Title

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Road Effects on a Population of Copperhead Snakes in the Land Between the Lakes National Recreation Area, K.Y.

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Abstract: With increasing human development encroaching on wild areas, an understanding of the interactions of wildlife in their natural surroundings is becoming imperative. Over the past few decades, a concern for the conservation of herpetofauna throughout the world has become prevalent. Lack of information on reptiles and amphibians have raised many questions on the effects of roads on their populations. In this study, snake movements on roads in a mostly natural area were examined. Individuals of the copperhead snake (*Agkistrodon contortrix*) were studied in the Land Between the Lakes National Recreation Area (LBL) in Kentucky. LBL is a 170,000-acre federally protected area between Kentucky Lake and Lake Barkley in Western Kentucky and Tennessee. On a typical night of road cruising, over 60 percent of the snakes captured are copperheads in this area. Over two hundred individual copperheads, both alive and dead, were observed during this study from April 2002 through October 2003. Males and females exhibited different frequencies of movements, while juveniles exhibited different frequencies of movements when compared to adults. Road-crossing sites were not random, showing a preference toward less maintained roads with a denser canopy cover. Slightly more snakes were found dead on the road (DOR) than alive on the road (AOR). Significantly higher percentages of DOR were also observed on the highly traveled road as compared to the less maintained roads. Thus, a concern arose with the high numbers of road mortality observed because even though the snakes preferred to cross in areas of low traffic and more cover, significantly higher mortality was seen on the high speed and high traffic road. With LBL being a fairly undisturbed area, this poses a concern for the survivability of the copperhead, along with other wildlife, in more densely populated areas.

Introduction

Movement in relation to habitat preferences is vital to the understanding of the ecology of many organisms. Studies of this type on how an organism relates to its environment can provide great insights into the biology of the species as a whole. Conservation efforts rely on these studies in order to create management plans for species or populations of special concern. Whether the reason for concern is natural or man-made, this holds true for snakes, as well as any other organism (Langley et. al. 1989; Bernardino and Dalrymple 1992; Bonnet et. al. 1999). Natural disasters, such as hurricanes, along with man-made issues, such as rapid development and overpopulation, are inevitable when working with any organism. When these issues arise, there is a need for knowledge of the natural history of the organisms affected to ensure their survival.

Snake movement has long been of interest and knowledge of which has increasingly become essential in the conservation of both common and threatened species. Due to their cryptic nature and the difficulty of locating them in their natural habitat, pertinent studies have lagged behind those of other vertebrate groups (Cross and Petersen 2001). Most movement is assumed to be associated with the attainment of resources such as prey, shelter, and hibernacula, as well as for purposes of reproduction (Pough et. al. 2001). Problems associated with the study of snake movement are attributed most often to two general factors: difficulties in the methodologies used to study movement in snakes (Cross and Petersen 2001), and the lack of relatively undisturbed natural areas in many regions. The latter problem, in particular, applies to many large snake species (Whitaker and Shine 2000).

Much of what we know now about snake movement has been derived from just a few sampling methods. Since the 1930's, one of the most widely used techniques for herpetological studies is known as "road-running" or "road cruising," (Klauber 1939; Dodd et. al. 1989; Bernardino and Dalrymple 1992; Pendley 2001). This involves driving along roads in search of animals that are crossing or thermoregulating along the roads. There are some limitations to road cruising, however. There are species or individuals who are more or less likely to cross roads (Shine et al. 2004), which can lead to potentially false population estimates. Also, direction of movement might be skewed due to human presence when coming upon an animal. Animals found dead on the road may also not have been moving in the direction they were found. Despite its limitations, road cruising is still a powerful tool. Since roads are open spaces, it is easier to see the animals than sampling in grassy or wooded areas, particularly in studying nocturnal animals (Dodd et. al. 1989; Bernardino and Dalrymple 1992). Road cruising can also provide estimates of road mortality rates within the study area (Dodd et. al. 1989; Bernardino and Dalrymple 1992, Shine et. al. 2004).

