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Cues Used by Raccoons to Find Turtle Nests: Effects of Flags, Human Scent, and Diamond-Backed Terrapin Sign

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ABSTRACT.—We simulated nests constructed in an area heavily used by ovipositing Diamond-backed Terrapins (*Malaclemys terrapin*) and foraging raccoons (*Procyon lotor*), to investigate the cues used by raccoons to locate terrapin nests. Marking nests with flags did not increase predation rates, and human scent decreased predation rates. Raccoons seemed to locate nests based on soil disturbance, ocean-water scent, or a combination of these cues.

Throughout their range, raccoons (*Procyon lotor*) are often important predators of turtle nests (Mitchell and Klemens, 2000). Cues they use to locate nests are largely unknown but probably involve both sight and olfaction, as raccoons have good eyesight and an excellent sense of smell (Zeloff, 2002). In addition to the natural cues that may be left behind by nesting turtles, researchers studying turtle reproductive ecology often mark the location of nests after observing oviposition, leaving potentially informative markers and human scent. Inexpensive marking techniques vary but include numbered stakes (e.g., Congdon et al., 1983) and vinyl flags (e.g., Feinberg and Burke, 2003; also F. Janzen and A. Georges, pers. comm.). Predators may learn to associate such marking techniques with the nearby presence of nests, and, thus, these markers may influence predation rates.

We investigated the importance of natural and artificial cues using artificial nests placed on the island of Ruler's Bar Hassock (RBH) in Jamaica Bay Wildlife

Refuge (JBWR), New York. Approximately 2000 nests of *Malaclemys terrapin* are laid each year on RBH, and raccoons depredate 93% of these nests (Feinberg and Burke, 2003). There are no other significant nest predators. Most of this predation occurs at night, but visibility at night at this site is often good (RLB, pers. obs.). Raccoons on RBH have had ample opportunity to learn about flags because orange vinyl flags, placed close to nests, have been used for five years to mark terrapin nests, and some individual raccoons have lived on the island for at least three years (K. M. Broadwater and R. L. Burke, unpubl. data). Our experiments were similar to those of Tuberville and Burke (1994) except that we used artificial nests; we worked in an area where raccoons potentially had extensive experience with flags; we avoided the use of equipment that might influence raccoon behavior; and we investigated cues other than just flags.

MATERIALS AND METHODS

Artificial nests were placed in three different areas of dunes and mixed grasslands, each of which was in-

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tensively used by nesting terrapins and nest-predating raccoons. Trials took place between 14 July and 5 August 2003, and between 5 and 30 July 2004, within the normal nesting season for this area. In 2003, 16 artificial nests were constructed for each treatment; in 2004, 40 nests were constructed for each treatment. Artificial nests were monitored for signs of digging by raccoons daily for four days after construction, because nearly all raccoon predation on terrapin nests occurs in the first four day after oviposition (Feinberg and Burke, 2003). Artificial nests were considered "depredated" if there were signs of raccoon digging anywhere between the flags at the nest site.

We constructed nine types of artificial nests with different combinations of features to explore which cues raccoons use to locate nests. Only eight treatments were constructed each year—Treatment 3 was used only in 2004, and Treatment 4 was only used in 2003.

Treatment 1 was a "control" treatment, in that we tried to simulate most closely a real terrapin nest flagged as nests have been on this site since 1998 (Feinberg and Burke, 2003). As was typically done during that time, flags were placed approximately 25 cm to each side of the nest. Nest holes were hand dug to a depth of approximately 10 cm, as is typical for terrapin nests of this area. Surgical gloves were worn to mask human scent, except where noted below. We filled the excavated hole with terrapin-scented sand, which we made by placing an adult female terrapin in a box with beach sand for at least 30 min (Marchand et al., 2002). The filled excavation was smoothed over to reduce visual cues, as terrapin nests in this area are nearly always visually inconspicuous.

Treatments 2 and 3, designed to test whether the flags themselves could serve as visual cues, were identical to Treatment 1, except that flags were placed farther from the nest for 2 (60 cm to each side) and for 3 (100 cm to each side). We assumed these flags would be too far apart to serve as good cues of nest location.

Treatment 4 was designed to determine whether raccoons had learned to associate orange flags specifically with nests but would ignore flags of other colors. This treatment was identical to Treatment 1, except green flags were used instead of orange.

Treatment 5 was designed to determine whether moisture itself was a cue to the presence of a nest. This treatment was identical to Treatment 1 except plain sand was used to fill the excavated hole.

Treatment 6 was designed to determine whether flags alone could serve as sufficient stimulus to cause exploratory digging. For this treatment, flags were placed as in Treatment 1, but no digging or other manipulations were used.

Treatment 7 was designed to determine whether human scent influenced predation rates. This treatment was identical to Treatment 1, except gloves were not worn, and human saliva was mixed with plain sand to fill the hole.

The last two treatments were designed to elucidate the importance of different scents as cues. These treatments were, therefore, identical to Treatment 6, except that for Treatment 8 approximately 50 mL of ocean water was poured over the "nest site" and for Treatment 9 approximately 50 mL of fresh water was poured over the "nest site."

