Quantifying Wildlife Road Mortality in Saguaro National Park

Natasha C. Kline and Don E. Swann
Saguaro National Park, AZ

Abstract

Roadkill is undoubtedly the greatest human-caused source of direct mortality to vertebrate animals in many parks and reserves, yet its overall impact remains poorly documented. To begin to quantify the effects of roadways on wildlife in Saguaro National Park, Arizona, park staff initiated regular roadkill surveys in January 1994. These surveys have documented 2,030 wildlife road mortalities during a three year period, and have enabled managers to identify specific areas and taxa of concern. Nevertheless, the number of individual animals observed are clearly only a small fraction of the number killed on roads in and adjacent to the Park. To calculate a more accurate estimate of total annual road mortality, we conducted studies to determine the effect of stochastic, short-term weather events; the length of time carcasses persist on roadways; and the observer error associated with our studies. Preliminary results of these studies provide what we consider a very conservative estimate of 7,155 vertebrates killed on Park through- and boundary-roads annually. This paper presents results of our roadkill surveys to date and discusses their implications towards wildlife management in protected areas near increasing external development.

Introduction

Roadkill is perhaps the greatest, directly human-caused source of wildlife mortality throughout the United States, and for some species its impacts are significant at the population level. The many impacts of roads on wildlife and natural systems are well documented (Evink et al. 1996, Andrews 1990, Diamondback 1990); however, few formal studies have been conducted to quantify the effects of road mortality across a range of different taxa in a specific area. In national parks and other natural reserves where preservation of native biodiversity is an important management goal, assessing the large-scale impacts of road mortality is essential, particularly where such data may support efforts to mitigate such impacts.

The high visibility of roadkills at Saguaro National Park (SNP), located in southern Arizona, U.S.A., has raised concerns that park roads are significantly impacting wildlife populations. As a first step in quantifying this impact, in November 1993 park staff and volunteers began collecting data on the numbers, taxa, and temporal and geographic distribution of animals killed on roads in and adjacent to the Park. Our initial goal was to identify seasonal and geographic patterns of roadkills in order to understand general trends and identify which roadways may deserve particular management attention. However, it became apparent early on that our survey efforts greatly underrepresented the numbers of actual roadkilled animals. For example, most toad species in the Sonoran desert are active almost exclusively at night during summer rains, emerging in mass during the first heavy rains in July to congregate, breed, drink and forage. In 1994 and 1995 toad roadkills went virtually undetected. However, when a roadkill survey in 1996 occurred on the morning after a summer rain, more than 200 toads were recorded, an event which greatly altered many trends in our existing dataset.

In addition, it was clear that other factors influence our ability to detect roadkills. Probably the most significant of these is the removal of carcasses by scavengers, which appears to be highly variable depending on location, season, taxa, and time of day. It was also inevitable that observers in a moving vehicle do not detect all roadkills actually present on the roads; and further, that ability to detect roadkills differs between observers, and roadways.

Therefore, to better estimate what percentage of the total animals killed were actually represented by our regular surveys, in 1997 we initiated additional survey efforts to address some of these sources of error. These methods include all-night surveys; ground-truthing our regular, driven surveys by observers on foot; and spot surveys of amphibians during summer rains. Our efforts to date are preliminary, as we continue to refine our methods and identify other potential sources of error. This paper summarizes our overall survey results from 1994-1996, and based on the results of the above studies, provides a conservative, preliminary estimate of the total annual number of roadkills at Saguaro National Park.

Study Site

Saguaro National Park was established in 1933 in order to preserve and protect its remarkable display of relatively undisturbed Sonoran desert vegetation, including the saguaro *(Carnegiea gigantea)* and other species of native cacti. Vertebrate fauna includes at least 49 species of mammals, ranging from montane species such as black bear (*Ursus americanus)* to desert species such as Merriam's kangaroo rat (*Dipodomys merriami*); eight amphibians; 49 reptiles; and 125 species of breeding birds. The Park consists of two disjunct districts, the Tucson Mountain District (TMD) and the Rincon Mountain District (RMD), which lie on opposite sides of Tucson, Arizona, one of the most rapidly-growing cities in the United States (Fig. 1). Tucson's current population of approximately 750,000 is more than twenty times the size it was when Saguaro was established (7Shaw et al. 1992). Like many national parks located near growing urban areas, roadways at Saguaro have received steadily increasing use in recent years. Altogether, the Park contains approximately ten miles of through roads, 20 miles of boundary roads, and 20 miles of scenic loop drives. Both Park visitation and use of park roads by commuters have increased dramatically in recent years. Traffic on the section of Picture Rocks Road that runs through the TMD has nearly doubled since 1988 and now totals more than 6,000 cars per day (NPS files 1997).

