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A Preliminary Investigation into the Short-term Effects of a Prescribed Fire on Habitat Quality for a Snake Assemblage

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Abstract.—**Early successional habitats in the northeastern United States, once generated in part by now rare fire events, are essential for a wide range of specialist species. Many snake species use open early successional habitats for basking (thermoregulation) and foraging, but individual species within an assemblage vary in their requirements. Consequently, management to maintain early successional habitats using prescribed fire may have varied effects on different species. We used a Before-After-Control-Impact (BACI) experimental design to explore how a snake assemblage responded to a prescribed burn intended to improve habitat quality for the endangered Eastern Massasauga Rattlesnake, *Sistrurus catenatus catenatus,* in an old field habitat in New York. Although we do not employ full statistical analysis given that the fire treatment was operationally applied only to one site, our results suggest that prescribed fire is an important influence of habitat quality for snakes. Further study is required to facilitate generalizations of our findings across multiple prescribed fires and to identify the mechanisms behind these apparent effects of prescribed fire on snake habitat.**

Key Words.—Gartersnake; *Lampropeltis*; management; milksnake; old field; reptile; *Storeria*; *Thamnophis*

Introduction

Low intensity fires were once a regular feature of landscapes throughout eastern North America. The frequency of these fires varied considerably; within the Longleaf Pine, *Pinus palustris*, forests of the southeastern coastal plain, fires occurred every two to three years and played an important role in the evolution of species associated with this system (Van Lear et al. 2005). Natural fires were much less common in the northeastern United States (e.g., Shumway et al. 2001), but these natural fires, in combination with burning by Native Americans (e.g., Chilton 2001), helped ensure that early successional habitats persisted as patches within forested landscapes. These early successional habitats provided refuge for a diversity of habitat specialists (e.g., Dessecker and McAuley 2001). However, the frequency of fire in landscapes of North America declined considerably throughout the 20th Century due to a combination of habitat fragmentation and fire suppression (Nowacki and Abrams 2008). Farm abandonment over the same time period further exacerbated the decline of early successional habitats (Litvaitis 1993; Dovčiak et al. 2005). As a result, early successional habitats and the organisms associated with them are among the most imperiled in North America (e.g., Noss 1988) and their restoration is an active goal in many areas.

Fire has important effects on wildlife habitats (Van Lear and Harlow 2000); in particular, fire decreases woody vegetation density and thus helps to maintain an open understory, especially important for ectothermic organisms (such as reptiles), which require open habitats for thermoregulation (Adolph 1990; Melville and Schulte 2001). Suppression of fire may quickly degrade habitat quality for reptiles if the area becomes shaded and insufficient to maintain thermal requirements (Webb et al. 2005). Snakes may be particularly sensitive to understory change and resulting shifts in thermal conditions (e.g., Blouin-Demers and Weatherhead 2001) as they often select habitats based on their ability to maintain desired body temperatures (Row and Blouin-Demers 2006a).

Given well-documented global declines of reptiles (Gibbons et al. 2000; Reading et al. 2010), it is important to understand how they respond to restoration of their fire-suppressed habitats (e.g., Perry et al. 2009). Reintroducing fire has been successful in restoring reptile populations and assemblages associated with fire-suppressed Longleaf Pine forests (Steen et al. 2013a, b). In addition, vegetation management to reduce plant canopy shade in fire-suppressed areas can increase the probability that individual refuge sites are used by rare reptiles (Webb et al. 2005). However, the relationships between management strategy, microclimate (habitat thermal quality), and responses of individual species can be complex (Sutton et al. 2013, 2014). Furthermore, most studies of these relationships have occurred in forested habitats or they were focused on a single target species (e.g., Dovčiak et al. 2013). Thus, it is difficult to generalize when attempting to summarize how reptiles respond to microhabitat change caused by prescribed fire (Elzer et al. 2013), particularly for snake species and assemblages of open or grassland habitats threatened by vegetative succession (Kjoss and Litvaitis 2001; Cagle 2008).

Old fields can represent important habitat for many snake species (Keller and Heske 2000) because they may be structurally similar to the natural early successional habitats that are now rare. These old-field habitats are actively managed in some areas by prescribed fire (Dovčiak et al. 2013). For example, prescribed fires are used to improve old field habitat quality for the Eastern Massasauga Rattlesnake, *Sistrurus catenatus catenatus* (USFWS 2012). Because prescribed fire is a widely used habitat management tool throughout the United States (Thompson and DeGraaf 2001) that influences snake assemblages (Wilgers and Horne 2006; Steen et al. 2013b), it is important to consider how this management strategy influences individual species, as they are unlikely to respond uniformly due to varying requirements related to thermal conditions, prey base, or microhabitat. In this study, we used a Before-After-Control-Impact (BACI) design to explore how experimental application of prescribed fire to improve habitat quality for an endangered target species (i.e., Eastern Massasauga Rattlesnake) in an old field environment affected habitat quality for more common but non-target snake species.

