

Habitat Preferences of Coastal Goannas (*Varanus panoptes*): Are They Exploiters of Sea Turtle Nests at Fog Bay, Australia?

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The habitat of a population of coastal goannas (*Varanus panoptes*) was assessed at Fog Bay, Australia, by a combination of scat analysis, radio tracking, burrow counts, and sightings. Tracks were followed to assess spatial and temporal beach use. Scat analyses showed that goannas ate a variety of prey from the beach and dunes. Sea turtle eggs were the dominant prey found in scats during the dry season. All four census methods showed that goannas selected the beach habitat and dunes, although habitat selection indices were highest for the beach. Goannas used the beach throughout the year with peak beach activity occurring in May and November. There was no indication that sea turtle nesting influenced the timing of beach activities or how long goannas spent on the beach. The seasonal activity patterns of *V. panoptes* at Fog Bay is unlike *V. panoptes* in other areas and appears to be related to food availability. Although goannas prey on a large portion of sea turtle nests on the Fog Bay mainland, more research is required on the demography of the sea turtles to assess whether this has impacts on the size of the sea turtle populations.

VARANUS *panoptes* (Varanidae) is the largest varanid lizard (commonly called goannas) of tropical Australia, attaining a snout-vent length (SVL) of up to 0.7 m and weighing up to 4 kg (Shine, 1986). There are few published reports of *V. panoptes* ecology. Christian et al. (1995) compared seasonal activity and energetics of *V. panoptes* on a floodplain with those in a woodland habitat. In the wet season (December to February) goanna activity and energy budgets were high in both locations, but in the dry (May to August) and dry-wet (September to November) transition, floodplain inhabitants had longer activity periods than those in the woodland. These differences were attributable to seasonal changes in food and/or water availability, suggesting that if prey are sufficiently abundant, *V. panoptes* may extend their activity period to maximize their potential to feed.

Like most goannas, *V. panoptes* is a prey generalist, eating anything it can subdue (Shine, 1986; James et al., 1992). Australian tropical coasts have an abundance of potential prey across a diversity of habitats, including Homolopsine snakes, crabs (*Uca* spp.; Searsarminae), and Mudskippers (*Periophthalmus* spp.) in the mangroves and salt flats. Numerous reptiles, mammals, insects, and crabs (e.g., *Ocyropsis* spp.; Searsarminae) inhabit the dunes; and seasonal bird and/or turtle nests are common on the beaches (Macnae, 1968; Trevallion et al., 1970). Additionally, monsoon forests, found behind many tropical shores, contain an abundance of insect, mammalian, and reptilian prey. Coastal waters contain various fish, aquatic insects, mollusks, and crustaceans. Accordingly, there ap-

pears to be an abundance of food at any time of year, depending on the habitat. Coastal goannas may thus select particular habitats to exploit seasonally abundant prey, enabling them to maximize their activity period.

At Fog Bay, Northern Territory, Australia, Flatback (*Natator depressus*) and, occasionally, Olive Ridley (*Lepidochelys olivacea*) Sea Turtles nest on the mainland coast between Native Point and Patterson Point (12°43'S; 130°20'E to 12°40'S; 130°21'E) and offshore island beaches between March and November. The most concentrated nesting occurs between June and August (Blamires and Guinea, 2003). An estimated 41 *V. panoptes* inhabit this 4.9 km of coast (Blamires, 2000), and it has been calculated that *V. panoptes* prey on over 50% of all turtle nests (Blamires and Guinea, 2003). Given concern regarding the level of predation on sea turtle nests on many north Australian rookeries (Vanderleley, 1996; Blamires and Guinea, 2003), it would be beneficial at this rookery to assess whether goannas move onto the beach in the nesting season to exploit sea turtle nests. The objectives of this study were twofold: (1) to determine the preferred habitat(s) of *V. panoptes* at Fog Bay, and (2) to assess whether spatial and temporal beach activity corresponds to sea turtle nesting or other activities.

