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Animal-borne video reveals seasonal activity patterns of green sea turtles and the importance of accounting for capture stress in short-term biologging

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ABSTRACT

Animal-borne biologgers or biotelemetry systems are commonly used to study the movements and behavior of large aquatic taxa. However, the effects of the tag deployment procedure and tag presence on animal behavior remain poorly studied. Using affordable, custom-made animal-borne video recorders, we analyzed the seasonal activity patterns of green turtles (*Chelonia mydas*) on a foraging ground and assessed the effects of deployment stress on turtle behavior by comparing turtle activities in 'standard' deployments (in which recording began immediately upon release, although we discarded the first 30 min of footage) with delayed-start deployments (in which recording began the following day). Turtles were more active during the warm season, spending more time swimming and surfacing, and less time resting than in the cold season. Turtles were also more likely to feed during the warm season, with all but one of the 99 observed feeding events occurring in the warm season. Turtle behavior also varied markedly between standard and delayed-start deployments. Standard deployments were dominated by swimming behavior presumably related to movement away from the capture site or exploring new habitat once a perceived safe distance away. In delayed-start deployments turtles spent less time swimming, more time resting and were more likely to feed (85 of 99 feeding events were recorded in delayed-start deployments) and engage in social interactions. The behaviors that replaced 'excess' swimming in standard deployments were season-specific. For example, in the cold season in standard deployments turtles spent a median 80% of their time swimming and 14% resting, while in delayed-start deployments these figures were effectively reversed. In the warm season, 'excess' swimming in standard deployments was replaced by feeding and other active behaviors in delayed-start deployments. These results provide a cautionary tale for the interpretation of short-term video data, demonstrating that, while 'normal' behaviors may be observed shortly after release, activity budgets can still be far from typical. Delayed-start functions or data exclusions guided by experimental research are therefore valuable to short-term biologging or biotelemetry studies. Potential effects on animal behavior from diverse animal-borne instruments, deployed for various purposes and lengths of time, warrant continued experimental attention.

1. Introduction

Animal-borne biologging and biotelemetry systems have become indispensible tools for studying the movements and behavior of large aquatic taxa. A critical assumption to generalizing patterns from tag data to population-level processes is that the data collected reflect normal behavior of the animal. However, this assumption is challenging to evaluate and, as Ropert-Coudert and Wilson (2004) put it: "Our subjective assessment that an animal is behaving 'normally' is probably one of the weakest links in the chain of events from logger design, testing, implementation, to analysis and interpretation of results". The effects of tag presence and the deployment procedure on animal behavior can vary widely with factors including the focal species, instrument type, tag size relative to body size, deployment duration and specific attachment methodology (Hawkins, 2004; Ropert-Coudert and Wilson, 2004; Wilson and McMahon, 2006). In long-term deployments (e.g., satellite tags) the cumulative effects of added drag or changes to an animal's specific gravity are a key concern for animal welfare and data quality (Ropert-Coudert and Wilson, 2004). By contrast, in short-term deployments in which data are collected shortly after release (e.g., animal-borne video), the effects of stress from the deployment procedure on animal behavior need to be considered in addition to the temporary physical effects of tag presence (Moll et al., 2007). Thus, research that quantifies these effects (e.g., Jones et al., 2011; Littnan et al., 2004) is needed to validate the analysis and interpretation of animal-borne instrument data.

Animal-borne video has been used to study the underwater behavior of diverse taxa including penguins (Ponganis et al., 2000), cetaceans

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(Calambokidis et al., 2007), pinnipeds (Bowen et al., 2002; Davis et al., 1999), sea turtles (Heithaus et al., 2002c) and large sharks (Heithaus et al., 2002a). To evaluate whether video tags influence animal behavior, it is common to compare behavior in video footage with observations of behavior made using other means or to expected normal behaviors. For example, Seminoff et al. (2006) found no difference in the swim speeds of green turtles (*Chelonia mydas*) fitted with video tags compared to turtles tracked using acoustic telemetry, and dive profiles of turtles with video tags were similar to records obtained using time–depth recorders (TDR). Similarly, dive depths and durations of adult and immature Hawaiian monk seals (*Monachus schauinslandi*) with video tags were similar to those of seals fitted with satellite tags or TDRs (Littnan et al., 2004; Parrish et al., 2000). Such results suggest that the presence of video tags does not influence animal behavior. However, the evidence is mixed. For example, Ponganis et al. (2000) observed shorter dive durations in emperor penguins (*Aptenodytes forsteri*) fitted with video recorders compared to those without. Other studies have found differences in the dive times of animals fitted with cameras compared to those with smaller TDRs, or have found that video data sets did not include some representative dive profiles from longer TDR records, which might indicate differences in behavior between deployment types (Thomson et al., 2011). Periods of elevated dive frequency during the first several hours of TDR deployments, suggestive of post-release stress, have also been noted (Hazel et al., 2009; Thomson et al., 2012a). Therefore, it is important to further develop methods of evaluating the assumption that animal-borne video recorders produce unbiased behavioral data.

