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The effect of road type and traffic intensity on amphibian road mortality

Abstract
Motor traffic can be a major cause of mortality for some species. Dispersing organisms may be hindered in landscapes with roads because they are more likely to come in contact with roads or even cross roads, and therefore these species may be more vulnerable to traffic mortality. In order to quantify the effects of vehicular traffic on the seasonal dispersal of amphibians and to better understand the implications of road kills on amphibian populations, an amphibian road mortality census was performed. The road mortality census was conducted along four 1-km sections of paved and unpaved roads within Land Between The Lakes National Recreation Area, KY. Roads were categorized as (1) two-lane, paved highway (2) two-lane, paved scenic road (3) gravel, off-highway road and (4) dirt and gravel side road. Traffic intensity was quantified as the amount of vehicles per hour for each studied section of road. Traffic volume was used as an index of the amount of potential amphibian road mortality, and the numbers of dead and live frogs, toads, and salamanders were counted along each 1-km segment of the roads to examine the potential relationship between road mortality and traffic intensity. As expected, the two-lane, paved highway on US 68/80 had the most traffic and also the greatest percentage of dead amphibians. On the other hand, the percentage of living amphibians was significantly related to the wetness index of each site and the air temperature. My results suggest that percent increases in traffic volumes may be a driving force negatively affecting amphibian populations in Land Between the Lakes National Recreation Area.

Introduction

Recently, there has been concern about amphibian declines around the world and the possible cause for such declines (Blaustein & Wake, 1990; Wyman, 1990; Blaustein et al., 1994). Several factors have been proposed as contributing to the declines of amphibians. Such factors include habitat destruction, the introduction of predators and exotic species, climate change, increased UV rays, pathogens, human consumption, pollution and pesticides, and natural population variability (Blaustein et al., 1994). Still, there seems to be a consensus about the fact that anthropogenic activities are responsible for many of the declines (Hels & Buchwald, 2001). Road mortality is an important factor that may be affecting amphibian declines, however few studies have addressed this issue (Fahrig et al., 1995; Hels & Buchwald, 2001).

Roads and road traffic may directly and/or indirectly affect animals. Direct impact causes immediate death or injury for amphibians (van Gelder, 1973; Kuhn, 1987; Wyman,1991; Ashley & Robinson, 1996). Indirectly, roads may increase animal mortality by affecting animal behavior, reproduction capabilities, fragmenting their habitat, exposing animals to harsh climates and substrates, exposing animals to chemicals, and roads may serve as a physical barrier and isolate populations (Mader, 1984; deMaynadier & Hunter, 1998; Hels & Buchwald, 2001). Furthermore, as Fahrig et al. (1995) mentioned, traffic volumes and density have increased greatly over the past two decades. Therefore, it may be presumed that mortality and injury inflicted by vehicles has increased with increased traffic.

Past studies have shown that roads can have major detrimental effects on amphibians. A study conducted on highway related toad mortality in a state nature reserve in the Netherlands reported 29% mortality for females crossing an asphalt road during breeding migration (van Gelder 1973).

Seibert and Conover (1991) performed a 14-month road-kill count of vertebrates and invertebrates on a dual highway in Athens County, Ohio, and they found that approximately 40% of the victims were amphibians. Wyman (1991) reported average mortality rates of 50.3% to 100% for salamanders (red-spotted newts and redback salamanders, respectively) attempting to cross a paved rural road in New York, and suggested that individual salamanders generally fare worse than frogs because they are slower moving and often "freeze" in response to approaching vehicles (as reported by deMaynadier and Hunter 1998). Ashley and Robinson (1996) recorded road mortality for >32,000 individuals over a 3.6 km two-lane road for a period of 716 days. Amphibians accounted for 92.1% of the total road mortality.

Considering the potential negative impacts of traffic intensity on dispersing amphibians, I decided to quantify the numbers of alive versus dead amphibians on roads of various substrates and traffic intensities within Land Between the Lakes National Recreation Area, KY (LBL). LBL is a natural recreation area where road expansion is projected to occur in the near future. The results of this study could aid in understanding the potential environmental impacts of road expansion on amphibian populations within LBL.

