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Impacts of Vehicle Road Traffic on Desert Tortoise Populations with Consideration of Conservation of Tortoise Habitat in Southern Nevada

Karin von Seckendorff Hoff[1] and Ronald William Marlow[2]

[1]*Department of Biological Sciences, University of Nevada Las Vegas, Las Vegas, Nevada 89154-4004 USA [E-mail: MarlowHoff@aol.com];*
[2]*Biological Resource Research Center, Biology Department, University of Nevada Reno, Reno, Nevada 89557 USA*

Abstract. – We surveyed desert tortoise (*Gopherus agassizii*) habitat for sign (live or dead tortoises, burrows, scat, etc.) at 100 m intervals from roads at seven different sites in southern Nevada. Traffic levels on the roads ranged from 25 to over 5000 vehicles per day. We detected reductions in tortoise sign abundance more than 4000 m from the road at the highest traffic level. We found a linear relationship between traffic level and the distance from the road that reduction in sign count could be detected. The cumulative impact of a network of roads significantly reduced the effective area of conserved habitat defined by management prescriptions that do not include road barriers. Traffic on roads and highways in desert tortoise habitat has a profound impact on tortoise populations and on efforts to conserve and manage this species.

Key Words. – Reptilia; Testudines; Testudinidae; *Gopherus agassizii*; tortoise; roads; traffic; conservation; management; Nevada; USA

Automobile-caused mortality of wildlife has been noted by scientists and conservationists for as long as automobiles have been in common use (Stoner, 1925; Washburn, 1925; Dreyer, 1935; Warren, 1936a, 1936b; Simmons, 1938; Dickerson, 1939). State and federal highway agencies now recognize the impacts of roads on a wide range of species (Evink et al., 1996), and concerns about wildlife mortality have resulted in proposals for erecting fences to exclude animal species from roads for many years (e.g., Storer and True, 1931).

Mortality resulting from vehicle collisions with tortoises has been reported throughout the world (*Geochelone radiata* – Goodman et al., 1994; *Testudo hermanni* – Lizana, 1993; Guyot and Clobert, 1997; *Testudo graeca* – Lopez, 1992; Lizana, 1993; *Agrionemys horsfieldi* – Kolodenko, 1981) and has frequently been cited as a significant population decline factor for desert tortoises (Berry, 1986a, 1986b; Boarman, 1991; RECON, 1991). Nicholson (1979) demonstrated that there were detectable reductions in tortoise sign up to one mile from roads and highways, and further, that those reductions were related to the age of the road. The California Department of Transportation and others recognized the impact its highways were having on tortoise populations and initiated studies of the nature of that impact and potential mitigation actions (Fusari, 1982, 1985; Berry, 1986a, 1986b; Boarman, 1991; RECON, 1991; Kline and Swann, 1998). In California it is now recognized that highways cause population-level declines through direct mortality (Berry and Nicholson, 1984; Lovich and Bainbridge, 1999).

In 1987, prior to the Federal listing of the desert tortoise (*Gopherus agassizzii*) as endangered or threatened, the Nevada Department of Transportation (NDOT) and the Federal Highway Administration (FHWA) entered into consultations with the Nevada Department of Wildlife (NDOW) and the Bureau of Land Management (BLM) concerning the widening and realignment of Nevada State Route 163 (SR 163) from U.S. Highway 95 (US 95) to near Laughlin, Nevada, on the Colorado River. Specific areas of concern were the impacts of this project on wildlife species using Hiko Springs, bighorn sheep crossing the highway, and desert tortoises population declines from individual tortoises being killed on the road. The biologists from NDOW and BLM recommended that the highway right-of-way be fenced to exclude tortoises and bighorn sheep and that under-highway corridors for movement of both species be provided through water culverts. The recommendations were not followed. After the Federal listing of the desert tortoise the FHWA initiated a formal consultation under Section 7 of the Endangered Species Act (ESA) with the U.S. Fish and Wildlife Service (USFWS) on this project. The USFWS issued a Biological Opinion in 1990 that left the necessity of mitigating for the death of tortoises on SR 163 and other Nevada highways unresolved, despite the overwhelming evidence that highway and road traffic significantly impacts adjacent tortoise populations.

Following the emergency Federal listing of the desert tortoise in 1989, Clark County, Nevada, obtained a permit for incidental take of tortoises in the Las Vegas Valley in exchange for enhancing tortoise habitat and management pursuant to the terms of a Habitat Conservation Plan (HCP). The site selected for the enhancement was on public lands administered by the BLM and the National Park Service (NPS) in Piute, Cottonwood and Eldorado valleys. This area has been included in each of the subsequent Clark County Habitat Conservation Plans as "conserved" tortoise habitat (RECON, 1991) and "Intensively Managed Areas (RECON, 2000). The area consists of Federal lands that are dissected by more than 800 km (500 miles) of roadway, including Federal and State highways, utility roads, and many mining, hunting, and off-highway vehicle tracks that