We examined a 2×8 contingency table for significant heterogeneity among the treatments from each year, using a goodness of fit test. On the basis of these results, we analyzed 12 comparisons (Treatment 1 vs. all other treatments, and Treatment 6 vs. 5, 8 and 9) post hoc with 2×2 contingency tables, using the two-tailed "unplanned tests of the homogeneity of replicates tested for goodness of fit" procedure (Sokal and Rohlf, 1981). This test uses critical values of the χ^2 -test based on Šidák's multiplicative inequality (Rohlf and Sokal, 1995) and compensates for both the post hoc nature of these tests and the fact that multiple tests are done simultaneously.

RESULTS

We regularly observed Raccoon footprints throughout the area during these experiments, and saw no sign of other nest predators. Overall, 48% (215/448) of the nests were "depredated." Of these, 71% were depredated in the first night, 10% in the second night, 13% in the third night, and 6% in the fourth night.

Only Treatment 6 (in 2004), the artificial nests that had been constructed with flags but without digging, and Treatment 7 (both years), the nests deliberately constructed so as to have high levels of human scent, had no predation at all (Fig. 1). Our control treatment, meant to simulate real terrapin nests, had the highest predation rate (88% and 95%, Fig. 1). There was significant heterogeneity among the treatments in 2003 ($G_H = 85.22$, $df = 7$, $P < 0.001$) and in 2004 ($G_H = 243.7$, $df = 7$, $P < 0.001$). Only two comparisons of the 2003 data showed significant differences between treatments at the $P \leq 0.05$ level: Treatment 1 vs. 6 ($G_H = 24.70$) and 7 ($G_H = 31.80$). Only five comparisons of the 2004 data showed significant differences between treatments at the $P \leq 0.05$ level: Treatment 1 vs. 5 ($G_H = 28.95$), 6 ($G_H = 85.61$), 7 ($G_H = 85.61$), 9 ($G_H = 60.4$) and Treatment 6 vs. 8 ($G_H = 36.18$). All $df = 9$. For the 2004 data, Treatment 5 vs. 6 ($G_H = 21.40$) was close to the $G_H = 23.526$ for $P \leq 0.05$ level.

DISCUSSION

Raccoons responded to some of our artificial nests in a manner much as they did to real Diamond-Backed Terrapin nests. Raccoons at this site depredate about 93% of terrapin nests, and most of this predation occurs in the first night after oviposition (Feinberg and Burke, 2003). Raccoons preyed upon our control nests at rates as high as their predation on real nests, and most artificial nests were depredated in the first night, as were real terrapin nests.

Our initial question was whether orange flags, placed close (25 cm away) to recently oviposited terrapin nests, increased the likelihood that they would be depredated. Because depredation rates for treatments 2 and 3, where flags were considered too distant from nests to indicate nest location, were similar to (and not significantly different) those of our main control, Treatment 1, we conclude that close flags did not increase the likelihood of depredation. Thus our results agree with those of Tuberville and Burke (1994) that experimenters using flags to mark nests may have no impact on predation rates.

The observation that predation rates were significantly lower for treatments with close flags but lacking either digging (6) or terrapin scent (5) suggests it is not

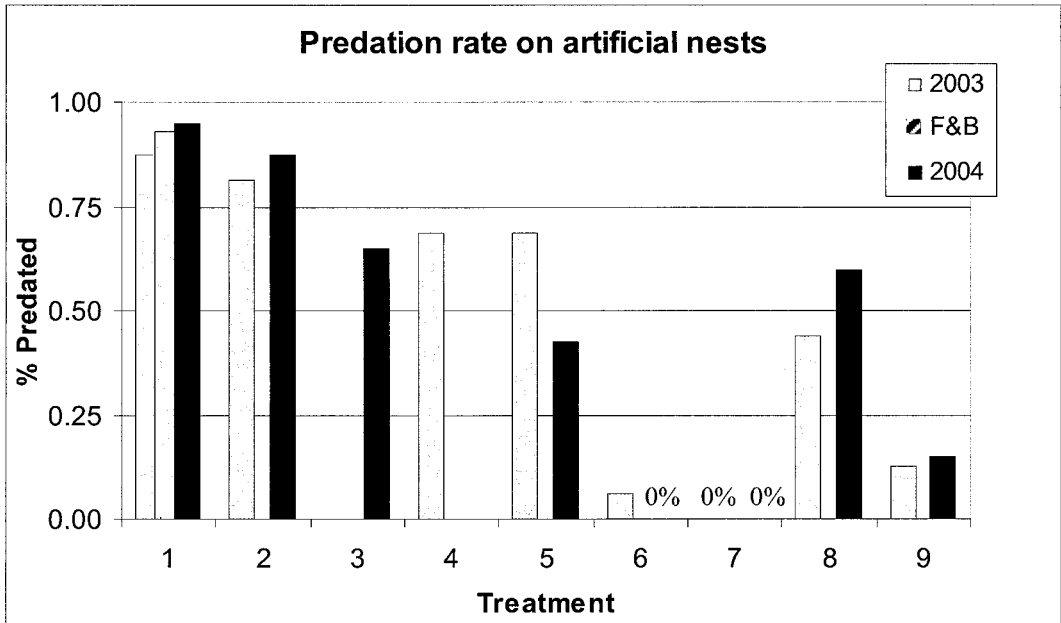


Fig 1. Comparison of depredation rates on real terrapin nests (F & B = Feinberg and Burke, 2003) with artificial nests constructed in 2003 and 2004. See text for description of treatments.

