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Comparative Spatial Ecologies of Female Painted Turtles (*Chrysemys picta*) and Red-Eared Sliders (*Trachemys scripta*) at Reelfoot Lake, Tennessee

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ABSTRACT. – Spatial distributions and movements of aquatic animals are typically defined by the dimensions of the aquatic system in which they live. Aquatic turtles often confound such definitions with terrestrial movements, and movements within the aquatic system remain largely undescribed. We studied the movements of adult female painted turtles (*Chrysemys picta*) and red-eared sliders (*Trachemys scripta*) in Reelfoot Lake, a large aquatic system. We determined the distance moved, home-range size, and habitat use to investigate interspecific variation, as well as the influence of habitat dimensions on turtle spatial ecology. Daily movements peaked for both species between May and August. *Trachemys scripta* exhibited longer movements, maintained larger home ranges, and selected deeper areas of the lake than did *C. picta*. Compositional analysis indicated that the shoreline habitat was used most frequently by both species, relative to its availability. However, although *C. picta* selected the shoreline above all other habitat types, *T. scripta* selected the open water areas of the lake as well. Morphological differences and dietary preferences likely explain much of the interspecific variation we observed. Turtle movements and home-range sizes we report are remarkably larger than previous estimates and may be related to the abundance of suitable habitat within Reelfoot Lake. These results demonstrate that turtle spatial ecology is strongly influenced by local environmental factors and illustrate the potential pitfalls of describing “typical” movements of aquatic turtles.

KEY WORDS. – Reptilia; Testudines; Emydidae; *Chrysemys*; *Trachemys*; turtle; movements; home range; habitat use; compositional analysis; telemetry; lake; Tennessee; USA

Freshwater turtles use a range of terrestrial and aquatic habitats throughout their relatively long lives, and their movements represent an important ecological link between these two ecosystems (Gibbons et al. 1990). In general, turtle movements fall into two categories: long-distance (i.e., dispersal or migration among adjacent aquatic habitats), and short distance (i.e., routine movements within a single body of water). Many of the causes and consequences of the long distance movements of aquatic turtles, particularly with respect to nesting and road mortality, have been described in some detail (Congdon and Gatten 1989; Steen and Gibbs 2004; Bowne et al. 2006). In contrast, the factors that influence the spatial ecologies of aquatic turtles within the aquatic system remain yet to be thoroughly explored. Several factors can influence turtle spatial ecology including age, sex, reproductive condition, and habitat characteristics (Plummer et al. 1997). In addition to these intraspecific factors, differences between species (e.g., in morphology, diet, or habitat preferences) can lead to differences in space use (Lindeman 2000; Ryan et al. 2008). A positive relationship between habitat dimensions (i.e., stream width) and turtle home-range size has been documented in lotic systems (Schubauer et al. 1990; Plummer et al. 1997). Although a similar relationship likely exists in lentic systems, none has been documented.

The painted turtle (*Chrysemys picta*) and red-eared slider (*Trachemys scripta*) are among the most abundant turtles in the southeastern United States and co-occur throughout much of their respective ranges (Conant and Collins 1998). *Chrysemys picta* is notably smaller than *T. scripta* and typically inhabits shallower bodies of water. The diets of each species are known to vary substantially according to local availability and consist of a combination of plant and animal material (Knight and Gibbons 1968; Padgett et al. 2010). Descriptions of *C. picta* space use have neglected the southern subspecies (*Chrysemys picta dorsalis*). Such comparative data could potentially reveal any latitudinal gradients with respect to space use. The unique evolutionary history of *C. p. dorsalis* (see Starkey et al. 2003) adds further value to such investigations.

With a few notable exceptions (e.g., Schubauer et al. 1990; Bodie and Semlitsch 2000), previous reports of *C. picta* and *T. scripta* spatial ecology are based on populations inhabiting relatively small aquatic systems including streams (Moll and Legler 1971; Florence 1975; MacCulloch and Secoy 1983), canals (Ryan et al. 2008), ponds (Zweifel 1989), and wetlands (Rowe 2003; Tran et al. 2007). Monitoring the movements of aquatic turtles within these small aquatic systems permits a thorough description of daily activity and behavior. However, these

same aquatic systems may ultimately restrict turtle movements and can lead to a somewhat limited view of their spatial ecology. Here, we describe the movements, home range, and habitat use of *C. picta* and *T. scripta* in a large aquatic system: Reelfoot Lake, Tennessee. We consider the effects of body size, diet composition, and habitat use on the spatial ecologies of these sympatric turtles. Finally, we consider the potential influence of habitat dimensions and quality on turtle space use.

METHODS

Study Site. — Reelfoot Lake is a 7250-ha aquatic system located in northwest Tennessee in the southeastern United States (long 89°26'W, lat 36°23'N). Formed during a series of earthquakes along the New Madrid fault zone in 1811–1812 (Van Arsdale et al. 1998), today much of Reelfoot Lake consists of ecotones that link 4400 ha of shallow open water (approximately 1.5 m deep) and 2850 ha of flooded bottomland forest. Reelfoot Lake wetlands are dominated by bald cypress (*Taxodium distichum*) and emergent vegetation including saw grass (*Cladium jamaicense*), swamp loosestrife (*Decodon verticillatus*), spatterdock (*Nuphar luteum*), and American lotus (*Nelumbo lutea*). In addition to painted turtles (*C. picta*) and red-eared sliders (*T. scripta*), the lake supports populations of common snapping turtles (*Chelydra serpentina*), false map turtles (*Graptemys pseudogeographica*), common musk turtles (*Sternotherus odoratus*), eastern mud turtles (*Kinosternon subrubrum*), eastern river cooters (*Pseudemys concinna*), and spiny softshell turtles (*Apalone spinifera*).

