

# SPATIAL ECOLOGY OF TIMBER RATTLESNAKES ON THE HARDWOOD ECOSYSTEM EXPERIMENT: PRE-TREATMENT RESULTS

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**Abstract.**—The timber rattlesnake (*Crotalus horridus*) is a species of conservation concern throughout much of its geographic range and may serve as a sentinel species in investigations of the effects of timber harvesting on forest reptiles. Our objective was to determine the effect of even-aged timber management regimes on timber rattlesnake home range and movements. During pre-treatment data collection in 2007 and 2008, we tracked 23 rattlesnakes on 4 units of the Hardwood Ecosystem Experiment in Indiana. Home-range sizes of male rattlesnakes (65.7 ha) were greater than non-gravid (20.6 ha) and gravid (17.6 ha) females. Home ranges were generally consistent among units and between treatments. These data will allow us to test for immediate responses of timber rattlesnakes to even-aged timber management.

## INTRODUCTION

Forest management agencies are under increasing pressure to justify land management practices, especially those that involve traditional silvicultural methods. Moreover, third-party certification of public and private forests has increased the need to identify negative impacts of timber harvesting on wildlife populations and adjust management plans accordingly. Forest wildlife of particular interest are area-sensitive species and species of conservation concern. The long-term sustainability of these species largely relies on public forest lands because of the fragmented ownership and turnover of private forest lands across the eastern United States (see Birch 1996).

The timber rattlesnake (*Crotalus horridus*) may serve as a sentinel species for long-term studies that examine the impacts of silvicultural practices, largely because of its behavioral and demographic characteristics. Behaviorally, timber rattlesnakes maintain strong fidelity to hibernacula, and they remain near these den sites during ingress and egress (Brown et al. 1982, Gibson 2003, Walker 2000). Gravid females tend to stay near hibernacula at birthing rookeries during the entire active season (Brown 1991, Martin 1993). Demographically, females do not reach sexual maturity until at least 7 to 11 years of age and reproduce every 3 to 5 years (Brown 1991, Martin 1993). Thus, timber harvesting occurring near den sites could have long-lasting ramifications for rattlesnake populations if it results in higher mortality or alterations of den sites.

Timber rattlesnakes are endangered throughout much of their range (Martin 1982), including Indiana, where they are restricted primarily to the Highland Rim Natural Region (Homoya et al. 1985) in forested areas with suitable den sites. Previous research on timber rattlesnakes in Indiana has provided insights into spatial ecology, den site selection, and habitat

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use (Gibson 2003, Gibson et al. 2008, Walker 2000) in forests not managed for timber. Although researchers have gained a better understanding of the ecology of this species in Indiana and other parts of its range, information regarding responses to human activities is limited. Reinert et al. (2011) observed some logging-related mortality (<2 percent) of timber rattlesnakes, but resultant habitat changes did not alter snake behavior and movement patterns 1 year post-harvest. In the long term, understanding how forest management alters timber rattlesnake habitat use and survival is important for sustaining their populations within Indiana and the Central Hardwoods Region.

We examined the effect of even-aged silviculture on timber rattlesnakes as part of the Hardwood Ecosystem Experiment (HEE). Our objectives were to:

1. Estimate timber rattlesnake home-range size and movement patterns prior to harvests;
2. Determine the immediate effects of timber harvests on timber rattlesnake home range, movements, and habitat use;
3. Estimate timber rattlesnake adult annual survivorship during the active and hibernation seasons;
4. Determine the genetic variation and structure of timber rattlesnakes; and
5. Assess den characteristics during the hibernation period.

This paper describes the methods and results of pre-harvest conditions of timber rattlesnakes on the HEE sites (objective 1) during 2007 and 2008.

## 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 composed of 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). Timber rattlesnake pre-treatment data collection took place on units 2, 5, 6, and 9 during 2007 and 2008.

