DRY-SEASON DISTRIBUTION AND ECOLOGY OF THE WARRADJAN (Carettochelys insculpta Ramsay) IN KAKADU NATIONAL PARK

by

ARTHUR GEORGES and RODNEY KENNETT

for

THE AUSTRALIAN NATIONAL PARKS AND WILDLIFE SERVICE

Water Research Centre

SCHOOL OF APPLIED SCIENCE, CANBERRA COLLEGE OF ADVANCED EDUCATION, P.O. BOX 1, BELCONNEN A.C.T. AUSTRALIA 2616
PHONE 062-522525, TELEX 62267 CANCOL AA, TELEGRAMS COLLADVED

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PLATE I. Warradjan is an Aboriginal name given to the Pig-Nosed Turtle, found only in the freshwater and estuarine reaches of rivers of southern New Guinea and northern Australia. This unusual turtle, bearing the scientific name Carettochelys insculpta, is the sole surviving member of a once widespread group with Tertiary fossils from Europe, North America and southern Asia. Anyone seeing the species for the first time will be struck by how very different it is from other Australian freshwater turtles. It is a large animal up to 56 cm long and weighing up to 22.5 kg. The head is withdrawn straight back into the shell (the neck flexes in a vertical plane) rather than swung to the side as in all other Australian freshwater turtles. It has flippers superficially resembling those of sea turtles rather than the limbs of freshwater species, a feature which led early biologists to mistakenly consider the species to be a link between the sea turtles and freshwater river tortoises. The species totally lacks the horny scutes that overlay the bony shell of most turtles. Instead the shell is covered with skin -- soft and cream-coloured on the undersurface, thin taut and greyish-brown above. The nostrils open at the end of a prominant fleshy proboscis through which the turtle inhales not only air at the surface, but also water when submerged. [Photo: R. Jenkins].

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CONTENTS

SUMMARY AND RECOMMENDATIONS

During the dry season, Carettochelys insculpta occupies permanent water in the South Alligator drainage from lowland billabongs in the black soil plains to plunge pools at the base of the Arnhem Land escarpment. It does not occur in the washpools above the escarpment, nor are there any reports of the species from marine or estuarine waters in the Park. Its wet season habits and distribution are unknown.

Adult specimens of Carettochelys can be captured on lines baited with meat, by hand with the aid of mask and fins, or by pursuing them with a boat and outboard motor until they bury in sand or weed and can be secured by a diver or from the boat with a long-handled dip net. Each turtle can be furnished with a unique mark by cutting notches in the shell margin using a semi-binary code based on the arrangement of the peripheral bony plates visible beneath the soft skin. Numbered cattle ear tags fixed to the shell with a hole drilled for the purpose, provide more visible but less permanent tags.

Carettochelys is abundant in the upper reaches of the South Alligator River. Mark-recapture methods yielded a density estimate for the Pul Pul Billabong (Stage III) of 33.8 turtles per ha or 67 turtles per km of channel. This represents a biomass of 227.4 kg/ha. The high density is thought to represent a dry season concentration of turtles that in the wet, would occupy a much wider range. The upper reaches of the South Alligator River may serve as an important dry season refuge for Carettochelys. Only one other such area is known to exist in Kakadu National Park -- Barramundie Creek, a tributary of the South Alligator River.

Of the 21 turtles examined in Pul Pul Billabong, 6 were mature males, 7 were mature females and 8 were juveniles. The adult sex ratio was not significantly different from 1:1. The presence of juveniles as a significant proportion of the population, one as small as 24 cm in length, and the collection of Carettochelys eggshells from nests uncovered by predators at the site, suggests that the upper reaches of the South Alligator River is an important focus for breeding and recruitment.

Carettochelys nests in clean fine sand adjacent to water in many permanent upland billabongs. The species has a protracted nesting season, ranging from mid July to early November, and individuals probably lay more than one clutch of eggs per season. In Kakadu, nests of Carettochelys suffer high mortality from predation by varanid lizards.

Carettochelys is a general omnivore that feeds on a wide variety of food including algae, aquatic macrophytes, fruits seeds and leaves of riparian vegetation, aquatic macro-invertebrates, and carrion. Its catholic tastes provide great scope for opportunism, and its diet varies greatly with variation in the foods available from locality to locality.

Information on utilization of Carettochelys by Aboriginal people in Kakadu National Park is presented.

From the data collected in the present study, and a discussion of management issues, we make the following recommendations (in brief):

1. Reduction in the densities of water buffalo will almost certainly decrease mortality among nests of Carettochelys in the South Alligator River (Stage III), and with subsequent recovery of the

habitat, will increase food supply during the dry. Action to reduce buffalo densities in Stage III to levels already achieved in Stage I should proceed without delay. Priority should be given to areas adjacent to the South Alligator River and its tributaries. Mining interests should be required to reduce buffalo densities in areas under their control, and to maintain densities at levels equal to or below those currently achieved in Stage I.

2. The importance of the upper reaches of the South Alligator River as one of only two known dry season refuges for Carettochelys in Kakadu National Park, possibly serving also as a focus for breeding and recruitment, should be formally brought to the attention of the companies involved in the proposed mining venture. These companies should also be made aware of the national and international concern for the conservation of this unique species.

3. The Plan of Management for Stage III and the "Conservation Zone" should include stringent requirements to protect the upper reaches of the South Alligator River from potential leakages from tailings dams, accidental releases or spillage, erosion and siltation. The mine should be prohibited from drawing water from the South Alligator drainage during the dry season, and should be required to provide adequate water storage to carry the mine through a prolonged dry season.

4. The current ban on recreational fishing to the east of the Pine Creek Road, especially fishing with baited hooks, should be maintained. Mining interests should be required to prohibit mine workers and others from fishing in the "Conservation Zone", should it be declared.

5. Carettochelys should be excluded from any enterprises designed to introduce tourists to traditional Aboriginal practices and foods, at least until detailed study of the population dynamics of the species enables the impact of such harvests to be assessed. Aboriginal peoples should be encouraged to continue their practice of collecting Carettochelys for local consumption only.

6. A.N.P.W.S. should support further research into the biology of Carettochelys because to date, little research has been conducted elsewhere. The wet season habits and habitat requirements of Carettochelys deserve special attention because knowledge of only dry season habits will not allow evaluation of all management decisions likely to affect Carettochelys populations.

7. Carettochelys is an endearing and unusual animal of considerable international interest, and should be given a high profile in promotional material on Kakadu National Park. The fact that the Park affords the species, one which many consider at risk, considerable protection, will enhance the standing of Kakadu National Park among people concerned with the conservation of world's threatened and endangered reptiles.

INTRODUCTION

As the sole surviving member of its family, the Warradjan or Pig-nosed turtle, Carettochelys insculpta, occupies an unusual position among living chelonians, representing all that remains of some 40 million years of independent evolution (Chen et al., 1980). The species is very distinct morphologically (Plate I), being perhaps the most suited of any freshwater turtle to an aquatic existence. It is large (carapace length may exceed 55 cm), its nostrils open at the end of a

prominent fleshy proboscis, its limbs are clawed and paddle-shaped like the flippers of sea turtles, and it lacks the epidermal scutes that overlie the shell of most turtle species (Cogger, 1975; Pritchard, 1979). Carettochelys is Australia's only freshwater cryptodire (its neck flexes in the vertical plane when its head is withdrawn).

Found only in the southern rivers of Papua New Guinea and the northern rivers of Australia, Carettochelys has generally been considered one of the rarest living chelonians. In Papua New Guinea, Carettochelys and their eggs are harvested for food, and wild populations are thought to be declining (Groombridge, 1982). Although considered a species at risk, there are few data on the biology of the species, especially data relevant to status and management. It is not known if its reputation as "rare" merely reflects its remote distribution or whether it also reflects low densities (Pritchard, 1979).

The existence of Carettochelys insculpta in northern Australia was not widely known until a specimen from the Daly River was reported in the scientific literature (Cogger, 1970; Peters, 1970). At the time there was some doubt as to whether the Daly population was merely a non-breeding outlier of the New Guinea populations or whether it was self-sustaining. However in 1972, a further specimen which had recently nested was collected in the South Alligator drainage (Yellow Waters billabong, Schodde et al., 1972) and the species is now known to nest regularly at both localities (Legler, 1982; Webb et al., 1986; Georges, 1987). 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., 1988) and the presence of Aboriginal rock paintings of

Carettochelys (Cann, 1980; Dupe, 1980; Georges, 1987), some dating back more than 7000 years (George Chaloupka, pers. comm.) suggest that the species has been a long term resident of northern Australia.

In northern Australia, Carettochelys occurs in the Daly (Cogger, 1970; Cann, 1972; Webb et al., 1986; Georges, 1987), Victoria (Cogger, 1975), South Alligator (Schodde et al., 1972; Legler, 1980, 1982; Press, 1986) and East Alligator drainages (Georges et al., 1988). Anecdotal reports suggest that the species is widespread in northern Australia, perhaps also occurring in the Darwin, Adelaide, McKinlay and Roper Rivers of the Northern Territory (Cann, 1972; Keith Day, pers. comm.; John Bywater, pers. comm.) and the Wenlock River on the west coast of Cape York (Keith Day in pers. comm.).

The project described in this report was designed to meet the following objectives:

1. To characterize and map preferred habitats and primary nesting areas for Carettochelys in Kakadu National Park.

2. To evaluate methods for capture and permanent marking of Carettochelys with an assessment of potential induced mortality.

3. To estimate abundance and gather fundamental data on the reproduction and dietary requirements of Carettochelys in Kakadu National Park.

4. To provide recommendations for the management and conservation of Carettochelys in Kakadu National Park.

The work is the result of five weeks spent in Kakadu National Park in September and October of 1987. Some data from a previous study conducted on the Daly River in 1986 are included where appropriate. The additional requirement, under the consultancy, for a literature review and annotated bibliography has been dealt with in a separate report (Georges, 1988).

DISTRIBUTION OF CARETTOCHELYS AND ITS NESTS

The distribution of Carettochelys in Kakadu National Park was determined from direct sightings of adults and nests, by collating published information, and by collating anecdotal reports from reliable sources.

Fig. 1 shows the current boundary of Kakadu National Park and the place names used in this report. Kakadu National Park covers approximately 19,600 km^2, with several hundred billabongs serving as potential habitat for Carettochelys so a representative sample of billabongs were selected for detailed study. A stratified sampling procedure was adopted, based in part on previously established knowledge of the nesting requirements of Carettochelys (Legler, 1982; Webb et al., 1986; Georges, in prep.). Aerial photographs of all billabongs in the Magela, Nourlangie, Jim Jim and South Alligator drainages within the park were examined carefully with a zoom-transferscope. Locations of major sandbars suitable for nesting were mapped and representative examples were later verified on the ground. Waterbodies available to Carettochelys were classified as fcllows (Fig. 2):

ZONE 0: MARINE

ZONE 1: ESTUARINE (subject to tidal and saline influence). There were no suitable nesting banks.

