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Tracking the endangered Northern Black Racer, Coluber constrictor constrictor, in Maine to determine areas of conservation importance

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Tracking the endangered Northern Black Racer, *Coluber constrictor constrictor*, in Maine to determine areas of conservation importance

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Abstract

The Black Racer (*Coluber constrictor*) is a large-bodied snake species found across North America. One subspecies, the Northern Black Racer (*C. constrictor constrictor*) is listed as endangered in Maine because of its restricted range in York County. Racers have generally been found to prefer open habitats and ecotones, but the specific habitat preferences of racers in Maine is unknown, hindering efforts to preserve habitat for racer conservation. To address this knowledge gap, the Maine Department of Inland Fisheries and Wildlife (MDIFW) has an ongoing project tracking black racer movements in Sanford and Kennebunk, Maine, and I had the opportunity to participate in this research. Over the summer of 2018, I collected point locations for radio-tracked snakes and recorded the predominant vegetation at each location. Behavioral observations were conducted by following select individuals for periods of one to two hours. To explore genetic differences between sub-populations, DNA was extracted from ventral scales taken from catalogued individuals and amplified for previously developed microsatellites. I found that the black racer population at Kennebunk Plains prefers open successional fields with dense cover provided predominantly by sweet fern and *Rubus* spp. Racers display strong anti-predator behavior and make use of trees and forests to flee predators. The dual importance of both fields and forests for racer conservation is thus emphasized. Racers roamed on average 77.3±46.1 meters per day and generally did not show differences in roaming behavior across individuals or throughout the tracking season. Racers at Kennebunk Plains made heavy use of rip-rap, presenting the possibility of creating human-mediated habitat to supplement natural areas. Initial genetic analyses did not reveal any stark differentiation between sub-populations.

Introduction

Snakes are experiencing population declines on a global scale (Reading et al. 2010), which is of considerable concern because snakes are indicators of ecosystem health (Beaupre and Douglas 2009) and provide numerous provisioning and cultural services to people (Valencia-Aguilar et al. 2013). Conservation of snakes can be difficult, however, because particular behaviors and requirements are unique to individual populations, especially those at the northern edge of their range (Martino et al. 2012, Croak et al. 2013, Diaz and Blouin-Demers 2017). Information on individual snake populations is sparse, but effective conservation plans require individualized studies of the species or populations at risk.

One such population in need of assessment is the Northern Black Racer (*Coluber constrictor constrictor*) in southern Maine. Racers were historically abundant in five of the southernmost counties in Maine but are now restricted to small sub-populations exclusively in York County (Mays and Todd 2007). They are currently classified as State Endangered and a Priority 1 Species of Greatest Conservation Need in Maine (Maine Wildlife Action Plan Revision 2016). The Maine Department of Inland Fisheries and Wildlife (MDIFW) has an ongoing study monitoring the population health and movements of Maine's racer population. Habitat fragmentation and automobile mortalities are thought to be responsible for the strong decline from historical populations, and fragmented populations are not necessarily all accounted for (Mays and Todd 2007). For example, a population of racers was discovered around Sanford Airport in 2004 during an environmental impact assessment for a new Walmart (Yorks, personal communication). Further studies of this threatened population are thus needed to implement effective conservation measures.

The Northern Black Racer is one of eleven subspecies classified more broadly as the Black Racer (*Coluber constrictor*). Racers are a large-bodied snake species found across North America aptly named for their anti-predatory behavior of rapidly fleeing danger as adults, but they are known to be aggressive and will strike if cornered (Creer 2005, Ernst and Ernst 2003). The eleven subspecies of racer are split according to morphological and geographical differences. The Northern Black Racer is distinguished by its white chin and otherwise entirely satin black coloration and ranges from the southern tip of Maine inland to Ohio and as far south as northeastern Alabama and Georgia (Tennant 2003, Ernst and Ernst 2003).

Racers are opportunistic predators with diets consisting largely of rodents, anurans, and other snakes (Halstead et al. 2008, Rosen 1991), although a large part of the Western Yellow-bellied Racer (*C. constrictor mormon*) diet consists of orthopteran insects (Shewchuk and Austin 2001). Predation by racers is thought to exclude smaller snake species from scrub habitats, emphasizing the large impact that racers can have on the ecosystem (Kjoss and Litvaitis 2001). Racers are in turn preyed upon by opossums, badgers, skunks, feral cats, and multiple birds of prey, serving as important energy conduits to higher levels in the food web (Ernst and Ernst 2003). This unique position in the food web makes racers good indicators of energy flow and overall intactness of the ecosystem (Beaupre and Douglas 2009). Predation of rodents by timber rattlesnakes has been found to indirectly reduce tick populations and the prevalence of Lyme disease (Kabay et al. 2013), and racers likely fill a similar niche.

<u>Habitat preferences</u>

One of the goals of the MDIFW study is to address the knowledge gap on specific habitat preferences of racers in Maine. Racers in other locations exhibit preferences for open successional fields and field-forest ecotone habitats (Carfagno et al. 2006, Carfagno and

Weatherhead 2006, Plummer and Congdon 1994). Interior forests are avoided (Carfagno and Weatherhead 2006) but are nonetheless critical because racers utilize logs for nest sites (Tennant 2003). Conserving large patches is recommended for sustaining snake populations with large range requirements, including racers (Kjoss and Litvaitis 2001). Racers will travel up to 160 meters in a day, with significant day-to-day roaming distances within a season (Weatherhead et al. 2010). Snake species at the northern edge of their native ranges furthermore exhibit greater roaming behavior. Eastern Yellow-bellied Racers (*C. constrictor flaviventris*) in Saskatchewan, Canada have home ranges from 11.2 ha to 714.4 ha, averaging 145 ± 46 ha (Martino et al. 2012). By comparison, racers in South Carolina have home ranges averaging 12.2 ha (Plummer and Congdon 1994), which emphasizes the greater than ten-fold increase in the home ranges of northern populations. Black racers in Maine, which are at the northern extent of their range, may also exhibit increased roaming behavior. This has strong implications for the conservation of this species, requiring the preservation of larger areas of habitat than would be required for more southern populations.

