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RELATING TEN YEARS OF NORTHERN RACCOON ROAD-KILL DATA TO THEIR ATTRACTION TO SEA TURTLE NESTS

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***Abstract*.—One of the primary threats to sea turtle reproduction in Florida is nest predation by Northern Raccoons (*Procyon lotor*). We examined 10 years of nest deposition data from a high-density sea turtle nesting beach at Sebastian Inlet State Park, Florida, USA, along with data on raccoon road-kills from the adjacent road, and data on park attendance (as an index of local traffic) to make inferences about raccoon activity patterns relative to turtle nesting. Northern Raccoon road-kills diminished during turtle nesting, even though local traffic was higher. Virginia Opossums (*Didelphis virginiana*), the only other mammal consistently found as road-kills, did not show a decrease during turtle nesting season, but only rarely function as primary predators of turtle nests. We believed the most logical interpretation was that the abundant food resource of turtle eggs attracts raccoons to the beach during turtle nesting and they do not leave the beach area until the nesting season ends. The large numbers of Northern Raccoon road-kills during the fall-winter might be a signal that management actions to protect turtle nests might be needed.**

Key Words.—*Caretta caretta*; *Chelonia mydas*; *Dermochelys coriacea*; endangered species; Green Sea Turtle; Leatherback Turtle; Loggerhead Turtle; nest predation

INTRODUCTION

Northern Raccoons (*Procyon lotor*) destroy substantial numbers of sea turtle nests in Florida and throughout the southeastern United States (Stancyk 1982). Nest predation is a critical threat to many endangered or even locally rare species (Hecht and Nickerson 1999), with the deleterious impacts of predation losses compounded by habitat loss (Reynolds and Tapper, 1996). Northern Raccoons exemplify an abundant native vertebrate that negatively impacts endangered species (e.g., Garrott et al. 1993). Northern Raccoons achieve extraordinary densities (up to 238/km^2) in urban, coastal Florida (Smith and Engeman 2002). In addition, these predators recognize and focus on high-density nesting areas (Lariviere and Messier 1998, Mroziak et al. 2000, Meshaka et al. 2007). The combination of urbanization and development of coastal Florida reduced the beach areas for successful sea turtle nesting. However, urbanization often benefits raccoon populations, as they flourish around human habitation due to the availability of food from refuse and friendly humans (Dickman 1987; Dickman and Doncaster 1987; Riley et al. 1998; Smith and Engeman 2002). We compared 10 years of reproductive data from a high-density turtle nesting beach in Sebastian Inlet State Park (SISP) with road-kill data of Northern Raccoons from the road parallel to the park's beach to gain further insight to raccoon activity relative to turtle nesting.

METHODS

***Study site.*—**SISP is on a barrier island at the juncture of Brevard and Indian River counties, Florida, USA. The park (ca. 324.5 ha) has 4.8 km of beach, which the Sebastian Inlet bisects (27° 51.6' N, 80 ° 26.9' W). State Road A-1-A runs parallel to the beach within 50 m of the foredune. This road has a routinely exceeded speed limit of 72 km/h (pers. obs.) and various wildlife species move to and from the beach experiencing differential risks of collision with vehicles (e.g., see Glista et al. 2007).

The 4.8 km of Atlantic coast beach is a nesting site for three species of sea turtles (U.S. Fish and Wildlife Service 1994): Loggerhead (*Caretta caretta*), Green (*Chelonia mydas*) and Leatherback (*Dermochelys coriacea*). This is a high-density nesting beach (~ 1000–1500 nests per year) with approximately 90% of nests being from Loggerhead Turtles (Florida Department of Environmental Protection. 2001. Sebastian Inlet State Park Unit Management Plan. State of Florida, Department of Environmental Protection. Tallahassee, Florida, USA.). The nesting aggregation at SISP is in the geographical center of U.S. Loggerhead nesting range. It is the second largest Loggerhead nesting aggregation in the world, making this conservation area crucially important to the global survival of Loggerhead Turtles (Meylan et al. 1995).