Radiotelemetry. — From May through June 2006, turtles were collected using sardine-baited hoop nets from Blue Basin, the largest and southernmost portion of Reelfoot Lake, as part of a more comprehensive demographic study. Standard morphometric measurements were recorded for each turtle (e.g., straight-line carapace length, straight-line plastron length, mass, secondary sexual characteristics). Because one of the original objectives was to identify nesting sites for *C. picta* and *T. scripta*, only gravid females were selected for telemetry. The presence of calcified eggs was determined using radiography (Gibbons and Greene 1979). Radio-transmitters (SI-2FT, 12 g; Holohil Systems Ltd, Ontario, Canada) were attached to the posterior marginal scutes using two stainless steel screws. The total weight of the transmitter package averaged 4.0% and 1.5% of turtle body weight for *C. picta* and *T. scripta*, respectively. The estimated lifespan of each transmitter was approximately 20 mo at 25°C. Twenty turtles were initially outfitted with radio-transmitters in 2006 (10 *C. picta*, 10 *T. scripta*). During the first season, three turtles were lost because of predation and four because of transmitter failure. It is unclear whether the presence of the transmitter directly influenced mortality in this study. In 2007, transmitters were attached to 2 additional *C. picta* and 3 additional *T.*

scripta, resulting in a total of 25 radio-tracked turtles between May 2006 and August 2007 ($n = 7$ in 2006 only; $n = 4$ in 2007 only; $n = 14$ in both 2006 and 2007).

All turtles were released at their original point of capture within 24 hrs and subsequently relocated using a hand-held receiver (Model R1000; Communications Specialists, Inc, Orange, CA) and a three-element Yagi antenna. Telemetry was conducted primarily by boat but also on foot when necessary. The frequency of turtle relocations varied according to turtle activity (Rasmussen and Litzgus 2010). Turtles were relocated two to three times per week during the active season and approximately once every 2 wks throughout the winter months. A handheld GPS (eTrex Legend Cx; Garmin International, Inc, Olathe, KS) was used to record the geographic location of each turtle, with an accuracy range of approximately 7 m. The coordinates of each turtle location were verified using field notes and aerial photographs. Coordinates were converted from a geographic coordinate system (D.dd) to a Universal Transverse Mercator (UTM) coordinate system (NAD83, Zone 16) for all spatial analyses.

Turtle Movements. — Straight-line distances between successive point locations were calculated using ArcGIS v. 9.2 (Environmental Systems Research Institute, Inc, Redlands, CA). To estimate the distance each turtle moved in a single day, the distance between successive points was divided by the number of days between relocations. This method provides the minimum distance moved between points and likely underestimates the turtle's actual movements (White and Garrot 1990; Millsbaugh and Marzluff 2001) but is useful for purposes of comparison. Using the individual as the unit of replication, mean daily movements were calculated for each turtle. These data failed the assumptions of normality and equality of variance despite transformations; therefore, a nonparametric Mann–Whitney rank sum test was used to compare the two species. Temporal patterns of turtle movement were examined by averaging an individual's daily movements for each month. These values were then log-transformed to meet the assumptions of normality and equality of variance and compared using a two-way repeated-measures ANOVA to examine the effect of species and month on turtle movements.

Home Range. — Home ranges were determined using two methods: (1) minimum convex polygon (MCP); and (2) 95% fixed kernel (FK). The MCP method calculates the smallest convex area encompassing every point location for an individual (Mohr 1947), whereas, the FK method produces a use distribution to describe the probability of locating an individual in a given area (Worton 1989). We also estimated sizes of turtle “activity centers” using the 50% FK method. Calculations were performed using the Animal Movement Extension (Hooge and Eichenlaub 2000) for ArcView v. 3.2 (Environmental Systems Research Institute). Smoothing factors (h) for the FK estimates were calculated using least-squares cross-validation (Seaman and

Powell 1996). Incremental area analysis was used to examine the relationship between home-range size and sampling intensity (Dreslik et al. 2003). Home-range size estimates failed the assumptions of normality and equality of variance despite transformations; thus, nonparametric Mann–Whitney rank sum tests were used to compare the two species.

Habitat Use. — To estimate microhabitat use, distance to shore and water depth were measured. When turtles were found within the boundaries of the lake, the distance of each relocation to the nearest shore was measured using a laser range-finder (Yardage Pro Sport, Bushnell, Overland Park, KS) and verified in ArcGIS v. 9.2. Water depth at each turtle relocation in 2007 was measured to the nearest 0.25 m using a weighted line (water depth was not recorded for relocations in 2006). These data failed the assumptions of normality and equality of variance despite transformations; therefore, a nonparametric Mann–Whitney rank sum test was used to compare the two species. To quantify macrohabitat use, Reelfoot Lake was divided into four broad macrohabitat types: (1) flooded forest (FOR; seasonally flooded hardwood forest); (2) open water (OW; 1–3 m deep, with numerous submerged cypress trees); (3) shoreline (SHR; edge habitat; < 1 m deep, within 25 m of shore); and (4) field (FLD; cropland adjacent to the lake). Geographic boundaries for each habitat type were delineated based on 2006 National Wetlands Inventory data (www.nwi.fws.gov) and manually adjusted in ArcGIS v. 9.2 using a 1-m ground resolution color digital orthophoto quarter quadrangle aerial photograph.

Compositional analysis was used to assess habitat selection of *C. picta* and *T. scripta* (Aebischer et al. 1993). For each turtle, habitat “availability” was defined as the proportions of each macrohabitat type within the MCP home range, and the frequencies of turtle relocation points within each macrohabitat type were viewed as the “used habitats” (Rasmussen and Litzgus 2010). Compositional analyses were performed in R v. 2.13 (R Core Development Team, Vienna, Austria) using the “adehabitat” package (Calenge 2006). Treatment of missing habitat types was dealt with according to Aebischer et al. (1993), by replacing values of 0% with a value an order of magnitude less than the smallest recorded nonzero proportion. All statistical analyses were performed in R v. 2.13. All means are reported ± 1 SE.

RESULTS

Turtle Movements. — Twelve gravid female *C. picta* and 13 gravid female *T. scripta* were radio-tracked between May 2006 and August 2007, yielding a total of 782 turtle relocations: 335 for *C. picta* and 447 for *T. scripta*. Estimates of daily movements of *C. picta* and *T. scripta* were 83.9 ± 13.4 and 212.9 ± 30.0 m/d, respectively, and differed significantly between species ($U = 16, p < 0.001$). The distances between successive

relocations were short (< 50 m/d); however, several long-distance movements were observed for both species (Fig. 1A). Two-way repeated-measures ANOVA revealed significant effects of both species ($F_{1,135} = 9.071, p = 0.003$) and month ($F_{1,135} = 13.486, p < 0.001$) on turtle movements. The distances between successive relocations were highest between the months of May and August for both species (Fig. 1B). The movements of both species decreased during the winter months, but turtles maintained some level of activity.

