Effects of Relocation on Movements and Home Ranges of Eastern Box Turtles

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ABSTRACT To examine effects of relocation on eastern box turtles (*Terrapene carolina*), we compared home ranges and movement patterns of 10 resident and 10 relocated box turtles in Davidson, North Carolina, USA. Home ranges of relocated turtles were approximately 3 times larger than those of resident turtles when measured by minimum convex polygons, 6 times larger than resident turtles when measured with 95% kernels and 7.5 times larger than resident turtles when measured by 50% kernels. Relocated turtles also moved a greater average distance per day than resident turtles. Additionally, 5 relocated turtles experienced mortality or disappearance compared to no mortality or disappearance of resident turtles. Our results raise questions about the success of relocation as a management strategy for eastern box turtles. (JOURNAL OF WILDLIFE MANAGEMENT 72(3):772–777; 2008)

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Many reptile populations have declined worldwide as a result of factors such as habitat loss and degradation, pollution, disease, and collection for food and the pet trade (Gibbons et al. 2000). One proposed management strategy for endangered reptiles is relocation, which is defined as the movement of a free-ranging animal or population of animals away from an area where they are threatened to an area historically occupied by that species (Dodd and Seigel 1991). Although some relocation programs have successfully established self-sustaining populations of mammals (44% success rate), the success rate for reptiles is considerably lower (19% success rate in 25 relocation projects; Griffith et al. 1989, Dodd and Seigel 1991).

One frequently relocated reptile species is the eastern box turtle (*Terrapene carolina*). Eastern box turtles are excellent candidates for relocation because they are threatened by expanding urbanization and the resulting loss of habitat (Dodd 2001, Bowen et al. 2004). Often, box turtle relocation occurs when concerned humans move turtles from roads or yards to a new location, when injured turtles are taken to wildlife rehabilitators and subsequently released in a different site, or when wildlife managers try to protect turtle populations by relocating them to a better habitat (Hartup 1996, Belzer 1997, Cook 2004). Results of most of these relocation attempts have been unsuccessful or inconclusive, indicating that the utility of relocation for eastern box turtles must be questioned (Mathis and Moore 1988, Belzer 1997, Cook 2004).

Changes in home range size and movement patterns are important indicators of the initial response of box turtles to relocation. Box turtles usually restrict their movements to a well-established home range, often following the same routes (Schwartz and Schwartz 1974, Posey 1979). However, displaced box turtles often execute initially irregular movements, followed by unidirectional movements, as a result of a homing mechanism (Lemkau 1970, Posey 1979). Alterations in home-range size and movement distance and direction can contribute to decreased survivorship through increased energy use, inability to find important resources, and increased chance encounters with other hazards (Belzer 1997). We evaluated effects of relocation on eastern box turtles by comparing home-range size, movement patterns and bearing, and survivorship between 10 relocated box turtles and 10 resident box turtles during the first year after relocation. We hypothesized that relocated box turtles would have larger home ranges and move further than resident turtles.

STUDY AREA

We conducted our study on the Davidson College Ecological Preserve (DCEP), an area of protected land (approx. 89 ha) adjacent to Davidson College, Mecklenburg County, North Carolina, USA (35°30′N, 80°50′W). The DCEP consisted of secondary-growth mixed pine and hardwood forests, along with several small streams, areas of old field habitat, gravel trails, and power line rights-of-ways (Willson and Dorcas 2004; Fig. 1).

METHODS

Because of the variation in movement behavior as a result of gender and associated reproductive activities, we chose to study the response of only adult female box turtles (Stickel 1950). We captured 10 female box turtles on the DCEP (residents) and acquired 10 female turtles (relocated turtles) with the help of local community members, who we notified of our study through our citizen-science box turtle mark–recapture program (Budischak et al. 2006, Hester et al. 2008). We chose a sample size of 20 turtles to make

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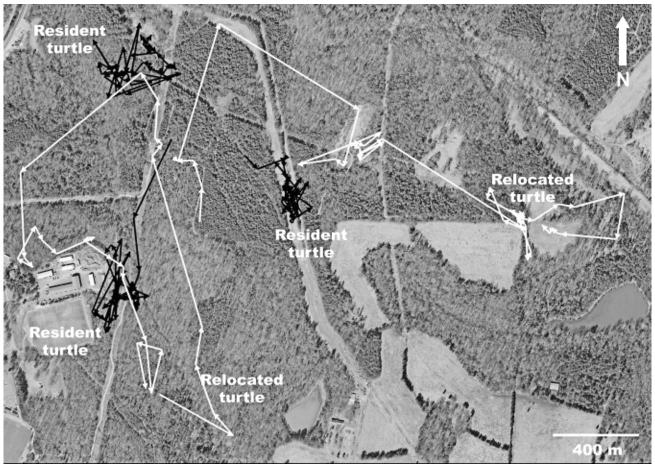