Methods

Site

Land Between the Lakes National Recreation Area consists of 170,000 acres in Lyon and Trigg counties, and it extends from western Kentucky to Tennessee between Kentucky Lake and Lake Barkley (Figure 1). It is actively managed by the USDA Forest Service, and its wildlife are managed in cooperation with the U.S. Fish & Wildlife Service, Kentucky Department of Fish & Wildlife Resources, and the Tennessee Wildlife Resources Agency. LBL is 89% forested, largely made up of oak and hickory, which makes it one of the largest contiguous blocks of forested land between the Mississippi River and Great Smoky Mountains (USDA Forest Service, 2002). The forest floor within LBL provides excellent habitat for terrestrial salamanders and woodland frogs. Also within LBL are over 500 small ponds (permanent and temporary) that have the potential to provide homes and/or breeding sites for a variety of amphibians (Scott et al., 1999). The bordering lakes, Kentucky Lake and Lake Barkley, may also provide habitat to amphibians.

I selected four 1 km road sections within LBL based on their substrate, level of traffic intensity, and similarity in surrounding habitat type (Figure 2). Section 1 is found on US 68/80, a two-lane

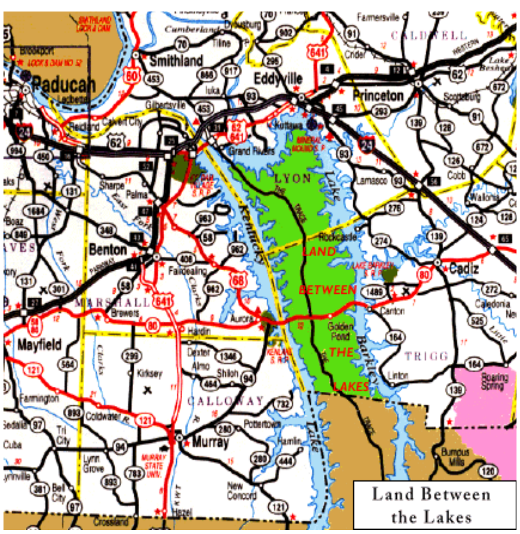

Fig. 1 Land Between the Lake National Recreation Area

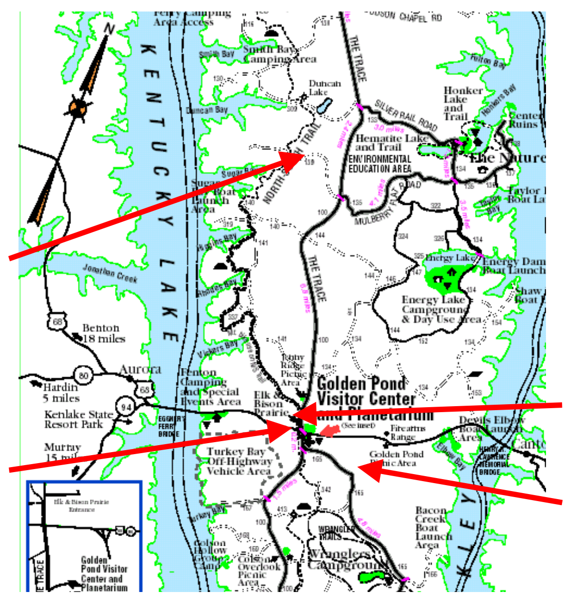

Fig. 2 Study sites within LBL

paved highway with a concrete median. Open fields, hardwood forests, roadside ditches, and a small permanent pond (Golden Pond) surround it. Section 2 is found on the north end of the Trace, a two-lane paved scenic road that is found between the visitor's center and the elk and bison prairie entrance. Section 2 is surrounded by hardwood forests, open roadside verges, roadside ditches, and three permanent ponds (Visitor's Pond, Golden Pond, and a pond at the entrance to the elk and bison prairie). Section 3 is found on a gravel road, located near Wrangler's Camp on the southern side of LBL. The habitat surrounding section 3 consists of open fields, hardwood forests, roadside ditches, and a small stream.

Data Collection

On ten evenings, between 2030 and 230 h, during the spring breeding season between 14 February and 6 April 2003, I traversed the four selected road sections and counted all dead and live frogs, toads, and salamanders along the 1 km sections of road. Amphibians were identified to species level and sex was also recorded (if identifiable). Vehicular traffic rates were recorded as the number of vehicles per hour, during the time of the census. The recorded observations occurred during nights with air temperatures of 40^{O}C or higher and with wetness conditions ranging from wet roads to heavy rain, since migratory behavior is constrained by the demands of water balance and thermoregulation (Pough et al., 2001). To account for the extended time taken to complete all four censuses during any given night, the order of censusing for each site was rotated for each night.

