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Home Ranges of Ornate Box Turtles in Remnant Prairies in North-central Illinois

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Abstract - Habitat loss has been a primary driver of biodiversity declines throughout the United States. Native prairie ecosystems represent some of the most significant losses in land cover, and subsequently, prairie-dependent species are some of the most imperiled. Therefore, understanding the ecology of species remaining in remnant portions of these ecosystems is important to help manage their populations. Using radio-telemetry, we examined minimum convex polygon (MCP) and 95% kernel density (KD) home ranges of 20 (5 female, 15 male) Ornate Box Turtles (*Terrapene ornata*) inhabiting two remnant prairies in north-central Illinois across two years and six seasons. Results showed that MCP and 95% KD home range estimates were comparable but smaller than other published studies, differed between years, across seasons, and among individual turtles within sites. These results provide valuable data to quantify the ecology of this threatened species in a remnant prairie habitat.

Keywords: kernel density, minimum convex polygon, overlap, radio-telemetry, *Terrapene ornata*

Introduction

Terrapene ornata (Ornate Box Turtle Agassiz 1857), is dependent on sand prairies, and ranges from the central and southern United States to northern Mexico (Ernst and Lovich 2009). Ornate Box Turtles are listed in Appendix II of the Convention on International Trade of Endangered Species of Wild Flora and Fauna (USFWS 1995). As a result of native prairie loss, and overexploitation via the pet trade, Ornate Box Turtles are also state-listed as endangered, threatened, or of special conservation concern across their U.S. range (Converse et al. 2005) and have recently been listed as threatened in Illinois (IESPB 2010). Therefore, establishing records of the ecology of Ornate Box Turtle populations within these areas of the state is imperative.

Examining spatial and seasonal ecology of box turtles (*Terrapene* spp.) is important to understand both the basic ecology of box turtles (Dodd 2002) and to develop effective management plans that can address the area and habitat use of this species to design management plans in areas undergoing active management (Redder et al. 2006). Box turtles have considerable variation in home range size (Dodd 2002; Redder et al. 2006; Habeck et al. 2019), for example, home ranges can range between 0.205 to over 28 ha (Habeck et al. 2019). For Ornate Box Turtles specifically, there are studies identifying robust populations across their range (Converse et al. 2005), including Illinois (Bowen et al. 2004; Refsnider et al. 2011). However, little is known regarding their spatial ecology and seasonal activity in habitats such as those in this study that are both disjunct and adjacent to unsuitable habitat. For two years, we studied spatial ecology and seasonal activity of adult Ornate Box Turtles inhabiting two remnant prairies in north-central Illinois. Our objectives were to quantify and compare Ornate Box Turtle home ranges by 1) year, 2) site, 3) season, 4) yearly overlap (i.e. site fidelity estimate), and by 5) individual turtle.

Methods

We conducted our study within the Goose Lake Prairie Nature Preserve (GLP; 1,027 ha) and Wilmington Shrub Prairie Nature Preserve (WSP; 58 ha)/Kankakee Sands Preserve (KSP; 225 ha) located in Grundy and Will Counties, Illinois, U.S.A., respectively (see Milanovich et al. 2017). Ornate Box Turtles were found in the spring of 2014 and 2015 using visual encounter surveys and trained turtle dogs. Upon capture, we affixed radio-transmitters (model R1850 [12 g] or model R1680 [3.6 g], Advanced Telemetry Systems, ≤ 5% of body mass) to a single carapacial scute using 5-min epoxy. We used ground-based radio-telemetry by foot to monitor turtles using a receiver (R410, Advanced Telemetry Systems) and a 3-element yagi antenna. For both years, we

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located turtles between 1 to 3 times per week from March through November, when hibernaculum locations are typically established (Milanovich et al. 2017). For each radiolocation, we visually located (when possible) the turtle and we recorded GPS coordinates using a handheld global positioning system unit (Garmin; Table 1). We quantified turtle home ranges using minimum convex polygons (MCP) and 95% kernel density (KD) estimations by using all turtle locations (i.e., no subsampling) and using ArcGIS 10.3, using the default setting and smoothing parameters for kernel density estimation. Minimum convex polygons are the smallest area convex polygon that includes all of the coordinates locations; while KD estimates map a utilization distribution by predicting how likely each pixel within a grid is used by that individual (Downs and Horner 2008). Minimum convex polygons are constrained by the number of data points collected and the sampling frequency of turtle locations (Börger et al. 2006). Our sampling interval of once per week for some periods (e.g., winter) may not be sufficient to represent the precise home range or spatial extent of each turtle, but we included them in analyses to compare with other studies of which this method was the only practical option, and to compare to 95% KD analyses to give context to our home range estimations. We examined differences in MCP and 95% KD home ranges of individual turtles across years and sites using a mixed-effect ANOVA, with site, year, and sex as fixed

Table 1. Sample size for radio-telemetry points for each individual Ornate Box Turtle within Goose Lake Prairie Nature Preserve (GL; 2014 *n* = 3; 2015 *n* = 10) and Wilmington Shrub Prairie Nature Preserve (WP/KSP; 2014 *n* = 3; 2015 *n* = 10) across seasons.

