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Demographic and health parameters of green sea turtles *Chelonia mydas* foraging in the Gulf of Carpentaria, Australia

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ABSTRACT: It is becoming increasingly apparent that the development of management initiatives for sea turtles depends on the collection of biological data at all life stages. Substantial gaps include a lack of data on both the population's demographic structure and reference values for biochemical parameters that can be used to assess the health and condition of sea turtle populations. Here we present comparative data on population demographics and biochemical blood parameters for green sea turtles *Chelonia mydas* in their foraging grounds of the Sir Edward Pellew (SEP) Islands in the Gulf of Carpentaria, Australia. Turtles within the adult size range for Australian green turtles comprised 54% of turtles caught. Of the turtles with curved carapace lengths (CCL) greater than 85 cm, 41 were adult males, one was an adult female, and 15 could not be confidently sexed. Continued surveys are needed to distinguish between the potential causes underlying this male-biased sex ratio and the difference between the sex ratio we found and those previously published for the population. Based on biochemical analysis of blood, green turtles in the SEP foraging grounds appeared to be healthy. However, mean levels of glucose and magnesium were generally lower than the ranges observed in other studies of clinically healthy green turtles. Additionally, glucose levels were lower in turtles with CCLs of over 85 cm.

KEY WORDS: Green turtles · *Chelonia mydas* · Health · Demography · Gulf of Carpentaria

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INTRODUCTION

For all threatened wildlife species, information is required not only from breeding animals, but also from those in their foraging environment. This is particularly needed for sea turtles because they are a slow to mature, long lived species, whose breeding and feeding sites are spatially separated. While there are volumes of empirical data to show the migratory nature of sea turtles, there is a growing body of literature that illustrates the need for conservation measures to operate on an ecological scale (Bjorndal 1985, Limpus & Limpus 2001, Hays et al. 2004, Hamann et al. 2005). A key component of these measures is developing an understanding of health and status indicators of turtles of all size classes within a foraging environment.

The Sir Edward Pellew (SEP) Islands (15.6° S, 136.7° E) are located in the southwestern corner of the Gulf of Carpentaria, Australia. Aboriginal people have resided in this coastal area for thousands of years, and sea turtles and other marine products form an important part of their diet and culture (Bradley 1997a,b, Baker 1999). Despite these long and traditional links, western science first became aware of the SEP Islands' significance as an important sea turtle foraging area in 1984, when Cyclone Kathy stranded several hundred sea turtles and dugongs on the mud flats near the mouth of the McArthur River (Limpus & Reed 1985a).

Although few data exist to indicate the conservation status of breeding or nesting sea turtle populations within the Gulf of Carpentaria, successful conservation of sea turtles in this region will rely upon the continued

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collection of baseline data and collaboration with the Aboriginal people who reside along much of the coastline. While several projects conduct baseline research on local sea turtle populations in the Northern Territory, these studies tend to focus upon nesting populations (Guinea 1994, Kennett et al. 2004, Schäuble et al. in press). Hence, there is a dearth of information on the foraging grounds, in particular those in the Gulf of Carpentaria. This is particularly so in a foraging area such as the SEP Islands, where turtles are traditionally hunted as a food source, the majority of the resident turtles are from a single genetic population (McCann 2002), and concerns have been raised about possible increases in the number of sick-looking turtles caught by local people (T.S., S.E. and Steve and Archie Johnston pers. comm.). Assessing the relative importance of different foraging sites and local conservation concerns is important for establishing conservation priorities and examining long-term trends in the status of foraging populations. For example, it may take several decades for mortality of juvenile turtles at a foraging area to feed through to a decline in nesting numbers; therefore, monitoring on foraging areas can be used as an early warning system about the health of breeding populations (Aguirre & Balazs 2000, Brenner et al. 2002, Christopher et al. 2003). Consequently, the objectives of the present investigation were to integrate closely with Aboriginal people on the issue of turtle conservation and to collect baseline data on foraging green sea turtles *Chelonia mydas* in the SEP region of the Gulf of Carpentaria with respect to population demographic and blood biochemical parameters.

MATERIALS AND METHODS

Study site and site visits. The SEP Islands lie at the mouths of the Wearyan and McArthur Rivers, 2 large rivers that drain the Barkly Tablelands region of the Northern Territory, Australia. The SEP group is the traditional land of both the Mara and Yanyula Aboriginal people. The catchment area is predominantly rural, with cattle grazing as the main primary industry. Situated close to the mouth of the McArthur River is the town of Borroloola with a population of approximately 1000 people. The McArthur River Mine (zinc-lead-silver) runs a seaport facility nearby at Bing Bong.