Materials and Methods

Study site.—Our study took place in Cicero Swamp Wildlife Management Area in Central New York State (43°8'N, 76°2'W). Climate in the region is continental and humid, with a mean annual temperature of 8.8° C and mean annual precipitation of 102 cm (Syracuse Hancock International Airport, 6 km from the study area; National Climatic Data Center. 2011. Local climatological data. National Oceanic and Atmospheric Administration, United States Department of Commerce. Available at http://www.ncdc.noaa.gov/oa/ncdc.html. [Accessed 26 February 2011]). Cicero Swamp Wildlife Management Area is a mosaic of upland forest, fields, and wetlands, and a portion of the area was impacted by an intense fire in 1892 (LeBlanc and Leopold 1992). We studied two old fields that were under active management (biannual mowing) by the New York State Department of Environmental Conservation as potential summer habitat for the endangered Eastern Massasauga Rattlesnake. The two fields were < 1 km apart and were planted with row crops until abandonment 15–20 y prior to this study. To evaluate the effects of fire as a potential alternative strategy for management of the Eastern Massasauga Rattlesnake and of other snake species, a prescribed burn was applied in early April 2010 in one of the fields (in lieu of mowing that year, Fig. 1), whereas the other was left unburned to serve as a control treatment. Additional details on the study area are provided in Dovčiak et al. (2013).

Snake surveys.—In 2010, we used artificial cover objects (Godley 2012) to systematically sample the snakes within the old fields during the vegetative season (June-August, effectively replicating efforts that took place in 2006; Patrick and Gibbs 2009). We placed 25 cover boards (decommissioned metal road signs, 0.7 × 0.7 m) in a 5 × 5 grid (70 × 500 m) in each treatment. We systematically monitored cover boards throughout the summer (20 surveys from early June to late August). Each survey consisted of lifting each cover board and recording the presence or absence of any snake species observed. We used the total number of detections per coverboard (hereafter, detections) in 2006 and in 2010 to determine if snake habitat quality was influenced by treatment by qualitatively comparing them to snake detections in control plots untreated by fire. The logistical concerns in applying prescribed fire required a large-scale manipulation at the scale of the whole old field. Therefore, we did not have replicates of the treatment and, consequently, can not statistically compare outcomes in burn and control treatments.