			Number of GPS locations			
Site/Year	**Turtle ID**	**Sex**	**Spring**	**Summer**	**Fall**	**% MCP overlap**
2014						
GL	761	M	6	8	8	43.6
GL	900	M	12	8	8	83.2
GL	960	F	14	8	8	60.8
WP/KSP	779	F	8	8	8	52.5
WP/KSP	841	M	9	8	9	43.2
WP/KSP	620	F	7	8	9	38.4
2015						
GL	601	F	15	5	8	–
GL	641	M	15	5	8	–
GL	662	M	15	5	8	–
GL	801	F	15	5	8	–
GL	861	M	15	5	8	–
GL	881	M	15	5	8	–
GL	941	M	15	5	8	–
GL	761	M	19	5	8	–
GL	900	M	20	5	8	–
GL	960	F	16	5	8	–
WP/KSP	701	M	15	6	8	–
WP/KSP	721	M	15	6	8	–
WP/KSP	741	M	15	6	8	–
WP/KSP	820	M	15	6	8	–
WP/KSP	921	M	14	6	8	–
WP/KSP	779	F	20	6	0	–
WP/KSP	841	M	20	6	8	–
WP/KSP	981	M	20	6	0	–
WP/KSP	681	M	15	5	8	–
WP/KSP	620	F	20	6	8	–

effects and individual turtle ID as the random effect (since we had multiple years of data for some individuals). To test for seasonal differences in MCP and 95% KD home range estimates within 2014 and 2015 (separately), we used one-way ANOVAs where the independent variable was the individual home ranges and the dependent variables were season (spring = April, May, and June; summer = July and August; fall = September, October and November) and site. We also calculated the percent overlap of MCP home ranges estimates between 2014 and 2015 for the 6 individuals radio-tracked across both years using the UNION tool in ArcGIS 10.4.1 and the equation from Refsnider et al. (2012) to estimate site fidelity between years. All statistical analyses were conducted in Statistica 13.3 (Statsoft, Inc, Tulsa, OK).

Results

In 2014 and 2015, respectively, 8 (5 male and 3 female) and 20 (15 male and 5 female) adult turtles were captured. No turtles were found to be predated during the study, but GPS locations for individuals varied as some transmitters were unable to be located during each visit (Table 1) and following spring 2014 transmitters of two turtles were unable to be located. This brought the sample size in 2014 from 8 to 6 turtles following spring 2014 until spring 2015. Minimum convex polygon (MCP) and 95% KD estimates of home range were not significantly different between years (F = 3.861, P = 0.066; mean MCP/KD in 2014 = 2.88/4.36 ha; mean yearly MCP/KD in 2015 = 5.32/6.49 ha), sites (F = 0.008, P = 0.930;), or sex (F = 2.016, P = 0.177; mean yearly MCP for females/males in 2014 = 1.68/3.60 ha; mean MCP for females/males in 2015 = 4.11/5.73 ha; mean yearly 95% KD for females/males in 2014 = 2.59/5.43 ha; mean 95% KD for females/males in 2015 = 3.14/5.73 ha) after accounting for individual turtles examined across years (Tables 2 and 3). For seasonal differences, we found that MCP estimates in 2014 were significantly greater in spring (1.5 ± 0.5 ha) than in summer (0.2 ± 0.0 ha; F = 4.670, P = 0.022) and in 2015, MCP estimates were significantly greater in spring (3.6 ± 0.6 ha) than summer (0.6 ± 0.2 ha) and fall (0.2 ± 0.1 ha; F = 27.209, P = ≤0.001; Tables 2 and 3). Furthermore, although we found that 95% KD estimates in 2014 did not significantly differ across seasons, the average home ranges in spring 2014 were measurably larger compared to summer and fall (F = 2.910, P = 0.079; Tables 2 and 3). In 2015, 95% KD estimates were significantly greater in spring (5.2 ± 1.1 ha) than fall (1.3 ± 0.5 ha; F = 7.143, P = 0.002; Tables 2 and 3). The percent overlap between MCP estimates in 2014 and 2015 for 6 turtles (3 at each site) was an average of 54% (range = 38 to 83%; Table 1).