## MATERIALS AND METHODS

### Snake Sampling

During parts of the active season (20 April to 15 August) in 2007 and 2008, we located snakes using three methods. First, we actively searched for timber rattlesnakes in appropriate habitat on and adjacent to HEE units. Specific locations were based on 2006 sightings by HEE personnel and recommendations by State Forest staff. Second, rattlesnakes were located opportunistically during this period by our field crew and other HEE field technicians. Finally, from 21 April to 16 May 2008, we trapped selected den sites on or near HEE units 2, 5, and 6 using fiberglass window screening covering den site entrances. All sides were secured to the ground using a combination of garden staples, logs, and rocks. At a single opening we secured a funnel trap constructed of 1.3-cm hardware cloth with a canvas funnel at one end. Traps were checked daily until their removal after egress from the dens.

All snakes were handled using snake hooks and handling bags. Upon initial capture of each snake, we measured total body length (TBL), snout to vent length (SVL) (both to the nearest 1 cm), and tail length (TL) (to the nearest 0.1 cm), and determined sex (via TL and/or cloacal probe), age (neonate TBL <20 cm; juvenile  $20 \text{ cm} \leq \text{TBL} \leq 80 \text{ cm}$ ; adult TBL >80 cm), and weight to the nearest 10 g (1 g for neonates). We implanted a Passive Integrated Transponder tag (AVID Identification Systems, Inc., Norco, CA) subcutaneously under the 7th ventral scute anterior from the vent within each snake and painted a portion of the base rattle section white to facilitate identification in the field. A small ventral scale clip

was collected from each snake for subsequent genetic analysis. For each snake location, we recorded the date, slope aspect, Universal Transverse Mercator coordinates, elevation, general weather, and snake behavior upon location (feeding, basking, hiding, or traveling). We also measured ambient and ground temperature and humidity using a handheld weather meter (Kestrel 3000, Nielsen Kellerman, Boothwyn, PA).

### Radio-Telemetry and Home Range

We tracked movements of a subset of timber rattlesnakes using radio-telemetry. We marked the location of capture with flagging and transported snakes from the field to a local Indiana Department of Natural Resources office. Purdue University veterinarians implanted radio transmitters (type AI-2T 25g; SI-2T 13.5g and 9.0g, Holohil Systems, Ltd., Carp, ON) using a method modified from Reinert and Cundall (1982). Transmitter selection was based on weight and girth of each snake. Following a 48- to 96-hour recovery time, snakes were returned to their exact point of capture and released.

Rattlesnakes were tracked by typical homing methods usually three times per week during the active season (18 April to 25 October). Coordinates were taken at the location of the snake or, when the snake was not visible, at its hiding location (e.g., log pile, hollow log). Data for all snake locations were recorded as described above.

We calculated 95-percent Minimum Convex Polygon (MCP) to estimate the home-range area of each snake (Hawth's Analysis Tools, ArcGIS 9.0, ESRI, Redlands, CA). We chose this method because MCPs allow comparison to previous research. Two snakes captured late during the 2008 season ( $\leq 5$  locations) were omitted from home-range analyses.

### Habitat

In 2007 (10 May to 25 July) we measured habitat characteristics for a subset of timber rattlesnake locations. Habitat data were collected after each snake

had moved but within 2 weeks of the location date to prevent disturbance to the snake and to minimize vegetative differences between the dates of actual location and vegetation sampling. We focused our sampling on habitat elements most important for timber rattlesnakes (Gibson 2003, Walker 2000). We estimated percentage cover of vegetation  $\leq 1.0$  m tall, coarse woody debris ( $\geq 10$  cm diameter), water, rock, and bare ground in a 2-m-radius circular plot using a sighting tube (James and Shugart 1970). The sighting tube consisted of a polyvinyl chloride pipe 15 cm long with two black thread crosshairs on one end. An observer held the sighting 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 in the sighting 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.

Percentage canopy cover was measured in a similar way using an 8-m-radius circular plot, but points were spaced 2 m apart on the N-S, E-W transects and 4 m apart on the N-S and E-W transects. For each habitat location, we collected the same data for a random point. Distance (30-100 m) and azimuth ( $1-360^\circ$ ) from each snake location were determined a priori using a random number generator. Even though these plots are not truly random because distance is restricted, they reasonably reflect the habitat available to each snake between successive locations (see Blouin-Demers and Weatherhead 2001).