Methods

Opportunistic and survey data. Roadkill data was collected by two methods. First, sightings of roadkills (hereafter, "opportunistic") were recorded on all roads by park staff and volunteers on an opportunistic basis during normal work duties or while commuting. Second, a regular survey transect (hereafter, "survey") of all boundary and internal park roads was conducted weekly by Resource Management staff. These surveys were usually conducted between 0830 and 1200 h on a designated weekday, on a standard route, and driven at speeds conducive to detection of most animals. When a possible roadkill was sighted, the driver pulled over to determine if it was a dead vertebrate, and

to collect data if it was. Procedures for opportunistic sightings were similar except that no standard route or time was designated. To facilitate the collection of accurate and conservative data, data forms were developed for recording each observed roadkill, its location, and the date. Volunteers and staff were requested to record all roadkills but to identify animals only to the extent they were certain. A map attached to the observation form provided location codes.

Results from January 1994 through December 1996 for TMD, and May 1995 through December 1996 for RMD, were entered into a database (Microsoft Access, version 2.0) and analyzed by taxa, location, season and road characteristics (paved vs. unpaved, through-park vs. boundary). Survey and opportunistic data were analyzed separately. Potential duplicate observations of the same animal were avoided by eliminating from the analysis any records of a species seen at the same location within two days by a different observer.

Toad surveys. To address the issue of whether toad species may be drawn to roads during summer rains, and thus particularly susceptible to road mortality, we conducted opportunistic surveys during monsoons on roads known to have high toad densities. We also conducted line transect surveys during these times to compare numbers of toads on roadways with numbers in adjacent habitat. Four transects of 0.5 miles -- two on a roadway, and two in parkland 100 m east of the road transects -- were walked during an evening of peak amphibian activity, and the results of these transects were compared. Due to time constraints and timing of amphibian activity only one transect survey was conducted in 1997.

Estimating total annual vertebrate mortality. To develop better estimates of the total number of animals killed on Park roads by accounting for scavenging and observer error, we conducted all-night surveys and ground-truthing surveys. Three all-night surveys were conducted in August-October 1997, which consisted of six to seven transects (each identical to our regular survey) with a short (0-2 hr) break in between. The first transect started at least one hour before sunset, and the sixth was conducted the following day, during the time of our regular weekly survey; when possible, a seventh survey was conducted immediately following the time of our regular survey. Data was gathered as during regular surveys. To minimize bias by prior knowledge of roadkill locations, three sets of observers were used in each survey. Analysis consisted of developing a capture history for each individual roadkill to calculate the length of time individual carcasses remained visible on the road, and to determine the percentage of animals known killed during the night that were also observed during morning surveys.

Ground-truthing surveys consisted of walking selected road segments within the study transects, and comparing the number of individual roadkills observed with the number observed during a regular driving transect conducted at the same time. We conducted ground-truthing surveys using park staff and high school student volunteers who were trained to correctly identify animals at least to class. Approximately 15 road miles were ground-checked in this way during three occasions with approximately 30 observers. Data was gathered on regular survey data sheets, and comparisons made between driven and on-foot survey results.

To estimate the total number of animals killed in the Park, we used the numbers observed only during weekly surveys. These numbers were adjusted by taxa by multiplying by 7 (number of days/wk), and by the reciprocal of the percentage (x100) of the ratio, for each taxa, of the number of roadkills remaining on roadways in morning compared with the minimum number known killed during the previous night. For estimates of the numbers of animals remaining in morning vs. minimum known killed, we used overall means based on the three all-night surveys conducted in 1997.

Results

Opportunistic and survey data. 1,472 roadkilled vertebrates were recorded on roads within and adjacent to the TMD during the three year period, including 316 amphibians, 277 reptiles, 192 birds, 530 mammals, and 157 unknown animals. In the RMD, 558 vertebrates were recorded during the 18 month period, including 111 amphibians, 97 reptiles, 128 birds, 206 mammals, and 16 unknown animals. Relative abundance of the most common species recorded differed slightly between the two districts of the Park, probably due to habitat differences. Relative percentages of different taxa did not vary greatly between opportunistic and survey results (Fig. 2), except for amphibians, whose road mortality was extremely episodic (see below). Opportunistic sightings were slightly higher for mammals and reptiles, and lower for birds, amphibians, and unknowns.

The greatest number of roadkills were observed during the summer months of July, August, and September, with a smaller peak occurring in May (Fig. 3); these high summer numbers reflect not only peaks for reptiles and amphibians, but higher numbers of mammals and birds as well. Because 1995 data was not collected for all months in the year in the RMD, we used 1997 data, otherwise not reported, to equalize the effort per month.

