettochelys* was relatively common in the southern flowing rivers of New Guinea and Lake Jamur. It seems likely that *Carettochelys insculpta* occurs in all of the major and some of the smaller southern-flowing rivers of Papua New Guinea and Irian Jaya, but the exact boundaries to its distribution are unknown. No published records of the species exist for rivers east of the Purari, but local native information (M.R. Rose, unpublished) indicates that its range extends to the Vailala River in the east.

The existence of *Carettochelys insculpta* in northern Australia was not widely known until a specimen from the Daly River was reported (Cogger, 1970; Peters, 1970). Evidence of breeding in Australia dates back to 1918 when eggs from the East Alligator River were lodged with the Victorian Museum (Georges et al, 1989) and the presence of Aboriginal rock paintings of *Carettochelys* in Kakadu National Park, Northern Territory (Cann, 1980; Dupe, 1980; Georges, 1987), some dating back more than 7000 years (George Chaloupka, *pers. comm.*), suggests that the species has been a long term resident of northern Australia. Nevertheless, Cogger and Heatwole (1981) have argued that the restricted range of *Carettochelys* (New Guinea and scattered coastal localities in the Northern Territory), the lack of recognized differentiation between the two areas, and the highly aquatic nature and estuarine tendencies of this species, suggests that it is a relatively recent immigrant from New Guinea to Australia. In northern Australia, *Carettochelys insculpta* occurs in the Daly (Cogger, 1970; Cann, 1972; Webb et al., 1986; Georges, 1987), South Alligator (Schodde et al., 1972; Legler, 1980, 1982; Press, 1986), East Alligator (Georges et al., 1989), and Victoria drainages (Cogger, 1975; Jessie Roberts, *pers. comm.*). There have also been anecdotal reports of the species from the Darwin, Adelaide, McKinlay, and Roper rivers of the Northern Territory (Cann, 1972; John Bywater, *pers. comm.*), and the Wenlock River on the west coast of Cape York (K. Day, *pers. comm.* to Webb et al., 1986). The distribution of *Carettochelys* in Australia clearly requires further investigation.

Habitat and Ecology

In Papua New Guinea, *Carettochelys insculpta* inhabits rivers (including estuarine reaches and river deltas), grassy lagoons, swamps, lakes and water-holes of the southern