Home Range. — All radio-tracked turtles were included in movement analyses; however, individuals monitored for less than 3 mo or with fewer than 17 relocations were excluded from home-range analyses to ensure robust estimates. This permitted the analysis of 10 *C. picta* and 12 *T. scripta*. Incremental area analysis did not reveal any sampling biases for the remaining individuals; bootstrap estimates of MCP home-range size reached an asymptote for each turtle (Fig. 2). Minimum convex polygon (MCP) home-range estimates for *C. picta* and *T. scripta* were 89.0 ± 25.3 ha and 327.6 ± 81.6 ha, respectively. Ninety-five percent FK home-range estimates for *C. picta* and *T. scripta* were 168.5 ± 79.6 ha and 465.9 ± 126.0 ha, respectively. *Trachemys scripta* exhibited significantly larger home ranges than did *C. picta* using both methods (MCP: $U = 23, p < 0.05$; FK: $U = 26, p < 0.05$). Sizes of “activity centers” for *C. picta* and *T. scripta* estimated using the 50% FK were 40.5 ± 23.6 ha and 71.6 ± 20.7 ha, respectively, and did not differ between the species ($U = 31, p > 0.05$).

Habitat Use. — Both species favored the shallow areas of the lake near the shoreline, but *T. scripta* also frequented the deeper water further from shore. Water depth at turtle relocations differed significantly ($U = 15, p < 0.01$), averaging 0.62 ± 0.05 m for *C. picta* and 1.51 ± 0.15 m for *T. scripta* (Fig. 1C). On average, *C. picta* and *T. scripta* were located 13.6 ± 2.9 m and 177.8 ± 35.7 m from the shoreline, respectively. Shoreline distances differed significantly between the species ($U = 1, p < 0.001$; Fig. 1D). Compositional analysis provided further evidence of habitat selection for both *C. picta* and *T. scripta* (Table 1; Fig. 3). Here, “>>>” indicates statistical significance at $\alpha = 0.05$. *Chrysemys picta* significantly selected the shoreline habitat over the open water and flooded forest and all habitats to the open field habitat (SHR >>> OW > FOR >>> FLD). In contrast, *T. scripta* significantly selected both the shoreline and open water habitats over the flooded forest and field habitats (SHR > OW >>> FLD > FOR).

DISCUSSION

The movements of adult female *C. picta* and *T. scripta* at Reelfoot Lake reveal strong seasonal trends. Egg production in these turtles peaks from mid-May to early June (Collins et al. 1997; Cobb 2008), which corresponds with the increase in activity observed in the

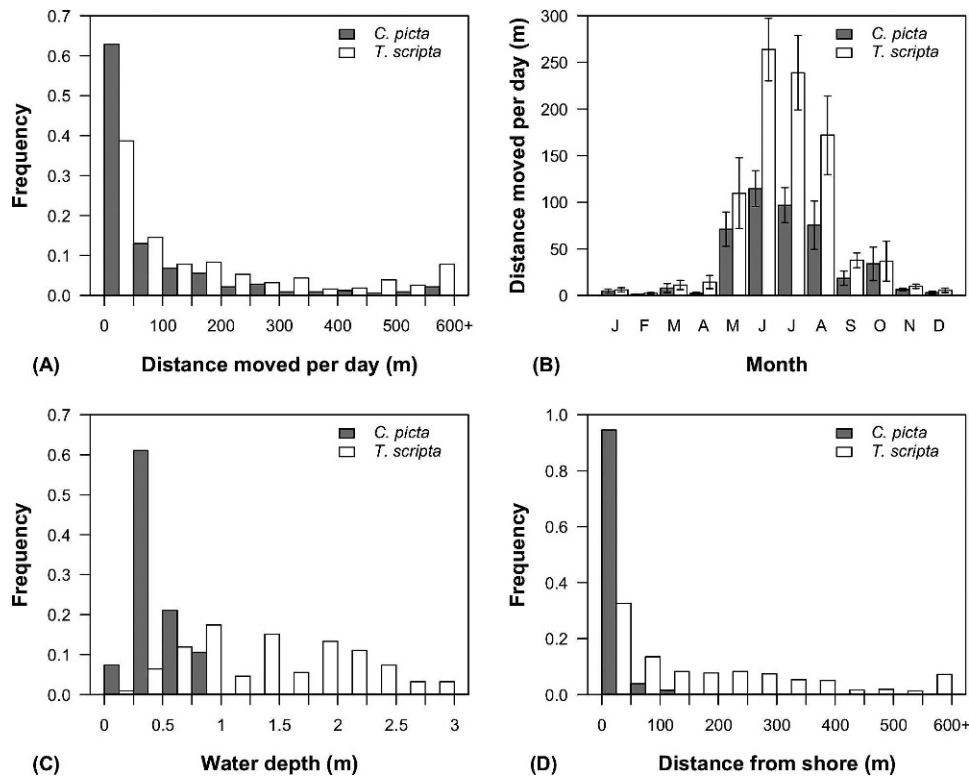


Figure 1. Daily distances moved, water depths, and distances from shore at relocations for adult female *Chrysemys picta* ($n = 12$) and *Trachemys scripta* ($n = 13$) at Reelfoot Lake. (A) Distances moved per day. Note that both species exhibited movements > 600 m/d. (B) Seasonal movements; bars represent monthly averages of daily movements ± 1 SE. (C) Water depths at relocation, based on 95 relocations for *C. picta* and 218 for *T. scripta*. (D) Distances from shore of relocation, based on 129 relocations for *C. picta* and 365 for *T. scripta*. Note that *T. scripta* were occasionally found > 600 m from shore.

present study. According to the “reproductive strategies hypothesis,” female turtles are expected to move furthest in late spring and early summer while gathering resources for the production of egg clutches and locating suitable nesting habitats (Morreale et al. 1984). Such patterns have been documented in *Chelydra serpentina* (Obbard and Brooks 1980), *Apalone mutica* (Plummer and Shirer 1975), *Graptemys flavimaculata* (Jones 1996), and *Emydoidea blandingii* (Rowe and Moll 1991). However, Arvisais et al. (2002) found no difference in activity levels between male and female *Glyptemys insculpta*, and Doody et al. (2002) observed no behavioral differences between gravid and nongravid *Carettochelys insculpta*, as the “reproductive strategies hypothesis” would predict.

