Brookhaven National Lab solar farm development impacts on eastern box turtle home ranges

Ryan Dougherty (Lafayette College, Easton, PA 18042) and Jennifer Higbie (Brookhaven National Laboratory, Upton, NY 11973)

Introduction

The construction of the Long Island Solar Farm (LISF) at Brookhaven National Laboratory (BNL), NY, is an example of attempts made to balance the need for wildlife conservation while also providing much needed renewable energy infrastructure to the area. LISF is a 32-megawatt solar photovoltaic power plant that began delivering power to Long Island, NY in November 2011. It is divided into six fenced areas, each containing 30cm X 10cm entrance doors located every 24m around the fenced solar arrays to allow movement of terrestrial fauna. There were approximately 45 acres of grassland and farms and 150 acres of trees, mostly pitch and white pine, displaced by the solar fields. The original plan was for the trees to be removed and understory brush and grasses to remain. Unfortunately, mulch was spread over the understory (ericaceous plants, blueberry bushes), which mostly killed off the remaining biodiversity in the solar fields. It took several years for any vegetation to grow back. Regardless of the preservation measures put in place, the white pine, spruce, pitch pine, oak, and maple forest is a much different environment than the solar fields which replaced it. Although biota-friendly measures were implemented to minimize environmental impacts, biodiversity was reduced from the area, and local biota lost roughly 195 ha of habitat. Food availability, plant composition, biodiversity, predator makeup, microclimate shifts due to solar arrays, and wildlife mortality can be affected by solar arrays (Hernandez, 2014). Given that local and federal regulations and policies have advocated against solar development in the built environment in the United States, it is likely that new solar developments will take place on natural land cover such as scrubland and herbaceous environments (Hernandez, 2015). If this is the case, it is more important than ever to assess the potential impacts that renewable energy development will have on native biota.

To broadly measure the effects LISF would inflict on biota on BNL property, eastern box turtles (*Terrapene carolina)* native to the area were outfitted with radio transmitters, and their home ranges were monitored from June 2011 to August 2018. Eastern box turtles are a popular species used in radio telemetry studies due to their low mobility, which makes home range area estimation easier and more accurate (Habeck, 2019). Therefore, eastern box turtles are great models for movement ecology. Additionally, the IUCN lists eastern box turtles as vulnerable with a decreasing population trend. Much of this population decline is due to vehicle related mortality, urbanization, habitat fragmentation, ranavirus infection, and illegal pet trading (Allender et al. 2006). This makes them an important species to monitor in relation to any construction that would negatively impact their native habitat.

Given the grass and forest habitat displaced by the solar fields, our objectives were: (1) to find out if the solar fields affect box turtle movement and home range size, (2) to estimate home range size of each turtle per year of tracking, and (3) determine if home range sizes differ between turtles who live in and around the solar field versus those that have had to interaction with the solar fields.

Methods

This study was conducted at Brookhaven National Laboratory located in Upton, New York. Turtles were divided into three condition groups based on their relation to the solar fields: [1] turtles whose home range intersected the solar fields (SF, n=17), [2] turtles whose home range laid adjacent to any of the solar fields without actually entering them (AD, n=7), and [3] turtles who had no interaction with the solar fields (NOSF, n=17). Straight-line distances were measured between the original location each turtle was found and its final transmitted location to assess the overall shift of home ranges between the three groups.

The data were analyzed with the program R using the package adehabitatHR (R Core Team 2014, C. Calenge 2006) and ArcGIS. Minimum Convex Polygons (MCP) and kernel utilization distribution ($K_{95\%}$) models at the 95% isopleth were used to compute the area within each turtle's home range. The $K_{95\%}$ uses a bivariate probability density function to give the probability density to relocate the animal at any place according to the coordinates of this place, in this case UTM. MCP was used in addition to $K_{95\%}$ because it is the most commonly used home range estimator for box turtles (Habeck 2019).