We carried out 6 survey trips during 2001 and 2002 to assess local sea turtle distribution in this area. Fig. 1 and Table 1 describe the areas within the SEP Island group that we surveyed, and the relevant length of each survey is listed in Table 2. Our surveys aimed to consider as many habitat types and as broad a geo-

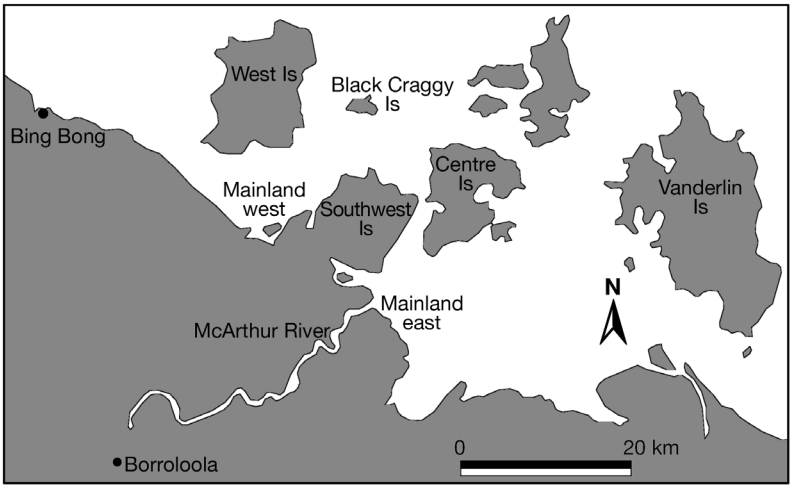

Fig. 1. Areas of the Sir Edward Pellew island group surveyed for foraging turtles

Table 1. Descriptions of the areas that were searched for sea turtles during 2001 and 2002

Area	Descriptions	Habitat type
Vanderlin Island	Entire western coastline from Cape Vanderlin to Clarkson Point	Reef, mangrove and seagrass
Southwest Island	Entire northern coastline	Rocky reefs and seagrass
Centre Island	Entire western coastline	Rocky reefs, mangroves and seagrass
Black Craggy	Around the entire island	Rocky and coral reefs
West Island (east coast)	From to the NE corner south to Tom Simon's outstation (close to the north of Crocodile Point)	Rocky reefs, mangroves and seagrass
West Island (west coast)	From Crocodile Point sand bar north to the NW corner of West Island	Rocky reefs, mangroves and seagrass
West Island (north coast)	From Manbung (turtle nesting beach) to the NE corner of the island	Rocky and coral reefs
Mainland west	From the SW coast of Southwest Island along the coast west to Bing Bong	Mangroves and seagrass
Mainland east	Approximately 5 km east from the McArthur River mouth	Mangroves and seagrass

Table 2. *Chelonia mydas.* Sightings and captures of foraging green turtles in the Sir Edward Pellew (SEP) Islands. In each case, areas were searched for 5 to 7 h d^{-1}

Location	Total sighted but not caught	Total sighted then caught	survey length (d)	Abundance per hour of searching
Vanderlin Island	0	0	1	0
Southwest Island	5	2	9	0.03
Centre Island	0	0	1	0
Black Craggy Island	16	3	6	0.08
West Island (east coast)	8	0	4	0
West Island (west coast)	2	0	2	0
West Island (north coast)	28	102	13	1.2
Mainland west of McArthur River	0	0	2	0
Mainland east of McArthur River	0	0	1	0

graphic range as possible. The local Aboriginal names for the main islands visited are as follows: Mammathumburru (West Island), Wathungka (Southwest Island), Jimmimila (Black Craggy) and Yuguie (Vanderlin Island) (Bradley 1997b).

Search methods. We utilised either a front steer 4.4 m aluminium hull boat or a 5 m aluminium rear steer boat to search for turtles. In either case, at least 2 experienced observers were at the front of the boat to locate turtles, one searching on each side of the boat. Search transects were carried out by conducting a weaving path in and out from the shallowest navigational waters (approximately 60 cm deep) to the deep waters (>5 m), where it was not possible to clearly see the bottom. For each catching day we spent between 5 and 7 h actively searching for turtles. Search methodology followed closely that used by researchers in Queensland (Limpus & Reed 1985b, Limpus et al. 1994a,b), in that if a turtle was seen, it was chased until it was either captured or lost. Chase and capture selections were made without regard to the size or location of the turtle. In all areas except the northern coast of West Island, we recorded details of the approximate size (juvenile, subadult or adult sized) and species of all turtles that were seen but not captured. All turtles that were not captured were lost after a chase.

