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Short-term responses of Timber Rattlesnakes (*Crotalus horridus*) to even-aged timber harvests in Indiana

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ABSTRACT

The Timber Rattlesnake (*Crotalus horridus*) is a species of conservation concern throughout much of the Midwestern United States. While the habitat preferences of Timber Rattlesnakes have been studied throughout much of its range, little empirical data is available on the effects of forest management on this species. During 2007–11, we monitored movements of 47 adult Timber Rattlesnakes using radio telemetry in southcentral Indiana. Snakes were tracked during one or more seasons (April-October) for two years prior to, and three years following scheduled timber harvests (4-ha clearcuts and 4-ha understory removal as the first stage of shelterwood harvests). Annual home range estimates (100% Minimum Convex Polygon [MCP]) for both sexes combined ranged from 1.6 ha to 271.3 ha. The average home range for males (68.8 ha) was larger than for either non-gravid females (22.7 ha) or gravid females (11.7 ha). Mean home range size using MCPs or kernel density estimates did not change from pre- to post-harvest in control sites or even-aged sites for either sex. The daily distance traveled by snakes and their proportional use of areas within harvest boundaries did not differ between treatment periods. Canopy and understory removal on a small scale (approx. 4 ha) in a forested landscape did not affect seasonal or fine-scale movements of adult Timber Rattlesnakes 1–3 years post-harvest. Our results suggest that this scale of timber harvesting is compatible with Timber Rattlesnakes.

1. Introduction

An ecosystem-based approach to forest management aims to sustain or enhance biodiversity, ecosystem services, and societal functions while also delivering more tangible public goods and services (Perry, 1998; USDA, 2011). However, this approach requires knowledge of how forest communities respond to different types of forest management techniques, particularly timber harvesting. While the effects of timber harvesting are better understood for birds (Annand and Thompson, 1997; Gram et al., 2003; Reidy et al., 2014; Kendrick et al., 2015), mammals (Kirkland, 1990; Ford and Rodrigue, 2001; Urban and Swihart, 2011; Kellner et al., 2013), and amphibians (Renken et al., 2004; Semlitsch et al., 2009; MacNeil and Williams, 2014), studies for reptiles have lagged behind despite documented declines in many species (Gibbons et al., 2000).

Canopy openings can alter reptile communities through changes in temperature (Pike et al., 2011), vegetative structure (Ross et al., 2000; Cantrell et al., 2013; Sutton et al., 2013), course woody debris (Cantrell et al., 2013), and prey availability (Pike et al., 2011; Kellner et al., 2013). At the local scale, reptile abundance generally increases in response to canopy removals in the short-term (Ross et al., 2000; Pike et al., 2011), but this affect may decline in the long term (Hu et al., 2013). The response level to different types of canopy and mid-story removals are species specific and depend on the type and scope of forest management techniques used (Renken et al., 2004; Pike et al., 2011; Sutton et al., 2013). However, this level of detailed habitat-use information is lacking for many species, likely due to the significant investment of the required time and resources. Studying responses of indicator species to forest management may be especially useful given limitations in resources. Snakes may be particularly useful indicator species for studying a variety of ecosystem responses (Beaupre and Douglas, 2009).

Indicator species are sensitive to disturbance and changes in their populations may have cascading effects on the ecosystem. Timber Rattlesnakes (*Crotalus horridus*) in particular may be a good indicator species for studying wildlife responses to forest management because they maintain strong fidelity to hibernacula, and they remain near these den sites for up to several weeks during ingress and egress (Brown et al., 1982). Gravid females also tend

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to stay near hibernacula during the entire active season (Brown, 1991; Martin, 1993). Thus, habitat changes around den sites may alter their quality, either positively or negatively, for gravid females and overwintering snakes. Second, Timber Rattlesnakes have ecological importance across their range in the eastern United States as large vertebrate predators in forest ecosystems (Clark, 2002; Martin et al., 2008). This high trophic position may allow for assessment of the cascading effects of timber harvesting on the food-web dynamics of forests.

Presumably when an animal selects a resource, it promotes the fitness of that animal (Millspaugh et al., 2012). Knowledge of how Timber Rattlesnakes alter their movements and home ranges in response to forest management techniques can inform how forest management affects habitat quality. Snakes have been shown to increase their home-range size in the presence of unsuitable habitat (Kapfer et al., 2010). Timber harvesting, prescribed burning, thinning, and timber stand improvement alter the structure or species composition of forest vegetation (Patton, 2011), and thereby, may affect habitat quality for Timber Rattlesnakes. While some level of forest management is necessary to maintain the biodiversity of forest communities (Renken et al., 2004), the appropriate scale of disturbance is not always clear. Reinert et al. (2011) found that Timber Rattlesnakes in Pennsylvania did not alter movements after a 154-ha commercial logging operation that was a shelterwood harvest with the exception of a single 20.2-ha clearcut. While snakes increased their use of the more structurally diverse habitat created by the logging, the authors did not report how snakes specifically used the clearcut area or if that use changed after harvest (Reinert et al., 2011).