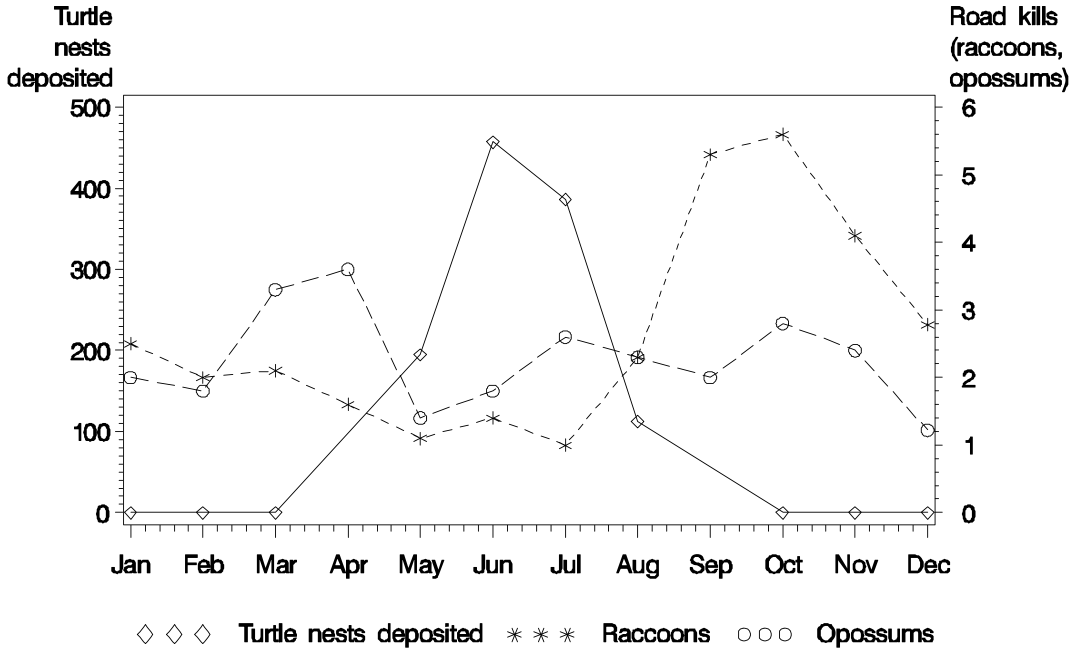

FIGURE 1. Monthly averages across 1990-1999 for: sea turtle nest deposition (3 species combined), Northern Raccoon road-kills, and Virginia Opossum road-kills at Sebastian Inlet State Park, Florida, USA.

Sea turtle nesting and road-kill surveys.**—**SISP rangers inspected the beach for new turtle nests each day from 1 May through 31 August during 1993–2002. Turtle nesting activities outside of these months are insignificant (e.g., Meylan et al. 1995; Engeman et al. 2003, 2005). Thus, turtle nest deposition is zero in most months. During nesting season the number of nests varies from month to month and year to year, and ranges up to nearly 700 nests/mo. Surveys took place within 0.5 h after sunrise, and surveyors recorded the number of new turtle nests each day.

Daily road-kill surveys took place during the same years (1993–2002), and consisted of cruising State Road A-1-A for dead wildlife at ca. 8–24 kph (e.g., Smith et al. 1994; Bard et al. 2002; Shwiff et al. 2003; Smith et al. 2003). We identified and recorded road-kill locations so that they would not be double counted the next day. We started surveys between 0745–0815. We recorded the number of each species found dead, and tabulated them by month. Because all vehicle traffic to the park would have to traverse State Road A-1-A, we used park attendance records to serve as an index of traffic volume on the only road through the park.

Data analyses.**—**We analyzed nesting and road-kill data to determine if there was a relationship between turtle nesting and Northern Raccoon activity. We compared average monthly road-kill rates between months when nesting did and did not occur. We used a randomized block design where the year was the blocking factor and analyzed this with a mixed linear model (e.g., McLean et al. 1991, Wolfinger et al. 1991) using SAS PROC MIXED with a restricted maximum likelihood estimation (REML) procedure (Littell et al. 1996). We also examined the correlation between monthly nest deposition and road-kills. Turtle nesting was non-normal because turtle nest deposition is zero in most months, but approaches 700 nests/mo during the nesting season. We, therefore, measured the strength of relationship between turtle nesting and the other variables with Spearman's rank correlation (ρ). We excluded April and September from our analyses because little nesting occurs during this time (e.g., Meylan et al. 1995; Engeman et al. 2003, 2005), and consequently, nests were not counted in these months.

