Movement Patterns and Habitat Use of Eastern Box Turtles at the Jug Bay Wetlands Sanctuary, Maryland

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Abstract: *Eastern box turtles (*Terrapene carolina carolina*) often are described as having small home ranges that are limited mostly to terrestrial habitats. In order to determine movement patterns, home range size, and habitat use of box turtles in a region including extensive wetland habitat (tidal and non-tidal), we initiated an investigation in fall 1998 at the Jug Bay Wetlands Sanctuary in southern Anne Arundel County, Maryland. We placed thread-trailing devices on 14 turtles in order to monitor hourly and daily movements. To determine larger-scale movements, habitat use, and home range size, we equipped three turtles with radio transmitters and monitored them from July to October 1998. Peak activity occurred between 10:00 a.m. and 1:00 p.m., based on observations of turtles with thread-trailing devices. Transmitter-equipped turtles used wetland habitats as often as terrestrial habitats, even though wetlands were much less extensive in the study area. Home range areas for these three turtles were 0.48 ha, 0.84 ha and 2.25 ha. Our study demonstrates that box turtles make extensive use of wetlands when available.*

Eastern box turtles (*Terrapene carolina carolina*) are distributed from southern Maine to Georgia and west to Michigan, Kansas and Texas (Ernst et al. 1994). Although box turtles have a broad geographical range and are considered common in many areas, they have experienced population declines in a number of locations (Stickel 1978, Williams and Parker 1987, Doroff and Keith 1990, Dodd 2001). Recent declines have been attributed to habitat destruction and fragmentation, over-collecting for the pet trade, mortality from vehicles on roadways, and chemical contamination of their environment (Dodd 2001). Anthropogenic factors, a late age of maturity and limited fecundity combine to make recovery from increased mortality difficult (Hall et al. 1999). Knowledge of the full range of habitats used by box turtles is crucial for conservation efforts that might be initiated to stabilize or increase their populations.

Habitat quality factors such as cool ambient air temperature, sufficient plant cover and moist soil (Reagan 1974) may influence turtle's activity patterns and use of habitat. For example, population density was greater and home range sizes were smaller for a box turtle population in a bottomland forest in Maryland that possessed many of these factors (Stickel 1950, 1989), than for populations in upland forests and fields in New York (Madden 1975). Madden attributed Stickel's (1950) higher densities to greater habitat diversity.

Although eastern box turtles often are described as primarily a terrestrial species, they may use aquatic resources for thermoregulation during periods of extreme heat (Ernst et al. 1994). An abundance of wetlands may increase overall habitat quality, especially during high summer temperatures. Ornate box turtles (*T. ornata*) living in deserts had larger home ranges than conspecifics living in more mesic habitats (Nieuwolt 1996). In order to assess the effect of habitat availability on movement patterns, home range sizes, and use of habitat, we employed thread-trailing devices and radio telemetry to study box turtles in wetlands and uplands in central Maryland.

Study Area

Our 45 ha study area was in the Jug Bay Wetlands Sanctuary on the tidal Patuxent River, Anne Arundel County, Maryland (Latitude 38° 46', Longitude 76° 42'). Public access in the sanctuary is limited to hikers, students and researchers.

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Wetland and aquatic habitats include tidal freshwater wetlands, small ponds, shallow streams, and forested non-tidal wetlands. Plant species in the tidal freshwater marshes are described in Odum et al. (1984). The upland forest, the dominant habitat in the study area, consists mostly of 30 to 80 year-old hardwood trees, dominated by American Beech (*Fagus grandifolia*), oak (*Quercus* spp.), Tulip-tree (*Liriodendron tulipfera*), Sweet Gum (*Liquidamber styraciflua*) and Red Maple (*Acer rubrum*), with an understory of American Holly (*Ilex opaca*) and Common Greenbriar (*Smilax rotundifolia*). A 1 ha managed meadow consists of grasses and forbs and six shrub patches.

Methods

Thread-trailing technique—Thread-trailing devices mounted to the rear carapace were used to examine the hourly and daily movement patterns of 14 turtles from 24 June to 21 July 1998. Each trailing device was a small sewing bobbin wound with 50 m of thread. This device weighed less than 10 g and the spools could be quickly changed in the field, causing little disturbance to turtles. Turtles were held overnight and were released the next morning at the point of capture. At release, the thread was tied to a plant, and the bobbin released thread as the turtle walked. Turtles were monitored hourly, when possible. Movement patterns were recorded by measuring the string trail left by the traveling turtle. The total string length (TSL) was recorded with a measuring tape to the nearest 0.5 m. Movements during each hour interval were mapped on graph paper. The straight-line distance (SLD) between the beginning and end of each observation period was recorded. Most turtles were monitored for an entire day (9:00 a.m. to 6:00 p.m., Eastern Daylight Time), after which the thread-trailing device was removed. Sample sizes varied across time periods because some turtles were not observed for an entire day.

