PRELIMINARY EVALUATION OF THE IMPACT OF ROADS AND ASSOCIATED VEHICULAR TRAFFIC ON SNAKE POPULATIONS IN EASTERN TEXAS

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Abstract

Roads and associated vehicular traffic have often been implicated in the decline of snake populations. Radio-telemetry studies have documented vehicle related mortality as a factor in Louisiana pine snake (*Pituophis ruthveni*) and timber rattlesnake (*Crotalus horridus*) populations in eastern Texas. The hypothesis that existing road networks depress populations of large snake species was tested using a trapping protocol to sample snake populations at five distances from road corridors: 50, 250, 450, 650, and 850 m. Results suggest that populations of large snake species are reduced by 50% or more to a distance of 450 m from roads with moderate use. There was no indication that trap captures had reached an asymptote at a distance of 850 m. On a landscape scale, quantification of the density of the road network suggests that populations of large snakes may be depressed by 50% or more across eastern Texas due to road associated mortality.

Introduction

Roads and associated vehicular traffic have increased enormously during the last several decades. Adams and Geis (1983) estimated that the United States contained 6.3 million km of roads occupying 8.1 million ha. The impact of these very high densities of roads and vehicular traffic on vertebrate populations is poorly known, but presumed to be substantial (Bennett 1991). Lalo (1987) estimated vertebrate mortality on roads in the U. S. at one million individuals per day.

Reptiles, including snakes, are particularly vulnerable to mortality associated with roads due to their slow locomotion, their propensity to thermoregulate on road surfaces, and intentional killing by humans when observed on road surfaces. The magnitude of reptile mortality is high (Ashley and Robinson 1996, Fowle 1996, Rosen and Lowe 1994, Ruby et al. 1994), but the population impacts of this mortality are not well known. Impacts are presumably species specific. Species exhibiting low reproductive rates and low adult mortality are often identified as being particularly vulnerable to population consequences of road associated mortality (Fowle 1996, Rosen and Lowe 1994, Ruby et al. 1994, Rudolph et al. 1998).

Road mortality of snakes has been identified as constituting a "sink" for local populations (Rosen and Lowe 1994). In eastern Texas road mortality has been suggested as the primary factor in the local extirpation of timber rattlesnake (*Crotalus horridus*) populations (Rudolph et al. 1998) and a significant cause of mortality in the Louisiana pine snake (*Pituophis ruthveni*). In order to quantify the magnitude of road associated mortality on snake populations in eastern Texas, we initiated a trapping survey of snakes adjacent to roads.

Study Area

This study was conducted on the Angelina National Forest (Angelina and Jasper Counties) in eastern Texas. The general habitat is pine forest (*Pinus palustris, P. taeda, P. echinata*) managed for timber production. A variable mixture of angiosperm tree species occurs, especially along drainages. A dense road network exists consisting of state highways, secondary highways, and U. S. Forest Service system roads.

Methods

The trapping protocol consisted of transects perpendicular to a roadway. Transects were selected, to the extent possible, to minimize habitat differences within a given transect. Traps were placed at 50, 250, 450, 650, and 850 m from the edge of the road right-of-way. Due to the density of the road network existing on the Angelina National Forest 850 m was the maximum length of transect that could be established. The entire length of each transect was at least 850 m from other roads to minimize confounding impacts to the extent possible. On occasion unmaintained "woods" roads with minimal traffic (<l vehicle/day) crossed the transect line or were within 850 m of the line. Average vehicle traffic volumes were obtained from the Texas Department of Transportation and the U. S. Forest Service.

Two transects (A and B) were established adjacent to Forest Service System Road 303 and a unsurfaced county road. These are gravel roads that are graded and maintained, and include cleared rights-of-way with drainage structures and contours. Average traffic volumes were less than 100 vehicles per day. Three transects (C, D and E) were established adjacent to Texas State Highway 63 in Angelina and Jasper Counties. Highway 63 is a paved two lane highway with paved shoulders. Average traffic volume is approximately 2400 vehicles per day.

Traps consisted of a plywood top and bottom 1.2 m X 1.2 m supported by wooden uprights 0.45 m tall. The sides were screened with hardware cloth (3.2 mm mesh). A hinged door in the top allowed access. Four funnel entrances were constructed of hardware cloth and wired into the midpoint of each side of the trap. Minimum funnel diameter was approximately 4 cm. Hardware cloth (3.2 mm mesh) drift fences were constructed of 61 cm wide strips buried approximately 10 cm in the soil. Drift fences extended 15.2 m from each funnel entrance. A water source was placed in each trap.