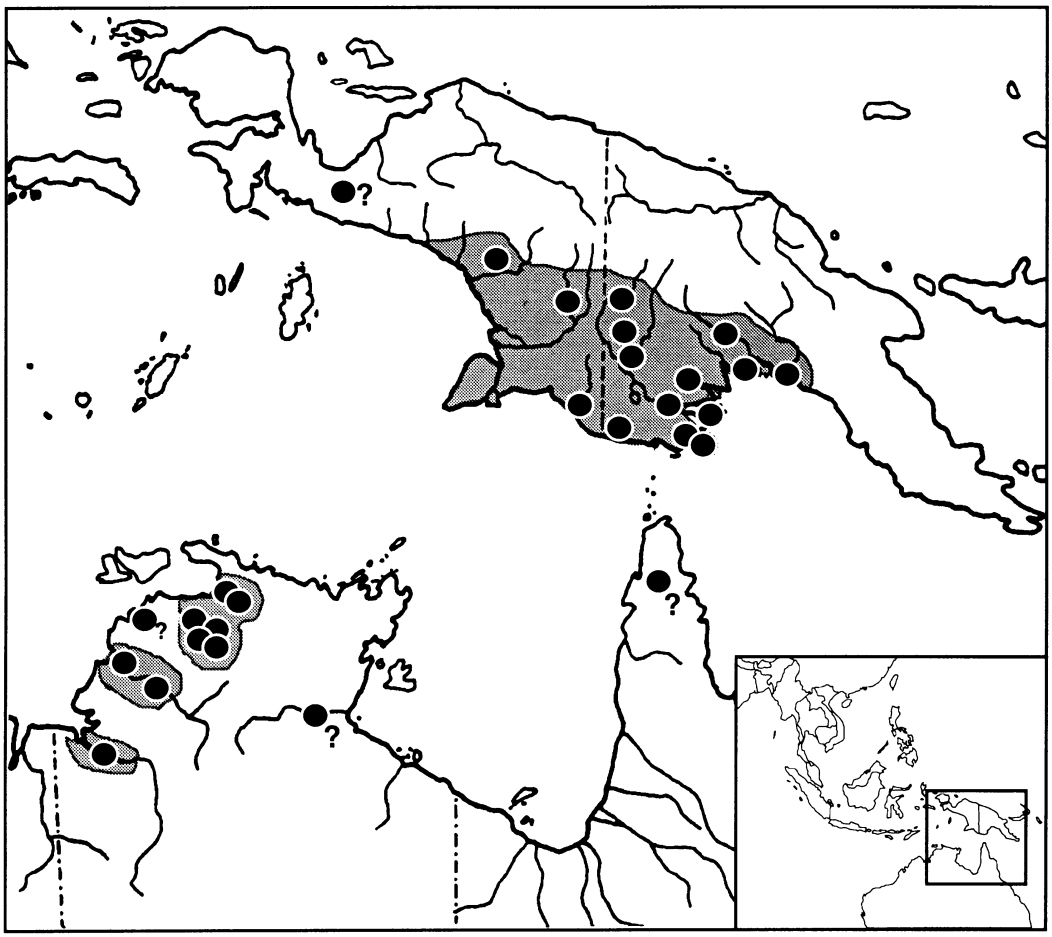

Figure 4. Distribution of *Carettochelys insculpta* in Indonesian Irian Jaya, Papua New Guinea, and Australia. Map modified from Iverson (1986). Dots indicate documented localities, question marks anecdotal records, and shading the presumed distribution.

lowlands (Liem and Haines, 1977; Groombridge, 1982). Locals of the Purari region claim that the hatchling turtles congregate in the lower delta and feed on vegetation and fruits of mangroves. In Australia, there are no substantiated reports of *Carettochelys insculpta* occurring in estuarine areas (Press, 1986; Georges and Kennett, 1989) but it is known from the clear, shallow, continuously-flowing waters of the Daly drainage (Cogger, 1970; Cann, 1972; Webb et al., 1986) and from lowland and upland billabongs and plunge pools of the Alligator Rivers region (Legler, 1980, 1982; Press, 1986; Georges and Kennett, 1989). The preferred dry season habitat in the Alligator Rivers region is typified by Barramundi Creek (Legler, 1982) and the Pul Pul Billabong (Georges and Kennett, 1989). Average depth was approximately 2 m but there were holes between 3 and 7 m deep. The substratum was sand and gravel covered with a thin layer of fine silt and litter. Fallen trees and branches, undercut banks, exposed tree roots, and local accumulations of litter provided a diverse range of underwater cover for turtles. The banks of the billabongs were covered with dense broadleafed forest, including *Ficus racemosa*, whose fruits and leaves are an important food source for *Carettochelys*. The many small sandbanks adjacent to the water provide ample nesting opportunity. Water flows through the billabongs in all months of most years.

Carettochelys is omnivorous, but tends more toward herbivory than omnivory (Groombridge, 1982). In the Gulf Province of Papua New Guinea, it feeds principally on the unripe fruits of the mangrove *Sonneratia* spp., possibly by cropping the fruits from the vegetation at high tide (M.R. Rose, unpublished data). Fruits from *Xylocarpus* sp., *Nypa fruticans*, *Canorium indicum*, *Antrocarpus incisor*, and the wild "pit pit" *Sachhorum robistum* are also eaten. Animal foods include the molluscs *Batissa violocea*, *Nerita* sp., and *Centhidea* sp., and the crustacean *Siyellu serrata*. In Australia, *Carettochelys* feeds on the leaves, fruits and flowers of riparian vegetation, especially the fig *Ficus racemosa*, the bush apple *Syzygium forte*, and the screw pine *Pandanus aquaticus* (Schodde et al., 1972; Legler, 1982; Georges and Kennett, 1989). Other foods include aquatic insect larvae, crustacea, mollusca, and fishes and mammals possibly eaten as carrion, as well as aquatic plants such as algae, *Vallisneria* sp. and *Najas tenuifolia* (Cogger, 1970; Schodde et al., 1972; Legler, 1982; Georges et al., 1989; Georges and Kennett, 1989). The wide range of acceptable foods provides great scope for opportunism, and the diet varies significantly with the foods available from locality to locality.

In New Guinea, *Carettochelys insculpta* nests in the late

dry season between September and December (Cogger, 1975; Cann, 1978; Pernetta and Burgin, 1980), but as eggs appear in the Kikori markets as late as February (Groombridge, 1982), the nesting season may extend to the end of January. Nesting in the Kikori District spanned 19 weeks in 1981-82 (M.R. Rose, unpublished data). *Carettochelys* also nests in the late dry season in Australia. The nesting season on the Daly River extends between mid August and early October (Georges and Kennett, 1989). Nesting is more protracted in the Alligator Rivers, ranging from mid July to early November (Georges and Kennett, 1989). Bimodal distributions of nesting dates both in the Kikori District of Papua New Guinea and the Daly River of Australia provide circumstantial evidence of multiple clutching (see also Legler, 1980), a conclusion supported by examination of reproductive tracts of three specimens dissected during the nesting season at Kikori (M.R. Rose, unpublished data).