In many parts of the world, the lack of fairly undisturbed, natural areas can further complicate the study of snake movement. Many areas are highly developed, which has resulted in persecution and road mortality (Langley et. al. 1989; Bernardino and Dalrymple 1992; Bonnet et. al. 1999; Whitaker and Shine 2000). It is ironic that one technique used to study and collect snakes (road cruising) is the result of intrusion into their natural environment and is largely responsible for habitat loss and mortality. With such rapid development across the world, it is often difficult, therefore, to study any animal in its truly "natural" surroundings. Protected areas can provide insights as to how animals may behave in undisturbed areas, while studies in developed areas can provide information on the adaptability of an organism to human activities.

With a broad distribution across the easterly United States, the copperhead, *Agkistrodon contortrix*, may prove to be of particular interest in the study of snake movement. Its relative abundance across this range is highly variable, with many areas in which it is considered rare, and others where it may be one of the most abundant snake species (Fitch, 1960; Gloyd and Conant, 1990; Conant and Collins 1998). Copperheads are found in a range of habitats throughout their geographic range including coastal marshes, mixed deciduous forest, and pine forests, and some have also readily adapted to human habitats (Fitch and Shirer, 1971; Conant and Collins 1998).

One area in which the copperhead is particularly abundant is the Land Between the Lakes National Recreation Area in Kentucky and Tennessee (figure 1). LBL is a 170,000-acre federally protected area between Kentucky Lake and Lake Barkley (Lynn 1994). This area can provide an exceptional source of baseline population data for many species because of its relatively undisturbed nature. Since there are several roads that are found throughout LBL, this area can also provide some insight into snake behaviors in relation to roads. This study focuses on the location and road types at the crossing sites of copperhead snakes, as well as looking at mortality of these snakes in association with these roads.

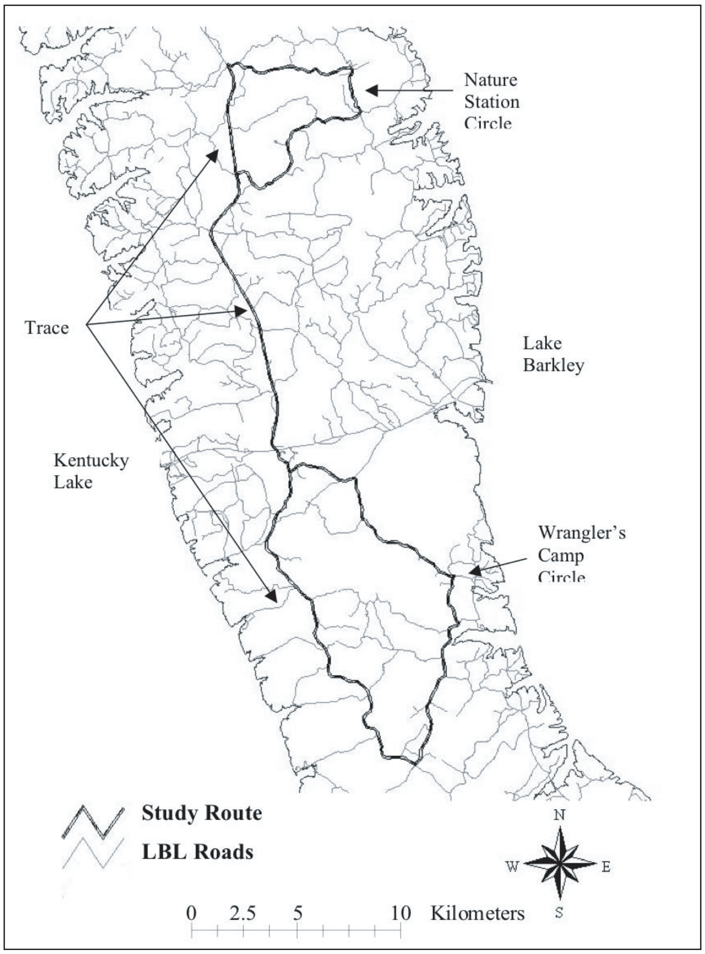

Figure 1. Map of study area in the Land Between the Lakes National Recreation Area, Kentucky.

