Comparison of Eastern Box Turtle (*Terrapene carolina carolina*) home ranges in relation to summer precipitation trends in Upton, New York

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Abstract

The Eastern Box Turtle (EBT), *Terrapene c. carolina*, is a species internationally listed as vulnerable found throughout Eastern North America. With recent declines throughout the region, there is a critical need to examine all aspects of their shifting home ranges and habitat requirements. Using radio-telemetry, our study examined the home ranges of 12 turtles during the summer months of June 2012 to July 2018. Although there is a great deal of individual variation in seasonal home range shifts, precipitation levels may play an important role in their movements for survival, yet it is understudied. Rainfall has been described as a favorable condition for EBT as it has been shown to stimulate activity. Our approach consisted of using geospatial information systems (GIS) to find the area of each turtle's home range each summer from 2012 to 2018 through minimum convex polygon (MCP) estimates. These estimates were then compared with the corresponding rainfall during that period, and drought versus non-drought periods. Mann-Whitney tests showed distinct differences in drought vs non-drought years in June, but no differences in July. Through simple and multiple linear regressions, our results showed no significant relationship between rainfall and home range. Although precipitation or drought did not show a relationship with EBT home range, we did find that there are significant differences between 2013 vs. 2018 and 2015 vs. 2018. The variable or variables causing this difference is still unknown. This research, builds on current long-term understanding of EBT home range movements. As a result, this can be applied to the future understanding of home range and habitat use patterns of EBT, both of which are fundamental to guiding land management and conservation practices for EBT and other turtle species.

Introduction

The Eastern Box Turtle, *Terrapene carolina carolina*, is a species currently listed as vulnerable by the International Union for the Conservation of Nature (IUCN), and on Appendix II by the Convention on International Trade in Endangered Species (CITES), throughout eastern North America (van Dijk

2011, UNEP-WCMC 2014). Over the past few decades, there has been 50%-75% decline in various populations throughout the eastern United States (Donaldson and Echternacht 2015). Possible threats that contribute to these recent declines include habitat loss, vehicle strikes, illegal collection, infectious disease, and climate change- i.e. premature overwintering emergence. These threats are amplified by slow recovery from losses due to the species slow maturation and low reproductive success (Greenspan et al. 2015, Dodd 2001, Erb and Willey 2011). Home ranges of *T. c. carolina* are typically found to be 1-5 ha in size (Dodd 2001), but have been found to reach upwards of 20-25 ha (Schwartz et al. 1984; Ernst and Lovich 2009). Some individuals appear stationary, some even occupying the same home ranges for decades, but home range size has been shown to vary between individuals with influences from various seasonal cues and nest site selection (Hall et al. 1999, Erb and Willey 2011). Therefore, it is important to estimate home range areas across a variety of variables such as weather patterns, habitat types, geographic regions, and other environmental disturbances (Greenspan et al. 2015).

Although there have been some differences resulting from low efficiency in tracking *T. c. carolina* and data interpretation, the number of box turtles recorded in Maryland has shown an evident decline over the span of 50 years. Increasing evidence suggests that changes in hydrology could be a significant factor in their decline (Hall et al. 1999). Studies show that weather can have large impacts on the movements of *T. c. carolina*, with warm, humid, sunny days following rainfall stimulating the most movement (Dolbeer 1969, Dodd 2001). While weather induced activity and seasonal movements of *T. c. carolina* have been studied, home range changes due to weather or climate have remained unstudied. In addition, between the 2015 and 2016 summer months of June-August, Long Island experienced moderate and severe droughts, respectively (NIDIS 2018), but there have been no studies examining the effect of drought or rainfall on *T. c. carolina* home range sizes.

Methods

Study Site-

We conducted this study at Brookhaven National Laboratory located in Upton, Long Island, New York. The 2,145-ha property is mainly dominated by pine barren forests and the laboratory's 81-ha solar farm located in the southeastern corner of the property. The Peconic River and various operable units such as waste management areas, upland recharge areas, landfills and a sewage treatment plant also intersect the property.