Turtle capture and sample collection. All turtles were captured by rodeo methods (Limpus & Reed 1985b). Briefly, once a turtle was sighted, it was chased, captured by hand and then brought aboard the boat for processing. Each turtle was tagged with 2 titanium flipper tags and had its curved carapace length (CCL) measured. Tags were applied to the proximal front flipper tagging location as per Limpus (1992). Turtles with CCLs of less than 85 cm were assumed to be immature (Limpus et al. 1994a). Turtles with CCLs above 85 cm may be either large immatures or adults. Maturity and sex for these individuals can only be reliably assessed morphologically for adult males (tails longer than 25 cm from the carapace indicate adult males) (Limpus & Reed 1985b, Limpus et al. 1994a). We measured tail length from the carapace on almost all large turtles. Turtles were examined for external signs fibropapilloma disease, parasites and high loads of epibionts (Limpus et al. 1994a).

Blood sample collection. During the trip to West Island in April 2002, blood samples were taken from 35 of the 107 green turtles caught to allow a health study (using biochemical analyses). Sampling was restricted to West Island because on this April 2002 trip no turtles were caught at the other sites. Samples were collected from 14 turtles with a CCL less than 85 cm and from 21 turtles greater than 85 cm. From each turtle, a 4 ml blood sample was collected from the dorsal cervical sinus (Owens & Ruiz 1980, Limpus 1985). Blood samples were transferred to sodium citrate-coated vials and kept cool for up to 4 h prior to being centrifugation at 6500 rpm ($1000 \times g$) for 5 min to separate out the plasma. Plasma samples were stored in liquid nitrogen until processing. Plasma aliquots were sent to the Northern Territory Department of Primary Industry and Fisheries, Berrimah Veterinary Laboratories, for biochemical parameter analysis using commercial kits; creatinine, glucose, ALT, AST, creatine phosphokinase, protein, calcium, phosphorus and total serum iron (Roche Diagnostics), albumin and magnesium (Trace Scientific), urea and uric acid (Randox Laboratories) were determined following the methods of Whiting (2002). Test parameters were selected based on routine animal health screens that are run for reptiles by the Berrimah Veterinary Laboratories, and those used by Bolten & Bjorndal (1992) and Hasbun et al. (1998).

Statistics. Group means are reported as mean ± standard deviation. All statistical tests were carried out using SPSS. Where the data failed to meet the assumptions of parametric statistics, groups were analysed using Mann-Whitney and Kruskal-Wallis tests. Significance was accepted at $p < 0.05$.

RESULTS

Green turtle sightings and captures differed significantly between individual areas within the SEP region (Table 2). Specifically, the highest abundance per search effort occurred around the rocky/coral reef areas, and predominantly on the reefs of the northern coastline of West Island (Table 2). Poor water clarity frequently reduced turtle sightings and captures. We were most successful during the months of October and April, rather than July to September, because there was less wind to stir up sediments. Water on the northern reefs of West Island tended to be clearest on a falling tide. Overall, we saw 188 turtles and caught 107. Only 2 turtles were caught more than once, and both were recaptured within 100 m of their initial capture site. Blood samples were only collected from these turtles at one capture time.

Of the 42 adult turtles that could be reliably assessed for sex and maturity based on CCL and tail length, 41 (98%) were adult males. This difference is significantly different to a 1:1 ratio (chi square with Yates correction $c^2 = 18.11$; $p < 0.001$). One of these males had a CCL of only 82.9 cm but was classed as an adult male because of his very large 35.5 cm tail. The only morphologically confirmed adult female caught was an individual initially tagged by the Queensland Parks and Wildlife Service's Queensland Turtle Research Project in the southern Great Barrier Reef (primary tag number T32557, CCL 113.5 cm). She had been first tagged in 1987 while nesting at Northwest Island, Queensland. This was the only turtle caught with tags from a study other than our own.

In addition to the turtles whose morphology clearly indicated their sex and adulthood, we captured one large individual (CCL 85.6 cm) with a tail length (22 cm) and differentiation that suggested masculinity but was not sufficient large to confirm maturity, 15 individuals of unknown sex and maturity with CCLs of between 89.9 and 105.9 cm, and 49 juvenile or subadult turtles with CCLs of less than 85 cm. Blood samples were taken from 15 of the adult males (tails longer than 25 cm), 8 large turtles of unknown sex and maturity (CCL > 85 cm), the large male of unknown maturity, and 20 individuals of less than 85 cm CCL. A histogram of the CCL distribution of the green turtles caught is given in Fig. 2.