MATERIALS AND METHODS

Base map preparation.—The study area was the northernmost mainland peninsula between Native Point and Patterson Point at Fog Bay, Northern Territory, Australia. The peninsula is

surrounded by sea, with Fog Bay to the north and west and Port Patterson to the east. The maximum distance east to west was approximately 5 km. I divided the area every 1.0 to 1.4 km, along the western facing beaches of Fog Bay, according to natural boundaries such as bisecting water-ways and rocky outcrops, into four beaches: 1, 2, 3, and 4. I divided each beach into 100-m sectors, marked by a metal stake on the dune, from which coordinates (Map Grid; AGD66 datum) were obtained using Global Positioning System (Magellan 2000, Magellan Systems, San Dimas CA). A series of three aerial photographs of the area (Department of Lands Planning and Environment, Northern Territory) were scanned, mosaiced and georeferenced (using ERDAS Imagine; ERDAS, Atlanta) to create a base map onto which field data were overlaid using a Geographic Information System (GIS). Water, beach, mangrove, salt flat, dune, and monsoon forest habitats were recognized from aerial photographs and polygons representing the areas they encompass were overlaid onto the base map using ArcView 3.1 GIS software (ESRI, Redlands, CA). The area of each habitat was calculated using ArcView's spatial analysis tool. The total area of the peninsula was calculated to determine the proportion of total area each habitat occupied.

Scat analysis.—To identify the habitats occupied by goannas, I used a combination of scat analysis, radio tracking, burrow counts, and sightings. To determine habitat use by scat analyses, I walked for one hour, in a random direction, through each habitat every day during fortnightly trips, lasting three to seven days, over 21 months (March 1997 to December 1998). All *V. panoptes* scats encountered were collected and their habitat type and GPS positions were recorded. I assumed that all large reptilian scats were from *V. panoptes* as it was the only large-bodied terrestrial reptile seen in the area. Remains of prey found in the scats were sorted in the laboratory to the lowest possible taxonomic level from bone (vertebrates), scale (reptiles, fish), cuticle (insects), carapace, claw (crustaceans), or eggshell, using museum specimens as keys. Identifiable prey were soaked in 70% alcohol for 24 h, sieved through a 150-mm sieve (Endicott's, London), oven dried (at 105 C) for seven days, and weighed on an electronic balance (Type 1507, Sartorius, Gottingen, Germany) to attain a dry mass of each prey. All fauna that were sighted while searching for scats were recorded and the habitat noted. These notes, and/or reference to museum records, were

used to determine where *V. panoptes* was likely to have encountered each prey item.

Radio telemetry.—Sixteen *V. panoptes* were captured by hand or trap, and the five largest were radio tracked to determine their habitat usage over time. Only five goannas were chosen for radio tracking because of the financial limitations of the project. I measured the mass (using a Salter hanging balance; 20 kg \pm 0.1 kg), SVL, and total length (using a flexible, fiberglass measuring tape to the nearest millimeter) of the five individuals before fitting a 150 mm, 24 g, 2-stage radio transmitter (TX2-ICP-1; Biotel, Adelaide) to the base of the tail with adhesive tape. Transmitter battery life expectancy was approximately eight months. I squeezed the base of the tail to expose a hemipenis to determine gender. Each subject was located once daily during each trip using a Biotel RX3 radio receiver connected to a 2EY two-element directional antenna. The location of each subject was determined by following the transmitter signal until the goanna was sighted. Occasionally, when a subject detected my presence and moved, a precise location could not be taken, so a series of three compass bearings, to the direction of the peak signal were taken from stakes, designating sector borders, 300 m apart. From these bearings a triangulated area was calculated with error polygons applied to account for signal reflection (Garrott et al., 1986). Each location was recorded according to beach, sector, and habitat. Minimum convex polygons were created around radio tracking points and minimum occupancy areas, and the proportion of each habitat used by goannas during the tracking period were calculated using ArcView spatial analysis.

