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HOW QUICKLY ARE ROAD-KILLED SNAKES SCAVENGED? IMPLICATIONS FOR UNDERESTIMATES OF ROAD MORTALITY

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Abstract: Annually, millions of snakes are killed on roads in the United States. Because of their potential abundance and ease of collection, many researchers have used road-killed snakes to examine community composition, movement patterns, and population dynamics. However, few previous studies have accounted for snake carcasses that are removed from roads by scavengers. Snake carcasses were placed at randomly selected locations along 2 km of road, one traversing maritime forest and the other surrounded by dune habitat. Carcasses in forested habitat were removed more often (100% vs 40%) and more quickly (8 hr vs 11 hr) than those placed in dune habitat. Half of the carcasses (50%) were removed within eight hours of placement and all carcasses were removed at night. Species and size of carcasses did not affect removal time. Removal time and scavenging intensity of snake carcasses most likely varies across regions and habitats. Furthermore, because scavenging appears to occur quickly and to such a significant extent, it may confound results of studies examining patterns of road-mortality. Thus, investigators that use data from road-killed snakes would benefit from a concurrent investigation of scavenging and application of appropriate correction factors to avoid underestimation of snake mortality.

Key Words: Road mortality; Scavenging; Reptiles; Conservation.

INTRODUCTION

Annually, millions of vertebrates are killed on the 6.5 million km of roads in the United States (Rosen and Lowe 1994; McCurry-Schmidt 2010). Because of a variety of physiological (Klauber 1939; Sullivan 1981), behavioral (Andrews and Gibbons 2005), migratory (Seigel and Pilgrim 2002), and morphological attributes, snakes are often one of the most heavily impacted taxa. Roads may reduce the size and viability of snake populations (Rosen and Lowe 1994; Row et al. 2007), cause population and genetic isolation (Clark et al. 2010), and degrade habitat (Sullivan 1981; Freeman and Bruce 2006) for certain snake species. As a result, snake-road mortality has garnered significant research attention (reviewed in Andrews et al. 2008).

The high abundance of road-killed snakes in some areas may provide researchers with a unique opportunity to investigate snake-road interactions with minimal effort. Surveys for snake carcasses on roads can provide insight into community composition (Klauber 1939; Bernardino and Dalrymple 1992), species abundances (Hellman and Telford 1956; Enge and Wood 2002), migratory and reproductive timing (Bonnet et al. 1999), and diet (Freeman and Bruce 2006). However, the availability of snake carcasses on roads also provides ample opportunites for enterprising scavengers including raccoons (*Procyon lotor*), red fox (*Vulpes vulpes*), vultures (*Cathartes aura* and *Coragyps atratus*), opossum (*Didelphis virginiana*), red imported fire ants (*Solenopsis invicta*) and other snakes (e.g., DeVault and Krochmal 2002; DeVault et al. 2003; Antworth et al. 2005; DeGregorio and Nordberg in press). In situations where researchers and scavengers both actively seek road-killed carcasses, the two may be in direct competition.

It is easy to imagine that in such competitive instances a scenario in which the "early bird" gets the dead snake. How early (or how often or at what times) a researcher needs to be in the field to out compete scavengers is a question that must be taken into account in the experimental design of studies seeking data using road-killed snakes. Many studies that collect snakes from roads conduct surveys on a daily basis (Bonnet et al. 1999; Enge and Wood 2002; Shepard et al. 2008; DeGregorio et al. 2010) or less frequently (Bernardino and Dalrymple 1992; Ciesiolkiewicz et al. 2006; Jochimsen 2006). Few studies have experimentally tested the time to removal of carcasses on roads. In one notable exception Antworth et al. (2005) reported most baited snake and chicken carcasses were removed within 38 hr on a Florida road. In a similar study conducted in Wales, UK, Slater (2002) determined that wildlife road mortality may be underestimated by a factor of 12–16 because of the efficient removal of carcasses by scavengers.

