

SPATIAL ECOLOGY AND BEHAVIOR OF EASTERN BOX TURTLES ON THE HARDWOOD ECOSYSTEM EXPERIMENT: PRE-TREATMENT RESULTS

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Abstract.—To understand better how eastern box turtles (*Terrapene carolina carolina*) are affected by forest management practices, we monitored movements of box turtles prior to silvicultural treatments within the Hardwood Ecosystem Experiment (HEE) in Indiana. During 2007 and 2008, we tracked 23–28 turtles on six units of the HEE. Estimated minimum convex polygon home-range sizes (range 0.8–187.7 ha) varied among units and across years but were similar among slated treatment types (control, even-aged, and uneven-aged). These data will allow us to test for short-term responses of box turtles to silvicultural practices aimed at oak (*Quercus*) regeneration.

INTRODUCTION

Timber harvests and other management practices may change the vegetation structure and microhabitat climate within forests and can affect a wide variety of forest wildlife (Goldstein et al. 2005, Gram et al. 2003, Renken et al. 2004, Sullivan and Sullivan 2001). Although some data suggest that logged areas are associated with moderate increases in bird and reptile diversity (Fredericksen et al. 2000), it is not clear whether this observation can be considered a general trend. Recent attempts to assess the effects of timber harvests on ectothermic species often suffer from a lack of replication or comparable pre-harvest data (e.g., Goldstein et al. 2005, McLeod and Gates 1998). The majority of these herpetofaunal studies focused on harvest effects on amphibian populations (e.g., Hocking and Semlitsch 2008, Knapp et al. 2003, Rittenhouse and Semlitsch 2009, Semlitsch et

al. 2009), whereas relatively little is known about the impacts on reptile populations.

Moreover, existing data suggest not only that reptiles are sensitive to habitat perturbations, but that the impacts are more pervasive and severe than for amphibians (Gibbons et al. 2000). Behavioral and population changes of reptiles relative to habitat alterations are often difficult to assess because of their stochastic patterns of activity, large home ranges, and low densities. The Hardwood Ecosystem Experiment (HEE) site is rich in reptilian diversity, with more than 20 species known to occur within its boundaries. The eastern box turtle (*Terrapene carolina carolina*) offers potential in studying responses to timber harvesting given its distribution within and use of forested habitats.

The eastern box turtle is a relatively long-lived reptile (50+ years) (Stickel 1978) native to forested regions across the eastern United States. Box turtles have experienced substantial population declines over the past several decades, particularly in areas dominated by agriculture (Hall et al. 1999, Stickel 1978, Williams and Parker 1987). Causes for these declines likely include habitat loss and degradation,

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but the response of box turtles to forest management is largely unknown. There is some evidence that breaks in forest canopy cover may be beneficial for thermoregulation (Hallgren-Scaffidi 1986), and other open areas such as meadows or agricultural fields are often used as nesting sites (Dodd 2001, Nazdrowicz et al. 2008). Areas harvested for timber may also increase local food sources and cover items such as herbaceous biomass relative to unharvested sites (Perison et al. 1997).

Other evidence suggests that box turtles are sensitive to environmental disturbances that affect local habitat features (Currylow 2011, Dodd 2001). Therefore, annual losses of a relatively small proportion of adults may result in a gradual decline toward local extirpation (Belzer 2002, Doroff and Keith 1990). The eastern box turtle, however, is the longest-lived reptile to occur throughout the eastern forests. Further investigation is needed to understand how timber harvests affect this K-selected species of conservation concern during both active and inactive seasons.

We examined the effects of even-aged and uneven-aged forest management on eastern box turtles as part of the HEE. Our overall objectives of the project were to:

1. Determine box turtle home-range size and movement patterns prior to harvests;
2. Examine the short-term effects of timber harvests on box turtle home range, movements, habitat use, and thermal ecology during the active season;
3. Characterize the hibernation thermal behavior of box turtles within a managed forest landscape; and
4. Estimate the adult annual survival rate of eastern box turtles using radio-telemetry.