Burrow counts.—Each *V. panoptes* burrow (distinguished from crab, skink and bird burrows by a characteristic shape and size; Blamires, 2001) encountered during surveys was marked by attaching surveyor's tape to nearby vegetation or an implanted stake. The GPS position and habitat of each burrow were recorded and these data were overlaid onto base maps to determine the nearest beach and sector. Each time I sighted a goanna during walks through the area, its habitat was recorded, and a GPS reading was taken. These locations were then plotted onto the base map, and, except for goannas sighted on the beach, the nearest beach number and sector was recorded.

Calculating habitat selection index.—For each of the methods used to locate goannas spatially (scat location, radio tracking, burrow location,

and sightings), a habitat selection index (\hat{w}) was calculated for each of the habitats (beach, dunes, mangroves, salt flats, monsoon forest, and water) from the equation (Manly et al., 1993):

$$\hat{W} = o_i / \pi_i$$

where o_i = the proportion of the population sampled in each habitat, and π_i = the proportion of total study area each habitat occupies. The habitat selection index was converted to a standardized habitat selection index (B_i) for each habitat by calculating the proportion of total of habitat selection index utilized, by the equation (Manly et al., 1993):

$$B_i = \hat{W}_i / \Sigma \hat{W}$$

A chi-squared, log-likelihood test was used to determine whether habitats were used in proportion to their availability, and 95% confidence intervals were calculated. Habitat selection indices lying outside the confidence intervals denoted habitat selection (Manly et al. 1993). Temporal variations in habitat occupation was not determined because radio tracking was the only census method to provide information on individuals and the number of goannas tracked were too few. To identify the significance of sea turtle nesting season on goanna activity, only patterns on the beach were of interest; thus, these were assessed in a temporal context.

Beach use.—I determined spatial (among the four beaches) and temporal (monthly) trends in beach use by *V. panoptes* by counting and measuring their tracks. Goannas tracks are unique (King and Green, 1993), and individuals may be readily identified (Blamires, 2000), enabling estimations of the likely number of individuals on the beach. The number of times per day a *V. panoptes* traversed the dunes was assessed each survey period, over 12 months (July 1997 to June 1998), by raking the beach clear of tracks each morning and counting, measuring, and clearing all fresh tracks traversing the dunes in the previous 24 h. All track counts were done between approximately 0600 h and 0800 h when the low light made individual tracks easy to distinguish (Pianka, 1986). For every fresh track encountered, the individual foot and tail dimensions, to nearest millimeter (Blamires, 2000), and the distance, from the point of dune crossing to the point of beach exit, was measured with a ruler and flexible 100-m measuring tape, respectively. The mean track distance was calculated for each month. The number of excavated sea turtle nests each track encountered was also recorded. Correlation co-

efficients between length of individual tracks and the number of sea turtle nests encountered per track were calculated.

I divided the year into three periods according to sea turtle nesting density (for nesting data, see Blamires and Guinea, 2003): June to August was the peak nesting period, December to February was the nonnesting period, and March to May and September to November were pre- and postnesting periods, respectively. One-way analyses of variance was used to determine whether there were seasonal differences in the number of goanna tracks traversing the dunes per day, the total lengths of the tracks, and the mean track lengths.

To determine whether there was a temporal variation in how *V. panoptes* used the beach to search for Ghost Crabs, I estimated the abundance of Ghost Crabs by counting the number of Ghost Crab burrows that traversed transects running from the high tide mark to the dune crest. Three transects were used in each sector of each beach at 30, 60, and 90 m from each sector border. Transects were sampled on two consecutive days in two separate trips (i.e., a total of four times) in both the wet (December 1997) and dry (June 1998) season. Correlation coefficients for each season were calculated between the mean Ghost Crab abundance and the mean number of goanna tracks traversing the dune in each sector.

