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Status of the Flatback Sea Turtle (*Natator depressus*) Rookery on Crab Island, Australia, with Notes on Predation by Crocodiles

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ABSTRACT. – The conservation status of the world's largest rookery of the flatback sea turtle (*Natator depressus*) on Crab Island, Australia, was assessed. During six weeks in the austral winter of 1997, female flatbacks came ashore on 4234 occasions, with a mean of 103.3 turtle tracks per night. Almost 300 more turtle tracks were observed from 6–19 July than during the same two-week period of a previous study in 1991, lending credence to the notion that this nesting aggregation remains robust. Saltwater crocodiles (*Crocodylus porosus*) consumed the turtles at a minimum rate of one per week, and we describe one incident of crocodile predation witnessed directly. Human harvest of turtle eggs was of low intensity and appeared sustainable. We recommend continued protection of Cape York and its associated marine ecosystems in order to ensure the persistence of Crab Island's highly significant turtle rookery.

KEY WORDS. – Reptilia; Testudines; Cheloniidae; Crocodilia; *Natator depressus*; sea turtle; nesting; conservation; predation; *Crocodylus porosus*; Cape York; Australia

The flatback sea turtle, *Natator depressus*, is restricted in range to the continental shelf of Australia, occurring as far north as Irian Jaya (Limpus et al., 1993), with nesting ranging down the northern coastline of Australia to Bundaberg on the east coast and to Barrow Island on the west (Limpus, 1971; Limpus et al., 1993; Prince, 1994). The largest known rookery of the flatback occurs on Crab Island, an uninhabited sand cay in the Gulf of Carpentaria belonging to the aboriginal community of Injinoo (Limpus et al., 1983a). Because of the remote location and inhospitable reputation of the island, sea turtle research at this site has been limited to three studies, widely separated in time. Bustard (1972) described the results of a month-long stay on Crab Island by one of his assistants, who tagged 180 turtles in November–December 1970. Drawing upon a series of short visits in the late 1970s, Limpus et al. (1983a) reported that the turtles nesting on Crab Island were flatbacks, not green turtles (*Chelonia mydas*) as indicated by Bustard (1972), and that these turtles nest on Crab Island year-round, with a peak of hundreds per night occurring in the middle of the austral winter. Limpus et al. (1993) confirmed high reproductive productivity for the flatbacks on Crab Island during two weeks of July 1991, and described various aspects of the turtles' nesting ecology.

Flatbacks have been shown to perish in significant numbers in the nets of the Australian northern prawn fishery (including the Gulf of Carpentaria), where they have been identified as the most frequent marine turtle bycatch (Poiner and Harris, 1996). This fishery tripled in size from the 1970s to 1980s (Somers, 1990), and the effects of the resulting increased annual take of turtles are unknown.

Flatback turtles nesting on Crab Island are also potentially threatened by regular egg harvesting by the local aboriginals (Limpus et al., 1983a, 1993; Miller and Limpus, 1991). Despite the low intensity of this harvest in previous years, egg-collecting is both mechanized (via gasoline powered boats) and unmonitored, factors which could lead to overexploitation. The indigenous communities also occasionally catch and eat adult female flatbacks at Crab Island, though the meat of green turtles is preferred over that of flatbacks in the Torres Strait (Limpus et al., 1983a). The only published feeding ground recovery of a tagged Crab Island flatback occurred in southern Irian Jaya, where the turtle was consumed (Limpus et al., 1993). The number of *N. depressus* thus caught and eaten in Indonesia is presumably far smaller than the many thousands of *C. mydas* harvested in that nation (Daly, 1994), but may still represent an important source of mortality for the Crab Island flatbacks.

In light of these threats, and given the well-known plight of sea turtle populations worldwide, it is important to perform occasional field studies at significant, yet remote, rookeries such as Crab Island to monitor them for otherwise unobserved degradation (Godley et al., 2001). Conducted six years after the last reported research in 1991, the present study evaluates the continued nesting success and further describes the nesting ecology of Crab Island's major population of sea turtles. Predation by saltwater crocodiles, *Crocodylus porosus*, upon the flatbacks is also described and quantified for the first time. The status of the flatback nesting population, along with the significance of the crocodile-turtle interaction, are discussed, and preliminary recommendations are made for ensuring the future of Crab Island as an internationally significant natural area.