Carettochelys typically chooses clean fine sand adjacent to water in which to nest (Cann, 1978; Pernetta and Burgin, 1980; Legler, 1982; Webb et al., 1986; Rose, pers. obs.), but also nests in mud and loams at some localities (Slater, 1961; Cogger, 1975-Plate 59 and *pers. comm.*; Groombridge, 1982; Rob Elvish, *pers. comm.*; Rose, pers. obs.). It nests upon sand banks adjacent to water in the middle reaches and mouths of rivers, on sandy shores of islands in river deltas, and on coastal beaches (Rhodin and Rhodin, 1977; Groombridge, 1982; Webb et al., 1986; Georges and Kennett, 1989). Nesting activity has been reported from the Strickland, Purari, Kikori, Turama, Era, Pai, and Fly rivers of Papua New Guinea (Waite, 1905; Pernetta and Burgin, 1980; M.R. Rose, unpublished data), the Setekwa and other southern rivers of Irian Jaya (Boulenger, 1914; Cann, 1978, 1980), and the Daly, South Alligator and East Alligator rivers of northern Australia (Schodde et al., 1986; Georges et al., 1989; Georges and Kennett, 1989).

The eggs are white, hard-shelled, and almost perfectly spherical (Ramsay, 1886) with a mean diameter of 38.7 ± 1.3 mm and a mean weight of 33.7 ± 3.5 g for eggs from the Daly River of northern Australia (Webb et al., 1986). Eggs from the East Alligator River were somewhat larger (42.0-44.8 mm, n=15, Georges et al., 1989), more in keeping with the size of eggs in New Guinea (Purari River: 38-46 mm, mean 42.9 mm, n=108, Pernetta and Burgin, 1980; Kikori River: means 42.8 ± 2.3 mm, 45.7 ± 0.7 g, M.R. Rose, unpublished). Both the ultrastructure (Erben, 1970) and the gross morphology of the eggshell and the egg constituents (Webb et al., 1986) have been described.

Clutch sizes range from 7 to 19 in the Daly River of northern Australia (Webb et al., 1986; Georges, 1987) and from 8 to 39 in New Guinea (De Rooij, 1915; Cann, 1978; Pernetta and Burgin, 1980; Groombridge, 1982; M.R. Rose, unpublished). Some of the largest clutches claimed may have been laid by more than one female, in areas where there was intense nesting activity (Cann, 1978). Nests of *Carettochelys insculpta* are recorded as being subject to predation by monitor lizards (Pernetta and Burgin, 1980; Legler, 1982; Georges and Kennett, 1989) and man (Cann, 1974; Pernetta and Burgin, 1980; Groombridge, 1982; Press, 1986; Georges and Kennett, 1988). Those that survive require 64 to 74 days (at 30°C) to develop to a point where hatching is possible (i.e., until yolk internalization) after which they enter an embryonic aestivation within the egg (Webb et al., 1986). At onset of aestivation, metabolic rate decreases precipitously and embryonic growth ceases. Yolk is used during diapause at a rate that yielded an estimate of 59 days to yolk exhaustion at 28°C to 30°C (Webb et al., 1986). Hatching can be stimulated by reducing oxygen availability, either by submerging eggs in water or replacing the atmosphere that surrounds them with nitrogen, suggesting that in the field, hatching is stimulated either by early season rains or by actual flooding (Webb et al., 1986; A. Georges, in prep). Incubation period for 30 natural nests from the Kikori River of Papua New Guinea was between 86 and 102 days (average nest temperature 31.6°C) (M.R. Rose, unpublished data). This presumably included a substantial period of aestivation, which would account for the discrepancy between these findings and those of Webb et al. (1986).

The hatchling sex ratio of *Carettochelys insculpta* is influenced by the temperature that prevails during incubation, both under constant conditions in the laboratory (Webb et al., 1986) and under fluctuating conditions in field nests (Georges, 1987; Georges, 1992). Embryos incubated at a constant 28°C and 30°C become males, whereas those incubated at 32°C become females (Webb et al., 1986). The laboratory threshold for sex determination is not known precisely (between 30° and 32°C, Webb et al., 1986), but under field conditions, the threshold of 31.6°C (Georges, 1987) agrees with the average nest temperature in New Guinea of 31.6°C (M.R. Rose, unpublished data).

There is some information on natural levels of survivorship (83.2% of eggs hatched from 30 Papua New Guinea nests (M.R. Rose, unpublished data) but none on rates of recruitment to the parent population, nor is it known how long the young turtles take to reach maturity.

Population Status

Carettochelys insculpta was long considered one of the rarest turtles in the world (Groombridge, 1982) but it is not certain whether this reputation reflected its remote distribution or truly low population densities (Pritchard, 1979a). In fact, many have considered it to be fairly common where it occurs in both Australia and New Guinea (Brongersma, 1958; Slater, 1961; Cann, 1974, 1980; Press, 1986; Shelley Burgin, *pers. comm.*), but there are few precise estimates of population size. Georges and Kennett (1989) found *Carettochelys* to be widespread between the tidal reaches and the head-waters of the South Alligator River in Australia, and that high densities may be present in the upper reaches during the dry season (33.8 ± 11.3 turtles per ha in small discrete ponds on the main channel). Populations of *Carettochelys* in the Kikori River District of Papua New

Guinea (Gulf Province) are reported to have been severely depleted in the last 20 years, and the populations in the Western Province appear to be declining (Rose, 1981; Groombridge, 1982). It is reported as rare in Irian Jaya, with a sparse and limited distribution (Anonymous, 1978), but this conflicts with the observations of Cann (1974, 1978, 1980). Regardless of high densities in some areas within its range, *Carettochelys* is both geographically and taxonomically a relictual species. Locally abundant species with restricted ranges are sometimes more vulnerable than scarce but widely distributed species.

