Observations of Snakes and Game Birds in a Managed Pine Barren in Massachusetts

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Abstract - *Pinus rigida* (Pitch Pine)–*Quercus ilicifolia* (Scrub Oak) barrens require active management to maintain, but the effects of forest management on snakes and game birds is poorly understood. We conducted vegetation surveys and examined incidental encounter data of a variety of snake and game bird species on a managed pine barren in Montague, MA, from 2008 to 2018. We recorded 73 observations, including 44 *Coluber constrictor constrictor* (Northern Black Racer) and 7 *Meleagris gallopavo* (Wild Turkey) nests. All of our observations were in managed habitats (Scrub Oak, treated Pitch Pine, and powerline corridors) which had low (<30%) tree canopy cover. Observed densities of Northern Black Racers did not significantly vary among these open-canopy habitats, or with time since treatment between 2 to 8 years since initial harvest in treated Pitch Pine. We did not conduct extensive surveys in unmanaged, closed-canopy Pitch Pine forests; thus, we were unable to determine the relative use by racers and game birds of unmanaged versus managed habitats. Nevertheless, snakes and game birds were using and nesting in the managed habitats at least to some extent. Our findings on racers and game birds from this study are preliminary, but combined with results from other studies, they suggest that ecosystem management in pine barrens can benefit snakes and game birds, along with a wide variety of other taxa.

Introduction

Pinus rigida Mill. (Pitch Pine)–*Quercus ilicifolia* Wangenh. (Scrub Oak) (PPSO) barrens are a globally threatened ecosystem in the northeastern United States (Motzkin et al. 1999, Noss and Peters 1995). Pitch Pine–Scrub Oak barren ecosystems are found on sandy or rocky soils and depend on natural or anthropogenic disturbances (Bried et al. 2014, Nowacki and Abrams 2008). The suppression of natural disturbances, such as wildfire, and the spread of development have caused a decline in the quality, extent, and continuity of pine barrens habitat (Forman and Boerner 1981, Gifford et al. 2010). Given the decline of natural disturbances in the region, there is a need to restore and maintain these at-risk ecological communities using forest management techniques such as prescribed fire, herbicide, canopy removal, and other mechanical treatments (Jordan et al. 2003, Motzkin et al. 2002, Schlossberg and King 2015).

Ecological restoration and forest management is already underway in pine barrens across the Northeast (Ryan 2012). Management plans may partially focus on specific Species of Greatest Conservation Need, such as the federally endangered

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Lycaeides melissa samuelis Nabokov (Karner Blue Butterfly; Albany Pine Bush Preserve Commission 2017). However, management plans are often less targeted on a single species and may attempt to broadly restore the entire pine barrens ecosystem (Albany Pine Bush Preserve Commission 2017, Hawthorne 2017, Lougee 2015). Forest management in southern PPSO barrens is also focused on mitigating widespread tree mortality due to the recent climate-induced, northward expansion of *Dendroctonus frontalis* Zimmermann (Southern Pine Beetle; Dodds et al. 2018, Lesk et al. 2017).

Studies have examined the effects of management on the unique wildlife communities found in PPSO barrens, including research on invertebrates, birds, and herpetofauna (Akresh and King 2016, Barber 2015, Grand et al. 2004, Pascale and Thiet 2016, Stewart and Rossi 1981). In Massachusetts, King et al. (2011) found that tree harvests in pine barrens create habitat for many shrubland passerine bird species that are declining throughout the region (King and Schlossberg 2014). Studies have also been conducted on certain species of snakes within pine barrens, such as *Pituophis m. melanoleucus* (Daudin) (Northern Pinesnake) (Zappalorti et al. 2015) and *Heterodon platirhinos* Latreille (Eastern Hognose Snake) (Buchanan et al. 2017). A radio-tracking study on Eastern Hognose Snakes found that these snakes select to use managed, open-canopy shrubland habitat and avoid untreated, closed-canopy forests within pine barrens, and snakes using treated areas had smaller home ranges (Akresh et al. 2017).