Four transects (A-D) were installed in January-February 1997 and a fifth transect (E) was installed in February 1998. Transects were operated during 1997 and 1998 from approximately 1 March to 31 October. Traps were checked once per week and all animals were removed. All snakes were returned to the laboratory where species, total length, and sex were recorded. PIT tags (Avid, Inc.) were implanted and snakes were returned to the capture site and released 50 m from the capture trap the week following capture. All subsequent recaptures were recorded. Recaptured individuals were included in the analyses because nearly all recaptured individuals were subsequently captured in different traps, including captures spanning the total range from traps 50 m to 850 m from road rights-of-way. For all other vertebrates, species and number were recorded, and they were released immediately.

A series of habitat measurements were taken at each trap location. Basal areas of canopy trees were determined with a 1-factor metric prism. Canopy closure was measured at the endpoint of each drift fence with a spherical densiometer and values averaged for each trap location. Percent cover of herbaceous and woody understory vegetation (to 1 m in height) was visually estimated within a 11.3 m radius circle centered on the trap midpoint. Foliage density (horizontal cover) was estimated using a density board (MacArthur and MacArthur 1961).

The distribution of snake captures among transects was compared within years by heterogeneity $?^2$. If transects were similar, we pooled data within and across years and compared trap distances with a pooled $?^2$. If the pooled $?^2$ indicated differences among trap locations, we used simple linear regression to look for a trend (positive or negative).

Results

Because the drift fences and traps were constructed using 3.2 mm mesh hardware cloth, very small species and individuals were not captured. A total of 156 individual snakes (including 18 recaptures) of 11 species was captured in 1997 (4 transects) and 156 individuals (including 21 recaptures) of 13 species were captured in 1998 (5 transects) for a total of 312 captures (Table 1). Heterogeneity ?^{2} analysis indicated that within years the distribution of snake captures was similar among transects and consequently transects were pooled within and across years. In all three cases (1997 snake captures, 1998 snake captures, and all snake captures) the pooled ?^{2} analysis indicated highly significant differences among traps at different distances from roads (Table 2). Simple linear regression was used to search for linear trends in these data. In 1997 snakes and total snakes there was a significant linear trend of positive slope (Table 2). The data for 1998 did not reach significance at the 0.05 level, however the slope was positive.

A total of 397 individuals of 28 species of other vertebrates were captured, 260 in 1997 and 137 in 1998 (Table 3). Anurans, lizards, and rodents (71, 73, and 173 individuals respectively) were the primary taxa captured. An extreme drought presumably resulted in fewer individuals being captured in 1998. These data were analyzed in the same way as the snake data (Table 2). Heterogeneity ?^{2} indicated that the transects could be pooled, and the pooled ?^{2} analysis, was not significant at the 0.05 level indicating no significant differences among traps at different distances from roads. Simple linear regression did not detect a significant linear trend in these data.

The number of individuals captured in relation to distance from road rights-of-way for snakes in 1997 and 1998, and other vertebrates in both years combined, are presented graphically in Fig. 1.

Habitat data are summarized in Table 4. The variation in habitat measures between trap locations is substantial. Regression analyses revealed only three significant linear trends in relation to distance from road corridors among the 25 instances examined (5 transects X 5 habitat variables). The significant regressions were scattered among three habitat variables and three transects, and the numerical differences within these transects were not large.

Discussion

The data support the hypothesis that snake mortality associated with roads and vehicle traffic reduces the abundance of larger snakes for substantial distances from road corridors. Snake abundance, inferred from the trap success measured in this study, is reduced by more than 50% adjacent to roads compared with the abundance 850 m from roads. For all data combined, trap success remained low up to a distance of 450 m from road corridors and then increased substantially.

The combined data did not show any evidence of reaching an asymptote at the maximum distance (850 m) from road corridors. Due to the existing road density we were unable to locate transects suitable for quantifying trap success at distances greater than 850 m. Consequently, we were unable to measure the full impact of road corridors on snake populations on the Angelina National Forest.