The question of normality was assessed with the ggformula package, and the Shapiro-Wilkes test from the stats package in R (R Core Team, 2014). Both MCP and $K_{95\%}$ home range data was not normally distributed. In order to adhere to the rule of independence, each turtle's home range area was averaged by the number of years it had been tracked. Since the area of one year's home range data would inform the following years home range data then treating each year as an individual point would break the rule of independence. We tested the null hypothesis that there was no difference between home range sizes among the three conditions with Asymptotic K-Sample Fisher-Pitman Permutation Tests using the coin package (R Core Team 2014). This test was used to compare the three groups MCP and $K_{95\%}$ estimated home ranges. Given the larger sample size of SF and NOSF, asymptotic K-Sample Fisher-Pitman Permutation Tests were performed solely between the two groups as well. The final distance in meters between each eastern box turtles first transmitted location and their final transmitted location was measured as a way to compare distance traveled between the three conditions. Final distance was determined to be normally distributed with a qq-plot using the ggformula package in R (R core team 2014).

Results

An alpha level of 0.05 was used for all statistical tests. The Shapiro-Wilkes test for normality provided significant results, thus concluding the home range area data was not normally distributed (MCP: W = 0.82356, p-value = 1.786e-05; $K_{95\%}$: = 0.53042, p-value = 2.887e-10). With the use of the MCP and $K_{95\%}$ estimates, the mean home range area of SF turtles was similar to that of AD and NOSF (MCP: chi-squared = 3.4485, df = 2, p-value = 0.1783; $K_{95\%}$: chi-squared = 2.0383, df = 2, p-value = 0.3609). Additionally, the difference in home range area was not significant between SF and NOSF (MCP: Z = -1.7094, p-value = 0.08737; $K_{95\%}$: Z = -1.3941, p-value = 0.1633). Refer to Table 1 for mean (± SD) home range area of each condition using MCP and $K_{95\%}$ estimators. The results of a one-way ANOVA indicated a significant difference between SF, AD, and NOSF turtle's final distances ($F = 3.391$, $p < 0.05$). SF turtles (n=18) had a mean distance of 567 m, AD (n=7) turtles mean final distance was 283 m, and NOSF (n=19) turtles mean final distance was 267 m. Figure 2 displays a boxplot comparing the median, Q1, Q3, and interquartile ranges between the three home range conditions.

Discussion

It was hypothesized that the solar farm development would have an impact on the home range area of eastern box turtles due to the displacement of vital habitat by LISF. There were no statistically significant data to back this claim, but given the general trend (Table 1), it would be beneficial to conduct this study again with a larger sample size. Although a p-value of .087, comparing the mean MCPs between SF and NOSF turtles, is not statistically significant, it points to evidence that home range size was affected by LISF. The average home range area was larger for SF turtles than both AD and NOSF turtles measured with MCP, $K_{95\%}$ and $BB_{95\%}$ estimators. Another indicator that eastern box turtle home range was altered by LISF implementation is the significant final distance results between SF, NOSF and AD turtles. Figure 1. displays the disparity between box turtles with home ranges intersecting LISF, and AD and NOSF box turtles. These data indicate that over the 8 years of monitoring, SF turtles have gradually been shifting their home range. When the habitat of eastern box turtles is disturbed, they are known to expand their home range area and travel further than individuals with a stable environment (Hestor 2019, Habeck 2019). There are many factors that have been documented to affect home range size in turtles. Box turtles need protection from the elements, food access, certain precipitation levels, available nesting sites, and proximity to other individuals (Dodd, 2001). Their home range is known to increase in response to their habitat lacking any of these factors.

As solar power becomes more popular on the east coast, it is imperative that developers make decisions with wildlife conservation as one of the main concerns. Large swaths of deciduous forest should be a last resort for new development not only because forests provide vital habitat for vulnerable populations like amphibians and reptiles, but also because of biomass loss caused by deforestation. There are less ecologically deleterious options such as manipulating the built environment. For example, the photovoltaic electricity production potential is massive within city and suburban rooftops, and only a fraction of potential city wide photovoltaic capacity has been reached in most cities (Kouhestani, 2019). Taking advantage of unused space in the built environment for solar development will protect vulnerable species like the eastern box turtle from further harm. Given that solar power is meant to be a sustainable alternative to protect the planet from long term ecological destruction, the short term impacts of its implementation should also be considered.