Thread-trailing devices were left on eight turtles overnight to monitor night and early morning activity. Overnight sampling was performed on individuals that had stopped moving for several one-hour observation periods or were in resting forms. Three turtles broke free of the limited thread supply, but each was easily relocated and its total travel distance was estimated. However, distances traveled by overnight turtles were excluded from analyses because estimates of turtles that escaped thread-trailing devices represent minimum distances traveled (SLD), and overnight movements occurred during an unknown time period.

Radio Telemetry—Two males (#187 and #193) and one female (#195) were equipped with radio transmitters (Johnson's Telemetry; 50 g; 46 cm antenna). Turtle #187 was equipped with a transmitter on July 1; turtle #193 on July 9; and turtle #195 on July 13. Each individual weighed more than 500 g. Transmitters were attached with PC-7 epoxy to 2nd and 3rd vertebral scutes on males, and to 1st and 2nd rear pleurals on the female. We used silicone sealant to smooth the surface from the shell to the transmitter in order to prevent entanglement as the turtle traveled. Transmitter antennas were allowed to hang behind the turtle.

Each turtle was relocated almost every day in the morning (8:00 a.m. to 10:00 a.m.), afternoon (12:00 p.m. to 2:00 p.m.) and evening (4:00 p.m. to 6:00 p.m.) until August 1. Additional observations between August 28 and October 30 further refined home range size and shape. SLD from the previous observation was recorded at each observation. Turtle locations were plotted on a map that was divided into 20 m^2 grids. Home range sizes were estimated using the 100% minimum convex polygon method, and maximum home range length was determined by connecting perimeter observation locations on the gridded map.

Habitat Use—Habitats were categorized as forest, meadow, tidal wetland, or non-tidal wetland. Turtles observed within 10 m of meadow, non-tidal, and tidal habitats were considered associated with those habitats. Non-tidal wetland habitats included streams, floodplains, and muddy seepages. Habitat type was recorded for all turtles studied, however we only analyzed habitat use for the three turtles equipped with radio transmitters.

Weather conditions were recorded during each observation period. Ambient air temperature was recorded daily at the sanctuary weather station. Precipitation was recorded as rain, drizzle, or no precipitation. The potential effect of precipitation on movement could not be evaluated because little rain occurred during the sampling periods. Analysis of variance (ANOVA) and Tukey's multiple comparison tests were used to assess the relationship between movement and time period, movement and temperature, and habitat use and temperature. Significance levels for all tests were $p \leq 0.05$.

Results

Movements: thread-trailing technique—The actual distance (total string length or TSL) that a turtle traveled within a time period usually deviated from the measured straight-line-distance (SLD) between sightings as the time interval increased. For example, on one day female #191 traveled 99.5 m TSL between 8:30 a.m. and 5:50 p.m., but returned to within 5 m SLD of the location where she was originally released (Fig.1). Although the SLD for this turtle was much less than the TSL for a 1-day period, the difference between distance measurements was less for shorter time intervals (Fig. 1). Incidental observations and examination of thread-trails revealed that turtles changed direction frequently because of structures such as large logs in their path.

Average distance traveled per hour (10.3 m) peaked between 10:00 and 11:00 a.m. and decreased as the day progressed (Fig. 2). Only one individual traveled after 3:00 p.m. Travel distance varied through the day (Tukey's multiple-comparison test, $p < 0.05$), however, one-hour time periods were not different ($p > 0.05$). Six of seven turtles that were equipped with thread-trailing devices overnight traveled some distance before they were observed again at 9:00 a.m. We did not detect a relationship between ambient air temperature and distance traveled during one-hour intervals ($p > 0.05$). Turtles were active at all air temperatures recorded during the study (19°C to 35°C).

Movements: radio telemetry—The mean distance traveled by the three radio-equipped turtles was not different among observation periods ($p > 0.05$, Fig. 3). Mean distance traveled was 50 m per day, but distance varied considerably among individuals (14 m, 64 m, and 72 m per day). Mean distance traveled per time period differed among turtles ($p < 0.05$). We did not detect a relationship between ambient air temperature and distance traveled ($p > 0.05$). Turtles were active at all temperatures recorded (18°C to 36°C). Turtle #193 remained submerged in mud in the non-tidal floodplain area for more than a week when daily high temperatures exceeded 31°C.

