

Terrestrial Movements and Microhabitat Selection of Overwintering Subadult Eastern Mud Turtles (*Kinosternon subrubrum*) in Southwest Georgia

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ABSTRACT.—Although there is increasing recognition of the importance of terrestrial habitat to aquatic fauna, little is known about the specific habitat requirements of these species at a fine scale within the terrestrial landscape. Our knowledge of subadult life stages of many species, specifically aquatic turtles, is particularly depauperate. We used radio-telemetry to determine the timing and extent of terrestrial movements of 11 subadult Eastern Mud Turtles, *Kinosternon subrubrum*, during the winter. We also quantified microhabitat variables (ground cover composition, shrub cover, and canopy cover) of temporary refugia and overwintering sites (hibernacula) of radio-tagged turtles. On average, hibernacula sites were 72 m from the wetland (defined as the water's edge). Turtles remained at hibernacula a mean of 107 days before emerging in the spring. Radio-tagged turtles selected winter hibernacula with a large component of leaf and pine litter and less tree cover than temporary refugia. The leaf litter may provide stable temperature and soil moisture at hibernacula for overwintering turtles, whereas the open canopy may expose turtles to relatively higher temperatures in the spring prior to emergence.

The conservation implications of terrestrial movements by aquatic fauna has recently received attention (e.g., Bennett et al., 1970; Burke and Gibbons, 1995; Semlitsch and Bodie, 2003), yet basic information for freshwater turtles, such as a description of upland refugia, is lacking for many species. Aquatic turtles in the genus *Kinosternon* often make extensive use of terrestrial habitat for nesting, overwintering or for dispersal to other wetlands (Skorepa and Ozment, 1968; Bennett, 1972; Gibbons, 1983; Buhlmann and Gibbons, 2001). Although the importance of terrestrial buffers around wetlands to accommodate these activities in turtles has become increasingly well recognized (Burke and Gibbons, 1995; Semlitsch and Jensen, 2001), little is known about the specific habitat requirements of nesting and overwintering turtles within the terrestrial landscape. This is of particular concern in the southeastern United States, where management activities such as application of prescribed fire may influence habitat quality at this scale. Wilson (1999) examined nest site selection in Striped Mud Turtles (*Kinosternon bauri*) at the microhabitat scale and determined that turtles nested more often in proximity to grasses or other herbaceous vegetation than at random, more open sites. Vegetative cover near the nests is thought to ameliorate thermal extremes. One might expect a similar effect of vegetation on overwintering turtles. No study that we are aware of has examined overwintering sites of mud turtles at the microhabitat scale.

Although dispersal to terrestrial winter refugia has been fairly well documented in adult mud turtles, much less is known about subadult turtles. Eastern Mud Turtles (primarily adults) at a wetland in South Carolina moved a maximum of 134.5 m from a wetland to refugia in mixed oak/pine forest and a pine plantation, where they burrowed in loose sandy soils (Buhlmann and Gibbons, 2001). Reports of movements up to 300 m from a wetland to winter

refugia have been reported (Bennett, 1972). However, movement patterns of subadult turtles may differ from those of adults (Gibbons, 1986). A lack of movement information for subadult mud turtles is not surprising, as they are cryptic and often difficult to trap (Ream and Ream, 1966). However, it is essential to better understand habitat requirements, including at the microhabitat level, of all life stages.

In this study, we monitored movements of subadult Eastern Mud Turtles at a seasonal wetland in southwest Georgia, and used radio-telemetry to identify winter hibernacula. We then examined characteristics of hibernacula and temporary refugia to determine whether turtles were selecting particular microhabitats.

MATERIALS AND METHODS

Study Area.—This study was conducted at the Joseph W. Jones Ecological Research Center at Ichauway (31°13'N, 84°29'W), an approximately 11,500-ha reserve in Baker County, Georgia. Ichauway is primarily a longleaf pine (*Pinus palustris* Miller) forest with undisturbed, native ground cover. The property is managed intensively with prescribed fire to maintain a pine/grassland community. Scattered individual hardwoods and hardwood patches exist within the longleaf pine matrix as a result of natural and manmade fire shadows. The property has over 30 seasonally inundated isolated wetlands including the study wetland.

The study wetland basin is 0.56 ha in size and contains blackgum (*Nyssa sylvatica*), buttonbush (*Cephalanthus occidentalis*), persimmon (*Diospyros virginiana*), and mixed grasses and sedges. The wetland is surrounded by mixed pine (*Pinus* spp.)/hardwood (*Quercus virginiana* and *Quercus nigra*) with patchy native ground cover that includes wiregrass (*Aristida stricta*) and broomsedge (*Andropogon* spp.). The wetland is enclosed in a drift fence with paired pitfall traps at 20-m intervals around the fence. Pitfall traps are checked every one to two days, depending on rainfall patterns.

