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A regional scale assessment of habitat selection and home range of the eastern rat snake in pine-dominated forests

Jennifer M. Howze[a,*], Kimberly J. Sash[b], John P. Carroll[c], Lora L. Smith[a]

[a] Joseph W. Jones Ecological Research Center, 3988 Jones Center Drive, Newton, GA 39870, USA
[b] Tall Timbers Research Station & Land Conservancy, 13093 Henry Beadel Drive, Tallahassee, FL 32312, USA
[c] University of Nebraska, School of Natural Resources, 3310 Holdrege Street, Lincoln, NE 68583, USA

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ABSTRACT

An animal's spatial ecology may provide insight into how resources are distributed or potentially limiting across its home range. Some species with broad geographic distributions may exhibit intraspecific variation in space use among populations given the spectrum of available habitat across their range. Animals may need to move further in habitats with limited resources thereby lowering survival. Species, like the eastern rat snake (*Pantherophis alleghaniensis*), occur throughout the eastern USA and are thought to be strongly tied to hardwood forests. However, their occurrence in pine-dominated forests in the southeastern USA suggests they have broader habitat requirements than previously noted. Our objective was to investigate patterns of habitat use and spatial ecology for eastern rat snakes across multiple pine-dominated forests in Southern Georgia and Northern Florida to capture regional differences in eastern rat snake resource use. We examined home range and habitat use at multiple spatial scales for 30 radio-telemetered snakes from three sites; one in Georgia (Pebble Hill) and Florida (Tall Timbers) during 2004–2005 and one more northern site in Georgia (Ichauway) during 2010–2012. Snakes tracked on Ichauway had a mean home range size that was 3.9 times larger (95% Mean Convex Polygon [MCP], 13.6 ± 8.2 ha) than the estimate for Tall Timbers (3.5 ± 3.2 ha) and 2.6 times larger than the estimate for Pebble Hill (5.3 ± 3.2 ha). Snakes at all three sites selected primarily open edge and pine habitat at the landscape scale and were most likely to be found in large, mature oak trees (*Quercus* spp.). At Ichauway, hardwood removal activities associated with longleaf pine (*Pinus palustris*) restoration reduced the number of hardwood trees per hectare by 33% in hardwood removal areas from 1998 to 2014. This management approach included limiting suitable large oak trees that rat snakes use and may help explain the variation in home range size and the number of snakes captured at Ichauway ($n = 14$) compared to the other two sites (Tall Timbers, $n = 154$, Pebble Hill, $n = 127$).

1. Introduction

The breadth of an animal's movements and spatial ecology can be influenced by many factors, including reproduction (Bertrand et al., 1996; Gibbons and Semlitsch, 2001), food availability (King and Duvall, 1990; Mares et al., 1982; Shine et al., 2003), environmental conditions (Blouin-Demers and Weatherhead, 2001a, 2001b; Lillywhite, 2001; Webb and Shine, 1998), and habitat structure/resource availability (Gregory et al., 2001; Kie et al., 2002; Pasinelli, 2000). Given similar diet preferences and reproductive ecology within a species, habitat type and availability may have the largest influence on plasticity of space use across a species' geographic distribution. Animals may need to travel longer distances if particular resources are limiting, possibly impacting survival, due to increased energy expense and predation risk (Gregory et al., 2001).

The biologically diverse longleaf pine (*Pinus palustris*) ecosystem was once the dominant habitat type across the Coastal Plain of southeastern USA. Currently, it is one of the most globally endangered ecosystems in North America (< 5% remains), mainly due to conversion to agriculture and industrial pine plantations, urban development, and fire suppression (Noss et al., 1985; USDA, 2016; Ware et al., 1993). In the absence of frequent fire, longleaf pine forests become hardwood dominated systems (Gilliam and Platt, 1999; Heyward, 1939). Species that require open canopy pine forests and abundant herbaceous ground cover, including the red-cockaded woodpecker (*Picoides borealis*, Rudolph et al., 2002), gopher tortoise (*Gopherus polyphemus*, Yager et al., 2007), and snakes, like the eastern diamondback rattlesnake (*Crotalus adamanteus*), and the eastern indigo snake (*Drymarchon*

* Corresponding author.
E-mail address: jennifer.howze@jonesctr.org (J.M. Howze).