Annual roadkills per mile, based on raw survey data, averaged 11.5 in TMD, and 6.0 in RMD. Figure 4 illustrates that annual rates varied greatly between roadways that ran through the Park where access at night is controlled (2.4 roadkills/mile), and similar through-roads which are publically maintained and open at night (10.9 roadkills/mi). Paved roads had higher annual mortality rates (13.1 roadkills/mile) than dirt roads (1.3/mile) (Fig. 4).

In addition to seasonal fluctuations, road mortality was extremely episodic for some taxa. For example, during 90% of regular surveys, no roadkilled amphibians were recorded. However, during one event in July 1996, recorded opportunistically, a large number (>50) of Couch's spadefoots (Scaphiopus couchi) were observed killed on a 2.4 mile road segment in the RMD; and during a regular survey in September 1996, which by chance followed a night of heavy rain, 279 roadkilled toads, nearly all Sonoran desert toads (Bufo alvarius), were observed. Figure 5 indicates the significant impact that such episodic events can have on overall roadkill survey results. Results from an all-night survey conducted at RMD during a rainy evening in 1997 confirmed that high numbers of amphibians may be killed during such events. In this event, Couch's spadefoots that were observed during the all-night survey were quickly scavenged (Fig. 6), with only 15 of at least 63 individuals killed persisting long enought to be counted at the normal survey time on the following day. Results of amphibian transect surveys on and off road in 1997 were inconclusive due to low sample size. In the single survey conducted, one toad was observed on the transect in desert habitat; six toads were observed on the road, and two toads were observed on the road shoulder.

Estimating total annual vertebrate mortality. During the three all-night surveys, a total of 327 observations of 113 individual vertebrates were observed killed on roads. Of this total, only 27, or 23.9%, were observed during the transect conducted during the time of regular morning surveys. This percentage is an overestimate because the high number of amphibians killed during the first all-night survey did not allow us to identify individuals, and so we used the maximum number observed on a transect as the total number killed during the night (Table 1). The number of roadkills, and the average length of survival on the roads varied greatly by taxa, by survey, and by transect. The first August survey was conducted during a rain, and large numbers of amphibians were observed; the October survey was conducted after many reptiles and amphibians had retreated into hibernation. Mean survival time for non-amphibian

carcasses on the roads was 2.37 trips (SD=3.54), or approximately six hours. Animals that disappeared were either not observed by later drivers or scavenged: a number of potential scavengers were observed on roads during these surveys, including greater roadrunner (*Geococcyx californianus*), common raven (*Corvus corax*), turkey vulture (*Cathartes aura*), striped skunk (*Mephitis mephitis*) and coyote (*Canis latrans*).

Table 1. Minimum total number of roadkilled vertebrates observed on all-night surveys at Saguaro National Park, 1997. Numbers in parenthesis represent the number of animals detected during the sixth survey, conducted during regular survey hours. Exact numbers of amphibians during the 5-6 August survey could not be determined due to very large numbers; 63 represents the minimum number killed, based on the most roadkills observed during any one survey.

	Amphibians	Reptiles	Birds	Mammals	Total
5-6 August	63 (15)	4 (1)	7 (3)	3 (1)	77 (20)
19-20 August	9 (2)	10 (2)	5 (1)	6 (2)	30 (7)
6-7 October	0 (0)	4 (0)	0 (0)	2 (0)	6 (0)
Total	72 (17)	18 (3)	12 (4)	11 (3)	113 (27)

Results of the ground-truthing (foot) surveys clearly indicate that a portion of animals killed by cars remain undetected by drivers; but our current sample size precludes use of these numbers for calculating an estimated error rate. During the first survey, six toads and one snake were seen by observers on foot, and only one toad was seen by the observer driving. However, the toads and snake were dried and fragmentary, clearly >24 h old. In the second survey, a fresh bobcat and cottontail, and a decomposed javelina were seen by observers on foot, and only the cottontail was seen by the observer driving. In the third survey, two unidentified mice (at least one decomposed) and an unidentified fresh bird were seen by observers on foot, and the observer driving detected no roadkills.

Based on our survey data from 1994-96, and preliminary results from all-night surveys, we calculate the number of vertebrates killed on roadways in and on the boundaries of Saguaro National Park to be 7,155 annually. Figures for individual vertebrate classes are 1,300 amphibians, 1,982 reptiles, 1,029 birds, 2,227 mammals, and 617 unknown animals. Because of the episodic event of roadkilled Sonoran Desert toads, which were not removed from roads at the same rate as other toads, we did not adjust numbers upward for this species, and included in our estimate only the number observed for this species. Because we did not attempt to include data on the number of animals missed by drivers or other potential factors, these estimates are conservative.

Discussion

Quantifying the effects of park roads on all taxa is an important first step in guiding long-term decisions about road access, closure, engineering, and signage. Scientifically based estimates of the numbers of roadkills and potential impacts to wildlife populations can be a valuable tool for managers trying to mitigate the effects of roads.