METHODS

Limpus et al. (1993) provided a description of the geology, climate, and flora of Crab Island, and include a detailed vegetation map. The island (10°59'S, 142°06'E) is a crescent-shaped sand cay less than 100 m wide at the center, with a 5.5 km long beach on the west, and an expansive tidal mud flat in the eastern bay (Fig. 1).

We camped on Crab Island from 14 June to 25 July 1997, a total of 42 nights. Immediately upon arrival the existing turtle tracks on the entire western beach were counted, with each set of one up-track and one down-track taken as representing the emergence of a single female turtle. The tracks were marked through in the sand after being counted, preventing tracks from being counted more than once (Limpus et al., 1993). Each subsequent morning this process was repeated, with fresh turtle crawls from the night before being easily distinguished. The western beach was divided into 16 sectors paced at roughly 340 m each along the spring high tide line (Fig. 1), and the number of turtle tracks per sector each morning was counted. Turtle tracks were identified to species by the relative width of the crawl through the sand. Narrow flipper tracks were counted as those of hawksbill (*Eretmochelys imbricata*) or olive ridley (*Lepidochelys olivacea*) sea turtles and were easily distinguishable from the wide tracks left by flatbacks. No other sea turtle species has been observed nesting on Crab Island (Limpus et al., 1983a, 1993).

Newly emerged *N. depressus* clutches were located during the morning track counts by following fan-shaped arrays of hatchling tracks to their sources. Nests located near camp were excavated in the afternoon. The numbers of empty eggshells remaining at the bottom of the nests were recorded, providing a measurement of the number of turtles that had hatched. Also recorded from excavated nests were the number of live and dead hatchlings left in the nest, the status of any unhatched eggs (undeveloped or developed), and any evidence of predation upon eggs by crabs (Limpus et al., 1993). Any live hatchlings found in the nests were released on the beach.

Each night, beginning one hour before high tide, we patrolled the beach between sectors 4 and 7, an area centered around the largest frontal sand dune on the island. As noted by Limpus et al. (1993), two workers could not safely or effectively patrol the entire beach for nesting turtles at night, due to the size of the island and the presence of foraging crocodiles in the adjacent surf. Patrolling continued until two subsequent inspections of the target sectors failed to reveal any newly emergent nesting turtles. Each turtle located was measured with a flexible tape for curved carapace length (CL) and curved carapace width (CW), according to the methodologies set by the Queensland Turtle Research Project, described in Limpus et al. (1983a). Tagged turtles were noted as recaptures and the tag numbers were recorded. Unmarked turtles were not tagged. The success of each turtle's nesting attempt (whether or not they deposited eggs) was noted, and as many freshly-laid clutches of eggs as possible were marked. After the departure of the nesting turtle, these fresh nests were measured for depth and the contained eggs were counted with a minimum of rotation. The eggs were replaced and reburied in the nests within two hours of deposition, a period in which such handling appears to cause little egg mortality (Parmenter, 1980).

Aspects of the nesting ecology of the flatbacks quantified during the present study were compared when possible to similar data taken by Limpus et al. (1993), using two-sample independent t-tests with pooled estimates of variance. The mean CL growth rate calculated from recaptures was also compared using a one-sample t-test to a hypothetical mean of zero (Zar, 1996). Two-tailed probabilities of obtaining the calculated t-ratios were generated using Release 12.21 of the statistical program Minitab (Minitab, 1998), and all probabilities calculated were considered significant if $p < .05$.

