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Nest-Site Selection in the Eastern Box Turtle, *Terrapene carolina carolina*, in Illinois

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ABSTRACT. — We characterized the microhabitat features of nests constructed by eastern box turtles, *Terrapene carolina carolina*, in central Illinois. All nests were sited in open habitats; 87.5% of them were depredated within 72 hours of oviposition. Nest sites differed from random sites in vegetation height and composition, percentage ground and canopy cover, and light intensity. Land management practices that provide open areas suitable for box turtle nesting activity might make these areas more attractive to potential nest predators.

Patterns of habitat selection are an important aspect of the natural history of an animal because of the potential impacts on individual fitness (e.g., offspring production and survivorship). Nest site selection is critical to oviparous taxa. Developing embryos at selected sites have a greater chance of survival than those at random sites (Wilson 1998); thus, natural selection should favor the evolution of nest-site selection (Schwarzkopf and Brooks 1987; Temple 1987; Kolbe and Janzen 2002). Research

has shown that many turtle species actively select specific locations or microhabitats for their nests (e.g., *Malaclemys terrapin* [Burger and Montecvecchi 1975], *Kinosternon baurii* [Wilson 1998], *Chelydra serpentina* [Kolbe and Janzen 2002]). The choice of a nest site is important because it will influence the likelihood of predation of both eggs and hatchlings as well as affect the temperature and moisture content at which the eggs develop (Bodie et al. 1996; Dodd 2001). The microhabitat (primarily soil moisture content and temperature) surrounding the nest site affects the developmental rate (Cagle et al. 1993), the sex of offspring (Wilhoft et al. 1983), and some fitness characteristics of the hatchlings such as size and growth rate (Burger 1976; Packard et al. 1985; Janzen 1993).

Terrapene carolina carolina (eastern box turtle) is a terrestrial turtle found predominantly in deciduous forests and woodlots throughout much of the eastern United States (Conant and Collins 1991). Here, we examined nest sites of *T. c. carolina* on a multipurpose tract of land in central Illinois to determine if nest sites differed in microhabitat variables compared to those of random sites.

Methods. — The study was conducted at the Rhodes-France Scout Camp (RFSC) in western Shelby County, Illinois. RFSC contains 200 ha of mainly oak-hickory forest, 40 ha of which are used by the scouts (primarily in June and July) and camp staff who have built permanent structures (buildings and pavilion support posts) and created various open areas within the forest for campsites. The camp is bordered on the north and west by agricultural fields (corn, soybean, alfalfa) and on the south and east by a grazed cattle pasture. We restricted our study to the eastern third of the camp (containing all RFSC camping sites).

Beginning in April 2001, female turtles ($n = 15$) with a carapace length of greater than 120 mm had a radio transmitter (Advanced Telemetry Systems model 7PN) glued to the right posterior of the carapace using rubber silicone sealant. Mean transmitter mass was 35 g, or 7.5 % of the subject mass (mean ± 1 SD = 468.3 \pm 108.0 g). After affixing the transmitter, we released each turtle at its site of capture. We assumed that oviposition would take place from late May to early June (Ernst et al. 1994; Phillips et al. 1999). As such, all females carrying transmitters were located in the first week of May 2001 and radiographed to determine presence of shelled eggs. We recorded the clutch sizes of the gravid females (only 5 of the 15 originally outfitted with transmitters) and returned them to their capture sites.

The 5 subjects were located daily, at which time we recorded their position (using a Magellan Map410 geographic positioning system), activity, and mass (± 0.1 g). Box turtles often nest in the evening hours (Legler 1960; Congello 1978; Dodd 2001) so we always located females between 1700 and 2100 hours to increase the chance of finding a turtle while it was nesting. We also searched both forested and cleared areas of RFSC for nesting activity by unmarked females (each of which,

Table 1. Kolmogorov–Smirnov results for measured microhabitat variables of eastern box turtle nest sites ($n=24$) and random sites ($n=75$) at Rhodes–France Scout Camp, Shelby County, Illinois, during summer 2001.^a

Variable	Nest sites	Random sites	χ^2 value	p value
% Woody vegetation	0.0 \pm 0.0	10.9 \pm 20.1	21.73	< 0.001
% Bare ground	39.1 \pm 36.0	15.5 \pm 24.4	9.60	0.02
% Leaf litter	3.3 \pm 4.9	26.6 \pm 28.6	15.50	< 0.001
% Herbaceous cover	59.5 \pm 35.5	47.2 \pm 34.2	4.98	0.17
% Canopy cover	25.6 \pm 39.1	71.3 \pm 38.3	19.92	< 0.001
Light intensity (lux)	656.7 \pm 399.3	138.7 \pm 216.2	31.20	< 0.001
Vegetation height (cm)	8.3 \pm 4.8	37.4 \pm 46.3	18.67	< 0.001

^a Means are reported \pm 1 SD.

when found, was subsequently marked with a unique set of notches filed on the carapace). Locating females in the evening hours made it relatively easy to determine if a female would lay eggs that night. We located an additional 19 nesting females in this manner for a total of 24 nests, all constructed between 17 June and 5 July.