This paper describes the methods and results of pre-harvest data collection (objective 1), which occurred in 2007 and 2008. For detailed descriptions of objectives 2 through 4, refer to Currylow (2011) and Currylow et al. (2012), respectively.

STUDY AREA

The study area was located within Morgan-Monroe State Forest (MMSF) and Yellowwood State Forest (YSF) in Morgan, Monroe, and Brown Counties in south-central Indiana. The area is characterized by steep ridges and valleys covered with a mixture of oak-hickory (*Quercus-Carya*) and American beech-maple (*Fagus grandifolia-Acer*) forests. The study area and HEE study design are described in detail by Kalb and Mycroft (this publication). Box turtle pre-treatment data collection took place on units 4-9 during 2007 and 2008.

MATERIALS AND METHODS

Radio-Telemetry and Home Range

We initially located adult box turtles by visual encounter surveys and opportunistically while conducting other field work. Upon initial capture, we recorded sex, weight (to nearest 10 g), and carapace length and width (to nearest 0.1 cm). We assigned a unique ID number and marked each turtle using a triangular file along marginal scutes following a modified Cagle scheme (Cagle 1939, Ernst et al. 1974, Ferner 2007). For the initial location site and all subsequent locations, we recorded the date, observer, slope aspect, ambient temperature (°C) and humidity, elevation, ground temperature (°C) and humidity, Universal Transverse Mercator coordinates (North American Datum 1983, Zone 16N), general weather condition (cloud cover and precipitation), and general condition of the turtle.

To obtain estimates of home-range size, we affixed a radio transmitter (model RI-2B Holohil Systems, Ltd., Carp, ON) to the carapace of 4-6 turtles in each unit. Sex ratios and numbers of turtles were equally divided among sites and management classes when possible. We radio-tracked (by homing) 23-28 turtles 2-3 times per week during at least one active season (May through October). For each tracked location, we recorded the location data as described above. We calculated 100-percent Minimum Convex Polygons

(MCP) to estimate the home-range area of each turtle (Hawth's Analysis Tools, ArcGIS 9.0, ESRI, Redlands, CA). Turtles with <20 locations were omitted from home-range analyses for that active season (Row and Blouin-Demers 2006).

Habitat

From 5 June to 15 August 2007, we measured habitat characteristics for every other turtle location and a random location (see below). We estimated percentage cover for vegetation ≤ 1.0 m tall, coarse woody debris (≥ 10 cm diameter), water, rock, and bare ground within a 2-m-radius circular plot using a sight tube (James and Shugart 1970). The sight tube consisted of a polyvinyl chloride pipe 15 cm long with two black thread crosshairs on one end. An observer held the sight tube 1 m above and perpendicular to ground level and walked a series of four transects 4 m in length across the plot. Along the N-S and E-W transects, the observer recorded the number of hits (plant material at the center of the crosshairs) in the sight tube beginning at the start and every 0.5 m along both transects, skipping the plot center after the first transect. Along the remaining NW-SE and NE-SW transects, the observer stopped every 1 m along each transect for 25 observations per plot. Numbers of hits in the crosshairs of the tube were summed for each habitat variable and multiplied by 4 to estimate percentage cover.

To assess how habitat at turtle locations differed from available habitat, we collected the same data as above for random points. Distance (30-100 m) and azimuth (1-360°) from a given turtle location were randomly determined a priori. Although these plots are not truly random because distance was restricted, they reasonably reflected the habitat available to each turtle for that day based on typical daily movements of box turtles (Igley et al. 2007) rather than habitat available across the entire study site.

RESULTS

We located and processed 236 turtles during the pre-harvest period and tracked the movements of 28 turtles for an average of 36 locations each (range = 14-45) during at least 1 active season (Table 1). Estimated home-range sizes were variable (range 0.8-187.7 ha; Table 1) and some turtles made atypical movements in one or both years. Turtle #406 exhibited transient behavior (Dodd 2001) in both years and was excluded from further comparisons. During an extended hot and dry period in 2007, turtle #603 moved 1.2 km from unit 6 and remained along a lake margin from 25 July to 6 September. We did not observe this behavior during 2008 or subsequent years (Currylow 2011). The resultant MCP home range (54.6 ha) was thus inflated and not included in subsequent comparisons. The removal of turtles #406 and #603 reduced the variation in home-range sizes considerably (range 0.8-22.1 ha).