Home Ranges—The home range size of three radio-equipped turtles was 0.48 ha (#193), 0.84 ha (#187) and 2.25 ha (#195). Mean home range was 1.19 ha (Fig. 4). Turtles #187 and #193 had home ranges of similar maximum length (approximately 170 m). Turtle #193 traveled more than 90 m between forest/meadow and wetland habitats, but did not appear to use much of intervening habitat, resulting in an elongated shape to his home range. Female

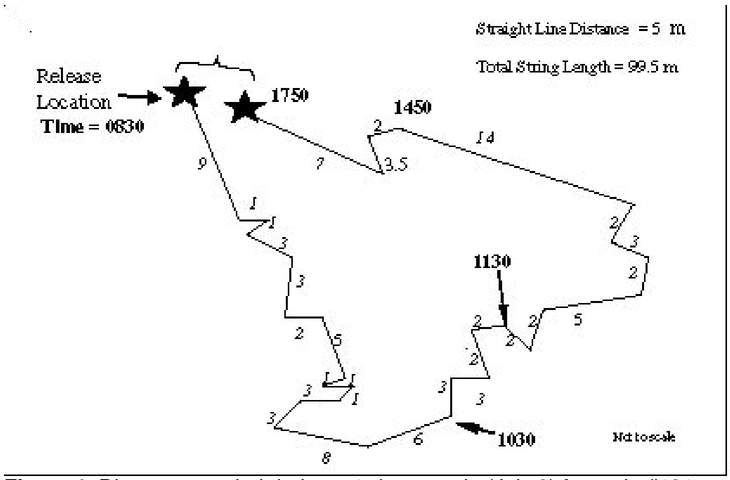

Figure 1. Distance traveled during a 1-day sample (July 8) for turtle #191 equipped with a thread-trailing device. Times in which the turtle reached the approximate location indicated are in bold. Numbers in italics represent trail segment lengths (m).

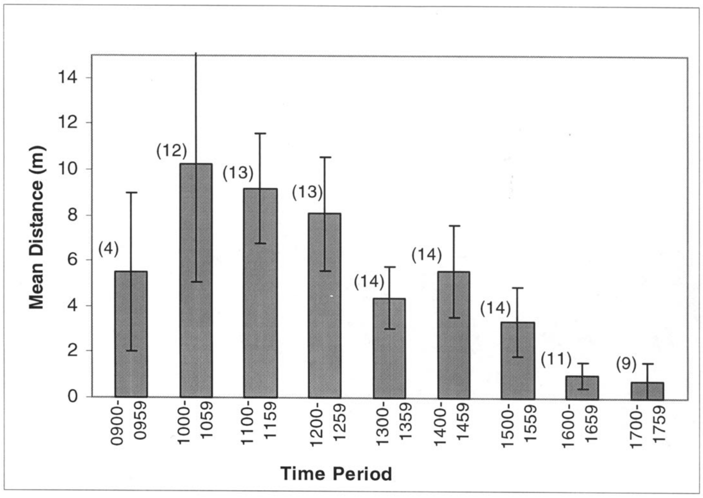

Figure 2. Mean distance traveled by box turtles equipped with thread-trailing devices. Standard errors and sample sizes are presented for each bar.

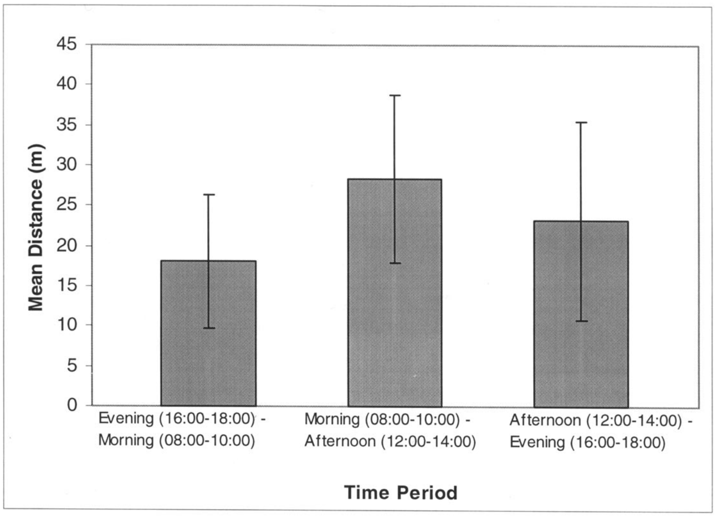

Figure 3. Mean distances traveled by three turtles equipped with radio-transmitters. Distances traveled were not different among time periods ($p > 0.05$). Standard errors are presented for each bar.