RESULTS

Scat analysis.—A total of 212 *V. panoptes* scats were found, contributing to a total of 1093 g of dried scat material. Of this, 555 g (50.80%) were from prey items observed mostly on the beach, and 538 g (49.20%) from prey items observed in the dune/grassland habitat (Table 1). There were no prey items found that were observed in the water, mangroves, salt flats, or monsoon forest (Table 1). One Seasarmid carapace was found, but it was from a species I only observed among the dunes. The major beach-inhabiting prey items consumed were *N. depressus* eggs (312 g), from scats collected between April and November, and Ghost Crabs (109 g; Table 1). Prey items most probably from the dune were rats (*Rattus rattus*; 166 g), Agile Wallabies (*Macropus agilis*; 161 g) and grasshoppers (112 g; Table 1). The remains of very few bird or bird eggs were retrieved from scats. Scats were found predominantly on the beach and dunes (Table 2). Four scats were collected in the mangroves, and one was collected on the salt flats (Table 2). The distribution of habitats in which scats were found was not proportional

TABLE 1. PREY ITEMS, IDENTIFIED TO THE LOWEST POSSIBLE TAXONOMIC RANK, FOUND IN GOANNA SCATS AT FOG BAY OVER THE STUDY PERIOD AND THEIR DRY WEIGHTS AND THEIR HABITAT OF MOST LIKELY ENCOUNTER. * indicates the habitat was deduced from direct observations at the site. ^b indicates these were also seen on the beach. ^m indicates these were also seen in the mangroves.

Class	Order	Species	ID. from	Dry mass (g)	Habitat
Mammal	Rodents	<i>Rattus rattus</i>	Teeth/bone	166	Dune/grassland
		<i>Hydromys chrysogaster</i>	Teeth/bone	68	Beach*
	Marsupials	<i>Melomys burtoni</i>	Teeth/bone	2	Dune/Grassland
		<i>Macropus agilis</i>	Teeth/bone	161	Dune/Grassland* ^b
Reptiles	Squamates: -Skinks	<i>Carlia spp.</i>	Tail	15	Dune/Grassland
		<i>Ctenotus spp.</i>	Tail	36	Dune/Grassland*
	-Pygopods		Bone	1	Dune/Grassland
	-Geckos		Bone	2	Dune/Grassland*
	-Varanid		Bone/Scale	39	Dune/Grassland* ^{bm}
	-Colubrid	<i>Boiga irregularis</i>	Teeth	4	Beach*
	Cheloniids				
	-Eggs	<i>Natator depressus</i>	Egg	312	Beach*
	-Hatchlings	<i>Natator depressus</i>	shell/scutes	20	Beach*
	Crustaceans	Brachyura: -Ocypodid	<i>Ocypode spp.</i>	Carapace/claw	109
			Carapace	1	Dune/Grassland* ^m
-Seasarmid			Cuticle/legs	112	Dune/Grassland*
Insects	Grasshoppers		Cuticle	3	Dune/Grassland*
	Beetles		Cuticle	3	Dune/Grassland*
	Cockroaches		Cuticle	42	Beach*

to availability ($\chi^2_{df=5} = 2721.90$; $P < 0.001$). The habitat selection indices (B_i) calculated showed the beach and dunes to be preferentially selected ($B_i = 0.83$ and 0.17 , respectively, outside the 95% confidence limits; Table 2). Mangroves and salt flat habitats went largely avoided, and no scats were located in the monsoon forest or water (Table 2).