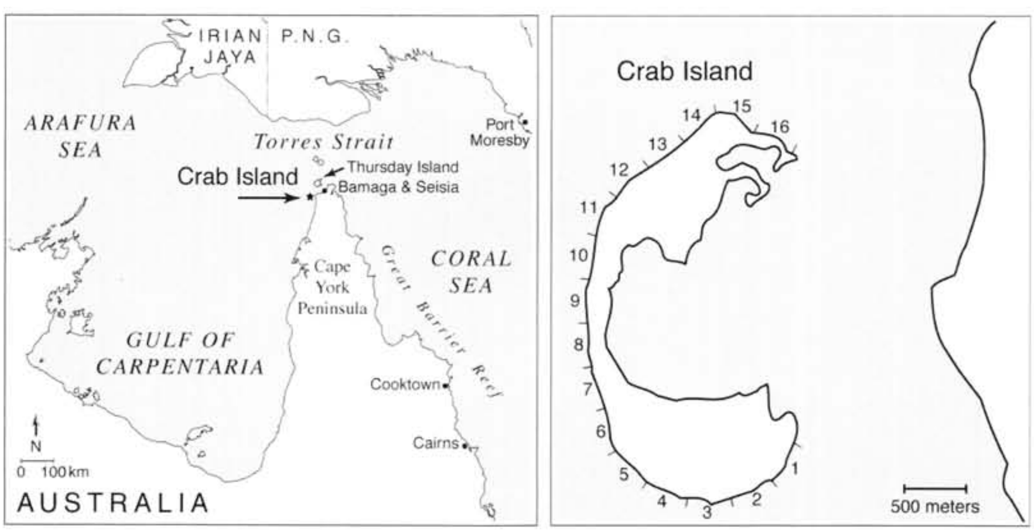

Figure 1. Maps of Crab Island, Australia. The locations of the 16 beach sectors used for monitoring turtle tracks are shown in the close-up view of the island, which was adapted from Limpus et al., 1993.

RESULTS

During this 6-week study 4234 flatback sea turtle emergences occurred on the beach at Crab Island, as evidenced by the morning track counts, at an average of 103.3 emergences every 24 hours (s.d. = 68.3, $n = 41$, range = 6–266). The number of turtle tracks varied markedly from day to day, often by as many as 100 (Fig. 2). Upon our arrival, there were 362 tracks over the entire beach, representing the minimum number of emergences in the two weeks prior to the study period at observed rates of track decay (Limpus et al., 1993). On one occasion we witnessed the daytime nesting attempt of a hawksbill turtle, and tracks of hawksbill or olive ridley turtles were observed on 7 other occasions during the six weeks. No turtles of other species were observed, and turtle nesting occurred in all 16 sectors. Sectors 12 and 11, located in the middle of the northern arm of the island, received the most turtle crawls, and sector 16 had the least (only 2). However, on a given night turtle nesting peaked quite variously in one of sectors 3 through 12 and 14. Of the 158 turtles monitored for nesting success, 127 oviposited, giving a nesting success rate of 80.0%. Multiplying the number of turtle tracks by the nesting success yields an estimate of 3387 clutches of flatback eggs laid during the study period.

An average of 5.36 clutches of flatback hatchlings emerged each day (s.d.= 5.22, $n = 41$, range = 0–22) with a total of 220 clutches over the entire 41 days. However, high wind and precipitation erased all signs of the shallow hatchling tracks on at least six mornings, so the hatchling emergence record should be viewed as incomplete. The low numbers of nests hatching during our study do suggest that turtle nesting in the previous two months (April–May) was much lower than observed during June and July.

Ten of the 158 turtles we examined for nesting success had been tagged during previous studies on Crab Island, seven of which had been measured at first capture. Three of the ten turtles had been tagged during brief visits to the island by Queensland Turtle Research Project volunteers in 1992 and 1993, and the remaining seven were tagged during the 1991 Limpus et al. (1993) study. By comparing past CL measurements to our data the first estimate for the growth rate of nesting adult female flatbacks of the Crab Island population has been calculated at 0.101 cm/yr (s.d. = 0.24, $n = 7$, range = -0.26–0.45). This value was not significantly different from zero ($t = 1.11$, $p > 0.20$). None of the tagged recaptures were observed to nest again during the present study, and so no renesting interval can be calculated. Therefore, it is also unknown how many turtles are represented by the 4234 nesting attempts made during the 6-week study.