Data Analyses

All statistical analyses of the data obtained from the study were performed using Minitab™ statistical software. One-way Analysis of Variance models were used to examine the relationships between alive and dead amphibians to the wetness indices, temperatures, and sites. Multiple regression analyses were run with alive and dead amphibians as the models and temperature, traffic intensity, and the number of alive or dead amphibians as the predictors.

Results

In total there were 185 dead and 351 live amphibians, representing eleven species, recorded over the 10 nights studied. Four of the eleven species were victims to road mortality. The number of alive amphibians were significantly (α=0.05) different among the wetness indices (P = 0.005) and temperatures (P < 0.001) (Figures 3-4). Still, there was a significant difference in the number of dead animals according to the different

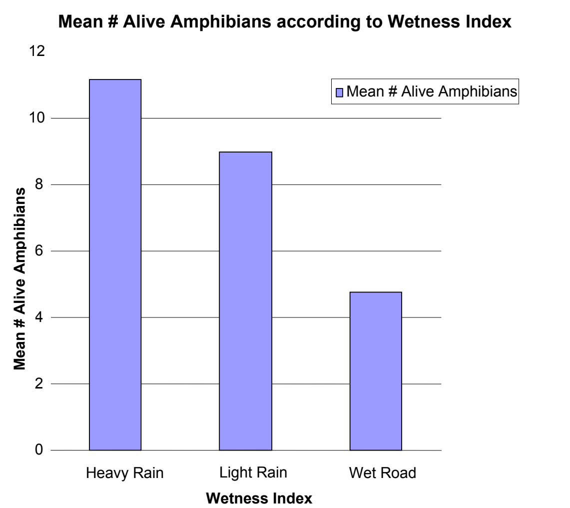

Fig 3. The mean number of alive amphibians according to each wetness index

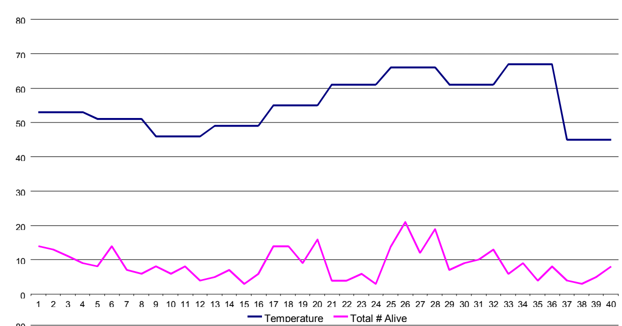

Fig. 4 Trends in temperature change and the amount of alive amphibians at each site

sites (P < 0.001) (Figure 5). Regression analyses showed that the number alive (P = 0.001) and the traffic intensity (P < 0.001) were significant predictors for the number of amphibians dead (R = 0.61) (Figures 6-7).

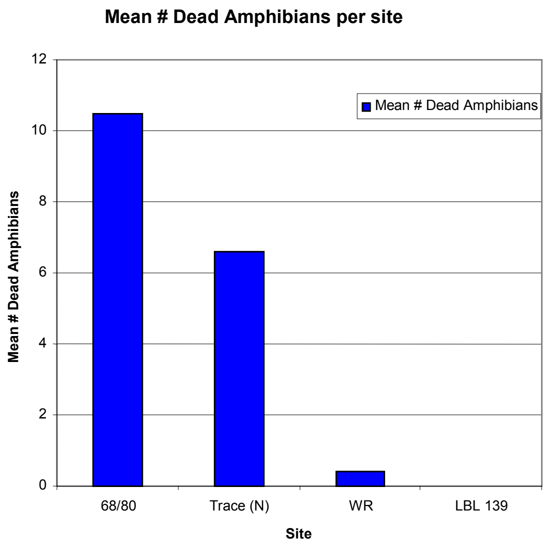

Fig. 5 The mean number of dead amphibians for each site

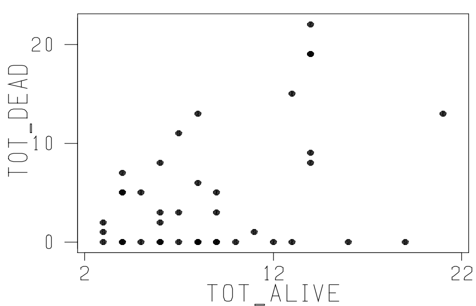

Fig. 6 Scatterplot of the total number dead amphibians against the total number of alive amphibians