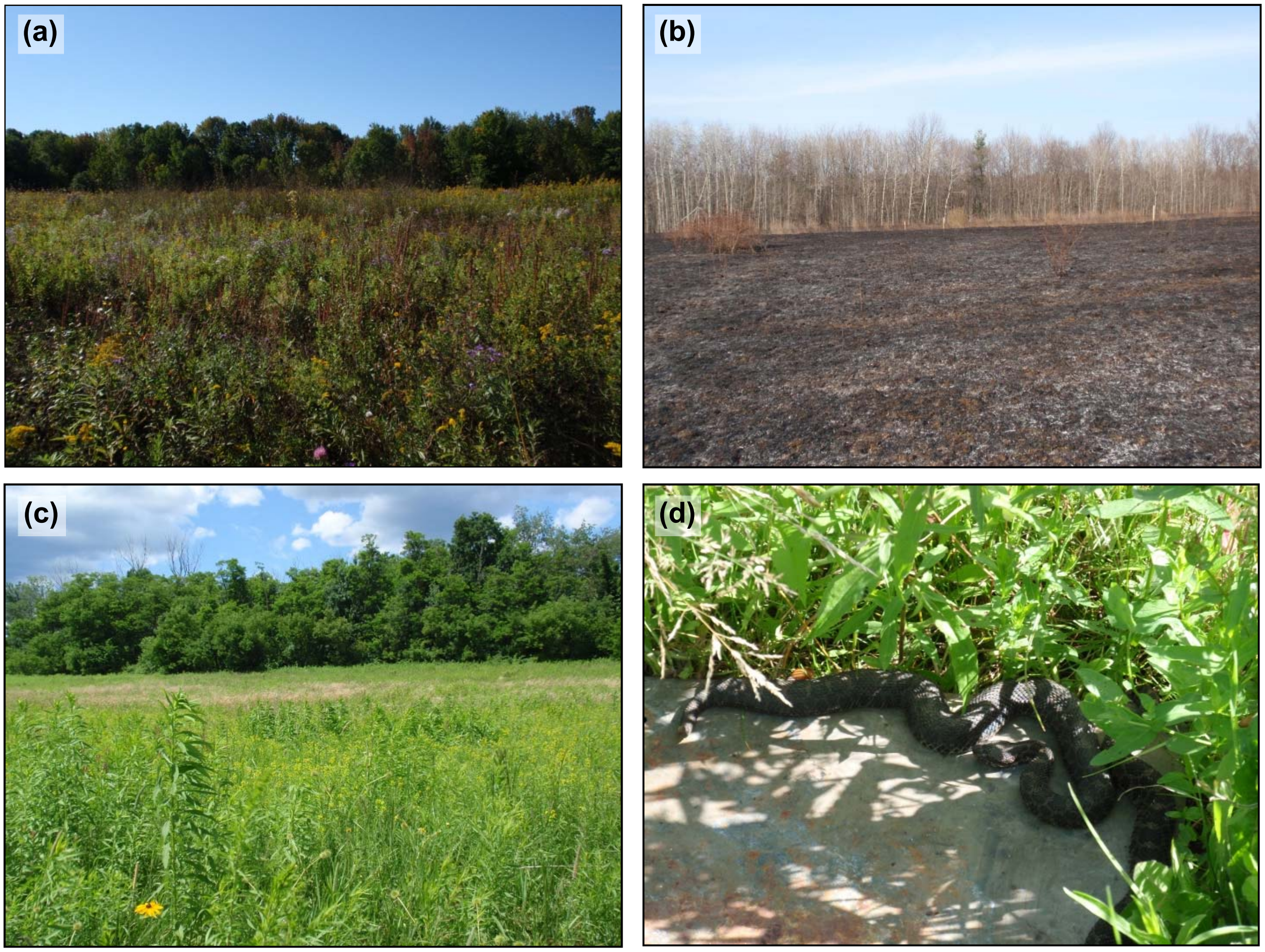

FIGURE 1. Old-field habitat managed for Eastern Massasauga Rattlesnake (*Sistrurus catenatus catenatus*) in Cicero Swamp Wildlife Management Area, New York; a) before the prescribed fire in the Fall 2009, b) immediately following the prescribed fire in early April 2010, and c) later in mid-summer following the prescribed fire. d) an Eastern Massasauga Rattlesnake resting on top of one of the cover boards used for snake surveys. (Photographed by P. Osborne).

RESULTS

Over the course of the study, we detected Eastern Gartersnakes, *Thamnophis sirtalis sirtalis*, (621 detections), Northern Brownsnakes, *Storeria dekayi dekayi*, (143 detections), Eastern Massasauga Rattlesnakes (35 detections), Eastern Milksnakes, *Lampropeltis triangulum triangulum* (nine detections), and Northern Watersnakes, *Nerodia sipedon sipedon* (nine detections). Eastern Massasauga Rattlesnake observations increased considerably after the prescribed fire (Dovčiak et al. 2013); here we focus on examining the responses of the remaining and generally more common (i.e., not endangered) species within the snake assemblage that were not specifically targeted by the experimental management treatment (prescribed fire).

We found that individual species likely vary in their responses to prescribed fire. When comparing detections between the treatments (control, burn) and over time (pre- and post-treatment), detections of Eastern Milksnakes and Northern Brownsnakes appeared to be maintained by the prescribed fire; both species appeared to decline in detections in the control, but remained stable in the old field treated with fire (Fig. 2A, B). Eastern Gartersnakes, the most commonly observed species, showed little response to treatment or over time (albeit detections did appear to decline in controls; Fig. 2C). In contrast, Northern Watersnakes, which were rarely encountered in this system, did not appear to respond to habitat treatment (Fig. 2D). Trends among Eastern Gartersnakes may have masked any treatment effects on some of the less common species when considering overall snake detections (Fig. 2E).