Radio Telemetry-

Six eastern box turtles were fitted with radio transmitters in 2012, and six in 2013 (for a total of 12 turtles) and given unique notch codes (v-notches filed into the marginal scutes). Radio transmitters were glued to the vertebral scutes of each turtle's carapace with epoxy glue and were replaced every two to three years depending on battery life. Each of the 12 turtles were tracked using radio telemetry antennas approximately twice a week during the summer months starting June 2012 and ending 25 July 2018. Two of the study turtles were not found in June 2017, and one in July 2017. For each turtle's tracking session, we recorded the time, GPS location (UTM with accuracy of ± 3m), temperature, humidity, microhabitat, and macrohabitat at which each turtle was found. At the completion of our study, transmitters were removed, and the turtles were released at their last known location.

Data Analysis-

All data from 2012-2017 were collected by various interns, excluding the current authors. Maps were generated in ArcGIS 10.5.1 for each turtle based on their GPS location data gathered each year. Minimum Convex Polygons (MCP) were created to find the total area (ha) estimate of each turtle's home range. Home range data was categorized as non-drought (2012-2014, 2017-2018) and drought (2015-2016) based upon the National Integrated Drought Information System's (NIDIS) classifications, and

Mann-Whitney U Tests were performed in Microsoft Excel. We ran a Mann-Whitney U Test for June 2012-2018 and another for July 2012-2018, with N1 being non-drought and N2 being drought. Another Mann-Whitney test was performed with N1 being June 2012-2018 and N2 being July 2012-2018, in order to determine if there are significant home range differences between the two months. NIDIS lists June-August 2015 as Moderate Drought (D1) and June-August 2016 as Severe Drought (D2). For the purpose of this study, we chose to begin from the D1 level as opposed to Abnormally Dry (D0) because D1 is the first mention of drought and the first development of some water shortages. Rainfall data was obtained from Brookhaven National Laboratory's Environmental and Climate Sciences Department. The cutoff date for the rainfall data and turtle location data for this study was 25 July 2018. We performed a simple linear regression between rainfall per month and that month's MCP home range estimate combining all data without respect for year or individual. We also performed a multiple linear regression using turtle ID, year, rainfall per month, and MCP home range estimates for that month. A one-way ANOVA and post-hoc Tukey were also performed on the MCP home range data by year.

Results

Our Mann-Whitney U Test for June 2012-2018 (N1=52, N2=24, U=341), with N1 being non-drought and N2 being drought, resulted in a p value of 0.001. The results of our Mann-Whitney U Test for July 2012-2018 (N1=53, N2=24, U=481), with N1 being non-drought and N2 being drought, gave a p value of 0.088. Our Mann-Whitney U Test for 2012-2018 (N1=76, N2=77, U=2825), with N1 being June and N2 being July, resulted in a p value of 0.712.

We conducted a simple linear regression combining all data without respect for year or individual and found no significant relationship between rainfall in a particular month and that month's home ranges (R2=0.007, P=0.306). We performed a multiple linear regression using turtle ID, year, rainfall in a particular month, and home range that month and found no significant relationship between each turtle's home range per month per year and the rainfall of the same period (R=0.018, P=0.425). None of these variables alone approached significance, with the lowest P value at 0.234. A one-way ANOVA test showed significant differences in home range by year (F=3.454, DF=6, P=0.006). These differences were explained by a post-hoc Tukey test due to differences between 2013 vs 2018 (P=0.010) and 2015 vs 2018 (0.040). Values in 2012 and 2018 were unusually low, but the small sample size for 2012 prevented that year from being significantly different than high years. The small 2012 and 2018 home range values remained unexplained by our analyses.