Although we have recently improved our knowledge of some bird and snake species in managed PPSO barrens, the effects of forest management on other species are not well understood. For example, *Coluber constrictor constrictor* L. (Northern Black Racer) is a large predatory snake that has been previously found in PPSO barrens (Stewart and Rossi 1981), but their response to disturbance in this ecosystem is unknown. The Northern Black Racer has experienced population declines in the north part of its range (Maine Department of Inland Fisheries and Wildlife 2003, New Hampshire Department of Fish and Game 2015), and further understanding of this species' habitat needs could help to prevent or mitigate its decline. Occupancy and nesting of game birds such as *Meleagris gallopavo* L. (Wild Turkey) and *Scolopax minor* Gmelin (American Woodcock) are also relatively understudied in northeastern pine barrens, despite being valued by the hunting community (Hazel et al. 1990). Previous research modelling landscape dynamics in midwestern pine barrens have shown forest management can impact *Tympanuchus phasianellus* (L.) (Sharp-tailed Grouse) populations (Akçakaya et al. 2004, Radeloff et al. 2006).

To help fill in knowledge gaps of wildlife usage of managed northeastern pine barrens, we herein present information on observations of snake and game birds collected while conducting a broader program of wildlife research in a Massachusetts inland pine barren. The objective of our study was to demonstrate how ecosystem management in pine barrens can provide habitat for multiple, non-target taxa. We report nesting activity and other useful characteristics of our observations in relation to canopy harvests and forest management (e.g., years since treatment [YST], distance to edge), although further standardized research is needed for in-depth statistical analyses on habitat selection. Nonetheless, our preliminary findings may help better comprehend snake and game birds' occupancy in managed pine barrens and assist in a more wholistic understanding of the effects of pine barrens ecosystem management on wildlife.

Field-Site Description

We collected data in the Montague Plains Wildlife Management Area (MPWMA), in Montague, MA (42.563°N, 72.533°W). The ~600 ha site is located in the Connecticut River Valley, and is characterized by Pitch Pine stands, Scrub Oak barrens, powerline corridors, and deciduous forest (Fig. 1; King et al. 2011, Motzkin et al. 1996). Since 2000, the Massachusetts Division of Fisheries and Wildlife has conducted management to reduce wildfire risk and promote PPSO barren communities, including host plants for state-listed Lepidoptera species (Hawthorne 2017). In 2000, the MPWMA consisted of mostly closed-canopy Pitch Pine forest, but extensive tree harvesting occurred during 2004–2008 and 2014–2017, and almost all stands have now been harvested to 10–50% canopy cover. Additional management activities included understory mowing, prescribed burning, and herbicide applications to maintain a shrubland habitat (MassWildlife 2019). Surrounding land features include agricultural fields, closed-canopy forests, urban development in the towns of Lake Pleasant and Millers Falls, and 2 water bodies: Lake Pleasant and Green Pond.

The 3 main habitat types we surveyed within the MPWMA were Scrub Oak barrens, treated Pitch Pine stands, and powerline corridors. Scrub Oak barrens were dominated by Scrub Oak and some *Quercus prinoides* Willd. (Dwarf Chinquapin Oak) with some *Vaccinium* spp. (lowbush blueberry) in the ground cover (King et al. 2011). Relatively small areas (<5 ha) of the Scrub Oak barrens were mowed or burned during a given year, but management occurred throughout 2000–2018 (Akresh et al. 2015). Treated Pitch Pine stands had a tree canopy dominated by Pitch Pine, with an understory of Scrub Oaks and other tree saplings, and *Vaccinium* spp., *Carex pensylvanica* Lam. (Pennsylvania Sedge), and various ferns and forbs (Akresh 2012). The understory vegetation density varied among treated Pitch Pine plots and also with YST; more recently harvested, mowed, or burned plots had shorter vegetation and a less dense understory structure between 1–3 m in height compared to older plots (Akresh et al. 2015). For the plots used in our analyses (see below), 1 treated Pitch Pine plot was initially harvested in 2004, another in 2006, and 2 in 2007 (Akresh et al. 2015). Extensive Pitch Pine harvests also occurred in 2014–2017, including in areas in the center of the site, where strips of closed-canopy forest were also retained to assist with future reintroduction of Lepidoptera species (Hawthorne 2017). Powerline corridors had no trees within them, were dominated by *Spiraea alba* Du Roi (White Meadowsweet) and other short shrubs, forbs, and graminoids (Akresh 2012). Powerline corridors were treated with herbicide applications every 4–5 years.