Figure 1. Examples of movement vectors for 3 resident (black) and 2 relocated (white) eastern box turtles on the Davidson College Ecological Preserve in Mecklenburg County, North Carolina, USA, between 2 May 2004 and 15 June 2005. Arrows represent direction and length in meters of the turtles' movements between each tracking episode. Note that relocated turtles traveled in more arc-like paths than did resident turtles. Individuals represented here had total distances and average distances moved per day that were closest to mean values for resident and relocated turtles, respectively.

frequent relocations and careful observations of all turtles feasible. Relocated turtles were captured in a variety of habitats, including backyards of suburban areas, roadsides, pastures, and golf courses. We captured all resident turtles within forested areas or along trails on the DCEP. Trained members of the Davidson College Herpetology Laboratory recorded carapace length, plastron length, mass, approximate minimum age, and original capture location of each turtle upon capture (Budischak et al. 2006; Table 1). All turtles had a carapace length between 118 mm and 136 mm and a mass between 366 g and 540 g (Table 1).

We acquired turtles between 2 May and 15 June 2004 and rereleased or relocated them within 48 hours of capture. We released relocated turtles at randomly chosen sites on the DCEP that were 0.8 km to 38.0 km away from their original home range. The DCEP had a large, local population of box turtles that were distributed relatively evenly throughout the preserve; thus, we released all relocated turtles in habitat used by the local box turtle population. We released resident turtles at their original capture locations. Prior to their release, we attached radiotransmitters (SB-2; Holohil Systems Ltd., Carp, ON, Canada; mass = 4 g) to all 20 turtles with stainless-steel wire and cable ties threaded through small holes drilled in the posterior marginal scutes. All procedures were approved by the Davidson College Animal Care and Use Committee (protocol no. 3-06-11; 2006).

We radiotracked all turtles for one year after their initial capture date unless a turtle died or could not be located (Table 1). We chose one year for the study duration because many other relocated turtles show the greatest amount of movement and highest mortality rates within the first year postrelocation (e.g., gopher tortoises [*Gopherus polyphemus*], Ashton and Burke 2007; eastern box turtles, Cook 2004). We tracked turtles every 2 to 3 days during the active season (5 May–31 Oct 2004, and 27 Mar–15 Jun 2005) and once weekly while turtles were hibernating (31 Oct 2004–27 Mar 2005). We handled turtles for one transmitter replacement, which occurred in the field. We recorded geographic coordinates (Universal Transverse Mercator [UTMs], World Geodetic System 1984; 3-m accuracy) at each turtle location. We did not disturb turtles leaving the DCEP and allowed them to wander at will; however, we tracked them more frequently to monitor their behavior and condition. After we tracked a turtle for a full year, we removed its transmitter. We released resident turtles at their most recent location and returned relocated turtles to their original capture locations.

To estimate size of the turtles' home ranges, we calculated the 95% minimum convex polygon and 50% and 95% kernels with the Animal Movement Extension (Hooge and Eichenlaub 1997) in a Geographic Information System (GIS). We compared relocated turtles' home-range estimates for each calculation method with those of resident turtles with single-factor analysis of variance (ANOVA).

With the Polyline function in the Animal Movement Extension in ArcView (Hooge and Eichenlaub 1997), we calculated total distance each turtle moved since its release, straight-line distance between its final location and release point (the net distance), and straight-line distance from its release point to its most distant location. These measures allowed us to assess the shapes of the turtles' paths as well as the overall magnitude of their movement. We compared these distances between relocated and resident turtles with single-factor ANOVAs. We also analyzed the difference between the average distance traveled per day by resident and relocated turtles (total distance/day radiotracked) with a single-factor ANOVA. To evaluate distance moved per day during each month, we compared average distance traveled per day in each month between the 2 groups of turtles with a repeated-measures ANOVA (SAS 9.1, Cary, NC). We also determined distances traveled by resident and relocated turtles in the first 10 days and in the first month postrelocation and evaluated these distances with 2 single-factor ANOVAs. Finally, we examined effect of relocation distance (distance between the turtles' original capture point and its release point) on total and farthest distances moved by turtles, as well as minimum convex polygon, 50% kernel home range, and 95% kernel home range with a linear regression. We performed all regression analyses and single-factor ANOVAs with $\alpha = 0.05$.

