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Habitat use of breeding green turtles *Chelonia mydas* tagged in Dry Tortugas National Park: Making use of local and regional MPAs

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ABSTRACT

Use of existing marine protected areas (MPAs) by far-ranging marine turtles can be determined using satellite telemetry. Because of a lack of information on MPA use by marine turtles in the Gulf of Mexico, we used satellite transmitters in 2010 and 2011 to track movements of 11 adult female breeding green turtles (*Chelonia mydas*) tagged in Dry Tortugas National Park (DRTO), in the Gulf of Mexico, south Florida, USA. Throughout the study period, turtles emerged every 9–18 days to nest. During the intervals between nesting episodes (i.e., inter-nesting periods), the turtles consistently used a common core-area within the DRTO boundary, determined using individual 50% kernel-density estimates (KDEs). We mapped the area in DRTO where individual turtle 50% KDEs overlapped using the USGS Along-Track Reef-Imaging System, and determined the diversity and distribution of various benthic-cover types within the mapped area. We also tracked turtles post-nesting as they transited to foraging sites 5–282 km away from tagging beaches; these sites were located both within DRTO and in the surrounding area of the Florida Keys and Florida Keys National Marine Sanctuary (FKNMS), a regional MPA. Year-round residency of 9 out of 11 individuals (82%) both within DRTO and in the FKNMS represents novel non-migratory behavior, which offers an opportunity for conservation of this imperiled species at both local and regional scales. These data comprise the first satellite-tracking results on adult nesting green turtles at this remote study site. Additional tracking could reveal whether the distinct inter-nesting and foraging sites delineated here will be repeatedly used in the future by these and other breeding green turtles.

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1. Introduction

Marine protected areas (MPAs) are a common conservation management tool for providing protection to sensitive marine resources, including threatened and endangered species. Although the scales of individual MPAs vary worldwide and with respect to differing goals (e.g., enhancing fisheries resources, protection of benthic resources, prohibition of extractive uses), the value of spatial information is paramount in the design and evaluation of MPAs (Agardy, 2000; Roberts, 2000; Costello et al., 2010). For MPAs designed to protect marine vertebrates, a priori knowledge of spatial habitat-use patterns helps in prioritization of area-based protection strategies for conservation (Hyrenbach et al., 2000; Block et al., 2011; Maxwell et al., 2011).

In recent years, satellite-telemetry studies have broadened our understanding of the spatial habitat-use patterns of many wide-ranging marine vertebrates, especially during the breeding season (seabirds: Hyrenbach et al., 2006; marine mammals: Bailey et al., 2009; sea turtles: Zbinden et al., 2007; Schofield et al., 2010; see also reviews by Godley et al., 2008; Hart and Hyrenbach, 2009). For marine turtles in particular, tracking females during and after the nesting season has revealed specific at-sea high-use areas and migration corridors, key links between nesting beaches and foraging grounds (Godley et al., 2002, 2010; Seminoff et al., 2008; Shillinger et al., 2010; Hart et al., 2012). In addition, tracking of marine turtles at-sea has helped to delineate zones of overlap with fishing activities (Polovina et al., 2000, 2004) and has uncovered important differences in migration strategies (McClellan and Read, 2007; Mansfield et al., 2009). Although documented turtle use of areas within proposed MPAs has recently promoted significant conservation in Gabon and Congo for olive ridleys (see Maxwell et al., 2011), such determination of spatial "hotspot" use for marine turtles has most often come after MPA boundaries are set (see Witt et al., 2010).

A species of marine turtle with circum-global distribution, *Chelonia mydas* (Linnaeus, 1758) uses nesting and foraging grounds throughout tropical and subtropical waters (Hirth, 1997; Seminoff, 2004). Green turtles consume seagrasses and marine algae

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(Bjorndal, 1980), and their grazing plays a key role in maintaining structure and productivity of seagrass pastures in the Caribbean (Thayer et al., 1982, 1984; Zieman et al., 1984; Moran and Bjorndal, 2005). The species is listed as Endangered by the International Union for the Conservation of Nature (Groombridge, 1982; Groombridge and Luxmoore, 1989; Seminoff, 2004) and threatened under the US Endangered Species Act in all areas, except for breeding populations in Florida and on the Pacific coast of Mexico, which are listed as endangered (NMFS and USFWS, 1991). Seminoff (2004) estimated that the global population of green turtles has declined between 48% and 67% over the last three generations (~130 yrs); as such, identification of habitats used by green turtle populations is a critical element of management and conservation strategies (Hamann et al., 2010). In United States Atlantic waters, green turtles nest in small numbers in the US Virgin Islands and in Puerto Rico, and in larger numbers along the east coast of Florida (NMFS and USFWS, 1991). Although the east coast of Florida has the largest breeding assemblage of green turtles in the US, at-sea habitats used during the time between nesting episodes (i.e., inter-nesting habitats) and foraging-ground locations of these turtles are not yet known.

Green turtles in some locations are highly migratory, undertaking complex movements through geographically disparate habitats during their life cycle (Musick and Limpus, 1997; Plotkin, 2003; Craig et al., 2004; Troëng et al., 2005; Seminoff et al., 2008). The generally accepted life-history model for mature green turtles is that they breed approximately every 2 yrs (Broderick et al., 2002) in the vicinity of their natal beach (Allard et al., 1994; Plotkin, 2003), lay eggs at approximately 2 week intervals (Carr et al., 1974) and then return to distinct foraging areas (Broderick et al., 2007) where they rely on a diet rich in seagrass and marine algae (see Bjorndal, 1980).