Methods

Copperhead seasonal movement patterns along roads were evaluated along LBL roads from April 2002 through October 2003. These routes were the Nature Station Circle (Mulberry Flat Road and Silver Trail), Wrangler's Camp Circle, and the Trace connecting the two (figure 1). Data were collected by road cruising between dusk and dawn (Bernardino and Dalrymple, 1992; Pendley, 2001). Vehicle speeds did not exceed 40 km/h during collection. Select road routes within LBL were sampled between the months of April and October.

For each date of data collection, start time, ending time, temperature, rainfall, wind, sun and moon rise, sun and moon set, moon illumination, distance traveled, and average speed were recorded. Live snakes were bagged and taken in for measurements, marking (scale clipping (Brown and Parker, 1976b)), and sexing. Data from road-killed snakes were recorded on site. For each data point, time of observation, location, status (alive on road (AOR) or dead on road (DOR)), sex, recapture, UTM points, direction traveled, scale clip number (AOR or recapture only), snout-vent length (SVL), total length, and release date and time (AOR only) were recorded. A juvenile was defined as any copperhead that is under 35 cm where sex could not be determined without probing. Also, for individuals that size or smaller, there is little likelihood of that individual being older than one year, thus not sexually mature (Fitch, 1960). An unidentifiable individual was either an AOR who avoided capture or a DOR and crushed to the point that sex was indeterminable.

Global Positioning System (GPS) Universal Transverse Mercator (UTM) coordinates were taken at five-kilometer distances beginning at the north end of where the Wrangler's Camp Circle and Trace meet and ending at the southern point of where the Nature Station Circle and the Trace meet using a Garmin™ E-Trex Venture GPS unit (Garmin Ltd. Taiwan) (figure 2). This was done in order to provide reference areas along the route for later statistical analyses of snake observation location data. At each point of observation, GPS coordinates were also recorded. Coordinates were recorded monthly from April through October. They were then uploaded and plotted on maps using ArcInfo™ and ArcView™ software

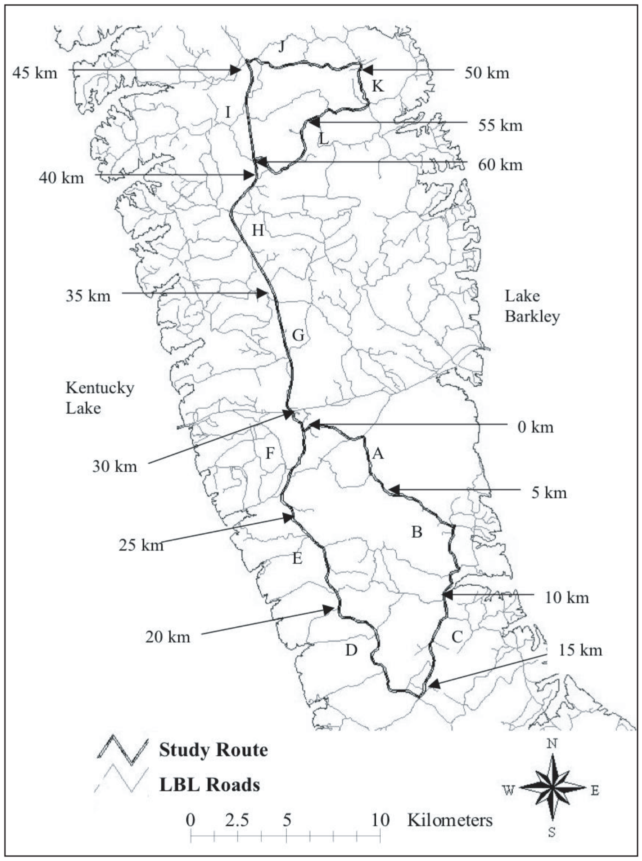

Figure 2. Distance at 5 kilometer intervals along the study route beginning at Wrangler's Camp Circle and ending at the end of the Nature Station Circle. Each letter signifies a section used in analysis.