Discussion

The p value of June 2012-2018 generated by our first Mann-Whitney U Test (p=0.001) was less than our critical value of 0.050, and we therefore can reject the null and assume June non-drought vs June drought home range areas to be distinct. The same test for July 2012-2018 generated a p value of 0.088, which is greater than 0.05, so we can accept the null and assume there is not enough evidence to claim July non-drought vs July drought home range areas to be distinct. While we did not have enough evidence to support that drought affected July home ranges, we were able to support that drought affected June home ranges. This difference may be due to nesting habits, or may even stem from other sources such as humidity and heat, instead of drought. Another factor which may affect these results is our classifications of drought conditions. Years we classified as “non-drought” included years labeled by the NIDIS as Abnormally Dry (D0), and our “drought” years, 2015 (D1) and 2016 (D2), experienced different drought severities (NIDIS 2018). Our second Mann-Whitney U test generated a p value of 0.712, which is greater than 0.05, so we can accept the null and assume there is not enough evidence to claim 2012-2018 June vs July home range areas to be distinct.

Our simple linear regression revealed a P value of 0.306, which is greater than our critical value 0.05, indicating no significant relationship between a month’s rainfall and home ranges. Our multiple linear regression revealed similar results, with the lowest P value at 0.234, which is also higher than our critical value of 0.05. Another simple linear regression, this time testing average home range with precipitation yielded a P value of 0.924 (greater than 0.05). These results indicate that June and July precipitation from 2012-2018 did not affect EBT home range areas. Our one-way ANOVA test on home ranges revealed significant (P=0.006) differences in the home range areas of different years, with a p value greater than our critical value of 0.05. The years causing these differences, 2013 vs 2018 (P=0.010) and 2015 vs 2018 (P=0.040), were revealed in a post-hoc Tukey test, with the P values from those years both being less than 0.05. Construction of sewage treatment basins in 2013 overlapping with multiple study turtles' historic home ranges may have caused turtles to increase the area of their home ranges in order to access less disturbed habitats. Low home range values in 2012 and 2018 may be related to capture frequencies in those years, where turtles were captured a maximum of once per day, and other years turtles may have been captured twice per day. However, 2012's small sample size prevented the year's home range data from being significantly different from other years. These results show that precipitation alone does not alter EBT June and July home range areas.

Other factors may be fully responsible for home range differences, or may be amplified by precipitation. These factors include surface water, heat, and substrate (Dodd 2001). Additional causes may include habitat (Erb and Willey 2011), humidity, construction, capture frequencies, implants and surgery, and nesting. Box turtle home range area may even be attributed to "individual preference" (Dodd 2001). Limitations of this study include discrepancies in data collection by various interns, such as estimation of GPS locations, misreading notch codes, data input, and disorganization or loss of field notes. While causes of EBT home range size changes largely remain unknown, this research helps to guide future studies and can be applied to various conservation practices for box turtles. We encourage further exploration of additional variables and their relations to box turtle home ranges.

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Appendix

Table 1. Annual June and July Precipitation (inches) from 1 June 2012 - 25 July 2018 at Brookhaven National Laboratory, Upton, NY.

Year	Precipitation (in)
2012	16.00
2013	12.51
2014	4.93
2015	6.07
2016	4.59
2017	7.23
2018	5.42

Table 2. Annual June and July MCP area estimates (ha) of each turtle from June 2012 – 25 July 2018 at Brookhaven National Laboratory, Upton, NY.