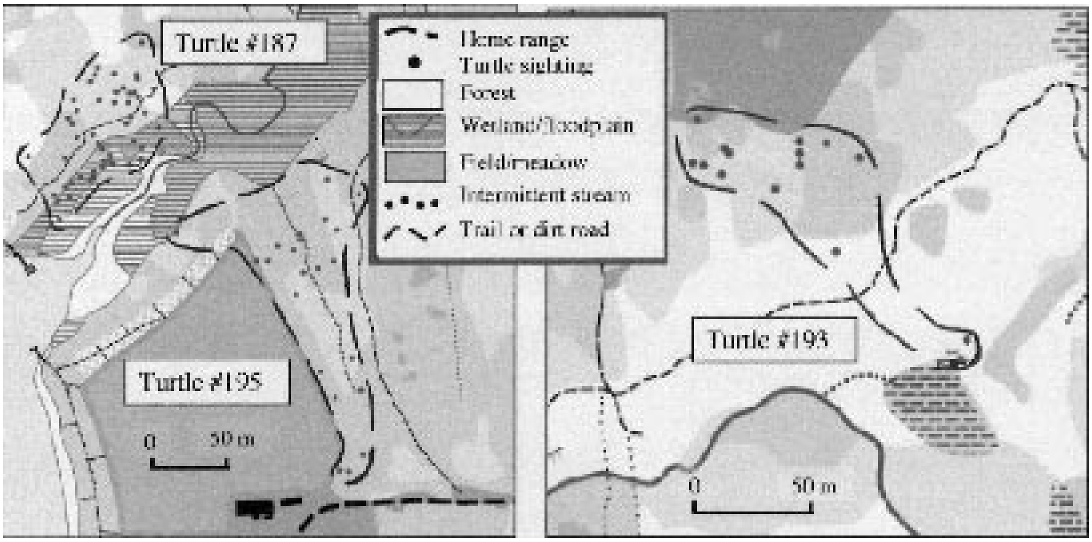

Figure 4. Home ranges of three radio-equipped Box Turtles.

#195 had the largest minimum convex polygon (2.25 ha) and the greatest maximum-length home range size (260 m).

Habitat Use—All radio-equipped turtles used wetlands and the creek floodplain. Turtle #187 was the only radio-equipped individual with a home range that encompassed tidal wetlands (Fig. 4). We grouped habitats as either wetland (tidal and non-tidal wetland) or upland (forest and meadow) because individual turtles did not have access to all habitat types. When sightings in these habitats were grouped, 52% of sightings were of turtles occurring in, or within 10 m of, wetland habitat. Individual turtles showed a similar pattern of wetland use: 48% of sightings of #187 were in or adjacent to a wetland, 45% for #193, and 64% for #195. Habitat use by the three radio-equipped turtles was greater for forest (40%) than non-tidal floodplain (36%), tidal wetland (16%), and meadow (8%) habitats (Fig. 5).

The mean temperature at which turtles were observed differed among habitat types ($p < 0.05$, Fig. 6). Turtles were observed in non-tidal wetlands (31°C) at higher temperatures than when they were observed in tidal wetlands (27°C), meadow (26°C), and upland forest (28°C). Temperature differences between grouped wetland (30°C) and grouped upland (28°C) habitats were not significant ($p > 0.05$). Two turtles showed tendencies for occupying wetland habitats at warmer temperatures: #187: 32°C (wetland) vs. 28°C (upland), and #193: 31°C (wetland) vs. 27°C (upland), but #195 deviated from this trend: 28°C (wetland) vs. 28°C (upland).