The increase in turtle activity measured in the summer may also be in response to changes in air or water temperature (Gibbons 1967; Ernst 1972; Grayson and Dorcas 2004). Water temperature was significantly correlated with the frequency and distance moved by *Macrochelys temminckii* (Harrel et al. 1996); yet the activity levels of *C. picta* in a small marsh in Michigan were independent of environmental temperatures (Rowe 2003). Although turtles in cooler climates become inactive throughout much of the winter (Ultsch 2006; Greaves and Litzgus 2007; Ryan et al. 2008), turtles at Reelfoot Lake maintained low levels of activity all year

despite carapace temperatures as low as 2.5°C (V.A. Cobb, unpubl. data, 2007).

Trachemys scripta moved further, maintained larger home ranges, and used deeper water further from shore than did *C. picta*. *Chrysemys picta* were exclusively found in water < 1 m deep and only rarely ventured > 50 m from the shoreline, whereas *T. scripta* seemed to use a greater variety of habitats at Reelfoot Lake. Even at distances > 500 m from shore and depths > 2 m, we observed turtles moving in the water column and basking on cypress stumps. A number of factors have been identified that may influence spatial behavior, both within and among species (Perry and Garland 2002). Within a given environment, the size of an animal’s home range may be related to its age, sex, reproductive condition, morphology, or diet (Harestad and Bunnell 1979; Gompper and Gittleman 1991; Galois et al. 2002; Litzgus and Mousseau 2004). Because we selected gravid female turtles for telemetry, factors such as age class, sex, and reproductive condition cannot fully explain the differences we observed between *C. picta* and *T. scripta* at Reelfoot Lake. Schubauer et al. (1990) reported a correlation between home-range size and carapace length for female *T. scripta* in South Carolina. Jaeger (2008) found no such relationship between individual body size and daily movements or home-range size for either

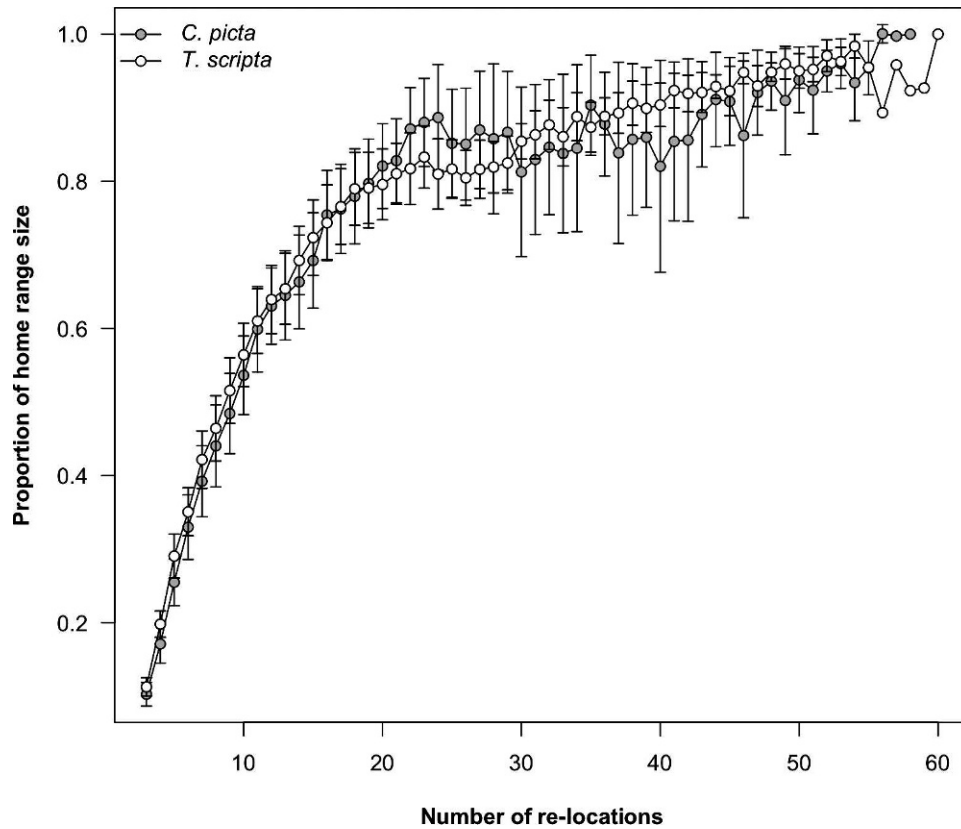


Figure 2. Incremental area analysis of minimum convex polygon (MCP) home-range estimates for adult female *Chrysemys picta* ($n = 10$) and *Trachemys scripta* ($n = 11$) at Reelfoot Lake. Bootstrap estimates of each turtle’s MCP home range reached an asymptote as sampling effort (i.e., number of relocations) increased, indicating an absence of sampling bias.

species at Reelfoot Lake; however, it should be noted that the straight-line carapace lengths of telemetered turtles did not vary substantially within either species. Monitoring the movements of individuals of more varied sizes may be necessary to reveal a relationship between body size and spatial ecology.

Although our results suggest that morphology does not account for the variation within each species,

fundamental morphological differences between *C. picta* and *T. scripta* likely account for the interspecific patterns we observed. *Trachemys scripta* are larger and have longer limbs than *C. picta* (Conant and Collins 1998). As expected, *T. scripta* were frequently relocated several hundred meters from the edge of the lake; yet *C. picta*

Table 1. Results of compositional analysis (Aebischer et al. 1993) indicating macrohabitat selection (SHR = shoreline, OW = open water, FOR = flooded forest, FLD = field) by adult female *Chrysemys picta* ($n = 10$) and *Trachemys scripta* ($n = 11$) radio tracked between May 2006 and August 2007 at Reelfoot Lake. Habitat types are ranked in order of most (1) to least (4) selected. Matrices of pairwise comparisons and associated p -values are provided (* indicates significant difference at $\alpha = 0.05$).