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couperi) (Hoss et al., 2010; Hyslop et al., 2014) are thought to have declined in fire-suppressed forests. But other species, within the former range of the longleaf pine ecosystem associated with hardwoods, e.g., certain songbirds (Conner et al., 2002), raccoon (*Procyon lotor*, Kirby et al., 2017) and rat snakes (*Pantherophis* spp., Blouin-Demers and Weatherhead, 2001a, 2002; Fitch, 1963; Reinert, 1993; Stickel et al., 1980), may have benefitted from increases in hardwoods in pine forests. Eastern rat snakes (*P. alleghaniensis*) are predators of eggs and chicks of the northern bobwhite (*Colinus virginianus*), a popular gamebird species in the southeastern U.S. (Staller et al., 2005) and the federally protected red-cockaded woodpecker (Jackson, 1978; Neal et al., 1993). Hence, there is considerable interest in whether fire suppression may, indirectly, have resulted in increased populations of eastern rat snakes, as well as in identifying habitat restoration methods to minimize impacts of this native predator (Sash, 2007; Stapleton, 2005). Although historic data on eastern rat snake abundance are lacking, we suspected that snakes may use habitat resources differently across their range, especially in areas where management and restoration practices select against preferred habitats. Therefore, our objective was to investigate patterns in habitat use for eastern rat snakes across multiple pine-dominated forests. We focused on three managed pine forests in South Georgia and North Florida to capture regional and management-specific differences in eastern rat snake resource use.

2. Materials and methods

2.1. Study area

We collected data on three privately-owned pine-dominated properties in southwest Georgia and northern Florida that were managed for restoration and conservation of southeastern pine forest endemic species (e.g. red-cockaded woodpecker, gopher tortoise) and northern bobwhite quail hunting. All three sites were managed with prescribed fire (1–3 year rotation) and hardwood removal to restore fire corridors and promote an open canopy pine forest with species-rich ground cover (Edwards et al., 2013). Additionally, wildlife food plots within pine forests were maintained for northern bobwhite quail management. Daily temperatures for the region ranged from 18 °C to 33 °C in summer and from 2 °C to 21 °C in winter (U.S. Climate Data, 2017).

2.1.1. Ichauway

Ichauway, the research site of the Joseph W. Jones Ecological Research Center, was located in Newton, Georgia, USA, within the Dougherty Plain, characterized by a karst topography and sandy soils. The 12,000 ha site was dominated by mature second growth longleaf pine with undisturbed (i.e. wiregrass, *Aristida stricta*) and old field (i.e. *Andropogon* spp.) ground cover. Large solitary hardwoods, primarily oaks (*Quercus* spp.), were scattered within pine dominated forests, fire shadows, and roads and closed-canopied hardwood forests were located adjacent to 45 km of streams and rivers (Ichawaynochaway Creek and Flint River), in mesic depressions, ephemeral drainages, around depressional wetlands, and in upland habitats with a history of lower fire frequency (> 3 years).

2.1.2. Tall timbers Research Station & Land Conservancy and Pebble Hill Plantation

Tall Timbers Research Station & Land Conservancy (1,300 ha), located in Tallahassee, Florida, USA, and Pebble Hill Plantation (1,200 ha), located in Thomasville, Georgia, USA, fell within the Red Hills Region, an area characterized by red clay soils and hilly topography (Edwards et al., 2013). Both sites were dominated by second growth loblolly pine (*P. taeda*), shortleaf pine (*P. echinata*), and longleaf pine, and ground cover was comprised of either old field (Tall Timbers) or both old field and native ground cover, including wiregrass (Pebble Hill). Closed-canopied hardwood forests, comprised of oaks, black gum (*Nyssa sylvatica*), sweetgum (*Liquidambar styraciflua*), and southern magnolia (*Magnolia grandiflora*) were located primarily along periodically inundated drainages that extended throughout both properties.