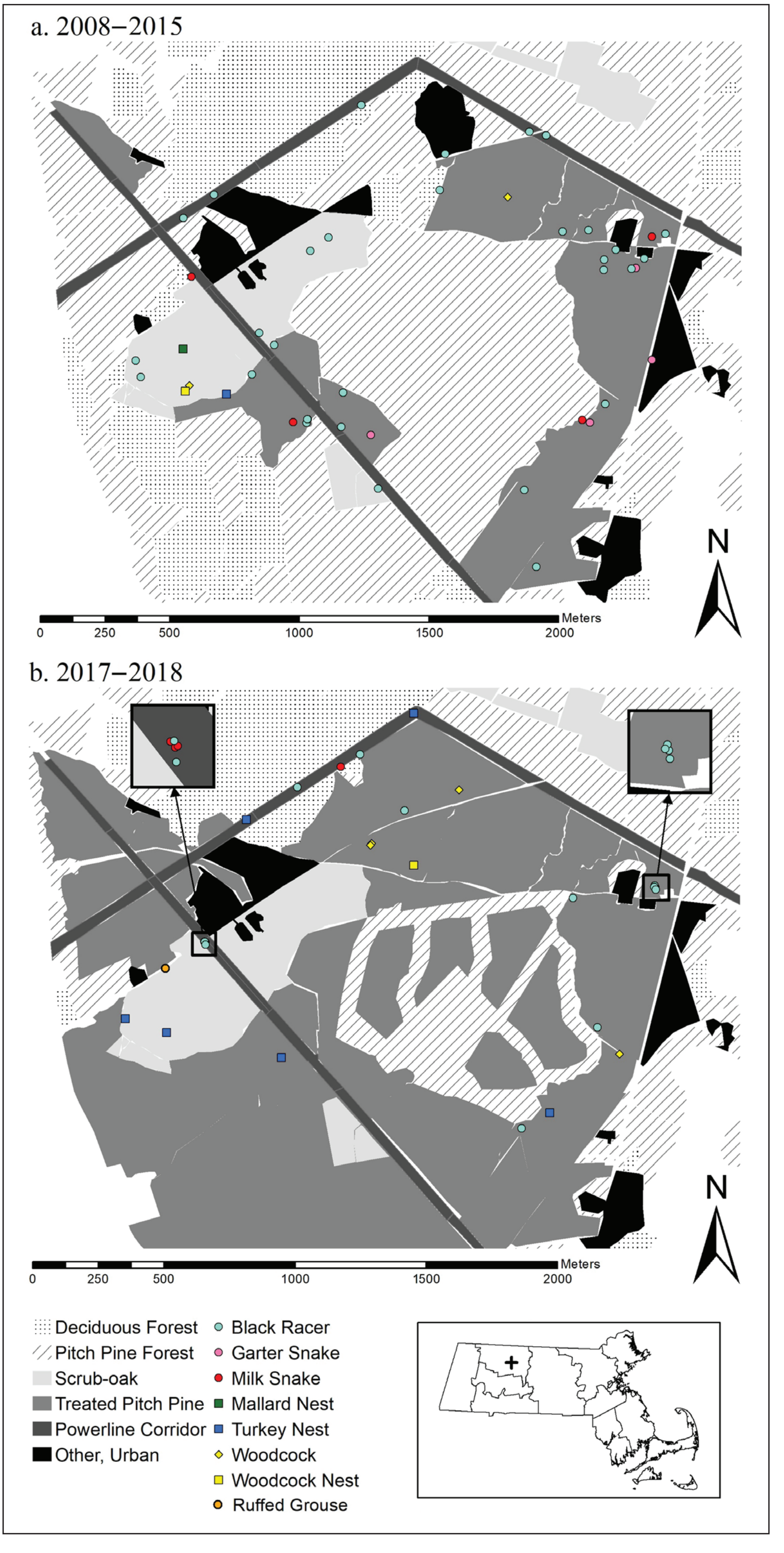

Figure 1. Vegetation cover types and observations of game birds and snakes in a managed pine barren in Montague, MA, during (a) 2008–2015 and (b) 2017–2018. Extensive tree harvesting occurred in 2014–2017.

