

The Impact of Roads on the Timber Rattlesnake, (*Crotalus horridus*), in Eastern Texas

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Abstract

Roads and associated vehicular traffic have the potential to significantly impact vertebrate populations. In eastern Texas we compared the densities of paved and unpaved roads within 2 and 4 km radii of timber rattlesnake (*Crotalus horridus*) locations and of random points. Road networks were significantly more dense at random points than at snake localities. A similar relationship was detected within permanent stream corridors where extant populations of rattlesnakes are concentrated. Our data suggest that roads and associated vehicular traffic have had a detrimental impact on the current distribution of *C. horridus* in eastern Texas.

Introduction

Roads, and numbers of associated motorized vehicles, have increased enormously during the twentieth century. In 1983 it was estimated that the United States contained 6.3 million km of roads occupying 8.1 million ha (Adams & Geis 1983). The impact of high densities of roads and vehicles on vertebrate populations is poorly known, but presumed to be substantial (Bennett 1991). Direct mortality is certainly substantial. Ehmman and Cogger (1985) estimated that five million amphibians and reptiles were killed annually on roads in Australia. Lalo (1987) estimated vertebrate mortality on roads in the U.S. at one million individuals per day.

The impact of this mortality on populations is a critical issue. Bennett (1991), in a review of the literature, concluded that, for most species, mortality associated with roads "did not exert a significant pressure on population dynamics or conservation status." In selected species, however, the impact can be substantial. Species of large body size, small and declining populations, and species with behaviors that frequently bring individuals into contact with roads are most frequently cited in relation to significant impacts (Bennett 1991). Harris and Gallagher (1989) concluded that mortality on roads is the major known source of mortality for some large, endangered species, including the American crocodile (*Crocodylus acutus*), key deer (*Odocoileus virginianus*), and Florida panther (*Felis concolor*).

Snakes, due to their linear body plan, slow locomotion, and propensity to bask on road surfaces, are particularly vulnerable to mortality associated with roads. Large rattlesnakes are also vulnerable to direct killing by humans when conspicuous on road surfaces (Adams et al. 1994) because of their economic value and prevailing negative opinions of snakes in general.

The timber rattlesnake (*Crotalus horridus*) occupies an extensive range in eastern North America (Conant & Collins 1991; Martin 1992). It is typically a species of closed canopy forested habitats (Brown 1993; Collins & Knight 1980; Dundee & Rossman 1989; Mount 1975; Reinert 1984) and occurs throughout the available altitudinal range. Populations are declining in most portions of its range, most noticeably in the

north, where the use of communal hibernacula increases vulnerability to human predation (Brown 1993; Galligan & Dawson 1979). The species has been extirpated from substantial portions of its original range (Brown 1993; Martin 1992), and some populations have required special protection. Less information is available on southern populations. However, they also are vulnerable to habitat alteration and direct killing by humans. In Texas, populations are thought to be declining, and the species is listed as threatened (Anonymous 1992).

Patterns of occurrence of *C. horridus* in eastern Texas suggest that the existing road network is impacting populations of this rattlesnake. In this paper we test the hypothesis that the occurrence of *C. horridus* is negatively associated with areas of high road density.

Study Area and Methods

Recent records (1975-1994) of *C. horridus* were obtained from an 18-county area (Fig. 1) in eastern Texas, comprising most of the Timber Belt or Pineywoods Region of Correll and Johnston (1970). *C. horridus* is the only species of *Crotalus* occurring within the study area. Elevations range from 25 to 150 m, and local relief is generally less than 25 m. Species of *Quercus*, *Carya*, *Fraxinus*, and *Liquidambar* predominate in bottomland forests. Adjacent to major drainages these forests are subject to extensive periodic flooding. *Pinus*, *Quercus*, *Carya*, and a diverse array of other species predominate in upland forests.

The region is predominately rural. Timber production is the primary land use, but extensive areas have been converted to pasture. Agricultural crops, important in the past, have declined precipitously in recent decades.

Specimen and sighting records of *C. horridus*, and corresponding locality data, were obtained from museum collections and individuals. In the case of sight records, persons were carefully questioned to establish the validity of their information and reliability of the observer. Records that could not be located to within 250 m on maps were not included.