Radio tracking.—Sex, SVL, mass, tracking period, number of positive locations and estimated occupancy area for the five radio tracked goannas are shown in Table 3. The highest number of

radio tracking locations were in the dune grasslands (between 67 and 76%; Table 4). Although mangrove was the predominate habitat of the area (Table 2), it contributed about 6% of all radio tracking locations. No *V. panoptes* were ever located in the water or monsoon forest. Habitat use by radio tagged goannas was not in proportion to habitat availability ($\chi^2_{df=5} = 685.07$; $P < 0.001$). The habitat selection indices (B_i) calculated from radio tracking showed that beach ($B_i = 0.51$) and dunes ($B_i = 0.48$) were preferentially selected since their habitat selection indices were outside the 95% confi-

TABLE 2. CALCULATION OF STANDARDIZED HABITAT INDEX (B_i), AS A PROPORTION OF SELECTION INDEX (\hat{W}), BASED ON SCAT COUNTS. Where population proportion (π_i) is calculated as a percentage of the total area for each of the habitats covered. Sample counts are the number of scats encountered in each habitat. Sample proportion (o_i) is the sample count as a percentage; and selection index is calculated by $\hat{W} = o_i/\pi_i$ (Manly et al., 1993). Confidence intervals are shown. * denotes values outside the 95% confidence interval.

Habitat	Population proportion π_i	Sample count	Sample proportion o_i	Selection index \hat{W}	Standardized index B_i	95% Confidence interval
Beach	1.90	98	46.23	24.33	0.83*	0.40–0.53
Dune	10.20	109	51.42	5.04	0.17*	0.44–0.58
Mangrove	60.40	4	1.89	0.03	0.00	0.00–0.04
Salt flat	17.40	1	0.47	0.03	0.00	0.00–0.01
Monsoon forest	10.00	0	0.00	0.00	0.00	—
Water	0.10	0	0.00	0.00	0.00	—
Total	100.00	212	100.00	29.43	1.00	

TABLE 3. THE SEX, SVL, MASS, TRACKING PERIOD, NUMBER OF FIXES TAKEN, AND OCCUPANCY (AS DETERMINED BY MINIMUM CONVEX POLYGONS USING ARCVIEW SPATIAL ANALYSIS) AREAS OF EACH *Varanus panoptes* RADIO TRACKED AT FOG BAY OVER THE STUDY PERIOD.

Subject	Sex	SVL (cm)	Mass (kg)	Tracking period	Number of locations	Occupancy area (ha)
1	Female	34.0	1.7	May–June 1997 (38 days)	6	38.04
2	Female	41.5	2.2	June–Dec. 1997 (174 days)	48	31.47
3	Male	58.0	3.2	April–Sept. 1998 (161 days)	27	62.22
4	Female	57.0	2.6	July–Sept. 1998 (78 days)	10	28.67
5	Male	55.6	2.8	July–Dec. 1998 (129 days)	33	92.21

dence limits. The salt flats and mangroves ($B_i = 0.01$ and 0.15 , respectively) were not preferentially used (Table 4).

Burrow locations and sightings.—Four hundred four goanna burrows were located over the study period and 73.0% of these were located on the beach. One hundred seven (26.48%) burrows were located in the dunes, and two were located in the mangroves (0.50%; Table 5). No burrows were located on the salt flats or in the monsoon forest. Chi-squared analysis showed burrow distribution to be disproportional to availability ($\chi^2_{df=5} = 11,211.14$; $P < 0.001$). Habitat selection indices from burrow locations showed that goannas preferentially selected the beach ($B_i = 0.94$), and dunes ($B_i = 0.06$) as their habitat selection indices were outside the 95% confidence limits (Table 5). A total of 29 goannas were sighted over the study period. The distribution of sightings was not proportional to habitat availability ($\chi^2_{df=5} = 648.07$; $P < 0.001$) with the majority being seen on the beach, a habitat shown to be selected for ($B_i = 0.92$; outside the 95% confidence limits; Table 6). The dunes were less preferred ($B_i = 0.07$) but still outside the 95% confidence limits (Table 6). There was one goanna sighted in both the mangroves and salt flats (Table 6).