Threats to Survival

Carettochelys insculpta is highly prized as a food item by the indigenous peoples within its range both in Australia and New Guinea (Schultze-Westrum, 1963; Cann, 1980; Press, 1986) and it is important to the subsistence economies of several Papuan communities (Pernetta and Burgin, 1980). Both the adults and their eggs are collected, consumed, and sold throughout the range in Papua New Guinea. In Kikori Market alone, over 5000 eggs were sold between October 1980 and February 1981 (Groombridge, 1982). In the following year, over 20,000 eggs were collected and consumed in Kikori and three surrounding villages (M.R. Rose, unpublished data). In the breeding season, villagers collect female turtles and their eggs when they come to shore to nest, or they locate nests by systematically prodding sand banks with a stick or spear. In some areas, pit-traps are checked daily for nesting turtles that have fallen into them on the previous night (Groombridge, 1982). Outside the nesting season, the turtles are caught by hand from boats in shallow water and swamps, on lines baited with crab or de-shelled mussels (Groombridge, 1982), or in basket traps (Schultze-Westrum, 1963).

In northern Australia, turtles are regularly eaten by Aborigines, and *Carettochelys insculpta* are favored by some for their size and flavor (Cann, 1980; Press, 1986). Traditionally, men used to climb trees on the banks of billabongs and spear the turtles when they came near the surface (Georges, 1987). Alternatively, *Carettochelys* could be hunted by diving on top of them from the bank or by waiting quietly in the water while others herded the turtles. Today, however, they are more often caught on hand lines baited with wallaby or buffalo meat (Cann, 1972; Georges, 1987). There are no reports of Australian Aborigines harvesting the eggs of *Carettochelys*.

Groombridge (1982) considers that traditional hunting of turtles and harvesting of eggs in southern New Guinea is the principal threat to the species. Stereotyped nesting habits render *Carettochelys insculpta* (like sea turtles) extremely susceptible to over-exploitation. 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 clan warfare has decreased, people have moved from the hinterland to more convenient locations along the river banks. *Carettochelys* populations in New Guinea are reported to have declined sharply between 1960 and 1980 (Groombridge, 1982). There are few data on levels of exploitation in Australia. Georges and Kennett (1988) report an annual take of 19 turtles by two Aboriginal families at Nourlangie Camp, but without adequate data on population numbers and recruitment, it is not known whether this exceeds a sustainable yield.

Feral water buffalo pose a major threat to pig-nosed turtles and their habitat in the Alligator Rivers region of northern Australia. The sand banks used for nesting by *Carettochelys* are also used as easy access to water and as resting places at night by water buffalo. This led Archie Carr to comment in a letter to Pritchard (1979b) that *Carettochelys* may have become much more restricted in its Australian distribution since the introduction of water buffalo. In 1987, buffalo densities in Goodparla Station (now part of Kakadu National Park) were so high that all potential nesting banks were heavily trampled. Such trampling is known to destroy nests (Georges and Kennett, 1989). Water buffalo also destroy the riparian vegetation upon which the turtles depend in the dry season for food, by foraging on young plants and by structurally destroying the banks of billabongs. While this may initially benefit *Carettochelys* by increasing underwater cover afforded by fallen trees, branches, and litter, it can only have long-term deleterious effects on the populations.

Agricultural and pastoral activities in the catchments of the Daly drainage have the potential to seriously impact *Carettochelys* populations where stocking rates are high, the riparian vegetation is cleared, or land used is so intensive as to cause erosion and siltation of water courses.

Mining activity in sensitive areas such as Kakadu National Park may pose a potential threat to the environment and the fauna that depends upon it (Dames and Moore, 1987; Georges and Kennett, 1988). Exploration and mining for gold by chemical extraction is planned for the headwaters of the South Alligator River, in the region identified as providing important refuge ponds for *Carettochelys* in the dry season (Georges and Kennett, 1988, 1989). Contaminated rainwater run-off, accidental discharges from the tailings dam or treatment plant, or accidental spillage of hazardous industrial chemicals at stream or tributary crossings during transport to the mill site are all potential sources of destructive pollution of the South Alligator River. Demands on water for mining operations may deplete the water table and reduce water levels in the shallow billabongs used by *Carettochelys* as dry-season refuges. Upgrading river crossings and causeways may restrict the free movement of turtles during the early dry season.