Discussion

The movements of the turtles was related to the time of day, but results were not significant among hours. Turtles equipped with thread-trailing devices seemed to be most active in the late morning to early afternoon and mostly inactive after 4:00 p.m. Stickel (1950) noted that box turtles in Maryland were only active during the day. Six turtles equipped with thread-trailing devices apparently traveled before our first morning sample, suggesting some early morning movement. The distance traveled by radio-equipped turtles peaked in the late morning to early afternoon time period, but these distances were

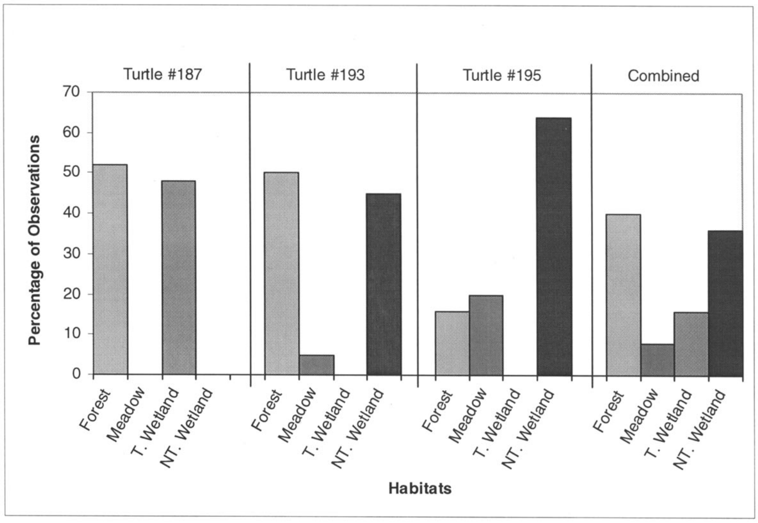

Figure 5. Percent of observations occurring in forest, meadow, tidal wetlands (T. Wetland), and non-tidal wetlands (NT. Wetland) for the three radio-equipped turtles and the combined habitat use for all turtles.

not significantly different from the other two time periods (early morning and late afternoon).

Turtles were active at all temperatures that occurred during our study: 18°C to 36°C. Stickel (1950) found both active and inactive turtles under favorable environmental conditions. Temperature can be an important influence on activity. Box turtles have a preferred body temperature between 24°C and 32°C and movements below 10°C are rare (Adams et al. 1989). Although we were not able to evaluate the effect of precipitation on movements, other researchers have noted increased turtle activity when it rains (Lemkau 1970, Dolbeer 1971, Madden 1975). Desert box turtles (*T. ornata luteola*) generally avoided activity during extreme temperatures unless it was raining (Nieuwolt 1996). Favorable environmental conditions (i.e. moist soil and high humidity) in bottomland habitats in summer may increase turtle activity (Stickel 1950). Extensive wetlands in our study area may provide conditions conducive to turtle movement at higher temperatures, conditions that are lacking in xeric habitats.

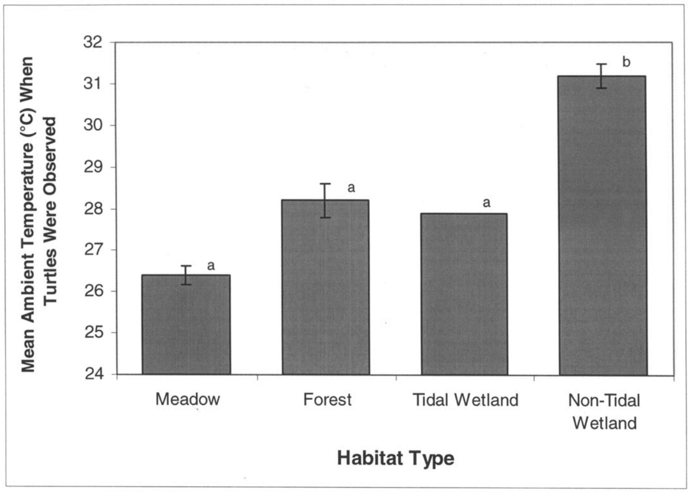

Figure 6. Mean ambient temperatures that radio-equipped turtles were observed in meadow (n = 2), forest (n = 3), tidal wetland (n = 1), and non-tidal wetland (n = 2) habitats. Letters identify significantly different groups (Tukey's multiple comparison test, $p < 0.05$). Standard errors are presented for each bar.

Thread-trailing devices were very effective for determining the exact distance traveled by a turtle over a short time period (e.g., one-hour). By using thread-trailing devices we were able to show that actual daily movement can be considerably greater than the SLD value that is commonly recorded using radio-telemetry. Turtle #191 (Fig. 1) was a striking example. Stickel (1950) reported that a turtle in her study area at the nearby Patuxent Wildlife Research Center in Laurel, Maryland, traveled 139 m in a day, but the straight-line distance was only 52 m. Moreover, we observed individuals in the same location (e.g., resting forms) during both consecutive and non-consecutive sampling periods. Furthermore, daily and seasonal shifts in movement may be missed when observations are infrequent. Re-sightings of radio-equipped or individually marked (notched) individuals that are separated by extended time intervals will represent minimal distances traveled and caution should be used when interpreting such results. Radio telemetry, however, was more useful for examining home range size and habitat use. A combination of thread-trailing devices and radio telemetry could be used to determine the sampling frequency required to attain a desired accuracy.