Beach use.—The mean number of tracks traversing the beach each day during the period July 1997 to June 1998 peaked in November and May (Fig. 1), which were both outside the peak *N. depressus* nesting period. Eighty-six tracks were observed, with 28 (32.60%) tracks observed between September and November (late dry season) and 34 (39.50%) between April and June (early dry season). There was no significant difference in the number of individual tracks on the beach among the four nesting periods (ANOVA, $F_{3,8} = 0.95$; $P = 0.46$), nor was there any difference in the length of individual tracks ($F_{3,8} = 1.59$; $P = 0.28$). When the pre- and postnesting season data were incorporated into the nesting season and compared with the nonnesting season there was no significant difference in number of individual tracks ($F_{1,10} = 0.79$; $P = 0.40$) or length of individual tracks ($F_{1,10} = 0.02$; $P = 0.80$) between seasons. There was no significant relationship between length of individual tracks and the number of sea turtle nests encountered per track ($R = -0.20$; $P = 0.44$). There was a significant positive relationship between the number of individual tracks traversing the dunes and Ghost Crab abundance, in each sector, in the wet season ($R = 0.57$; $P < 0.01$) but not in the dry season ($R = 0.06$; $P = 0.68$).

TABLE 4. CALCULATION OF STANDARDIZED HABITAT INDEX (B_i), AS A PROPORTION OF SELECTION INDEX (\hat{W}), BASED ON RADIO TRACKING LOCATIONS. Where population proportion (π_i) is calculated as a percentage of the total area, for each of the habitats covered. Sample counts are the number of scats encountered in each habitat. Sample proportion (o_i) is the sample count as a percentage; and selection index is calculated by $\hat{W} = o_i/\pi_i$ (Manly et al., 1993). Confidence intervals are shown. * denotes values outside the 95% confidence interval.

Habitat	Population proportion π_i	Sample count	Sample proportion o_i	Selection index \hat{W}	Standardized index B_i	95% Confidence interval
Beach	1.90	18	14.75	7.77	0.51*	0.08–0.21
Dune	10.20	91	74.59	7.31	0.48*	0.67–0.82
Mangrove	60.40	11	9.02	0.15	0.01	0.01–0.16
Salt flat	17.40	2	1.64	0.09	0.01	0.00–0.04
Monsoon forest	10.00	0	0.00	0.00	0.00	—
Water	0.10	0	0.00	0.00	0.00	—
Total	100.00	122	100.00	15.32	1.00	

TABLE 5. CALCULATION OF STANDARDIZED HABITAT INDEX (B_i), AS A PROPORTION OF SELECTION INDEX (\hat{W}), BASED ON BURROW COUNTS. Where population proportion (π_i) is calculated as a percentage of the total area, for each of the habitats covered. Sample counts are the number of scats encountered in each habitat. Sample proportion (o_i) is the sample count as a percentage; and selection index is calculated by $\hat{W} = o_i/\pi_i$ (Manly et al., 1993). Confidence intervals are shown. * denotes values outside the 95% confidence interval.

Habitat	Population proportion π_i	Sample count	Sample proportion o_i	Selection index \hat{W}	Standardized index B_i	95% Confidence interval
Beach	1.90	295	73.02	38.43	0.94*	0.69–0.77
Dune	10.20	107	26.48	2.60	0.06*	0.22–0.31
Mangrove	60.40	2	0.50	0.01	0.00	0.00–0.01
Salt flat	17.40	0	0.00	0.00	0.00	0.00–0.00
Monsoon forest	10.00	0	0.00	0.00	0.00	—
Water	0.10	0	0.00	0.00	0.00	—
Total	100.00	404	100.00	41.04	1.00	

DISCUSSION

Varanus panoptes uses the beach extensively at Fog Bay, most likely for food. Goannas consumed a variety of prey taxa, consuming predominantly *N. depressus* eggs between March and November. The large number of burrows on the beach and dunes in May to September (Blamires, 2001), would indicate that *V. panoptes* relies heavily on excavation for food, although many prey items, such as insects, skinks, geckos, snakes, and Water Rats, are probably consumed alive. Scavenging on carrion appeared to be another strategy, indicated by the consumption of *M. agilis*, whose large body size makes it impossible for *V. panoptes* to overpower. It was assumed no mammalian, reptilian, or insect prey were consumed in the monsoon forest, since no radio tagged *V. panoptes* used this habitat.