In addition to naturally occurring habitat, racers have been found to frequent areas disturbed by humans. Racers preferentially occupy woodland areas recently disturbed by fire (Howey et al. 2016, McLeod and Gates 1998) or by logging activities (i.e., clear cutting; Crosswhite et al. 2004, McLeod and Gates 1998, Enge and Marion 1986), since these areas are thought to support more of the racer's preferred rodent prey. This hypothesis may also underlie racers' preference for ecotones, although Carfagno et al. (2006) found that small mammal abundance was not any higher along forest ecotones, which suggests that other factors are likely to determine racers' habitat preferences. Common Garter Snakes (*Thamnophis sirtalis*) and Red-bellied Snakes (*Storeria occipitomaculata*) in northern populations, for example, prefer open fields over woodlands for better thermoregulation opportunities (Diaz and Blouin-Demers 2017), a factor that may also influence racer distribution. In open grassland habitats, racers tend to avoid recently burned areas (Setser and Cavitt 2003), contrary to aforementioned findings in forested areas. Since racers generally avoid interior forests (Carfagno and Weatherhead 2006), anthropogenic activity in woodland areas may thus represent an avenue for habitat generation in otherwise unsuitable locations, as opposed to racers benefitting from disturbance in all habitats. Although natural disturbances facilitate the establishment of new habitats for racers (Lorimer and White 2003), human intervention that accelerates this process could greatly benefit the Maine population. For example, controlled burns conducted at Kennebunk Plains (the location of one of Maine's racer sub-populations) help to maintain suitable racer habitat (The Nature Conservancy 2019). One the other hand, preference for disturbed areas and ecotones may bring racers into close contact with humans, who generally have a negative impression of snakes and pose a threat to racers through intentional killings (Maine Wildlife Action Plan 2016). This is another concern for conservation managers trying to balance habitat management while minimizing human interaction.

Conservation genetics

Racers belong to the genus Coluber, which arose approximately 11 million years ago during the mid-Miocene and has since split into six major clades separated by geographic and genetic barriers (Burbrink et al. 2008). The most recent split occurred during the early Pleistocene between the Panhandle Florida and Eastern clades, of which the latter includes the Northern Black Racer. The discrepancy between the number of major clades and recognized subspecies emphasizes the importance for more careful taxonomic classification. Burbrink et al. (2000) criticize the use of morphological and geographical characteristics to delineate subspecies, since this method is likely to misinterpret the number of subspecies due to plastic characteristics and overlapping ranges. A more solid foundation for subspecies delineation based on genetics removes these errors. Understanding the genetic structure of populations of a species has important implications for conservation managers who need to determine if different sub-populations should be considered separate entities that each require a conservation management plan.

The racer population in Maine is particularly vulnerable to losses in fitness due to genetic drift because it is a restricted population at the northern edge of its range (King 2009). Evidence that isolated species are exceptionally susceptible to genetic divergence has been reported for Yellow-bellied Racers in Saskatchewan, Canada, which differ significantly in microsatellite sequences across separate river valley sub-populations (Somers et al. 2017).

In order to better protect Maine's racer population, a more thorough understanding of their specific habitat preferences and behaviors is required. Generalized assumptions based on other racer populations likely do not necessarily apply to Maine's population because of different pressures faced by populations at the extreme limit of their range (Martino et al. 2012, Croak et al. 2013, Diaz and Blouin-Demers 2017). Simply preserving a large area of land may not suffice because northern populations may exhibit differential habitat utilization (Diaz and Blouin-Demers 2017). These populations warrant further conservation because they are at greater risk of genetic drift. There are four known sub-populations of racers in Maine corresponding to four separate sites: Kennebunk Plains, Sanford Airport, Lebanon, and Wells Barren (Figure 1). Although these populations are all in close proximity (Kennebunk Plains and Sanford Airport, for instance, are about five kilometers apart), they are separated by tracts of forest that hinder movement between sub-populations. Current management plans treat these separate sub-populations the same (Maine Wildlife Action Plan 2016), but a more rapid pace of divergence could require more individualized management if each sub-population is genetically distinct. The goal of this study is to examine the habitat preferences, behavior, and genetic structure of Maine's racer population to better inform conservation practices.

Figure 1. Locations of the four known sub-populations of Northern black racer in York County (inset). The blue line represents a distance of 5 km.

Methods

<u>Field Sites</u>

Telemetry studies were conducted at two field sites in York County, Maine: Kennebunk Plains and Sanford Airport. Kennebunk Plains is largely a pine barrens ecosystem covered with sweet fern, blueberry, and grasses. It is bisected by a dirt road and surrounded on the fringes by deciduous forests, encompassing a total of 135 acres (The Nature Conservancy 2019). The northern half of the park is maintained by the Maine Department of Inland Fisheries and Wildlife (MDIFW) and the southern half is maintained by The Nature Conservancy (Yorks, personal communication). A power station in the northeast quadrant is the only large structure built on the plains and provides a major source of disturbed habitat in the form numerous piles of rip-rap surrounding the site. Several paths are available for public use, but otherwise the plains are undisturbed. The Sanford Airport consists of a small airstrip used by small aircraft. The surrounding area is covered with short grasses and bordered by secondary growth, deciduous forest.