In addition to the green turtles listed above, 3 immature hawksbill turtles *Eretmochelys imbricata* were caught and tagged on the northern reef of West Island (CCLs 36.2, 37.3, and 56.5 cm). No turtles of either species were observed to have external signs of fibropapilloma disease or other indicators of poor health or condition such as high epibiont loads, parasites or anorexia.

Blood biochemical assays

Results for the biochemical analyses are presented in Table 3. Biochemical analyses for 8 samples could not be completed across all parameters due to limited volume or sample haemolysis.

Glucose was the only biochemical parameter to show a significant difference (Mann-Whitney $U = 73.50$, $p = 0.036$) between large turtles (CCL ≥ 85 cm) and small turtles (CCL < 85 cm) with glucose levels higher in small subadult turtles (Table 3).

There were significant differences among the 3 sample groups (Table 3) for albumin (Kruskal-Wallis $c^2 = 6.70$, $p = 0.035$), globulin (Kruskal-Wallis $c^2 = 6.66$, $p = 0.036$), albumin:globulin ratio (Kruskal-Wallis $c^2 = 10.37$, $p = 0.006$), and uric acid (Kruskal-Wallis $c^2 = 6.28$, $p = 0.043$).

Based on the observation of mean ranks, males had lower albumin levels than both adult sized turtles with short tails and subadults. Adult sized turtles with short

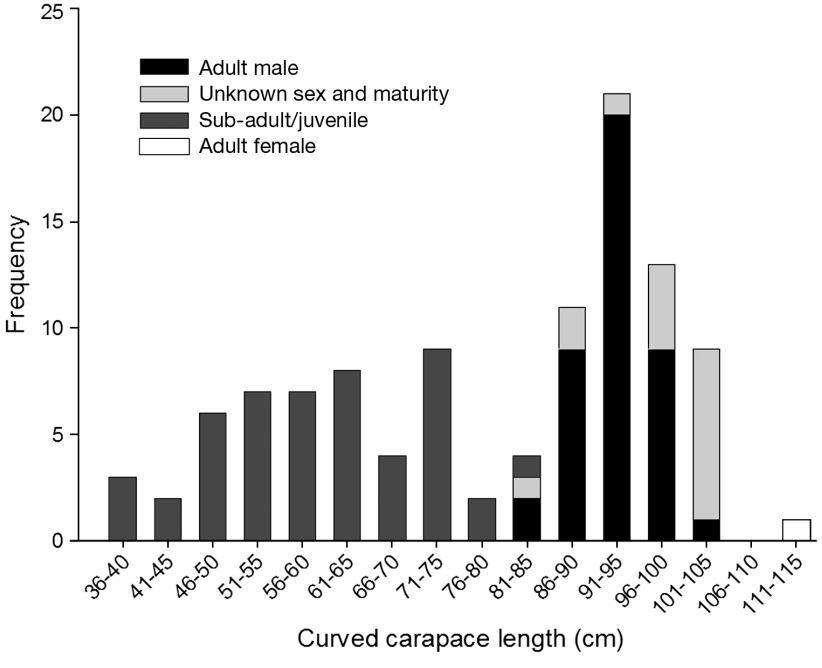

Fig. 2. *Chelonia mydas*. Curved carapace length (CCL) distribution of the green turtles caught in the Sir Edward Pellew Islands

Table 3. *Chelonia mydas*. Biochemical assays of blood samples from green turtles in the Sir Edward Pellew (SEP) Islands. CCL = curved carapace length, SD = standard deviation, N = sample size, ALT = alanine aminotransferase, AST = aspartate aminotransferase. NB: The 82.9 cm male with a 35.5 cm tail has been included in the subadult category