Turtle ID	2012mcp (ha)	2013mcp (ha)	2014mcp (ha)	2015mcp (ha)	2016mcp (ha)	2017mcp (ha)	2018mcp (ha)	Mean Area (ha)
1R12L	0.971	1.580	2.478	8.307	5.024	0.000	2.502	18.717
3R2L11L	0.321	1.530	0.974	4.370	0.276	3.647	2.184	11.430
1R3L4R9R	0.000	7.135	0.844	1.955	2.286	0.150	0.328	12.417
2R3L10L	0.000	3.612	2.760	6.797	9.118	0.742	1.216	23.203
2R3L12L	0.000	3.440	0.712	2.124	1.775	0.512	0.126	8.581
3R3L10L	0.000	0.382	0.928	18.341	1.081	0.873	0.174	21.630
3R3L8L1R	0.000	16.490	3.140	1.427	1.116	0.017	0.794	22.303
8R2L10L	0.403	6.246	5.331	1.829	0.988	0.828	0.497	15.696
9R2L4L	1.879	6.816	3.597	12.915	7.095	6.183	1.822	38.746
3R10R3L	0.000	9.296	5.271	0.500	8.587	3.338	0.569	27.073
3R11L	0.010	26.440	4.473	1.328	8.015	1.019	0.060	41.294
1R2L11L	1.309	0.515	0.199	13.877	4.825	16.578	0.055	37.311

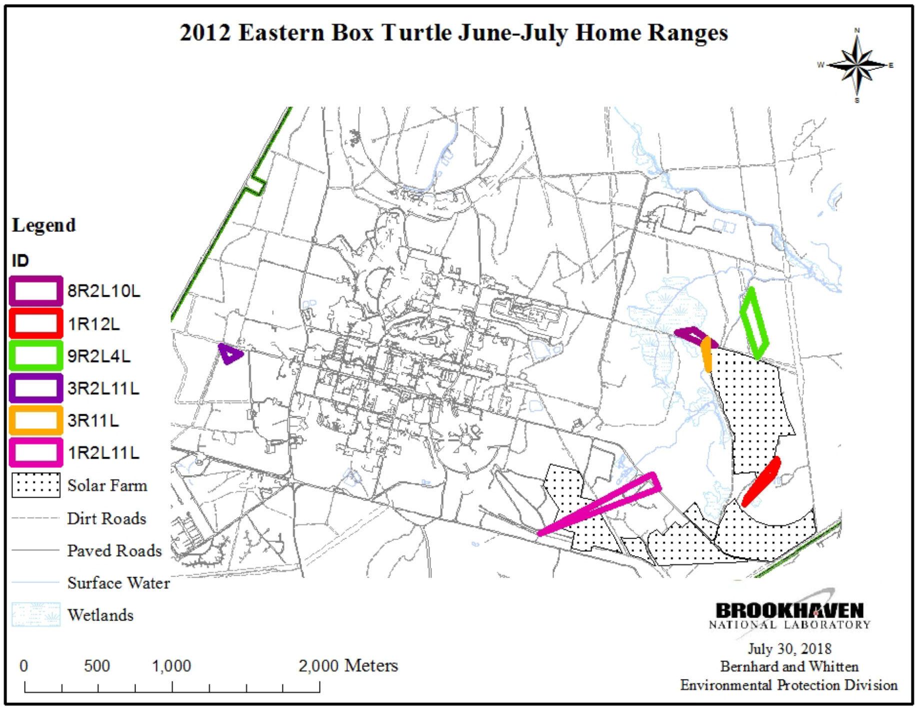

Figure 1. Map of 2012 Eastern Box Turtle June-July Home Ranges at Brookhaven National Laboratory, Upton, NY.