Results

Three hundred seven copperheads were observed within the study areas. Only one animal was recaptured throughout the entire study. One hundred six males, 102 females, 46 juveniles, and 53 unidentifiable individuals were observed. The numbers of snakes observed per month, dividing observations between males, females, juveniles, and unidentifiable individuals is illustrated in figure 3. The average percentage of observations per month for each was 34.2% for males, 36.1% for females, 14.5% for juveniles, and 15.2% for the unidentifiable specimens. The number of males and females observed were fairly uniform. A chi-square analysis of the total observations of males and females showed no significant difference between the numbers of each observed (α=.05; p=.782; Chi-Square value=.077). However, when comparing males and females within months, chi-square analyses indicated that significantly higher numbers of males than females were observed in August (α=.05; p=.046; Chi-Square value=5.70).

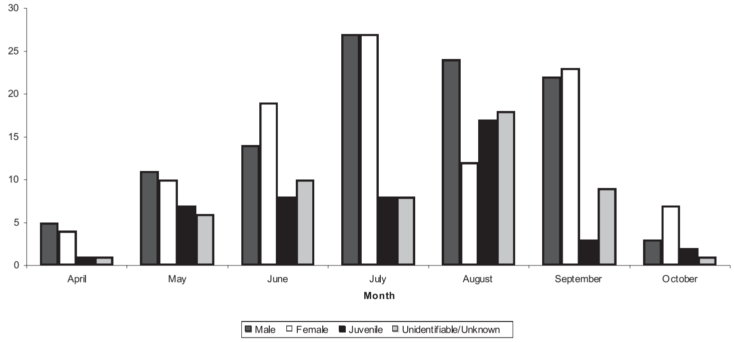

Figure 3. Number of male, female, juvenile, and unidentifiable copperheads observed per month.

Road crossing of the snakes was not uniform across sites. In a comparison between crossing sites, a chi-square analysis (α=.05) indicated that the snakes had different frequencies of crossing sites between the five-kilometer reference areas, suggesting non-uniform movement (p<.001; Chi-Square value=103.32). Snakes were found most often within reference areas A through D (located on the Wrangler's Camp Circle) and within area K (located on the Nature Station Circle) (See figure 2 for reference areas), with area A and B with significantly higher observations than the other reference areas and E, H, I, and L with significantly lower observations (Scheffé-type post-hoc test; Dunn critical value=2.94; α=.05; Chi-Square values=54.7 (A), 16.3 (B), 5.24 (E), 9.49 (H), 6.19 (I), and 7.21 (L)).

Seasonal variation in crossing sites was also seen (figure 4). Significantly more animals were found on the Wrangler's Camp Circle than the Trace in June, July, and August (Scheffé-type post-hoc test; Dunn critical value=2.77; α=.05; Chi-Square values=48.1, 24.4, 50.8). Significantly more observations of animals on the Nature Station Circle than on the Trace were also seen in June, July, and August (Scheffé-type post-hoc test; Dunn critical value=2.77; α=.05; Chi-Square values=14.3, 11.6, 21.8), however, more animals were observed on the Trace than on the Nature Station Circle in September (Scheffé-type post-hoc test; Dunn critical value=2.77; α=.05; Chi-Square value=12.3). When compared, there were significantly more snakes observed on the Nature Station Circle in June (Scheffé-type post-hoc test; Dunn critical value=3.15; α=.05; Chi-Square value=14.85), while more were observed on the Wrangler's Camp Circle than the Nature Station Circle in August (Scheffé-type post-hoc test; Dunn critical value=3.15; α=.05; Chi-Square values=15.9).