Telemetry and Behavior

The MDIFW has an ongoing telemetry project that involves surveying, marking, and tracking racers at the four sites that they are known to occupy. Captured racers were marked via ventral scale clippings according to Brown and Parker (1976) and implanted with a PIT tag on the left lateral side using a large syringe. Ventral scale clippings were saved in ethanol for later genetic analysis. Select racers were surgically implanted with radio trackers and monitored one to three times a week from early May through late October 2018 using an R-1000 telemetry receiver with an RA-14K VHF antenna (Telonics, Inc. 2019). Once an individual was pinpointed, UTM coordinates were taken with a GPSMAP® 60CSx GPS receiver (Garmin, Ltd. 2007), and the predominant vegetation, distance from sighting, and other noticeable behaviors were recorded. Individuals that were found in a suitably open location were followed to obtain long term behavioral data. If possible, observations were made at a distance to avoid influencing the snake's natural behavior. Coordinate data were compiled in a single Google Earth document. Coordinates were analyzed in ArcMap (ESRI 2017) to determine straight-line distance between successive observations. Roaming distance was then calculated as the straight-line distance between successive observations divided by the number of days between said observations. All non-spatial data analysis was conducted in R (R Core Team 2017). All surveys and observational work were carried out under MDIFW Wildlife Scientific Collection Permit #2018-205. All procedures were conducted with the approval of the Colby College Institutional Animal Care and Use Committee (IACUC) under protocol #2018-01.

Genetic Analysis

DNA was extracted from scale clippings using a Qiagen DNeasy Blood and Tissue Kit following the manufacturer's protocol. The only modifications were a doubling of proteinase K and an extension of the digestion period (to 24+ hours) to allow for the complete breakdown of hard tissues (Sara Ruane, personal communication). Out of a set of 12 previously determined microsatellites for *Coluber constrictor* (Klug et al. n.d.), four were tested based on the following restrictions: 1.) microsatellites that deviated from Hardy-Weinberg equilibrium were removed, 2.) microsatellites that had multiple repeat motifs were removed, 3.) microsatellites with low expected heterozygosity were removed, and 4.) microsatellite primers with a melting temperature (T_a) around 60 ºC were preferred (Table 1). Microsatellites were amplified via polymerase chain reaction (PCR) and examined initially by running the product out using gel electrophoresis to determine the success rate of the primers. Successful products were PCR amplified again with 6-FAM labelled primers to allow for better length determination of the microsatellites. All primers were ordered from Eurofins Genomics LLC.

Table 1. Microsatellites and associated primers used during genetic analysis.

GenBank Accession #	Microsatellite sequence name	Forward primer	Reverse primer
GQ371180	CCPKV09	AAACTTCCCTTACCCCATGC	CTTGCTAAGCGACCCTTG
GQ371181	CCPKU15	GGAGGCGAGTCAAACAGTTG	CAATCCAAGGCAGAAGAGG
GQ371182	CCPKS19	CGAGATGTGTCCAGCTTCTG	ACTTTGGGGGAATTCCAG
GQ371185	CCPKR31	GCCCATCCACAAGTGAATC	ATAACGGAATGCTGGCAAAG

Results

Racers were tracked from May 1 to October 26, 2018 by myself and wildlife biologists at MDIFW. Collectively, 173 point locations were collected between four radio-tracked snakes at Kennebunk Plains (n = 75; Figure 2) and five radio-tracked snakes at Sanford Airport (n = 98; Figure 3). I personally made 13 excursions to Kennebunk Plains, observing 33 point locations and collecting nearly five hours of observational data. All observations occurred during daytime hours. Snakes roamed on average 77.3±46.1 meters per day throughout the tracking season (Figure 4). An ANOVA test revealed significant differences in individual roaming behavior ($F = 2.281$, $p = 0.027$), but a follow-up Tukey's HSD test only showed a significant difference between individuals M145 and M146 ($p = 0.020$) while all other individual combinations were