Carettochelys is easily caught on baited lines (Cogger, 1970; Georges and Kennett, 1988). Populations may be decimated by increased fishing activity in the dry-season refuges by mine workers and others allowed into the mining area. Although fishing may be prohibited for non-Aboriginal employees of the mine, any restrictions will be difficult to apply to Aboriginal employees (substantial proportion of the total) and those who accompany them, as the Aboriginal

community remains the traditional owner of the head-waters of the South Alligator River.

The issue of allowing mining and extensive gold and uranium exploration within Kakadu National Park has not been resolved at the time of writing, and the atmosphere of confrontation is not conducive to finding a compromise that serves both the long-term interests of the unique biota of the region and the interests of a sustainable Australian economy (Georges, 1990a, 1990b).

Similar concerns are felt for New Guinea populations. Gold and copper are being mined on the Fly River at Ok Tedi and standards for the protection of the environment there have been questioned (Georges, 1990b). Quite apart from the risk of environmental contamination, mining and other commercial operations organized by expatriate interests will increase river traffic which will in turn increase the number of turtles and eggs taken.

Conservation Measures Taken

There have been several calls for *Carettochelys* to be given a high priority in conservation funding. In view of its restricted range and its importance to the subsistence economy of many native peoples in Papua New Guinea, Pernetta and Burgin (1980) recommended that investigation of the biology and population status of *Carettochelys* be given high priority. Groombridge (1982) recommended that studies of the biology and distribution of the species in Papua New Guinea and Australia, and of the distribution, population status, and levels of exploitation in Irian Jaya be undertaken. He indicated that the IUCN/SSC Tortoise and Freshwater Turtle Specialist Group planned a high priority project on the ecology, reproduction, and economic potential for the long-term management of *Carettochelys*. Because of lack of fundamental information, *Carettochelys* received a classification of K – "Insufficiently Known" – in the Red Data Book (Groombridge, 1982) and is not listed in the Appendices of CITES (1973). It has since received an Action Plan Rating of 1 (known threatened species in need of specific conservation measures) by the IUCN/SSC Tortoise and Freshwater Turtle Specialist Group (IUCN, 1989).

Groombridge (1982) reported that no conservation measures have been implemented in Papua New Guinea, although the declaration of certain wildlife management areas may protect it from non-native hunting pressures.

In Australia, *Carettochelys* benefits from both State and Federal legislation prohibiting the exploitation of native fauna by all but Aboriginal peoples. It is protected throughout its documented range by the National Parks and Wildlife Conservation Act of 1975 in Kakadu National Park and elsewhere in the Northern Territory by the Territory Parks and Wildlife Conservation Act of 1982 (R. Jenkins, *pers. comm.*). Export is prohibited under the Wildlife Protection (Regulation of Exports and Imports) Act of 1982. However, such legislation does not protect the species from habitat destruction or modification. The provision of national parks and reserves would appear to be an appropriate response to ensure the conservation of a species that is locally abundant within a limited distribution. In Australia, Kakadu National Park affords the species considerable protection, and an intensive buffalo control program is now in place. However, as outlined above, the park is currently a compromise between conservation, mining, recreation, and other interests, and the annexation of important regions in the headwaters of the South Alligator drainage for mining by chemical extraction is still high on the agenda for some elements of government.

Conservation Measures Proposed

In view of the importance of *Carettochelys* as a food source for local people and the decentralized nature of the wildlife management authority in Papua New Guinea, any conservation measures need to be introduced with sensitivity (IUCN, 1989). There have been calls for the introduction of a scheme to protect nest sites against over-exploitation, perhaps allied to a closed season for hunting and egg collecting. However, firm data on trends in population numbers and levels of exploitation of *Carettochelys* for meat and eggs that could be used in support of these calls are lacking.

Preliminary research indicates the need for the following measures in Papua New Guinea, focusing especially on the Fly River catchment (IUCN, 1989):

- Comparative studies on the impact of different levels of exploitation of this species are needed to serve as a foundation for future monitoring of the turtle populations, and to enable future advice to be given to local communities to help them protect *Carettochelys* and its eggs.
- An assessment of the current intensity of exploitation is required to provide a basis for monitoring, and if necessary, controlling future trends in exploitation with changes in human populations and practices.
- An evaluation of the principal habitat requirements of *Carettochelys* is required in order to evaluate and respond to the potential impact of proposed, or potential, projects in river catchments, such as hydroelectric schemes, mangrove clearing, woodchipping, etc.
- Population data are required to determine whether a management program for ensuring a sustainable harvest of *Carettochelys* is necessary and attainable.
- The population studies must be associated with research into the possibility of integrating a sustainable harvest system into local economies. This will almost certainly need to be backed up with a public awareness and education campaign. The program will also include provision for training local wildlife staff and maintaining their operations.