We pooled home ranges by year for each proposed treatment type to determine if box turtle spatial use differed among control, even-aged, and uneven-aged units prior to timber harvests. Home-range size differed little between sex or proposed treatments (Fig. 1), but differed with respect to year and unit when pooled by sex (Fig. 2). Except for units 7 and 9, home-range size was larger during 2008. Mean home-range size within unit 8 was more than double the mean size for all units considered together.

SUMMARY AND FUTURE WORK

Mean home-range sizes were much larger than earlier studies and nearly double the largest published estimates (for a complete review, see Currylow 2011). Home ranges were not consistent between years (Fig. 2), but were fairly comparable among treatment types pooled across years (Fig. 1) and among units, with the exception of unit 8 (Currylow 2011: Fig. 2). Prolonged hot and dry conditions during summer 2007 may have contributed to annual differences but do not explain differences among units within the same year.

Table 1.—Box turtle home-range estimates^a on HEE units 4-9 during the pre-harvest period (2007 and 2008).

Turtle ID#	Unit	Sex	Weight ^b (g)	2007		2008	
				Number of locations	Home range (ha)	Number of locations	Home range (ha)
400	4	F	470	38	1.6	lost	
402		M	320	35	1.8	38	5.6
404		F	390	34	2.3	39	4.8
406		M	435	31	130.9	32	187.7
500	5	M	455	28	2.0	42	2.8
503		F	410	33	1.6	42	10.0
504		M	510	31	1.4	43	2.0
506		F	420	32	1.0	40	1.5
602 ^c	6	F	465	43	1.6	24	-
610 ^c		F	300			11	-
603		F	400	40	54.6	42	3.1
605		M	490	45	1.8	40	9.2
607		M	490	43	3.6	42	4.9
615		M	600			34	2.0
616		F	420			41	2.7
700	7	M	365	35	2.7	35	1.0
704		M	395	33	4.3	39	1.4
706		F	535	29	2.0	38	2.1
708		M	475	39	2.9	36	1.2
20	8	M	415	23	7.1	33	22.1
800		F	405	38	2.6	39	16.5
806		M	455	14	-	40	2.6
814		M	440			20	0.8
848		M	460			37	1.2
900	9	F	470	41	4.1	33	3.0
904		M	240	39	1.4	36	1.5
906		F	530	39	5.4	36	5.0
908		M	455	40	1.3	34	1.7
Mean ^d					2.6		4.6

^a 100-percent Minimum Convex Polygon (Hawth's Analysis Tools, ArcGIS 9.0)^b Weight at initial capture in grams^c Turtle #602 died on July 11, 2008 from injury of unknown source and was replaced by #610.^d Calculations of means do not include turtle #406 or #603.