The speed and extent to which scavengers remove snake carcasses from roads is unresolved for most geographic regions; these parameters also likely vary across regions and habitat types. Understanding the timing, speed, and intensity of carcass removal is critical for studies attempting to infer road mortality rates as these factors have the potential to confound results. Our objectives were to 1) experimentally test scavenging rates and time to removal of snake carcasses on two roads located on Bald Head Island, North Carolina, 2) assess timing of carcass removal, and 3) compare scavenging rates and time to removal of snake carcasses in two coastal habitat types.

METHODS

Study site.—Bald Head Island (BHI), is an 800 ha barrier island located in southeastern North Carolina (33°50′14″N, 78°00′01″W). The majority of the island is forested and contains large tracts of intact maritime forest including the Bald Head Island Maritime Reserve, a 75 ha forest preserve free of development. The island is bordered to the north by 4,000 ha of protected salt marsh habitat with the Atlantic Ocean located to the East and South and the Cape Fear River to the West. Much of the western portion of BHI has been converted to a golf course with 15 freshwater lagoons and large expanses of managed lawn. The southern portion of the island is mostly sand dune with sparse low-growing vegetation and little to no tree canopy. There are currently 1,000 homes on the island; however town ordinance requires that the natural habitat around each house may not be cleared and there are currently fewer than 200 year-round residents.

Approximately 35 km of paved road exist on the island. Roads have two lanes which are often divided by a median of dune or maritime forest vegetation. BHI is separated from mainland North Carolina by a 5 km wide section of the Cape Fear River and can only be accessed via passenger ferry departing Southport, NC. Vehicular traffic on island is restricted to electric golf carts and the rare gas-powered vehicle used by public emergency personnel and private contractors. Posted speed limits do not exceed 29 km/hr. Despite the predominance of slow-moving golf carts, considerable snake road mortality has been documented (DeGregorio et al. 2010).

Sampling methods.—To investigate how long road-killed snakes remain on a road before being scavenged, ten trials in which a pair of snake carcasses was placed at randomly chosen locations along two roads and their time to removal was recorded. Road-killed snake carcasses were opportunistically collected from 1 May to 29 June 2010. Each carcass was identified to species and its snout to vent length (SVL) measured. Only recently road-killed carcasses that had not been torn open were collected for use in this study to control for body condition. All carcasses were kept frozen until used in a trial at which time they were completely thawed prior to placement. The two specimens used in each trial were the same species and of similar size (<150 mm size difference). Two specimens were simultaneously placed at randomly determined locations along a 2 km road traversing the maritime forest and a 2 km road traversing dune habitat.

Each trial took place over a separate 24-hr period between 20 July to 1 August 2010. To best simulate real circumstances, carcasses of diurnal snake species [Rough Green Snakes (*Opheodrys aestivus*) and Black Racers (*Coluber constrictor*)] were placed on roads in the early afternoon and carcasses of nocturnal or crepuscular snakes [Yellow Rat Snakes (*Pantherophis alleghe-niensis*) and Scarlet Snakes (*Cemophora coccinea*)] at sundown. All carcasses were placed on the periphery of the road to avoid constant collisions with traffic and subsequent rapid deterioration of carcass condition. Carcasses were visually inspected every hour for the first three hours after they were set and every four hours afterward for a 24-hr period. Carcasses that were not scavenged during the 24 hr period were removed.

Data analysis.—Each carcass was characterized as scavenged or not scavenged based upon whether or not they were removed from the road. Scavenging speed of each carcass was determined by quantifying the amount of time between the placement of a carcass and the time at which it was observed missing. Because some of our carcass checks were spaced four hours apart scavenging may have occurred hours earlier than recorded; as a result all of our estimates of time to removal are conservative meaning that they overestimate the time snake carcasses remained on roads. For analyses requiring a non-zero value for time to removal, the value of 24 was assigned, indicating that carcasses remained unremoved for a 24 hr period. A Kruskall-Wallis test was used to examine differences in scavenging speed between species (Zar 2009). Species for which no difference in mean time to removal was detected were grouped for further analysis. A Chi-square test was used to compare time to removal between carcasses on the maritime forest road and the dune road (Zar 2009). Linear regression was used to describe the relationship between snake size (SVL) and scavenging speed (Zar 2009). All tests were performed with SPSS 15.0 (SPSS Inc. Chicago, IL) and alpha levels were set at 0.05.