Discussion

Home range estimates. A considerable amount of work has described the home ranges of both Eastern and Ornate Box Turtles (see Table S1 of Habeck et al. [2019]) for inclusive list of studies). Although comparisons between our study and other individual studies highlight some notable similarities and differences, it is critical from a management and conservation perspective to understand how our study fits into the broader trends of box turtle spatial ecology and analyses. Our results show MCP home range estimates of adult Ornate Box Turtles differed between years, across seasons, and among individual turtles within sites. Minimum convex polygon estimates were, on average, smaller in 2014 than 2015 (Tables 1, 2), which may be due to an increase in the number of loca-

Table 2. Sample size, mean, standard error, and minimum and maximum minimum convex polygon (MCP) and 95% kernel density (KD) home range estimates as hectares (ha) for Ornate Box Turtles (male and female combined) in Will and Grundy Counties, Illinois in 2014 and 2015.

			MCP			95% KD		
		n	Mean	SE	Min-Max	Mean	SE	Min-Max
Spring	2014	8	1.5	0.5	≤ 0.1-3.6	4.2	1.7	≤ 0.1-11.7
	2015	20	3.6	0.6	0.3-8.2	5.2	1.1	0.4-18.3
Summer	2014	8	0.2	0.0	≤ 0.1-0.3	0.6	0.2	≤ 0.1-1.7
	2015	20	0.6	0.2	≤ 0.1-3.2	2.5	0.8	0.1-13.9
Fall	2014	6	0.3	0.2	≤ 0.1-1.5	1.2	1.1	≤ 0.1-6.5
	2015	19	0.2	0.1	≤ 0.1-0.9	1.3	0.5	≤ 0.1-8.8
Total year	2014	8	2.9	0.8	0.9-7.2	4.4	1.8	0.7-16.7
	2015	20	5.3	0.9	0.4-13.6	6.5	1.6	0.7-29.5

Table 3. Mixed-effect and one-way ANOVA results investigating whether Ornate Box Turtle home range estimates differed between years or sites after accounting for individual, or across seasons. The * indicates a significant difference ($P \leq 0.05$).

		MCP			95% KD		
Type	df	MS	F	*P*	MS	F	*P*
Mixed effects							
Year	1	24.497	3.861	0.066	11.067	0.560	0.464
Site	1	0.105	0.008	0.930	6.488	0.090	0.768
Sex	1	27.952	2.016	0.177	126.235	1.590	0.224
Turtle ID	17	11.741	3.067	0.134	62.529	239.526	0.324
Year*Site	1	0.013	0.004	0.956	1.385	0.3.421	0.357
Year*Turtle ID	5	3.982	0.525	0.757	0.962	0.056	0.998
One-way							
Season (2014)	2	3.946	4.670	0.022*	30.214	2.910	0.079
Error	19	0.845	–	–	10.380	–	–
Season (2015)	2	67.000	27.209	≤ 0.001*	93.880	7.143	0.002*
Error	56	2.462	–	–	13.142	–	–

tions in 2015 (but see Habeck et al. 2019 for non-significant relationships between home range estimates and sample size). Across both 2014 and 2015, we found the percent overlap of MCP was similar to turtles found in northwest Illinois (Refsnider et al. 2012) and Iowa (Bernstein et al. 2007), and suggests among-year site fidelity and lack of territoriality of these 6 individuals. Home range estimates in our study were similar or smaller than mean home ranges of adult Ornate Box Turtles (see review in Habeck et al. 2019).