We determined if any of the turtles had a consistent bearing with the Circular Point Statistics function in the Animal Movement Extension of the GIS (Hooge and Eichenlaub 1997; Rayleigh's test, 95% CI). If a consistent bearing was present, we examined the direction of the turtle's bearing to see if it was directed towards its original capture location. In addition, we compared mortality and disappearance rate of relocated turtles to that of resident turtles throughout the year.

Table 1. Physical characteristics, relocation details, and fate for relocated and resident eastern box turtles on the Davidson College Ecological Preserve in Mecklenburg County, North Carolina, USA, between 2 May 2004 and 15 June 2005. We report carapace length and initial mass to provide approximate size of each turtle.

Turtle	Min. age (yr)	Carapace length (mm)	Initial mass (g)	Distance relocated (km)	No. of days radiotracked	No. of core areas in 95% kernel	No. of core areas in 50% kernel	No. of relocations	Fate
Relocated	15	129	414	7.0	98	[a]	[a]	28	Unknown
Relocated	[b]	123	[b]	1.4	359	2	1	67	Survived
Relocated	12	129	405	38.1	367	1	1	68	Survived
Relocated	16	136	536	7.2	376	4	2	76	Survived
Relocated	20	123	419	6.3	49	1	3	14	Overheated on railroad
Relocated	18	120	407	13.0	366	2	2	74	Survived
Relocated	15	122	386	16.7	64	[a]	[a]	23	Hit by car
Relocated	15	129	486	5.2	344	3	1	58	Hit by lawnmower
Relocated	23	118	366	6.4	367	5	1	67	Survived
Relocated	16	122	506	0.8	143	1	2	36	Predated
Resident	18	126	439	0	366	1	1	69	Survived
Resident	20	122	395	0	367	2	1	72	Survived
Resident	19	120	390	0	365	2	1	72	Survived
Resident	16	134	489	0	365	3	1	75	Survived
Resident	16	120	416	0	365	2	1	70	Survived
Resident	18	120	441	0	361	1	1	71	Survived
Resident	25	122	366	0	365	2	1	76	Survived
Resident	17	129	410	0	368	4	1	72	Survived
Resident	18	122	378	0	361	4	2	73	Survived
Resident	13	118	392	0	361	3	2	67	Survived

[a] Too few data points were recorded to calculate home range.
[b] Turtle age and mass were unknown.

RESULTS

We radiotracked relocated turtles for an average of 253.20 ± 45.60 ($\bar{x}$ ± SE) days and resident turtles for an average of 364.40 ± 0.80 days (Table 2). Both resident and relocated box turtles were active until November 2004 and emerged the following spring from 3 April to 29 April 2005. We observed 3 resident turtles laying eggs between 13 June and 6 July 2004, though we saw no relocated box turtles laying eggs. However, we found both resident and relocated turtles interacting and mating with resident male turtles from July to October 2004.

Relocated box turtles had average home ranges that were approximately 3 times larger than those of resident turtles when measured by minimum convex polygons ($F_{18} = 9.01$, $P = 0.008$), 6 times larger than resident turtles when measured with 95% kernels ($F_{18} = 11.90$, $P = 0.003$), and 7.5 times larger than resident turtles when measured by 50% kernels ($F_{18} = 7.15$, $P = 0.01$; Table 2). Most relocated turtles had 50% kernel home ranges consisting of multiple, fragmented core areas (Table 1), whereas no resident turtle had a 50% kernel home range with >2 core areas (Table 1). We found no relationship between relocation distance and turtle's home range size for any of the home range calculation methods (min. complex polygon: $R^2 = 0.06$, $P = 0.47$, $F = 0.56$; 95% kernel: $R^2 = 0.17$, $P = 0.24$, $F = 1.64$; 50% kernel: $R^2 = 0.09$, $P = 0.39$, $F = 0.84$).

We found no difference in total distance moved by relocated and resident turtles ($F_{19} = 0.308$, $P = 0.59$), although relocated turtles moved on average 394 m farther than did resident turtles (Table 3). Relocated turtles also traveled an average straight-line distance from their release point that was twice as far as that of resident turtles' ($F_{19} = 13.76$, $P = 0.002$; Table 3), and the average distance between their final and release locations was also twice as large as that of resident turtles' ($F_{19} = 9.34$, $P = 0.007$). Relocated box turtles showed more sprawling, arc-like, or circular movement patterns than did resident turtles, whose movements were often restricted to repeated use of a smaller area (Fig. 1).