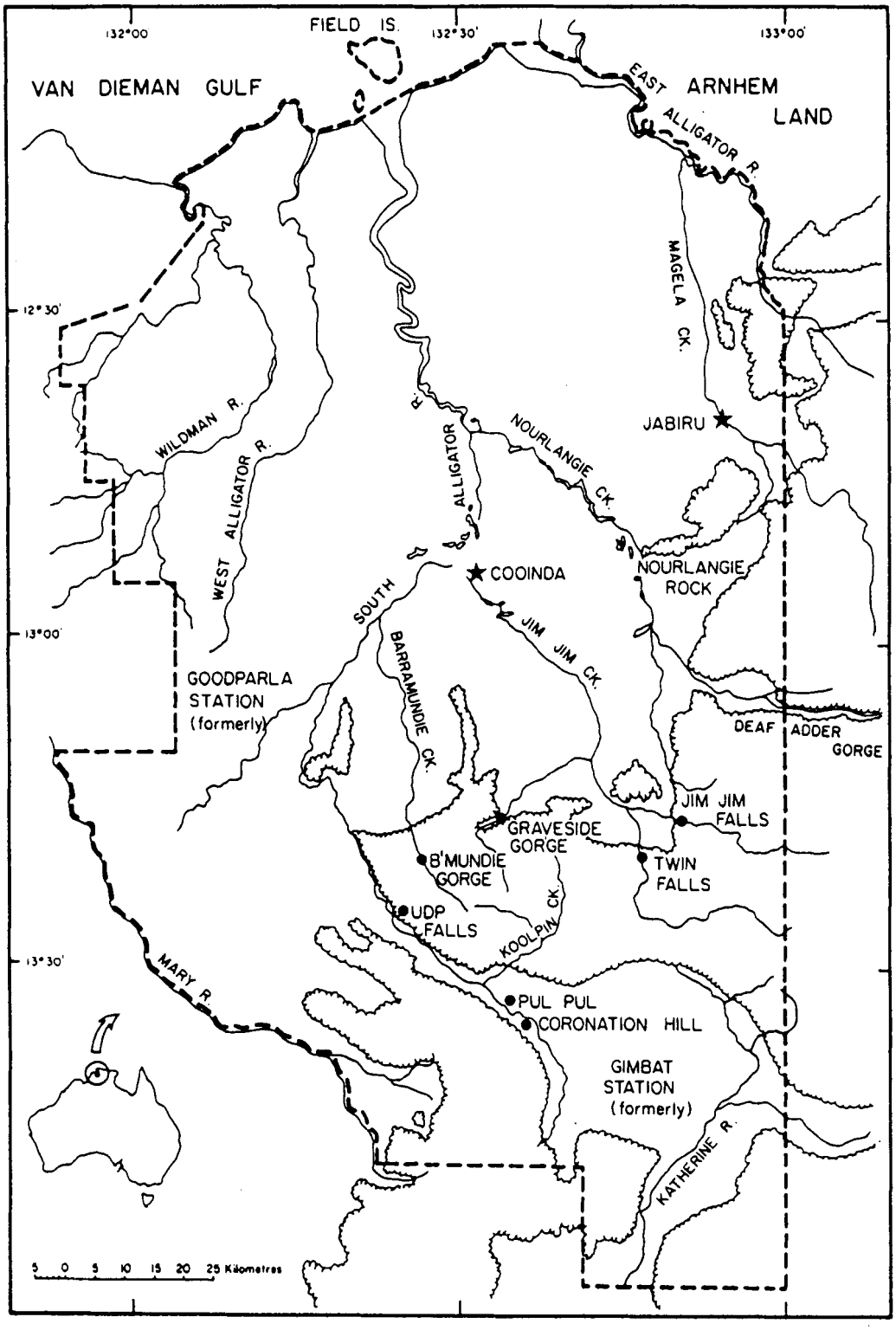

Fig. 1. A map of Kakadu National Park showing the current boundary and place names used in this report.

ZONE 2: LOWLAND BILLABONGS IN BLACK SOIL PLAINS (e.g. Yellow Waters and Jabiluka Billabong). These billabongs contained no suitable nesting areas.

ZONE 3: UPLAND BILLABONGS

A: Lower reaches in paperbark forest adjacent to black soil plains (e.g. Alligator Billabong, Bucket Billabong). Typically two or three potential nesting banks were located adjacent to creek inflows on the upland side.

B: Middle Reaches, large deep stable billabongs (e.g. Jim Jim Billabong, Binji Waters). Sand banks accumulated at the inflows and outflows of the main channel and adjacent to creek inflows.

C: Middle-Upper Reaches, small shifting billabongs with sandy bottoms and shallow pools (e.g. Sandy Billabong). Sand was very abundant both above and below the waterline forming suitable nesting banks on bends, at the inflows and outflows of the main channel and by accumulating behind debris.

D: Upper Reaches, small shallow pools and creek channels not visible on 1:100 000 topographic maps or aerial photographs (e.g. Barramundie Creek, headwaters of the South Alligator River). Large sand bars formed at the inflows of the main channel and where sand accumulated behind debris. Eroded banks also provided sufficient falling sand for nesting.

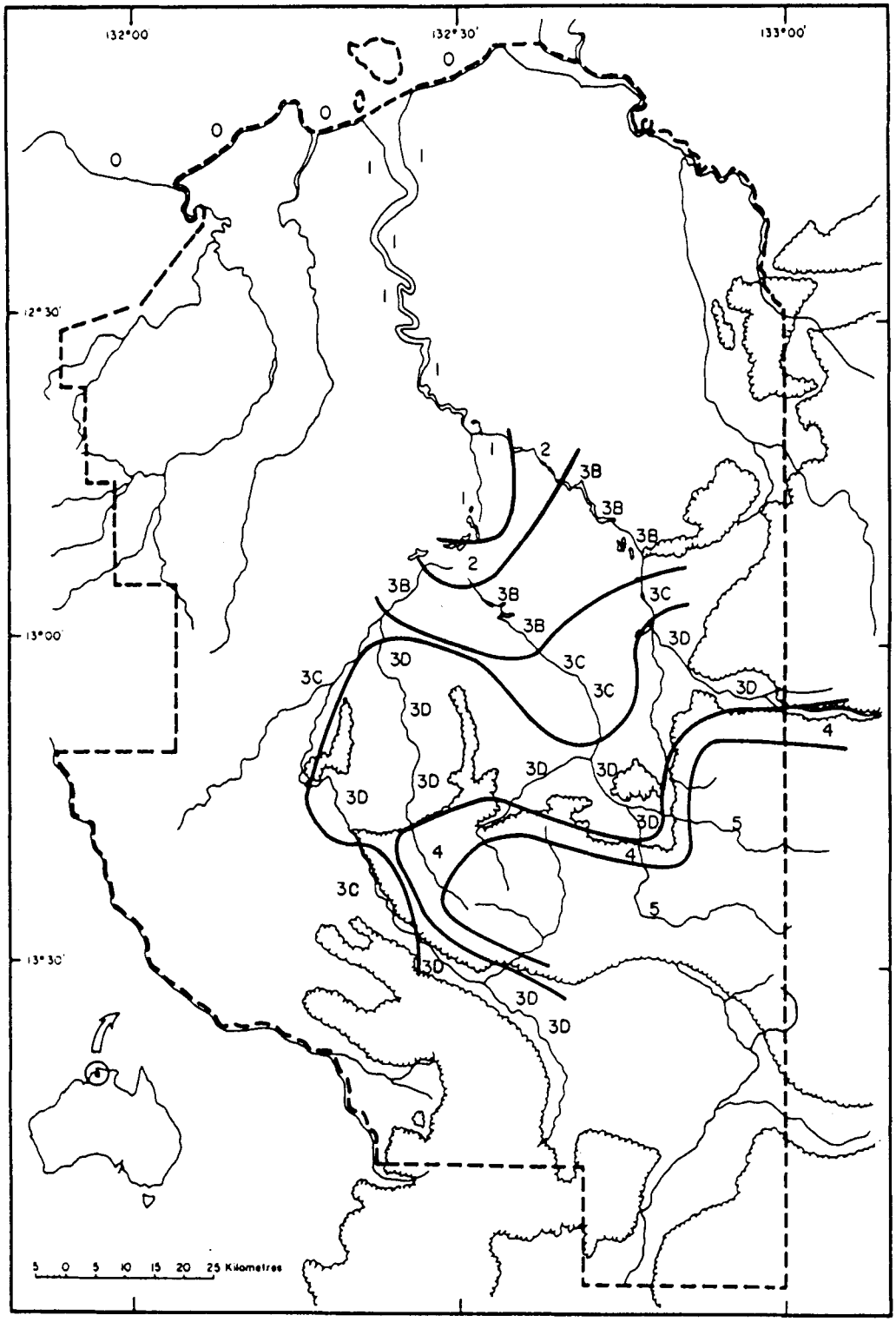

Fig. 2. A map of Kakadu National Park showing the distribution of billabongs classified as described in the text. Zone 0 : Marine; Zone 1 : Estuarine; Zone 2 : Lowland billabongs; Zones 3A-D : Upland billabongs; Zone 4 : Plunge pools at the base of the escarpment; Zone 5 : Washpools above the escarpment. Not shown are Zone 3A billabongs which are on the boundary of Zones 2 and 3B. The illustrated zones only have meaning for the billabongs they contain, and are drawn with little regard for surrounding topography.

ZONE 4: PLUNGE POOLS (e.g. Jim Jim Falls). Sand banks have formed where sand has accumulated in eddies during the wet only to be exposed during the dry.

ZONE 5: WASHPOOLS ABOVE THE ESCARPMENT. There is sufficient sand for nesting but it is not abundant.

Within Zones 2 and 3, the billabongs can be further classified as to whether they are permanent or ephemeral, or whether they are in the main channel or a side-channel or side creek.

Billabongs within each of the Zones 2, 3 and 4 were selected on the basis of availability, with due respect for the wishes of the Aboriginal community, and accessibility. The original intention was to survey these billabongs for both adults and nests, but high turbidities caused by an exceptionally dry year and buffalo activity prevented spotlight surveys for adults. Instead, observations on adults were generally incidental to activities involved in locating nests.

During the dry season, Carettochelys occupies billabongs throughout the South Alligator drainage below the escarpment (Fig. 3). It has been observed in lowland billabongs (Zone 2) such as Yellow Waters (Schodde et al., 1972) and in the large deep stable upland billabongs of the middle reaches of the drainage (Zone 3B) -- in Jim Jim Creek, Nourlangie Creek and the South Alligator River. Carettochelys must contend with high densities of saltwater crocodiles in these billabongs. The turtles are also found further upstream in the shallower clearer waters of Zones 3C and 3D, where they are regularly hunted by Aboriginal people in the dry, and there are reports of them from the plunge pools of Deaf Adder Gorge (Tony Press, pers. comm.) and Twin Falls (Legler, 1982). They are

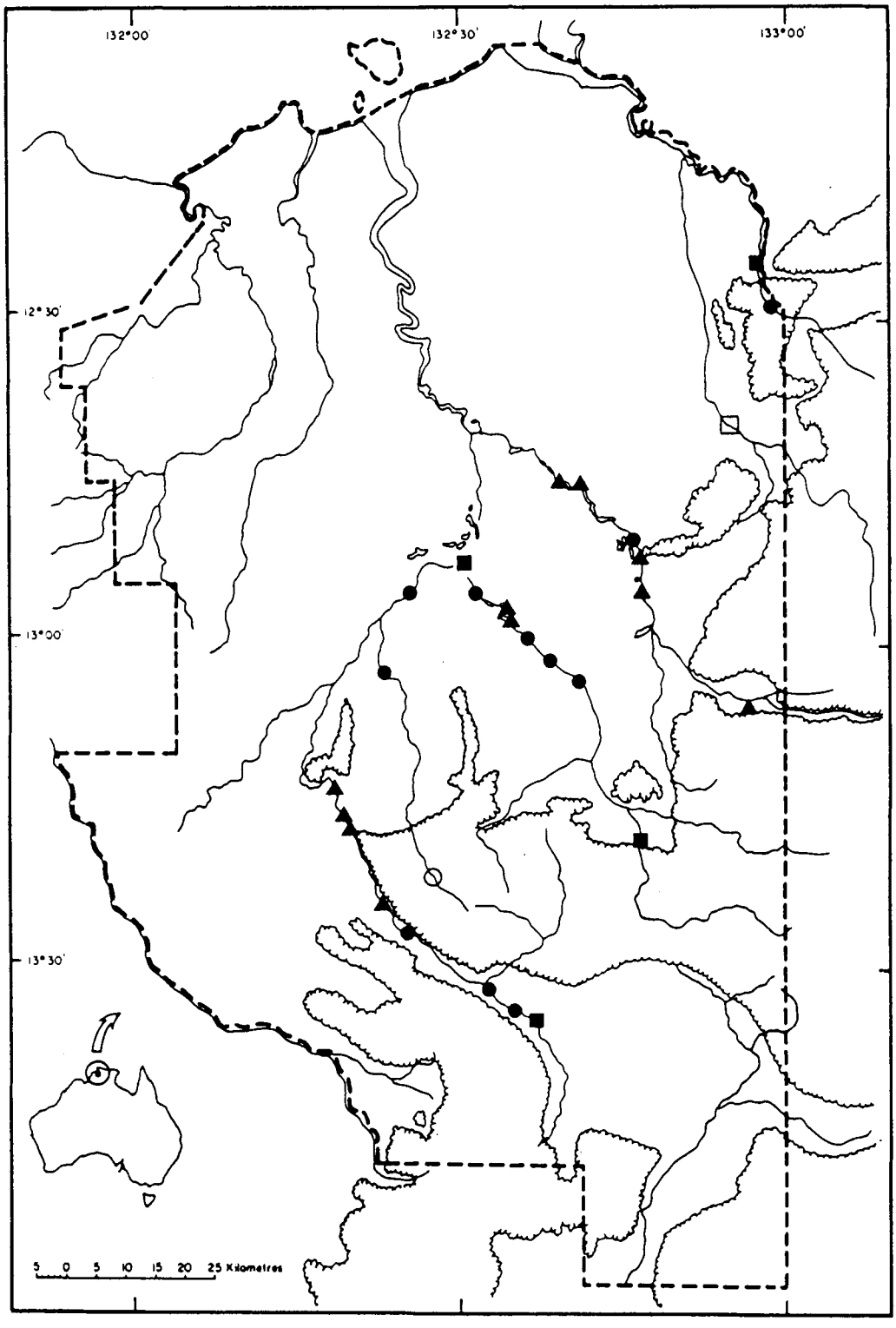

Fig. 3. A map showing the known dry-season distribution of Carettochelys insculpta in Kakadu National Park. The map is based on data collected in the present study (●), on published accounts (■) and on anecdotal reports from reliable soruces (▲). Full details are given in Appendix A. The hollow symbols show where Carettochelys is known not to occur in the dry season.