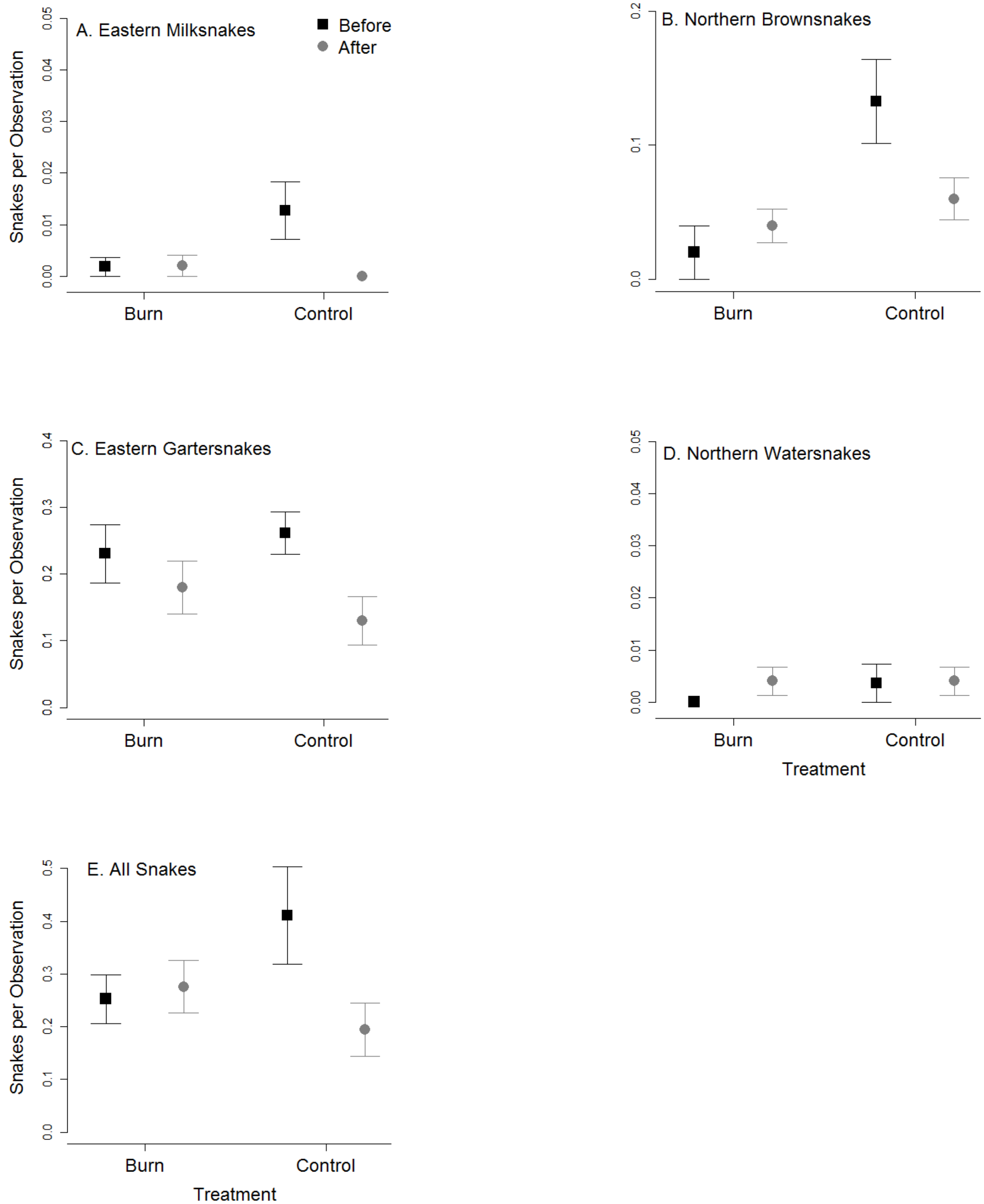

FIGURE 2. Frequency of snakes per cover-board observation in prescribed fire (burn) and control treatments in old field snake habitats in Cicero Swamp Wildlife Management Area, New York before and after the treatments. a) Eastern Milksnakes, *Lampropeltis triangulum triangulum*, b) Northern Brownsnakes, *Storeria dekayi dekayi*, c) Eastern Gartersnakes, *Thamnophis sirtalis sirtalis*, d) Northern Watersnakes, *Nerodia sipedon sipedon*, and e) all snakes pooled together. Values are means ± 1 standard error.

DISCUSSION

In this study, we used standardized sampling techniques to determine how detections of snakes within an old field habitat changed in response to prescribed fire, as compared to a control old field that received no treatment. Our observations suggest that snakes will likely alter their habitat use following prescribed burns; however, we decline to use statistical analyses to explore these trends further because only one field was subject to treatment and it is impossible for us to avoid pseudoreplication (Hurlbert 1984). Our study was designed to determine whether management at our study was likely to influence microhabitat quality. Further studies are required to determine the greater generality of patterns that we observed or the mechanisms behind these patterns.

It is important to consider detectability when using the relative number of encounters to make inferences about reptile response to habitat change (Mazerolle et al. 2007; Driscoll et al. 2012), but in practice it is difficult to incorporate detection probabilities into estimates of abundance for terrestrial snakes because of our limited ability to sample them (Steen 2010; Steen et al. 2012a). Given the brief amount of time between treatment (i.e., prescribed fire) application and snake surveys, we do not suggest our results reflect changes in population size in response to habitat management. However, by maintaining a preferred body temperature, such as through use of high quality microhabitats, snakes are likely to increase their fitness (Huey and Kingsolver 1989) and this change in fitness could eventually result in changes in population size. Long-term monitoring together with mark-recapture techniques (e.g., Lind et al. 2005; Smith et al. 2012, 2013) may generate information regarding whether an increase in the amount of high-quality habitat causes actual population change. Longer-term studies would also allow us to determine how the herbaceous growth stimulated by prescribed fire (Briggs and Knapp 1995; Dovčiak et al. 2013) affects microhabitat quality.