Despite the need for accurate estimates, sound data for evaluating road mortality is difficult to obtain. Our original approach, to count the numbers of animals killed by weekly morning surveys, provided much preliminary data, but it was apparent that these surveys did not fully describe overall road mortality in the Park. Indeed, preliminary results of our studies to evaluate factors influencing detection of roadkills provide evidence that most animals killed by cars are not detected by surveys. Of the factors that influence our ability to detect roadkills, which include factors that are difficult to evaluate such as animals dying away from roadways, two factors, scavenging and observer error, appear to be of greatest significance.

Scavenging. High rates of scavenging affect not only our ability to detect roadkills, but may also have an overall impact on ecosystems where cars, roads, and natural areas come together. Scavengers such as ravens, vultures, roadrunners, and coyotes are regularly seen on road surveys, and a recent study of coyotes along the Park boundary indicated population densities of 3.7 coyotes per ha, one of the highest reported in the southwest (McClure 1993).

Although many animals, particularly mammals, are killed during the night, our all-night surveys indicated that most scavenging takes place during early morning hours. The length of time that carcasses remain on roads appears highly variable. Cottontails observed by park staff as they commute to work are very often not recorded during surveys an hour later, but observations of roadkilled Sonoran desert toads, a species which is toxic and highly unpalatable to many scavengers, suggest that they may remain on roadways for several days. Similarly, some carcasses may be unavailable to certain scavengers at certain times. For example, a large mammal carcass may need to be opened by a larger animal before it can be accessed by a raven or turkey vulture.

Results from our all-night surveys indicate that, on average, no more than 24% of the total number of animals killed between sunset and early morning (approximately 0800 h) remained on the road during the time of our typical morning surveys. Yet some species, particularly diurnal lizards, continued to be detected as new roadkills during the morning survey. This indicated to us that in addition to all-night surveys, 24-hour surveys should be conducted to determine roadkill and scavenging rates over an entire day.

Because scavengers remove animals at a continuous but variable rate, continuous road surveys will always underestimate it to some extent. An alternative and potentially more precise approach is to conduct experimental work with carcasses of different species placed on roadways at different times and seasons, and to measure the length of time they remain visible on the road.

Observer error. The limited ground truthing data collected thus far indicates that observers in vehicles often fail to detect roadkills, although we are not certain as to the rate. Observer error probably varies between surveyors, but is also defined by environmental factors (weather, season) and road conditions. On roads with heavy, fast-moving traffic and no shoulders, surveyors are sometimes prevented from driving slowly enough to detect all roadkills, or stopping in order to properly identify roadkills that are observed. Furthermore, for logistical reasons, surveys in the TMD are usually conducted by two persons (both observing), and in the RMD by one person, which may bias results and affect comparisons between districts. By replicating the ground truthing surveys throughout the year in both districts, we hope to obtain an accurate correction factor to apply to survey data to account for observer bias.

Despite problems with detection of roadkills, we believe that our data do capture important real trends and patterns of road mortality in SNP. The bimodal peaks in spring and summer (Fig. 3), also represent the general, overall activity pattern of Sonoran desert animals, which suggests that our data reflects actual patterns of road mortality; the similarity in trends between the survey and opportunistically collected data (Fig. 2) provide further validation of this.

Management Implications. We have documented thousands of roadkills in SNP, but we do not know the extent to which they affect wildlife populations, which is our ultimate concern. Based on our observations and the literature (Reudiger 1996, Fowle 1996, Adams and Geis 1983, Rosen and Lowe 1994, Ruby et al. 1994), we suspect that certain species with low reproductive rates and naturally low adult mortality rates, have, are, or will suffer population declines or even local extinction in the Park, particularly at the TMD, from road mortality. At SNP these species may include: Sonoran desert tortoise (*Gopherus agassizii*), gila monster (*Heloderma suspectum*), tiger rattlesnakes (*Crotalus tigris*), Sonoran desert toads, and mountain lion (*Felis concolor*). Because we do not have good information on the status of wildlife populations in the Park, thus far, we have only been able to begin to explore road mortality effects in certain toad populations. Through our on/off road transects during monsoons, we are attempting to determine if roads and the conditions which surround them are actually attracting toads, and therefore acting as a "sink" on local populations. Roads acting as sinks affecting local animal populations have already been documented in toads (Fahrig et al. 1995), snakes (Rosen and Lowe 1994), tortoises (Ruby et al. 1994), and other animals (Ashley and Robinson 1996).

Our results confirmed that road mortality is a larger issue in the TMD, which is smaller (24,000 acres compared to the 67,000 acre RMD), and surrounded and bisected by roads. That paved roads had higher animal mortality rates than unpaved roads was not surprising; however, the magnitude of the difference (13:1) is remarkable. Similarly, it is useful to quantify that fewer animals are killed on internal (loop) roads which are closed at night, to similar through-roads, since these are the types of data needed to justify and develop management policy and mitigation.