If a female was active when found, she was observed from a distance (≥ 5 m) every half hour until nightfall to determine if she was nesting or until oviposition was completed. We recorded nesting dates and precipitation data for Pana, Christian County, Illinois (Midwest Climate Center, approximately 14 km away from RFSC). We determined the coincidence of nesting activity with precipitation events using a χ^2 goodness-of-fit test ($\alpha=0.05$).

To minimize disturbance at the nest prior to hatching, we waited until July to quantify the microhabitat of nest sites using methods similar to those of Wilson (1998). We visually estimated the proportion of each of the following characteristics within a 1-m² area centered on each nest site: bare ground, herbaceous plants, woody plants, and leaf litter. Vegetation height was measured to the nearest 10-cm interval with a measuring tape. We measured canopy cover with a spherical densiometer, and light intensity with a light meter (Extech Instruments, ± 1 lux).

Also in July, the same microhabitat measurements were recorded at 75 randomly selected sites within the same area of RFSC in which all nests were found. We located these sites by pacing randomly determined distances along 100-m parallel transects spaced 15 m apart within the study area (i.e., a transect could include both forested and relatively open habitat). Random sites were marked with a flag that defined the center of the 1-m² plot for vegetation measurements. The microhabitat features from nesting and random sites were then compared using Kolmogorov–Smirnov goodness-of-fit (KS) tests for continuous data ($\alpha=0.05$; Zar 1999).

Results. — We located 24 nests from both marked and unmarked females, usually by direct observation of nesting activity. Half of the females (50%) constructed nests during or within 24 hours of a precipitation event, but there was no relationship between the occurrence of rainfall and nesting activity ($\chi^2=2.06$, $p=0.72$). All subjects constructed nests in either open areas within the

camp (campsites or unpaved roadways) or a grazed meadow bordering the eastern boundary of the camp. Twenty-one of the nests (87.5%) were destroyed by predators within 72 hours of oviposition, with 18 of these depredation events occurring within 24 hours of oviposition. The relative clutch mass of the remaining 3 nests averaged 0.10 (following Shine and Schwarzkopf 1992).

Nest sites differed from random sites in percentage of woody vegetation, bare ground, leaf litter, canopy cover, vegetation height, and light intensity. When compared to random sites, nest sites were characterized as having shorter vegetation, less leaf litter, more bare ground, less woody vegetation, less canopy cover, and higher light intensity than random sites (KS tests, $p < 0.02$; Table 1). Herbaceous cover did not differ between nest sites and random sites ($p=0.17$).

Discussion. — Of the 24 nesting events observed, 21 ended in depredation of the nest (most within 24 hours). Although we could not positively identify the predator(s) that destroyed the nests (see Temple [1987] for possible taxa), we suspect that raccoons were responsible for the majority of the predation. In spite of a trapping and removal effort by the RFSC staff, our site has relatively high raccoon abundance, perhaps because of other sources of supplemental food (i.e., young campers leaving food around their campsites). Given the pattern of land use at RFSC, female box turtles at this site oviposited their eggs in areas that are less than ideal for survival.

All female box turtles at RFSC constructed nests at sites that differed from random sites for all variables except percentage of herbaceous cover. The subjects placed their nests in open areas within RFSC or in a meadow adjacent to the camp. Previous studies have indicated that nesting female turtles usually construct nests in areas that receive sufficient sunlight and are free of debris (Legler 1960; Congello 1978; Messinger and Patton 1995) because such areas are warmer than sites with lower light levels and high canopy cover. Bare ground that is free of debris would ease nest cavity construction whereas tree and shrub roots in wooded areas might make digging a nest cavity more difficult. Females were easier to find in the open areas than in wooded areas and this might also explain why none were discovered nesting in the forest.

The fact that all the females in this study nested in disturbed clearings (campsites, roadways, or grazed fields) is important for at least 2 reasons. First, it indicates that anthropogenic open patches of habitat might have a potential use in helping increase turtle numbers for populations threatened by habitat loss. Secondly (and conversely), nesting in disturbed habitats may produce a negative effect on turtle populations by decreasing female reproductive success in areas where human disturbance is greater. The use of habitats for nesting that are different from habitats utilized during other parts of the activity season also has conservation implications. If the foraging range of a box turtle were protected, but not the nesting habitat, the loss of quality nest sites might lead to decreased egg and hatchling survival (Wilson 1998; Tucker and Paukstis 1999). Some daily movement distances by our subjects prior to nesting exceeded 500 m (straight-line distance) indicating that nesting habitats are potentially separate patches of habitat within a larger mosaic.