Methods

In 2009 and 2010, we measured vegetation structure among the 3 managed habitat types (Scrub Oak barrens, treated Pitch Pine stands, and powerline corridors) using point-intercept vegetation surveys (King and DeGraaf 2000, Chandler et al. 2009). As part of a larger study, we chose vegetation sampling points within *Setophaga discolor* (Vieillot) (Prairie Warbler) territories. We first selected 20 equally spaced locations along 89 transects; each transect spanned the full length of a Prairie Warbler territory and transects varied from 60 to 160 m long (Akresh 2012, Akresh et al. 2015). At each location on each transect, we then chose a random direction perpendicular to the transect and paced out a random distance to reach a vegetation sampling point, using a random number table to choose a distance between 0 and half the width of the territory (up to 20–50 m from the transect line). At each sampling point, we recorded overstory canopy cover, overstory height, understory height, and understory vegetation density. We defined overstory as vegetation taller than 3 m, and understory as vegetation shorter than 3 m. We then combined the 20 vegetation sampling points per territory. We measured overstory canopy cover as the proportion of the 20 sampling points in which overstory vegetation was present (i.e., overstory was visually observed directly above a 3-m pole). Overstory and understory heights were recorded at each 3-m pole sampling point and then averaged across the 20 sample points. We measured vegetation density as the number of times vegetation contacted the 3-m density pole within 0.5-m height intervals, and then averaged the values over the 20 sampling points per survey.

Given that prairie warbler territories encompassed almost the entire area of the 3 habitat types surveyed at the site in 2009–2010, we believe this vegetation data adequately documented the vegetation structure among habitat types, despite not being directly related to snakes or game birds. We examined the following vegetation metrics among the 3 habitat types in statistical analyses: understory vegetation density at six 0.5-m intervals, understory height, overstory height, and overstory canopy cover. Using the R statistical program version 4.0.3 (R Core Team 2020), we conducted non-parametric Kruskal–Wallis tests to analyze among-habitat differences separately for each vegetation variable, as some of the variables did not fit normal distributions. We also conducted post-hoc Dunn's tests to examine pairwise comparisons (Dunn 1961) and adjusted pairwise *P*-values using the Bonferroni–Holm method (Holm 1979).

Incidental data on snakes and game birds were collected over an 11-year period (2008–2018), primarily in the 2008–2012 and 2017–2018 field seasons. We surveyed the site between late April and early August. In 2009–2012, we visited 7 open-canopy, treated plots in the study site approximately every 2–4 days and recorded the snake and game bird observations while we were mapping prairie warbler territories and nest searching (Akresh et al. 2015, 2019, 2021a). We extensively surveyed 4 plots in treated Pitch Pine (15.1, 22.5, 7.8, and 10.8 ha), 2 in powerline corridors (4.2, 5.7 ha), and 1 in Scrub Oak (28.7 ha) in each year between 2009 and 2012. Survey effort and time spent within these 7 plots was fairly standardized across plots in 2009–2012. We also surveyed the site every 2–4 days in 2013, approximately every week in 2008 and 2014–2017, and occasionally (~15 visits throughout the study site) in 2018. Additionally, in 2017–2018 we checked 2 cover boards in the site several times per season. During the latter years, the survey effort was less standardized across plots, and we also visited additional treated Pitch Pine areas that were newly created; we therefore examined observations from 2008–2018 descriptively and only examined 2009–2012 in our statistical analyses (below).

We recorded observations of focal species during 2008–2012 and 2017–2018, but we failed to record many observations of snakes or game birds between 2013 and 2016, despite detecting focal species in the field in these years. We did not include incidental observations of hognose snakes in this study, as these observations were already examined in Akresh et al. (2017). For almost all observations, we recorded the date, species, habitat type, and GPS location. We primarily surveyed open-canopy habitats; very little time was spent surveying within closed-canopy forests.

We obtained geographic information system (GIS) layers of habitat types and management treatments in the study site (MassWildlife 2019). Using field records, the treatment layers, and aerial imagery, we classified the habitat type of each occurrence as either Scrub Oak, treated Pitch Pine, or powerline corridor. We manually created GIS layers for roads and fire breaks, as well as for closed-canopy forest versus open-canopy shrubland edges (Akresh and King 2016, Akresh et al. 2017). We then calculated the distance from each encounter to the nearest road/fire break, and forest edge, in ArcGIS 10.6 (ESRI 2018).

We used the Northern Black Racer data from 2009–2012 to conduct a generalized linear mixed model (GLMM) examining the effect of habitat type on abundance of that species. We fit the response count data, the number of racers seen per plot in a given year, to a Poisson distribution. We included an offset in the model, the natural log of the surveyed plot area, to account for the size of the plots in our analysis (Akresh et al. 2021b, Zuur et al. 2009). We accounted for repeated surveys of the same plots over multiple years by including a random effect of plot, using the 'glmmTMB' package (Brooks et al. 2017). We conducted post-hoc Tukey's tests between habitat types using the 'multcomp' package (Hothorn et al. 2008). Means and standard errors were presented.