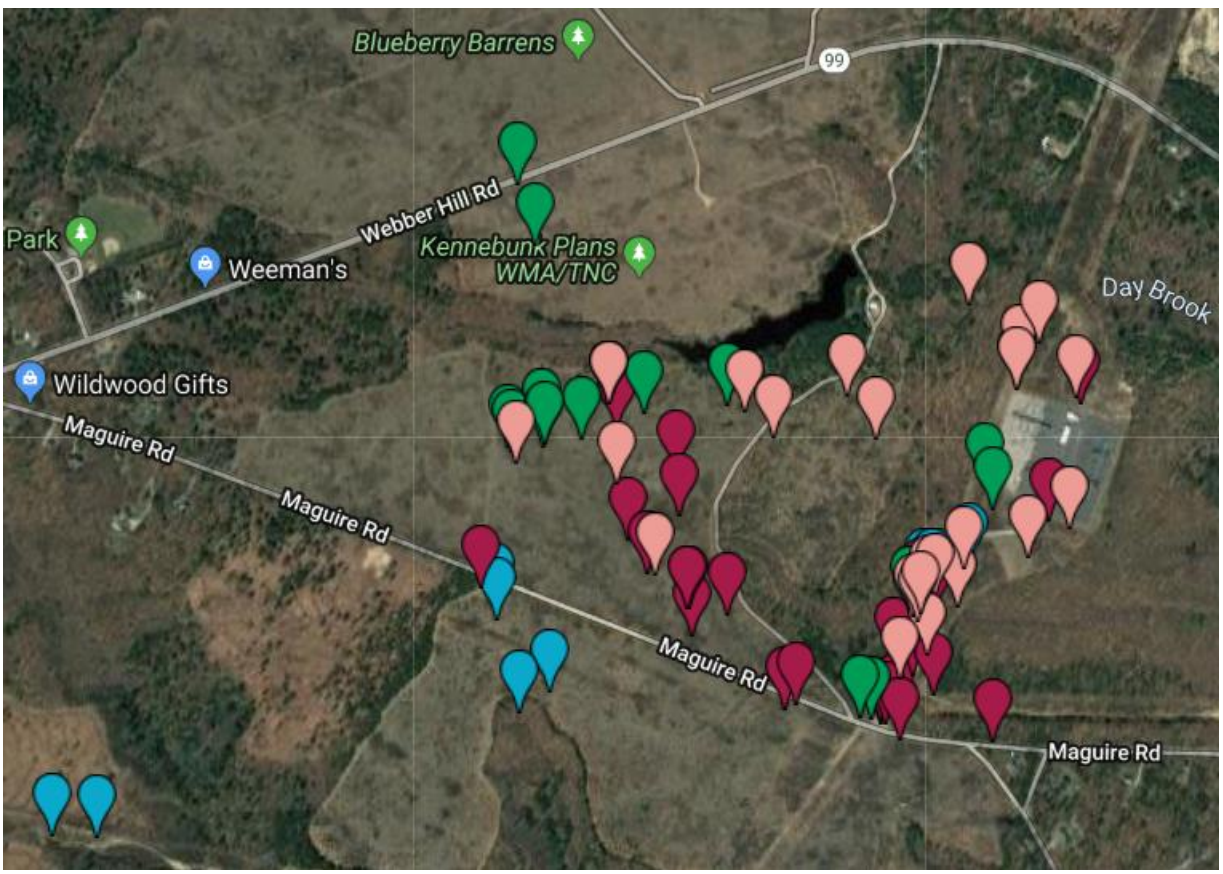

Figure 2. Point locations collected for racers at Kennebunk Plains from May 1-October 26, 2018. Each color represents a different individual.

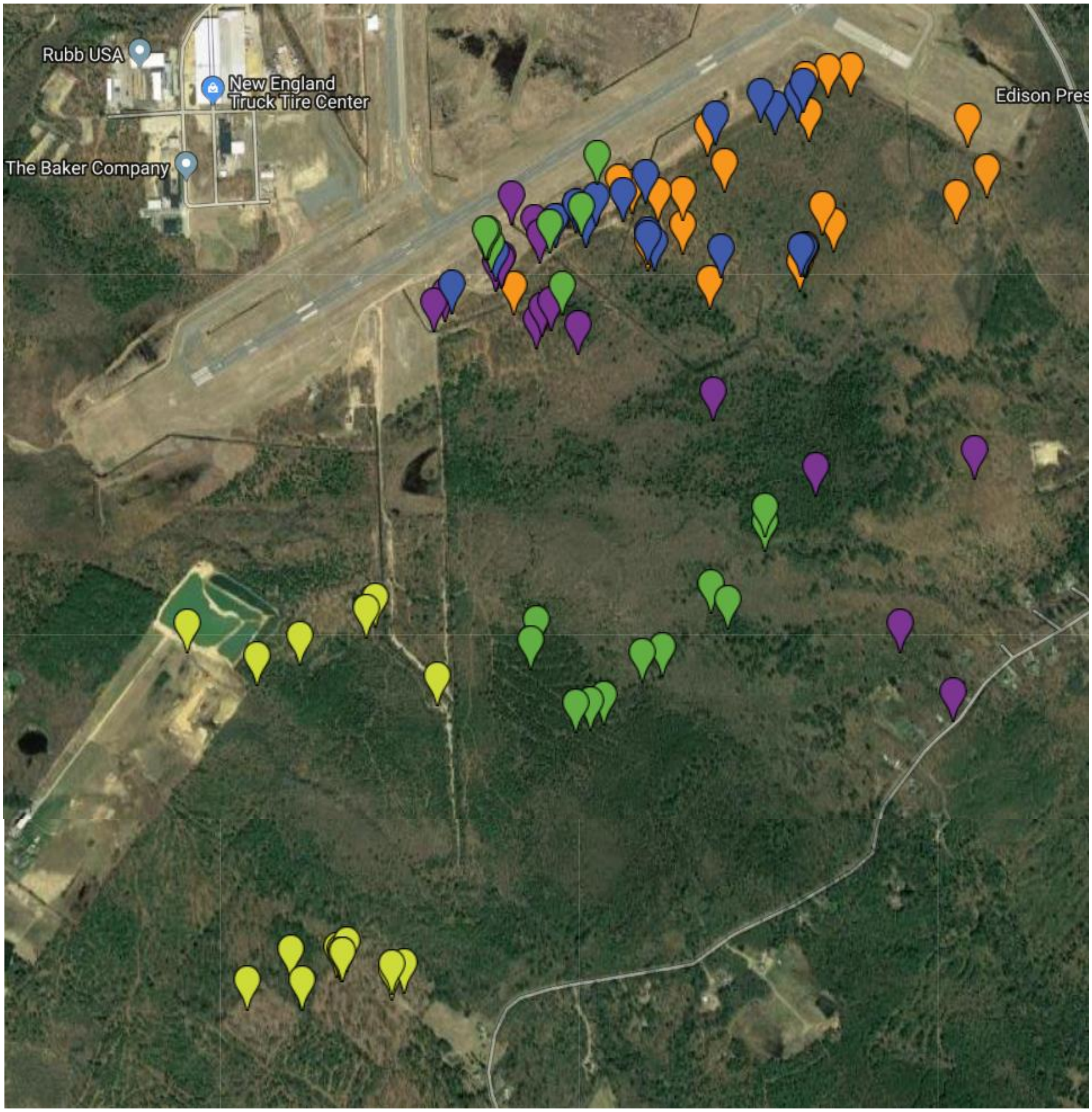

Figure 3. Point locations collected for racers at Sanford Airport from May 1-October 26, 2018. Each color represents a different individual.

not significant. Roaming behavior also varied little across the tracking season. Linear models were created to examine trends in roaming behavior, and only individual M145 showed a significant trend ($R^2 = 0.153$, $p = 0.045$; Figure 5).