Because of logistical constraints, collection of habitat data was limited to 2007. During post-harvest we will expand our sampling efforts (number of snakes and units) and data collection methodology. We will measure the distance to the nearest rock (maximum length  $\geq 10$  cm), log (maximum diameter  $\geq 10$  cm), tree

(diameter at breast height [d.b.h.]  $\geq 7.5$  cm), understory tree (d.b.h.  $< 7.5$  cm, height  $> 2.0$  m), and shrub (height  $< 2.0$  m) in four quadrants (Reinert 1984). Values will be averaged among the four quadrants for each location and random point. We also will record for logs their maximum diameter, decay class (Maser et al. 1979), and a visual estimate of the percentage lying on the ground.

Only totals and means are reported in this paper. Detailed statistical analyses of pre- and post-harvest results are presented elsewhere. Those analyses will use a generalized linear mixed model to test for differences in home range and habitat use among treatment types pre- and post-harvest (SAS Institute Inc. 2004). We will include unit, year, sex (and breeding condition), and their interactions as fixed effects and animal ID nested in year as a random effect. Habitat models also will include behavior

type (e.g., feeding, resting) because of its potential influence on habitat use (e.g., downed woody debris). Moreover, use (or avoidance) of harvest openings may result from a specific habitat requirement related to timber rattlesnake biology.

## RESULTS

Fifty-five rattlesnakes were captured and marked in both years. We tracked 23 rattlesnakes (10 males, 13 females) during part or all of the 2007 and 2008 active seasons in the HEE control units 2 and 5 and the HEE even-aged units 6 and 9 (Table 1). Gravid and non-gravid females were grouped separately since gravid females are known to reduce movements and shift habitat use (Brown et al. 1982, Reinert and Zappalorti 1988, Reinert et al. 2011, Walker 2000). One female we tracked was gravid in 2007; three females were gravid in 2008.

**Table 1.—MCP Home-range size of timber rattlesnakes, 2007 and 2008. Values for gravid females are noted with an asterisk (\*).**

| HEE unit (treatment) | Snake | Sex | Weight <sup>a</sup> | 2007<br>Home range (ha) <sup>b</sup><br>(number of locations) | 2008<br>Home range (ha) <sup>b</sup><br>(number of locations) |
|----------------------|-------|-----|---------------------|---------------------------------------------------------------|---------------------------------------------------------------|
| 2 (control)          | 249   | F   | 950                 |                                                               | 75.6 (36)                                                     |
|                      | 881   | F   | 800                 |                                                               | - (5)                                                         |
|                      | 272   | F   | 840                 |                                                               | 28.3 (29)                                                     |
|                      | 161   | F   | 1,170               | 41.1 (23)                                                     | *10.7 (40)                                                    |
|                      | 528   | M   | 2,770               | 96.9 (23)                                                     | 143.2 (37)                                                    |
|                      | 122   | M   | 930                 | 27.4 (23)                                                     | 34.6 (40)                                                     |
|                      | 201   | M   | 1,525               |                                                               | 75.6 (25)                                                     |
| 5 (control)          | 41    | F   | 260                 | 1.6 (22)                                                      | 20.5 (37)                                                     |
|                      | 961   | F   | 560                 |                                                               | 16.1 (24)                                                     |
|                      | 980   | F   | 1,080               |                                                               | *12.2 (24)                                                    |
|                      | 900   | F   | 1,165               |                                                               | *7.6 (19)                                                     |
|                      | 489   | M   | 1,520               | 77.0 (34)                                                     | 71.2 (38)                                                     |
|                      | 510   | M   | 2,570               | 60.7 (27)                                                     | 90.7 (27)                                                     |
|                      | 448   | M   | 1,040               |                                                               | 103.4 (29)                                                    |
| 6 (even-aged)        | 23    | F   | 420                 | 5.1 (34)                                                      | 8.8 (43)                                                      |
|                      | 431   | F   | 700                 | 12.8 (53)                                                     | 12.5 (44)                                                     |
|                      | 401   | F   | 730                 | *39.8 (46)                                                    | 5.4 (43)                                                      |
|                      | 292   | M   | 1,130               | 92.0 (49)                                                     | 54.3 (46)                                                     |
|                      | 313   | M   | 1,240               | 13.8 (44)                                                     | 25.1 (42)                                                     |
|                      | 471   | M   | 760                 |                                                               | 7.8 (42)                                                      |
| 9 (even-aged)        | 231   | F   | 380                 |                                                               | 20.1 (34)                                                     |
|                      | 80    | F   | 700                 |                                                               | - (4)                                                         |
|                      | 1580  | M   | 1,450               |                                                               | 93.8 (26)                                                     |