Apart from the Alligator Rivers Region, the only other known concentration of pig-nosed turtles in northern Australia is in the Daly River. The Daly River is largely unprotected and control of even the river banks and important riparian vegetation is largely in private hands. The Northern Territory Government lacks a coherent river and wetlands conservation strategy, but there are some promising initiatives on the horizon. A conservation and recreation develop-

ment strategy for the wetlands between Darwin and Arnhem Land escarpment is currently under consideration, although this strategy will not address problems faced in the Daly River catchment.

The land conservation section of the Conservation Commission of the Northern Territory is encouraging landholders in the Daly catchment to clear only in accordance with land capability, and the landholders are responding to this encouragement. They see the folly of clearing areas that are only peripherally suitable for agriculture or grazing. We may have seen the last of the wholesale clearing of land including drainage gullies and areas down to the water-line as has happened in the past in the Daly catchment. Another welcome initiative is the formation of land care groups encouraged by the Conservation Commission, such as the group recently formed in the Mary River region. These groups involve a broad spectrum of people interested in seeing both our heritage and our useful resources preserved.

The Northern Territory Government should be encouraged to develop these initiatives further. Urgent consideration should be given to protecting the section of the Daly River corridor between Policeman's Crossing and the Junction of the King River, and to protecting the riparian vegetation throughout the Daly drainage.

Captive Husbandry

Procedures for egg collection, transportation, and artificial incubation have been established and can be incorporated into management programs with the option of accurately predicting and controlling hatchling sizes, sexes, amounts of internalized yolk, and incubation times (Webb et al., 1986).

Carettochelys can be readily kept in aquaria in clean water maintained at a temperature between 28 and 30°C. A spacious tank with a diversity of underwater cover is required if two or more specimens are housed together, as even small individuals can become aggressive and will habitually inflict damage to others of their species if confined together. In captivity, they will accept and thrive on a diverse diet of figs, apples, other fruits, eel weed (*Vallisneria* sp.), small fishes, and shrimp.

Hatchling and sub-adult specimens are particularly susceptible to fungal white spot (*Sphagnalium* sp.), which if not treated promptly may kill young animals within a week (M. Palmer-Allen, *pers. comm.*). It can be effectively treated by removing all loose skin and scabs and painting the skin liberally with 1% Mercurichrome or Acriflavine Solution, which is allowed to dry before the animals are returned to the tank.

Captive specimens are held in Australia at the Berry Springs Zoo (Darwin), Taronga Park Zoo (Sydney), Hartley Creek Crocodile Farm (Cairns), Beewah Animal Park (near Nambour), and the University of Canberra. Only the first two organizations are in a position to mount a captive breeding program. Specimens at Berry Springs mated in 1989 after having been transferred from an outdoor enclosure earlier in the year, and the female subsequently laid eggs on the bottom of the aquarium. The aquarium now has an artificial nesting bank and the curator anticipates successful breeding in the near future (L. Moyes, *pers. comm.*).

Current Research

Current research in Australia is supported by the Australian National Parks and Wildlife Service and the Conservation Commission of the Northern Territory. Studies of the effects of temperature on hatchling sex ratios in the field (Georges, 1992), nesting ecology (A. Georges, in prep.), and population ecology (Heaphy, 1990) are nearing completion. A proposal for a study of the seasonal movements and wet season habitat requirements of *Carettochelys* in the Alligator Rivers region is being developed.

In Australia, it is important to know more of the distribution of *Carettochelys* if only to better assess the importance of the two known populations in the Daly River and the Alligator Rivers region. Work is also required to determine an ecological basis for the restricted distribution of *Carettochelys* which, according to data at hand, has very broad habitat requirements. Studies to date have not addressed seasonal movements and wet season requirements, nor do they address the requirements of juveniles, and the answers may lie there. Such information is needed before the possible impact of proposed or potential development within catchments (Groombridge, 1982; Georges and Kennett, 1988) can be assessed, and before the adequacy of existing reserves for protecting the species can be judged.

LITERATURE CITED

Anonymous. 1978. Pendomen Pengelolaan Satwa Langka Di Indonesia. Jilid 1; Mammalia, Reptilia dan Amphibia. Bogor: Direktorat Jenderal Kehutanan (Direktorat Perlindungan dan Pengeawetan Alam), 103 pp.

Baur, G. 1891a. The very peculiar tortoise, *Carettochelys* Ramsay, from New Guinea. Science 17:190.

Baur, G. 1891b. On the relations of *Carettochelys*, Ramsay. Amer. Nat. 15:631-639.

Boulenger, G.A. 1887. On a new family of pleurodiran turtles. Ann. Mag. Nat. Hist. (5)19:170-172.

Boulenger, G.A. 1898. Exhibition of, and remarks upon, a dancing-stick from New Guinea to which two skulls of the chelonian *Carettochelys insculpta* were attached. Proc. Zool. Soc. London 1898(4):851.

