

### Body Temperatures and Winter Feeding in Immature Green Turtles, *Chelonia mydas*, in Moreton Bay, Southeastern Queensland

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Cheloniid turtles are usually limited to waters warmer than 20°C (Márquez, 1990) and at lower water temperatures ( $T_w$ ) they may show different behavioral and/or physiological responses compared to turtles from warmer temperatures. Using sonic telemetry, Mendonça (1983) showed that immature green turtles (7.8–54.5 kg) changed their behavior at water temperatures of 11–18°C, making random, long-distance movements and occupying deeper waters, whereas in waters >25°C turtles exhibited site philopatry and selected a home range which included shallow water feeding habitats. Torpor has been recorded at low water temperatures in both black (*Chelonia mydas agassizi*) and loggerhead turtles (*Caretta caretta*) (Felgar et al., 1976; Carr et al., 1980). Lethargic, easily handled black turtles have been found in the muddy edges of underground troughs in the Gulf of

California (Felgar et al., 1976) and large numbers of torpid loggerheads were trawled from the bottom off Cape Canaveral, Florida. The loggerheads were apparently buried in the substrate, with coverings of sulfurous mud on the buried portions and epifauna on the exposed carapace (Carr et al., 1980). "Cold-stunning" also may occur (Witherington and Ehrhart, 1989). Cheloniid turtles exposed to  $T_w$  below 10°C may be immobilized completely or even killed (Schwartz, 1978). Of 123 loggerhead, 342 green turtles, and two Kemp's ridleys (*Lepidochelys kempi*) collected from Indian River Lagoon, Florida, following cold stunning events from 1977 to 1986, 19.6% of all turtles died (Witherington and Ehrhart, 1989). It appears, however, that cold-stunning events are restricted to shallow regions where turtles have little opportunity to retreat from prevailing conditions (Orgen and McVea, 1981).

Low  $T_w$  can also affect the nutritional physiology and feeding ecology of marine turtles. Food consumption in post-hatchling green turtles increases linearly with increasing  $T_w$  (Davenport et al., 1989), a relationship which, when extrapolated downwards, predicts that food intake in post-hatchling green turtles (80–150 g) would cease between 15°C and 16°C. This agrees well with observations by Mendonça (1983) that immature green turtles apparently ceased feeding when  $T_w$  fell below 18°C, retreating to warm, deep-water where food was not available.

Some turtles, particularly large individuals, have been recorded with body temperatures ( $T_b$ ) well above  $T_w$ , induced either metabolically or behaviorally. Data from free-swimming adult green turtles shows that  $T_b$  can be maintained up to 8°C above an ambient  $T_w$  of 29.1°C (Standora et al., 1982), whereas active immature green turtles had a  $T_b$  only 1–2.5°C above an ambient  $T_w$  of 18–25°C (Heath and McGinnis, 1980). Such increases are, presumably, due primarily to metabolism associated with high levels of activity. Cheloniid turtles also can elevate  $T_b$  by basking on land (aerial basking) or while at the water surface (aquatic basking) (Spotila and Standora, 1985). The  $T_b$  of adult green turtles increased when beached during the day (Standora et al., 1982) and aerial basking by green turtles in the Hawaiian archipelago frequently has been recorded (Balazs and Ross, 1974). Experiments on a captive loggerhead turtle demonstrated that  $T_b$  can be elevated above ambient by aquatic basking (Sapsford and van der Riet, 1979).

Despite water temperatures which fall well below 20°C in winter (Newell, 1971), Moreton Bay (27°30'S, 153°18'E) in temperate southeastern Queensland has a resident population of green turtles of all sizes, from small immatures to mature adults of both sexes (Limpus et al., 1994). They annually experience temperatures known to be stressful to marine turtles elsewhere in the world, yet show no sign of torpor or other effects from cold. This suggests that they may have different thermal sensitivities from populations elsewhere or, perhaps, can raise body temperatures sufficiently to offset the effects of low temperature.

In order to examine the latter possibility, we measured  $T_b$  of immature individuals in Moreton Bay, i.e., those animals most likely to be unable to uncouple  $T_b$  from the temperature of the ambient water.