Parameter	All samples					CCL < 85 cm (subadults)				
	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N
Creatinine (µmol l^{-1})	25.20	7.33	45.90	11.50	27	22.03	3.66	27.80	15.80	10
Urea (mmol l^{-1})	1.14	0.79	3.60	0.10	35	0.94	0.75	2.30	0.20	14
Glucose (mmol l^{-1})	1.61	0.89	3.00	0.00	33	1.94	0.79	3.00	0.50	14
ALT (U l^{-1})	10.00	8.51	32.00	0.00	27	9.30	8.98	32.00	0.00	10
AST (U l^{-1})	191.33	102.14	473.00	34.00	27	177.00	83.42	310.00	34.00	10
Creatine phosphokinase (U l^{-1})	808.08	475.19	1770.00	142.00	24	997.44	543.84	1770.00	142.00	9
Protein (g l^{-1})	37.98	13.05	66.70	5.40	35	39.94	14.93	66.70	5.40	14
Albumin (g l^{-1})	16.56	6.13	29.10	3.20	24	18.31	7.11	29.10	3.20	9
Globulin (g l^{-1})	17.36	4.14	24.40	7.80	24	18.40	2.82	21.40	13.70	9
Albumin/globulin ratio	1.03	0.49	2.40	0.40	24	1.04	0.36	1.60	0.50	9
Calcium (mmol l^{-1})	1.89	0.49	2.73	0.81	28	2.12	0.39	2.72	1.43	11
Phosphorus (mmol l^{-1})	1.69	0.54	3.53	0.58	28	1.51	0.40	2.02	0.58	11
Magnesium (mmol l^{-1})	4.06	1.81	9.70	1.57	27	4.08	2.10	9.70	1.57	10
Total serum iron (µmol l^{-1})	6.99	2.96	14.20	2.20	28	6.51	3.34	12.30	2.20	11
Uric acid (µmol l^{-1})	52.90	32.96	148.00	8.80	27	52.18	32.13	116.00	8.80	10
	CCL ≥ 85 cm + tail < 25 cm (adult females and large immatures)					CCL ≥ 85 cm + tail > 25 cm (adult males)				
Creatinine (µmol l^{-1})	30.20	11.39	45.90	19.90	4	26.10	7.51	40.50	11.50	13
Urea (mmol l^{-1})	1.47	0.51	2.20	0.60	7	1.17	0.92	3.60	0.10	14
Glucose (mmol l^{-1})	1.38	0.98	2.80	0.30	5	1.37	0.91	2.90	0.00	14
ALT (U l^{-1})	14.75	13.89	30.00	2.00	4	9.08	6.28	23.00	1.00	13
AST (U l^{-1})	236.25	163.42	473.00	123.00	4	188.54	99.29	443.00	65.00	13
Creatine phosphokinase (U l^{-1})	563.50	275.81	873.00	261.00	4	742.09	446.01	1671.00	406.00	11
Protein (g l^{-1})	41.60	13.89	64.00	21.50	7	34.21	10.36	64.00	19.00	14
Albumin (g l^{-1})	21.70	7.44	28.40	13.70	3	13.96	3.83	20.10	9.00	12
Globulin (g l^{-1})	10.67	2.49	12.30	7.80	3	18.26	3.86	24.40	9.90	12
Albumin/globulin ratio	2.03	0.32	2.40	1.80	3	0.77	0.21	1.10	0.40	12
Calcium (mmol l^{-1})	1.81	0.55	2.16	1.00	4	1.73	0.51	2.73	0.81	13
Phosphorus (mmol l^{-1})	1.67	0.24	1.99	1.43	4	1.84	0.67	3.53	0.88	13
Magnesium (mmol l^{-1})	3.43	0.25	3.75	3.22	4	4.24	1.90	9.10	2.72	13
Total serum iron (µmol l^{-1})	7.20	2.70	10.50	3.90	4	7.32	2.87	14.20	4.40	13
Uric acid (µmol l^{-1})	96.25	44.80	148.00	44.00	4	40.12	16.55	73.00	20.00	13

tails had lower globulin levels than males and subadults. Males had a lower albumin:globulin ratio than adult sized turtles with short tails and sub adults. Adult sized turtles with short tails had higher uric acid levels than males and subadults.

DISCUSSION

Biological data collection and management actions for threatened species of marine wildlife need to be spread over spatial and temporal scales that complement the species' ecological scale. (Bjorndal 1985, Limpus & Limpus 2001, Hays et al. 2004, Hamann et al. 2005). Yet for a variety of reasons, despite the recognised need, basic demographic and/or baseline health data are not available for many populations throughout the world, including threatened populations of the green turtle *Chelonia mydas*. The collection and monitoring of information on population characteristics for threatened species such as demographic characteristics, health, and condition will aid species conservation, because it will increase the ability to make timely management decisions at necessary spatial and temporal scales.

Genetic studies have determined that the *Chelonia mydas* foraging in the SEP Islands are predominately derived from the Gulf of Carpentaria genetic population (McCann 2002). This population has nesting rookeries spread from the western coast of Cape York to northeast Arhnem Land with the main nesting areas occurring in the Wellesley Island group, Vanderlin Island, northeast Arhnem Land and Groote Eylandt (Limpus & Chatto 2004, Hamann et al. in press). Our study represents the only study on foraging area population dynamics and health for this green turtle population.