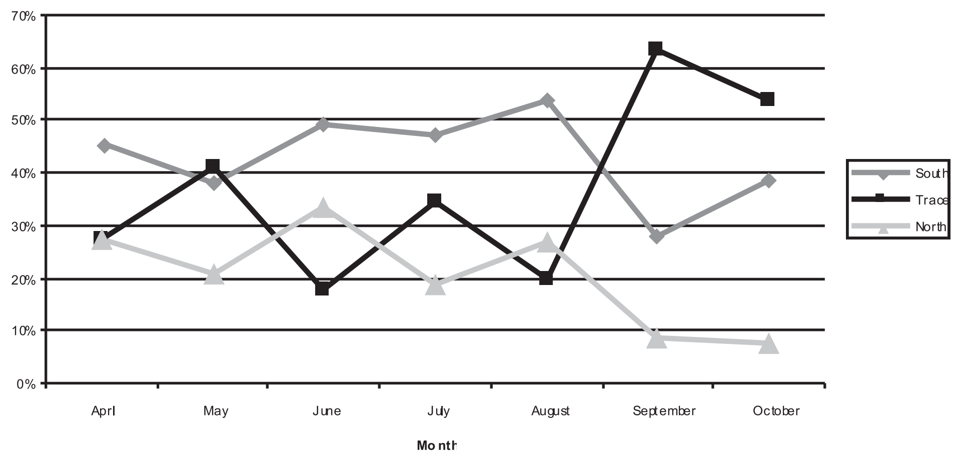

Figure 4. Percent snakes observed along the Nature Station Circle, Wrangler's Camp Circle, and the Trace per month.

The overall percentage of snakes found AOR compared to DOR was close to equal (48.3% AOR and 51.7% DOR) (figure 5). The frequency of those found AOR compared to DOR, however, varied significantly within August and September (Chi-Square test α=.05; p=.0436, p=.0243). Due to small sample size, April and October were subjected to an exact binomial test and were not significant (α=.05; p=.558, p=.267,). Snakes observed in August showed 24% lower DOR observations (p=.044). The percentage of DOR snakes found in July and September were 20% and 21% higher (p=.094, p=.024, respectively).

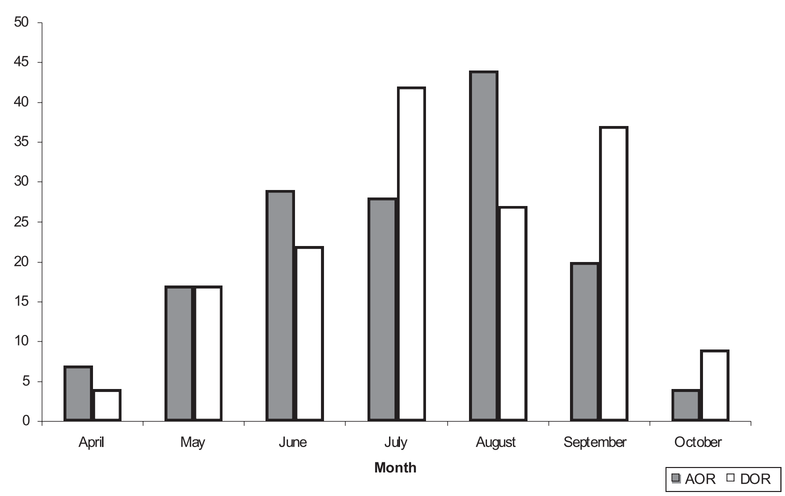

Figure 5. Monthly AOR and DOR observations for Agkistrodon contortrix.

A difference in frequency of DOR snakes compared with AOR snakes was noted within the reference areas (figure 6). There were significantly higher differences in percentages of DOR snakes were observed within reference areas D, E, F, H, and I, all along the Trace (Chi-Square test α=.05; p=.002, p=.0001, p=.0001, p=.0063, p=.0008). In contrast, significantly more AOR snakes were observed in reference areas K and L within the Nature Station Circle (Chi-Square test α=.05; p=.0008, p=.0210). There were no significant differences between AOR and DOR snakes observed within reference areas A, B, C, G, and J (Chi-Square test α=.05).