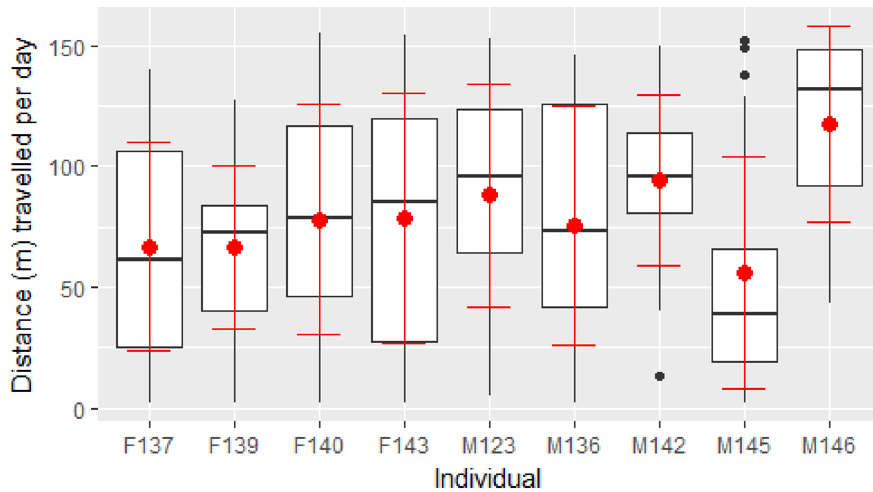

Figure 4. Roaming behavior observed for each tracked individual. Individuals are named numerically and start with an *F* if female and an *M* if male. Collectively, snakes travelled on average 77.3±46.1 meters per day (individual mean and standard deviation are shown in red). Distance travelled per day was determined by dividing the distance between successive observations by the number of days between said observations.

However, this trend seemed to be largely controlled by data points from August 31 onward, with data prior showing a large amount of variability. Therefore, a second linear model was created just for the former data ($R^2 = 0.479$, $p = 0.023$; Figure 6).

<u>Kennebunk Plains population</u>

For the Kennebunk Plains population, locations were clustered in two areas. Thirty-one point locations occurred in open successional fields and 39 point locations occurred along/around a small utility road leading to an electrical power station. Two locations occurred along a sandy strip at the southern edge of the park, although these points were for the same individual during successive weeks and likely represent an abnormality. Only three locations occurred in forests. Of the 75 point locations collected at Kennebunk Plains, I personally collected 33 points. For twelve points out of this latter set, visual observation was not achieved because racers were in underground burrows, and locations were recorded at the entrance of burrows. For points where

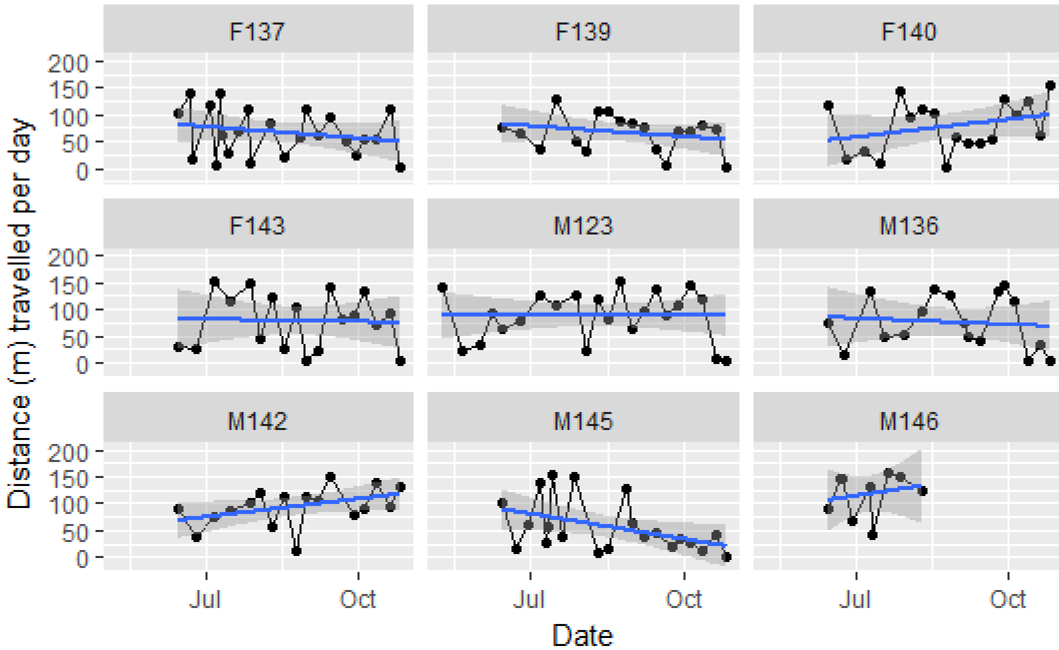

Figure 5. Roaming behavior observed for each tracked individual as a function of the date. Dates run from May 1-October 26, 2018. Although there is a large amount of variance between observations, a linear fit (blue line) does not show strong trends in roaming behavior across the season. Data for M146 is absent because this individual died during the tracking season.

a visual was achieved, observations occurred largely within three meters (n = 17) of a sighted racer (Figure 7). Beyond three meters, sightings drop off (n = 4), and no sighting occurred from more than five meters away. Locations where

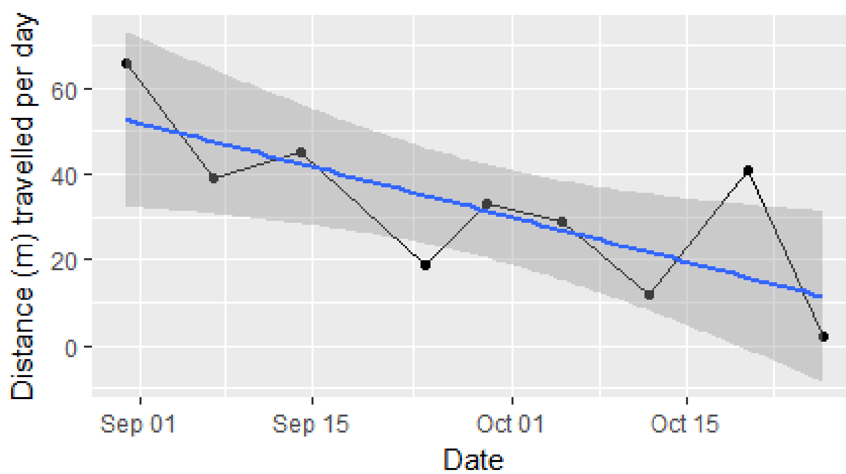

Figure 6. Roaming behavior observed for individual M145 from August 1-October 26. A linear model (blue line) revealed a significant downward trend (R^2 = 0.479, p = 0.023).

racers occurred were dominated by sweet fern (*Comptonia peregrina*; n = 10) and *Rubus* spp. (n = 9; Figure 8). To a lesser degree, racers occupied areas dominated by lowbush blueberry

(*Vaccinium angustifolium*; n = 4), leaf litter (n = 3), and open grasses (n = 2). For seven observations, rip-rap made up a prominent component of the surrounding habitat.