Boulenger, G.A. 1914. An annotated list of the batrachians and reptiles collected by the British Ornithologist's Union expedition and the Wollaston expedition in Dutch New Guinea. Trans. Zool. Soc. London 20(5):247-268.

Brongersma, L.D. 1958. The Animal World of Netherlands New Guinea. Groningen: J.B. Wolters, 70 pp.

Cann, J. 1972. Notes on some tortoises collected in northern Australia. Victorian Nat. 89:165-168.

Cann, J. 1974. Collecting in Irian Jaya during 1972. Roy. Zool. Soc. Bull. Herpetol. 1(3):4-14.

Cann, J. 1978. Tortoises of Australia. Sydney: Angus and Robertson, 79 pp.

Cann, J. 1980. Confessions of a tortoise freak. Geo 3(2):50-

69.
Chen, B.Y., Mao, S.H., and Ling, Y.H. 1980. Evolutionary relationships of turtles suggested by immunological cross-reactivity of albumins. Comp. Biochem. Physiol. 66B:421-425.
CITES. 1973. Convention on International Trade in Endangered Species of Wild Fauna and Flora. Washington: CITES Secretariat.
Cogger, H.G. 1970. First record of the pitted-shelled turtle, *Carettochelys insculpta*, from Australia. Search 1:41.
Cogger, H.G. 1975. Reptiles and Amphibians of Australia. Sydney: A.H. and A.W. Reed, 660 pp. Revised editions in 1979, 1983, 1986.
Cogger, H.G. and Heatwole, H. 1981. The Australian reptiles: Origins, biogeography, distribution patterns and island evolution. Monographia Biologicae 41:1331-1373.
Dames and Moore International. 1987. Coronation Hill Project: Biological Survey of the Coronation Hill area. Unpubl. Final report for BHP Engineering (Job No. 15265-001-073), July 1987.
De Rooij, N. 1915. The Reptiles of the Indo-Australian Archipelago I: Lacertilia, Chelonia, Emydosauria. Leiden: E.J. Brill, 334 pp.
De Rooij, N. 1922. Reptiles (Lacertilia, Chelonia and Emydosauria). Nova Guinea (Zool) 13:133-153.
Dupe, K.V. 1980. The pitted shelled turtle *Carettochelys insculpta* in the Northern Territory. North. Terr. Nat. 1(3):14.
Erben, H.K. 1970. Ultrastrukturen und mineralisation rezenter und fossiler Eischalen bei Vogeln und Reptilien. Biomineralization 1:1-66.
Frair, W. 1983. Serological survey of softshells with other turtles. J. Herpetol. 17:75-79.
Frair, W. 1985. The enigmatic plateless river turtle, *Carettochelys*, in serological survey. J. Herpetol. 19:515-523.
Gadow, H. 1901. Amphibia and Reptiles. In: S.F. Harmer and A.E. Shipley (Eds). The Cambridge Natural History, Vol. 8. London: Macmillan and Co., 668 pp.
Georges, A. 1987. The pig-nosed turtle—warradjan. Aust. Nat. Hist. 22:230- 234.
Georges, A. 1990a. Management of the pig-nosed turtle in northern Australia. Aust. Ranger Bull. 5(4):32-35.
Georges, A. 1990b. The pig-nosed turtle in Kakadu National Park—A submission to the Kakadu Conservation Zone Enquiry. Submission KA 90/59, Resource Assessment Commission, Dept of Prime Minister and Cabinet, Canberra.
Georges, A. 1992. Thermal characteristics and sex determination in field nests of the pig-nosed turtle *Carettochelys insculpta* (Chelonia:Carettochelydidae) from northern Australia. Australian Journal of Zoology 40(5): 511-521.
Georges, A. and Kennett, R. 1988. Dry-season distribution and ecology of the warradjan (*Carettochelys insculpta* Ramsay) in Kakadu National Park. Report to A.N.P.W.S., February 1988. 62 pp.
Georges, A. and Kennett, R. 1989. Dry season distribution and ecology of *Carettochelys insculpta* (Chelonia: Carettochelydidae) in Kakadu National Park, northern Australia. Aust. Wildl. Res. 16:323-335.
Georges, A., Choquenot, D., Coventry, A.J., and Wellings, P. 1989. A note on *Carettochelys insculpta* (Testudinata: Carettochelyidae) from northern Australia. Northern Territory Nat. 11:8-11.
Groombridge, B. 1982. The IUCN Amphibia-Reptilia Red Data Book. Part 1. Testudines, Crocodylia, Rhynchocephalia. Gland, Switzerland: IUCN Publ., 426 pp.
Hay, O.P. 1908. The fossil turtles of North America. Carnegie Inst. Wash. Publ. 75:1-568.
Heaphy, L. 1990. Ecology of the pig-nosed turtle *Carettochelys insculpta* in northern Australia. Ph.D. Thesis. University of New South Wales, Sydney.