Species	OW	FOR	FLD	Rank
<i>C. picta</i>				
SHR	0.0012*	0.0111*	0.0001*	1
OW		0.0010*	0.0648	3
FOR			0.0258*	2
FLD				4
<i>T. scripta</i>				
SHR	0.4743	0.0005*	0.0005*	1
OW		0.0010*	0.0012*	2
FOR			0.4598	4
FLD				3

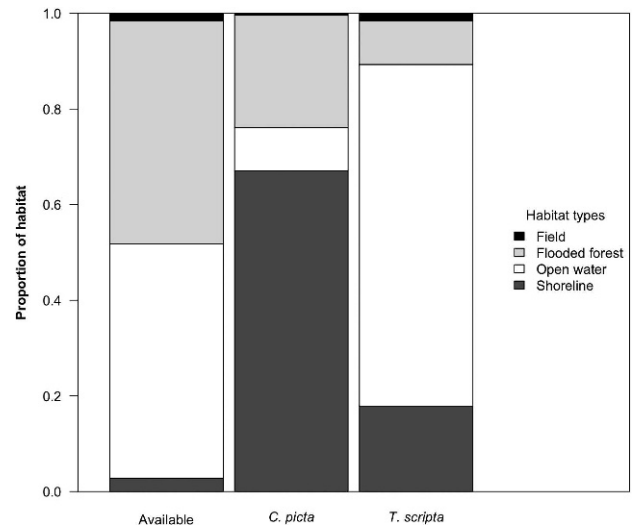


Figure 3. Macrohabitat use by adult female *Chrysemys picta* ($n = 10$) and *Trachemys scripta* ($n = 11$) at Reelfoot Lake. See Methods for description of habitat types.

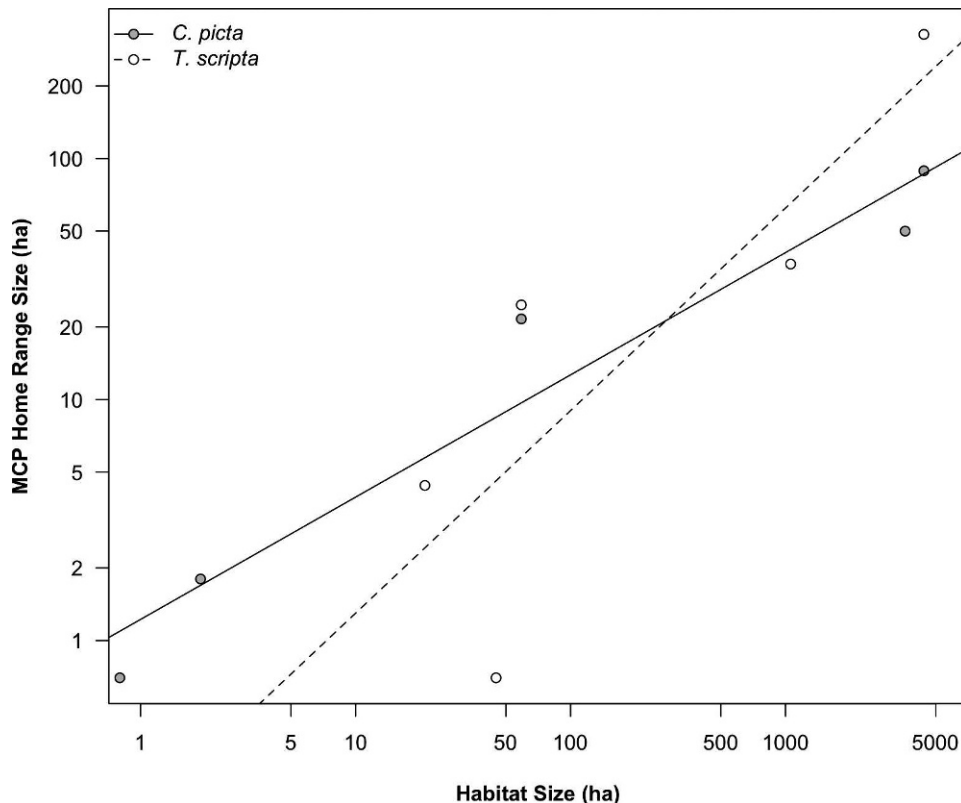
Table 2. Published estimates of minimum convex polygon home-range size for *Chrysemys picta* and *Trachemys scripta* inhabiting aquatic systems of various sizes.

Species	Location	Habitat type	Habitat size (ha)	Home range (ha)	Reference
<i>C. picta</i>	Michigan	Marsh	0.8	0.7	Rowe 2003
	Saskatchewan	River	–	6.0	MacCulloch and Secoy 1983
	Pennsylvania	Pond	59.0	21.6	Saba and Spotila 2003
	Ohio	Marsh	3600.0	50.0	Tran et al. 2007
<i>T. scripta</i>	Tennessee	Lake	4400.0	89.0	Present study
	Tennessee	River	45.0	0.7	Florence 1975
	Panama	River	–	3.6	Moll and Legler 1971
	Indiana	Canal	21.0	4.4	Ryan et al. 2008
	Pennsylvania	Pond	59.0	24.7	Tran et al. 2007
	South Carolina	Lake	1056.0	36.5	Schubauer et al. 1990
	Tennessee	Lake	4400.0	327.6	Present study

were never found more than 40 m from the shoreline and were consistently in water less than 1 m deep. Both species favored the shoreline, but *T. scripta* also used the open water habitat at Reelfoot Lake. Larger turtle species may be better able to swim long distances more quickly (Gibbons et al. 1990; Pace et al. 2001) and may be better equipped to effectively forage in deeper water (Lindeman 2003).

The morphological differences between *C. picta* and *T. scripta* may also lead to energetic differences. Larger species tend to require more resources than smaller ones, which may force them to move further and maintain larger home ranges to obtain sufficient food resources

(Perry and Garland 2002). Both species are omnivorous; their diets are quite variable and reflect local abundances of food items (Knight and Gibbons 1968; Parmenter and Avery 1990; Padgett et al. 2010). Stomach contents were not examined in the present study; therefore, we can only speculate on the effect of dietary preferences on turtle movements at Reelfoot Lake. Historically, *C. picta* at Reelfoot Lake fed primarily on aquatic plants (Parker 1939), whereas as much as half of the diet of *T. scripta* at other locations may consist of animal matter (e.g., invertebrates and fish carrion; Marchand 1942; Lindeman 2000). A more carnivorous diet of *T. scripta* would potentially explain our observations. Trauth et al. (2004)

**Figure 4.** Published estimates of minimum convex polygon (MCP) home-range size show positive relationships relative to the size of available habitat for *Chrysemys picta* ($r^2 = 0.94$, $p < 0.01$) and *Trachemys scripta* ($r^2 = 0.70$, $p = 0.08$). Note that both axes are log-transformed.

suggested that *T. scripta* may out-compete the smaller *C. picta* where they occur sympatrically, resulting in smaller body sizes and lower population densities of *C. picta*. We found no evidence of any direct competition between these two turtle species. An analysis of contemporary dietary preferences of these turtles could potentially elucidate the movement patterns we observed.