Examining just treated Pitch Pine plots between 2009 and 2012, we also conducted an analysis on the effect of time since treatment on abundance of Northern Black Racers. Using treatment data, we identified the number of years since the initial canopy removal in each treated Pitch Pine plot per year. As in Akresh et al. (2015), we chose to focus just on treated Pitch Pine plots when examining time since treatment, because treatment patches within Scrub Oak and powerline corridors were small and difficult to quantify and match with our survey effort. We again conducted a GLMM with the response as the number of Northern Black Racers seen in a plot, per year, fit to a Poisson distribution, with the predictor as the time since treatment in the plot, and we included an offset of the log of plot size and a random effect of plot. The samples sizes for other snake species and game birds observed in 2009–2012 were not large enough to analyze.

Results

The 3 habitat types we surveyed varied significantly in their vegetation structure, height, and canopy cover (Table 1). Scrub Oak barrens had dense understory vegetation with very low (<10%) tree canopy cover. Treated Pitch Pine and power line corridors had less understory vegetation between 1 and 2.5 m compared to Scrub Oak barrens, and had slightly more tree canopy cover (surveys included some trees on the edge of the powerline corridors).

We recorded a total of 73 encounters of focal snake and game-bird species between 2008 and 2018. We encountered focal species primarily in May (56% of observations) and June (29% of observations), with the remainder of detections in late April, July, and August.

We recorded separate observations of 44 Northern Black Racers, 8 *Lampropeltis triangulum triangulum* (Lacépède) (Eastern Milksnake), and 4 *Thamnophis sirtalis* (L.) (Common Garter Snake) using open canopy, managed habitats. Snakes were seen 0–156 m (median = 13 m) from roads or fire breaks and 1–200 m (median = 60 m) from forest edges. Snakes were found on the ground in dense and open understory vegetation, on or near dirt roads, and under or on anthropogenic and natural cover objects (Fig. 2). One Northern Black Racer was observed 1 m above ground in Scrub Oak vegetation. The 2 dense clusters of snake sightings in 2017–2018 were under cover boards (1 on the eastern side of the study site, and 1 on the western side; Fig. 1).

We observed 20 Northern Black Racers in 7 focal plots during 2009–2012. Although there was some among-habitat variation in the observed mean density of the snakes (Table 2), this did not significantly differ among the 3 habitat types (the 3 Tukey's pairwise comparisons were all $P > 0.05$). Examining 4 treated Pitch

Table 1. Vegetation characteristics from point-intercept vegetation surveys ($n = 89$) in 3 habitat types in the study site during 2009–2010. Values shown represent per-survey means averaged again across the surveys in each habitat type, with standard errors in parentheses. χ^2 statistics and P-values are shown from Kruskal–Wallis tests. Letter superscripts that are different denote statistically significant pairwise comparisons ($P < 0.05$), from Bonferroni-Holm adjusted, post-hoc Dunn's tests.

	Scrub Oak	Powerline corridor	Treated Pitch Pine	χ^2	P
Density 0.00–0.50 m	3.51 (0.27)^A	4.15 (0.2)^A	3.76 (0.21)^A	5.6	0.060
Density 0.51–1.00 m	2.63 (0.24)^A	1.79 (0.2)^B	1.53 (0.13)^B	14.7	<0.001
Density 1.01–1.50 m	1.98 (0.19)^A	0.64 (0.1)^B	0.63 (0.06)^B	27.1	<0.001
Density 1.51–2.00 m	1.15 (0.17)^A	0.35 (0.1)^B	0.41 (0.06)^B	20.0	<0.001
Density 2.01–2.50 m	0.41 (0.07)^A	0.19 (0.07)^B	0.13 (0.03)^B	13.4	0.001
Density 2.51–3.00 m	0.07 (0.03)^A	0.36 (0.12)^B	0.09 (0.03)^A	9.4	0.009
Understory height (m)	1.39 (0.05)^A	0.78 (0.03)^B	0.82 (0.04)^B	33.8	<0.001
Overstory height (m)	8.44 (0.78)^A	12.77 (1.17)^B	14.41 (0.71)^B	17.4	<0.001
Overstory canopy cover (%)	7.19 (1.2)^A	18.13 (2.87)^B	18.14 (1.41)^B	14.7	<0.001

Pine plots in 2009–2012 when they were between 2–8 years since harvest treatment (Table 2), observed densities of Northern Black Racers were not significantly influenced by time since treatment ($n = 16$, $z = 1.1$, $P = 0.28$).