IUCN. 1989. Tortoises and Freshwater Turtles. An Action Plan for their Conservation. Gland, Switzerland: International Union for the Conservation of Nature and Natural Resources, 47 pp.
Iverson, J.B. 1986. A Checklist with Distribution Maps of the Turtles of the World. Privately printed, 283 pp.
Legler, J.M. 1980. Taxonomy, distribution and ecology of freshwater turtles in the Alligator Rivers region, Northern Territory. Unpubl. Rprt., Office of the Supervising Scientist, Canberra, 12 Sept 1980 (Suppl. Rprt. 1 July 1982).
Legler, J.M. 1982. The ecology of freshwater turtles in the Alligator Rivers region. Unpubl. report to the Office of the Supervising Scientist, Canberra, 30 Nov 1982.
Liem, D.S. and Haines, A.K. 1977. The ecological significance and economic importance of the mangrove and estuarine communities of the Gulf Province, Papua New Guinea. Purari River (Wabo) Hydroelectric Scheme Environ. Stud. 3: 1-35.
Longman, H.A. 1913. Herpetological notes. Part I.—Systematic. Including the description of one new species. Mem. Queensl. Mus. 2:39-45.
Meylan, P.A. 1988. *Peltochelys* Dollo and the relationships among the genera of Carettochelyidae (Testudines: Reptilia). Herpetologica 44:440-450.
Ogilby, J.D. 1907. Catalogue of the Emydosaurian and Testudinian reptiles of New Guinea. Proc. Roy. Soc. Queensl. 19:1-31.
Pernetta, J.C. and Burgin, S. 1980. Census of crocodile populations and their exploitation in the Purari area (with an annotated checklist of the herpetofauna). Purari River (Wabo) Hydroelectric Scheme Environ. Stud. 14:1-44.
Peters, U. 1970. Die Papua-Schildkröte (*Carettochelys insculpta*) in Australien! Aquar. Terr. Z. 23:182-183.
Press, A.J. 1986. The Gagudju species survey. Unpubl. Report to the Australian National Parks and Wildlife Service, Canberra.
Pritchard, P.C.H. 1979a. Encyclopedia of Turtles. New Jersey: T.F.H. Publ., 895 pp.
Pritchard, P.C.H. 1979b. Taxonomy, evolution, and zoogeography. In: Harless, M. and Morlock, H. (Eds.). Turtles: Perspectives and Research. New York: John Wiley and Sons, pp. 1-42.
Ramsay, E.P. 1886. On a new genus and species of fresh water tortoise from the Fly River, New Guinea. Proc. Linn. Soc. New South Wales 1:158-162.
Rhodin, A.G.J. and Rhodin, S.D. 1977. Iakttagelser från en herpetologisk samlingsresa till Papua New Guinea. Snoken (Nat. Swedish Herp. Assoc.) 7(2/3):65-72.
Rose, M.R. 1981. Draft Red Data Book account of *Carettochelys insculpta*. Unpubl. report. 21-Apr-81.
Schodde, R., Mason, I., and Wolfe, T.O. 1972. Further records of the pitted- shelled turtle (*Carettochelys insculpta*) from Australia. Trans. Roy. Soc. South Aust. 96:115-117.
Schultze-Westrum, T. 1963. Die Papuaschildkröte aus Neuguinea. Natur und Museum, Frankf. 93(4):119-127.
Slater, K.R. 1961. Reptiles in New Guinea. Aust. Territories 1(5):27-35.
Strauch, A. 1890. Bemerkungen über die Schildkrötensammlung im Zool. Museum der Kaiserl. Akad. Wiss. St Petersburg. Mem. Acad. St Petersbourg (7)38(2):1-127.
Vaillant, L. 1894. Essai sur la classification generale des cheloniens. Ann. Sci. Nat. 7(16):331-345.
Waite, E.R. 1905. The osteology of the New Guinea turtle (*Carettochelys insculpta*, Ramsay). Austral. Mus. Rec.

6:110-118.
Walther, W.G. 1922. Die Neu-Guinea-Schildkröte *Carettochelys insculpta* Ramsay. Nova Guinea (Zool.) 13:607-704.
Webb, G.J.W., Choquenot, D., and Whitehead, P.J. 1986. Nests, eggs, and embryonic development of *Carettochelys insculpta* (Chelonia: Carettochelidae) from northern Australia. J. Zool. Ser. B (Lond.) 1(3):521-550.
Wermuth, H. 1963. Die Papua-Weichschildkröte, *Carettochelys insculpta* Ramsay. Aquar.Terr.-Zeitschr. (Stuttgart) 16:341-343.
Williams, E.E. 1950. Variation and selection in the cervical central articulations of living turtles. Bull. Amer. Mus. Nat. Hist. 94:505-562.
Zangerl, R. 1959. Rudimentäre Carapaxbeschuppung bei jungen Exemplaren von *Carettochelys* und ihre morphogenetische Bedeutung. Vierteljahrsschr. Naturf. Ges. Zurich 104:138-147.