Table 1 summarizes the data taken during the present study from nesting turtles, fresh nests, and emerged nests, and compares the observed values with similar data recorded by Limpus et al. (1993). Our measures for CL, fresh clutch size, emerged clutch size, predated eggs, and numbers of hatchlings remaining in the emerged nests were quite similar to and not significantly different from the data presented by Limpus et al. (1993). The fresh nests we measured were significantly deeper (mean difference 6.7 cm) to the bottom, and the emerged nests we examined had significantly higher hatching and emergence successes, and consequently higher numbers of emerged hatchlings, than those recorded by the former study. The higher hatching success is attributable to the significantly fewer unhatched and undeveloped eggs per clutch we observed.

We observed at least 4 saltwater crocodiles (*Crocodylus porosus*) inhabiting the waters around Crab Island, with visually estimated lengths of 1, 2, 2, and 3–4 m. These crocodiles were frequently seen sunning at various locations along the western beach, and were occasionally also found in the mudflats behind the island. We were told by two separate informants that a 5–6 m crocodile had been shot near Crab Island the year before (1996), but no crocodiles of such great size were observed during the present study. One fisherman also reported that crocodiles nest in the interior swamps of the island during the wet season.

During the 6 weeks, a minimum of 7 *N. depressus* were killed by crocodiles. On four morning track counts, and on the day of our arrival at Crab Island, we found on the beach indirect evidence of crocodile predation on flatbacks, including intersecting tracks, blood, and pieces of turtle. These indications of crocodile-turtle interactions always were seen

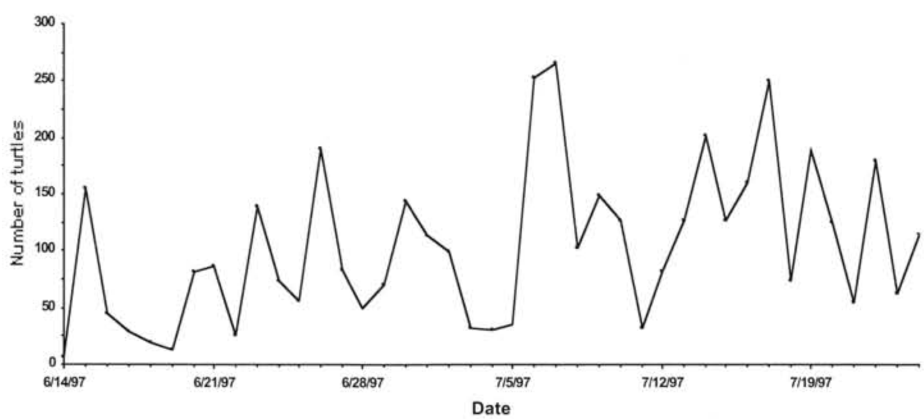

Figure 2. The number of flatback turtles, *Natator depressus*, which came ashore each night on the western beach of Crab Island between 14 June and 24 July 1997 as evidenced by track counts.

Table 1. *Natator depressus* nesting data taken in the present study, with pooled variance t-test comparisons to the data of Limpus et al. (1993). Significant two-tailed p-values indicated by * ($p < 0.05$).

	Present Study			Limpus et al. (1993)				
	Mean	s.d.	n	Mean	s.d	n	T	p
Nesting females								
Curved carapace length (cm)	88.0	3.09	69	88.2	2.80	315	-0.053	0.5980
Curved carapace width (cm)	72.6	2.87	69	Not measured				
Fresh nests								
Clutch size (eggs)	57.0	7.31	54	55.9	9.57	32	0.600	0.5500
Depth to nest bottom (cm)	65.0	10.52	54	58.3	7.21	36	3.330	0.0012*
Emerged nests								
Clutch size (total)	56.0	6.91	33	54.6	9.37	39	0.695	0.4890
Emerged hatchlings	52.2	7.77	33	42.9	12.99	39	3.618	0.0006*
Undeveloped eggs	1.4	1.32	33	4.1	5.10	39	-2.962	0.0042*
Unhatched eggs	0.9	1.44	33	5.7	5.98	39	-4.461	<0.0002*
Predated eggs	0.6	1.54	33	0.2	0.59	39	1.290	0.2010
Live hatchlings in nest	0.5	1.66	33	0.5	1.73	39	-0.112	0.9110
Dead hatchlings	0.4	1.48	33	1.3	2.51	39	-1.761	0.0826
Hatching success (%)	95.0	5.05	33	81.8	17.29	39	4.211	<0.0002*
Emergence success (%)	93.4	8.21	33	78.6	18.55	39	4.265	<0.0002*