We observed 10 game bird nests (7 turkey, 2 woodcock, and 1 *Anas platyrhynchos* L. (Mallard), and 7 additional game birds (6 American Woodcock, 1 *Bonasa umbellus* (L.) [Ruffed Grouse]) in open canopy habitats (Fig. 1). Game birds and

Figure 2. (a) A camouflaged American Woodcock sitting on its nest within dense Scrub Oak habitat. (b) A separate sighting of an American Woodcock nestling. (c) A large Northern Black Racer observed on downed woody debris. (d) an Eastern Milksnake and Eastern Hognose Snake observed together underneath a cover object (metal sheet).

Table 2. The number of individuals observed, the total area surveyed summed across years, and the observed mean density of Northern Black Racers per plot and year (SE in parentheses) among habitat types within 7 plots in 2009–2012. Values also are presented among 2–8 years since treatment (YST) categories within 4 treated Pitch Pine (TPP) plots. Only 1 plot each was surveyed with a YST of 7 and 8, and therefore no SE was presented for those mean density values.

	Racers observed	Total area surveyed (ha)	Racer density per plot and year (individuals/ha)
Treated Pitch Pine (TPP)	14	220	0.06 (0.01)
Scrub Oak	2	115	0.02 (0.01)
Power ine corridor	4	39	0.10 (0.04)
TPP YST 2	1	38	0.03 (0.03)
TPP YST 3	2	45	0.04 (0.04)
TPP YST 4	4	45	0.07 (0.04)
TPP YST 5	4	54	0.06 (0.04)
TPP YST 6	1	17	0.05 (0.05)
TPP YST 7	1	11	0.09 (NA)
TPP YST 8	1	10	0.10 (NA)

their nests were seen 0–176 m (median = 24 m) from roads or fire breaks, and 10–215 m (median = 98 m) from forest edges. Game bird nests were often found in

Figure 3. (a) A powerline corridor where we found several Wild Turkey nests; note the dense understory and open-canopy. (b) A turkey nest, hidden underneath the vegetation. (c) the same nest site shown in (b) with a closer view of the eggs.

dense, shrubby vegetation and were well concealed (Figs. 2, 3). Roosting woodcock and their nests were often observed near stands of *Populus tremuloides* Michx. (Quaking Aspen) saplings.

Discussion

Although we only surveyed open-canopy, treated areas within the study site and we were unable to determine snake and game bird use of closed-canopy forest, the observed species were using managed areas at least to some extent. In 2017 and 2018, most of the site consisted of open-canopy stands, and we suspect that the snakes, especially those observed far from unmanaged closed-canopy stands, were not moving through these open areas but instead were residing in them as part of their core home ranges, as we have found previously for Eastern Hognose Snakes (Akresh et al. 2017). Additionally, game birds were not solely traversing through the managed areas as evidenced by our observations of multiple game-bird nests in these open-canopy habitats.

Snakes were likely using the managed, open-canopy habitats, which have dense understory vegetation, because these areas provide food resources, cover from predators, and higher temperatures compared to the closed-canopy, untreated stands (Gregory et al. 1987, Halstead et al. 2009). Thermoregulatory benefits of open-canopy habitat are particularly important for a wide variety of snake species residing in temperate areas at the northern edge of these species' ranges (Blouin-Demers and Weatherhead 2001, Clifford et al. 2020, Cunnington and Cebek 2005, Diaz and Blouin-Demers 2018, Peet-Pare´ and Blouin-Demers 2012). For instance, Row and Blouin-Demers (2006) found that Milksnakes prefer high-quality thermal habitats such as fields and rocky outcrops in Ontario, Canada. Carfagno and Weatherhead (2006) observed racers selecting forest edges and avoiding the interior of closed-canopy forest in Illinois. Throughout their range, racers appear to prefer open-canopy, shrubby areas, including those that have been periodically managed by fire (Howey et al. 2016, Johnson 2019, Plummer and Congdon 1994).