The development of effective mitigation depends on the identification of the specific issues and an understanding of these problems in context with the affected species local natural history/ecology. Unfortunately, effective mitigation is often species or taxa specific, expensive (extensive road repairs/changes), politically unpopular (road closures), or ultimately beyond the control of a protected area's management jurisdiction. SNP, particularly the TMD, is becoming so encroached upon by development and urbanization that no amount of internal mitigation will prevent wildlife from being affected by the associated habitat loss and road mortality. This is especially true of larger vertebrates, especially predators, which need larger home ranges and which will invariably range out of the park (Reudiger 1996).

Conclusions

Thousands of animals per year are killed on roads in and adjacent to Saguaro National Park. Even our corrected estimate of 7,155 animals/yr is clearly an underestimate of the numbers that are actually killed, and we do not know the extent to which they affect animal populations. Nevertheless, these high numbers appear to corroborate our concern that roadkill is a phenomenon with the potential to affect wildlife populations in the Park.

We plan to continue to quantify wildlife mortality in the Park in order to further understand and describe the overall trends and patterns, and to identify the species which may be significantly impacted, and ultimately, to try to develop effective mitigation of these impacts.

Acknowledgements

Many volunteers and park staff collected data for this study. Roadkill observers extraordinaire include: Danny August, Linda Burback, Gene Cunningham, Rich Hayes, Mark Holden, Scott McCarthy, Vivian MacKinnon, Eveline Martin, Stu Moser, Tommi Stoecker, Fred Stoecker, Pam Swantek, Sinji Topoian, Mike Ward, and Jane Williams.

References Cited

Adams, L.W. and A.D. Geis. 1983. Effects of roads on small mammals. Journal of Applied Ecology 20:403-415.

Andrews, A. 1990. Fragmentation of habitat by roads and utility corridors: a review. Australian Zoologist 26(3&4):130-141.

Ashley, E.P. and J.T. Robinson. 1996. Road mortality of amphibians, reptiles and other wildlife on the Long Point causeway, Lake Erie, Ontario. Canadian Field Naturalist 110(3):403-412.

Diamondback. 1990. Ecological effects of roads. Pp 1-5 in J. Davis, ed. Killing roads: a citizens' primer on the effects and removal of roads. Earthfirst Biodiversity Project Special Publication, Tucson, AZ.

Evink, G.L., P. Garrett, D. Zeigler, and J. Berry (editors). 1996. Trends in Addressing Transportation Related Wildlife Mortality. Proceedings of the transportation related wildlife mortality seminar in Tallahassee, Florida, 1996. Florida Department of Transportation, Tallahassee, FL (unpaginated).

Fahrig, L., J.H. Pedlar, S.E. Pope, P.D. Taylor, and J.E. Wegner. 1995. Effect of road traffic on amphibian density. Biological Conservation 73:177-182.

Fowle, S.C. 1996. Effects of roadkill mortality on the western painted turtle (Chrysemys picta bellii) in the Mission Valley, western Montana. In G.L Evink, P. Garrett, D. Zeigler and J. Berry, eds. Trends in Addressing Transportation Related Wildlife Mortality. Proceedings of the transportation related wildlife mortality seminar in Tallahassee, Florida, June 1996. Florida Department of Transportation, Tallahassee, FL (unpaginated).

McClure, M.F. 1993. Densities and diets of coyotes near Saguaro National Monument. MS thesis, University of Arizona, Tucson, Arizona. 54pp.

Rosen, P.C. and C.H. Lowe. 1994. Highway mortality of snakes in the Sonoran desert of southern Arizona. Biological Conservation 68:143-148.

Ruby, D.E., J.A. Spotila, S.K. Martin, and S.J. Kemp. 1994. Behavioral responses to barriers by desert tortoises: implications for wildlife management. Herpetological Monographs 8:144-160.

Ruediger, B. 1996. The relationship between rare carnivores and highways. In Trends in Addressing Transportation Related Wildlife Mortality. Op. cit.

Shaw, W.W., A. Goldsmith, and J. Schelhas. 1992. Studies of urbanization and the wildlife resources of Saguaro National Monument. In C.P. Stone and E.S. Bellantoni, eds. Proceedings of the Symposium on Research in Saguaro National Monument, January 1991. Southwest Parks and Monuments Association, Tucson, AZ. 227pp.