on mornings with low tides, and occurred in the interval of beach between the water's edge and the mark of the last high tide. The tracks followed a consistent pattern: the turtle emerged from the water as though on a normal nesting crawl, with the crocodile emerging apparently shortly after and several meters away. The crocodile tracks veered towards those of the turtle, and the point of their intersection was marked by a large area of scuffed sand, blood, and bits of shell. From the site of the attack either the crocodile tracks alone emerged, indicating the crocodile was carrying the turtle to the water, or, on one occasion, both the turtle's and the crocodile's tracks headed into the water side by side, indicating the crocodile followed the turtle to the ocean. The hind footprints of the crocodile in each case measured 27 cm long.

Two incidents provided more direct evidence of crocodile predation upon the turtles. On the morning of 5 July, an adult female flatback (CL 91.7 cm) was found mauled and upside down, yet still alive, on the beach. The left side of the turtle's face was fractured, its left front flipper was torn off, and its plastron was loosely attached to its carapace on one side. A large crocodile surfaced briefly in the adjacent surf as the turtle was inspected. Tracks in the sand clearly indicated an attack by the crocodile, whose hind footprints also measured 27 cm.

On the afternoon of 11 July, a similar-sized crocodile was observed preying upon an adult flatback in the surf. The crocodile was first seen at around 1300 hrs (at low tide) holding the turtle in its jaws, with large amounts of blood staining the water. There were no tracks in the sand to suggest the turtle had been attacked on the beach and carried to the water. The crocodile bit down several times, and next rolled completely over three times with the turtle in its mouth. The crocodile then ripped off one of the turtle's flippers, raised its jaws out of the water, and swallowed the flipper. Apparently the turtle was released while the crocodile swallowed, as afterwards the crocodile retreated further into the surf and surfaced without the turtle, which was not seen again. The crocodile may have been disturbed by our presence on the beach at this point, as it returned to the edge of the shore, looked directly at us, and opened its jaws two or three inches, baring its teeth. After several minutes of watching us from the water's edge, the crocodile retreated into the water, where during the rest of the afternoon it was repeatedly observed swimming along shore.

Observed predators upon eggs and hatchlings included flocks of nankeen night herons (*Nycticorax caledonicus*), smaller crocodiles, ghost crabs (*Ocypode* sp.), and humans. The night herons were active predators of hatchlings as they emerged from the nests, and on several occasions we found hatched turtle nests surrounded by scores of heron tracks, with no evidence of any hatchling's survival. The tracks of small crocodiles (estimated lengths 1–2 m) were also found intermingled with those of the herons, and presumably these crocodiles were also consuming hatchlings. Ghost crabs were found in two emerged nests, and were believed to have been responsible for perforating the majority of the eggs noted as predated in Table 1. In addition, one ghost crab was found gripping a dead flatback hatchling in its claws on the beach at night. Numerous small to medium-sized (2 m) sharks were seen patrolling the western beach and tidal mudflats behind the island, and a local fisherman suggested that wild pigs (an exotic species) seasonally visited the island when sand bars bridged the narrow gap to the mainland. Pigs, along with monitor lizards (*Varanus* sp.) are known to consume many of the flatback nests laid on the nearby mainland (Limpus et al., 1993), but we observed neither of these predators on Crab Island.

During the study period, at least 10 groups of people visited the island, and a minimum of 6 of these groups (all indigenous) collected an estimated total of 15 clutches of *N. depressus* eggs, representing 0.44% of the estimated number of clutches laid during the 6 weeks. The egg collectors found the nest cavities by probing with lobster spears into the sand-filled depressions left by the turtles. No adult female turtles were killed. One group of non-indigenous visitors, who had come specifically to see the nesting turtles, set a large bonfire during the night, disorienting a clutch of flatback hatchlings on their way to the ocean. Two fishing guides from Seisia and their clients stopped on Crab Island during the day while fishing in the area, but it was unclear whether these were structured visits with turtle eco-tourism in mind. There was a noticeable amount of trash on the beach (including metal barrels, an old refrigerator, and numerous light bulbs), most of which appeared to have been deposited on the island as flotsam. Otherwise the island remained free of human disturbance.