The combined data for other vertebrate species suggests that roads and associated vehicular traffic are not having a significant impact on populations of these other species. However, these data are numerically dominated by rodents, anurans and lizards, species characterized by short generation time, rapid recruitment, and small home ranges compared to large snakes. It is not surprising that we did not detect major impacts on these taxa given the scale at which we were sampling. These data also suggest that the effect that we observed was due to direct mortality on larger snakes, rather than an indirect impact on the prey base of snake populations.

Although substantial habitat variation occurred among trap sites, patterns paralleling the increase in snake captures with increasing distance from road corridors were not strong. Only three significant linear regressions among the 25 examined suggests that habitat differences are not responsible for the pattern of snake captures. Despite the variation in habitat, not generally correlated with distance from road corridors, significant patterns were still detected in the snake trap data.

The magnitude of the impact on snake populations was relatively similar for the high traffic volume state highway and the lower traffic volume forest service system and county roads. The reason for this similarity is not immediately apparent. It may be that snakes are so susceptible to road related mortality that even moderate traffic volumes effectively remove nearly all of those individuals whose home range, or at least core areas, include the road corridor. Traps at 50 m, and even greater distances, may only be sampling those surviving individuals whose home range did not include the road corridor. In the case of larger snakes, it may be that essentially the full impact of vehicle related mortality along road corridors occurs at relatively low traffic volumes, on the order of a hundred vehicles per day. Additional data are required to address this hypothesis in more detail.

The observed deficit in snake captures, approximately 50% out to distances of 450 m from road corridors, and the lack of any indication of reaching an asymptote at the maximum distance sampled (850 m) suggests a very substantial impact on snake populations at the landscape level. Quantification of the road system on the southern portion of the Angelina National Forest revealed that 79% of the landscape is within 500 m of a highway or Forest Service System Road. This suggests that a substantial proportion of the expected snake fauna has been eliminated across the landscape due to road related mortality.

Acknowledgements

We thank the Texas Parks and Wildlife Department and the U. S. Fish and Wildlife Service for partial support for this study through Section 6 of the Endangered Species Act. We thank M. B. Keck and R. R. Fleet for constructive comments on an early version of the manuscript and N. E. Koerth for statistical assistance. We also thank C. Collins, T. Trees, and J. Niederhofer for assistance in the field.

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TABLE 1. Numbers of snakes trapped by transect and year at 50, 250, 450, 650, and 850 meters from edge of road right-of-way.

		Trap Distance from Road (m)					
Transect	Year	50	250	450	650	850	total
A	1997	6	12	14	11	17	60
	1998	9	9	10	5	12	45
B	1997	8	1	2	10	13	34
	1998	1	2	2	2	7	14
C	1997	3	0	9	12	12	36
	1998	1	7	6	14	14	42
D	1997	5	10	1	4	6	26
	1998	3	6	0	5	8	22
E	1998	6	8	6	7	7	34
Total	1997	22	23	26	37	48	156
Total	1998	20	32	24	32	48	156
Total	1997/98	42	55	50	69	96	312

TABLE 2. Trend analysis of snakes and other vertebrates trapped at various distances from edge of road right-of-way.

Category	Heterogeneity χ^2	Pooled χ^2	Linear Trend[1]
Snakes 1997	19.6 (P = 0.080)	15.9 (P = 0.003)	P = 0.02
Snakes 1998	13.7 (P = 0.602)	14.8 (P = 0.005)	P = 0.08
Total Snakes	39.1 (P = 0.001)	28.9 (P = 0.001)	P = 0.03
Total Other Vertebrates	3.9 (P = 0.426)	9.4 (P = 0.052)	P = 0.75

[1] Probability associated with test of slope equal to zero using simple linear regression.

TABLE 3. Numbers of non-snake vertebrates trapped by year at 50, 250, 450, 650 and 850 meters from edge of road right-of-way.

	Trap Distance from Road (m)					
Year	50	250	450	650	850	total
1997*	55	55	30	55	65	260
1998	29	27	26	28	27	137
Total	84	82	56	83	92	397

* Transects A-D only.