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Movements and Microhabitat Characterizations.—From October 2005 through June 2006, subadult Eastern Mud Turtles captured at the drift fence were measured to the nearest 1 mm (straight-line carapace length), weighed, and individually marked by shell notching (Cagle, 1939) and with passive integrated transponders (PIT, Biomark, Inc., Boise, ID). Passive integrated transponders were approximately 11 mm long, weighed <0.1 g, and were implanted using methods described in Buhlmann and Tuberville (1998). From 31 October through 2 November 2005, we radio-tagged 11 subadult mud turtles (56–70 mm carapace length; Frazer et al., 1991; Ernst et al., 1994) as they exited the wetland to determine dispersal distances and identify winter refugia sites. Transmitters (model BD-2, Holohil Systems, Ltd., Ontario, Canada.) weighed 1.8 g (approximately 4% of the turtle's body mass) and were attached to the posterior vertebral scute with epoxy.

All turtles were released within 96 h of capture on the opposite side of the fence. Radio-tagged turtles were tracked 1–2 times a week until they stopped moving and were located approximately once a week thereafter. In late February, when short (<1 m) subterranean movements were detected, we began locating turtles approximately every other day to identify time of emergence. When transmitter batteries failed toward the end of the study, we were able to confirm the presence of turtles within hibernacula by scanning the sites with a PIT tag reader. Because the sites were not always visited daily, all estimates regarding the timing of turtle movements were accurate to within 0–3 days.

At each location, we recorded whether turtles were above or below ground. Below ground sites where a turtle spent more than 30 days were considered hibernacula. All other below ground sites were considered temporary refugia. Microhabitat variables for hibernacula and temporary refugia were quantified (via visual estimation) within a 1-m² quadrat centered around the turtle using the following cover class categories: <1%, 1–5%, 6–15%, 16–25%, 26–50%, 51–75%, 76–100%. Variables measured included bare ground, litter (including leaves and pine straw), coarse woody debris, herbaceous ground cover (≤ 0.25 m), woody ground cover (≤ 0.25 m), and shrubs (woody cover ≤ 1 m). In addition, we estimated the tree canopy cover within the quadrat with a spherical densiometer. Means were presented ± 1 SD. We used Arcmap to select 30 random points (roughly equal to the number of turtle locations) within a 90-m buffer around the drift fence. This buffer represented the maximum dispersal distance (straight-line distance between the water's edge and final location) of tagged turtles. Microhabitat data, as described above, were collected at all turtle locations and random points on the same day, within 40 days of the turtles first reaching their hibernacula (turtle locations were revisited). We used a chi-square test to determine whether mean percent cover (calculated using cover class midpoints) differed among hibernacula, temporary refugia, and random sites.

The wetland dried down to four shallow pools of water during the study. To obtain an accurate estimate of dispersal distance over land, we measured the distance from each turtle location to the

nearest water's edge, hereafter referred to as "water edge," with a Trimble Pathfinder® Pro XR GPS (Global Positioning System). The GPS was accurate to within 1 m. We also determined the distance from hibernacula to the wetland jurisdictional boundary, hereafter "wetland basin," based on GIS landcover data. Turtle locations were recorded with a GEO3 GPS (Trimble Navigation, Ltd., Sunnyvale, CA) handheld unit with an accuracy of ± 1 –5 m. Straight-line distance between locations (including the distance between the nearest water edge and capture point) was determined with ESRI's Arcmap version 9.1 and Hawth's Tools for ArcGIS. In February 2006, prior to emergence, we measured the depth of the turtles (from the soil surface to the top of the carapace) by probing the hibernacula sites.

RESULTS

Hibernacula.—Turtles reached hibernacula sites 11 ± 8 days after release at the drift fence (range = 0–24 days). On average, turtles used three different sites (range = 1–5), including their eventual hibernacula site. Turtles traveled a total distance (straight-line distance between recorded locations) of 106 ± 48 m (range = 40–198 m) from the water's edge to hibernacula sites. Hibernacula sites were 72 ± 30 m straight-line distance from the nearest water's edge (range = 24–108 m) and 67 ± 27 m from the wetland basin (range = 19–98 m). Four of the turtles used temporary refugia for a mean of eight days prior to settling at hibernacula sites. On average, turtles spent 107 ± 11 days (range = 92–121 days) at hibernacula. Turtles did not aggregate during hibernation; the closest individuals were 16 m apart. In hibernacula sites, turtles were 1.9 ± 1.1 cm below the substrate surface (range = 0.1–3.9 cm).