<sup>a</sup> Weight at initial capture, in grams.

<sup>b</sup> 95-percent Minimum Convex Polygon, Hawth's Analysis Tools, ArcGIS 9.0

Average MCP home-range sizes varied by sex and ranged from 1.6 to 103.4 ha (Table 1). The home-range size of males averaged 65.7 ha (SE = 9.8). The home-range of non-gravid females averaged 20.6 ha (SE = 5.9); gravid females averaged 17.6 ha (SE = 10.5). Four gravid females were tracked during the pre-harvest period; only one of these was on an even-aged unit. Thus, average home-range size of gravid snakes should be viewed cautiously. Although the number of locations per snake was variable (range 19-53, average 34) because some snakes were not tracked an entire field season, home-range size was not correlated to sampling intensity ( $r = 0.09$ ).

Home-range size was generally consistent among units with two exceptions: females in unit 2 had a larger home range and males in unit 6 had a smaller home range (Fig. 1). Home-range sizes were similar when grouped by treatment type (Fig. 2). Inconsistencies among units and between treatments may be due in

part to body size (i.e., larger females and males tended to be in control units, Table 1). Regardless of sex, larger snakes had larger home ranges ( $r = 0.73$ ).

## SUMMARY AND FUTURE WORK

This study provides information on the spatial ecology of timber rattlesnakes in a managed forest. Our estimates of home-range size were comparable to other studies conducted in New Jersey (Reinert and Zappalorti 1988), New York (Brown et al. 1982), and West Virginia (Adams 2005). However, our home-range estimates were less than half those of Walker (2000) (males = 174 ha, females = 72 ha) even though both studies were conducted within the same region of Indiana with similar topography and plant composition.

Walker (2000) studied rattlesnakes at Brown County State Park, which differs from the HEE sites with