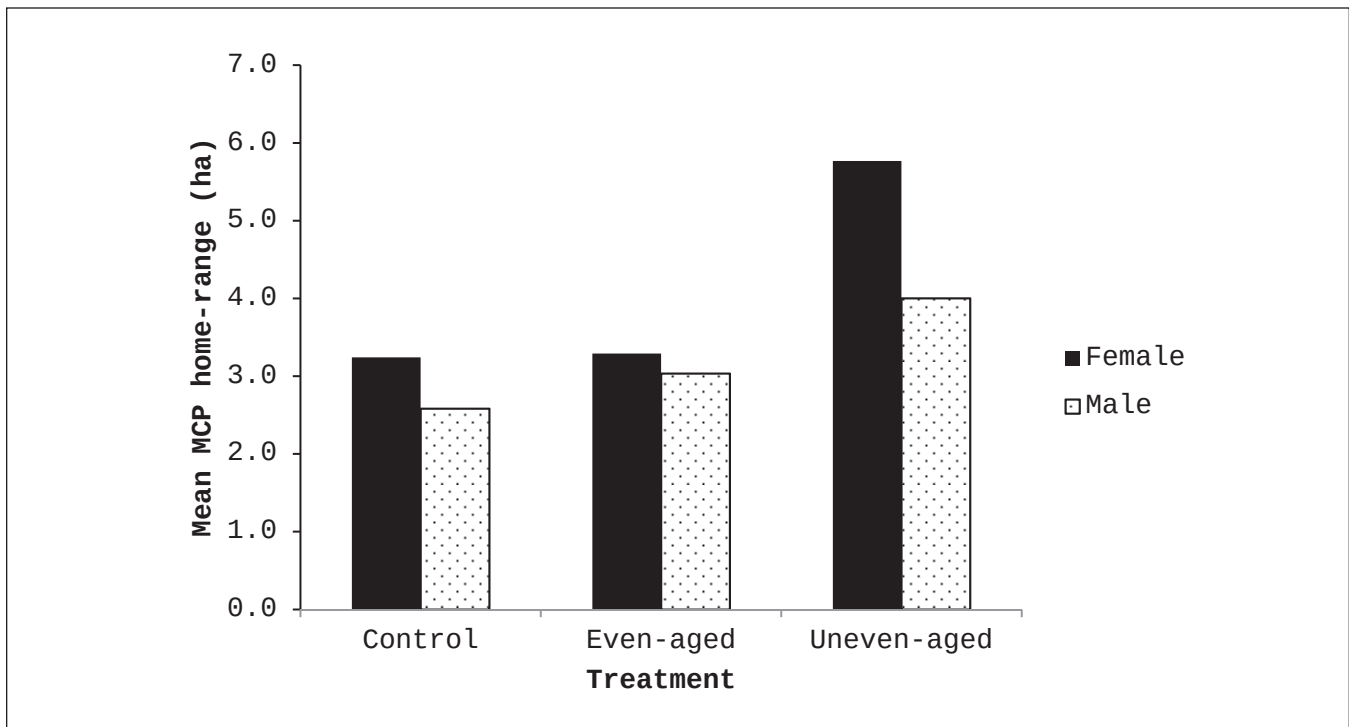


Figure 1.—Mean home-range sizes (100-percent Minimum Convex Polygon) for box turtles in control (N=8), even-aged (N=11), and uneven-aged (N=8) HEE management units during the pre-harvest period (2007 and 2008).