Moreton Bay is a large semi-enclosed Bay which has surface  $T_w$  in the range of 17–28°C, with an average temperature of 23°C (Newell, 1971). On the

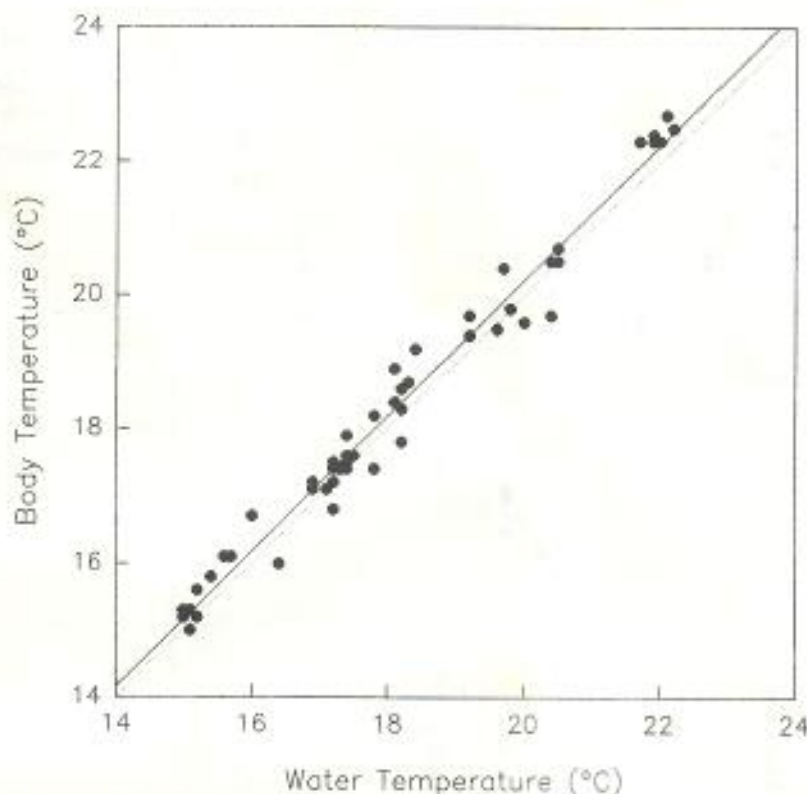


FIG. 1. Body temperature plotted against ambient water temperature for immature green turtles on the Moreton Banks. (Solid line = line of best fit, Dotted line = line with slope of 1.)

eastern margin of Moreton Bay are the Moreton Banks, a shallow seagrass habitat (1–6 m depth at Mean High Water; Anonymous, 1987) where values of surface Tw have been recorded as low as 14.7°C (Preen, 1992).

Turtles were captured on the Moreton Banks using the "turtle rodeo" method (Limpus and Reed, 1985), which involves chasing them with a speedboat and diving onto them. Turtles were caught in depths ranging from one to six meters within 2–3 min of sighting, thus minimizing the possibility of measuring Tb values increased artificially by a long chase.

At capture, Tb and corresponding Tw were measured immediately using an indoor/outdoor thermometer with a flexible thermoprobe (Micronta Instruments Inc.). The thermometer was checked in a water bath over a range of 8–45°C against a certified mercury thermometer (Dobbie Instruments Pty. Ltd.,  $\pm 0.1$ °C). The maximum deviation from the certified thermometer was 0.1°C, which was deemed insignificant. Body temperatures were measured by inserting the lubricated thermoprobe approximately 15 cm into the cloaca, as described by Hirth (1962) and Mrosowsky (1980), for an equilibration period of 2–3 min. After recording Tb, the surface Tw at the site of capture was measured with the same thermoprobe at a depth of approximately 15 cm. We also looked for any turtles exhibiting aerial or aquatic basking behavior.

To determine if turtles had fed immediately prior to capture, we examined mouth contents. This is known to be a valuable measure of feeding activity

(Johnstone and Hudson, 1981), although somewhat biased because some turtles lose their mouth contents during capture (Limpus et al., 1994).

Turtles were measured for midline curved carapace length (CCL) using a flexible tape measure ( $\pm 0.5$  cm) and weighed using 10 or 100 kg Salter spring balances ( $\pm 0.1$  and  $\pm 0.5$  kg respectively) (Limpus et al. 1984). Not all turtles captured were weighed.