also reported from the East Alligator River within the park (Georges et al., 1988; Ian Morris, pers. comm.; Fig. 3).

Carettochelys is not found in Barramundie Gorge during the dry. The water there is exceptionally clear and has been thoroughly searched on several occasions by several people, including ourselves. Nor do they appear to be found in the Magela system (Legler, 1982; Dave Walden, pers. comm.; Ross Jeffree, pers. comm.), the biota of which has been the subject of intensive study related to the Ranger Uranium Mine. Carettochelys does not occur above the escarpment. There are no reports of Carettochelys from marine or estuarine areas of the park, though it occupies saline estuarine environments in Papua New Guinea (Groombridge, 1982).

It is not known whether Carettochelys is present in the West Alligator or Wildman Rivers as these were not surveyed in the present study. Nor is anything known of the seasonal movements and wet season distribution of the species. There is a suspicion the Carettochelys disperses to the lowland floodplains during the wet and withdraws to the upper reaches of the drainage during the dry. Certainly it is difficult to otherwise explain the high population densities in the upper reaches of the South Alligator River and Barramundie Creek during the dry (see below), but at present there are no firm data.

Carettochelys nests in many permanent upland billabongs (Zone 3, Fig. 4). The distribution map for nests shown in Fig. 4 is somewhat misleading because surveying for nests in areas heavily stocked with buffalo was made very difficult by the damage done to potential nesting banks. Sand banks often provide easy access to water and in some areas within Gimbat Station and the overstocked Goodparla Station, virtually

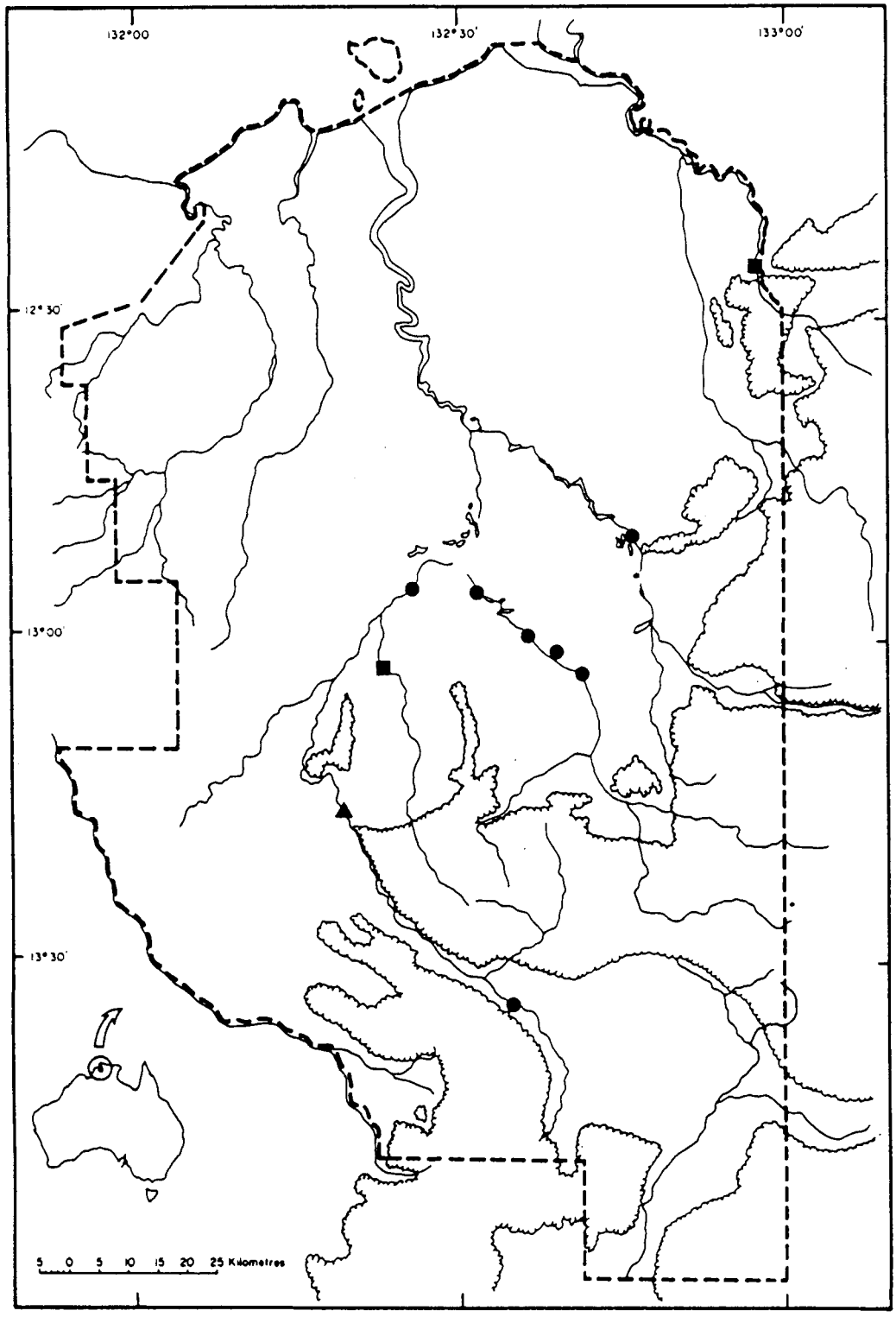

Fig. 4. A map showing the known distribution of nesting areas for Carettochelys insculpta in Kakadu National Park. The map is based on data collected in the present study (●), on published accounts (■), and on anecdotal reports from reliable sources (▲). Full details are given in Appendix A.

every square inch of potential nesting area had been recently disturbed by a hoof. Hence the apparent low nesting activity in the South Alligator River proper, compared to that in Jim Jim Creek, probably does not reflect reality.

There has been one reliable report of Carettochelys nesting on banks of mud in the freshwater reaches of rivers in Papua New Guinea (Cogger in pers. comm. with Georges, 1988; Plate 59 of Cogger, 1975). The female Carettochelys collected from Yellow Waters in Zone 2 and found to have fresh corpora lutea on the ovaries (Schodde et al., 1972), may have nested in the black soil of the banks of the billabong, as no sand banks were available. However in the dry, all of this black soil but for a few centimetres next to the water is rock hard, so it would seem more plausible that the turtle nested in an adjacent upland billabong which may have had some connection to Yellow Waters during 1971.

It is highly unlikely that Carettochelys nests in the gelatinous tidal mud of the estuarine reaches of the South Alligator drainage. This mud, quite different from the silty loams of the freshwater reaches, would provide an anaerobic environment unsuited to the incubation of eggs. Furthermore, there have been no reports from estuarine reaches of the distinctive tracks left by Carettochelys, despite frequent surveys for crocodiles since 1980 in which mud-slides are often noted.

EVALUATION OF CAPTURE METHODS

Adult specimens of Carettochelys can be captured on lines baited with meat, by hand with the aid of mask and fins, or by pursuing them

with a boat and outboard motor until they bury in sand or weed and can be secured by a diver or from the boat with a long-handled dip net. Of the three methods, hand capture with the aid of a mask and fins was the most effective (Plate II), though it is limited to clear waters free of saltwater crocodiles (Crocodylus porosus). During the day, pig-nosed turtles can be found buried in the litter covering the river-bed or hidden beneath submerged logs and branches or in submerged cavities in undercut banks. When approached cautiously, they will remain motionless for long enough to allow the diver to grasp the carapace at its anterior and posterior ends. The turtle can then be maneuvered toward the surface. Should the turtle escape, the speed that they can achieve makes pursuit virtually impossible.

Capture from a small aluminum punt was the second most effective method (capture to sighting ratio of 7:10 in the shallow waters of the Daly River). The method can be used in clear waters by day or by night with the aid of a strong spotlight (Plate III). The method was of limited value in Kakadu National Park because the water of most billabongs was too turbid, though with the virtual eradication of water buffalo planned for the near future, this situation may change.

The effectiveness of capture using baited lines was not fully evaluated because of the potential harm inflicted in removing the hook, which was invariably swallowed, or the harm done later if the hook were left in place. Aborigines use the method with success in Kakadu National Park but they seldom fish with the sole purpose of catching pig-nosed turtles. Although they may fish in an area where they have high expectations of catching a pig-nosed turtle, generally they target a wide range of species of fish and turtles. Three pig-nosed turtles in

PLATE II(above). Carettochelys insculpta can be captured by hand with the aid of mask and fins in clear water free of saltwater crocodiles [Photo: A. Georges].

PLATE III(left). Alternatively, Carettochelys insculpta can be captured in clear water by pursuing them with a boat and outboard motor until they bury in sand or weed and can be secured with a long-handled dip net [Photo: A. Georges].

one day is considered an exceptional catch, and low yields coupled with the risk of permanently harming the turtles, suggests that fishing with line and hook would be of limited value in scientific surveys.

Methods not yet tried but likely to prove successful are gill nets (checked regularly) and baited traps. The latter, in the form of basket traps, are successful in capturing the species in Papua New Guinea (Schultze-Westrum, 1963), and some form of large baited trap may prove successful in regions where the water is too turbid to permit the methods outlined above.

EVALUATION OF MARKING METHODS

Contrary to popular belief, the shell margin of adult and sub-adult Carettochelys is rigid and amenable to marking with notches as is traditional for freshwater turtles. The shell of Carettochelys lacks the horny scutes used in most other turtle species to establish a semi-binary code in which each individual can be uniquely identified. Instead, the semi-binary code must be based on the arrangement of the peripheral bony plates visible beneath the soft skin. By cutting rectangular notches in these peripheral plates, a unique mark can be given to each of 699 turtles. Should this prove insufficient, a full binary code could be employed (4095 unique numbers) or codes could be duplicated for each of the two sexes. Unfortunately the periphery of the shell of Carettochelys is well endowed with blood vessels, and after one year the notches may have changed shape considerably through the process of healing. It seems likely however that the notches could be reliably used to identify individual turtles for many years.

Difficulty arises when applying the semi-binary notching scheme to hatchling Carettochelys because the peripheral plates do not calcify

until later in life and so are not visible beneath the covering skin. To complicate matters, the indentations in the boundary of the hatchling carapace do not reflect the arrangement of the peripheral plates that are to form, but rather the arrangement of horny scutes that the species presumably had in times past. A marking scheme based by necessity on these indentations will not correspond to the marking scheme outlined for adults, when the hatchlings grow larger. The alternative of marking adults at the junction of the peripheral plates should be avoided, because such notches will weaken the shell structurally and are more likely to obscure with time.