Size distribution

A determination of the size class distribution of turtles foraging in a particular area can provide insight into the local and regional population dynamics of the species and assist with assignments of status. For example, it has been suggested that one of the reasons the Tortuegero *Chelonia mydas* population has not declined to the same extent as many other Caribbean green turtle populations, despite high harvest rates, is because there were large numbers of turtles in all age classes in the foraging areas (Bjorndal 1985, Bjorndal et al. 1999). In our study we found a similar size class distribution in the SEP Islands to that reported for *C. mydas* from Heron Reef in Queensland (Limpus & Reed 1985b). However, the distribution was different to that found in Fog Bay in the Northern Territory (Whiting 2002) and Moreton Bay in Queensland (Limpus et al. 1994a). Both of these latter sites had high numbers of immature turtles and few adults. However, size class distribution of *C. mydas* in foraging areas has been found to differ between sites and is presumably dependent on a combination of ontogenetic shifts in food and/or habitat requirements as well as the level or selectivity by size of use (Limpus et al. 1994a). Although we did not record any recently recruited *C. mydas*, the minimum size of juvenile green turtles in our study is similar to that of juvenile *C. mydas* from other populations when they arrive at foraging areas (Limpus et al. 2004a, 2005).

Sex ratio

The adult sex ratio of *Chelonia mydas* caught in this study appears to be significantly male biased. Forty-one adult males were caught compared with only one confirmed adult female turtle. We also caught 15 large individuals that could not be sexed with confidence. However, even if these individuals were all adult females, the male bias would still be strong. In contrast, Limpus & Reed (1985a) observed a bias towards larger individuals that were not adult males when they surveyed *C. mydas* stranded on the mud flats between the mouths of the McArthur and the Wearyan Rivers (an area of the mainland in close proximity to the SEP Islands) in the aftermath of Cyclone Kathy in 1984. If the stranded turtles represent a sexually unbiased sample of the offshore population (Limpus & Reed 1985a), this might suggest several things and disaggregating between possibilities will require future surveys in the SEP Islands area.

First, the differences between our data and that of Limpus & Reed (1985a) could reflect fine-scale, local variation in sex ratio, modest sample sizes or sampling bias. There was no reason to suspect that our sampling methods were biased towards male captures, as the techniques were the same as Queensland studies where sex ratios are usually found to be female biased or 1:1 (Limpus & Reed 1985b, Limpus et al. 1994a). Neither was the male bias caused by return of males from breeding grounds prior to return of females. Most of our sampling took place at times of non-breeding or low breeding intensity in the region (Bustard 1972, Limpus et al. 1984, Hope & Smit 1998, Hamann et al. in press). Additionally, no courtship was observed and extensive and/or fresh courtship damage would be expected on adult males who had recently bred and/or migrated back from breeding grounds; this was not observed, however.

Second, fine-scale local variation in sex ratio between our data and that of Limpus & Reed (1985a) could reflect sampling habitat. While we caught most of our turtles on the northern reefs of West Island, Limpus & Reed (1985a) reported data from turtles that stranded in the mangroves adjacent to the McArthur River mouth. While sex ratio has been found to be independent of size class for *Chelonia mydas* at Heron Island, Moreton Bay and Shoalwater Bay in Queensland (Limpus & Reed 1985b), size-related differences have been found in Fog Bay and Torres Strait (Whiting 2002, Hamann et al. 2005). In these two latter studies, populations were substantially biased towards juvenile turtles, and the authors speculated that larger turtles were occupying deeper water habitats, and were thus only occasionally seen on reef flats. The question of sample size adequacy will be best answered through additional studies in the SEP Islands. Studies incorporating laparoscopic sexing and maturity analysis of turtles will be particularly valuable. Given the serious apparent lack of adult females in the population, and relevant interactions with indigenous natural resource management actions and hunting practices, additional survey and monitoring of the population is strongly encouraged.

Blood biochemical assays

Whiting (2002) found that clinically sick green turtles from Fog Bay in the Northern Territory, Australia, had elevated urea and AST levels and reduced calcium (n = 3 individuals). Clinically sick hawksbill turtles (n = 3) from the same study had elevated potassium, urea and creatine kinase levels. Heavy parasite loads were suggested as a possible cause of these differences in blood biochemistry. In contrast, we found no strong evidence from blood analyses that individual *Chelonia mydas* caught in the SEP Islands were clinically stressed or unhealthy. Mean values for all blood parameters except glucose and magnesium fell within ranges observed for clinically normal/healthy individ-

uals of this species at other locations (Bolten & Bjorndal 1992, Hasbun et al. 1998, Aguirre & Balazs 2000, Whiting 2002, Jacobson et al. 2004).