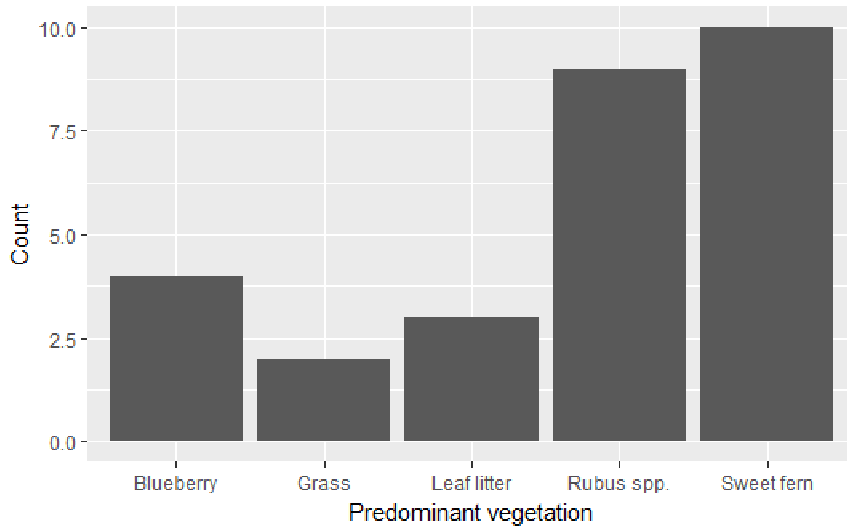

Figure 7. Classification of the most predominant vegetation observed at the locations where racers were found. The count (y-axis) records the number of times a particular vegetation type dominated accounting for all individuals observed throughout the tracking season.

Behavior

On six occasions, located snakes were in a suitable area for long-term observation. Racers exhibited strong anti-predator behavior when I attempted to follow them, slithering away and hiding beneath brush as much as possible whenever my approach was detected. Observation of behavior uninfluenced by my presence thus proved impossible, but multiple specific anti-predator behaviors were observed. Racers often paused while travelling to raise their heads above the ground to maintain a lookout. On four occasions, snakes crossed the forest-plains boundary in

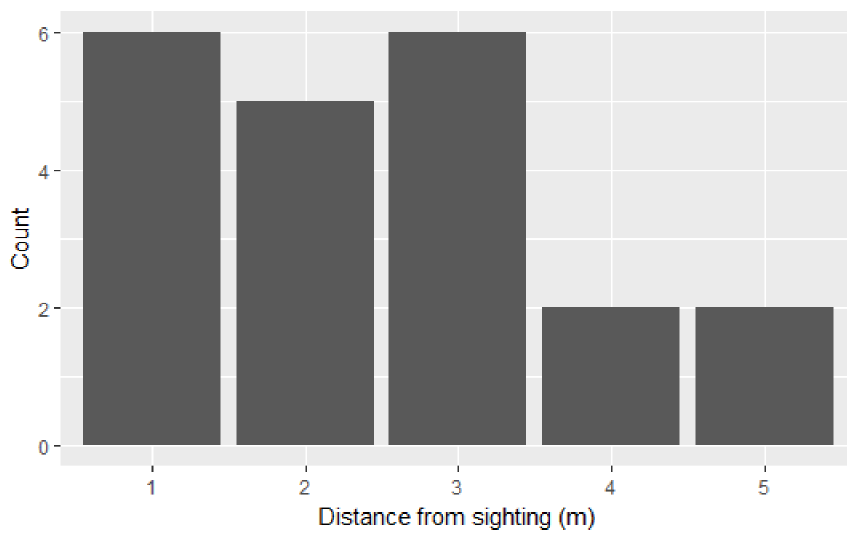

Figure 8. Breakdown of the distance to an observed racer the moment when a visual was obtained. The count (y-axis) records the number of times a particular distance was noted, accounting for all individuals observed throughout the tracking season.

what I assume was an attempt to hinder my pursuit. For one observation in particular, this boundary was crossed six times. On two occasions, racers climbed up into small bushes after being followed for some time. This may not necessarily have been an anti-predator tactic since these individuals only climbed about a meter off of the ground, which was within easy reach for me to capture them if desired.