Notches, although permanent, have the disadvantage in that they are not visible at a distance, and the animal must be recaptured to be identified. To overcome this, a plastic cattle ear tag (Allflex medium female flange, small male button) can be attached to the shell through a hole drilled in the lateral margins of the carapace (Plate IV). Numbers can be applied to the tags with a broad tip pen (Allflex B6), or tags can be pre-printed with a number and return address. The numbered tags can be easily read at night in clear water with the aid of a spotlight.

Applying numbers to the carapace with aquatapox paints, used with some success on marine turtles (David Carter, pers. comm.), proved unsuccessful on Carettochelys as the numbers became unreadable in a matter of days or weeks. The technique had the added disadvantage of rendering marked animals much more conspicuous than unmarked animals, thus seriously affecting the accuracy of most estimators of population statistics based on mark-recapture.

Freeze branding was not tried, but should be considered for trials in any future studies.

PLATE IV. Unique numbers can be assigned to each animal by attaching a cattle ear tag to the shell through a hole drilled in the lateral margins of the carapace [Photo: R. Kennett].

PLATE V. Stomach contents can be removed from the stomachs of Carettochelys insculpta without harm to the turtles by stomach flushing [Photo: A. Georges].

ABUNDANCE AND POPULATION STRUCTURE

Population estimates were based on an intensive study undertaken in Pul Pul Billabong of Kakadu National Park Stage III (Plate VI). This billabong was chosen because the water was clear, free of saltwater crocodiles, and within one of two regions known to Aborigines as a good place for Carettochelys. As a Zone 3D billabong, Pul Pul Billabong was broadly similar to those of Barramundie Creek described by Legler (1982) as the preferred habitat of Carettochelys. At the time of sampling, it was approximately 400 m long and 20 m wide with a modal depth of 1.2 m and a maximum depth of 3.0 m. The substratum was of 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 billabong were covered in a dense broad-leafed forest, including the important food species Ficus racemosa. The many small sand banks adjacent to the water were more than adequate in number and size for nesting. Water flows through Pul Pul Billabong in all months of the year. Carettochelys shares the billabong with the Northern Snapper (Elseya dentata), the Saw-shelled Snapper (Elseya latisternum) and the Northern Yellow-faced Turtle (Emydura "australis").

On September 26th, 1987, seven specimens of Carettochelys were captured by hand with the aid of mask and flippers. They were measured, marked and released. One week later, on the 3rd, 4th and 5th of October, 18 turtles were caught of which 4 were recaptures. Using these data, the Petersen Method, incorporating the modification suggested by Bailey (1951, 1952), yielded a population estimate of 27 $\pm$ 9 turtles. This represents 33.8 $\pm$ 11.3 turtles per ha or 67 turtles per km of

PLATE VI. Pul Pul Billabong in Stage III of Kakadu National Park near Coronation Hill [Photo: R. Kennett].

PLATE VII. A sand bank in Miurella Park of Kakadu National Park used for nesting by Carettochelys insculpta [Photo: A. Georges].

channel. The corresponding estimate of biomass was 227.4 kg/ha. Although these figures may seem extraordinarily high for an animal thought to be rare, they are considered accurate for the following reasons:

1. Twenty-one of the estimated 27 turtles were actually caught and measured,

2. Several studies have shown the Petersen Method to yield accurate estimates for closed populations when sampling intensity is greater than 75% (Seber, 1973; Georges, 1982). In this study, sampling intensity was 78%,

3. The Pul Pul population was certainly closed to immigration and emigration and, given the short duration of the study, was closed to recruitment and mortality,

4. Marked and unmarked animals did not respond differently to the approach of a cautious swimmer to any noticeable degree.

Production within the Pul Pul billabong alone is probably insufficient to maintain the observed population density. Instead the high density probably represents a dry-season concentration of turtles that in the wet, would occupy a much wider range. The upper reaches of the South Alligator River may serve as an important dry season refuge for Carettochelys. Only one other such area is known to exist in Kakadu National Park -- Barramundie Creek, a tributary of the South Alligator

River (Fig. 1).

Measurements of the 21 turtles included maximum curved carapace length, head width from tympanum to tympanum and body weight. They yielded the following statistics:

Carapace length:	Mean 38.7 ± 1.6 cm	(24.3 -- 48.1)
Head width:	Mean 6.6 ± 0.3 cm	(4.4 -- 8.7)
Weight:	Mean 6.7 ± 0.8 kg	(1.7 -- 13.5)

Relationships for predicting body weight from carapace length and head width, and for predicting carapace length from head width are given in Figures 5 to 7. There appeared to be some sexual dimorphism in head width, so relationships involving this variable were calculated separately for males and females.

Mature males can be distinguished from females of the same size by the tail which needs to be much larger in males to enable successful copulation. However, tail length is difficult to measure on live turtles, and a method not requiring a subjective judgment involves inserting a small finger, with the palm of the hand facing ventrally, into the cloaca. The grooved penis is immediately evident in males.

Males reach smaller maximum sizes than females (Fig. 8). The largest male Carettochelys observed in Pul Pul billabong had a carapace length of 44 cm and weighed 9.0 kg. By comparison, the largest female had a carapace length of 48 cm and weighed 13.5 kg. However even larger females can be found in the park as a skull, the remains of a meal, had a width of 9.25 cm corresponding to a carapace length of 50.7 cm and a weight of 16.9 kg. The record weight is held by a female from Papua New Guinea which weighed 22.5 kg (Groombridge, 1982).

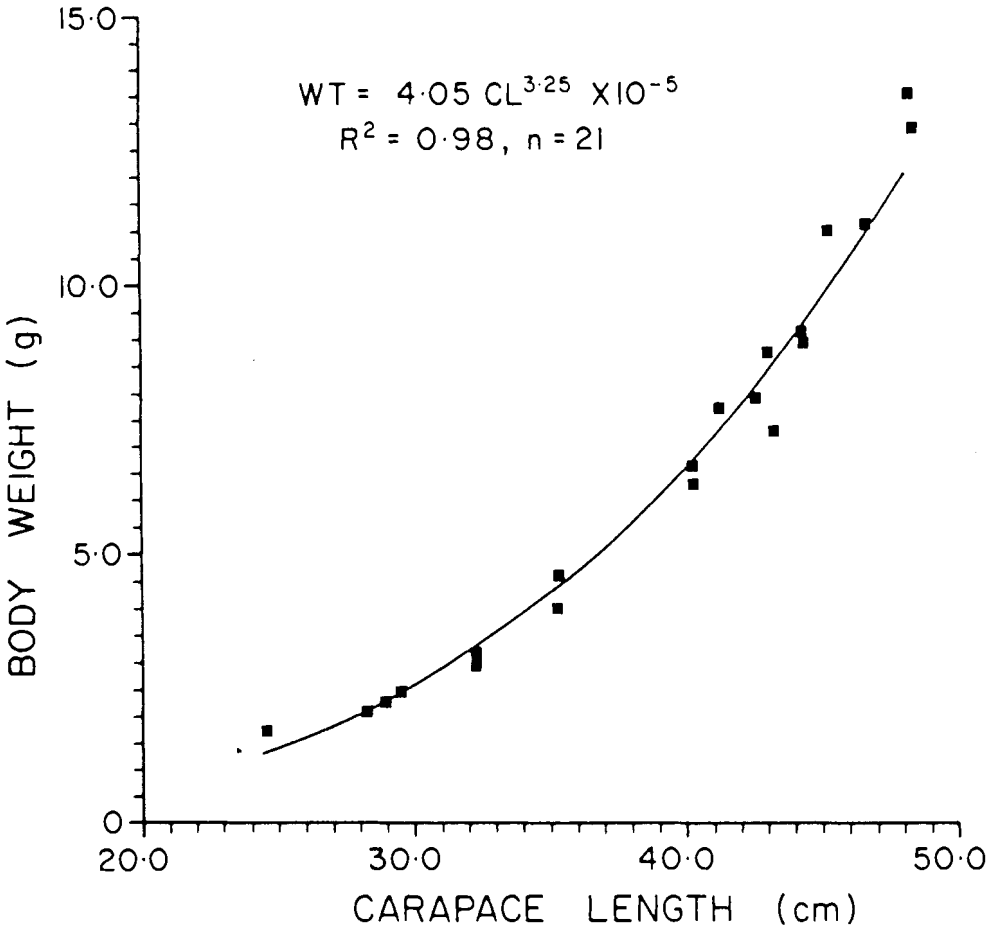

Fig. 5. The relationship between body weight and maximum curved carapace length for Carettochelys insculpta.

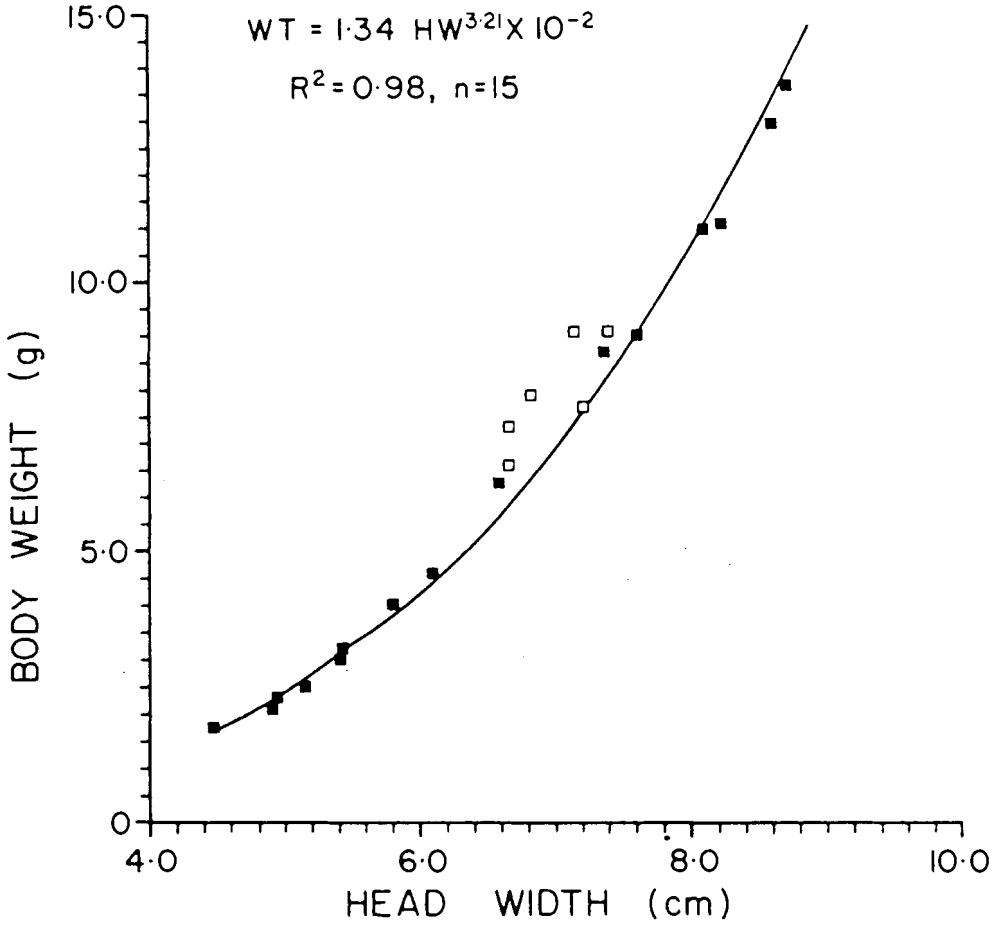

Fig. 6. The relationship between body weight and head width (tympanum to tympanum) for juvenile and female Carettochelys insculpta (■). For males (□), adjust the predicted body weight by a factor of 1.14.