All snake locations were plotted on Texas State Department of Highways and Public Transportation General Highway Maps (scale 1:126,720). Roadways had been revised on all maps between 1989 and 1993, most in 1993. In addition, a random stratified sample of points (4 per county) was located on the 18 county maps within the study area. Circles of 2- and 4- km radius were delineated around all snake locations and around random points. Using the General Highway Maps, the lengths of all roadways indicated within the established radii were determined. Hard-surfaced roads were recorded separately. Substantial lengths of roads not indicated on the General Highway Maps exist within the study area. These roads generally receive significantly less use than the mapped roads and are more abundant in the upland portions of the study area. Unmapped roads were not included in the analysis. Distances from sample

and random points to the nearest perennial stream also were determined.

T-tests were used to compare distances between snake locations and random points and the nearest permanent stream. T-tests were also used to compare the total length of roads within the designated radii between snake locations and random points. A similar analysis using the subset of snake locations and an equal number of random points located within 3 km of permanent streams was also performed.

Results

A total of 36 *C. horridus* locality records were obtained between 1990 and 1994 within the 18 county study area. Examination of the locality data suggested that most *C. horridus* records were associated with perennial streams, especially the larger rivers. Mean distance of snake locations to perennial streams (1.1 km) was less than that of random points (5.1 km). This difference was highly significant ($t = -7.34$, $P < 0.0001$).

The total lengths of mapped roads within 2 and 4 km of snake sample locations and random points were also significantly different (Table 1). The mean lengths of total mapped roads within 2 and 4 km of snake sample points were 4.09 km and 13.43 km. Corresponding lengths for random points were 7.01 km and 21.44 km. These differences were significant at 2 km ($t = -8.94$, $P < 0.0001$) and at 4 km ($t = -2.68$, $P < 0.0088$). Significant differences were also found for hard-surfaced and dirt roads when compared separately (Table 1).

A similar analysis of the subset of snake locations and random points located within 3 km of permanent streams ($n = 25$) was also conducted (Table 2). The mean lengths of total mapped roads within 2 and 4 km of snake sample points were 4.20 km and 13.22 km, respectively.

Corresponding lengths for random points were 7.82 km and 23.70 km. These differences were significant at 2 km ($t = -3.87$, $P < 0.0003$) and 4 km ($t = -6.78$, $P < 0.0001$). Significant differences were also found for hard-surfaced and dirt roads when compared separately (Table 2).

Table 1
Road lengths (km) within 2 and 4 km of all snake collection points ($n = 36$) and random points ($n = 72$).

	Snake locations	Random locations	Prob.*
Hardsurfaced roads w/in 2 km.	1.76	3.03	$t = -2.66$, $P < 0.0095$
Hardsurfaced roads w/in 4 km.	5.40	9.25	$t = -3.71$, $P < 0.0004$
Unsurfaced roads w/in 2 km.	2.33	3.98	$t = -2.99$, $P < 0.0039$
Unsurfaced roads w/in 4 km.	8.03	12.19	$t = -4.17$, $P < 0.0001$
Total roads w/in 2 km.	4.09	7.01	$t = -8.94$, $P < 0.0001$
Total roads w/in 4 km.	13.43	21.44	$t = -2.68$, $P < 0.0088$

* t -test using Satterthwaite correction for unequal variances.

Table 2
Road lengths (km) within 2 and 4 km of snake collection points ($n = 25$) and random points ($n = 25$) within 3 km of permanent streams.

	Snake locations	Random locations	Prob.
Hardsurfaced roads w/in 2 km.	1.56	3.32	$t = -3.06$, $P < 0.0036$
Hardsurfaced roads w/in 4 km.	4.98	10.50	$t = -4.02$, $P < 0.0002$
Unsurfaced roads w/in 2 km.	2.64	4.50	$t = -2.31$, $P < 0.0253$
Unsurfaced roads w/in 4 km.	8.24	13.20	$t = -3.88$, $P < 0.0003$
Total roads w/in 2 km.	4.20	7.82	$t = -3.87$, $P < 0.0003$
Total roads w/in 4 km.	13.22	23.70	$t = -6.78$, $P < 0.0001$

Discussion

The current distribution of *C. horridus* within the eastern Texas study area is significantly associated with areas having a lower density of roads. This association is significant even though the snake locality data were strongly biased toward presence of roads; 16 of the 36 records were of snakes crossing or dead on roadways.

Road densities vary within the study area. Two situations exist where mapped road densities are low. One consists of large industrial forest landholdings devoted to short rotation pine silviculture. These areas generally have a well developed network of private roads not indicated on the General Highway maps. They typically receive substantial use, especially during the fall hunting seasons. These areas also have reduced squirrel (*Sciurus spp.*) populations, a primary prey of adult snakes in the region, due to the prevailing silvicultural practices that result in infrequent occurrence of hardwoods and young age of pines. Recent *C. horridus* records were uncommon in these areas.