Glucose levels were significantly lower in larger turtles than those with CCLs of less than 85 cm, and overall mean glucose levels tended to be lower than reported in previous studies (Bolten & Bjorndal 1992, Hasbun et al. 1998, Aguirre & Balazs 2000, Whiting 2002, Jacobson et al. 2004). This could reflect ontogenetic and geographical differences in diet and/or digestive efficiency. Magnesium levels were higher than those observed by Whiting (2002) across all size classes. Urea levels were within the range observed by Whiting (2002) for turtles from Fog Bay, but lay at the low end of the spectrum. The generally lower urea levels may indicate lower dietary protein levels for the SEP Islands *Chelonia mydas* population or lower parasite loads (Whiting 2002). However, the clinical significance of these differences is presently unknown.

Although we found statistically significant variation in albumin, globumin, albumin:globulin ratio and uric acid between sexes and size classes of green turtles in this population, in each case mean values were within the ranges published for *Chelonia mydas* in the Caribbean and the Arabian Gulf (see Bolten & Bjorndal 1992, Hasbun et al. 1998). The variation of albumin and globulin between size classes may reflect variation in diet and health respectively (Pages et al. 1992). However, while more information is required on how these parameters vary with season, differing age classes, maturity and reproductive status before more specific conclusions can be made, our data can be used as a baseline from which to compare levels in stranded and sick individuals.

Studies focusing on seasonal and ontogenetic variation in dietary preferences and biochemical indicators are warranted to address causes and consequences of variations found in our study. Given the importance of marine turtles in indigenous people's culture, population declines and health issues are of direct concern to local indigenous communities. In particular, over the last 5 yr local traditional owners and turtle hunters have voiced concerns about the perceived increase in sick turtles in waters around the SEP Islands (T. Simon, S. Evans and S. and A. Johnston pers. comm.). While there have been no systematic surveys to document clinical signs and assign cause, studies such as ours will enable a baseline which future clinical studies can use to compare biological parameters.

CONCLUSIONS

Marine turtle populations throughout northern Australia are faced with increasing pressure from a suite of factors such as fishery bycatch, ghost nets, marine pollution and high predation of eggs and hatchlings (Limpus & Chatto 2004). The waters around the SEP Islands are a significant habitat for *Chelonia mydas* that breed in the Gulf of Carpentaria (McCann 2002, Kennett et al. 2004). Our study is the first to describe the population structure and provide a biochemical assessment of *C. mydas* for this population and it will provide an important dataset for assessing future impacts such as cyclone damage to seagrass communities and the proposed McArthur River Mine expansion on marine turtle health.

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LITERATURE CITED

Aguirre AA, Balazs GH (2000) Blood biochemistry values of green turtles, *Chelonia mydas*, with and without fibropapillomatosis. Comp Haematol Int 10:132–137

Baker R (1999) Land is life: from bush to town, the story of the Yanyuwa people. Allen & Unwin, Sydney

Bolten AB, Bjorndal KA (1992) Blood profiles for a wild population of green turtles (*Chelonia mydas*) in the southern Bahamas: size-specific and sex-specific relationships. J Wildl Dis 28:407–413.

Bjorndal KA (1985) Nutritional ecology of sea turtles. Copeia 1985:736

Bjorndal KA, Wetherall JA, Bolten AB, Mortimer JA (1999) Twenty-six years of green turtle nesting at Tortuguero, Costa Rica: an encouraging trend. Conserv Biol 1999: 126–134

Bradley J (1997a) How can a whitefella know it all? Indigenous science-western science and marine turtles. In: Kennett R (ed) Marine turtle conservation and management in Northern Australia. Centre for Indigenous Natural and Cultural Resource Management and Centre for Tropical Wetlands Management, Northern Territory University, Darwin, p 25–32

Bradley J (1997b) Li-anthawirriyarra, people of the sea. Yanyuwa relations with their marine environment. PhD thesis, Northern Territory University, Darwin

Brenner D, Lewbart G, Stebbins M, Herman D (2002) Health survey of wild and captive bog turtles (*Clemmys muhlenbergii*) in North Carolina and Virginia. J Zool Wildl Med 33:311–316

Bustard HR (1972) Sea turtles: natural history and conservation. Collins, London

Christopher MM, Berry KH, Henen BT, Nagy KA (2003) Clinical disease and laboratory abnormalities in free-ranging desert tortoises in California (1990–1995). J Wildl Dis 39: 35–56

Guinea ML (1994) Nesting seasonality of the flatback turtle *Natator depressus* (Garman) at Fog Bay, Northern Territory. In: James RC (ed) Proc Australian Marine Turtle Conservation Workshop, November 1990. Queensland Department of Environment and Heritage and Australian Nature Conservation Agency, Canberra, p 150–153

Hamann M, Grayson J, Marsh H (2005) Raising indigenous awareness and promoting on-ground recovery activities for marine turtles and dugong in Torres Strait. Final project report to the Department of Environment and Heritage, Canberra, p 1–94