RESULTS

Ten trials were conducted between 20 July and 1 August 2010 with 20 snake carcasses (10 *O. aestivus*, 4 *P. alleghaniensis*, 4 *C. constrictor*, and 2 *C. coccinea*) placed at randomly selected locations. All ten (100%) of the carcasses placed on the maritime forest road were scavenged, while four (40%) of the carcasses on the dune road were taken (Table 1) within a 24 hr period. Half of all carcasses (50%) were removed by scavengers within 8 hr of placement (Fig. 1). No difference was

Table 1. Intensity, timing, and speed of removal of snake carcasses by scavengers on Bald Head Island, NC.

Habitat	Number Of Carcasses Placed	Number Of Carcasses Scavenged	Mean (± SE) Hours To Removal	Percent Removed At Night
Maritime Forest	10	10	8.1 ± 2.2	100
Dune	10	4	11.7 ± 8.1	100
Combined	20	14	9.8 ± 4.2	100

detected in scavenging speed for the different species ($\chi^2 = 3.65$, df = 3, p = 0.30), therefore all species were grouped for analysis. Carcasses located in maritime forest were removed by scavengers faster ($\bar{x} = 8.1$ hr ± 2.2) than those located in dunes ($\bar{x} = 20.7$ hr ± 2.2; $\chi^2 = 8.57$, df = 1, p = 0.03). However, if only scavenged carcasses are considered, mean removal time of dune carcasses is reduced to 11.7 ± 8.1 hr. No relationship was detected between carcass length and scavenging rate (F = 0.21, $r^2 = 0.01$, p = 0.66). All scavenging events took place between the hours of 19:30 (dusk) and 06:15 (dawn) regardless of when carcasses were placed.

DISCUSSION

When 20 snakes carcasses were placed at randomly determined locations on two different roads, 70% were scavenged within 16 hr. Carcasses removed from roadsides were taken during the first night they were placed and 50% were removed during the first 8 hr (Fig. 1). Although several carcasses on the dune road were never removed, carcass removal occurred as quickly as 1 hr on the forest road. Scavenging has long been acknowledged as a significant source of carcass removal along roadsides by numerous animals of various taxa (DeVault and Krochmal 2002; DeVault et al. 2003). Antworth et al. (2005) documented an even higher rate of snake carcass removal (97%) than we did and a high rate of removal of chicken carcasses (60–76%), although the study allowed a 36 hr window for scavenging to occur whereas we only provided 24 hr. The majority of carcasses placed on roadsides by Antworth et al. (2005) were removed within 36 hr while Bumann and Stauffer (2002) reported a mean removal time of 68 hr with a minimum of 1 hr 46 min for dead grouse in Virginia.

Removal of carcasses can be influenced by time of day, weather, temperature, species and condition of carcass, traffic density, topography, season, and species of predators (Bumann and Stauffer 2002; Slater 2002). Although our results did not indicate differences in removal time for different species of snakes, we did notice a significant difference in removal time by habitat type. Carcasses in forested habitat were removed more often (100% vs 40%) and more quickly (8 hr vs 20 hr) than those placed in dune habitat, likely reflecting differences in scavenger distribution across BHI. Both our results and those of Antworth et al. (2005) indicate no difference in removal time of carcasses based upon their size. Slater (2002) attributed much of the observed scavenging in his study on feral cats (*Felis familiaris*) while Antworth et al. (2005) predominantly credited raccoons, vultures, and fire ants. Vultures on BHI are rare and fire ants and feral cats have not become established; instead, all predation observed by the authors was the result of red fox and on one occasion sow bugs (*Armadillidium* spp.). The rarity of vultures and lack of fire ants on BHI likely contributes to the lack of diurnal carcass removal noted in our study as compared to those of others (Antworth et al. 2005).