DISCUSSION

Many of the aspects of turtle nesting ecology on Crab Island observed in 1997 appear unchanged since the Limpus et al. (1993) study. In addition to the statistically compared data, nesting success (80.0% [1997] vs. "between 76.7 and 84.8%" [1991]), the species and abundance of egg and hatchling predators, and nesting turtle species composition (primarily flatbacks) all remained the same. However, flatback eggs hatched with a higher degree of success during 1997, suggesting that incubation conditions were slightly more favorable than in 1991, most likely because of unmeasured variation in temperature or precipitation. The increased depth of fresh nests we observed might simply reflect the imprecision involved with measuring nest depths in heavily disturbed sand, but alternatively could be in some way connected to the noted higher incubation success. In contrast to Limpus et al. (1993), the peak sectors for turtle nesting were on the northern, rather than the southern, arm of the island, a change for which we have no explanation.

The extremely slow growth rate calculated for *N. depressus* from recaptures represents the first such estimation for the Crab Island nesting population, and is typical of breeding females of other marine turtle species (Limpus, 1994). Parmenter (1995) provided the only other published growth rate for flatbacks, 0.0119 cm/yr at the Peak Island rookery, a rate that was also not significantly different from zero. We only recaptured 7 of the 483 tagged females of the 1991 study, but this is most likely because of the high rate of failure experienced with Monel tags on this species (Limpus, 1992).

The observed incidence of turtles consumed by crocodiles at Crab Island (1.17 turtles killed/wk) is nearly three times as high as that recorded by Ortiz et al. (1997), who, in the only other study to quantify regular crocodile predation upon sea turtles, documented 9 olive ridleys, *Lepidochelys olivacea*, consumed by American crocodiles, *Crocodylus acutus*, at Playa Nancite, Costa Rica, in 5 months (about 0.41 turtles killed/wk). The present study documents a crocodile's attack of a sea turtle in the water, which Ortiz et al. (1997) suggested as a possibility but did not observe. Our observations of the crocodile's rolling and flipper-severing behavior agree with those described by Ortiz et al. (1997) for an attack on land. Given the difficulty of distinguishing between individual large crocodiles, and that most of our observations of evidence of crocodile/turtle interaction were limited to infrequent mornings with low tides, more predation may be occurring on Crab Island. Crocodiles have undoubtedly been consuming flatbacks on the island for a very long time, and there is no reason to suspect this predation in any way imperils the *N. depressus* rookery.

Overall during our 6-wk study we recorded 22% fewer nesting tracks per night than the Limpus et al. (1993) study (103.3 vs. 132.7); however, during the same 14 calendar days (6–19 July) that both studies were conducted we observed almost 300 more nesting tracks (2130 vs. 1839). We sampled over a longer period of time, and likely recorded more of the June "build-up" to the peak period of turtle nesting, thus lowering the overall average. Our finding of hundreds more tracks in July of 1997 than in 1991 is moderate evidence against a sharp decline in the Crab Island *N. depressus* nesting population over the previous 6 years, because if the population was declining, then the odds would clearly be against actually finding more tracks after a long interval. Without an estimate of the year-to-year variability in the numbers of nesting flatbacks, more complex analysis (e.g., Bjorndal et al., 1999) is impossible, and we do not consider our data to be sufficient to indicate a population increase.