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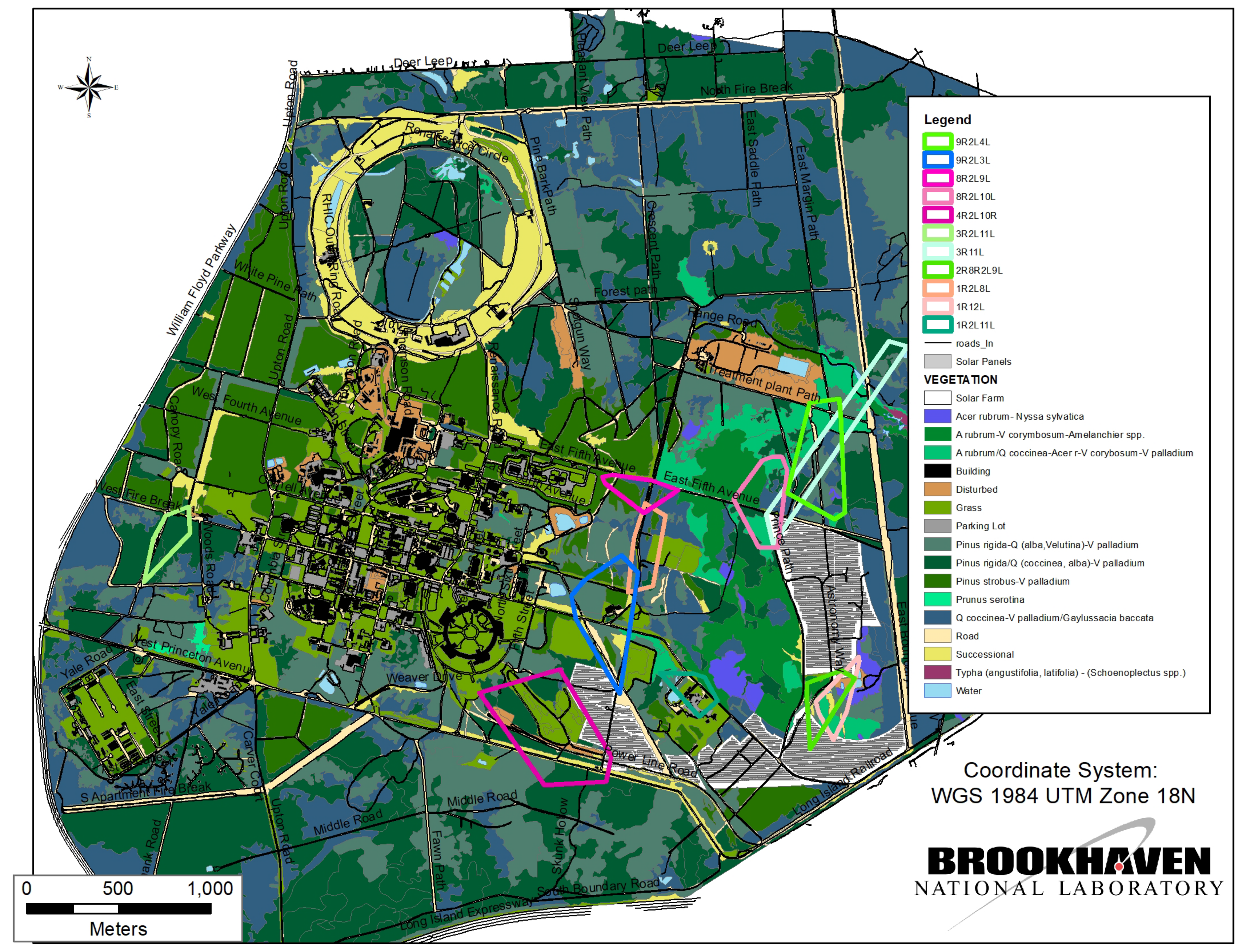

Figure 1. Map of Brookhaven National Laboratory property. Colors differentiate vegetation type, and colored outlined polygons are 95% minimum convex polygons for each eastern box turtle monitored in 2012.