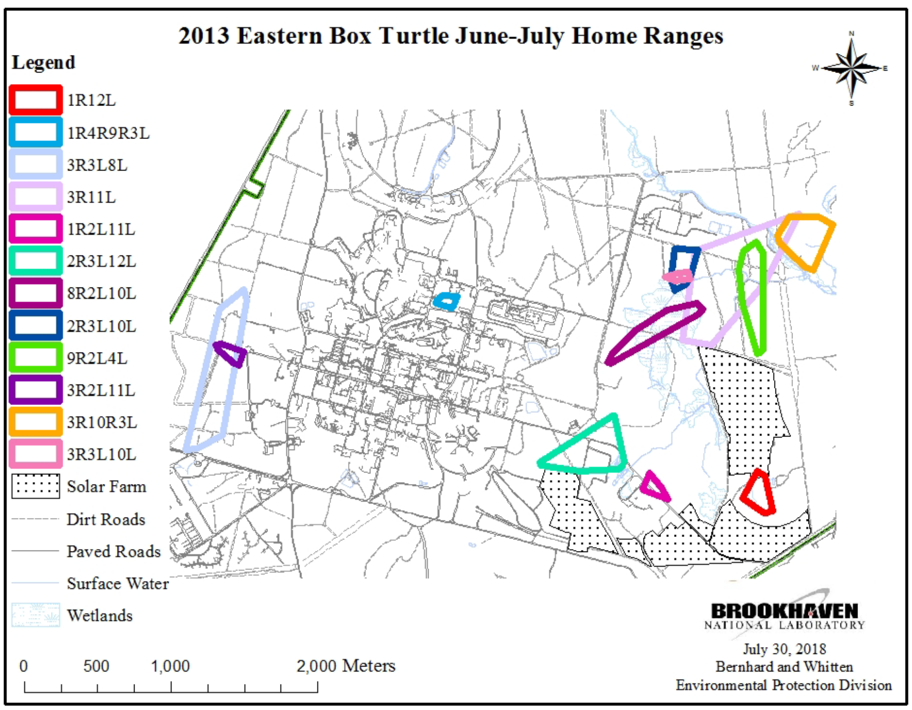

Figure 2. Map of 2013 Eastern Box Turtle June-July Home Ranges at Brookhaven National Laboratory, Upton, NY.

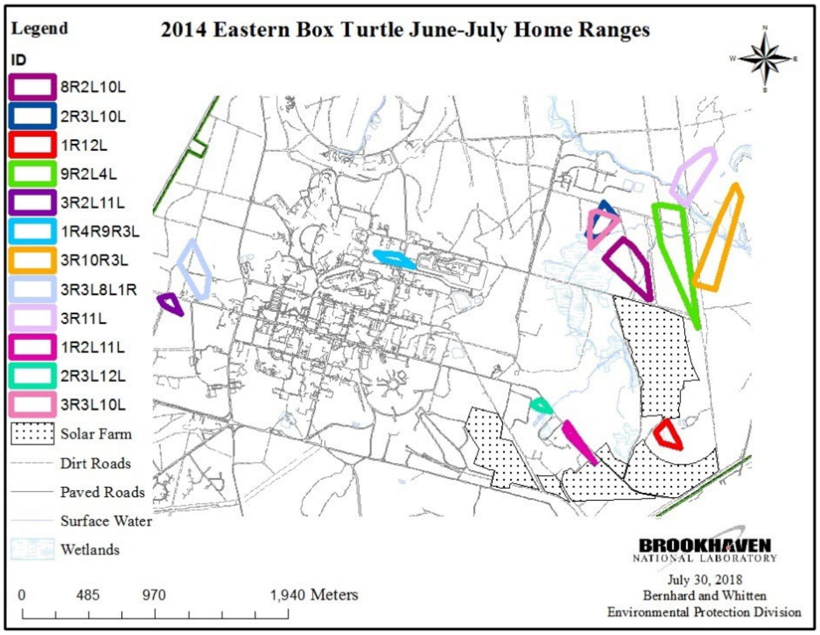

Figure 3. Map of 2014 Eastern Box Turtle June-July Home Ranges at Brookhaven National Laboratory, Upton, NY.