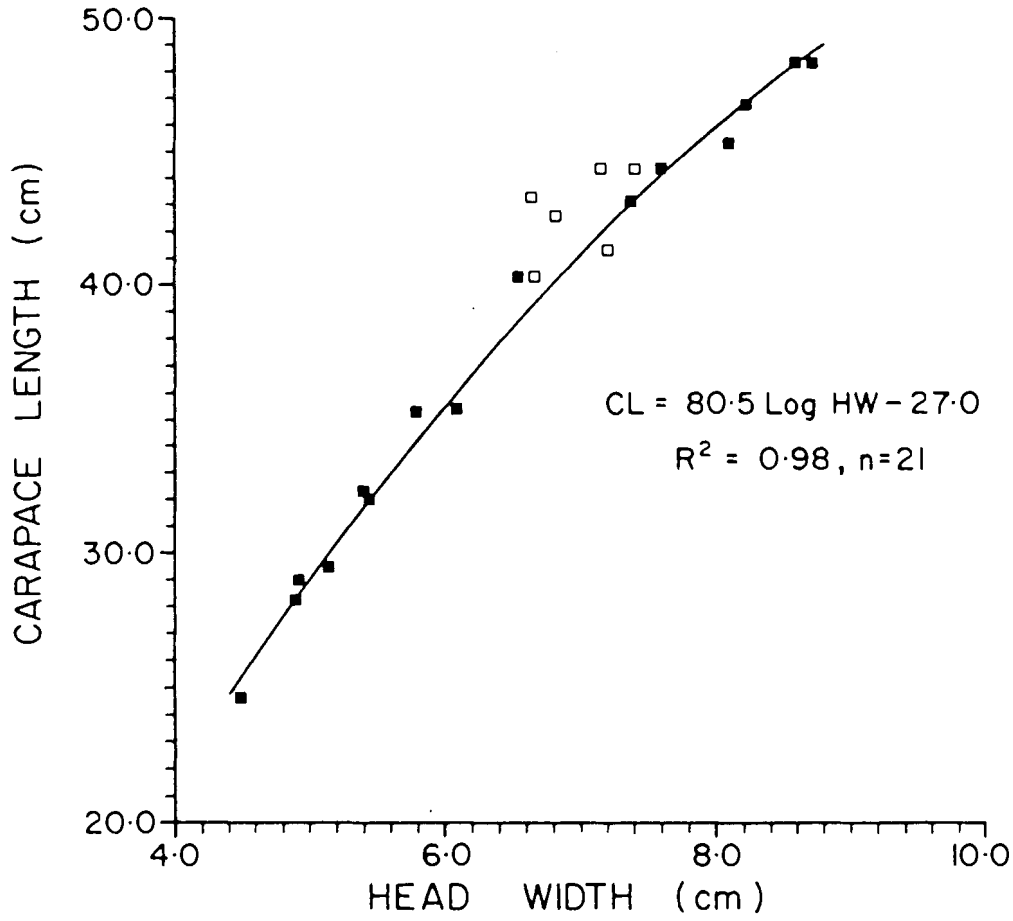

Fig. 7. The relationship between maximum curved carapace length and head width for juvenile and female Carettochelys insculpta (■). The curvelinearity of the relationship was significant ($p<0.0001$). For males (□), adjust the predicted carapace length by a factor of 1.04.

The population structure of the Pul Pul population is depicted in Fig. 8. Of the 21 turtles examined, 6 were mature males, 7 were mature females and 8 were juveniles. One of the juveniles was a male (CL = 35.0 cm) on the verge of becoming sexually mature as the penis was clearly evident but the tail was not yet fully enlarged. The adult sex ratio of 6:7 was not significantly different from 1:1. Sex of Carettochelys is strongly influenced by the temperature prevailing during incubation (Webb et al., 1986), so sex ratios may vary considerably from locality to locality.

The presence of juveniles as a significant proportion of the population, one as small as 24 cm in length, and the collection of Carettochelys eggshells from nests uncovered by predators at the Pul Pul site, suggests that the upper reaches of the South Alligator River might be an important focus for breeding and recruitment. This is contrary to the unsubstantiated claims of Dames and Moore (1987).

There are no firm data on the abundance of Carettochelys in Zone 2 or Zones 3A to 3C, and it would not be valid to extrapolate the high densities observed in Pul Pul Billabong to other areas within the park. Densities in the large deep billabongs of Zones 3A and 3B and in the billabongs of the black soil plains are unlikely to be anywhere near as high as in the Pul Pul Billabong, both because of scaling factors (turtle abundance is more likely to correlate with billabong circumference than with area) and because Aborigines have less success in hunting there. However, the presence of nesting activity in the Mardugal/Jim Jim complex, and the occasional sightings reported for many upland billabongs, suggest that Carettochelys is not uncommon in some

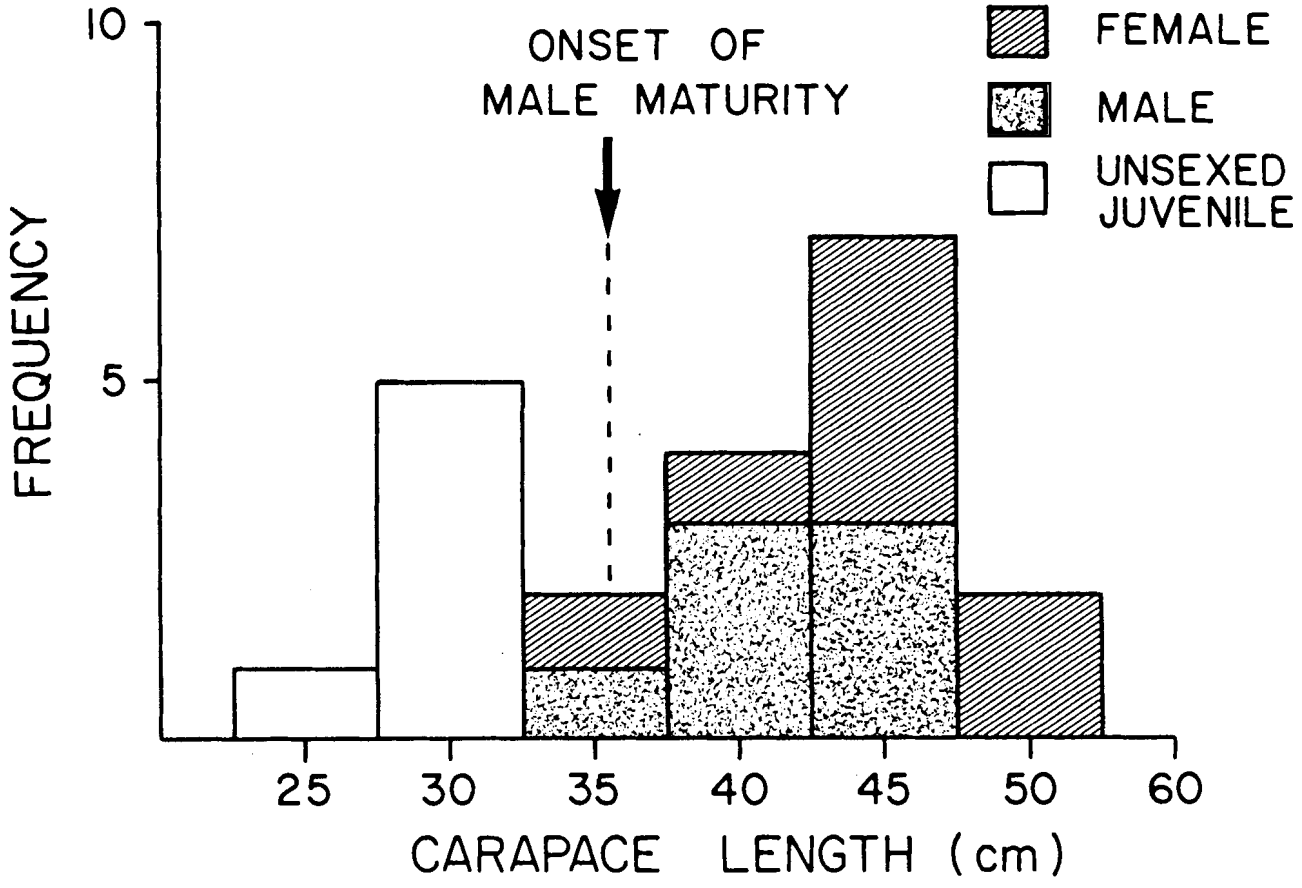

Fig. 8. Size distribution of 21 Carettochelys insculpta collected from Pul Pul billabong in Stage III of Kakadu National Park.

Zone 3A and 3B upland billabongs and in some Zone 2 lowland billabongs (e.g. Yellow Waters).

REPRODUCTION

Observations on nesting in Kakadu National Park were generally consistent with those made at the Daly River (Webb et al., 1986; Georges, in prep.). Carettochelys nests in clean fine sand adjacent to water. All sand banks used for nesting are in direct contact with the water and banks with sand falling into the water and adjacent to deep pools and underwater cover are preferred (Plate VII). Sand banks separated from the water by grass or other vegetation, mud or logs are not used, even though in all other respects they appear suitable. During this study, no nests or signs of nesting activity were found in gravel, silt, mud or sandy loams, though these are widely available.

Of the 12 nests located in the present study, only one had not been destroyed by predators, probably Varanus panoptes or V. gouldii. Hence data on the nests, eggs and hatchlings from Kakadu (Table 1) are necessarily limited. Considerably more data are available for the Daly River population. Because they are likely to be generally applicable to populations elsewhere in northern Australia, and because they have not yet been published elsewhere, they are included in Table 2.

Data on the nesting dates of Carettochelys in Kakadu can be summarized as follows:

17-JULY-86: Specimen captured by Aborigines in the South Alligator River above the Pine Creek Road crossing purged eggs in the vehicle (Wellings, pers. comm).

23-AUG-86: An egg collected from Home Billabong (South Alligator Drainage) was passed in to the Darwin Headquarters of the Conservation Commission of the Northern Territory. The egg was estimated to be less than one week old.

25-AUG-87: Nest from Kingfisher Billabong on Jim Jim Creek was estimated on the basis of its embryo (see Webb et al., 1986) to have been laid on this date.

28-AUG-81: Fresh nest located at Barramundie Creek by Legler (1982)

6-SEP-81: Fresh nest located at Barramundie Creek by Legler (1982)

6-OCT-87: Nesting attempt at Miurella Park Billabong with fresh tracks and eight test digs. A nest could not be located.

5-NOV-71: Schodde et al. (1972) dissected an animal caught in Yellow Waters Billabong to reveal fresh corpora lutea on the ovaries, a sign of recent egglaying. The ovaries also contained many enlarged follicles suggesting that yet another clutch of eggs was to be deposited.

6-NOV-81: Fresh nest located at Barramundie Creek by Legler (1982).

These data suggest a protracted nesting season, ranging from mid-July to early November, and opens the possibility that individuals of the

TABLE 1. Characteristics of nests, eggs and hatchlings from Kakadu National Park. These data are primarily from nests previously robbed of eggs by predators, as only one intact nest was located in the present study. Carapace length here is straight-line maximum.

	Mean ± SE	Range	N
NESTS			
Distance from water	2.16 ± 0.28 m	1.1 - 3.7 m	8
Height above water	0.59 ± 0.04 m	0.4 - 0.7 m	8
Slope at sand surface	17.5 ± 2.0°	11.3 - 26.6°	8
Depth to top of uppermost egg	12.5 cm	12 -- 13	2
Depth to bottom of lowest egg	19.5 cm	18 -- 21	2
Temperature (10.00 am, 21-Sept)	29.1°C	--	1
Clutch size	15.0 ± 1.0	14 - 16	2
% infertility	0.0%	--	1
EGGS			
Length	41.8 ± 0.03 mm	40.6 - 43.5 mm	15
Width	40.6 ± 0.01 mm	39.6 - 41.4 mm	15
Weight	40.2 ± 0.51 g	36.5 - 42.6 g	14
HATCHLINGS			
Weight	24.7 ± 0.84 g	22.0 - 28.0 g	6
Carapace length	56.1 ± 0.91 mm	52.4 - 58.6 mm	6

TABLE 2. Characteristics of nests, eggs and hatchlings from the Daly River in the vicinity of Oolloo Crossing.