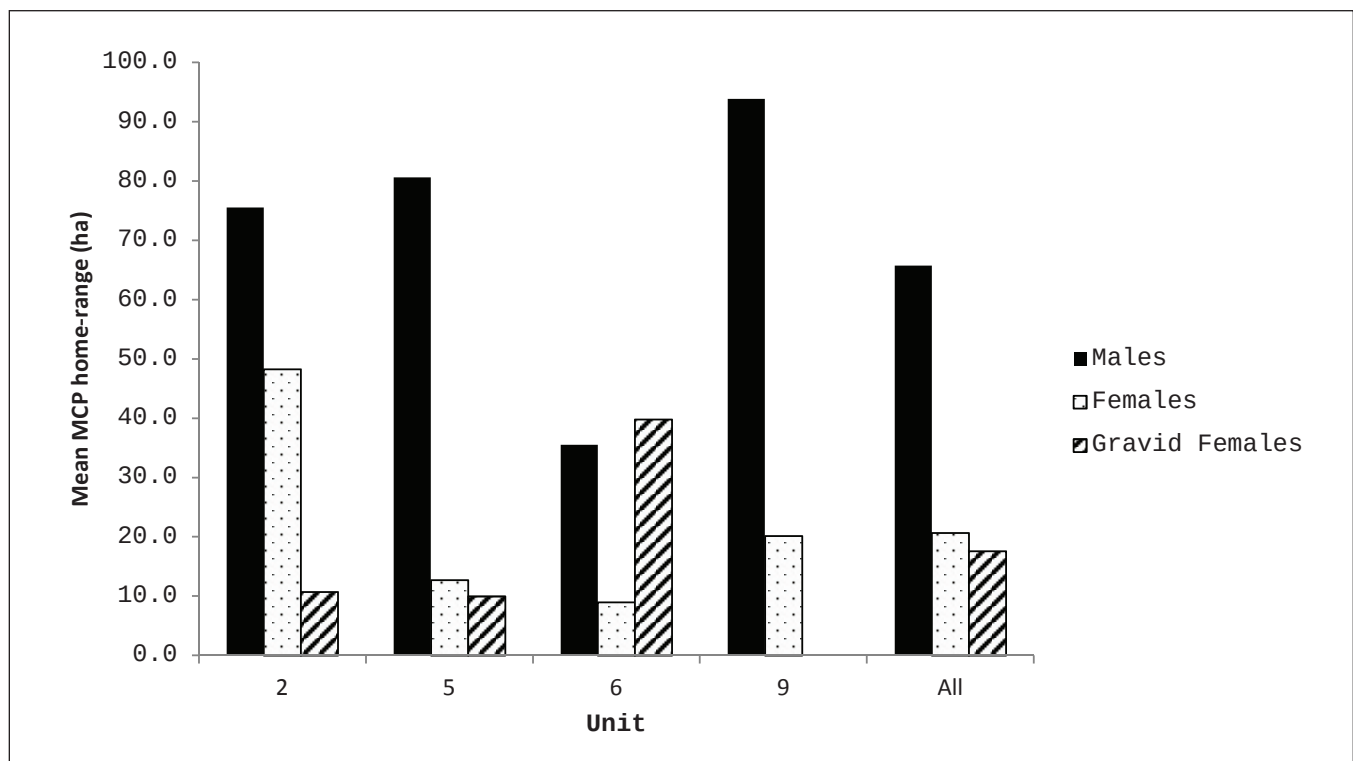


Figure 1.—Mean home-range sizes (95-percent Minimum Convex Polygon) pooled across years for male, non-gravid female, and gravid female timber rattlesnakes in HEE management units (2, 5, 6, and 9) during the pre-harvest period (2007 and 2008).