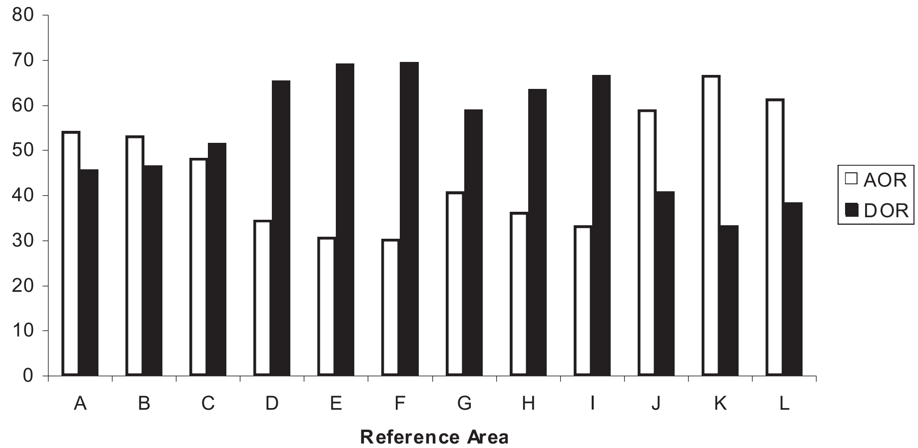

Figure 6. Percentage AOR and DOR per reference area.

Gender and age with reference to the AOR/DOR status were also observed (figure 7). Males and females did not show a significant difference in status when all months were pooled (Chi-Square test α=.05, p=.133), but were significantly different in May and July, where males were more likely to be found DOR (Chi-Square test ?=.05, p=.0156, p=.0038). There was a significant difference between adults and juveniles when all months were pooled, where juveniles were more likely to be found AOR (Chi-Square test α=.05, p=.0239). In July, in particular, adults were more likely to be found DOR than juveniles (Chi-Square test α=.05, p=.0024).

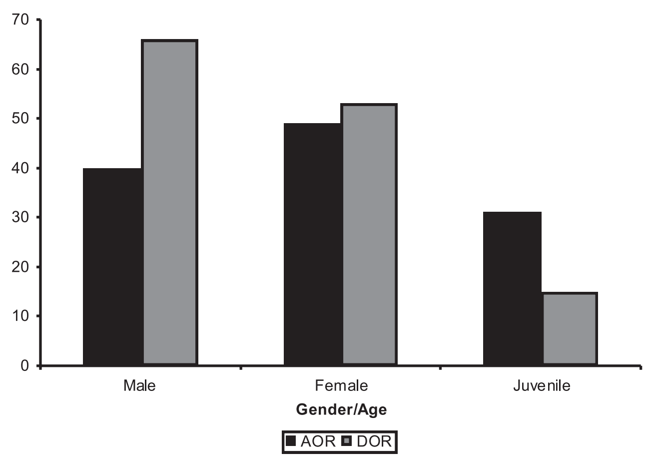

Figure 7. Gender and Age Differences in AOR and DOR snakes observed.

The average copperhead snout-vent lengths (SVL) within each month are illustrated in figure 8. An ANOVA (α=.05) and Tukey comparison were used to determine differences between the monthly average SVL of the copperheads. The average SVL of the snakes observed in April and in September were significantly greater than the average SVL of the snakes observed in the remaining months (p<.001). A Spearman's Rho Correlation was also computed between average SVL and the air temperature on observation nights, showing a significant negative correlation between the two variables (α=.01, correlation value=.40, p<.001). It showed that the warmer the air temperature was, the better the chances of finding a smaller sized snake.