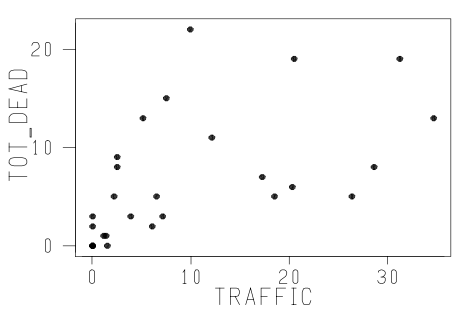

Fig. 7 Scatterplot of the total number dead amphibians against the traffic intensity

Discussion

My results provide evidence that traffic exerts a negative effect on amphibian populations within Land Between the Lakes National Recreation Area (LBL). Roads that had higher traffic rates also had a higher amount of amphibian mortality. Roads have been shown to affect movement, dispersal, and population density of many species (Fahrig et al., 1995; Hels & Buchwald, 2001). The fact that there was a higher proportion of dead frogs, toads, and salamanders on the highly trafficked roads suggests that differential road mortality may contribute to the observed differences in amphibian abundance (Fahrig et al., 1995). Other road and traffic-related variables, such as pollutants and toxins in road run-off, exhaust emissions, temperature differences in substrate, noise and vibrations, may also affect amphibian densities either by causing direct mortality or interrupting amphibian behavior or physiological processes (Buchanan, 1993).

Fahrig et al. (1995) suggest that there are two approaches to studying the effects of human and environmental impacts on natural populations. One can either study a population or populations over time, during the course of impact, or spatially, by examining different levels of impact over a wide area. I used the second method, a spatial impact assessment, to examine differences in road mortality over different road types with varying vehicular traffic rates and road size variables. This approach may prove to be useful when studying amphibians, because their numbers are naturally variable over time, and long-term studies (though very helpful) may be unrealistic for conservation studies in which answers are without ado (Fahrig et al., 1995).

As recent evidence has shown that amphibian populations are likely to be declining, road mortality may be a factor contributing to these declines (Blaustein & Wake, 1990; Wyman, 1990; Blaustein et al., 1994). My data suggests that it is most beneficial for amphibians to take the road less traveled (pun intended!). Road widening and expansion of US 68/80 and the proposed development in western Kentucky, may increase traffic rate within LBL and may also spoil the visual appeal of the natural recreation area and increase amphibian mortality (Kentucky New Era, 2002). Potential road traffic volume increases and other forms of development near and within LBL may have serious negative consequences on amphibian populations traversing these areas in order to travel between overwintering and breeding sites.

There are a few suggested ways by which amphibian road mortality could be reduced. Barriers, in conjunction with underpasses or toad tunnels could separate vehicles from amphibians, while allowing amphibians to travel between different habitats. One concern with this approach is that predation may be increased by funneling both predators and prey through the underpass or tunnel, which may shift the amphibian mortality from being traffic-related to predation (Fahrig et al., 1995). Another possibility would be to educate and alert drivers of areas of concern, where amphibians have been recorded crossing. Frog and salamander crossing signs could alert drivers of these special areas of concern, and they may also contribute to more cautious driving throughout the LBL area, which may reduce other wildlife mortality and traffic accidents. Nevertheless the effectiveness of such signs may want to be examined. Nevertheless, this approach combined with barriers and toad tunnels or underpasses would probably minimize road and vehicular traffic-related effects on amphibian populations.

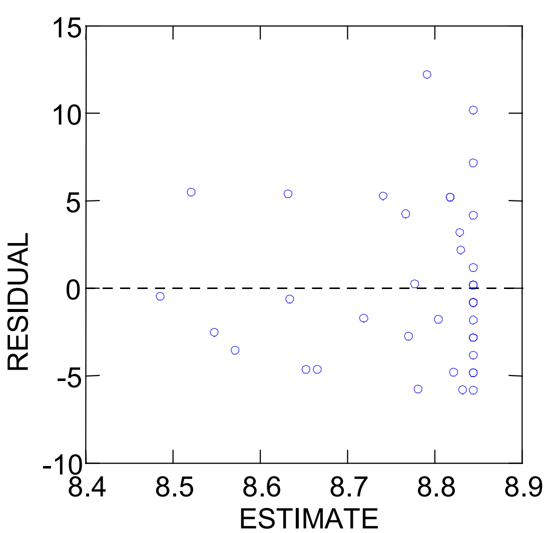

Fig. 8 Plot of residuals against predicted values

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