For Northern Black Racers in 2009–2012, we did not find significant variation in recorded density among open-canopy habitat types, or between 2–8 years since treatment in treated Pitch Pine plots. Our results are preliminary and further radio-tracking is needed to fully determine habitat preferences and use for this species. We did not survey treated Pitch Pine plots 0–1 years since treatment in 2009–2012, so these plot ages were not included in our analysis of Northern Black Racer data. However, previous studies at our site have found that the lack of vegetation cover immediately after intensive management often does not provide bird or snake habitat (Akresh and King 2016; Akresh et al. 2015, 2017), and managers may want to consider fire-return or mowing intervals greater than 1–2 years in pine barren shrublands to provide time for the vegetation to regrow, and to allow for food and cover resources to renew (Wood et al. 2019).

For game birds, we detected Wild Turkey, American Woodcock, and Ruffed Grouse adults, and turkey and woodcock nests, in the 3 managed habitats: Scrub Oak barrens, treated Pitch Pine, and powerline corridors. Ruffed Grouse has been previously observed in several pine barrens (Beachy and Robinson 2008, Cave et al. 2021, Grand and Cushman 2003, King et al. 2011), as have Wild Turkey (Cave et al. 2021, Devlin 1997) and American Woodcock (Gifford et al. 2010, Hudgins et al. 1985, Stone 1894). Although few published studies have previously found game bird nests in managed northeastern PPSO barrens (but see Devlin 1997), studies in other forest types have observed woodcock to use and nest in early-successional habitat, especially aspen stands (Bakermans et al. 2015, Gregg and Hale 1977, McAuley et al. 1996). Additionally, Wild Turkeys have been found elsewhere to strongly select for nest sites in open-canopy forests with dense understory vegetation (Little et al. 2016, Streich et al. 2015, Yeldell et al. 2017). For a variety of ground-nesting game birds, the dense, understory vegetation created by tree harvests in PPSO barrens is beneficial by providing nest concealment and potentially improving nest survival (Drilling et al. 2020, Harris et al. 2009, Wood et al. 2019).

Further research on snake and game birds use and nesting in managed pine barrens is needed, as our study was preliminary and only focused on 1 inland, highly functioning site. Using standardized surveys that specifically target game birds would be beneficial (Bakermans et al. 2015), as well as matching these surveys with vegetation metrics used by forest managers (Lott et al. 2021). Our previous hognose snake study in the MPWMA had little success using cover boards, drift fences, and standardized searches to find hognose snakes (Akresh et al. 2017), but perhaps different techniques or more intensive surveys would result in more snake observations using a more standardized approach (Martin et al. 2017). Interestingly, there appeared to be "hotspots" of snake observations and activity (Northern Black Racers, Eastern Milksnakes, and Eastern Hognose Snakes) in the northeastern treated Pitch Pine and western Scrub Oak areas of the site (Akresh et al. 2017). Further examination of interspecific interactions and niche partitioning among snake species in pine barrens would be intriguing (Steen et al. 2014a, 2014b), especially given that Northern Black Racers prey on other snakes (Gibbons 2017), and we occasionally observed multiple species under the same cover object (Fig. 2).

Conclusion

Given suppression of natural wildfires in PPSO barrens, managers currently need to conduct tree harvesting, mowing, prescribed burning, or other methods to reduce wildfire risk and restore this ecological community (Bried et al. 2014, Jordan et al. 2003). Our preliminary study shows that declining snake species, such as the Northern Black Racer, and game birds, including Wild Turkey and American Woodcock, are using open-canopy, managed areas and could be benefiting from forest management. Overall, our findings are consistent with previous research (e.g., Cave et al. 2021, Howey et al. 2016). Although the primarily goals of management in the MPWMA were to promote ecological restoration and to support Massachusetts state-listed Lepidoptera and plant species (Hawthorne 2017), we found that there may be an ancillary benefit for game birds and snakes. Ecosystem and multi-species management (Akresh et al. 2021c, Simberloff 1998, Taft et al. 2002) appears to be a viable approach in PPSO barrens; our research adds to the growing body of literature showing that managed and restored barrens throughout the Northeast provide habitat to a wide variety of snakes, birds, invertebrates, and other taxa, many of which are of conservation concern (Corbin and Thiet 2020, King et al. 2011, Leuenberger et al. 2016, Tucker and Rehan 2019, Wheeler 1991).

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