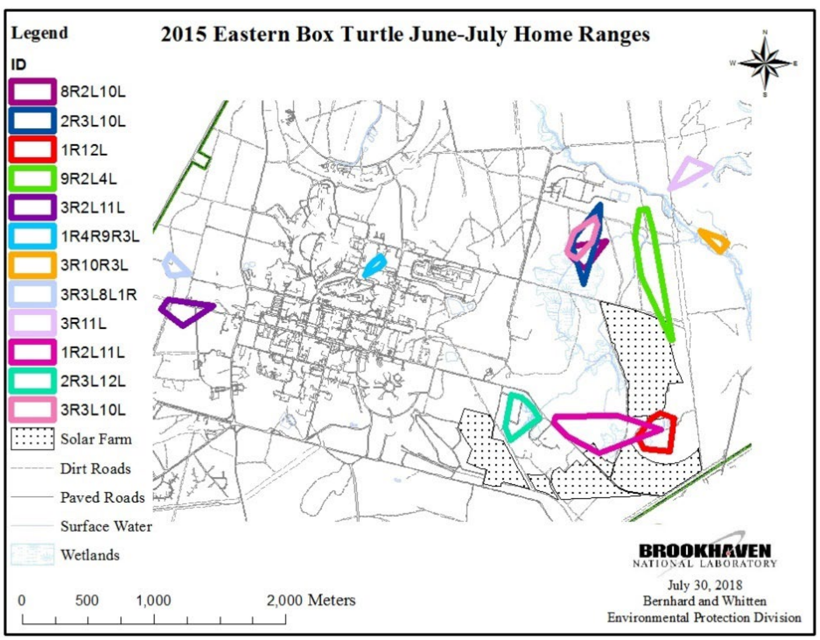

Figure 4. Map of 2015 Eastern Box Turtle June-July Home Ranges at Brookhaven National Laboratory, Upton, NY.

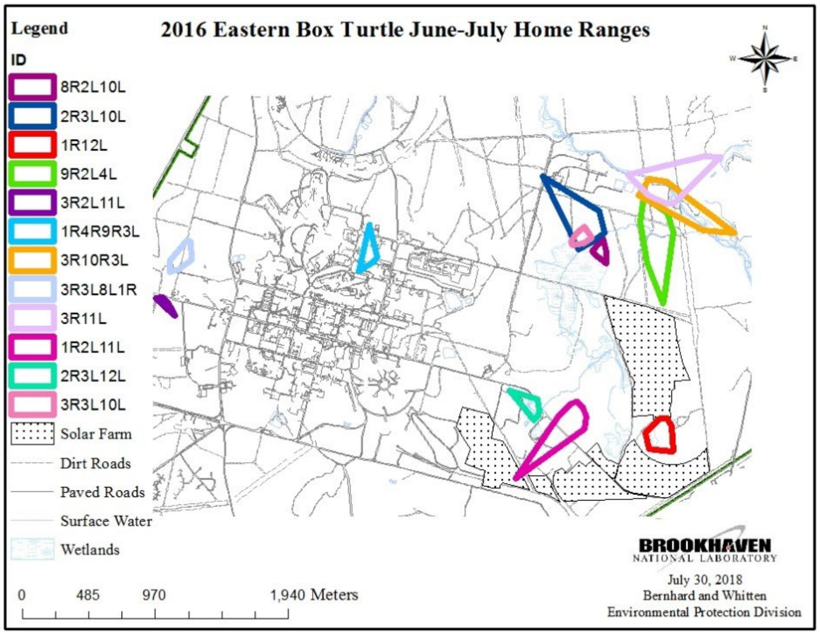

Figure 5. Map of 2016 Eastern Box Turtle June-July Home Ranges at Brookhaven National Laboratory, Upton, NY.