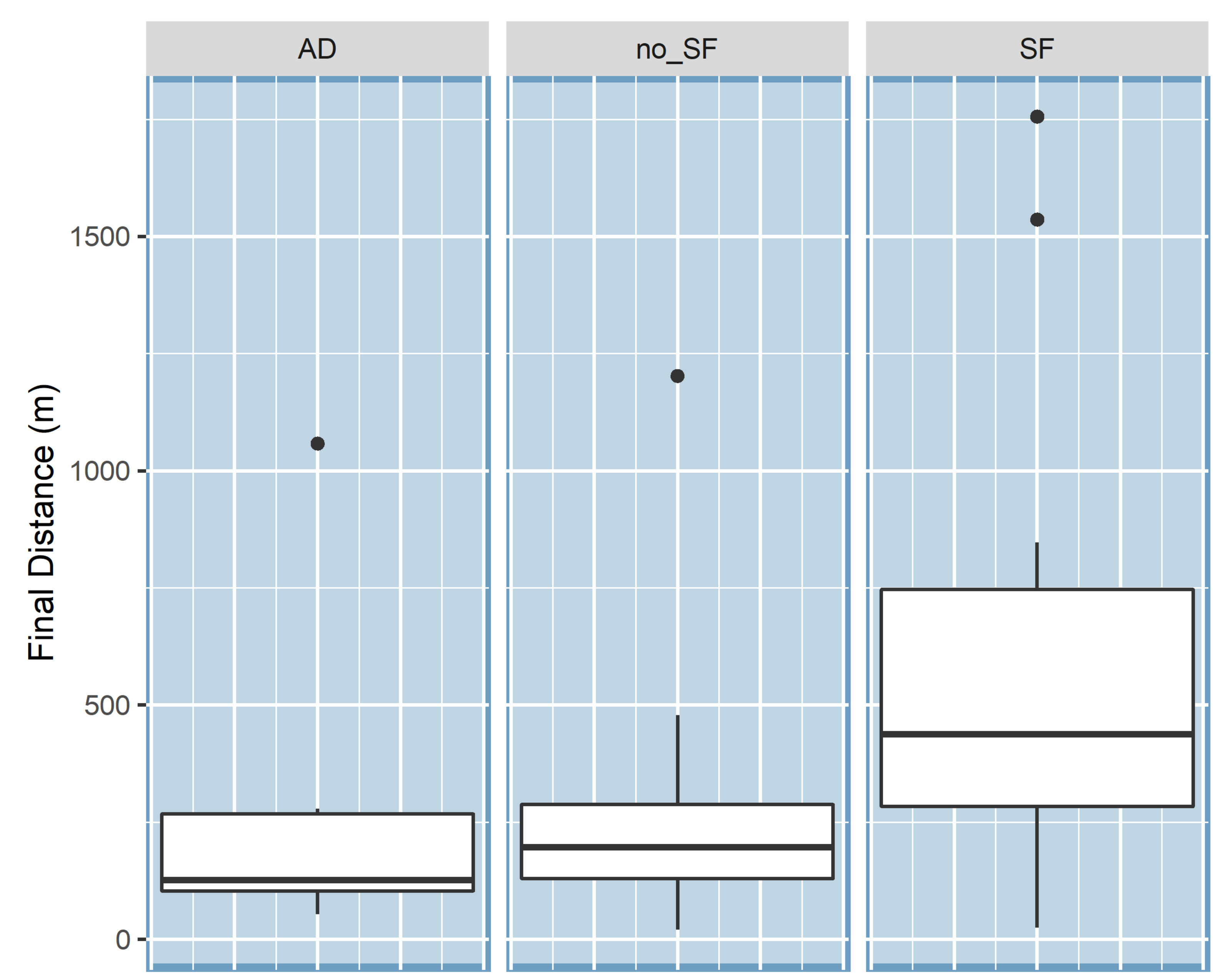

Figure 2. Final distance boxplot between three eastern box turtle groups (AD[n=7], SD[n=18], no_SF[n=19]). Distance measured betw een first tracking location and final tracking location. Dots represent statistical outliers

Location	n	MCP (ha)	$K_{95\%}$ (ha)
Solar fields	17	7.41 ± 5.53	7.62 ± 10.90
Adjacent	7	4.70 ± 4.57	6.22 ± 7.78
No solar field interaction	17	4.60 ± 3.54	3.77 ± 2.73

Table 1. Mean (+ standard deviation) home ranges of *Terrapene carolina* for each home range condition calculated using 95% minimum convex polygon (MCP) and 95% kernel utilization distribution ($K_{95\%}$) estimators.

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