Biologging and biotelemetry methods video have proven very useful for studying the at-sea behavior of marine turtles. In large part, this derives from turtles' large body size, relatively flat carapace for instrument attachment, and their accessibility for instrumentation in many regions, particularly on nesting beaches and in shallow foraging areas. Animal-borne video, specifically, has provided new insights into marine turtle foraging ecology, locomotion, diving behavior and social interactions (Arthur et al., 2007; Burkholder et al., 2011; Heithaus et al., 2002c; Reina et al., 2005; Seminoff et al., 2006; Thomson et al., 2012b). Compared with direct in-water observation (e.g., Booth and Peters, 1972; Schofield et al., 2007), animal-borne video allows for longer-term observation of behavior without the risk of observer presence influencing turtle activities. Furthermore, turtle-borne video has been used to assess the extent to which specific behaviors can be inferred from stand-alone dive profiles, which are more common and affordably obtained (Seminoff et al., 2006; Thomson et al., 2011). As the technology continues to improve (e.g., higher video resolution, more memory, longer battery life, smaller size), and larger sample sizes can be affordably obtained, video data-logging techniques will be able to address a greater breadth of research questions.

One such question pertains to seasonality of turtle behavior. In subtropical and temperate foraging habitat, sea turtles often experience marked seasonal variation in water temperature, which can have pronounced effects on their physiology and behavior. These effects are often studied using dive profiles. For example, Southwood et al. (2003) observed longer dives by juvenile green turtles in Australia during winter, while Hochscheid et al. (2005, 2007) have documented dives by overwintering Mediterranean loggerhead turtles (*Caretta caretta*) lasting several hours or more at water temperatures between ca. 14 and 16 °C. However, it is difficult to assess the proportion of time turtles allocate to specific activities using indirect indices of behavior such as dive profiles (Seminoff et al., 2006; Thomson et al., 2011). In this regard, animal-borne video is useful because it allows direct observation of turtle behavior across seasonal temperature gradients.

Our objectives here are threefold. First, we introduce an affordable, custom-made turtle-borne video tag equipped with a high-definition video camera that is suitable for use in shallow (<60 m) coastal habitats. Second, we examine seasonal variation in the activity profiles of green turtles on a subtropical foraging ground in Shark Bay, Western Australia. Third, to assess the effects of capture stress on turtle behavior, we compare activity budgets in deployments where recording began immediately upon release (although we exclude the first 30 min from analysis) with deployments where the start of recording was delayed until the following day.

2. Methods

2.1. Study site and turtle capture

Shark Bay, Western Australia is a large, subtropical embayment located ca. 800 km north of Perth. It is a shallow (mostly <15 m) system characterized by offshore seagrass banks, deeper sand-bottom channels and open plains, and expansive nearshore sand–seagrass flats. Mean monthly water temperatures in Shark Bay vary from ca. 15–19 °C in winter to 22–25 °C in summer (Heithaus, 2001), although daily temperatures can exceed these extremes by several degrees. Green and loggerhead turtles use this area as a foraging ground year round (Heithaus et al., 2002b, 2005). Turtles were captured by hand during haphazard searches of the study area in a small center-console boat that had a water-level platform at the stern onto which turtles could be easily maneuvered. Turtle length (CCL) was measured and sex was categorized based on tail morphology: turtles were considered male if tail length was >25 cm and all others were considered 'unclassed', which would include adult females and immature turtles of both sexes (Limpus et al., 1994). Titanium flipper tags, provided by the Department of Environment and Conservation, were applied to a proximal scute of each foreflipper.

2.2. Animal-borne video recorders

From July to November, 2012, video tags were deployed on turtles as part of a larger foraging ecology study. Tag packages (Fig. 1, Supplementary Video 1) were similar to the short-term, remote-release time–depth recorder tags used previously to study turtle diving behavior in Shark Bay (Thomson et al., 2012a). A buoyant base made of syntactic foam (Syntech, VA, USA) was shaped to accommodate several tag components, which were fixed in place using a 5-minute epoxy. Each tag included a VHF radio transmitter (Telonics, Inc., AZ, USA) and a GoPro® Hero or Hero2 HD video camera (GoPro, CA, USA). The camera was situated at the front of the tag. A plastic zip tie was inserted through vertical holes drilled in the foam base and looped around the standard GoPro® clip, which was set into the foam base and then epoxied permanently in place. A camera in an underwater housing could then be easily mounted on and removed from the secured clip. Some tags also included a Wildlife Computers (WA, USA) MK10 data logger to track turtle movements for the foraging ecology study. Note that, without a large data logger, tag configuration can be altered to reduce size for use on smaller animals (Appendix 1). Tags were attached to a turtle by affixing a small square of nylon mesh to the carapace on the first vertebral scute using epoxy and another on a vertebral scute behind the posterior end of the tag when set in place. Zip ties were run through the loops of each mesh square to dissolving zinc–magnesium pop-up links, which dissolve in seawater and allow the package to release, and then from each link to monofilament loops inserted through the front or back end of the tag (Fig. 1). Tag packages were weighted to be slightly positively buoyant and float vertically at the surface with the VHF transmitter above the water following release from the turtle.

We conducted two types of deployments: 'standard' deployments, in which video recording began immediately upon release, and delayed-start deployments, in which the start of video recording was delayed until the following day. In the standard video deployments, the GoPro® Battery BacPac™ was used to extend the duration of video recording (Table 1). Delayed-start deployments were obtained by replacing the addition battery with a timer delay control chip (www.cam-do.com), which allows programming time lapse or delayed-start