Standardized habitat indices indicated that the beach habitat was selected by *V. panoptes* at Fog Bay even though it comprised a relatively small proportion of the available habitat. Scat locations, burrow locations, and sightings indicate considerable preference for the beach over

all other habitats (Tables 2, 4, 5). Although selected for, dunes habitation was not as extensive as the beach. According to the census methods herein, there was no evidence to suggest that *V. panoptes* inhabit the monsoon forest or waterways of Fog Bay. Higher dune standardized habitat indices were attained by radio tracking, probably because goannas inhabiting the beach were seeking shelter among the dune in response to being approached. However, the beach and dune habitats may be equally preferred by *V. panoptes*, with selective defecation and burrowing on the beach influencing habitat selection indices when calculated from scat and burrow counts. The dunes provide goannas with more cryptic retreats than the beach, and this may be a reason for lower numbers of sightings in the dunes compared to the beach.

All four census methods and analysis of the scat contents suggested that goannas preferred the beaches and dune habitats. Not surprisingly, the habitats of their prey coincided with *V. panoptes* preferred habitats. All of the four census methods suggested that *V. panoptes* made limited

TABLE 6. CALCULATION OF STANDARDIZED HABITAT INDEX (B_i), AS A PROPORTION OF SELECTION INDEX (\hat{W}), BASED ON SIGHTINGS. Where population proportion (π_i) is calculated as a percentage of the total area, for each of the habitats covered. Sample counts are the number of scats encountered in each habitat. Sample proportion (o_i) is the sample count as a percentage; and selection index is calculated by $\hat{W} = o_i/\pi_i$ (Manly et al., 1993). Confidence intervals are shown. * denotes values outside the 95% confidence interval.

Habitat	Population proportion π_i	Sample count	Sample proportion o_i	Selection index \hat{W}	Standardized index B_i	95% Confidence interval
Beach	1.90	19	65.51	34.48	0.92*	0.48–0.83
Dune	10.20	8	27.59	2.70	0.07*	0.11–0.44
Mangrove	60.40	1	3.45	0.06	0.00	0.00–0.11
Salt flat	17.40	1	3.45	0.20	0.01	0.00–0.11
Monsoon forest	10.00	0	0.00	0.00	0.00	—
Water	0.10	0	0.00	0.00	0.00	—
Total	100.00	29	100.00	37.44	1.00	

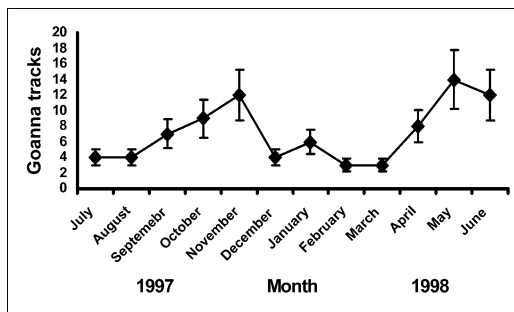


Fig. 1. Mean (± 1 SD) daily number of individual *Varanus panoptes* tracks traversing the beach, calculated four for each month between July 1997 and June 1998.

use of mangrove and salt flat habitats despite their high availability. This may be attributable to *V. panoptes*'s preference for fossorial foraging (Blamires, 2001). It would be expected that the compacted, water saturated soil and semidiurnal tidal flooding of these habitats would not facilitate fossorial foraging or burrowing. Mangrove habitats may, however, be used occasionally for purposes such as thermoregulation and retreat (Blamires and Nobbs, 2000). Mangroves may have been represented in radio tracking because goannas fled into them when being approached. *Varanus panoptes* never used monsoon forests or entered the water. The reasons for this are obscure, as prey would be expected to be available in both habitats, and the monsoon forest would supply shelter. *Varanus panoptes* is also a capable swimmer and can dive to attain aquatic prey (Martin, 1990).