	Mean ± SE	Range	N
NESTS			
Distance from water	3.97 ± 0.30 m	0.7 - 7.4 m	39
Height above water	1.55 ± 0.13 m	0.3 - 3.0 m	39
Slope at sand surface	1.59 ± 1.1°	0.0 - 30.6°	39
Depth to top of uppermost egg	14.1 ± 0.5 cm	6.5 - 21.0 cm	36
Depth to bottom of lowest egg	21.7 ± 0.4 cm	15.0 - 27.5 cm	36
Estimated Maximum Temperature	35.4 ± 0.4°C	31.3 - 41.0°C	37
Estimated Minimum Temperature	30.9 ± 0.4°C	25.7 - 36.7°C	37
Soil Moisture Content (by wt)	2.62 ± 0.27%	1.6 - 4.5%	12
Clutch Size	10.5 ± 3.9	4 - 15	39
% Infertility	24.8 ± 3.88%	0.0 - 85.7%	38
EGGS			
Length	38.6 ± 0.09 mm	31.1 - 42.1 mm	366
Width	37.9 ± 0.09 mm	31.1 - 41.1 mm	366
Weight	32.8 ± 0.21 g	18.0 - 41.6 g	357
HATCHLINGS			
Weight	19.1 ± 0.30 g	15.3 - 23.4 g	49

species lay more than one clutch per year (see Legler, 1980; Groombridge, 1982). There is some suggestion that as conditions vary from locality to locality, so do the nesting dates, which would also contribute to the spread of observed nesting dates.

On the Daly River, in the vicinity of Oolloo Crossing, the first signs of nesting activity were observed as tracks on sand banks on 7-Aug-86, but the first nest was not deposited until 19-Aug-86. The nesting season extended from 19-Aug-86 until 8-Oct-86. Examination of the egglaying dates provided strong evidence that Carettochelys lays two clutches of eggs per season at the Daly River site.

DIET

Carettochelys is an omnivorous species with tendencies more towards herbivory than towards carnivory. It is a generalist that draws upon a wide variety of food including algae, aquatic macrophytes, fruits seeds and leaves of riparian vegetation, aquatic macro-invertebrates, and carrion. Its catholic tastes provide great scope for opportunism, and its diet varies greatly with variation in the foods available from locality to locality.

In Pul Pul Billabong in the upper reaches of the South Alligator River, the turtles were eating mainly fruits and leaves of the fig Ficus racemosa, algae, and fish presumably eaten as carrion (Table 3). Further downstream, near the crossing of the Pine Creek Road, a specimen was found to contain the remains of a flying fox Pteropus alecto together with the leaves and fruits of the Bush Apple Syzygium (probably S. forte). Another specimen, a male caught by the Gangale family in Jim Jim Creek on the 5th of April 1987, had a gut packed with fruits and

TABLE 3. Items from the stomachs of 24* specimens of Carettochelys insculpta from Pul Pul Billabong in Kakadu National Park. The items were removed by stomach flushing (Legler, 1977, Plate V). Percentage occurrence gives the number of stomachs that contained one or more items of a particular food type, expressed as a percentage of the total number of stomachs examined. Percentage by weight gives wet weights of each food type expressed as a percentage of the total wet weight of food extracted. A '+' indicates a contribution of less than 1%.

Food Type			Percentage Occurrence	Percentage Weight
PLANT MATERIAL			**92.1**	**92.0**
Div. CHLOROPHYTA	*Spirogyra* sp.		8.3	34.6
Div. MAGNOLIOPHYTA	*Ficus racemosa*	Fruit	70.8	19.3
		Leaves	62.5	38.1
MISC. (Mushrooms, etc.)			4.1	+
ANIMAL MATERIAL			**42.3**	**8.0**
Cl. INSECTA				
O. ODONATA (Corduliidae, Gomphidae)			8.3	+
Cl. CRUSTACEA				
Palaemonidae (*Macrobrachium rosenbergii*)			8.3	1.5
PICES			29.2	6.5
Black Bream (*Hephaestus fuliginosus*)				
Barramundi (*Lates calcarifer*)				
Catfish (Ariidae, Plotosidae)				
MISC. (Formicidae, Murid faecal pellet)			8.3	+
Raw Totals			24 turtles	199.5 g

* Recaptures were flushed again if caught some time after the previous flushing. Two specimens, not included, yielded no food items when flushed. Their stomachs were presumed empty.

leaves of Pandanus aquaticus, interspersed with the hair bones and flesh of a flying fox. In Nourlangie Creek, a turtle caught under similar circumstances was found to have a stomach full of the Water Nymph Najas tenuifolia (Najadaceae). Among published reports, Legler (1982) found that Carettochelys from the Twin Falls area of Jim Jim Creek were eating Eucalyptus flowers, Melaleuca leaves and miscellaneous fruits and seeds, whereas in the South Alligator River they were eating predominantly figs. Mammalian vertebrae and mussel shell were found among the faeces. A specimen from Yellow Waters (Schodde et al., 1972) defaecated large quantities of Pandanus fruit, leaves (Melaleuca and Leguminosae), seeds, roots, pieces of aerenchymatous plant stem and traces of animal material. The animal material included fragments of water snails (Thiaridae), water boatmen (Corixidae), water beetles (Dytiscidae: Homoeodytes scutellaris, Hydrophilidae: Hydrophilus latipalpus) and ants (Iridomyrex sp.).

Clearly, Carettochelys is an opportunistic omnivore which, in the dry season, feeds principally on vegetable matter supplemented with aquatic and terrestrial invertebrates and carrion. Its diet in the wet season is completely unknown.

ABORIGINAL UTILIZATION

Carettochelys is highly prized as a food item by the indigenous peoples within its range both in Australia and in 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). In northern Australia, turtles of all species are regularly eaten by Aborigines, but Carettochelys is favoured by some for its size and flavour (Cann, 1980; Press, 1986). The following account

is based on discussions between Peter Wellings and Carla Ngalyorrun, Rosie Hart, Dolly Marrawuldan, Minnie Alderson, George Minghum and Nipper Gabarrigi, supplemented by our discussions with Minnie Alderson and Topsie Woods of Spring Peak and Peter Byers of the Jawoyn people.

Traditionally in the Alligator Rivers region, men used to climb trees on the banks of billabongs and spear the turtles in the flipper (kunberl) with a pronged spear (djalakkiradj). Alternatively, Carettochelys could be hunted by diving on them from the bank, or by waiting quietly in the water while others herded the turtles in. The turtles are still hunted with spears by the Jawoyn people in the clear upper reaches of the South Alligator River, but today they are caught more often on hand lines baited with wallaby or buffalo meat. The change in practice has been brought about not only by European influence but also by the increased turbidity of upland billabongs following the introduction of buffalo. Good places to fish for turtle are beneath the overhanging branches of fruiting trees, particularly the fig Ficus racemosa, as fruits and seeds of riparian vegetation make up a substantial proportion of the dry-season diets of all short-necked turtle species. Aboriginal people make good use of this knowledge. Although they do not appear to hunt Carettochelys specifically, choosing instead to angle for a wide range of fish and turtle species, Aboriginal people can readily identify areas for which there is a high expectation of catching Carettochelys. At least one strong line with a large hook is set in addition to other lines, with the aim of securing turtle, generally the northern snapper Elseya dentata or Carettochelys.

Once caught, the turtle is roasted whole in a pit. For a large turtle like Carettochelys, the anterior lobe of the plastron is cut away

and the stomach and intestines are removed. The contents are squeezed out by running the gut through thumb and forefinger, and the gut is cooked separately. Hot stones are placed inside the turtle's body, and the turtle is placed ventral surface down in the pit and covered in coals, hot rocks, paperbark and then soil (Plate VIII). Cooking takes between 1 hr and 1 hr 30 mins.

There are very few data on the levels of exploitation of Carettochelys by Aboriginal people in Kakadu National Park. However Peter Wellings, a ranger stationed at Nourlangie Camp, kept detailed records of numbers of Carettochelys captured and eaten by the Nourlangie people (basically two families) in 1986. The data are as follows:

28-Mar-86	Sth Alligator Crossing, Pine Creek Road	1
1-May-86	Sth Alligator River, upstream of above	1
10-May-86	" " " " " "	4
24-May-86	" " " " " "	4
9-Jun-86	" " " " " "	4
19-Jun-86	" " " " " "	1
17-Jul-86	" " " " " "	3
24-Aug-86	" " " " " "	1
	TOTAL	19

These data confirm general impressions that Carettochelys are not hunted in the wet, though one specimen was caught incidentally while fishing in the wet of 1986/87 from the bridge where the Pine Creek Road crosses Nourlangie Creek.

In the Daly River Mission area, refrigeration and improved transport have encouraged removal of more turtles than are required for immediate use by the local community. There are reports of bags of

PLATE VIII. In northern Australia, turtles of all species are regularly eaten by Aborigines, but Carettochelys insculpta is favoured by some for its size and flavour [Photo: P. Wellings].

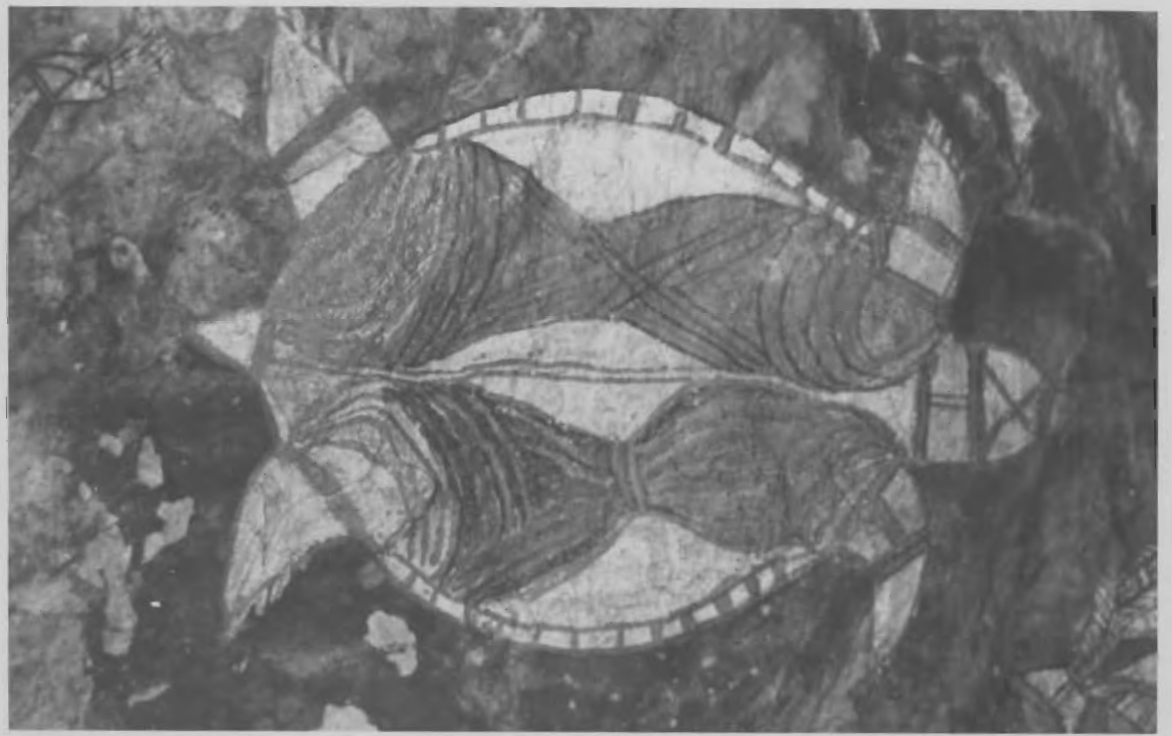

PLATE IX. As a major dietary item, Carettochelys insculpta is well represented in Aboriginal rock art of the Alligator Rivers region and Arnhem Land. This example is from Little Nourlangie Rock in Kakadu National Park [Photo: A. Georges].

turtles of various species having been transported 220 km to Darwin for the benefit of friends and relatives. The extent of this sort of trade and its likely impact on Carettochelys populations in northern Australia is unknown, but there is no evidence of it occurring among the Kakadu peoples.