Our results show MCP home range estimates of adult Ornate Box Turtles differed between years, across seasons, and among individual turtles within sites, but not by sex. Minimum convex polygon estimates were, on average, smaller in 2014 than 2015 (Tables 1, 2), which may be due to an increase in the number of locations in 2015 (but see Habeck et al. 2019 for nonsignificant relationship between home range estimates and sample size). Across both 2014 and 2015, we found MCP estimates of 6 turtles averaged 53% overlap (range = 38 to 83%), which is similar to turtles found in northwest Illinois (Refsnider et al. 2012) and Iowa (Bernstein et al. 2007), and suggests among-year site fidelity for these 6 individuals. Home range estimates in our study were also similar to mean home ranges of adult Ornate Box Turtles in northwestern Illinois (MCP values; Refsnider et al. 2012) and New Mexico (minimum polygon values; Nieuwolt 1996), but smaller, on average, than reports from Iowa (MCP values; Bernstein et al. 2007), Arizona (MCP values; Hall and Steidl 2003), and Wisconsin (geographic isopleths values; Doroff and Keith 1990)and intensively monitored (≥20 relocations. These differences in box turtle home ranges across studies may be due to differences in ecoregion, indicated by Habeck et al.'s (2019) meta-analysis of 26 box turtle home range studies that found Ornate Box Turtles home range estimates are larger in more arid ecoregions (e.g., West-central semi-arid prairies) vs. wetter ecoregions (e.g., Central USA plains; where our study is located). Furthermore, the generally smaller home range estimates of our Ornate Box Turtles may be due to limited suitable habitat available. Populations in our study inhabit an area adjacent to agriculture and urbanization, and thus, these may limit expansion opportunities. Given our results are similar to those studies conducted in presumably higher quality habitats, it suggests our results may be generalizable to unstudied areas of lower quality or non-homogenous habitat.

Variation in box turtle home range sizes within a given ecoregion can also be attributed to seasonal abiotic environmental factors such as temperature, precipitation, and quality and availability of resource patches in a landscape. For example, Tucker et al. (2015) found 95% of Ornate Box Turtle activity in northwestern Illinois occurred when ambient temperatures were between 11.3 and 32.9°C, and that from May to September, activity was highest on days when rain occurred. Converse et al. (2002) showed a negative relationship with activity levels and temperature in Ornate Box Turtles in Nebraska. Bernstein et al. (2007) found no seasonal variation in Ornate Box Turtle MCP home range from May to September in Iowa, but did find kernel density home ranges differed. Our study showed larger MCP home ranges in spring than in summer or fall, but kernel density home ranges were not significantly different. We believe this supports that some populations of Ornate Box Turtles can expand their home range during spring and fall months.

Berstein et al. (2007) suggest variation in seasonal home range can be explained by mating and nesting behavior of both males and females, and this is corroborated by Habeck et al. (2019). Our results can also be linked to variation in precipitation and temperature, as precipitation in 2014 and 2015 in our study region was higher during spring months (total 31.5 cm [mean = 0.36/day] and 48.0 cm [mean = 0.53/day], respectively) compared to summer (22.9 cm [mean = 0.16/day) and 13.2 cm [mean = 0.20/day], respectively (Young et al. 2017). In addition, since our model did not find sex or individual turtle I.D. explained any statistical variance in home range we believe there is considerable intraspecific variation in spring home range size in these populations.

Finally, we found that home ranges varied significantly among individuals within sites, but individual home ranges overlapped from year to year. These results indicate that individuals maintain familiar home ranges among years, but that each individual varies. More generally, these findings underscore the importance of accounting for individual variation during analyses (DeGregorio et al. 2017; Roe et al. 2020). More recent studies have described this variation as individual turtle personalities, which can affect predation risk, body temperature, movements, and survivorship (Kashon and Carlson 2018; Allard et al. 2019; Roth et al. 2020; Carlson and Tetzlaff 2020).

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Literature Cited

Allard, S.M., G.A. Fuller, L.L. Torgerson-White, M. Starking, and T. Yoder-Nowak. 2019. Personality in zoo-hatched Blanding's turtles affects behavior and survival after reintroduction into the wild. *Frontiers in Psychology* 10: 2324. https://doi.org/10.3389/fpsyg.2019.02324.

Bernstein, N.P., R.J. Richtsmeier, R.W. Black, and B.R. Montgomery. 2007. Home range and philopatry in the ornate box turtle, *Terrapene ornata ornata*, in Iowa. *American Midland Naturalist* 157: 162–174. https://doi.org/10.1674/0003-0031(2007)157[162:HRAPIT]2.0.CO;2.

Bowen, K.D., P.L. Colbert, and F.J. Janzen. 2004. Survival and recruitment in a human-impacted population of ornate box turtles, *Terrapene ornata*, with recommendations for conservation and management. *Journal of Herpetology* 38: 562–568. https://doi.org/10.1670/78-04a.

Carlson, B.E. and S.J. Tetzlaff. 2020. Long-term behavioral repeatability in wild adult and captive juvenile turtles (*Terrapene carolina*): Implications for personality development. *Ethology* 126: 668–678.

Converse, S.J., J.B. Iverson, and J.A. Savidge. 2002. Activity, reproduction and overwintering behavior of ornate box turtles (*Terrapene ornata ornata*) in the Nebraska Sandhills. The *American Midland Naturalist* 148: 416–422.