Relocated turtles moved an average of 9.38 m more per day than did resident turtles over the year ($F_{19} = 8.51$, $P = 0.009$; Table 3). Resident turtles traveled a greater distance per day in July and September of 2004 and January, February, March, and July of 2005, and relocated turtles traveled greater distances per day in June, August, October, November, and December of 2004 and April, May, and June of 2005 (Fig. 2). However, we found no difference in average movement per day during any month between relocated and resident turtles ($F_{18} = 0.13$, $P = 0.725$). Relocated turtles did not travel farther than residents in the first 10 days ($F_{19} = 0.21$, $P = 0.65$; Table 3) or in the first month postrelocation ($F_{18} = 1.05$, $P = 0.31$; Table 3).

No box turtle demonstrated a consistent mean bearing (Animal Movement Extension, Hooge and Eichenlaub 1997; Circular Point Statistics; Rayleigh Z-value ranged from 0.02 to 1.34, P-values ranged from 0.09 to 0.48). However, one relocated turtle returned to its capture location and another relocated turtle traveled approximately half of the way to its capture location before being killed by predation.

Relocated turtles experienced higher mortality and disappearance rates than did resident turtles. Four relocated box turtles died compared to no resident box turtles (Table 1). One relocated turtle became trapped between railroad tracks and overheated, one was hit by a car, one was

Table 2. Mean number of days tracked and home range sizes for relocated and resident eastern box turtles on the Davidson College Ecological Preserve in Mecklenburg County, North Carolina, USA, between 2 May 2004 and 15 June 2005. All mean home range sizes were significantly different between resident and relocated turtles. All means are ±1 standard error. Significant differences between resident and relocated turtles are indicated with an asterisk (*).

	No. of days tracked		MCP[a] home range (ha)		Kernel 95% home range (ha)		Kernel 50% home range (ha)	
Turtle	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Relocated	253	45.6	18.02*	3.60	18.26*	4.40	2.60*	0.80
Resident	364	0.80	6.45	1.40	2.80	0.70	0.34	0.10

[a] MCP = min. complex polygon.

apparently killed by a feral house cat, and one was hit by a hay mower. In addition, one relocated box turtle had an unknown fate as a result of possible transmitter failure (Table 1). All resident turtles survived the duration of the study.

DISCUSSION

Relocated turtles had larger home ranges, moved greater average distances per day, and moved greater distances from their release points than did resident turtles. This increased movement made relocated turtles more likely to encounter threats associated with urbanization (e.g., roadways, railroads, pets), possibly contributing to the higher mortality rate we observed among relocated turtles. In addition, relocated turtles may have been less likely to find resources in the unfamiliar environment, may have been more susceptible to disease, and may have used more energy during the course of their movements. Our data suggest that relocation is not a suitable conservation strategy for eastern box turtles, although multi-year studies with a larger sample size would help to clarify long-term effects of relocation on these turtles.

Alterations in home range size are significant for box turtles because they normally retain the same home ranges throughout their life (Claussen et al. 1991). In our study, relocated turtles had a larger average home range than did resident turtles when measured by MCP, 95% kernel, and 50% kernel. Larger home ranges for relocated reptiles have also been reported for three-toed box turtles (*Terrapene carolina triunguis*), rattlesnakes, and eastern hognose snakes (*Heterodon platirhinos*; Hare and McNally 1997, Plummer and Mills 2000, Rittenhouse et al. 2007). The larger home ranges of relocated turtles in our study may reflect their unfamiliarity with their new environment, their attempt to find an appropriate area containing needed resources, or an attempt to return to their original home range (Posey 1979, Mathis and Moore 1988, Hare and McNally 1997). In addition, we found relocated turtles to have more centers of activity (based on 50% kernels) than did resident turtles, which supports the contention that relocated turtles were more mobile and were occupying more areas.

Despite the tendency of relocated turtles to have larger home ranges, 2 relocated turtles in our study had home ranges that were similar in size to those of resident turtles, demonstrating variability in individual responses and indicating that these turtles may have begun to establish home ranges postrelocation. A similar phenomenon occurred in box turtle relocation projects in New York and Pennsylvania, USA, where 47% and 40% of relocated turtles, respectively, established home ranges over ≥2 years (Belzer 2002, Cook 2004). Given more time, some relocated turtles remaining in DCEP might have begun to establish home ranges.