Microhabitat variables differed between temporary refugia and overwintering hibernacula ($\chi^2 = 14.3$, df = 6, $P < 0.0001$) and between turtle locations and random sites (temporary refugia vs. random sites: $\chi^2 = 73.0$, df = 6, $P < 0.0001$; hibernacula vs. random sites: $\chi^2 = 40.9$, df = 6, $P < 0.0001$). Hibernacula sites had more litter, less herbaceous cover, and less tree cover than temporary sites (Table 1). Hibernacula differed from random sites in that they had higher coverage of litter, herbaceous plants, and shrubs.

Emergence.—Two peaks of emergence from hibernacula were detected, four turtles emerged between 22 February and 24 February, and five turtles emerged between 9 March and 12 March. The remaining two turtles emerged on approximately 16 February and 3 March.

Nine of the 11 radio-tagged turtles were recaptured at the drift fence as they attempted to enter the wetland in spring of 2006. Two radio-tagged individuals were not recaptured over the course of the study. The time between emergence from hibernacula to recapture at the drift fence for the nine turtles was 31 ± 28.1 days (range = 1–92 days). Turtles rarely entered and exited the wetland at the same location. On average, turtles were recaptured 79 ± 53.5 m (range = 0–160 m) from their original capture site along the drift fence.

TABLE 1. Microhabitat characteristics of terrestrial refuge sites of subadult Eastern Mud Turtles, *Kinosternon subrubrum*, in Southwest Georgia. Hibernacula were sites where a turtle spent more than 30 days, whereas all other below ground sites were considered temporary refugia.

Microhabitat variables (% cover)	Hibernacula (N = 11)	Temporary refugia (N = 15)	Random locations (N = 30)
	Mean \pm 1 SD	Mean \pm 1 SD	Mean \pm 1 SD
Bare ground	2.4 \pm 3.8	1.8 \pm 3.3	7.4 \pm 22.1
Litter	81.4 \pm 20.4	67.7 \pm 29.9	66.2 \pm 32.9
Coarse woody debris	4.8 \pm 10.9	8.7 \pm 22.4	2.4 \pm 3.9 ^a
Woody ground cover	17.6 \pm 12.2	12.7 \pm 12.5	9.5 \pm 11.5
Herbaceous ground cover	37.0 \pm 37.5	53.0 \pm 34.8	26.0 \pm 32.0
Shrub cover	26.4 \pm 21.1	26.5 \pm 27.1	11.4 \pm 15.0
Tree cover	44.9 \pm 18.5	57.4 \pm 13.5	48.5 \pm 21.4

^a N = 29.

DISCUSSION

In this study, subadult Eastern Mud Turtles hibernated, on average, 72 m from the water's edge (67 m from wetland basin), which is comparable to that reported for adult turtles in other studies (44.6 m, Buhlmann and Gibbons, 2001; approximately 45 m, Wetmore and Harper, 1917; 100 and 300 m, Bennett, 1972), and our results further emphasize the critical importance of upland habitats to freshwater turtles (e.g. Burke and Gibbons, 1995). Subadult mud turtles also traveled considerable distances before reaching their hibernacula (up to 198 m), suggesting an even more extensive use of the landscape surrounding the wetland. In addition, although we did not monitor movements after emergence from hibernacula, turtles spent up to 92 days in the uplands before reentering the wetland, indicating that mud turtles make use of the terrestrial environment during the active season as well.

Our findings indicate that subadult Eastern Mud Turtles select winter hibernacula with higher components of litter and woody and herbaceous species in the ground cover than random sites. Hibernacula also had higher shrub cover than random sites and a more open tree canopy than temporary sites. The litter may provide stable temperature and soil moisture at hibernacula for overwintering turtles, whereas the open tree canopy may expose turtles to relatively higher temperatures in the spring prior to emergence. However, effect of increased ground cover and decreased canopy cover on the microenvironment of hibernacula site was not determined in this study.

Our results provide support for use of prescribed fire to manage uplands and embedded isolated wetlands in the southeastern United States. In the absence of fire, or if prescribed fire is applied during winter months when wetlands typically contain water, hardwoods (including oaks in particular) can become established in and around isolated wetlands in the longleaf pine ecosystem (Kirkman, 1995; Kirkman et al., 2000). Many of these oaks are fire resistant and can ultimately form a closed canopy that shades out herbaceous ground cover. Growing season (spring and summer) fires may suppress oaks in the understory, creating a shrub layer that is apparently important to overwintering subadult Eastern Mud Turtles and may further enhance habitat by maintaining an open canopy with abundant herbaceous ground cover. Further studies are needed to

determine whether juvenile and adult Eastern Mud Turtles, and other species, show a similar pattern in microhabitat selection in terrestrial habitats. In situations where hardwood succession has occurred around isolated wetlands, mechanical removal of hardwoods may be needed to allow reintroduction of fire.

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