Eastern Massasauga Rattlesnakes responded positively to the prescribed burn in this system (Dovčiak et al. 2013) in ways that may be comparable to the species included in this study. For example, Eastern Milk Snakes are found in a wide variety of habitats in the northeastern United States (Ernst and Ernst 2003) but they likely prefer forest edges and other even more open habitats (Row and Blouin-Demers 2006b). Thermoregulation is an important consideration in Eastern Milksnake habitat selection and behavior (Row and Blouin-Demers 2006a) and the prescribed burn may have created microhabitats representing a preferable thermal environment. The presence of these preferred microhabitats in the burned old field could explain why the number of Eastern Milksnake detections did not decline there as they did in our control field; this may also explain comparable trends observed for the Northern Brownsnake.

In contrast to most of the species considered within this study, Eastern Gartersnake detections did not appear influenced by the burn treatment, reemphasizing that it is inappropriate to make generalizations regarding herpetofaunal response to habitat change (Barrett and Guyer 2008). Because there was no apparent difference in the number of Eastern Gartersnake detections between the burned old field and our control site, our results are consistent with previous work suggesting the species does not select habitat at a large spatial scale (i.e., the landscape, Steen et al. 2012b). We suggest that the use of fire to create early successional habitat is unlikely to have an effect on Eastern Gartersnakes, although the presence of suitable microhabitats will be maintained because of the high habitat heterogeneity.

The apparent trends we observed may also be influenced by changes in the abundance of snake prey items. In general, invertebrate populations likely decline immediately following low-intensity fire (Swengel 2001), but species associated with the system respond positively to the new herbaceous growth in the months following the disturbance (Provencher et al. 2002). However, much of this work relates to arthropods; there is limited information related to the response of soft-bodied invertebrates to disturbance, particularly within our study system, and these organisms likely represent important prey items for the two most commonly detected species in our study (i.e., Northern Brownsnakes and Eastern Gartersnakes; Ernst and Ernst 2003). Eastern Massasauga Rattlesnakes and Eastern Milksnakes on the other hand, prey largely on small mammals (Ernst and Ernst 2003; Weatherhead et al. 2009) and small mammal populations may benefit from both microhabitat variation (Manson et al. 1999) and prescribed burns (Masters et al. 1998). Finally, Eastern Milksnakes are ophiophagous, which suggests they could be responding to the presence of other snakes in the area rather than any feature of the habitat; similarly, the presence of this predatory snake may reduce abundances of sympatric species (e.g., Steen et al. 2014a). Future research may also consider whether sympatric species are competing over prey with the potential to influence their habitat use (e.g., Steen et al. 2014b).

Large and partially decayed wood debris may serve as important refuge sites for small snakes (Hecnar and Hecnar 2011). By experimentally applying cover objects (i.e., cover boards) at sites where none otherwise occurred, we were able to control for the potential influence of cover and focus our experiment on snake response to vegetation changes. Therefore, it is important to emphasize that the amount of woody debris is likely to be reduced after application of prescribed burning (Fahnestock and Agee 1983) and this may negatively affect habitat quality. Perhaps similarly, the addition of cover objects to our study fields may confound our ability to identify how snake habitat quality changes in their absence following the application of prescribed burning.

BACI designs (Green 1979; and modified by subsequent authors) are powerful frameworks for detecting environmental change. Our work suggests BACI experimental design may be important for adequately characterizing snake response to habitat change. Specifically, potential effects of the prescribed burn to Northern Brownsnakes and Eastern Milksnakes may not have been indicated if not for decreasing numbers of the species observed in the control old field between 2006 and 2010. In contrast, if we had not included a control old field, we may have concluded that prescribed burns affected Eastern Gartersnakes due to a decreasing number of detections of this species on treated sites between 2006 and 2010. Overall though, we are cautious not to conclude how the changes in the number of detections we recorded relate to habitat quality. Specifically, more snakes observed under a single coverboard could indicate the surrounding microhabitat was high-quality and attracted snakes. On the other hand, perhaps the surrounding microhabitat was actually low-quality, forcing nearby snakes to take cover under our artificial cover objects. Thus, we conclude only that the treatment (i.e., prescribed burning) is an important influence on snake habitat use.