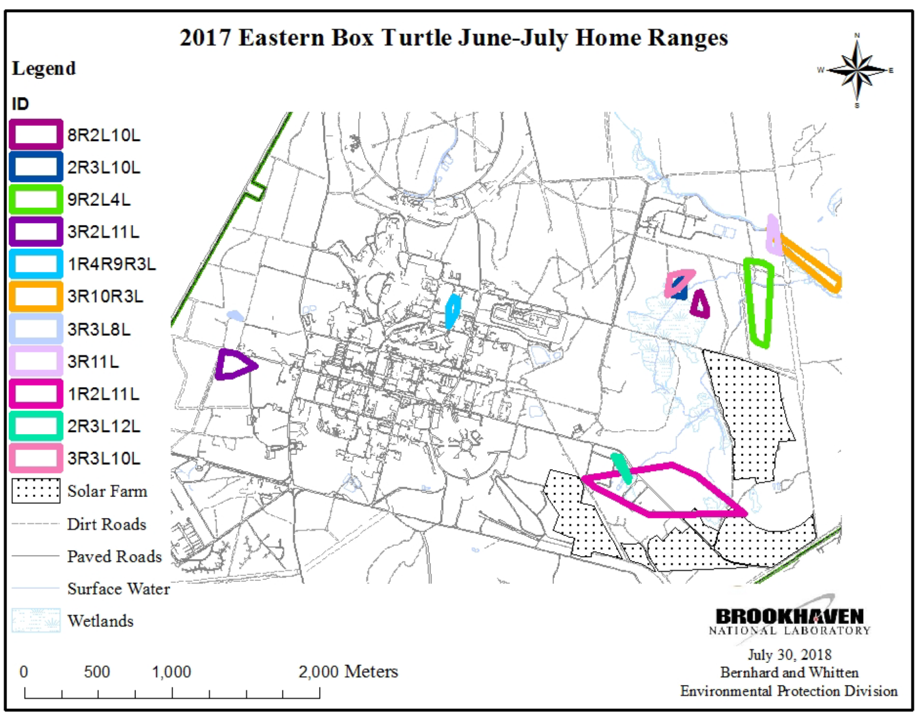

Figure 6. Map of 2017 Eastern Box Turtle June-July Home Ranges at Brookhaven National Laboratory, Upton, NY.

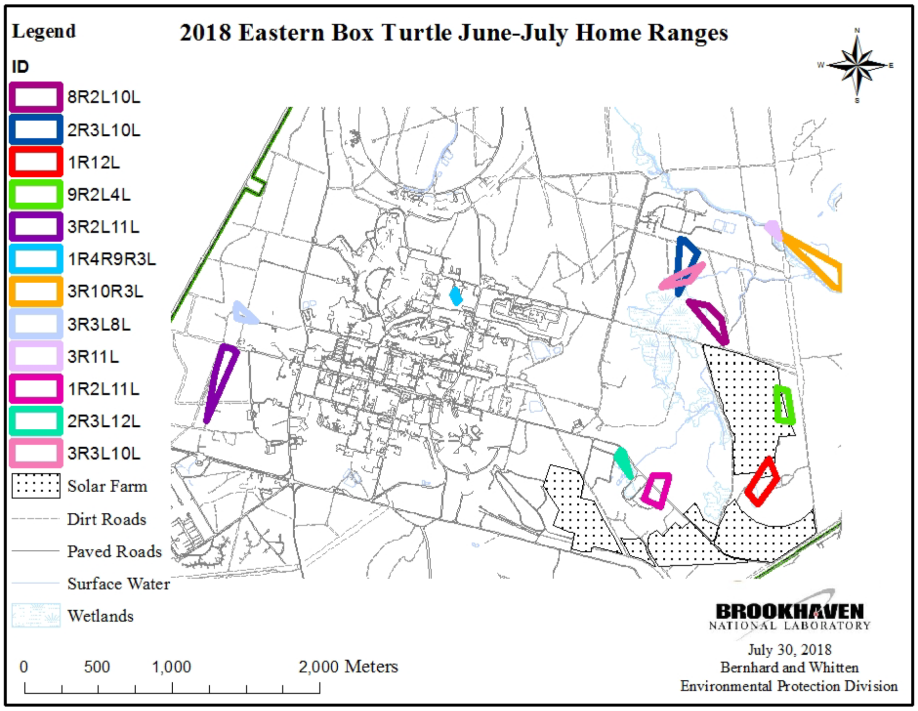

Figure 7. Map of 2018 Eastern Box Turtle June-25 July Home Ranges at Brookhaven National Laboratory, Upton, NY.