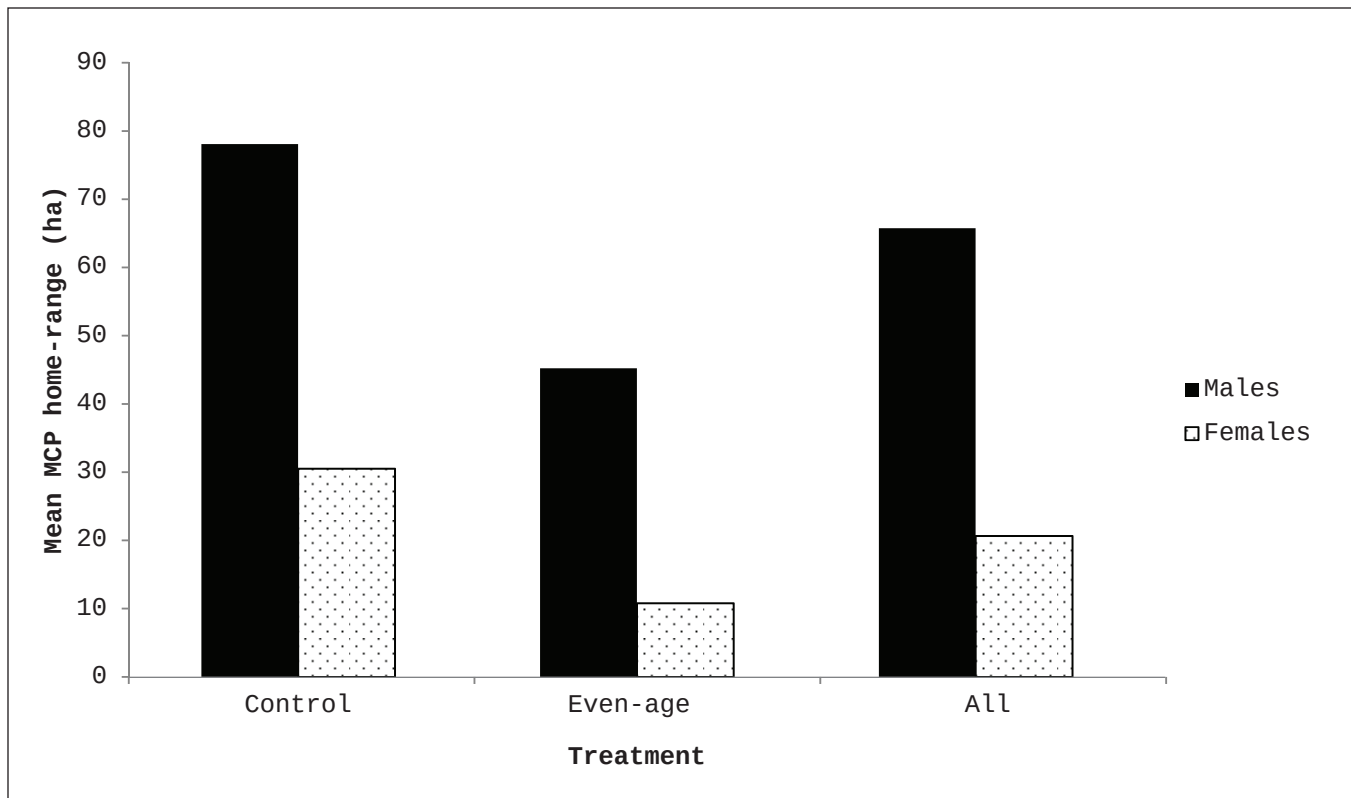


Figure 2.—Mean home-range sizes (95-percent Minimum Convex Polygon) pooled across years for male and female timber rattlesnakes in control (2 and 5) and even-age (6 and 9) HEE management units during the pre-harvest period (2007 and 2008).

respect to forest management (no timber is harvested except for removal of hazards and maintenance of vistas) and deer management. Before regular deer herd-reduction hunts began in 1993, deer at Brown County State Park had not been subjected to a legal harvest for decades and had an estimated prehunt density of 21.7 deer/km<sup>2</sup> (Swihart et al. 1998). The relatively high deer density resulted in reduced plant heights and densities that varied from neighboring Yellowwood State Forest (Webster 1997). It is not clear whether differing deer and/or timber management regimes or other factors produced the wide difference in rattlesnake home-range size between the studies.

Methods of harvesting that create early successional habitat and woody debris, which are both considered beneficial to timber rattlesnakes (Rittenhouse et al. 2007), could enhance habitat for timber rattlesnakes. Unmerchantable logs and tree tops were left in the HEE harvest areas and could provide foraging habitat

for rattlesnakes as suggested by Rittenhouse et al. (2007). Urban and Swihart (this publication) studied the small mammal communities on the HEE as the basis for quantifying small mammal response to timber harvests. Future work could explicitly test timber rattlesnake responses to harvest in terms of predicted small mammal abundances rather than habitat structure alone.

Reinert et al. (2011) found that changes in habitat structure caused by logging in Pennsylvania did not impact timber rattlesnake use, at least in the short term. Habitat structure of sites they measured were more variable immediately after logging and tended to have more fallen log cover and decreased surface vegetation. Reinert et al. (2011) also found that mortality (intentional and accidental) was primarily a function of the logging operation itself rather than changes in habitat structure. They suggested that educational programs and policies restricting the



intentional killing of rattlesnakes may further reduce negative impacts associated with harvests and harvest activities.

Management strategies to reduce mortality may also consider minimizing logger encounters with timber rattlesnakes by adjusting the timing and proximity of harvests to timber rattlesnake den sites. Timber harvesting conducted in proximity to den sites, especially during ingress or egress when snakes are more concentrated near dens, would likely increase chance encounters. However, adjusting the timing of harvest outside of egress and ingress may not reduce vulnerability of gravid females, which tend to stay closer to the dens throughout the active season (Brown 1991, Martin 1993) and bask in open areas (Gibson et al. 2008, Walker 2000). The loss of reproductive females could have a disproportionate impact on population sustainability given their age to sexual maturity and infrequent reproduction (Brown 1991, Martin 1993).