the flags themselves that indicate nest locations to raccoons but digging and/or the scent of terrapins instead. These results differ from those found by Mroziak et al. (2000) who found that sea turtle nests covered by antipredator cages were depredated by raccoons at higher rates than noncaged nests. They also found that most depredation on caged nests occurred in the latter half of incubation (Mroziak et al. 2000), but even if compared immediately after oviposition, caged nests were depredated at higher rates than noncaged nests (K. Rusenko, pers. comm.). Raccoons at their site were so highly trained to the use of cages as cues that any cages left on the beach, with or without nests, were excavated (K. Rusenko, pers. comm.). We have not detected a similar phenomenon at flagged terrapin nests at JBWR.

We further considered the possible impact of other cues that might indicate the locations of terrapin nests to raccoons, such as human scent, increased soil moisture, subsurface soil disturbance, flag color, "Diamond-Backed Terrapin-scent," and "ocean water scent." We found that flag color had no apparent influence on predation rates. A dramatic result we detected was associated with Treatment 7, in which human scent was deliberately augmented. This treatment had significantly lower predation rates than our main control (Treatment 1). This indicates that raccoons are not attracted to real terrapin nests by human scent as we expected, and they may actually be repelled.

Results from Treatment 5 indicate that nest excavation, even when carefully refilled and, in the absence of other cues, can serve to raise predation rates to levels similar to the control (1). We conclude that soil disturbance, perhaps detected visually, is an important cue indicating nest location to raccoons. Researchers

who avoid disturbing the soil surface around nests may avoid influencing predation rates.

The sand surrounding freshly laid terrapin nests is typically damp (RLB, pers. obs.), and this is presumably caused by voiding of the turtle's bladder prior to egg laying, as has been observed in other turtles (RLB, pers. obs.; Patterson, 1971). Patterson (1971) found that this liquid facilitated digging and delayed predation. In contrast, we found that artificial "nests" made with ocean water (8) had much greater levels of predation (44–60%) than did similar nests made with fresh water (9, 13–15%). These differences were large but not statistically significant. However, when coupled with the observations that those nests made with fresh water alone (9) were depredated significantly less than the control, and that ocean water poured on the ground (8) resulted in significantly higher "depredation" rates than flags alone, these results suggest that raccoons distinguished between the scent of fresh water and the scent of ocean water. Thus, the presence of ocean water may serve as an important olfactory cue to predators, and this should be investigated further. For example, this result might be different for raccoons that routinely depredate nests of freshwater turtles, rather than those of terrapins.

Our results should reassure researchers studying reptile nests and predation rates that markers, even as conspicuous as flags, may not influence predation rates. Further, our results suggest that both surface soil excavation and turtle scent, together or separately, can be important cues for predators. Researchers that do not alter either of these factors may have little or no influence on nest predation rates.

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Sex Differences in Body Size and Ectoparasite Load in the Ball Python, *Python regius*

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ABSTRACT.—Sexual dimorphism in body size, body condition (body mass relative to body size), and relative head size was investigated on 1250 field-caught *Python regius* (Togo, western Africa). Sexual dimorphism was often undetectable in neonates. By contrast, sexual dimorphism was apparent for many traits in adults. Adult females were larger and had a higher body condition than males; they also had longer jaws relative to their body size. This suggests that females and males follow different growth trajectories from birth to adulthood. In support of this, neonate females had a higher postnatal growth rate than males. Fecundity was strongly correlated with body size in females; a larger body size may be favored by fecundity selection in this sex. Our data show that females mature at a large body size: 95 cm in snout–vent length (SVL). The estimated external parasite load (number of ticks) was higher in adult males than females, perhaps because males encounter more ticks during movements.

Sexual size dimorphism is widespread among animals, and its evolutionary interpretation has attracted considerable scientific attention (Darwin, 1871; Campbell, 1972; Wade, 1976; Shine, 1986). Sexual dimorphism is well documented in snakes, involving a variety of traits such as body size, body shape, head dimensions, tail length, size at maturity, coloration,

scalation, and body plan (Fitch, 1981; King, 1989; Shine, 1991, 1993, 1994; Bonnet et al., 1998). Sexual dimorphism in such traits may be generated by sexual selection (for instance, larger body size in males relative to females being favored by male–male combat; Shine, 1978, 1994); selection for fecundity (for example, large female's body size being favored because it provides more space to hold the clutch; Shine, 1989, 1993); ecological factors (such as dietary divergence between the sexes; Shine, 1986, 1989; Camilleri and Shine, 1990); or different combinations of these selective forces (Shine, 1989, 1993).

In reptiles, analysis of the evolutionary processes influencing sexual dimorphism and their ecological

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