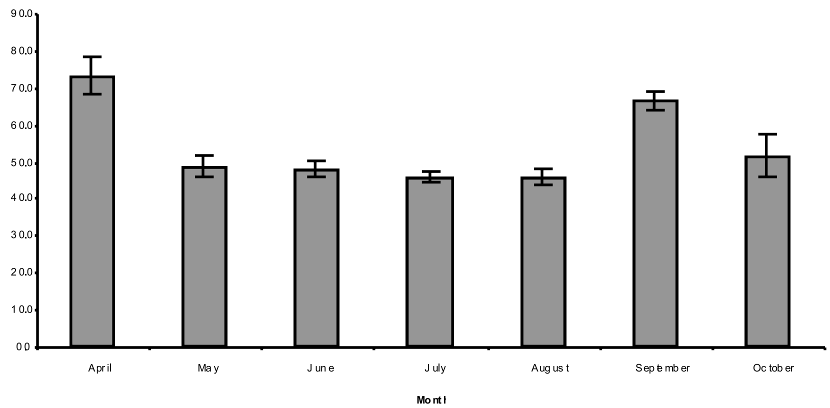

Figure 8. Mean snout-vent lengths of *Agkistrodon contortrix* observations per month.

Discussion

Movement

The majority of copperheads were observed from late spring to early fall. Observations began in April and continued through October. Since there was only one recapture, however, population size cannot be accurately estimated. Nevertheless, with the large number of individuals observed, it can be postulated that LBL contains a large and healthy population. Accounting for around fifteen percent of the total captures, the numbers of juveniles observed can also be seen as an indication of high recruitment into the population. Fitch (1960) noted that in a sample of 637 copperheads collected in eleven seasons, 213 (33%) were juveniles under 40 cm. However, this sample was taken in the fall when the females had finished birthing and when most snakes in this population had returned to the hibernacula, providing a concentration of the population.

The non-random locations of the road-crossing sites are due mostly to the road type at those sites. The roads with significantly more crossing sites are less maintained than those with fewer sites. Most individuals were found on secondary roads associated with the Nature Station and Wrangler's Camp Roads with a corresponding dearth of sightings along the main north/south road, the Trace. Significantly more snakes were observed in areas A and B along the Wrangler's Camp Circle, while significantly fewer were observed along the Trace in areas E, H, and I, as well as one section of the Nature Station Circle (area L). Area L on the Nature Station Circle connects directly to the Trace and is highly traveled, as it is the most direct route to the Nature Station where multiple programs are offered during the year. The Trace, which connects the two areas, is a more heavily traveled road with wider shoulders and verge (Mandt, 2004). The edges of the Trace are mowed, with much wider verge than the other roads, and much less, if any, canopy cover (Mandt, 2004). This may contribute to the lower number of sightings due to lack of cover and potential dangers. However, data for other snake species (including smaller snakes such as the earth snake, *Virginia valeriae*) do not show this pattern (Mandt, 2004).

The Wrangler's Camp Circle and Nature Station Circle have at least some canopy cover and smaller verge than the Trace (Mandt, 2004). The slight increase in observations along the Trace during late season months may be a reflection of less shading in the other areas. Due to the colder weather late in the season, the more open canopy areas could also provide more sites for basking, thus providing a thermoregulatory advantage. This increase could also be due to late season searching for hibernation sites.

Road Mortality

The numbers of snakes found AOR versus DOR were fairly even throughout the season. A trend was seen toward an increase in DOR in July and September, but was not significant. This does, however, correspond with high traffic time between July and September in the LBL region, where an average of about 1.5 million people annually visit the park (Schmittou pers. com. based upon 2003 records). The significantly higher percentages of DOR snakes along the Trace, while significantly more AOR snakes were found within the Nature Station Circle, raises concern for the more traveled roads, as well. Such high mortality in a population is of special concern in a National Recreation Area where the balance between recreational use and wildlife welfare must be considered.