The prescribed fire in our study system was used to prevent regrowth of woody vegetation and associated microclimatic changes (Dovčiak and Brown 2014) to improve habitat quality for the endangered Eastern Massasauga Rattlesnake (Shoemaker and Gibbs 2010). However, we found that this fire likely influenced habitat quality for additional species of snakes that reside within the same system but are not of immediate conservation concern. The most likely explanation for these observations is that the relatively high microhabitat heterogeneity caused by the prescribed burn (Dovčiak et al. 2013) created or maintained areas that were suitable for thermoregulation, finding prey, and escaping predation. Natural landscapes continue to change in the northeastern United States (Drummond and Loveland 2010); we suggest high habitat heterogeneity (Smith et al. 2013) that includes occasional prescribed fire to maintain or promote early successional patches will help ensure that high quality microhabitats exist for the snake assemblages occurring in old field habitats.

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LITERATURE CITED

Adolph, S.C. 1990. Influence of behavioral thermoregulation on microhabitat use by two *Sceloporus* lizards. Ecology 71:315–327.

Barrett, K., and C. Guyer. 2008. Differential responses of amphibians and reptiles in riparian and stream habitats to land use disturbances in western Georgia, USA. Biological Conservation 141:2290–2300.

Blouin-Demers, G., and P.J. Weatherhead. 2001. Thermal ecology of Black Rat Snakes (*Elaphe obsoleta*) in a thermally challenging environment. Ecology 82:3025–3043.

Briggs, J.M., and A.K. Knapp. 1995. Interannual variability in primary production in tallgrass prairie: climate, soil moisture, topographic position, and fire as determinants of aboveground biomass. American Journal of Botany 82:1024–1030.

Cagle, N.L. 2008. Snake species distributions and temperate grasslands: a case study from the American tallgrass prairie. Biological Conservation 141:744–755.

Chilton, E.S. 2001. The archeology and ethnohistory of the contact period in the northeastern United States. Reviews in Anthropology 29:337–360.

Dessecker, D.R., and D.G. McAuley. 2001. Importance of early successional habitat to Ruffed Grouse and American Woodcock. Wildlife Society Bulletin 29:456–465.

Dovčiak, M., and J. **Brown**. 2014. Secondary edge effects in regenerating forest landscapes: vegetation and microclimate patterns and their implications for management and conservation. *New Forests* 45:733–744. DOI:10.1007/s11056–014–9419–7.

Dovčiak, M., L.E. Frelich, and P.B. Reich. 2005. Pathways in old-field succession to White Pine: seed rain, shade, and climate effects. Ecological Monographs 75:363–378.

Dovčiak, M., P.A. Osborne, D.A. Patrick, and J.P. Gibbs. 2013. Conservation potential of prescribed fire for maintaining habitats and populations of an endangered rattlesnake, *Sistrurus c. catenatus*. Endangered Species Research 22:51–60.

Driscoll, D.A., A.L. Smith, S. Blight, and J. Maindonald. 2012. Reptile responses to fire and the risk of post-disturbance sampling bias. Biodiversity and Conservation 21:1607–1625.

Drummond, M.A., and T.R. Loveland. 2010. Land-use pressure and a transition to forest-cover loss in the eastern United States. BioScience 60:286–298.

Elzer, A.L., D.A. Pike, J.K. Webb, K. Hammill, R.A. Bradstock, and R. Shine. 2013. Forest-fire regimes affect thermoregulatory opportunities for terrestrial ectotherms. Austral Ecology 38:190–198.

Ernst, C.H., and E.M. Ernst. 2003. Snakes of the United States and Canada. Smithsonian Books, Washington, D.C., USA.

Fahnestock, G.R., and J.K. Agee. 1983. Biomass consumption and smoke production by prehistoric and modern forest fires in western Washington. Journal of Forestry 81:653–657.

Gibbons, J.W., D.E. Scott, T.J. Ryan, K.A. Buhlmann, T.D. Tuberville, B.S. Metts, J.L. Greene, T. Mills, Y. Leiden, S. Poppy, and C.T. Winne. 2000. The global decline of reptiles, déjà vu amphibians. BioScience 50:653–666.

Godley, J.S. 2012. Sampling with artificial cover. Pp. 249–255 *in* Reptile Biodiversity: Standard Methods for Inventory and Monitoring. McDiarmid, R.W., M.S. Foster, C. Guyer, J.W. Gibbons, and N. Chernoff (Eds.). University of California Press, Berkeley, California, USA.

Green, R.H. 1979. Sampling Design and Statistical Methods for Environmental Biologists. Wiley, New York, New York, USA.

Hecnar, S.J., and D.R. Hecnar. 2011. Microhabitat selection of woody debris by Dekay's Brownsnake (*Storeria dekayi*) in a dune habitat in Ontario, Canada. Journal of Herpetology 45:478–483.

Huey, R.B., and J.G. Kingsolver. 1989. Evolution of thermal sensitivity of ectotherm performance. Trends in Ecology and Evolution 4:131–135.