Although we were initially concerned that transmitters might affect behavior, no discernable effect was observed. We actually watched two radio-equipped turtles as they attempted to copulate with other turtles. Each turtle was weighed after transmitters were removed and none showed any significant weight loss. Lemkau (1970) did not report any adverse effects on turtles with a 70-g transmitter package, and others have experimentally demonstrated the ability of box turtles to carry large extrinsic loads (Wren et al. 1998).

Our home range area (0.48 ha to 2.25 ha) and maximum length estimates (170 m to 260 m) are similar to those made by Stickel (1989) at the Patuxent Wildlife Research Center. She recorded the mean home range area for males of 1.2 ha and for females it was 1.1 ha. Maximum home range length in her study for males was 146 m and for females was 144 m. Home range areas for box turtles in Missouri (Schwartz and Schwartz 1974) and in New York (Madden 1975) were larger than those in our study.

Turtles occurring in low quality habitats may have larger home ranges than those living in optimal habitat (Stickel 1950, 1989). Stickel's (1989) home range estimates of box turtles in a bottomland forest with considerable wetland habitat were smaller than those reported for areas containing mostly upland forest and meadow habitats (Madden 1975). Diemer (1992) noted that some gopher tortoises (*Gopherus polyphemus*) occurring in xeric habitats had larger home ranges than tortoises in mesic habitats. It should be noted, however, that differences in published home ranges might be related to the computational technique used (Nieuwolt 1996, Dodd 2001), as well as to the number of observations made and seasonal or annual shifts in size and shape of home ranges (Williams and Parker 1987). Home-range size estimates for this study were based on only three turtles over a four-month observation period. Our results therefore represent minimum home range estimates because of potential seasonal shifts in habitat use.

Turtles in our study were observed in or near wetland habitats as often as upland habitats, despite the greater abundance of upland forest habitat. Box turtles in Indiana disproportionately used maple stands (Williams and Parker 1987), although wetland habitat did not appear to be available in abundance. Box turtles in Pennsylvania (Strang 1983) showed no preference for upland, lowland, or pine knob habitat. Box turtles in New York favored forest-field ecotones (Madden 1975).

Other researchers have noted seasonal shifts in habitat utilization (Reagan 1974, Doroff and Keith 1990, Dodd et al.1994). Three-toed box turtles (*T. c. triunguis*) moved from meadow habitat in spring to forest habitat in the summer (Reagan 1974). Similarly, ornate box turtles in Wisconsin shifted in mid-summer from prairies to forest and wetland habitats (Doroff and Keith 1990).

When air temperatures were high, box turtles used non-tidal wetland habitats more than tidal-wetland, meadow, and forest habitats. They may have used non-tidal wetlands for aestivation and thermoregulation on very hot days. Interestingly, at higher temperatures turtles were not observed in tidal wetland habitats more often than in upland habitats. Tidal habitats, unlike non-tidal wetlands, which are often shaded by a canopy, provide little shade, making ambient temperatures there similar to meadow habitats.

Turtles with access to wetland habitat at the Sanctuary may also benefit from increased feeding opportunities. One of us (Marchand pers. obs.) observed turtles in tidal wetlands feeding on Amber Marsh Snails (Succineidae: *Oxyloma effusa*), and he identified the exoskeletal fragments of crayfish and other aquatic invertebrates in box turtle feces. Barbour (1950) reported snails and crayfish as a significant food source, making up 60% and 15% of box turtle diet by volume, respectively.

Box turtle densities in the sanctuary are highest in non-tidal wetlands bordering Two-run Creek (Swarth unpubl. data). High habitat diversity may also explain the higher population density of box turtles in a bottomland forest at the Patuxent Wildlife Research Center (Madden 1975, Stickel 1950, 1989). A high concentration of turtles associated with floodplain non-tidal habitats suggests that these habitats may be preferred over drier meadows and upland forest for much of the active season. Locales with a high diversity of habitats, especially wetlands with abundant aquatic resources and moist, shady conditions, may be important in maintaining dense, healthy populations. Box turtles may not, therefore, be as "terrestrial" as once assumed. For a fuller understanding of habitat utilization, researchers must examine more thoroughly the role that wetlands can play in the lives and population stability of box turtles.

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