Movement patterns exhibited by relocated turtles in our study are reminiscent of movements of turtles and other reptiles in unfamiliar habitats. In other studies, box turtles placed in an unknown habitat initially showed erratic movement, followed by straight-line movement towards their previous location as a result of their homing mechanism (Lemkau 1970, Posey 1979). Translocated timber rattlesnakes (*Crotalus horridus*) also demonstrated extensive movements (3–5 times greater than residents) away from the release site during the first active season after their release and moved in concentric circles and arcs, a behavior that was also exhibited by relocated box turtles in Maryland and several of the relocated turtles in our study (Posey 1979, Reinert and Rupert 1999). These arcing patterns may be a further indication that the relocated animal is searching for a suitable home range or attempting to return to its original home range.

No turtle in our study moved in a significantly directed manner, indicating that none of the turtles exhibited direct homing behavior. However, one turtle that had been relocated 843 m returned to its capture location, taking a somewhat circuitous route and demonstrating that homing may not always occur in a straight line. Several studies

Table 3. Movements of relocated and resident eastern box turtles on the Davidson College Ecological Preserve in Mecklenburg County, North Carolina, USA, between 2 May 2004 and 15 June 2005. All means are ±1 standard error. Significant differences between resident and relocated turtles are indicated with an asterisk (*).

	Total distance moved (m)		Distance moved/day (m)		Net distance moved (m)		Distance from release point to furthest point (m)		Distance moved in first 10 days (m)		Distance moved in first month (m)	
Turtle	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Relocated	3542	450.80	17.98*	3.10	520.20*	78.05	711.60*	77.45	209.20	68.20	914.83	84.57
Resident	3148	330.80	8.60	0.90	253.40	39.07	377.10	46.20	247.20	46.90	756.79	128.98

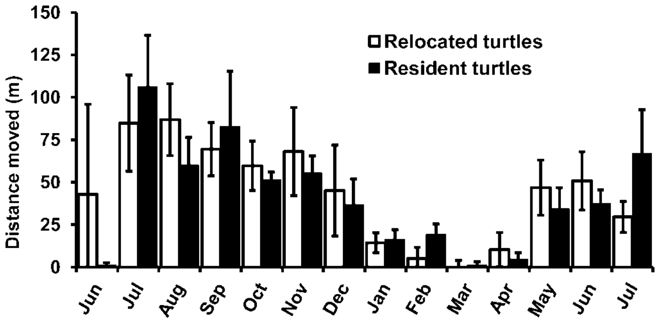

Figure 2. Mean distance traveled per active day each month for both resident ($N = 10$) and relocated ($N = 10$) eastern box turtles on the Davidson College Ecological Preserve in Mecklenburg County, North Carolina, USA, between 2 May 2004 and 15 June 2005. We defined active days as days in which we found the turtles in a different location than the previous time they were radiotracked. Bars represent between 2 and 20 active turtles with between 2 and 10 new locations per turtle each month (turtles were less active during winter). Error bars represent ±1 standard error.

indicate that box turtles do exhibit homing behavior. For example, 82 of 434 ornate box turtles (*Terrapene ornata*) in Kansas returned to their original home ranges after being relocated approximately 2.5 km, but box turtles moved >3 km were unable to home (Metcalf and Metcalf 1970, Posey 1979). It is possible that most turtles in our study were moved too far from their original home ranges to be able to home accurately.

Four relocated turtles died during our study and one had an unknown fate, though no deaths or disappearances occurred among the resident turtles. All turtles that died in our study were killed after they had wandered outside the DCEP and into nearby neighborhoods, railroads, roads, and farm fields (Kornilev et al. 2006). Higher mortality rates among relocated animals was also reported in timber rattlesnakes (63.3%; Reinert and Rupert 1999), eastern hognose snakes (100%; Plummer and Mills 2000), and other eastern box turtles (28.3%; Cook 2004). High mortality rates among relocated turtles and other reptiles emphasize threats, such as cars, lawn mowers, subsidized predator populations, and construction, faced by animals that are placed in unfamiliar environments.

Management Implications

Relocating box turtles to a new location could endanger the relocated turtle. Box turtles treated by wildlife rehabilitators should be released as close as possible to the location where they were found to minimize mortality. However, if relocation is the only management option available, penning turtles for a time after they are relocated may help them establish a new home range (Tuberville et al. 2005). More extensive studies are needed to understand long-term effects of relocation on turtle movements. Further research on methods for the reduction of mortality in relocated box turtles and other animals is also needed.

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