Hurlbert, S.H. 1984. Pseudoreplication and the design of ecological field experiments. Ecological Monographs 54:187–211.

Keller, W.L., and E.J. Heske. 2000. Habitat use by three species of snakes at the Middle Fork Fish and Wildlife Area, Illinois. Journal of Herpetology 34:558–564.

Kjoss, V.A., and J.A. Litvaitis. 2001. Community structure of snakes in a human-dominated landscape. Biological Conservation 98:285–292.

LeBlanc, C.M., and D.J. Leopold. 1992. Demography and age structure of a central New York shrub-carr 94 years after fire. Bulletin of the Torrey Botanical Club 119:50–64.

Lind, A.J., H.H. Welsh, and D.A. Tallmon. 2005. Garter Snake population dynamics from a 16-year study: considerations for ecological monitoring. Ecological Applications 15:294–303.

Litvaitis, J.A. 1993. Response of early successional vertebrates to historic changes in land use. Conservation Biology 7:866–873.

Manson, R.H., R.S. Ostfeld, and C.D. Canham. 1999. Responses of a small mammal community to heterogeneity along forest old-field edges. Landscape Ecology 14:355–367.

Masters, R.E., R.L. Lochmiller, S.T. McMurry, and G.A. Bukenhofer. 1998. Small mammal response to pine-grassland restoration for Red-cockaded Woodpeckers. Wildlife Society Bulletin 26:148–158.

Mazerolle, M.J., L.L. Bailey, W.L. Kendall, J.A. Royle, S.J. Converse, and J.D. Nichols. 2007. Making great leaps forward: accounting for detectability in herpetological field studies. Journal of Herpetology 41:672–689.

Melville, J., and J.A. Schulte, II. 2001. Correlates of active body temperatures and microhabitat in nine species of central Australian agamid lizards. Austral Ecology 26:660–669.

Nowacki, G.J., and M.D. Abrams. 2008. The demise of fire and "mesophication" of forests in the eastern United States. BioScience 58:123–128.

Noss, R.F. 1988. The Longleaf Pine landscape of the southeast: almost gone and almost forgotten. Endangered Species Update 5:1–8.

Patrick, D.A., and J.P. Gibbs. 2009. Snake occurrences in grassland associated with road versus forest edge. Journal of Herpetology 43:716–720.

Perry, R.W., D.C. Rudolph, and R.E. Thill. 2009. Reptile and amphibian responses to restoration of fire-maintained pine woodlands. Restoration Ecology 17:917–927.

Provencher, L., K.E.M. Galley, A.R. Litt, D.R. Gordon, L.A. Brennan, G.W. Tanner, and J.L. Hardesty. 2002. Fire, herbicide, and chainsaw felling effects on arthropods in fire-suppressed longleaf pine sandhills at Eglin Air Force Base, Florida. Pp. 24–33 *in* The Role of Fire for Nongame Wildlife Management and Community Restoration: Traditional Uses and New Directions. Ford, W.M., K.R. Russell, and C.E. Moorman (Eds.). General Technical Report NE-288, U.S. Forest Service, Northeastern Research Station.

Reading, C.J., L.M. Luiselli, G.C. Akani, X. Bonnet, G. Amori, J.M. Ballouard, E. Filippi, G. Naulleau, D. Pearson, and L. Rugiero. 2010. Are snake populations in widespread decline? Biology Letters 23:777–780.

Row, J.R., and G. Blouin-Demers. 2006a. Thermal quality influences effectiveness of thermoregulation, habitat use, and behaviour in Milk Snakes. Oecologia 148:1–11.

Row, J.R., and G. Blouin-Demers. 2006b. Thermal quality influences habitat selection at multiple spatial scales in Milksnakes. Ecoscience 13:443–450.

Shoemaker, K.T., and J.P. Gibbs. 2010. Evaluating basking habitat deficiency in the threatened Eastern Massasauga Rattlesnake. Journal of Wildlife Management 74:504–513.

Shumway, D.L, M.D. Abrams, and C.M. Ruffner. 2001. A 400-year history of fire and oak recruitment in an old-growth oak forest in western Maryland, U.S.A. Canadian Journal of Forest Research 31:1437–1443.

Smith, A.L., C.M. Bull, and D.A. Driscoll. 2012. Post-fire succession affects abundance and survival but not detectability in a Knob-tailed Gecko. Biological Conservation 145:139–147.

Smith, A.L., C.M. Bull, and D.A. Driscoll. 2013. Successional specialization in reptile community cautions against widespread planned burning and complete fire suppression. Journal of Applied Ecology 50:1178–1186.

Steen, D.A. 2010. Snakes in the grass: secretive natural histories defy both conventional and progressive statistics. Herpetological Conservation and Biology 5:183–188.