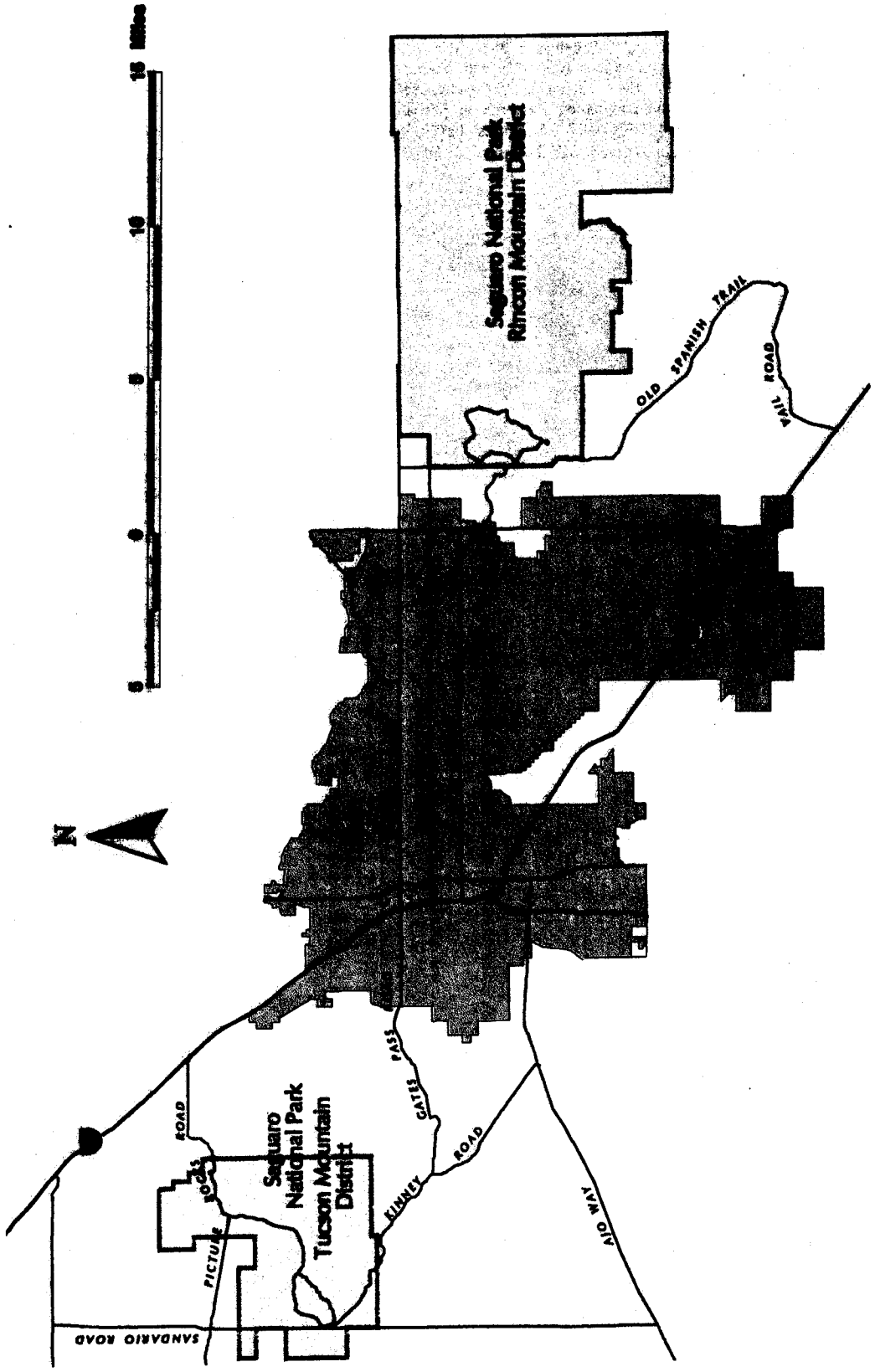

Figure 1.
Map of Tucson, Arizona, showing both districts of Saguaro National Park: Tucson Mountain District (west), and Rincon Mountain District (east). Map produced with the assistance of the Advanced Resource Technology Lab, University of Arizona.