In our study, gravid females had a slightly smaller home-range size than non-gravid females on average. The home-range size of female #161 decreased 74 percent from 2007 (non-gravid) to 2008 (gravid), whereas female #401 demonstrated the opposite trend (Table 1). It remains unclear how the movement behavior of gravid females could inform timber harvest decisions, but the areas around den sites should be a priority for future work.

We had no a priori knowledge of rattlesnake den locations on the HEE sites. The 23 snakes we tracked during the pre-harvest period returned to 13 different den sites, none of which was located within a planned harvest boundary. As the cutting cycles on the HEE progress, we will investigate potential impacts as a result of timber harvesting and the associated activities relative to proximity to den sites, based on home-range size and shift, linear movement parameters, and habitat use.

Although we can make some predictions of how timber rattlesnakes will respond to even- and uneven-age management based on prior studies and their biological needs, the HEE will help us quantitatively assess responses. With these data, we will be able to make management recommendations for timber rattlesnakes that may also benefit other forest reptiles (see Currylow et al., this publication). For example, many species of snakes (eastern hog-nosed snake [*Heterodon platirhinos*], milk snake [*Lampropeltis triangulum*], rough green snake [*Opheodrys aestivus*], gray rat snake [*Pantherophis spiloides*]) and lizards (five-lined skink [*Plestiodon fasciatus*], broad-headed skink [*P. laticeps*], eastern fence lizard [*Sceloporus undulatus*]) were observed when we tracked timber rattlesnakes for our study. Some of these species potentially could be impacted by management techniques (Ross et al. 2000) that result in canopy openings and edges and increased amount of down woody debris. Current management strategies for reptiles and amphibians are based on the scientific information available but lack species-specific recommendations for mammals and birds (e.g., Kingsbury and Gibson 2002). With information gained from the HEE, we should be able to inform forest management decisions that are more inclusive of the specific needs of timber rattlesnakes and the other forest reptiles that will help maintain the integrity of forest ecosystems in the Central Hardwoods Region.

This paper summarizes pre-harvest timber rattlesnake home ranges. Future work will provide a more complete picture of timber rattlesnake ecology and the impacts of timber harvesting. First, we will determine the immediate effects of timber harvests on timber rattlesnake spatial ecology and habitat use by comparing home-range size and shift, movement parameters, and vegetation and habitat characteristics between treatment types pre- and post-harvest. Timber rattlesnakes on the HEE sites spend more than half their lives hibernating. We will also evaluate the structural and thermal characteristics of den sites.

These data will be compared with available sites in harvest openings and the forest matrix and can also serve as a baseline level with which to compare as the habitat structure changes with future harvests. Finally, we will estimate timber rattlesnake adult annual survivorship during the active and hibernation seasons and determine the genetic structure and variability of timber rattlesnakes on the HEE. These studies will provide data useful for evaluating the long-term population viability of timber rattlesnakes in managed forests.

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## LITERATURE CITED

- Adams, J.P. 2005. **Home range and behavior of the timber rattlesnake (*Crotalus horridus*)**. Huntington, WV: Marshall University. 104 p. M.S. thesis.
- Birch, T.W. 1996. **Private forest-land owners of the northern United States, 1994**. Resource Bulletin NE-136. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 293 p.
- Blouin-Demers, G.; Weatherhead, P.J. 2001. **Habitat use by black rat snakes (*Elaphe obsoleta obsoleta*) in fragmented forests**. Ecology. 82(10): 2882-2896.
- Brown, W.S. 1991. **Female reproductive ecology in a northern population of the timber rattlesnake, *Crotalus horridus***. Herpetologica. 47(1): 101-115.
- Brown W.S.; Pyle, D.W.; Greene, K.R.; Friedlaender, J.B. 1982. **Movements and temperature relationships of timber rattlesnakes (*Crotalus horridus*) in northeastern New York**. Journal of Herpetology. 16(2): 151-161.
- Gibson, S.E. 2003. **Movements and habitat preference of the timber rattlesnake (*Crotalus horridus*) in southern Indiana**. Fort Wayne, IN: Purdue University. 72 p. M.S. thesis.
- Gibson, S.E.; Walker, Z.; Kingsbury, B.A. 2008. **Microhabitat preferences of the timber rattlesnake (*Crotalus horridus*) in the hardwood forests of Indiana**. In: Hayes, W.K.; Beaman, K.R.; Cardwell, M.D.; Bush, S.P., eds. The biology of rattlesnakes. Loma Linda, CA: Loma Linda University Press: 275-286.
- Homoya, M.A.; Abrell, D.B.; Aldrich, J.R.; Post, T.W. 1985. **The natural regions of Indiana**. Proceedings of the Indiana Academy of Science. 94: 245-268.
- James, F.C.; Shugart, H.H., Jr. 1970. **A quantitative method of habitat description**. Audubon Field Notes. 24(6): 727-736.