Converse, S.J., J.B. Iverson, and J.A. Savidge. 2005. Demographics of an ornate box turtle population experiencing minimal human-induced disturbances. *Ecological Applications* 15: 2171–2179. https://doi.org/10.1890/04-0431.

DeGregorio, B.A., T.D. Tuberville, R.A. Kennamer, B.B. Harris, and I.L. Brisbin Jr. 2017. Spring emergence of Eastern Box Turtles (*Terrapene carolina*): influences of individual variation and scale of temperature correlates. *Canadian Journal of Zoology* 95: 23–30. https://doi.org/10.1139/cjz-2016-0149.

Dodd, C.K. 2002. *North American Box Turtles: A Natural History*. University of Oklahoma Press, Norman, Oklahoma, USA.

Ernst, C.H., and J.E. Lovich. 2009. *Turtles of the United States and Canada*. 2nd ed. Johns Hopkins University Press, Baltimore, Maryland, USA.

Habeck, C.W., M.P. Figueras, J.E. Deo, and R.L. Burke. 2019. A surfeit of studies: what have we learned from all the box turtle (*Terrapene carolina* and *T. ornata*) home range studies? *Diversity* 11: 1–12. https://doi.org/10.3390/D11050068.

Harden, L.A., J. Fernandez, J.R. Milanovich, B.P. Struecker, and S.R. Midway. 2018. Blood biochemical reference intervals for wild Ornate Box Turtles (*Terrapene ornata*) during the active season. *Journal of Wildlife Diseases* 54: 587–591. https://doi.org/10.7589/2017-09-222.

IESPB. Illinois Endangered Species Protection Board, Biennial Report, 2008-2010. 2010. 21, Springfield, Illinois, USA.

Kashon, E.A.F. and B.E. Carlson. 2018. Consistently bolder turtles maintain higher body temperatures in the field but may experience greater predation risk. *Behavioral Ecology and Sociobiology* 72: 9. https://doi.org/10.1007/s00265-017-2428-8.

Milanovich, J.R., B.P. Struecker, S.A. Warcholek, and L.A. Harden. 2017. Thermal environment and microhabitat of ornate box turtle hibernacula. *Wildlife Biology* 2017: 1–7. https://doi.org/10.2981/wlb.00295.

Redder, A., Jr. C.K. Dodd, D. Keinath, D. Mcdonald, and T. Ise. 2006. Ornate box turtle (*Terrapene ornata ornata*): A technical conservation assessment. USDA Forest Service, Rocky Mountain Region, Lakewood, Colorado.

Refsnider, J.M., T.S. Mitchell, H.M. Streby, J.T. Strickland, D.A. Warner, and F.J. Janzen. 2011. A generalized method to determine detectability of rare and cryptic species using the ornate box turtle as a model. *Wildlife Society Bulletin* 35: 93–100. https://doi.org/10.2744/Ccb-0919.1.

Refsnider, J.M., J. Strickland, and F.J. Janzen. 2012. Home range and site fidelity of imperiled ornate box turtles (Terrapene ornata) in northwestern Illinois. *Chelonian Conservation and Biology* 11: 78–83. https://doi.org/10.2744/CCB-0919.1.

Roe, J.H., A.L. Kish, and J.P. Nacy. 2020. Variation and repeatability of home range in a forest- dwelling terrestrial turtle: implications for prescribed fire in forest management. *Journal of Zoology* 310: 71–82. https://doi.org/10.1111/jzo.12732.

Roth, T.C., M. Rosier, A.R. Krochmal, and L. Clark. 2020. A multi-trait, field-based examination of personality in a semi-aquatic turtle. *Ethology* 126: 851–857. https://doi.org/10.1111/eth.13030.

USFWS. United States Fish and Wildlife Service. 1995. Changes in the list of species in appendices to the convention on international trade in endangered species of wild fauna and flora. *Federal Register* 60: 665–670.

Tucker, C.R., J.T. Strickland, B.S. Edmond, D.K. Delaney, and D.B. Ligon. 2015. Activity patterns of ornate box turtles (*Terrapene ornata*) in northwestern Illinois. *Copeia* 103: 502–511. https://doi.org/doi:10.1643/CH-15-249.

Young, A.H., K.R. Knapp, A. Inamdar, W.B. Rossow, and W. Hankins. 2017. The International Satellite Cloud Climatology Project, H-Series Climate Data Record Product. *Earth System Science Data* 10: 583–593. https://doi.org/10.5194/essd-10-583-2018.