Hamann M, Schauble C, Simon T, Johnson J, Dorr T, Kennett R (in press) Observations of nesting turtles in the Sir Edward Pellew Islands, Gulf of Carpentaria, Northern Territory, Australia. Mem Qld Mus

Hasbun CR, Lawrence AJ, Naldo J, Samour JH, Al-Ghais SM (1998) Normal blood chemistry of free-living green sea turtles, *Chelonia mydas*, from the United Arab Emirates. Comp Haematol Int 8:174–177

Hays GC, Houghton JDR, Myers AE (2004) Pan Atlantic turtle movements. Nature 429:522

Hope R, Smit N (1998) Marine turtle monitoring in Gurig National Park and Cobourg Marine Park. In: Kennett R, Webb A, Duff G, Guinea M, Hill G (eds) Marine turtle conservation and management in Northern Australia. Proceedings of a workshop held at the Northern Territory University 3–4 June 1997, Darwin. Centre for Indigenous Natural and Cultural Resource Management & Centre for Tropical Wetlands Management, Northern Territory University, Darwin, p 53–62

Jacobson E, Bjorndal K, Bolten A, Herren R, Harman G, Wood L (2004) Establishing plasma biochemical and hematocrit reference intervals for sea turtles in Florida. Archie Carr Center for Sea Turtle Research, available at: http://accstr.ufl.edu/blood_chem.htm

Kennett R, Munungurritj N, Yunupingu D (2004) Migration patterns of marine turtles in the Gulf of Carpentaria, northern Australia: implications for Aboriginal management. Wildl Res 31:241–248

Limpus CJ (1985) A study of the loggerhead turtle, *Caretta caretta,* in eastern Australia. PhD thesis, Department of Zoology, The University of Queensland, Brisbane

Limpus CJ (1992) Estimation of tag loss in marine turtle research. Wildl Res 19:457–469

Limpus CJ, Chatto R (2004) Marine turtles. In: National Oceans Office: Description of key species groups in the Northern Planning Area. National Oceans Office, Hobart, Tasmania, p 113–136

Limpus CJ, Limpus DJ (2001) The loggerhead turtle, *Caretta caretta*, in Queensland: breeding migrations and fidelity to a warm temperate feeding area. Chelon Conserv Biol 4: 142–153

Limpus CJ, Reed PC (1985a) Green sea turtles stranded by Cyclone Kathy on the south-western coast of the Gulf of Carpentaria. Wildl Res 12:523–533

Limpus CJ, Reed PC (1985b) The green turtle, *Chelonia mydas*, in Queensland: a preliminary description of the population structure in a coral reef feeding ground. In: Grigg G, Shine R, Ehmann H (eds) Biology of Australasian frogs and reptiles. Royal Zoological Society of New South Wales, Sydney, p 47–52

Limpus CJ, Fleay A, Guinea M (1984) Sea turtles of the Capricorn section, Great Barrier Reef. In: Ward WT, Saenger P (eds) The Capricorn section of the Great Barrier Reef: past, present and future. The Royal Society of Queensland, Brisbane, p 61–78

Limpus CJ, Couper PJ, Read MA (1994a) The green turtle, *Chelonia mydas*, in Queensland: population structure in a warm temperate feeding area. Mem Qld Mus 35: 139–154

Limpus CJ, Couper PJ, Read MA (1994b) The loggerhead turtle, *Caretta caretta*, in Queensland: population structure in a warm temperate feeding area. Mem Qld Mus 37:195–204

Limpus CJ, Limpus DJ, Arthur KE, Parmenter CJ (2005) Monitoring green turtle population dynamics in Shoalwater Bay: 2000 to 2004. Report to Queensland Environmental Protection Agency and Great Barrier Reef Marine Park Authority, Canberra, p 1–51

McCann MJ (2002) Identifying the origins of green turtles (*Chelonia mydas*) feeding in northern Australia, from genetic markers. Honours thesis, University of Canberra

Owens DW, Ruiz GJ (1980) New methods of obtaining blood and cerebospinal fluid from marine turtles. Herpetologica 36:17–20

Pages T, Peinado VI, Viscor G (1992) Seasonal changes in hematology and blood chemistry of the freshwater turtle *Mauremys caspica leprosa*. Comp Biochem Physiol 103A: 275–278

Schäuble C, Kennett R, Winderlich S (in press) Flatback turtle (*Natator depressus*) nesting at Field Island, Kakadu National Park, Northern Territory: a summary of nesting beach data for 1990–2001. Chelon Conserv Biol

Whiting S (2002) The ecology of immature green and hawksbill turtles foraging on two reef systems in north-western Australia. PhD thesis, Northern Territory University, Darwin

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