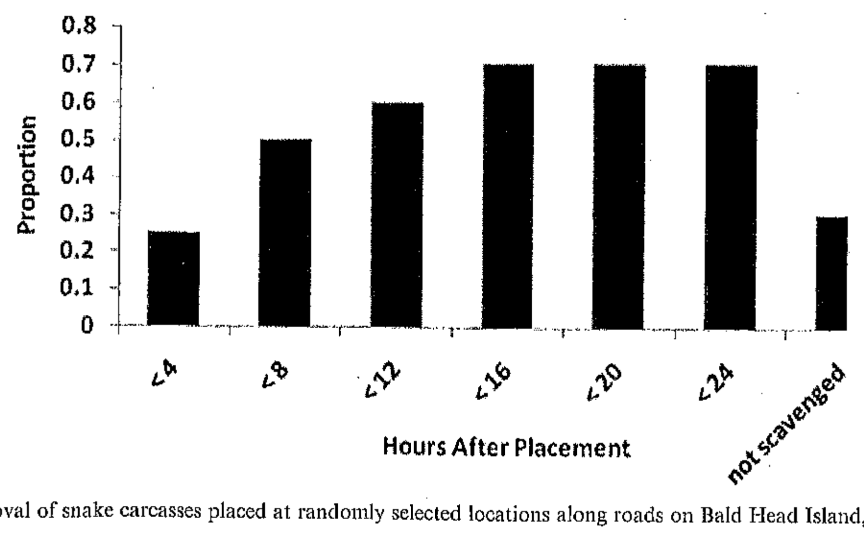

FIG. 1. Time to removal of snake carcasses placed at randomly selected locations along roads on Bald Head Island, NC during the summer of 2010.

Nocturnal removal of carcasses on BHI is likely attributable to the crepuscular and nocturnal foraging habits of the red fox (Macdonald 1977; Lovari et al. 1994).

The rapid and intense removal of road-killed carcasses by scavengers can have serious implications for researchers examining patterns in road-mortality. If surveys are not properly timed and conducted at an optimal frequency, researchers run the risk of seriously underestimating actual road-mortality. Slater (2002) estimated that actual mortality rates may be a factor of 12–16 times higher than rates calculated from observed carcasses on roads in the United Kingdom. Most studies that collect snakes from roads conduct surveys on a daily basis (Bonnet et al. 1999; Enge and Wood 2002; Shepard et al. 2008) or less frequently (Bernardino and Dalrymple 1992; Ciesiolkiewicz et al. 2006). Those studies likely underestimated mortality rates or fail to collect carcasses that may confound results. For instance, DeGregorio et al. (2010) documented roughly 200 road-killed snakes on BHI during the summer of 2009. Based upon the composition of their sample, the authors concluded that diurnal species were the type of snake most often encountered dead on the road. However, because all snake carcasses placed in our study were removed at night, the scarcity of nocturnal species documented by DeGregorio et al. (2010) may stem from prompt nocturnal scavenging; the result is likely an under-representation of nocturnal snakes in the sample. Future efforts to document snake road-mortality on barrier islands as well as other habitats should be structured so that the effect of scavengers is minimized, either by surveying twice daily or timing surveys to collect snake carcasses before scavenging occurs.

Very few studies have investigated patterns in snake carcass removal along roads. Carcass removal is likely influenced by a number of factors including time of day, weather, temperature, species and carcass condition, traffic density, topography, season, and species of predators (Slater 2002). Further investigations are needed to quantify the effects of the aforementioned variables on scavenging patterns. Until scavenging is better understood on multiple regional scales, we recommend that investigations of snake road-mortality incorporate a concurrent scavenging component to better compensate for local conditions and to tailor experimental designs to minimize confounding effects of carcass removal.

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