There are no reports of Australian Aborigines harvesting the eggs of Carettochelys, which is surprising given the value placed upon them and the high levels of exploitation in Papua New Guinea (Groombridge, 1982). It appears that Carettochelys does not nest in densities great enough in Kakadu National Park to make searching specifically for nests worthwhile. However, Aboriginal people know of the nesting habits of the species and eat the eggs when encountered by chance during other activities.

As a major dietary item, Carettochelys is well represented in the rock art of the Alligator Rivers region and Arnhem Land (Plate IX) and some of these paintings are estimated to be more than 7000 years old (George Chaloupka, pers. comm.). An Aboriginal dreaming ("Djang") is located in Deaf Adder Gorge of the Alligator Rivers region (Chaloupka et al., 1985) and the species and its origins are described in tribal legend. The Aborigines of the Kakadu region believe that Warradjan and Manbirri, the green sea turtle, are sisters (Manbirri being the younger). A long time ago when the saltwater was "going away", Manbirri decided to go with the salt water while Warradjan decided to stay in the freshwater with Naderrwo (Elseya dentata). It would appear from this that Carettochelys has been present in Australia from as far back as the last ice age when the seas receded, between 20,000 and 7,000 years ago. Stories about Carettochelys may be told with the aid of a

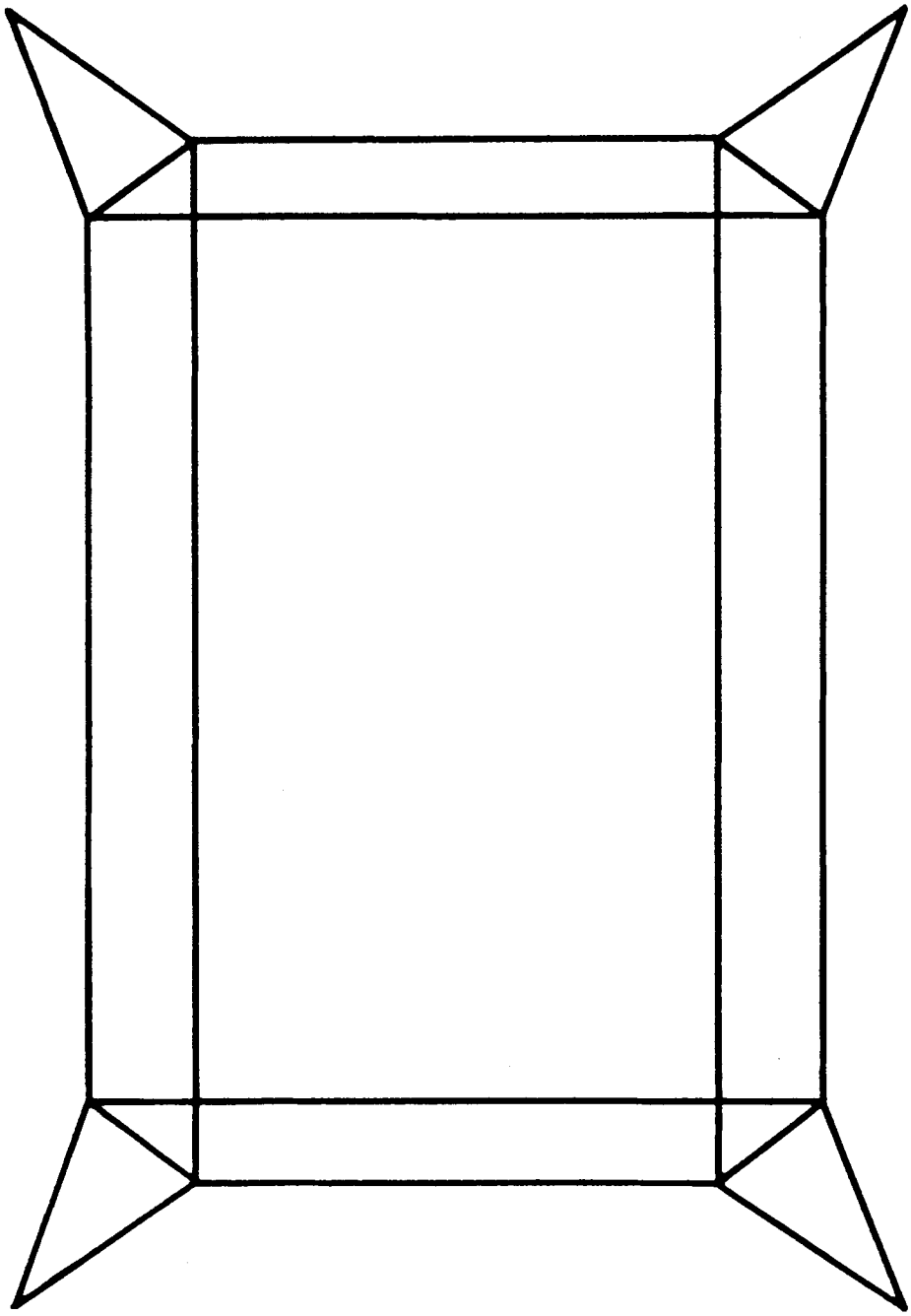

Fig. 9. A string figure of Warradjan from Kakadu National Park. It is formed from two pieces of string manipulated by two people, and measures approximately 50cm by 30cm [Peter Wellings, pers. Comm.]

"string figure". Warradjan is made from two lengths of string manipulated by two people, as shown to Aboriginal people by ancestral figures involved in some way in Warradjan's coming into being. The shape of the resulting string figure is shown in Fig. 9.

MANAGEMENT

Is Carettochelys rare? Certainly the results of this study show it to be widespread between the tidal reaches of the South Alligator River and the escarpment, and that high densities may be present in the upper reaches during the dry season. In the colloquial sense, Carettochelys cannot be considered rare in Kakadu National Park. However, the complexity of the biological concept of rarity is often obscured by the inadequacy of the English language to describe it, and at least seven distinct forms of rarity are recognized (Rabinowitz et al., 1986). The place occupied by Carettochelys among these seven forms is shown in Table 4. There can be little doubt that Carettochelys represents both a geographic and a taxonomic relic species (sensu Simpson, 1944) and that it is rare in the sense of being geographically restricted. Regardless of high densities in some areas within their ranges, locally abundant species with restricted ranges are possibly more vulnerable than scarce but widely distributed species.

Concern for Carettochelys is heightened by reports that Papuan populations have been depleted in the last 20 years through exploitation of adults and eggs by native peoples (Groombridge, 1982). Stereotyped nesting habits render Carettochelys insculpta (like sea turtles) extremely susceptible to over-exploitation, and levels of exploitation in the Gulf and Western Provinces have been exacerbated in recent times by the introduction of modern technology, principally outboard motors.

TABLE 4. The position occupied by Carettochelys insculpta and two other species of Australian freshwater turtles among the seven forms of rarity recognized by Rabinowitz et al. (1986).

GEOGRAPHIC DISTRIBUTION	Wide		Narrow	
HABITAT SPECIFICITY	Broad	Restricted	Broad	Restricted
SOMEWHERE LARGE	NOT RARE		Caretto-chelys	Rheo-dytes?
EVERYWHERE SMALL				Pseud-emydura

Also, since clan warfare has ceased, people have moved from the hinterland to more convenient positions along the river banks. Plans for intensive deforestation, woodchipping of mangroves and a hydro-electric scheme in the Gulf Province are also of concern because of the impact on rivers of the region and the turtles they contain (Groombridge, 1982).

Potential threats to the existence of Carettochelys in northern Australia include wholesale clearing of vegetation, in places down to the waterline, habitat degradation through overstocking, changed Aboriginal practices with the introduction of modern technologies and unscrupulous fishing practices. Although they are of particular concern for the Daly River populations (Georges, 1987), in the absence of adequate research there are no firm data to show that any of these potential threats are currently threatening Australian populations.

There are no management programmes in place for Carettochelys insculpta, though several authors have called for the species to be given a high priority in conservation funding. Pernetta and Burgin (1980) comment that although the species and its eggs are widely consumed by Papuans, there are no published data on the biology of the species, its status, or its distribution. In view of its restricted range and its importance to the subsistence economy of many native peoples in Papua New Guinea (Liem and Haines, 1977), Pernetta and Burgin recommend that investigation of the biology, ecology and population status of Carettochelys be given priority in future studies. Groombridge (1982) reported that the IUCN/SSC Chelonian Specialist Group plans a high priority project on the ecology, reproduction and economic potential for the long-term management and conservation of

Carettochelys, but the project has not yet begun.

The conservation and management of Carettochelys can be considered at three levels -- global, involving issues applicable throughout its range; regional, involving issues specific to, say, northern Australia or Papua New Guinea; and local, involving issues specific to a local area or drainage, for example Kakadu National Park. These three levels will be dealt with in turn below.

Global: 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, but this protection is not complete because the park is currently a compromise between conservation, mining, recreation and other interests. In addition, substantial parts of the Alligator Rivers catchment lie outside the park. The other known concentration of Carettochelys in northern Australia is in the Daly River. Unfortunately, the Northern Territory Government lacks a coherent river and wetland conservation strategy. The Daly River is largely unprotected and control of even the river banks and the important riparian vegetation is largely in private hands. Urgent consideration should be given to protecting the section of the Daly River between Policeman's Crossing and the junction of the King River, and to protecting the riparian vegetation throughout the Daly drainage.

In Papua New Guinea, Wildlife Reserves may afford Carettochelys some protection from habitat destruction, but not from exploitation by native peoples (Groombridge, 1982)

Related to the provision of reserves, is one of the most perplexing questions on the biology of Carettochelys. It is a highly mobile species with broad habitat requirements including a tolerance of marine conditions. It can breed on sand bars and mud banks in the upper reaches of rivers, on the shores of islands in estuarine deltas, and on coastal beaches. It is a general omnivore whose catholic diet allows great scope for opportunism in feeding. Why is it not more widespread, both in Australia and elsewhere? Further detailed information on the habitat requirements of both adults and juveniles is needed before this question can be answered. Such information is needed before the possible impact of proposed or potential projects in river catchments (mining, clearing, hydro-electric schemes, mangrove clearing or woodchipping, etc.) can be fully evaluated. Such information is also needed in judging the adequacy of existing reserves and in planning new reserves expected to ensure the conservation of Carettochelys. The value of protecting the habitat of adult turtles will be greatly diminished if the destruction of regions or elements of the environment essential to the survival of juveniles continues unabated, and unnoticed by those concerned with the well-being of the species.

Regional: In Papua New Guinea, there is the issue of over-exploitation of Carettochelys populations by native peoples and a good case exists for mounting a research programme with the following aims:

1. To provide data on the size and structure of populations of Carettochelys insculpta as a foundation for future monitoring of the turtle populations. Monitoring will enable assessment of the impact of continuing exploitation and assessment of any

legislative measures introduced to protect Carettochelys and its eggs.

2. To provide data on the current intensity of exploitation as a foundation for monitoring trends in exploitation with changes in human populations and practices.

3. To provide data on the population dynamics of Carettochelys (levels of mortality at various stages, recruitment, etc.) to determine whether management practices for ensuring a sustainable harvest are necessary and attainable.

4. To explore the possibility of farming Carettochelys on an economic basis to provide a source of protein for local inhabitants and to undertake the necessary studies of husbandry and related biological aspects.

The distribution, population status, and extent of utilization are very poorly known in Irian Jaya and these data are required (Groombridge, 1982).

In Australia, the distribution of Carettochelys is also very poorly known, as anecdotal reports suggest that it is much more widespread than existing records show. Levels of exploitation by Aboriginal people are also unknown for most of northern Australia. Circulation of turtles beyond the boundary of the local community, made possible by improved transport and refrigeration, may need further regulation. Current Northern Territory legislation prohibits trade in wildlife by Aboriginal peoples, but not distribution amongst friends or relatives.

Carettochelys should be excluded from any "wild foods" safaris run by Aborigines for the benefit of tourists. The Tiwi people conduct "Aboriginal life-style" safaris whereby tourists are shown how to catch and eat bush foods. These safaris have been very successful on Melville Island, a success that may encourage other Aboriginal communities to start similar enterprises. While many wildlife populations could be expected to sustain such harvesting, data on the population dynamics of Carettochelys are too few for a sound judgement, and inclusion of the species in wild foods safaris should be prevented.