In addition to Northern Raccoons, we analyzed road-kill data for other mammals for which sufficient data was available to assess the comparability of raccoon activity patterns to other mammals. We analyzed park attendance data in the same fashion as the road-kill data to identify possible relationships between traffic patterns and Northern Raccoon road-kill activity patterns.

RESULTS

Occurrence of road-killed Northern Raccoons demonstrated an inverse relationship to turtle nesting ($F_{1,9.06}$ = 10.29, P = 0.01, Fig. 1). Over twice as many road-kills/mo (3.2/mo) occurred during non-nesting months than during months with active nesting (1.5/mo).

Virginia Opossums, (*Didelphis virginiana*) were the only other mammal regularly recorded as road-kill (i.e., > 20/y, on average). Their abundance as road-kill varied throughout the year, showing no pattern relative to turtle nesting ($F_{1,88.1} = 0.35$, $P = 0.56$, Fig. 1). All other mammal species occurred too infrequently (< 7 road-kills/yr) for meaningful statistical analysis. Raccoon road-kills showed a negative rank correlation with turtle nesting ($\rho = -0.34$, $P < 0.0001$). No tight relationship between opossum road-kill frequency and turtle nesting was present, and the magnitude of the rank correlation was only half that for raccoons ($\rho = -0.18$, $P = 0.07$).

Park attendance was 10.4% higher ($F_{1,89} = 9.36$, $P = 0.003$) on average during turtle nesting months (52,325 visitors) than during months without nesting (47,392 visitors). There was a negative correlation between park attendance and abundance of raccoon road-kills ($\rho = -0.35$, $P < 0.001$), but attendance correlated positively with turtle nesting ($\rho = 0.24$, $P = 0.02$) suggesting that traffic increased, but raccoon road mortality decreased during the nesting season.

DISCUSSION

While we did not have data on actual traffic flows, park attendance data provided a logical basis to form a conservative index of road traffic. Northern Raccoon road-kills were highest when traffic was lowest. Furthermore, it is reasonable to expect traffic to increase near a beach during spring-summer holidays, as this would be a clear result of both institutionalized and natural seasonalities in visitation to the beach (Koenig-Lewis and Bishoff 2005). Virginia Opossums rarely prey on sea turtle nests (Woolard et al. 2004), although nests opened by other predators will attract them (e.g., Meylan et al. 1995; Stancyk 1982). In contrast, Northern Raccoons are the most destructive of a wide variety of sea turtle nest predators in Florida (e.g., Stancyk 1982; Garmestani and Percival 2005). Therefore, the fact that we observed little variation in the occurrence of Virginia Opossums despite an obvious relationship between Northern Raccoon activity and turtle nesting supports our hypothesis that raccoons shift their foraging behavior to beach habitats where abundant turtle eggs occur. The number of nests currently in the beach each month would be a more refined variable to relate with predator activity, but this could not be calculated because nest removal rates due to hatching, predation, overwash, etc. were not available. We suspect that if this information were available, a more sensitive determination of the attraction of turtle nests to raccoons might have been elucidated from road-kill data.
Our traffic results further support our hypothesis that Northern Raccoons shift their habitat use to beaches in response to turtle nesting. Typically, studies of road-killed animals aim to evaluate risks to the animals, index populations, or examine species compositions (e.g., Case 1978; Smith and Dodd 2003; Smith et al. 2003). Here, our purpose was to link raccoon road-kills to a foraging behavior, and we used known Northern Raccoon biology and an index of traffic levels to support the findings. Increased summer traffic should increase raccoon road mortality. Northern Raccoon litters in Florida are typically born in March and April, with weaning from mid-May to July (Kern, W.H., Jr. 2002. Raccoons. Report WEC–34, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, Florida, USA.). Thus, even if traffic remained unchanged through the year, we expected increased summer raccoon road mortality. Nevertheless, raccoon road-kills decreased significantly during the summer, suggesting they were not along roads as often as in other seasons.