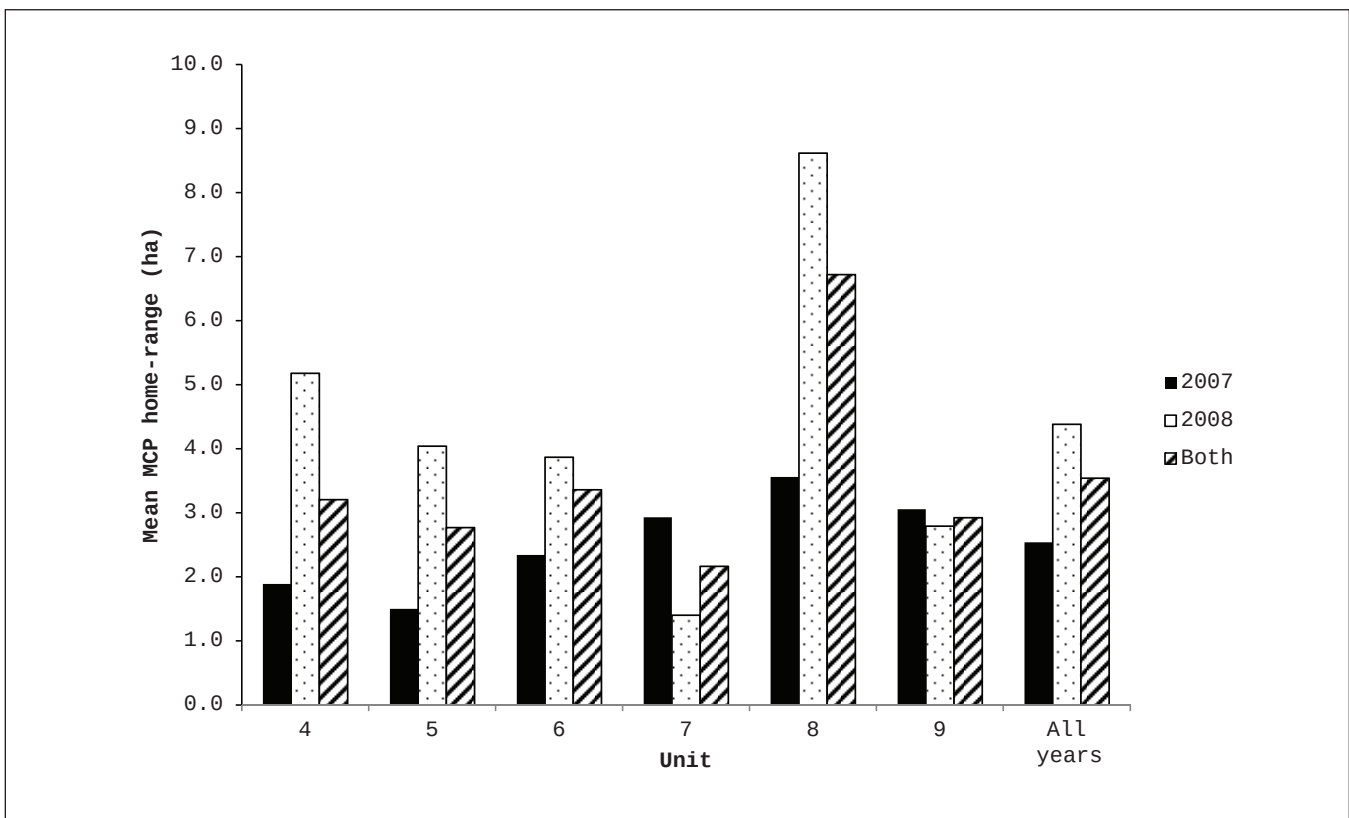


Figure 2.—Mean home-range sizes (100-percent Minimum Convex Polygon) for box turtles in HEE units 4-9 by year during the pre-harvest period. Data for sexes are pooled.

During the pre-harvest period, one female on unit 4 was lost during winter 2007-08 and another female on unit 6 died from injuries caused by an unknown predator. Currylow et al. (2011) estimated the annual survival of box turtles in the HEE study area during hibernation and active periods (2007-09). Their overall estimate of annual survival was 0.964 and was only slightly higher during the active period.

A primary goal of our work was to examine the short-term effects of timber harvests on box turtles. We continued to collect data during the post-harvest period until October 2010 as we tracked 50 turtles in at least one active season across all nine HEE units. We grouped sites by management class (clearcut, patch cut, and control) and evaluated treatment effects in the pre- and post-harvest data using a full factorial generalized linear mixed model with year, sex, management class, and their interactions as fixed effects and animal ID nested in year as a random effect to find any differences in annual MCP home ranges with relation to harvests (Currylow 2011).

Temperature plays an important part in ectotherm ecology; thus, we also studied thermoregulatory behavior of turtles during the post-harvest period (Currylow 2011; Currylow et al. 2012). We affixed iButton temperature dataloggers (model DS1921G-F5#, Maxim Integrated Products, Inc., Sunnyvale, CA) to the carapace of tracked turtles. Dataloggers recorded temperatures every 45 minutes during the active season (May-October) in 2009 and 2010. We randomly placed dataloggers at four locations within each HEE unit, resulting in 18 dataloggers in harvest openings and uncut areas combined. In a similar manner, we placed datalogger profiles at box turtle hibernacula and random sites within and outside of harvest openings on even-aged units during the hibernation season. We

assessed the impact of clearcuts on hibernation depth and the availability of potential hibernation sites in clearcuts based on temperature profiles at various depths and slope aspects (Currylow et al. 2012).

This study increases our understanding of box turtles' responses to timber harvesting as well as the general ecology of box turtles. Sampling across the relatively large geographic area encompassed by the HEE, the collection of pre- as well as post-harvest data, the inclusion of thermal behavior during both active and inactive seasons, and the relatively long study duration (4 years) are key strengths to the study. Our results will be a valuable contribution to our understanding of how different silvicultural treatments impact box turtles.

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