Local: Within Kakadu National Park, factors with the potential to cause a decline in Carettochelys populations are recreational fishing, hunting by Aboriginal peoples, proposed mining activities, and habitat destruction by feral animals and stock. Of these, only the last two are considered to pose a serious threat. Recreational fishing is now prohibited east of the Pine Creek Road, in the very areas where Carettochelys is most abundant. In any case, most recreational fishing is with lures and Carettochelys is only occasionally snagged on lures. There is no evidence to suggest that the level of exploitation by Aboriginal peoples is any greater than it was in pre-European times, and all turtles are caught for local consumption.

The proposed mine at Coronation Hill is supposed to be totally self-contained with no planned releases to the adjacent South Alligator River, but its proximity to major dry season concentrations of Carettochelys is of concern. Water in the vicinity of Coronation Hill eventually flows into the South Alligator River. If polluted, this water has the potential for effects in areas far removed from the mining

operation itself (Dames and Moore, 1987). The present study shows that the upper reaches of the South Alligator River in the vicinity of Coronation Hill, are important dry season refuges for Carettochelys, and may be an important focus for breeding and recruitment. Potential threats to these important populations posed by mining are great and include:

1. Contaminated rainwater run-off, accidental discharges from the tailings dam or treatment plant, or accidental spillage of hazardous industrial chemicals at stream crossings during transport to the mill-site are all potential sources of destructive pollution of the South Alligator River (see Dames and Moore, 1987). The accidental release from the far more sensitive Ranger Uranium Mine earlier this year acts as a sober reminder.

2. Demands on water for mining operations may deplete water levels in the shallow billabongs used by Carettochelys as dry-season refuges.

3. Upgrading of river crossings and causeways may restrict the free movement of turtles during the early dry as waters recede.

4. Populations may be decimated by increased fishing activity in the dry-season refuges by mine workers and others allowed into the mining area.

The Water Buffalo, Bubalus bubalus, exerts both a direct influence on Carettochelys through destruction of nests, and an indirect influence

PLATE X. Buffalo activity and the resulting destruction of riparian vegetation may initially assist Carettochelys insculpta by dramatically increasing the amount of underwater cover afforded by fallen trees, branches and litter [Photo: R. Kennett].

PLATE XI. In the long term, destruction of riparian vegetation by buffalo will have an adverse effect on Carettochelys insculpta, which depends in the dry season on fruits and leaves of particular species that grow adjacent to water. This photograph shows Shovel Billabong in which the riparian vegetation has been totally destroyed [Photo: A. Georges].

through habitat degradation. Sand banks provide easy access to water and are often used by buffalo as secure places to rest at night. In some areas within Gimbat Station and the overstocked Goodparla Station, virtually every square inch of potential nesting area had been recently disturbed by a hoof. Studies in the Daly River (Georges, in prep) have shown that stock can completely or partly destroy nests by causing sand falls that either bury or expose nests and by crushing nests under hoof. Carettochelys deposits its eggs in shallow nests (Tables 1 and 2) and even a misplaced human heel is sufficient to destroy several eggs in a nest. Once an egg is broken and putrefies, the entire nest is much more vulnerable to predation, which would normally only occur in the first few days after egglaying. It seems likely that recruitment of Carettochelys from the stretch of the south Alligator River that runs through Goodparla Station would be negligible. Nearly all nests would be destroyed by either the activity of buffalo or through predation.

Buffalo have a profound effect on riparian vegetation both by foraging on young plants and by structurally destroying the banks of billabongs and promoting erosion. Initially, erosion of banks and consequential destruction of riparian vegetation may assist Carettochelys by dramatically increasing the underwater cover afforded by fallen trees, branches and litter. This is very evident in Pul Pul Billabong (Plate X). However it is clear from the dietary analyses that in the dry, Carettochelys depends largely on the fruits and leaves of particular species that grow adjacent to the water. Destruction of this vegetation can only have long-term deleterious effects on the turtle populations. It would be difficult to imagine feeding activity by Carettochelys in Shovel Billabong during the dry contributing anything

to reproductive output for the year. The riparian vegetation of this billabong has been entirely destroyed and the banks seriously eroded as a result of buffalo activity (Plate XI).

Buffalo are also directly responsible for increased turbidity of billabongs in Kakadu National Park (John Bywater, unpubl. data). This is visually evident at the junction of Jim Jim Creek and the South Alligator River which drains Goodparla and Gimbat Stations. Water Buffalo densities in the Jim Jim catchment are strictly controlled, and the creek's relatively clear waters are in stark contrast to those of the South Alligator River when they mix in the wet (P. Wellings, pers. comm.). High turbidities and siltation will dramatically change the physico-chemical characteristics and biota of billabongs which may in turn influence turtle populations.

Goodparla and Gimbat Stations are now included in Kakadu National Park and there are plans to greatly reduce Water Buffalo densities when agreements with previous lease holders expire. Mining companies should be expected to undertake similar measures, especially in the "Conservation Zone" should it be declared.

RECOMMENDATIONS FOR KAKADU NATIONAL PARK

1. Reduction in the densities of water buffalo will almost certainly decrease mortality among nests of Carettochelys in the South Alligator River (Stage III), and with subsequent recovery of the habitat, may increase food supply during the dry. Action to reduce buffalo densities in Stage III to levels already achieved in Stage I should proceed without delay. Priority should be given to areas adjacent to the South Alligator River and its tributaries. Mining interests should be required to reduce buffalo densities in areas under

their control, and to maintain densities at levels equal to or below those currently achieved in Stage I.

2. The high densities of Carettochelys in proximity to Coronation Hill, including a substantial proportion of juveniles and evidence of breeding activity, should be formally brought to the attention of the companies involved in the proposed mining venture. This is particularly important because our findings are at odds with those of the recent biological survey commissioned by BHP (Dames and Moore, 1987). The companies involved in the venture should also be made aware of the national and international concern for the conservation of this unique species as expressed in the Red Data Book (Groombridge, 1982) and in the recently circulated IUCN draft Tortoise and Freshwater Turtle Action Plan to be published later this year. This concern stems both from the scientific value of the species and its value as a traditional food species for the local Aboriginal Community.

3. The Plan of Management for Stage III and the "Conservation Zone" should include stringent requirements to protect the upper reaches of the South Alligator River from potential leakages from tailings dams, accidental releases or spillage, erosion and siltation. The mine should be prohibited from drawing water from the South Alligator drainage during the dry season, and should be required to provide adequate water storage to carry the mine through a prolonged dry season.

4. The current ban on recreational fishing to the east of the Pine Creek Road, especially fishing with baited hooks, should be maintained. Carettochelys is found in highest concentrations in the area covered by the ban and, like all turtles, is particularly susceptible to capture on

baited lines. The hook, if swallowed, is impossible to retrieve without killing the turtle, and if left in place, it may also eventually cause its death. Mining interests should be required to prohibit mine workers and others from fishing in the "Conservation Zone" should it be declared.

5. Carettochelys should be excluded from any enterprises designed to introduce tourists to traditional Aboriginal practices and foods, at least until detailed study of the population dynamics of the species enables the impact of such harvests to be assessed. Aboriginal peoples should be encouraged to continue their practice of collecting Carettochelys for local consumption only.

6. A.N.P.W.S. should support further research into the biology of Carettochelys since to date, little research has been conducted elsewhere. The wet season habits and habitat requirements of Carettochelys deserve special attention because knowledge of only the dry season habits of the species will not allow evaluation of all management decisions likely to affect Carettochelys populations. In particular research is required to establish whether or not populations expand into the floodplains during the wet, then contract once more to the upper reaches of the drainage during the dry. More information is needed on the requirements of juvenile Carettochelys and on the population ecology of the species in Kakadu National Park.

7. Carettochelys is an endearing and unusual animal of considerable international interest, and should be given a high profile in promotional material on Kakadu National Park. The fact that the Park affords the species, one which many consider at risk, considerable protection, will enhance the standing of Kakadu National Park among

people concerned with the conservation of world's threatened and endangered reptiles. No other population of Carettochelys, either in Australia or in Papua New Guinea, receives similar protection.

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APPENDIX A: Full details of data used to constuct the distribution maps for *Carettochelys insculpta* and its nests in Kakadu National Park. A "+" refers to a sighting, a "-" to failure to find evidence of nests or adults, and a "." represents failure to look. Little value can be placed on the absences represented by "-" given the low survey intensities.

	BILLABONG	CODE	GRID REF		PRESENT STUDY		OTHER REPORTS		SOURCES
					Nests	Adults	Nests	Adults	
ZONE 2									
Jim Jim Ck	Yellow Waters	JJ01	8574.0	232.0	-	-	.	+	1,2,10
ZONE 3A									
Nourlangie Ck	Nourlangie No.1	NL07A	8588.5	245.5	.	.	.	+	13
South Alligator	Bucket	SA19	8577.5	223.6	-	-	.	.	
	Alligator	SA20	8575.6	221.6	-	-	.	+	4
	Pretty	SA21	8572.4	218.5	-	-	.	.	
ZONE 3B									
Jim Jim Ck	Cooinda Home	JJ02A	8571.5	231.0	-	-	.	.	
	Mardugal	JJ02B	8569.5	232.0	+	-	+	.	9
	Jim Jim	JJ02C	8568.0	234.0	+	-	.	.	
	Patonga Airstrp	JJ04	8567.0	236.0	.	.	.	+	4
	Patonga Home	JJ05	8565.8	237.0	-	-	.	+	4
	Flying Fox	JJ07	8562.2	240.0	+	+	.	+	9
Nourlangie Ck	Highway Xing	NL--	8581.6	254.6	.	.	.	+	1
	Binji Waters	NL08A	8588.1	248.0	-	-	.	+	1
	Miurella Park	NL11A	8578.4	256.1	+	+	.	+	7
	--	NL14	8576.8	259.6	.	+	.	+	1
South Alligator	Long	SA22	8570.0	221.2	+	-	.	.	
ZONE 3C									
Jim Jim	Kingfisher	JJ20	8554.5	249.2	+	-	.	+	1
	--	JJ10	8560.5	241.6	-	-	.	.	
	--	JJ12	8559.0	244.0	+	-	.	.	
Nourlangie Ck	Sandy	NL20	8572.0	259.1	-	-	+	+	2,3
South Alligator	Shovel	SA41	8528.4	209.5	-	.	.	+	9
	Kambolgie	SA48	8512.0	220.0	-	+	.	+	1
	--	SA32	8555.0	208.8	-	-	.	.	
	--	SA43	8517.4	216.0	-	-	.	+	1
ZONE 3D									
East Alligator	--	EA--	8620.0	281.6	.	.	.	+	2,3,14
Barramundie Ck	Barramundie Ck	BC01	8556.0	217.0	+	+	+	+	1,2,8
South Alligator	Gimbat	SA--	8497.4	240.6	.	.	.	+	11
	Pul Pul	SA--	8498.8	239.1	+	+	.	+	11
	Koolpin Xing	SA--	8501.2	235.2	.	+	.	+	11
	--	SA40	8532.0	209.0	-	-	.	+	1
	--	SA--	8529.8	210.5	.	.	.	+	1
	--	SA--	8537.0	208.0	.	.	.	+	1
ZONE 4									
Barramundie Ck	B'mundie Gorge	BC04	8522.0	226.0	-	-	.	.	
Jim Jim	Twin Falls	JJ29	8526.8	259.4	-	-	.	+	2,6,12
Nourlangie Ck	Deaf Adder Gorge	NL30	8550.0	276.0	.	.	.	+	5
South Alligator	UDP Falls	SA46	8513.5	220.2	-	-	.	.	

1 Peter Wellings
2 Ian Morris
3 Greg Miles
4 Dave Lindner
5 Tony Press
6 Marcus Sandford
7 Legler (1980)
8 Legler (1982)
9 Mandy Miur
10 Schodde *et al.* (1972)
11 Dave Walden
12 Andrew Wellings
13 Niel Fitzgerald
14 Georges *et al.* (1988)