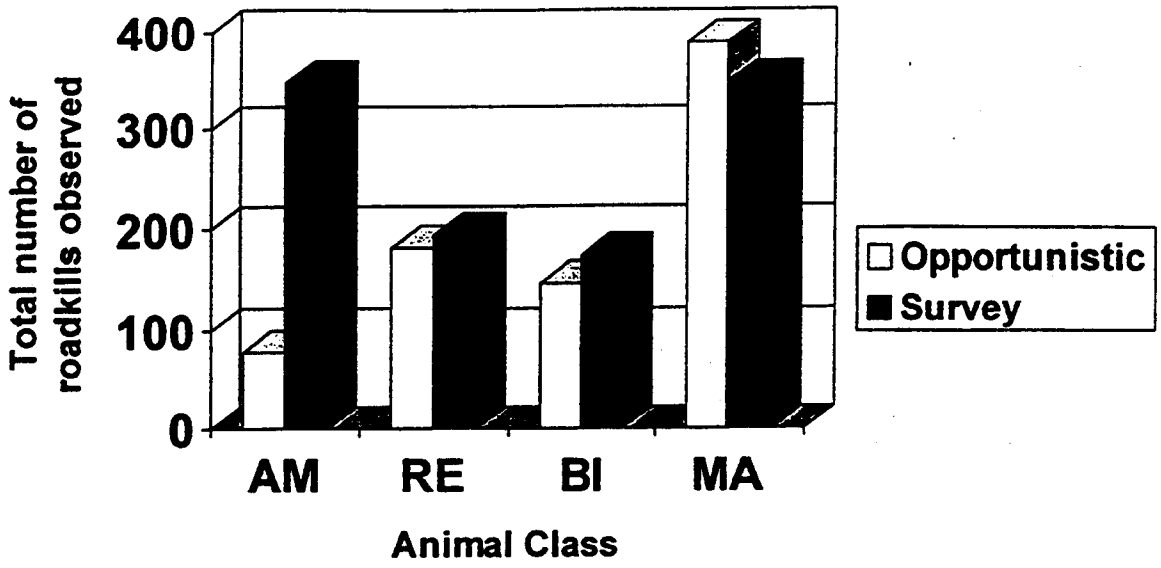

Figure 2.
Comparison of opportunistic vs. survey sightings of roadkills, by taxa, Saguaro National Park, 1994-1996. AM=Amphibians, RE=Reptiles, BI=Birds, MA=Mammals.

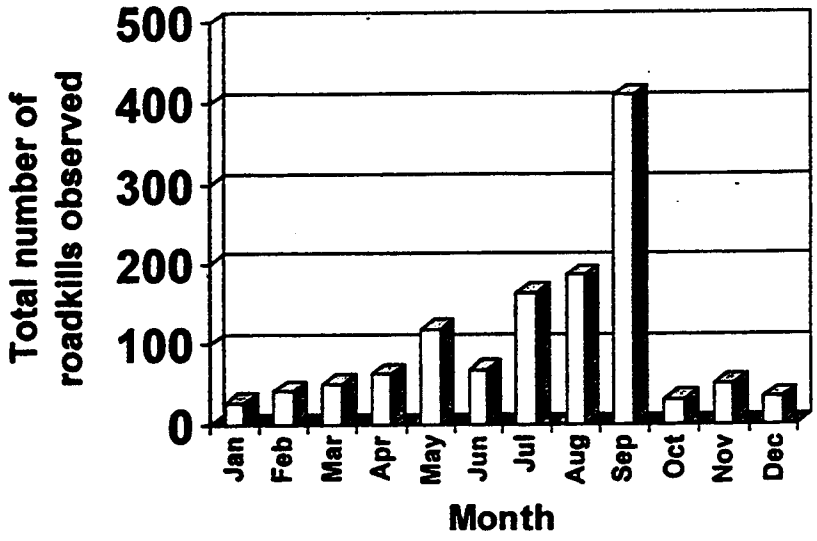

Figure 3.
Total numbers of roadkilled vertebrates observed by month, Saguaro National Park, 1994-1996. Survey data only, both districts.

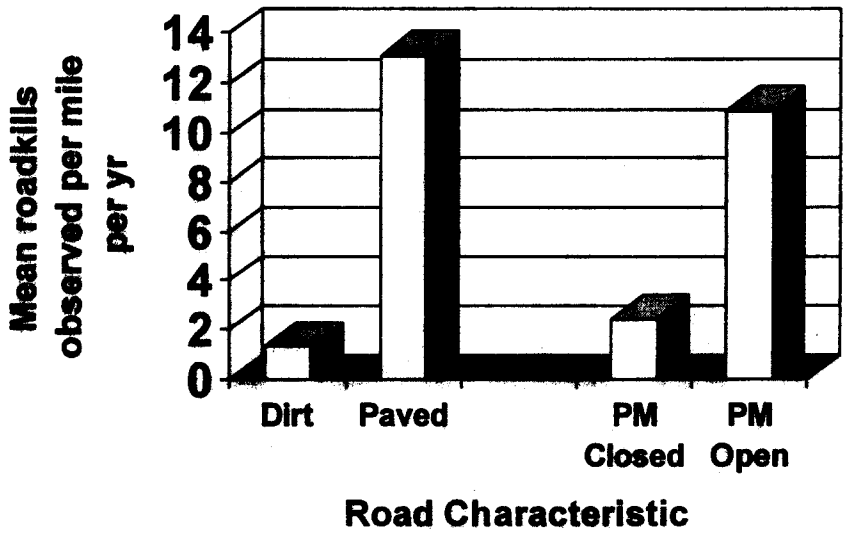

Figure 4.
Annual roadkills observed per mile at Saguaro National Park by type of road. Left side: dirt roads vs. paved roads. Right side: park through-roads which are open at night vs. through-roads which are closed at night.