The second situation with low road densities consists of the floodplains of perennial rivers and streams, areas associated with recent records of *C. horridus*. It is possible that timber rattlesnakes in Texas are primarily restricted to the vicinity of major drainages due to preference for habitat features associated with these areas. The relationship with road densities throughout the study area (Table 1) would then be a simple correlation because of habitat preference, and not the primary cause of the present distribution. However, the relationship with road densities adjacent to perennial rivers and streams supports a causal relationship between road density and snake occurrence. Within these riparian corridors the current distribution of timber rattlesnakes is negatively associated with the density of roads (Table 2).

In many other parts of its range *C. horridus* is not strictly associated with perennial streams or floodplain habitats. To the north and east of Texas the species occurs throughout a wide altitudinal range, including mountainous areas (Galligan & Dawson 1979; Reinert 1984; Collins & Conant 1991). In the Ouachita mountains, 200-300 km north of the current study area, *C. horridus* occurs at the higher elevations, e.g. 850 m on Magazine Mountain, Arkansas (D. C. Rudolph, Pers. Obs.).

On the Gulf Coastal Plain *C. horridus* generally is associated with hardwood and mixed pine and hardwood forests (Martin 1992). However, the species is rare or absent from longleaf pine habitats (Dundee & Rossman 1989; Mount 1975). Significant amounts of longleaf pine habitat occur in the southern portion of the study area and we obtained no records from these areas. The majority of the study area is upland mixed pine and hardwood forests, however, and very few records were from this habitat except adjacent to large bottomland hardwood habitats with few roads. Presumably, these upland habitats once supported substantial populations of *C. horridus*.

Preliminary results of an ongoing study of habitat utilization in Texas support this view. To date, we have placed radio-transmitters in 15 *C. horridus* and obtained relocations for periods of 5-20 months. Even though the study site is centered on the ecotone between bottomland and upland forest habitats, and contains substantial amounts of both habitats, only 2 of the 15 individuals have spent significant periods of time in the bottomland habitats. Twelve individuals have never crossed the ecotone into bottomland habitat. They have always been located in upland habitats similar to the large areas currently unoccupied, or only sparsely occupied, by the species in Texas.

In view of these findings, we hypothesize that the current distribution of *C. horridus* in eastern Texas is increasingly limited to the vicinity of perennial rivers and streams due to the high density of roads in adjacent upland habitats and mortality resulting from their proximity to roads. Populations adjacent to perennial rivers and streams are also impacted by mortality associated with roads and surviving populations are associated

with areas of low road density even within this portion of the landscape. The increasing reduction and fragmentation of relatively roadless areas potentially places the surviving populations in further jeopardy.

Several aspects of the biology of *C. horridus* increase its vulnerability to extirpation as road densities and vehicle traffic volumes increase. Compared to many vertebrate species, *C. horridus* is long-lived and exhibits low fecundity (Gibbons 1972; Brown 1991). Both of these attributes result in increased susceptibility to population decline when adult mortality rates are elevated (Lande 1988).

Aspects of the behavior of *C. horridus* also increase their exposure to mortality associated with roads. Adult *C. horridus* have large home ranges in the study area. Preliminary results indicate an average annual home range size (convex polygon method) of 44 ha (n=6 individuals, 8 snake-tracking years). Movement throughout a large home range potentially exposes individuals to roads on a frequent basis. Males have larger home ranges, in excess of 100 ha, due primarily to extensive movements associated with reproductive activities. Between mid-August and late October adult males wander widely within their home range in search of females. This behavior significantly increases the snakes' exposure to roads (Reinert & Zappalorti 1988; Martin 1992; Aldridge & Brown 1995; D. C. Rudolph, pers. obs.). During this period it is not unusual for individuals to move 1-2 km per week, and ultimately traverse loops up to 2 km in diameter. There are few places on the eastern Texas landscape where movements of this magnitude do not result in frequent crossing of roads.

Aldridge and Brown (1995) found that the frequency of encounters between *C. horridus* and humans was higher for males during the late-summer mating season in a New York population. They concluded that the resulting human induced mortality is a significantly higher cost of reproduction for males than for females, and that these costs are significantly higher for adult males during the mating season than the non-mating season. Limited data from Texas suggest a similar pattern (D. C. Rudolph, pers. obs.). The resulting mortality is the most likely cause of the current restricted distribution of *C. horridus* in eastern Texas.