2.2. Data collection

We used radio-telemetry to track movements and evaluate macrohabitats and refugia used by eastern rat snakes on all three study sites. Microhabitat scale resource use (at terrestrial and arboreal sites) was collected for Ichauway only.

2.2.1. Data collection on Ichauway

Snakes were captured in box trap arrays (Burgdorf et al., 2005) or by hand during the spring and summers of 2010 and 2011 under Georgia Department of Natural Resources Scientific Collecting Permits (29-WBH-09-151 and 29-WBH-10-109). For each snake captured, we collected snout-to-vent length (SVL), body mass, and identified sex through cloacal probing.

Thirteen adult eastern rat snakes (6 males and 7 females) were large enough (SVL > 120.4 cm, mass > 300 g) to implant 9 g radio transmitters (Model SI-2; Holohil Systems Ltd., Carp, Ontario, Canada) using methods described in Reinert and Cundall, (1982) and were tracked 1–2 times weekly from July 2010 to October 2012. We recorded snake locations using a GPS field computer with < 0.6 m accuracy (Trimble Nomad 800B datalogger, Landmark Spatial Solutions, Starkville, MS with Hemisphere Crescent A-101 Antenna, Scottsdale, AZ) and described the locations as follows for each tracking event: above ground, in tree, under coarse woody debris (CWD), underground (i.e. in a stump hole or animal burrow). To examine structural components of snake terrestrial microhabitat, we measured canopy cover using a spherical densiometer (Forestry Suppliers, Inc., Jackson, MS) and ground cover within a 1 m^2 plot centered on the snake location. Ground cover components measured included bare ground, litter, CWD, grasses, herbaceous vegetation, and woody midstory vegetation at two height classes (< 2 m and > 2 m). As a measure of available microhabitats, we collected the same ground cover data in a 1 m^2 plot at a random bearing (0°–360°) and distance (1–50 m) from the snake location. For snakes located above ground in arboreal microhabitat, we identified tree type (pine, oak, other hardwood), the presence of a tree cavity, and measured basal area of surrounding pine and hardwood trees using a 10 factor prism (Forestry Suppliers, Inc., Jackson, MS). We also measured diameter at breast height (dbh) and placed trees in the following size class categories: shrub (< 2.5 cm dbh), midstory (2.5–10.1 cm dbh), and overstory (> 10.1 cm dbh). As a measure of available trees, we collected the same data for the tree within the same size class that was closest to a randomly selected point within a 50 m buffer around each snake location. Random points and buffers were created in ArcGIS ver. 10.3.

2.2.2. Data collection on Tall Timbers and Pebble Hill

Snakes were captured using drift fence arrays and by hand capture in 2004–2005 at Tall Timbers and Pebble Hill under University of Georgia's Animal Care and Use Committee permits (A2001-1010-c1,c2), Georgia Department of Natural Resource permits (29-WMB-01-80 and 29-WMB-04-128), and Florida Fish and Wildlife Conservation permits (WX01277 and WX02136). For each snake captured, we collected the following morphological measurements: SVL, body mass, sex (through cloacal probing). We implanted 4-g radio transmitters (R1170; Advanced Telemetry Systems, Inc., North Isanti, MN) into 21 snakes (10 from Tall Timbers and 11 from Pebble Hill) that weighed > 300 g (Reinert and Cundall, 1982). From March 2004–October 2005, snakes were located four times a week during March through September and 2–3 times a week during October through February. During each tracking event, the snake's location was mapped using a GPS (Trimble GeoExplorer, Sunnyvale, CA) and was described as follows: above ground, in tree, under CWD, underground (i.e. in a stump hole or animal burrow). Neither terrestrial nor arboreal microhabitat data were collected at these two sites.