My findings that *V. panoptes* concentrate their activities in habitats rich in prey (i.e., the beach and dunes) at Fog Bay is similar to those of Christian et al., (1995), who found *V. panoptes* in woodland and floodplain habitats were active during the wet season, when prey was abundant, but restricted their activity in the dry season to the wetlands, where prey was available until late in the dry season. Sea turtles nest during the dry season at Fog Bay (Guinea, 1994; Blamires and Guinea, 2003), and sea turtle eggs were abundant in the diet of *V. panoptes* at this time. Although not statistically significant, *V. panoptes* activity on the beach was higher in the dry season than the wet season at Fog Bay, contrasting with the activity patterns of floodplain and woodland goannas (Christian et al., 1995). Therefore, it seems probable that sea turtle nesting has an influence in altering the activity period of *V. panoptes* at Fog Bay compared to other locations.

Despite the lack of correlation between number of tracks and number of nests across the

beach, *V. panoptes* activities were the highest on beach 4, the beach with the highest annual number of sea turtles nesting (Blamires and Guinea, 2003). This suggests that *V. panoptes* will forage at locations where it has the greatest chance of encountering preferred food, as reported for *V. gouldii* (Thompson 1992, 1995). There was no association between track length and number of sea turtle nests encountered, suggesting that sea turtle nesting density does not influence time spent on the beach. *Varanus panoptes* used sections of beach not nested on so that they may use the beach for purposes other than searching for sea turtle eggs during the dry season, such as, searching other prey or thermoregulation. In the wet season, there was a positive association between the number of *V. panoptes* tracks and the abundance of Ghost Crabs, but there was no such association in the dry season. Ghost Crabs were found in scats all year round, implying they are opportunistically consumed. The association between goanna tracks and Ghost Crab abundance in the wet season but not the dry may be more indicative of Ghost Crab activities than goannas. At Fog Bay goannas appear to consume few birds, or bird eggs, even though Rainbow Bee-Eaters (*Merops ornatus*), Reef Herons (*Egretta sacra*), Pied Oyster Catchers (*Haematopus longirostris*), and Beach Stone Curlews (*Esacus neglectus*) nested on the beach throughout the dry season. This is unusual because goannas have been implicated as predators of birds elsewhere (Cogger, 1959; Pianka, 1970). Perhaps abundance of other prey represses the requirement to search for birds and bird nests. Coastal habitats supply a range of potential prey for goannas throughout the year (e.g., crabs, mammals, lizards, cockroaches, and grasshoppers), and it may be coincidental that sea turtle nesting occurs when *V. panoptes* are most active on the beach. There may be a decrease in the number of mammals, lizards, and insects on the beach and dune in the dry season that is forcing *V. panoptes* to consume sea turtle eggs at this time.

My findings suggest that *V. panoptes* along the Fog Bay coast preferentially use the beach habitat, probably because most of its preferred prey is found there and may seasonally exploit sea turtle nests. Whether sea turtle nest predation by *V. panoptes* is threatening the sea turtle populations of Fog Bay requires assessment of the demographics of the sea turtle population (Frazer, 1986). It is known that most *N. depressus* nesting occurs on offshore islands in Fog Bay (Guinea et al., 1991), suggesting that *V. panoptes* predation on eggs laid on the mainland would probably be of little consequence to the size of

the *N. depressus* population. More research is required on the population dynamics (e.g., survivorship to adulthood, reproductive age, nesting range and seasonal recruitment) of *N. depressus* and *L. olivacea* at Fog Bay to fully understand any management implications of goannas preying on their nests.

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