Numerous studies on nesting green turtles have revealed varied post-nesting migratory behaviors. Decades of work focused on nesting green turtles at Ascension Island, a major rookery in the South Atlantic, have revealed long-distance migrations of up to ~2000 km toward the coast of South America (Mortimer and Carr, 1987; Luschi et al., 1998; Hays et al., 1999; Godley et al., 2001). Tracking of adult green turtles post-nesting in the Caribbean by Blumenthal et al. (2006) revealed a mean migration distance of 711.3 km (range 520–856 km) between breeding grounds in the Cayman Islands and scattered foraging sites, one of which was in the Florida Keys. Recent tracking of adult green turtles by Godley et al. (2010) in Guinea-Bissau (West Africa), showed migration distances of >1100 km. However, not all nesting green turtles undertake such long migrations. Intense tagging of nesting green turtles at Tortuguero, Costa Rica revealed mean migration distances of 512 km (Troëng et al., 2005). Moreover, recent evidence of even shorter migrations (mean = 35.5 km) or non-migratory behavior has been found for nesting green turtles in the Cocos (Keeling) Islands, Indian Ocean (Whiting et al., 2008). These differential migration distances for individuals from distinct rookeries indicate the need for additional tracking studies at under-studied green turtle-nesting grounds, and they have implications for design of MPAs intended to afford protection to imperiled green turtles.

In the US, an understanding of green turtle movement patterns in protected areas, such as national parks and national marine sanctuaries, is considered a priority for ongoing conservation efforts and Federal recovery plans (e.g., NMFS and USFWS, 1991). In a recent global analysis of adult green turtle satellite tracking data in tropical and subtropical habitats, Scott et al. (2012) observed that turtles were significantly aggregated in MPAs. However, this analysis did not include lesser studied green turtle populations such as those in the Gulf of Mexico. Thus, we aimed to assess MPA use by nesting green turtles captured within a US national park. Green turtles nesting in the Dry Tortugas National Park (DRTO), a remote cluster of islands in the US Gulf of Mexico west of the Florida Keys (see Study Site description, below), have not previously been studied.

Our primary goals were fourfold: (1) to investigate the habitat-use patterns of green turtles during their inter-nesting periods; (2) to quantify composition of benthic habitat utilized by turtles during inter-nesting; (3) to identify specific location of foraging grounds for DRTO green turtles; and (4) to classify turtle time spent per area with respect to local park boundaries and regional MPA extent. Thus, for the inter-nesting period, we specifically determined (a) number of nests per individual and duration of the inter-nesting period; (b) individual site-fidelity to the nesting beach; (c) location of core-use areas with respect to protected areas within DRTO; (d) level of site-fidelity to in-water core-use areas; and (e) benthic-habitat cover and depth in core-use areas. Post-nesting, we tracked all turtles to foraging destinations and classified these sites with respect to local and regional protected area boundaries.

2. Materials and methods

2.1. Study site

The Dry Tortugas is comprised of a cluster of islands approximately 100 km west of Key West, Florida (near 24°38′00″N, 82°55′12″W; Fig. 1A) in the US Gulf of Mexico. The region was designated a wildlife refuge in 1908, a national monument in 1935, and a national park in 1992. Of the seven islands that make up DRTO, Loggerhead Key is the largest (~1.5 km long × 250 m wide) and East Key (~400 m long × 100 m wide) is the smallest to host successful turtle nesting. DRTO lies within the Florida Keys National Marine Sanctuary (FKNMS), previously established in November 1990. The FKNMS protects the third largest coral barrier reef ecosystem in the world, including more than 6000 species of marine life, as well as cultural resources. In January 2007, an area 74 km^2 in DRTO was designated a Research Natural Area (RNA), creating a no-take preserve to foster ecological self-renewal by minimizing anthropogenic influences (e.g., anchoring and fishing; National Park Service, 2006; see Fig. 1A for RNA zones and regulations). The sandy beaches of DRTO are monitored by NPS as part of the State of Florida's marine turtle nest monitoring program (e.g., Witherington et al., 2009), but public access to East Key is prohibited and access to Loggerhead Key is limited.

2.2. Turtles at DRTO

Loggerhead and green turtles regularly nest on the sandy beaches of DRTO (Lenihan, 1997; Reardon, 2000; Van Houtan and Pimm, 2006). Non-submerged lands in DRTO include Loggerhead Key, East Key, Bush Key, Long Key, Garden Key, and Hospital Key (Fig. 1A), but 90% of turtle-nesting activity occurs on East and Loggerhead Keys (Reardon, 2000). Green turtle-nest densities on the ~3 km of sandy beaches used for nesting in DRTO are similar to those on the major green turtle colonies in southeast Florida (e.g., up to 50 nests km^{-1},Van Houtan and Pimm, 2006); in recent years, 186 and 127 green turtle nests were documented in DRTO in 2009 and 2010, respectively (K. Nimmo, National Park Service, pers. commun.), with nesting activity from June through October (Meylan et al., 1995; Reardon, 2000).

2.3. Green turtle captures and tagging

In 2010, we intercepted and tagged female green turtles early in the nesting season and after they had either finished nesting or completed a false crawl on East Key; in 2011, we intercepted