We took a replicated approach using treatments and controls to evaluate the effects of even-aged forest management (clearcut and shelterwood harvests) on the seasonal and fine-scale movements of Timber Rattlesnakes. This study was part of a larger study, the Hardwood Ecosystem Experiment, a long-term, landscape-level field experiment to study forest management and its impacts (Kalb and Mycroft, 2013). Tree canopy removal may increase habitat quality for Timber Rattlesnakes through increased availability of favorable thermal environments (Blouin-Demers and Weatherhead, 2002), vegetative cover (Gibson et al., 2008; Reinert et al., 2011), and prey abundance (Kellner et al., 2013). However, it may also create unsuitable habitat which snakes avoid by expanding their home-range size or altering their movements. We predicted that Timber Rattlesnakes would increase fine-scale movements in clearcuts and shelterwood areas to take advantage of the altered structure. We also predicted that seasonal home-ranges and daily movement distances would decrease in even-aged sites compared to controls since harvesting created more heterogeneous habitat structure and thermal profiles.

2. Materials and methods

2.1. Study area

This study was part of the Hardwood Ecosystem Experiment (HEE) in Morgan-Monroe State Forest (39°25′N, 86°25′W) and Yellowwood State Forest (38°50′N, 86°30′W) in south-central Indiana, USA (Kalb and Mycroft, 2013). These forests, which span >18,000 ha, lie at 180–280-m of elevation with slopes typically 23–35% (Jenkins and Parker, 1998; Kalb and Mycroft, 2013). Forest ridges and south-facing slopes are dominated by an overstory of black oak (*Quercus velutina*), white oak (*Quercus alba*), and shagbark hickory (*Carya ovata*), with dry ridge tops dominated by chestnut oaks (*Quercus prinus*). American beech (*Fagus grandifolia*), sugar maple (*Acer saccharum*) and flowering dogwood (*Cornus florida*) dominate understories on drier sites. Northern red oaks (*Quercus rubra*), tulip poplars (*Liriodendron tulipifera*), American beech, sugar maple, and hickories (*Carya* sp.) occur on mesic sites. The understory on mesic sites is largely beech and maple saplings. Sedges (*Carex* spp.) are prevalent on drier sites, whereas ferns and other perennials occur on the mesic areas and lowlands. The forests are managed for multiple uses including timber production, recreation, and wildlife habitat. A network of gravel service roads with occasional public roads are located throughout the study area. Additional details of the study area are published elsewhere (Carman, 2013; Jenkins, 2013; Kalb and Mycroft, 2013).

2.2. Experimental design and timber harvests

The HEE is separated into nine forest management units (303–494 ha) that encompass 3603 ha over 30 linear kilometers (Kalb and Mycroft, 2013). Units were randomly assigned one of three treatments – control, even-aged management and uneven-aged management (three replicates of each). This study included only the three control and the three even-aged units and the surrounding forest matrix. The even-aged management units each contained two 4-ha clearcuts and two 4-ha shelterwood areas. Harvests were implemented during October 2008 to January 2009. Clearcut harvests involved removal of all woody stems >30.48 cm diameter at breast height (DBH) followed by timber stand improvement (TSI) that removed the remaining woody stems and vines (Kalb and Mycroft, 2013). The shelterwood was a 3-stage system. During 2008–09, the first stage preparatory cut removed midstory and understory layers with some overstory stems to a minimum basal area at 13.8 m^2/ha (Kalb and Mycroft, 2013). This study encompassed only the first stage cut of the shelterwood system.

2.3. Snake sampling and radio telemetry

During each year of the study (2007–11), we initially captured snakes during their active season with searches of appropriate habitat within management units, and with traps located near den sites (2008 only). We also located snakes opportunistically during radio tracking and other field activities. Upon initial capture of each snake, we measured total body length (TBL), snout to vent length (SVL) in cm, and tail length (TL in mm), and determined sex (via TL and/or cloacal probe), age class (neonate TBL < 20 cm; juvenile 20 cm ⩽ TBL ⩽ 80 cm; adult TBL > 80 cm), and weight to the nearest 10 g. We marked each snake with a Passive Integrated Transponder (PIT) tag (AVID Identification Systems, Inc.) implanted subcutaneously. For each snake location, we recorded the date, slope aspect, UTM coordinates, elevation, and general weather.

We monitored the movements of a subset of Timber Rattlesnakes using radio-telemetry. Snakes were selected with the goal of equal representation of male and female snakes across the six management units (three control and three even-aged). For each selected snake, we marked the location of capture with flagging and transported the animal to a local Department of Natural Resources (DNR) office where Purdue University veterinarians surgically implanted radio transmitters (Holohil Systems, Ltd., type AI-2T 25 g; SI-2T 13.5 g and 9.0 g) using a method modified from Reinert and Cundall (1982). The battery life of transmitters ranged from one to three years. Snakes were recaptured prior to battery failure and received a new transmitter following the same surgical methodology. Transmitter selection for new and replacement surgeries was based on weight and girth of each snake. Following a 48- to 96-h recovery time, snakes were returned to their exact point of capture and released. Rattlesnakes were typically tracked three times per week during the active season (generally mid-April to early-October). We used handheld GPS units to record the location coordinates of each snake or, when

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