Both *C. picta* and *T. scripta* are capable of long-distance movements. MacCulloch and Secoy (1983) described multiple instances of *C. picta* moving > 5 km between sightings in a Saskatchewan river, whereas individuals of the Michigan population studied by Rowe (2003) moved an average of 83.8 m/d. Ryan et al. (2008) documented average movements of > 250 m/d for *T. scripta* inhabiting an Indiana canal. Movement estimates for closely related *Pseudemys concinna* include 122 m/d in an Illinois pond (Dreslik et al. 2003) and > 1.5 km/d in a Florida river (Kornilev et al. 2010).

Documented home-range sizes of *C. picta* and *T. scripta* are quite variable; yet all are notably smaller than those reported herein (Table 2). In the present study, *C. picta* moved as far as 800 m/d and maintained relatively large home ranges (MCP = 89.0 ha; FK = 168.5 ha). Similarly, these estimates of *T. scripta* movements (up to 1.6 km/d) and home-range size (MCP = 327.6 ha; FK = 465.9 ha) are the highest reported, to the best of our knowledge. We examined the movements of adult female turtles that were gravid in late spring; therefore, it is important to consider the potential effect of long-distance nesting forays. During the course of this study, we observed very few (< 5) terrestrial movements associated with nesting, all of which were located within the individual's existing home range.

Ross and Anderson (1990) suggested that the relatively large home ranges of *E. blandingii* in Wisconsin were the result of greater availability of suitable habitats. Arvisais et al. (2002) described a general trend for larger home ranges of *G. insculpta* at more northerly latitudes, arguing that turtles must move farther to meet their energetic requirements in habitats with lower productivity and higher fragmentation. Brown et al. (1994) compared the home ranges of *C. serpentina* inhabiting three habitats of varying levels of productivity and found no significant differences between sites. Habitat fragmentation may be an important factor in determining turtle spatial ecology in some cases (Edmonds 1998), but it cannot account for all of the observed variation (Hamernick 2000).

The influence of habitat size on home-range size of aquatic turtles has been considered previously. Plummer et al. (1997) identified a number of factors that may influence home-range size of turtles in lotic habitats and identified stream width as an important variable. Linear regression suggests a relationship between (log-transformed) available habitat size and (log-transformed) MCP home-range size for both species (*C. picta*: $r^2 = 0.94$, $p < 0.01$; *T. scripta*: $r^2 = 0.70$, $p = 0.08$; Table 2; Fig. 4). Accurately estimating the area of "available" habitat in lentic systems

can be difficult. For example, defining habitat availability based on the distribution of individual relocations may yield biased estimates. Nevertheless, local habitat characteristics should be explicitly considered and reported in any description of turtle spatial ecology.

The large home ranges observed in this study do not appear to be the result of low resource availability. Although we did not directly measure productivity, historical descriptions of Reelfoot Lake's aquatic habitats (Cagle 1937; Carr 1952), and the diversity and density of its contemporary turtle community (Cobb 2008) suggest an abundance of high-quality resources. The shallow basins and flooded cypress forests surrounding Reelfoot Lake support a diverse turtle community. Unlike Reelfoot Lake, most large lakes have deep-water areas that lack suitable basking locations (Florence 1975). As a result, the movements of aquatic turtles are often restricted to the shorelines of large lakes (Galois et al. 2002). This pattern was exhibited by *C. picta* at Reelfoot Lake, but the larger *T. scripta* were able to use virtually every portion of the lake. As such, we argue that the extensive spatial ecologies of both species in this study are largely influenced by the abundance of suitable aquatic habitats found at Reelfoot Lake.

In conclusion, we demonstrate contrasting patterns of space use for female painted turtles (*C. picta*) and red-eared sliders (*T. scripta*) at Reelfoot Lake, Tennessee. Examination of spatial data from the literature for both species suggests a relationship between space use and the physical attributes of the aquatic system, highlighting the difficulty in describing a "typical" home-range size for an aquatic turtle species. Future studies of turtle movement and activity should consider the role of habitat characteristics (e.g., size, shape, quality, human disturbance) on turtle behavior. A comparative approach could clarify the relative roles of morphology, diet, and habitat preferences in turtle spatial ecology.

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LITERATURE CITED

- AEBISCHER, N.J., ROBERTSON, P.A., AND KENWARD, R.E. 1993. Compositional analysis of habitat use from animal radio-tracking data. *Ecology* 74:1313–1325.