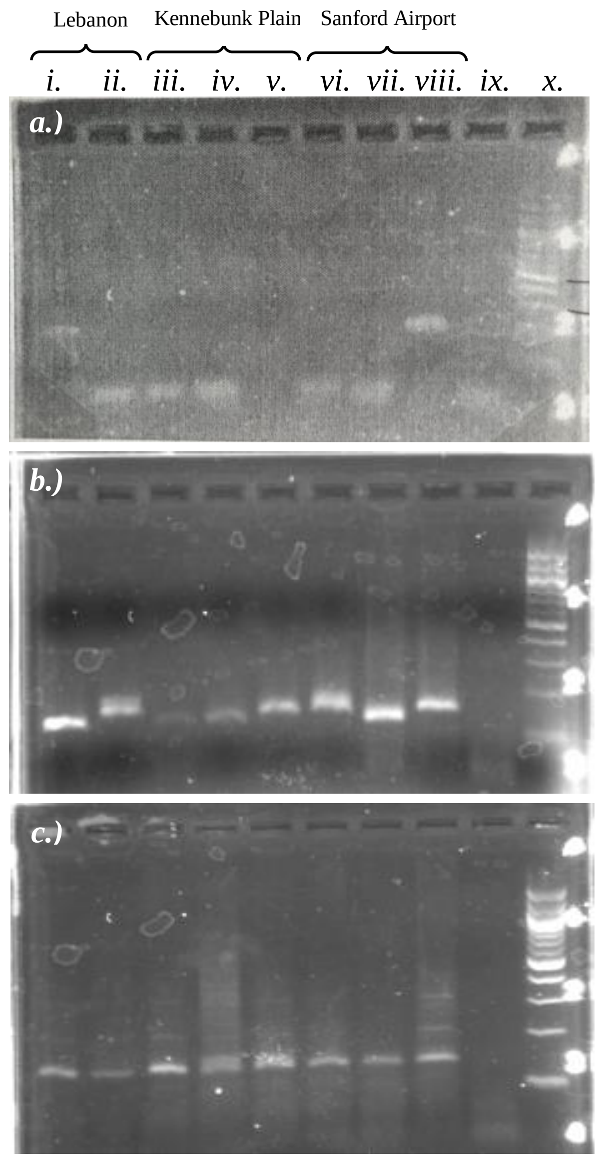

Figure 9. Electrophoresis gels showing initial testing for microsatellites (a.) CCPKV09, (b.) CCPKU15, and (c.) CCPKR31. Samples from three populations are included in each gel, labelled as follows: (i.) LE38, (ii.) LE74, (iii.) KP125, (iv.) KP126, (v.) KP135, (vi.) SA134, (vii.) SA140, (viii.) SA142, (ix.) negative control, and (x.) 100 bp ladder.

<u>Genetic Analysis</u>

The modified extraction protocol achieved successful DNA extraction from all samples (n = 58), averaging 11.9(± 4.8) ng DNA/µL per sample. Initial PCR trials proved successful for three out of the four tested microsatellites; microsatellite CCPKS19 was not successful and was excluded from further analyses. Initial testing for microsatellite CCPKV09 revealed two positive amplifications, one from the Lebanon population and one from the Sanford Airport population (Figure 9a). Both of these bands showed the same genotype. Initial testing for microsatellite CCPKU15 revealed positive amplifications for all eight samples tested (Figure 9b). Two distinct genotypes (referred to as genotype 1 for the shorter sequence and genotype 2 for the longer sequence) were seen across all three populations: the Lebanon population had one of each genotype, the Kennebunk Plains population had two samples with genotype 1 and one sample with genotype 2, and the Sanford Airport population had one sample with genotype 1 and two samples with genotype 2. Initial testing for microsatellite CCPKR31 revealed positive amplifications across all three populations, with only one genotype evident (Figure 9c). Some change can be seen between the bands, but since this is only evident as a steady gradient across the gel, this is likely an artifact of how the gel set or the angle at which the photo was taken.

Discussion

The Kennebunk population of Northern black racers displays a strong preference for open successional fields. This finding is consistent with habitat preferences of other racer populations, which occupy successional fields and forest-field ecotones (Carfagno et al. 2006, Carfagno and Weatherhead 2006, Plummer and Congdon 1994). Racers were specifically found in areas dominated by *Rubus* spp. and sweet fern, which provided more dense, leafy cover for racers to remain hidden while moving. Open grassy areas were avoided, suggesting that although racers prefer more open habitats, they still require some form of cover. Racers in South Carolina are found 50% of the time in shrub habitats (defined as thickets or grassland shrubs), showing a clear preference for denser areas (Plummer and Congdon 1994). The delineation of open successional fields as racer habitat should thus be limited to areas that have progressed beyond initial stages of succession and have acquired some woody cover; the extent/density of cover that delimits this threshold was not analyzed in this investigation and remains a question for future studies.

Preference for dense cover is a component of cryptic behavior in racers. In this study, snakes were so good at avoiding detection that it often required being nearly on top of them to get a visual. Longer observations proved difficult because of strong anti-predator behavior. Racers generally hid from sight, but two unique anti-predator strategies were observed. First, racers were observed climbing into small bushes while followed. Although the use of arboreal habitats has previously been documented for racers (Plummer and Congdon 1994, Ernst and Ernst 2003), the two instances in this study when racers climbed into small bushes presented an unusual case, since it was indeterminate whether or not this qualified as anti-predator behavior. Climbing made racers more visible and the bushes were too small to actually climb out of reach, so climbing did not provide any protection and actually exposed snakes to potentially greater danger. Climbing as an anti-predator strategy may be dependent on the size of the tree, even though racers will still climb unsuitably small bushes.

Second, racers were observed crossing back and forth across the forest-field ecotone. Racers are preyed upon by a wide range of predators (Ernst and Ernst 2003), so varied strategies may target different predators. Climbing trees may be an escape route against ground-dwelling predators, whereas crossing into the forest could provide better cover from aerial predators such as diurnal raptors. Since I did not fall into a strict predator category, I was able to observe both of these behaviors. Racers are named for their speed, but this moniker may be somewhat misplaced for this population, since cryptic anti-predator strategies were adopted more frequently than open flight. Specific modes of anti-predator behavior will need to be further examined to determine if behavior changes with the identity of the predator.

Although racers prefer successional fields in this study, there are nonetheless a handful of point locations in the forest, and previous studies consistently observe this trace use of forest habitats (Carfagno et al. 2006, Carfagno and Weatherhead 2006, Plummer and Congdon 1994). The behavioral findings suggest that utilization of forests extends beyond its role as simple habitat. Forests have a secondary role in both of the novel anti-predator strategies discussed. Adequately sized trees are needed for climbing to escape predators from below, and forests as a whole can provide adequate cover against predators from above. Racers have been documented using logs for nesting sites (Tennant 2003), providing a third unique contribution of forests to racer well-being. The consistent emphasis on racers' preference for open successional fields should thus not downplay their need for adjacent forests. Conservation managers need to prioritize both ecosystems for racer conservation.

