

## Novel insights into green sea turtle behaviour using animal-borne video cameras

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An animal-borne video camera and data-logger was used to collect behavioural data on green (*Chelonia mydas*) and loggerhead (*Caretta caretta*) turtles in Western Australia. This technique provided novel insights into the behaviour of green turtles including an apparent self-cleaning behaviour. Also, ctenophores and jellyfish might be more important in the diet of these turtles than previously thought.

An animal-borne video camera (National Geographic's 'Criticcam', Marshall, 1998; Heithaus et al., 2001), that integrates video data with environmental data (e.g. time, water depth, temperature) collection was used to study green (*Chelonia mydas*) and loggerhead (*Caretta caretta*) turtles in Shark Bay, Western Australia. The study was conducted in the Eastern Gulf (25°45'S 113°44'E, see Heithaus et al., 2002a), which is relatively shallow throughout with extensive shallow nearshore areas (usually <3.0 m depth) covered by sea grass or sand, shallow offshore sea grass banks (<4.0 m depth), numerous narrow, swift-current channels (6.5–12 m) covered by sand, and expanses of relatively deeper waters (6.5–15 m) with silt or sand bottoms.

From March–July 1999 and April–June 2000 video and data units were attached to 12 green turtles 76–103 cm curved carapace length (CCL) (28.2 video hours) and 13 loggerhead turtles 76–107 cm CCL (33.2 video hours) that were caught by hand (Heithaus et al., 2002b). A plexiglass plate was affixed to the carapace with cool-setting epoxy (Ten-Set™) and the instrument was attached to this plate using a small wire and magnesium washer. The camera and lens were angled down to obtain a consistent view of the head during foraging behaviour. Although the head occasionally made short darts outside the field of view while turtles swam in the water column, foraging on sea grass was not missed. The unit was programmed to stay attached to the turtle for 3–24 hours after which it would release using a burn wire mechanism or when the magnesium washer dissolved. Base plates sloughed off turtles after hours to several weeks. Once an instrument released from a turtle, it was retrieved using a VHF transmitter.

Two surprising findings about the behaviour of green turtles are described. First, a surprisingly large number of green turtles foraged on jellyfish and ctenophores. Nine of 11 (81.8%) green turtles that encountered jellyfish or ctenophores consumed a total of 67 of the 275 potential prey items of this sort recorded on video ( $\bar{x}$ =21.1% of encountered prey items consumed  $\pm$ 11.3% 95%CI). In all but one case, jellyfish and ctenophores were consumed while turtles swam in the water column and were small enough to be consumed in a single bite. However, one turtle scavenged a large jellyfish that was extracted from a sea grass bed and took several minutes to consume. If turtles were

to consume jellyfish and ctenophores at the observed average rate ( $\bar{x}$ =2.5 prey items/h  $\pm$ 2.8 95%CI, range=0–15 prey items/h) throughout daylight hours, they would consume approximately 40 each day. Although every green turtle spent considerable time in sea grass habitats, only two green turtles consumed sea grass, with each turtle grazing for less than two minutes.

These results are strikingly different from other studies of foraging by large green turtles, which are thought to be almost exclusively herbivorous (Bjørndal, 1997). Juvenile green turtles (<30 cm CCL) are carnivorous but are believed to switch to a mostly herbivorous diet when they move from pelagic to near-shore habitats, and to only occasionally consume animal matter including sponges, mollusc eggs, and jellyfish (see Bjørndal, 1997 for a review). Ctenophores and jellyfish are likely to be digested more rapidly than sea grass and algae, and thus are likely to be under represented in turtle stomach contents. This study suggests that jellyfish and ctenophores may be a more important component of green turtle diets than previously thought.

Green (but not loggerhead) turtles were recorded rubbing their bodies on sponges and rocks. Two green turtles were observed making repeated dives, and another made a single dive, to rub their bodies on sponges and rocks in an apparent self-cleaning behaviour (Figure 1). One turtle (GT8) was observed rubbing on sponges twice over 3 h while a second turtle (GT3) engaged in 19 rubbing bouts on rocks and sponges over 4 h. GT3 also filmed another turtle engaged in rubbing behaviour, indicating that rubbing is not a response to instrument attachment. During rubbing bouts, GT3 remained in a restricted area where sponges and rocks were plentiful but food was not.

Rubbing altered GT3's diving and breathing patterns: the turtle made significantly longer dives when rubbing ( $\bar{x}$ =9.8 min  $\pm$  2.9 min SD, N=15) than when not rubbing ( $\bar{x}$ =2.9 min  $\pm$ 1.3 min SD, N=30 dives excluding all dives made within 1 hour of capture;  $t$ =18.67,  $df$ =17,  $P$ <0.001) and took more breaths at each surfacing after rubbing dives ( $\bar{x}$ =3.2  $\pm$ 1.2 SD, N=15 surfacing bouts) than after non-rubbing dives to the same depth ( $\bar{x}$ =1.8  $\pm$ 1.0 SD, N=34 surfacing bouts;  $t$ =8.67,  $df$ =17,  $P$ <0.001).

Despite higher densities of green turtles in shallow habitats in the study area (Heithaus et al., 2002a,b) most encounters with conspecifics occurred in the rubbing area. All ten of GT3's



**Figure 1.** Video frame of a green turtle rubbing on a sponge. During bouts, turtles may rub the underside of their carapace, head, neck, and flippers. The camera and lens were angled downwards to provide a constant view of the head during foraging and rubbing.

encounters with other green turtles were in the rubbing area as were GT8's five encounters although these individuals spent considerable time in shallow sea grass and other deep habitats. For all other turtles, there were only three encounters with conspecifics, and all were in shallow sea grass habitats. This suggests that sponge-rubbing areas are important habitats for these turtles. Due to the small sample of rubbing turtles it is not possible to accurately assess the proportion of time green turtles devote to rubbing, however, it appears to be an important behaviour.

The combination of increased dive and surface times indicates that GT3 incurred a physiological cost to engage in rubbing, suggesting that the behaviour is beneficial. The most likely explanation for rubbing is self-cleaning. Green turtles engage in symbiotic relationships with cleaner fish in reef habitats (e.g. Losey et al., 1994), but Shark Bay habitats are largely sea grass or sand. Lacking access to cleaner species, turtles apparently seek out sparse patches of sponges and rock to rub against. This rubbing behaviour may serve to reduce the amount of biological growth on green turtles as they were covered in thick algae and encrusting organisms much less frequently than loggerhead turtles ( $\chi^2=26.1$ ,  $df=2$ ,  $N=100$  green turtles, 79 loggerhead turtles,  $P<0.001$ ).

The discovery of rubbing behaviour helps elucidate green turtle habitat use in Shark Bay. Dive shapes like those made by rubbing turtles may have been interpreted in previous studies as foraging dives (Hochscheid et al., 1999; Hays et al., 2000). Consequently, using traditional techniques, the rubbing habitat would have been misclassified as a foraging area.

This study shows that animal-borne video cameras equipped with time–depth recorders are a powerful tool for investigating the behaviour and foraging ecology of sea turtles and should continue to provide novel insights into habitat use as well as the cleaning, foraging and social behaviour of sea turtles in Shark Bay. Future studies using animal-borne imaging capabilities, in a variety of locations, are likely to greatly enhance our understanding of turtle foraging ecology and elucidate the generality of the results from Shark Bay.

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