- ARVISAIS, M., BOURGEOIS, J.C., LEVESQUE, E., DAIGLE, C., MASSE, D., AND JUTRAS, J. 2002. Home range and movements of a wood turtle (*Clemmys insculpta*) population at the northern limit of its range. *Canadian Journal of Zoology* 80:402–408.
- BODIE, J.R. AND SEMLITSCH, R.D. 2000. Spatial and temporal use of floodplain habitats by lentic and lotic species of aquatic turtles. *Oecologia* 122:138–146.
- BOWNE, D.R., BOWERS, M.A., AND HINES, J.E. 2006. Connectivity in an agricultural landscape as reflected by interpond movements of a freshwater turtle. *Conservation Biology* 20: 780–791.
- BROWN, G.P., BISHOP, C.A., AND BROOKS, R.J. 1994. Growth rate, reproductive output, and temperature selection of snapping turtles in habitats of different productivities. *Journal of Herpetology* 28:405–410.
- CAGLE, F.R. 1937. Egg laying habits of the slider turtle (*Pseudemys troostii*), the painted turtle (*Chrysemys picta*), and the musk turtle (*Sternotherus odoratus*). *Journal of the Tennessee Academy of Sciences* 12:87–95.
- CALENGE, C. 2006. The package adehabitat for the R software: a tool for the analysis of space and habitat use by animals. *Ecological Modelling* 197:516–519.
- CARR, A.F. 1952. *Handbook of Turtles: The Turtles of the United States, Canada, and Baja California*. New York: Cornell University Press, 542 pp.
- COBB, V.A. 2008. Status of turtle populations at Reelfoot Lake. Final Report ED-05-01679-00, Tennessee Wildlife Resources Agency, 89 pp.
- COLLINS, D.E., BENZ, G.W., AND DECK, J.E. 1997. Stock assessment of turtle species inhabiting Reelfoot Lake, with special emphasis on population structure and stability. Final Report ID-3-04887-3-00, Tennessee Wildlife Resources Agency, 156 pp.
- CONANT, R. AND COLLINS, J.T. 1998. *A Field Guide to Reptiles and Amphibians*. Eastern and Central North America. Boston: Houghton Mifflin Company, 616 pp.
- CONGDON, J.D. AND GATTEN, R.E., JR. 1989. Movements and energetics of nesting *Chrysemys picta*. *Herpetologica* 45:94–100.
- DOODY, J.S., YOUNG, J.E., AND GEORGES, A. 2002. Sex differences in activity and movements in the pig-nosed turtle, *Carettochelys insculpta*, in the wet-dry tropics of Australia. *Copeia* 2002:93–103.
- DRESLIK, M.J., KUHN, A.R., PHILLIPS, C.A., AND JELLEN, B.C. 2003. Summer movements and home range of the cooter turtle, *Pseudemys concinna*, in Illinois. *Chelonian Conservation and Biology* 4:706–710.
- EDMONDS, J.H. 1998. Population ecology of the stinkpot turtle (*Sternotherus odoratus*) in Georgian Bay, Ontario. Master's Thesis, University of Guelph, Guelph, Ontario, Canada.
- ERNST, C.H. 1972. Temperature-activity relationship in the painted turtle (*Chrysemys picta*). *Copeia* 1972:217–222.
- FLORENCE, T.H. 1975. A telemetric study of the activity of the red-eared turtle *Chrysemys scripta elegans*. Master's Thesis, Middle Tennessee State University, Murfreesboro.
- GALOIS, P., LEVELLE, M., BOUTHILLIER, L., DAIGLE, C., AND PARREN, S. 2002. Movement patterns, activity, and home range of the eastern spiny softshell turtle (*Apalone spinifera*) in northern Lake Champlain, Québec, Vermont. *Journal of Herpetology* 36:402–411.
- GIBBONS, J.W. 1967. Possible underwater thermoregulation by turtles. *Canadian Journal of Zoology* 45:585.
- GIBBONS, J.W. AND GREENE, J.L. 1979. X-ray photography: a technique to determine reproductive patterns of freshwater turtles. *Herpetologica* 31:86–89.
- GIBBONS, J.W., GREENE, J.L., AND CONGDON, J.D. 1990. Temporal and spatial movement patterns of sliders and other turtles. In: Gibbons, J.W. (Ed.). *Life History and Ecology of the Slider Turtle*, pp. 201–215. Washington, DC: Smithsonian Institution Press.
- GOMPPER, M.E. AND GITTLEMAN, J.L. 1991. Home range scaling: intraspecific and comparative trends. *Oecologia* 87:343–348.
- GRAYSON, K.L. AND DORCAS, M.E. 2004. Seasonal temperature variation in the painted turtle (*Chrysemys picta*). *Herpetologica* 60:325–336.
- GREAVES, W.F. AND LITZGUS, J.D. 2007. Overwintering ecology of wood turtles (*Glyptemys insculpta*) at the species' northern range limit. *Journal of Herpetology* 41:32–40.
- HAMERNICK, M.G. 2000. Home ranges and habitat selection of Blanding's turtles (*Emydoidea blandingii*) at the Weaver Dunes, Minnesota. Final Report to the Non-Game Wildlife Program, Minnesota Department of Natural Resources, 18 pp.
- HARESTAD, A.S. AND BUNNELL, F.L. 1979. Home range and body weight: a re-evaluation. *Ecology* 60:389–402.
- HARREL, J.B., ALLEN, C.M., AND HERBERT, S.J. 1996. Movements and habitat use of subadult alligator snapping turtles (*Macrochelys temminckii*) in Louisiana. *American Midland Naturalist* 135:60–67.
- HOOGE, P.N. AND EICHENLAUB, W. 2000. Animal movement extension to ArcView 2.0. Alaska Science Center–Biological Sciences Office, U.S. Geological Survey, Anchorage, AK.
- JAEGER, C.P. 2008. Spatial ecology of the painted turtle (*Chrysemys picta*) and red-eared slider (*Trachemys scripta*) at Reelfoot Lake, Tennessee. Master's Thesis, Middle Tennessee State University, Murfreesboro.
- JONES, R.L. 1996. Home range and seasonal movements of the turtle *Graptemys flavimaculata*. *Journal of Herpetology* 30: 376–385.
- KNIGHT, A.W. AND GIBBONS, J.W. 1968. Food of the painted turtle, *Chrysemys picta*, in a polluted river. *American Midland Naturalist* 80:559–562.
- KORNILEV, Y.V., DODD, C.K., JR., AND JOHNSTON, G.R. 2010. Linear home range, movement, and spatial distribution of the Suwanee cooter (*Pseudemys concinna suwanniensis*) in a blackwater river. *Chelonian Conservation and Biology* 9:196–204.
- LINDEMAN, P.V. 2000. Resource use of five sympatric turtle species: effects of competition, phylogeny, and morphology. *Canadian Journal of Zoology* 78:992–1008.
- LINDEMAN, P.V. 2003. Sexual difference in habitat use of Texas map turtles (Emydidae: *Graptemys versa*) and its relationship to size dimorphism and diet. *Canadian Journal of Zoology* 81: 1185–1191.
- LITZGUS, J.D. AND MOUSSEAU, T.A. 2004. Home range and seasonal activity of southern spotted turtles (*Clemmys guttata*): implications for management. *Copeia* 2004:804–817.
- MACCULLOCH, R.D. AND SECOY, D.M. 1983. Movement in a river population of *Chrysemys picta bellii* in southern Saskatchewan. *Journal of Herpetology* 17:283–285.
- MARCHAND, L.J. 1942. A contribution to a knowledge of the natural history of certain freshwater turtles. Master's Thesis, University of Florida, Gainesville.
- MILLSPAUGH, J.J. AND MARZLUFF, J.M. 2001. *Radio Tracking and Animal Populations*. San Diego: Academic Press, 474 pp.
- MOHR, C.O. 1947. Table of equivalent populations of North American small mammals. *American Midland Naturalist* 37: 223–249.
- MOLL, E.O. AND LEGLER, J.M. 1971. The life history of a Neotropical slider turtle, *Pseudemys scripta* (Schoepff), in