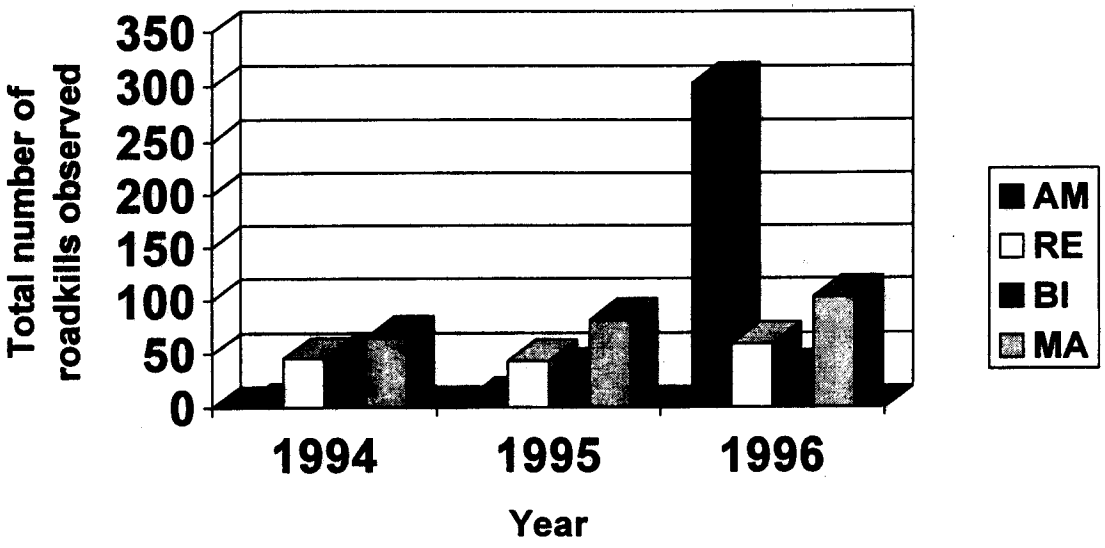

Figure 5.
Roadkills by taxa and year in the Tucson Mountain District, 1994-6. Survey data only. High values for amphibians in 1996 reflect the results of a single survey on 26 September 1996. See Fig. 2 for key to abbreviations.

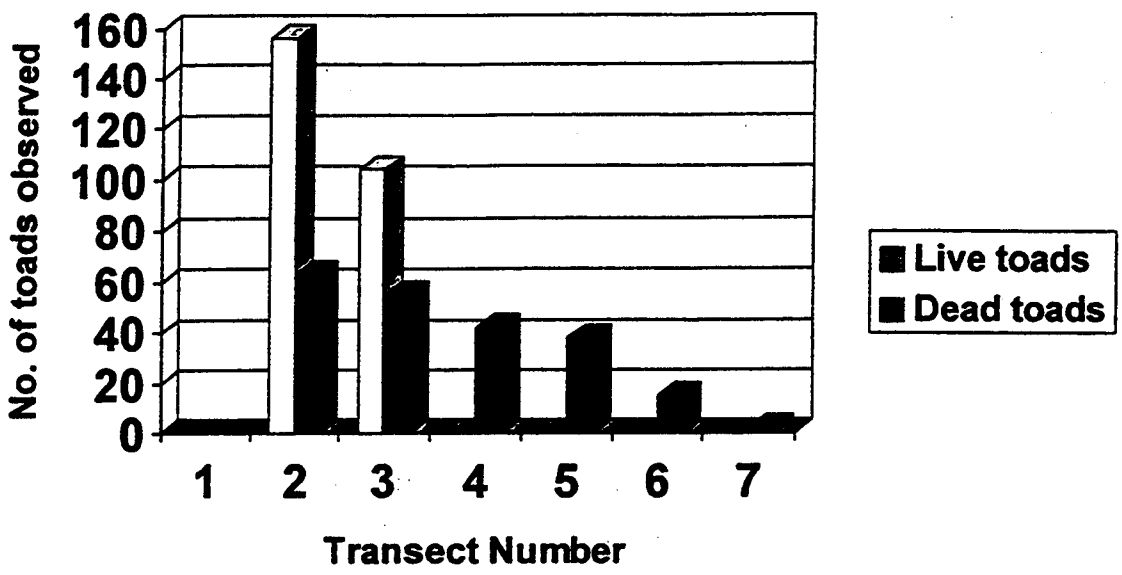

Figure 6.
Number of live and dead toads observed during each run of all-night survey, Rincon Mountain District, 5-6 August 1997. Transect 1 started 1800 h on 8/5 and transect 7 started at 1045 h on 8/6; transect 6 represents time of regular weekly survey.