Steen, D.A., C. Guyer, and L.L. Smith. 2012a. A case study of relative abundance in snakes. Pages 287–294 *in* Reptile Biodiversity: Standard Methods for Inventory and Monitoring. McDiarmid, R.W., M.S. Foster, C. Guyer, J.W. Gibbons, and N. Chernoff (Eds.). University of California Press, Berkeley, California, USA.

Steen, D.A., C.J.W. McClure, J.C. Brock, D.C. Rudolph, J.B. Pierce, J.R. Lee, W.J. Humphries, B.B. Gregory, W.B. Sutton, L.L. Smith, et al. 2012b. Landscape-level influences of terrestrial snake occupancy within the southeastern United States. Ecological Applications 22:1084–1097.

Steen, D.A., L.L. Smith, G. Morris, L.M. Conner, A.R. Litt, S. Pokswinski, and C. Guyer. 2013a. Response of *Aspidoscelis sexlineata* (Six-lined Racerunner) to habitat restoration in fire-suppressed *Pinus palustris* (Longleaf Pine) sandhills. Restoration Ecology 21:457–463

Steen, D.A., L.L. Smith, L.M. Conner, A.R. Litt, L. Provencher, J.K. Hiers, S. Pokswinski, and C. Guyer. 2013b. Reptile assemblage response to restoration of fire-suppressed longleaf pine sandhills. Ecological Applications 23:148–158.

Steen, D.A., C.J.W. McClure, W.B. Sutton, D.C. Rudolph, J.B. Pierce, J.R. Lee, L.L. Smith, B.B. Gregory, D.L. Baxley, D.J. Stevenson, and C. Guyer. 2014a. Copperheads are abundant where kingsnakes are not: relationships between the abundances of a predator and one of their prey. Herpetologica 70:69–76.

Steen, D.A., C.J.W. McClure, J.C. Brock, D.C. Rudolph, J.B. Pierce, J.R. Lee, W.J. Humphries, B.B. Gregory, W.B. Sutton, L.L. Smith, et al. 2014b. Snake co-occurrence patterns are best explained by habitat and hypothesized effects of interspecific interactions. Journal of Animal Ecology 83:286–295

Sutton, W.B., Y. Wang, and C.J. Schweitzer. 2013. Amphibian and reptile responses to thinning and prescribed burning in mixed pine-hardwood forests of northwestern Alabama, USA. Forest Ecology and Management 295:213–227.

Sutton, W.B., Y. Wang, C.J. Schweitzer, and D.A. Steen. 2014. Lizard microhabitat and microclimate relationships in southeastern pine-hardwood forests managed with prescribed burning and thinning. Forest Science 60:180–190.

Swengel, A.B. 2001. A literature review of insect responses to fire, compared to other conservation managements of open habitat. Biodiversity and Conservation 10:1141–1169.

Thompson, F.R.I., and R.M. DeGraaf. 2001. Conservation approaches for woody, early successional communities in the eastern United States. Wildlife Society Bulletin 29:483–494.

USFWS. 2012. Endangered and threatened wildlife and plants; Review of native species that are candidates for listing as endangered or threatened; Annual notice of findings on resubmitted petitions; Annual description of progress on listing actions. Federal Register, 471 Vol. 77, No. 225, Page 70017. U.S. Fish and Wildlife Service, Department of Interior.

Van Lear, D.H., and R.F. Harlow. 2000. Fire in the eastern United States: influence on wildlife habitat. Pages 2–10 *in* The Role of Fire in Nongame Wildlife Management and Community Restoration: Traditional Uses and New Directions. Ford, W.M., K.R. Russell, and C.E. Moorman (Eds.). USDA Forest Service Northeastern Research Station, General Technical Report NE-288.

Van Lear, D.H., W.D. Carroll, P.R. Kapeluck, and R. Johnson. 2005. History and restoration of the Longleaf Pine-Grassland ecosystem: implications for species at risk. Forest Ecology and Management 211:150–165.

Weatherhead, P.J., J.M. Knox, D.S. Harvey, D. Wynn, J. Chiucchi, and H.L. Gibbs. 2009. Diet of *Sistrurus catenatus* in Ontario and Ohio: effects of body size and habitat. Journal of Herpetology 43:693–697.

Webb, J.K., R. Shine, and R.M. Pringle. 2005. Canopy removal restores habitat quality for an endangered snake in a fire suppressed landscape. Copeia 2005:894–900.

Wilgers, D.J., and E.A. Horne. 2006. Effects of different burn regimes on tallgrass prairie herpetofaunal species diversity and community composition in the Flint Hills, Kansas. Journal of Herpetology 40:73–84.

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