Restriction of viable populations of *C. horridus* to areas of low road density also has the potential to significantly impact the demographic structure of the species. We assume that the species formerly occurred throughout most of the forested region of eastern Texas, with the notable exception of the longleaf pine belt. The present, or at least rapidly developing situation (with populations increasingly restricted to areas adjacent to major drainages characterized by low road densities) implies that demographic isolation is increasing. Moreover, alteration of bottomland hardwood habitats by reservoir construction, development of transportation corridors, and habitat conversions threatens to increasingly fragment the remaining once-continuous populations. This impact on a species with low reproductive rates and presumably low dispersal ability has serious implications for the continued survival of viable populations of *Crotalus horridus* in the southwestern portion of its range.

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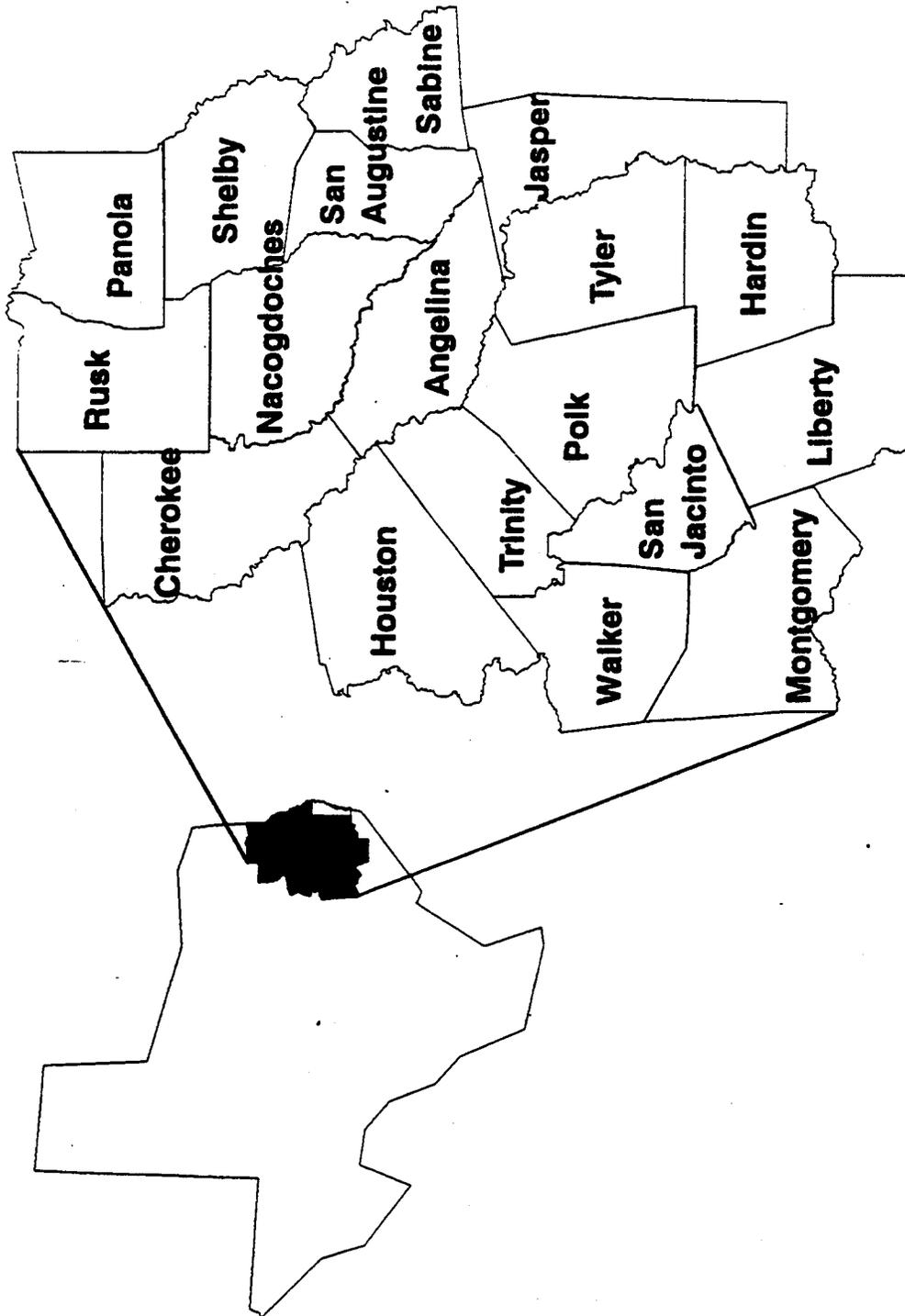


Figure 1.
Map of 18 county study area in eastern Texas.