When determining areas of relevant conservation importance for the survival of a species, managers must also consider the size of the area to be protected in addition to the ecosystems contained therein. Between the Kennebunk Plains population and Sanford Airport population, racers moved 77.3±46.1 meters per day. This is consistent for populations further south (104±5 meters per day) which corresponds to an average home range of 12.2 hectares (Plummer and Congdon 1994). Kennebunk Plains is approximately 54.5 hectares in size (The Nature Conservancy 2019), and since racers are not territorial and have overlapping home ranges (Yorks, personal communication), Kennebunk Plains is capable of sustaining a small population around a couple dozen racers. Martino et al. (2012) found that home ranges for a Canadian population of racers was much larger (145 ± 46 ha) than southern counterparts (12.2 ha; Plummer and Congdon 1994), suggesting that northern populations may require larger territories to have access to scarce resources. This was not observed for this study, although territories may be constrained by the size of the park.

In addition to habitat, protected areas must be able to sustain adequate food sources for racers. Racers are visual hunters (Ernst and Ernst 2003), and frequent head raising was noted in racers that I followed. This vigilance, however, also aided anti-predator behavior and made it difficult to assess other behaviors such as hunting. Foraging behavior and prey preference were not examined specifically in this study, although this population likely has similar hunting strategies and diets to other populations. The absence of other snake species at Kennebunk Plains, with the exception of unusually large garter snakes (Yorks, personal communication), suggests a diet heavy in other snake species, such as smooth green snakes, redbelly snakes, ribbon snakes, and small garter snakes (Kjoss and Litvaitis 2001). Other potential prey items commonly eaten by racers include rodents and anurans (Halstead et al. 2008, Rosen 1991), so examining the capability of an area to support these prey items will be important for sustaining racer populations.

In addition to preserving new areas for racer conservation, managers could focus on creating human-engineered habitat. Previous studies have indicated that racers at Kennebunk Plains will occupy artificial cover (Mays and Todd 2007), and individuals in this study displayed an especial affinity for occupying human-disturbed areas. The cluster of locations around the utility road leading to the electric power station was likely due to the extensive piles of rip-rap found along this avenue. Rip-rap consists of large piles of fist to head-sized rocks left behind or purposely placed by humans for drainage or structural landscaping. Along this road was a bridge made entirely of rip-rap, with numerous small piles in the immediate area, and racers were observed using these for habitat. The piles of rip-rap provided lots of holes that could serve as burrows for racers seeking escape from predators or the daytime heat. On one occasion, an individual at the Sanford Airport site was tracked to a pile of plastic traffic barriers, again demonstrating that human debris can serve as unintentional habitat for racers. Racers' presence in Maine may in fact be largely mediated by human disturbance; Kennebunk Plains is a heavily managed ecosystem (The Nature Conservancy 2019) and the Sanford Airport site is largely dominated by the airport.

This use of human-mediated habitat is a double-edged sword. On the one hand, it shows that humans are capable of creating suitable habitat (even if not always intentional) in which racers will readily occupy and thrive. Artificial rock habitats have already started to gain traction for supplementing snake habitat, having been demonstrated for the broad-headed snake (*Hoplocephalus bungaroides*) in Australia (Croak et al. 2010). However, disturbance of these areas by people actively searching for snakes quickly degraded these habitats (Pike et al. 2010). Human-mediated habitat also brings snakes into closer and more visible contact with humans, which can have negative consequences. Early on in the field season, one of our snakes was taken by a homeowner who found the snake on his property. Fortunately, this snake was returned and released back into the area, but this snake likely dealt with some negative effects of being captured and handled. There is a considerable amount of fear and animosity directed towards snakes, and some people will kill snakes on sight (Burghardt et al. 2009), adding further trouble to conservation managers. Since racers do not like to travel through forest interiors (Carfagno and Weatherhead 2006), wooded areas could be used as buffers to minimize racer-human contact, which would hopefully decrease incidental killing of racers.

Genetic Analysis

Preliminary analysis of microsatellites found similar genotypes between all three sub-populations and did not reveal any sharp distinctions. Since only two or three individuals were tested from each population, this sample is not large enough to make any conclusive statements. Future directions for microsatellite analysis will include examining many more individuals to increase robustness. Additionally, microsatellites will be amplified with 6-FAM labelled primers to allow for better length determination of the microsatellites. Genetic analysis to date focused on determining whether DNA could be extracted and whether previously identified microsatellites could be successfully amplified for this population. The aforementioned next steps will be required to determine any variation among sub-populations.

Conclusions and Conservation Recommendations

Given the cryptic nature of the Northern Black Racer, especial credence can be given to the old adage "out of sight, out of mind." However, the Northern Black Racer is deserving of our attention and continued conservation efforts. The black racer is an important meso-predator that serves as a conduit of energy higher up in the food web (Beaupre and Douglas 2009), and it can have a great influence on the community structure of the ecosystem (Kjoss and Litvaitis 2001). Snakes have been suggested as a potential indicator species (Beaupre and Douglas 2009), and racers may be especially key given the wide array of species that prey on them (Ernst and Ernst 2003). Protecting black racers is thus necessary to ensure the intactness of the ecosystem.

The black racer population at Kennebunk Plains prefers open successional fields with dense cover provided predominantly by sweet fern and *Rubus* spp. Forest ecosystems are rarely used but are nonetheless important components of racer ecology. Racers display strong anti-predator behavior and make use of trees and forests to flee predators. Forest ecosystems thus play an important if infrequent role and need to be incorporated into habitat preservation for racers. Individual snakes from the Kennebunk Plains and Sanford Airport populations did not exhibit roaming behavior different from that observed for southern populations, so home ranges are likely similar and can be used to approximate the size of an area adequate to sustain a healthy racer population. This may be somewhat difficult, however, since racer home ranges overlap. A better way to approximate the amount of habitat required can be to look at resources such as prey items, although this was not examined during this study. Racers at Kennebunk Plains also make heavy use of rip-rap, presenting the possibility of creating human-mediated habitat to supplement natural habitat. This, however, presents the problem of racers choosing to occupy areas marked by human activity, which could increase conflict between snakes and humans, largely to the snakes' harm. Artificial habitat can thus be used as a short-term solution, but longer-term plans should focus on preserving open successional fields and field-forest habitats. Further research and monitoring are required to elucidate non-anti-predator behavior and to determine potential genetic differences between racer sub-populations.

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