Future Research

Precise estimation of the total size of the Crab Island nesting population of flatbacks could require daily monitoring of Crab Island itself, many kilometers of adjacent mainland beaches, and several other Torres Strait islands (such as Kerr and Deliverance) that may also harbor substantial nesting of *N. depressus* of the same population (Limpus et al., 1989, 1993). Numerous turtles would have to be tagged and observed throughout the potentially year-round nesting season for many years in order to determine the necessary parameters (mean renesting interval, mean number of clutches/season, mean remigration interval). Such an involved and expensive effort we deem unnecessary, because it is primarily the trajectory of the flatback population size that is of immediate conservation interest, and major investigations into sea turtle population ecology are well underway at more convenient sites around the world. Instead we recommend that the Injinoo people themselves undertake a program of monthly track counts, which could be conducted quite easily during the course of regular visits to Crab Island and adjacent mainland beaches. The residents of the other rookery islands in the western Torres Strait should be encouraged to monitor their turtles as well. Counting the number of turtle tracks at all of these locations during two or three visits every month would clarify the annual pattern of nesting and indicate whether the population as a whole shows any future trends toward increasing or decreasing. The Queensland National Parks and Wildlife Service should provide the traditional owners with technical assistance in conducting these track surveys.

In addition, it would be of great interest to determine precisely the feeding-ground range of the turtles which nest on Crab Island, so that any existing human impacts within this range can be accurately assessed and prevented. Satellite tracking of several female turtles (e.g., Stoneburner, 1982) could quickly reveal the post-nesting migrations and feeding areas of *N. depressus* from Crab Island. DNA studies of small samples of flatback turtles from various mainland beaches and other island rookeries would also serve to delineate the genetic extent of the flatback population in the Gulf of Carpentaria and western Torres Strait.

The dramatic crocodile-turtle relationship deserves further study. Efforts should be made to document the actual numbers of turtles being consumed by crocodiles on the island, and to determine what effect the supply of turtles has on the growth and ecology of the crocodiles. We would anticipate that the ready supply of turtles allows crocodiles around Crab Island to grow rapidly after reaching adult size, perhaps explaining the island's reputation (C. Limpus, *pers. comm.*) for harboring extremely large individuals of *C. porosus*. As the flatbacks do not engage in arribadas (the mass nesting events of *L. olivacea*), which Ortiz et al. (1997) suggest may serve to deter crocodiles, it is also worth investigating whether nesting *N. depressus* employ alternate defense mechanisms, such as visual evasion, to escape predation.

Conservation Status and Recommendations

Understanding the conservation status of the population of flatback turtles that nest on Crab Island is complicated by the widely dispersed array of other nesting beaches utilized by *N. depressus* in the region (Limpus et al., 1993). Care must be taken, therefore, to distinguish in the discussion that follows between the status of the Crab Island rookery itself and the overall status of the flatback population of which Crab Island is a part. At the moment, longitudinal data are only available for the Crab Island rookery, where turtle nesting seems to have held stable at least since the 1991 survey of Limpus et al. (1993). The additional facts that Limpus et al. (1983a) describe wet-season nesting at levels comparable to those of Bustard (1972), and dry-season peak nesting comparable to our 1997 observations, lend credence to the notion that this rookery has remained relatively stable over a period of almost 30 years. Crab Island's continued reception of high intensity *N. depressus* nesting accords well with the minimal threats now posed to the rookery's turtles by indigenous egg harvests, trawling, and exotic nest predators, and with the relatively pristine nature of the regional ecosystem.

The small number of flatback eggs (0.44%) taken by humans seems to pose little danger to this nesting aggregation, and is comparable in occurrence to the egg collection reported in Limpus et al. (1993). The commercial harvest of sea turtles and their eggs is forbidden in Queensland waters (Nona, 1994; C. Limpus, *pers. comm.*), and barring a sharp rise in the popularity of flatback meat or turtle eggs, it is unlikely that traditional harvests by indigenous people will ever become a problem for the Crab Island turtles. Smaller nesting aggregations of flatbacks on more accessible islands could be imperiled by egg harvests of a greater magnitude than what occurs on Crab (Limpus et al., 1989), and these rookeries should therefore also receive monitoring attention. Flatbacks were recently omitted from a review of sea turtle conservation in Irian Jaya (Putrawidjaja, 2000) suggesting that the flatback harvest along the Indonesian coast may in fact be minimal, probably because few flatbacks occur there.