There were no significant differences in the number of males and females observed each month except in August. Gravid females tend not to move as much and may have spent most of August in a very small area, not traveling near the roads (Fitch, 1960; Sanders and Jacob, 1981). It is not known if females breed every year, thus the non-gravid females could have continued moving throughout the season while the gravid females remained in smaller home ranges for the other months (Sanders and Jacob, 1981). Since copperheads in this area do not use communal hibernacula in this area, the use of hibernacula for birthing is most likely not prevalent in this population (Zimmerer, pers. obs.). The significantly higher amount of DOR male snakes could be because male copperheads tend to move more frequently and have larger home range sizes than females (Fitch 1960, Fitch and Shirer 1971). Juveniles also tend to stay close to the area where they were born and have much smaller home range sizes than adults, which could explain the higher percentage of AOR as compared to adults (Fitch 1960).

Summary

Copperheads in the LBL region seem to follow similar behaviors as other populations of copperheads throughout their range. The population begins movement in early spring and continues through late fall. The patterns of activity observed appear to be unimodal, with activity beginning slow in early spring with a single crest of activity between late spring and late summer and tapering off in the fall (Moore, 1978). These activity patterns fit into the three general types of movements described by Fitch (1960), which include travel within a home range, travel to a new home range, and seasonal travel to and from a hibernaculum. Travel within home range, since it is the primary reason for movement, can explain the majority of the observations. Travel to a new home range, while it could explain some of the movement, cannot be determined without long-term telemetry data, or at least recapture data. Seasonal travel to and from hibernaculum, or in the case of this study, hibernation sites, may explain the early and late movements, particularly in the areas that differ significantly between the early and late months and the mid-summer months.

The road-crossing site data showed that these snakes probably have a preference for less developed areas, even though they have shown adaptability to human development (Fitch and Shirer, 1971; Conant and Collins, 1998). The Wrangler's Camp Circle and the Nature Station Circle, while less traveled than the Trace, are still frequented by visitors and the prevalence of the copperhead in these areas shows that these animals still thrive even with human activities.

The road side along the Trace has little to no cover protection. Copperheads have a preference for deciduous or mixed pine-deciduous forests in both rocky areas and areas of high ground cover (Gloyd and Conant, 1990). This is much more common around the Wrangler's Camp Circle and the Nature Station Circle. The areas along the northeastern edge of the Wrangler's Camp Circle and the easternmost edge of the Nature Station Circle showed the highest numbers of observations throughout the year, indicating that the amount of cover over the roads is important to whether or not snakes will cross a road at a particular point.

Probably the most disturbing results of this study were the high number of DOR snakes collected. This is a huge percentage of DOR snakes compared to AOR ones, even considering that dead snakes cannot escape capture. One must add, however, the potential of scavengers picking up dead snakes, thus removing individuals from the roads, and decreasing the DOR potential bias. All the reference areas along the Trace showed more DOR snakes than AOR snakes, indicating that this road in particular is an area of concern for mortality of all different species. Other studies have shown similar road mortalities and worse. In the Pa-hay-okee Wetlands in the Everglades National Park, it was discovered that seventy-three percent of all snakes observed in the main road of the park were either injured or dead (Bernardino and Dalrymple, 1992). Road mortality is becoming an increasing concern for protecting all species. If mortality such as this occurs in a protected area, it implies that unprotected areas are of an even greater threat to wildlife. Further road mortality studies are essential to this and other species conservation.

This study provides a template for management and for future studies of the copperhead in the LBL area. The lack of development within LBL provides fairly undisturbed habitat, with the exception to roads. With rapid human development infringing on wild areas, an understanding of the interactions of wildlife in their natural surroundings is becoming crucial to the conservation of both flora and fauna. The concern for the conservation of reptiles throughout the world has become prevalent in the recent past and the lack of information has raised many questions on their natural history (Gloyd and Conant, 1990; Cross and Petersen, 2001). Without the emphasis on the interactions of organisms and their environment, proper management of species cannot be executed. Studies such as this can be utilized to understand portions of natural history and can be applied to the conservation and management of species.

Biographical Sketches: Valorie Titus obtained her B.S. from Cazenovia College in 2001 and her M.S. in biology from Murray State University in 2006, where she studied road usage patterns of the copperhead snake in western Kentucky. She is currently a Ph.D. candidate at Binghamton University in the Department of Biology.

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