Fifty immature *C. mydas* were captured, and corresponding Tb and Tw measurements were recorded during ten separate sampling trips from 28 May through 2 October 1991. The turtles had an average CCL and weight of  $55.7 \pm 9.5$  cm (mean  $\pm$  std; range = 42.1–85.1 cm;  $N = 50$ ) and  $19.7 \pm 7.6$  kg (range = 9.2–39.5 kg;  $N = 41$ ) respectively. Values of Tb were highly correlated with Tw ( $r^2 = 0.98$ ;  $F_{1,49} = 2000$ ,  $P < 0.001$ ,  $Y = 0.019 + 1.01X$ ; Fig. 1) and the regression slope was not significantly different from 1 ( $\chi^2_{10} = 0.165$ ,  $P = 0.685$ ). Values of Tb were on average  $0.20 \pm 0.33$ °C (range =  $-0.7$  to  $+0.8$ °C relative to ambient,  $N = 50$ ) above Tw. There was no relationship with the increment between Tb and Tw ( $=\Delta T$ ) and CCL ( $r^2 = -0.05$ ,  $P > 0.5$ ) or  $\Delta T$  and body mass ( $r^2 = -0.05$ ,  $P > 0.5$ ). There were marked seasonal changes in Tb, following seasonal fluctuations in Tw (Fig. 2). The coldest temperature was recorded on 18 July, a Tb of 15°C at a surface Tw of 15°C. The maximum Tb was 22.7°C, recorded on 28 May at a Tw of 22.1°C. We saw no turtles that appeared to be either inactive or torpid, although animals captured in winter appeared less

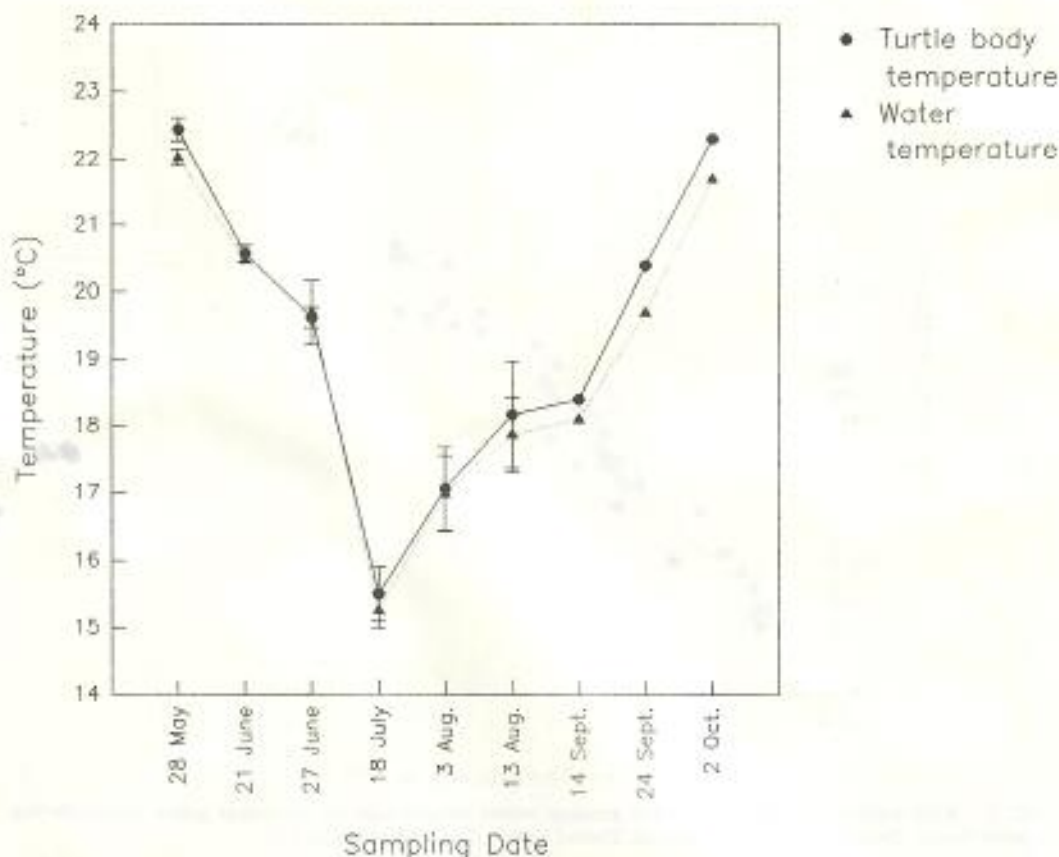


FIG. 2. Seasonal changes in water temperature and body temperature of immature green turtles on the Moreton Banks, from autumn, through winter, to spring (mean  $\pm$  SD).

energetic. Even on 18 July, when minimum Tb and Tw were recorded, turtles actively fled from the approaching catchboat. During the 24 d on which data were collected for this and a concurrent study (Read, 1991), no aerial or aquatic basking by green turtles was observed.