The impact of trawling upon the regional population of flatbacks, after tripling in the 1970s, most likely peaked in the early 1980s, when there were around 350 boats active in the northern prawn fishery (Northern Territory Department of Primary Industry and Fisheries, 1999). By 1998 the fishery had declined to only 130 licensed trawlers, with the entry of new boats restricted, and, starting in the 2000 season, the use of bycatch-reduction devices on all trawlers became mandatory (Australian Bureau of Rural Sciences, 2000). These changes should substantially lower the trawling-induced mortality (Crowder et al., 1995) of *N. depressus* in the Gulf of Carpentaria. The question remains as to whether the drowning of numerous turtles in previous decades of trawling will produce a yet-unseen decline in the numbers of nesting females in this population. Although such a delayed impact is certainly conceivable given the long lifespan of sea turtles, in this case, trawling should have drowned mature female turtles along with any sub-adult turtles killed (Robins, 1995), yielding immediate rookery declines not observed on Crab Island.

The predation of exotic wild pigs upon flatback nests on the mainland (Limpus et al., 1993), in contrast, could produce long-term declines in the overall Gulf of Carpentaria-western Torres Strait population. These declines would not necessarily become evident on Crab Island, given the nesting-beach fidelity displayed by *N. depressus* (Limpus et al., 1983b, 1984), a possibility that reinforces the need for extensive monitoring of this part of the population. While excluding pigs from mainland beaches would be difficult, these nest predators should definitely be prevented from establishing a presence on Crab Island.

In spite of the unknown severity of threats posed to the regional population by egg harvests and pig predation, the status of the major aggregation of flatback turtles nesting at Crab Island appears to be currently secure, in stark contrast to the general status of some of the world's other sea turtle species. We attribute the health of this turtle population to 1) the relative confinement of *N. depressus* to Australian territorial waters, where the species is now strongly protected from exploitation and bycatch mortality, and 2) Crab Island's isolation from centers of high human activity. The second assertion follows from the observation that human population growth, coastal development, and heavy tourism in other parts of the world have generally caused declines and disruptions in local sea turtle populations (Chan and Liew, 1996; Suarez and Starbird, 1996; Suganuma et al., 1999), even when the turtles themselves are protected (Witham, 1982; Horrocks and Scott, 1991; Jacobson and Figueroa Lopez, 1994; Brown and MacDonald, 1995; Broderick and Godley, 1996).

The Injinoo people should be encouraged to maintain the protection from commercial development they are now affording both the island and their adjacent mainland holdings. The potential exists, however, for the islanders to benefit financially from a low-impact turtle ecotourism project based upon visits to Crab Island without affecting the health of the rookery. If maintenance of traditional harvests and ecotourism fail to provide sufficient incentives, conservation organizations should consider offering to help the Injinoo meet this group's social and financial development goals in exchange for protection of the turtle rookery (e.g., Cox and Elmqvist, 1997, who described the successful exchange of school construction for protection of forest in Samoa).

Local protection efforts notwithstanding, regional increases in marine ecosystem degradation can affect even isolated turtle rookeries (Ehrenfeld, 1982; Shabica, 1982; Miller and Limpus, 1991), because the feeding grounds of a turtle population, especially those of the shallow-water feeding flatback (Limpus et al., 1983b; Poiner and Harris, 1996), extend over large expanses of coastline. Thus, even if the immediate vicinity of Crab Island was protected from all forms of development, the rookery could still suffer from regional increases in marine pollution, sedimentation, and ecosystem disruptions from trawling and overfishing, all of which can be associated with human population growth in coastal areas (Goeden, 1982; Zann, 1994; Steneck, 1998). Given the island's favorable local situation, future regional environmental degradation may now pose the greatest potential threat to the continued health of Crab Island's flatback rookery. We hope that leaders from the Queensland government, various aboriginal and islander groups, and conservation organizations will work together to ensure that the great majority of the Cape York Peninsula remains in pristine natural condition. Sea turtles are certainly resilient creatures and under certain conditions may be capable of coexisting with coastal development. Until more evidence exists of this potential, and given the turtle declines experienced in other nations, the precautionary principle suggests that regional protection may be necessary to maintain the health of Crab Island's highly significant turtle rookery. Such large-scale conservation efforts would also help protect the regional flatback population, and serve to maintain the incredibly rich biodiversity of Cape York and its surrounding marine ecosystems.

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