- Panama. Bulletin of the Los Angeles County Museum of Natural History 11:1–102.
- MORREALE, S.J., GIBBONS, J.W., AND CONGDON, J.D. 1984. Significance of activity and movement in the yellow-bellied slider turtle (*Pseudemys scripta*). Canadian Journal of Zoology 62:1038–1042.
- ORBARD, M.E. AND BROOKS, R.J. 1980. Nesting migrations of the snapping turtle (*Chelydra serpentina*). Herpetologica 36:158–162.
- PACE, C.M., BLOB, R.W., AND WESTNEAT, M.W. 2001. Comparative kinematics of the forelimb during swimming in red-eared slider (*Trachemys scripta*) and spiny softshell (*Apalone spinifer*) turtles. Journal of Experimental Biology 204:3261–3271.
- PADGET, D.J., CARBONI, J.J., AND SCHEPIS, D.J. 2010. The dietary composition of *Chrysemys picta picta* (eastern painted turtles) with special reference to seeds of aquatic macrophytes. Northeastern Naturalist 17:305–312.
- PARKER, M.V. 1939. The amphibians and reptiles of Reelfoot Lake and vicinity, with a key for the separation of the species and subspecies. Journal of the Tennessee Academy of Science 14:72–101.
- PARMENTER, R.R. AND AVERY, H.W. 1990. The feeding ecology of the slider turtle. In: Gibbons, J.W. (Ed.). Life History and Ecology of the Slider Turtle, pp. 257–266. Washington, DC: Smithsonian Institution Press.
- PERRY, G. AND GARLAND, T., JR. 2002. Lizard home ranges revisited: effects of sex, body size, diet, habitat, and phylogeny. Ecology 83:1870–1885.
- PLUMMER, M.V. AND SHIRER, H.W. 1975. Movement patterns in a river population of softshell turtle, *Trionyx muticus*. Journal of Herpetology 11:87–90.
- PLUMMER, M.V., MILLS, N.E., AND ALLEN, S.L. 1997. Activity, habitat, and movement patterns of softshell turtles (*Trionyx spiniferus*) in a small stream. Chelonian Conservation and Biology 2:514–520.
- RASMUSSEN, M. AND LITZGUS, J.D. 2010. Habitat selection and movement patterns of spotted turtles (*Clemmys guttata*): effects of spatial and temporal scales of analyses. Copeia 2010:86–96.
- ROSS, D.A. AND ANDERSON, R.K. 1990. Habitat use, movements, and nesting of *Emydoidea blandingii* in central Wisconsin. Journal of Herpetology 24:6–12.
- ROWE, J.W. 2003. Activity and movements of midland painted turtles (*Chrysemys picta marginata*) living in a small marsh system on Beaver Island, Michigan. Journal of Herpetology 37:342–353.
- ROWE, J.W. AND MOLL, E.O. 1991. A radiotelemetric study of activity and movements of the Blanding's turtle (*Emydoidea blandingii*) in northeastern Illinois. Journal of Herpetology 25:178–185.
- RYAN, T.J., CONNER, C.A., DOUTHITT, B.A., STERRETT, S.C., AND SALSBUURY, C.M. 2008. Movement and habitat use of two aquatic turtles (*Graptemys geographica* and *Trachemys scripta*) in an urban landscape. Urban Ecosystems 11:213–225.
- SABA, V.S. AND SPOTILA, J.R. 2003. Survival and behavior of freshwater turtles after rehabilitation from an oil spill. Environmental Pollution 126:213–223.
- SCHUBAUER, J.P., GIBBONS, J.W., AND SPOTILA, J.R. 1990. Home range and movement patterns of slider turtles inhabiting Par Pond. In: Gibbons, J.W. (Ed.). Life History and Ecology of the Slider Turtle, pp. 223–232. Washington DC: Smithsonian Institution Press.
- SEAMAN, D.E. AND POWELL, R.A. 1996. An evaluation of the accuracy of the kernel density estimator for home range analysis. Ecology 77:2075–2085.
- STARKEY, D.E., SHAFFER, H.B., BURKE, R.L., FORSTNER, M.R.J., IVERSON, J.B., JANZEN, F.J., RHODIN, A.G.J., AND ULTSCH, G.R. 2003. Molecular systematics, phylogeography, and the effects of Pleistocene glaciation in the painted turtle (*Chrysemys picta*) complex. Evolution 57:119–128.
- STEEN, D.A. AND GIBBS, J.P. 2004. Effects of roads on the structure of freshwater turtle populations. Conservation Biology 18:1143–1148.
- TRAN, S.L., MOORHEAD, D.L., AND MCKENNA, K.C. 2007. Habitat selection by native turtles in a Lake Erie wetland, USA. American Midland Naturalist 158:16–28.
- TRAUTH, S.E., ROBISON, H.W., AND PLUMMER, M.V. 2004. The Amphibians and Reptiles of Arkansas. Fayetteville: University of Arkansas Press, 440 pp.
- ULTSCH, G.R. 2006. The ecology of overwintering among turtles: where turtles overwinter and its consequences. Biological Review 81:339–367.
- VAN ARSDALE, R., PURSER, J., STEPHENSON, W., AND ODUM, J. 1998. Faulting along the southern margin of Reelfoot Lake, Tennessee. Bulletin of the Seismological Society of America 88:131–139.
- WHITE, G.C. AND GARROTT, R.A. 1990. Analysis of Wildlife Radio-Tracking Data. San Diego: Academic Press, 383 pp.
- WORTON, B.J. 1989. Kernel methods for estimating the utilization distribution in home range studies. Ecology 70:164–168.
- ZWEIFEL, R.G. 1989. Long-term ecological studies on a population of painted turtles, *Chrysemys picta*, on Long Island, New York. American Museum Novitates 2952:1–55.

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