Populations of *Terrapene* species have declined (Williams and Parker 1987; Doroff and Keith 1990; Schwartz and Schwartz 1991), and they are listed on Appendix II of the Convention on International Trade of Endangered Species of Wild Fauna and Flora (US Fish and Wildlife Service 1995). Information about nest site selection is important for management-related strategies (Landers et al. 1980; Dodd and Franz 1993). At RFSC, neither turtle nesting areas nor foraging ranges are protected, although the scouts using the camp each year are cautioned not to disturb any turtles they encounter. We are encouraged by the multipurpose land use practice at RFSC that promotes wildlife education among the scouts (and appears to have made the entire staff especially responsive when box turtles enter camping areas). Continuing this pattern of stewardship at RFSC can ensure a sustainable population of *T. c. carolina* because of the availability of nesting sites on the property.

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Diet of *Podocnemis unifilis* (Testudines, Podocnemididae) During the Dry Season in the Mamirauá Sustainable Development Reserve, Amazonas, Brazil

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ABSTRACT. – Stomach contents of *Podocnemis unifilis* sampled in white water *varzea* forest during the dry season in the Mamirauá Sustainable Development Reserve (Middle-Solimões River) had plant material in 100% of cases, with Poaceae and Bombacaceae the most frequently recorded. Poaceae leaves (67.7% frequency) and seeds (21.5% frequency) were common, as were fibers of the fruit *Pseudobombax munguba* (Bombacaceae; 38.5% frequency), with fruits in general contributing 45.9% of volume. Animal material was consumed in much lesser quantities—only 0.8% of total volume—but had a 37% frequency.

Ontogenetic changes and sexual differences in the composition of the turtle diet have been noted for some species of turtles (Graham 1971; Plummer and Farrar 1981; Hart 1983; Bury 1986; Moll 1990). The influence of age is perhaps due to changes in the physiological needs of the turtles, with an ontogenetic change from animal to plant matter. Smaller turtles often need to assimilate animal protein rich in calcium and proteins to allow them to grow rapidly (Hart 1983). As the turtle grows, energy restrictions may partially explain why they reduce the intake of animal prey. Small turtles, having less mass,

spend less energy searching for prey compared to larger individuals (Parmenter and Avery 1990), and the return obtained from small prey does not make up for the energetic cost for obtaining them (Georges 1982).

The influence of sex on variation in diet might be related to distinct physiological needs between males and females. Ramo (1982), studying *Podocnemis vogli* in Venezuela, found that males fed mainly on plant matter, while females fed more on mollusks and fish, and that this difference may have been due to calcium requirements for the formation of eggs. However, this remains hypothetical for turtles.

Podocnemis unifilis is widely distributed throughout the Amazon Basin in rivers and lakes, making it an important protein source for local inhabitants. There is marked sexual dimorphism, with females reaching 46.5 cm in carapace length and males 33.5 cm (Pritchard and Trebbau 1984). Previous studies on the diet of *P. unifilis* have been conducted in the wild (Medem 1964; Smith 1979; Almeida et al. 1986; Portal et al. 2002), in captivity (Acosta et al. 1995; Malvasio et al. 2003), and in black water habitat (Fachín et al. 1995). However, no study has focused on possible ontogenetic and sexual shifts in the diet of this species in *varzea* habitat (white water flooded forest). This was the aim of our study.

Methods. — We studied *P. unifilis* in the dry season in the Mamirauá Sustainable Development Reserve (MSDR). The MSDR is located on the floodplain between the Middle-Solimões and Japurá rivers, near Tefé, Amazonas, Brazil, covering an area of 1,124,000 ha. Being inundated by white water rivers, the forest in the MSDR is classified as *varzea*. The main characteristic of this environment is seasonal variation in water levels (Junk et al. 1989), associated with high loads of suspended and dissolved fertile matter (Junk 2000), allowing the production of large amounts of macrophytes, with the predominant species in the MSDR being *Paspalum repens*, *Echinochloa polystachya*, *Eichhornia crassipes*, *Pistia stratiotes*, and *Salvinia* spp. (Crampton 1999).

The wet season in the region extends from December to March, with the mean annual rainfall more than 2500 mm for Tefé. Temperature is practically constant year round; the daily average in 1984 was 29.5°C (Sociedade Civil Mamirauá 1996). Our study was undertaken in the Jarauá sector of the MSDR, located at 2°51'S, 64°55'W. Sampling included 15 lakes and 5 *ressacas* (portions of river channels that dry up or have their surfaces totally covered by macrophytes during the dry season).

We captured turtles in the dry season from September to December 2001. Turtle populations are more concentrated during the dry season than wet season, when animals are dispersed in the high waters of the flooded forest. We captured turtles using trammel nets; in each site, we used 430 m² of netting, corresponding to 2 trammel nets 82-m long and 2.65-m high each. The mesh size of the inner net was either 10 or 20 cm between knots, which allowed the capture of mid-size and large turtles. We