During the summer, the abundance of turtle nests represents a nutritious food resource on the beach, and this food resource is found along the entire Atlantic coast of Florida (Stancyk 1982; Mroziak et al. 2000; Engeman et al. 2003). Although we did not directly count Northern Raccoons on the beach, the passive tracking index results presented by Engeman et al. (2003) support the logic that raccoons migrated to the beach in response to turtle nesting. They found that Northern Raccoon numbers on the beach at Hobe Sound National Wildlife Refuge (HSNWR), ca 90 km south of SISP, rapidly increased within two weeks after the onset of heavy nesting by sea turtles.
The movement of Northern Raccoons to the beach while raising young provides the opportunity for juveniles to learn nest raiding behavior from their mothers. Investigation of such a learned cultural component to turtle nest predation is needed. On some beaches, most raccoon predation occurs on the night of egg deposition (Anderson 1981); whereas, predation rarely occurs this soon on other beaches (Ehrhart, L.M., and B.E. Witherington. 1986. Human and natural causes of marine turtle nest and hatchling mortality and their relationship to hatchling production on an important Florida nesting beach. Report to Florida Game and Fresh Water Commission, Tallahassee, Florida, USA. 141 p., Engeman et al. 2003). Engeman et al. (2003) demonstrated high efficacy in protecting turtle nests by using a passive tracking system to optimize predator management. As a consequence, predation on a high-density turtle nesting beach at HSNWR dropped from 42% to 29% in one year (Engeman et al. 2003). Another two years of nest protection through 2002 reduced Northern Raccoon and Nine-banded Armadillo (*Dasypus novemcinctus*) nest predation to 9% (Engeman et al. 2005). This suggests that learned migration to nesting beaches may be lost over a few generations. However, sustained reduction in nest predation requires continued vigilance, as seen at HSNWR when a spike in nest

predation followed upon removal of predator management (Engeman et al. 2006).

Our data provide further evidence of the attraction of turtle nests to Northern Raccoons, and the willingness of raccoons to move to those beaches. Thus, the relationship between Northern Raccoon road-kills and turtle nesting might be applicable to sea turtle conservation at beaches with high nest predation, if the beach has an associated road(s) that would permit observation of road-kills. In particular, Northern Raccoon road-kill patterns might be used as an indicator of their attraction to the nesting beach (i.e., potential risk for nest predation). Monitoring road-killed raccoons may indicate the risk for nest predation, and the need for anti-nest predator tactics. We recommend additional validation of Northern Raccoon road-kill information relative to turtle nesting data, and we also recommend practical predator monitoring on the beaches that have high risk of nest predation such as employed by Engeman et al. (2003, 2005) to further refine the need, timing, and placement of nest protection activities.

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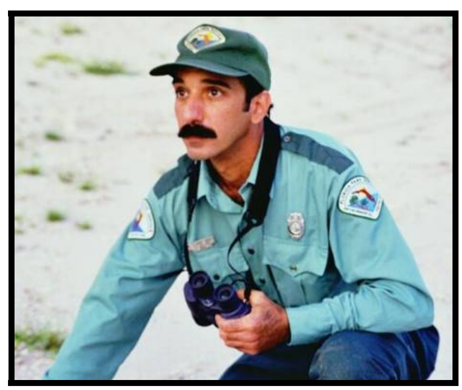

HANK SMITH (deceased) was the District Biologist for wildlife resources with the Florida Park Service in Hobe Sound; his region encompassing 25 state parks extending from Fort Pierce to Key West. He also was an Affiliate Research Assistant Professor of Biology and Environmental Studies at Florida Atlantic University, Wilkes Honors College supervising student research, internships, and theses. His research encompassed colonial waterbirds ecology, human disturbances on wildlife, bioeconomics of wildlife management, and exotic herpetofauna colonization dynamics in Florida. Hank passed away in 2008 and is sorely missed as a friend and colleague.