- Kingsbury, B.A.; Gibson, J. 2002. **Habitat management guidelines for amphibians and reptiles of the Midwest.** Fort Wayne, IN: Partners in Amphibian and Reptile Conservation. 57 p.
- Martin, W.H. 1982. **The timber rattlesnake in the Northeast; its range, past and present.** Herp Bulletin of the New York Herpetological Society. 17: 15-20.
- Martin, W.H. 1993. **Reproduction of the timber rattlesnake (*Crotalus horridus*) in the Appalachian Mountains.** Journal of Herpetology. 27(2): 133-143.
- Maser, C.; Anderson, R.G.; Cromack, K., Jr.; Williams, J.T.; Martin, R.E. 1979. **Dead and down woody material.** In: Thomas, J.W., ed. Wildlife habitats in managed forests: the Blue Mountains of Oregon and Washington. Agric. Handbk. 553. Washington, DC: U.S. Department of Agriculture, Forest Service: 78-95.
- Reinert, H.K. 1984. **Habitat separation between sympatric snake populations.** Ecology. 65(2): 478-486.
- Reinert, H.K.; Cundall, D. 1982. **An improved surgical implantation method for radio-tracking snakes.** Copeia. 1982(3): 702-705.
- Reinert, H.K.; Zappalorti, R.T. 1988. **Timber rattlesnakes (*Crotalus horridus*) of the Pine Barrens: their movement patterns and habitat preference.** Copeia. 1988(4): 964-978.
- Reinert, H.K.; Munroe, W.F.; Brennan, C.E.; Rach, M.N.; Pelesky, S.; Bushar, L.M. 2011. **Response of timber rattlesnakes to commercial logging operations.** Journal of Wildlife Management. 75(1): 19-29.
- Rittenhouse, C.D.; Dijak, W.D.; Thompson, F.R., III; Millspaugh, J.J. 2007. **Development of landscape-level habitat suitability models for ten wildlife species in the Central Hardwoods Region.** Gen. Tech. Rep. NRS-4. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 47 p.
- Ross, B.; Fredericksen, T.; Ross, E.; Hoffman, W.; Morrison, M.L.; Beyea, J.; Lester, M.B.; Johnson, B.N.; Fredericksen, N.J. 2000. **Relative abundance and species richness of herpetofauna in forest stands in Pennsylvania.** Forest Science. 46(1): 139-146.
- SAS Institute Inc. 2004. **SAS/STAT 9.1 user's guide.** Cary, NC: SAS Institute Inc. 5121 p.
- Swihart, R.K.; Weeks, H.P., Jr.; Easter-Pilcher, A.L.; DeNicola, A.J. 1998. **Nutritional condition and fertility of white-tailed deer (*Odocoileus virginianus*) from areas with contrasting histories of hunting.** Canadian Journal of Zoology. 76(10): 1932-1941.
- Walker, Z.J. 2000. **The spatial ecology of the timber rattlesnake (*Crotalus horridus*) in south central Indiana.** Fort Wayne, IN: Purdue University. 45 p. M.S. thesis.
- Webster, C.R. 1997. **The influence of white-tailed deer on plant communities within mesic forest: an examination of Indiana state parks.** West Lafayette, IN: Purdue University. 184 p. M.S. thesis.