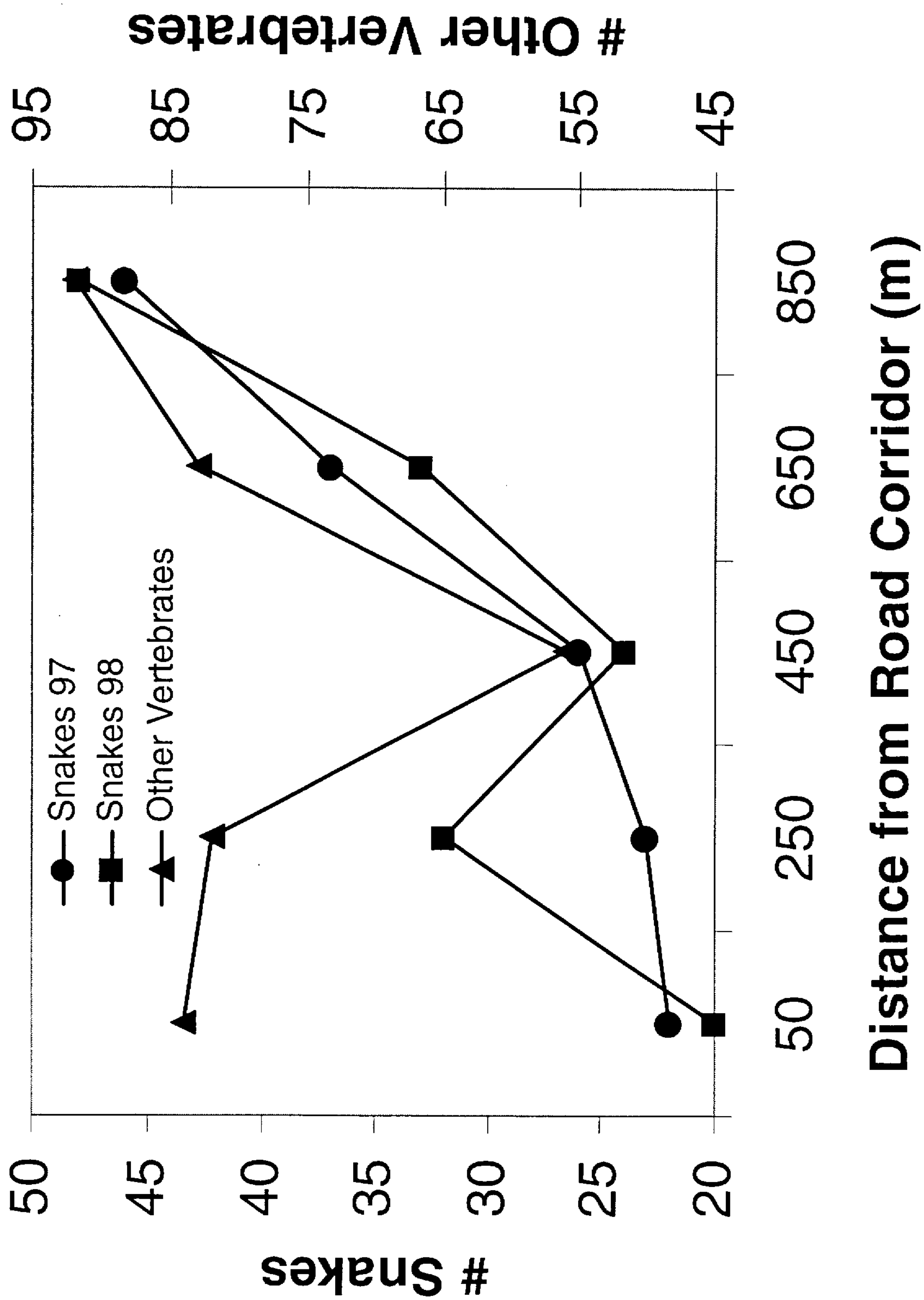

Figure 1.
Number of snakes and other vertebrates captured at 50, 250, 450, 650, and 850 m from road corridors.

TABLE 4. Probabilities associated with regression coefficients between habitat variables and distances from road rights-of-way.

Habitat Variable	Transect A	B	C	D	E
Canopy Basal Area	.3316	.3393	.3871	.0273*	.3542
Canopy Closure	.2580	.8361	.1942	.6042	.0351*
Foliage Density	.9256	.2509	.9785	.0974	.3373
% Woody Vegetation	.1553	.1933	.5594	.2920	.2075
% Herbaceous Vegetation	.6376	.5890	.3081	.0435*	.0596

* Significant regression ($P < 0.05$).