Buccal cavities were examined for food in 96 turtles. Actively feeding turtles were captured on each sampling trip. Thirteen (20.6%) of the 63 turtles examined during winter (June, July, August) had food or food traces and 50 (79.4%) did not. The buccal cavities of 8 (24.2%) of 33 captured during spring (September, October) contained food or food traces whereas 25 (75.8%) did not. These proportions are not significantly different ( $t = 0.46$ ,  $df = 48$ ).

Our results show that Tb of immature *C. mydas* in the Moreton Banks region does not deviate significantly from Tw throughout seasonal fluctuations in Tw in the range of 15 to 22.7°C (Fig. 2). Values of Tb exceeded Tw by an average of only 0.2°C, which is physiologically insignificant. The increment between Tb and Tw did not differ throughout the year, indicating that immature green turtles in this region do not elevate their body temperature by endogenous means or by basking at the surface. There was little variation in  $\Delta T$  within the population, and no correlation between  $\Delta T$  and CCL or body mass, indicating that larger turtles in the sampled range of sizes

were not exhibiting a thermal advantage over smaller individuals.

The data were generally consistent with similar measurements recorded from nesting and small cheloniids elsewhere. Hirth (1962) measured cloacal temperatures of green and hawksbill turtles (*Eretmochelys imbricata*) as they emerged to nest at Costa Rica and found that Tb varied from 0–3°C above that of the water. Similar differences in the increment between Tb and Tw were recorded for nesting olive ridley (*Lepidochelys olivacea*) and green turtles in Surinam and French Guiana (Mrosovsky and Pritchard, 1971). Heath and McGinnis (1980) recorded values of  $\Delta T$  of 1–2.5°C for active juvenile (2–4 kg) and sub-adult (50–60 kg) green turtles in waters of 18.5–21.5°C. The data presented for the Moreton Bay green turtles and that of Heath and McGinnis (1980) found that small immature turtles, even when swimming actively, did not exhibit the marked elevations in Tb seen in active, adult animals. Standora et al. (1982) recorded  $\Delta T$  of 3.7–8°C in an adult green turtle swimming rapidly in 29.1°C water off Costa Rica, whereas measurements of  $\Delta T$  in inactive adult green turtles were only 1–2°C. Thus, small or inactive cheloniid turtles do not maintain a large  $\Delta T$  compared to Tw, but conform closely to the ambient conditions over the full range of Tw. Hence, at low water temperatures, body temperatures, too, are expected to be low.

Despite low body temperatures in winter, that is, lower than the 18 C found by Mendonça (1983) to inhibit feeding by immature green turtles in Florida, the immature green turtles in Moreton Bay continued to feed. Ambient water temperatures in Moreton Bay have not been recorded near the minimums necessary to induce torpor or cold stunning, but it appears that juvenile green turtles here are more tolerant of cold, raising the possibility that there may be different physiological races of green turtles and, perhaps, other species as well. This is in agreement with the conclusions of Bowen et al. (1992) that there is a fundamental phylogenetic split between Atlantic-Mediterranean and Indian-Pacific green turtles. Furthermore, green turtles from Moreton Bay are primarily from the southern Great Barrier Reef (GBR) stock which are genetically distinct from northern GBR stocks (Norman et al., 1994). Taken together, these studies suggest caution in extrapolating physiological information among different populations or genetic stocks.

**Acknowledgments.**—Partial support of the study was provided by the Queensland Turtle Research Project of the Queensland Department of Environment and Heritage and by a University of Queensland Research Grant to MAR. Many thanks to the volunteers who gave their time to help catch turtles. Thanks to Tony Preen for making available his water temperature data from Moreton Bay. This assistance is gratefully acknowledged.

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Accepted: 10 January 1996.