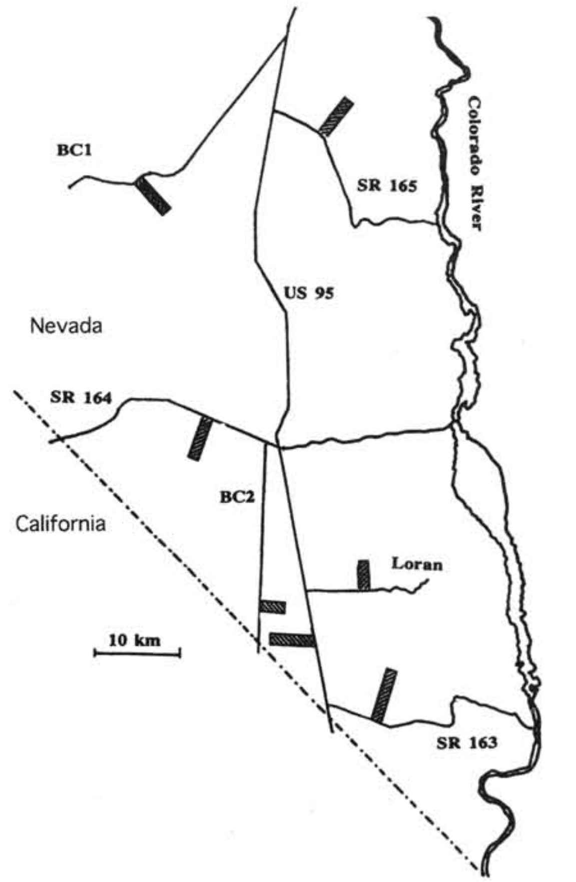

Figure 1. Map of locations of the 7 study sites. Major roads are marked. Plot sizes at the study sites are not to scale.

have been claimed as County roads. The terms of the HCP require that the impacts to tortoises within the Piute and Eldorado valleys of vehicle traffic on these roads and highways be evaluated and appropriate actions be taken to eliminate or fully mitigate those impacts.

To assist in that effort we have refined techniques for the more efficient assessment of impacts of vehicular road traffic on tortoise populations by examining types of data (tortoise sign), plot size, time of year, and sampling interval (transect spacing). Roads with traffic levels ranging from approximately 25 to 5000 vehicles per day have been examined. The relationship between traffic level and magnitude of the impact is examined. The implications of our findings to preserve design are discussed.

METHODS

Study Sites. — Seven sites in southern Nevada in the Piute–Eldorado–Cottonwood valleys were selected for evaluation (Fig. 1). These sites were selected because they were on paved or unpaved roads, in relatively homogenous creosote scrub habitat, with a low elevational gradient and, where possible, out of proximity to roads other than the one defining that site. Location of sites is given in miles to conform with current map scales and highway signage and for ease of replication, all other linear distances are metric. All sites are in what is generally considered to be suitable tortoise habitat. The sites are in the creosote scrub plant community dominated by *Larrea tridentata* and *Ambrosia dumosa*. All sites are well drained and dissected by small to moderate sized washes. Soils included sandy loam with gravel, cobbles, and small boulders.

1. U.S. Highway 95 (US 95). — This site is on a paved four-lane highway, approximately 1 mi south of the town of Cal-Nev-Ari (T31S, R64E, S6; T31S, R63E, S1, 2).

2. Nevada State Route 163 (SR 163). — This site is on a paved four-lane highway, approximately 3 mi east of the intersection with US 95 (T32S, R64E, S3; T31S, R64E, S34, 27, and 26).

3. Nevada State Route 164 (SR 164). — This site is on a paved two-lane highway, approximately 3 mi west of the intersection of US 95 and SR 164 in Searchlight (T28S, R62E, S36, 24).

4. Nevada State Route 165 (SR 165). — This site is on a paved two-lane highway, approximately 3 mi east of the intersection of US 95 and SR 165 (T24S, R63E, S36, 24).

5. Loran Road. — This site is on a paved but poorly maintained road to a U.S. Coast Guard loran station ca. 3 mi east of US 95 (T30S, R64E, S21).

6. County Road BC 1. — This site is on a graded and maintained unpaved electrical transmission line access road (the McCullough Pass Road), ca. 6 mi southwest of the intersection of US 95 and SR 165 (T25S, R63E, S9, 10, 15, 16).

7. County Road BC 2. — This site is on a graded and maintained unpaved electrical transmission line access road, ca. 4 mi southwest of Cal-Nev-Ari (T31S, R63E, S3, 4).

The surveyed areas at all sites encompassed 500 m along the axis of the road and began at the edge of the roadway and extended at least 1000 m away from the edge of the road. The US 95, SR 165, and BC 1 sites gradually decrease in elevation with distance from the highway while the SR 163, SR 164, BC 2, and Loran sites gradually increase in elevation.

Traffic Levels. — Four sites were on roads that are periodically equipped with Nevada Department of Transportation automatic traffic counters. US 95 and SR 163, 164, and 165 have experienced dramatic increases in traffic levels

Table 1. Average daily traffic (ADT) for the 4 major roads in the Piute and Eldorado valleys in southern Nevada (Nevada Department of Transportation, 1991, 1992). For the other 3 study sites, Loran Road was estimated at 25 in 1992, and BC 1 and BC 2 had no data.

Year	US 95	SR 163	SR 164	SR 165
1982	1890	1025		
1983	2180	1360	320	100
1984	2240	1530	345	115
1985	2360	1840	285	195
1986	2700	2110	330	175
1987	3010	2600	375	150
1988	3500	3000	430	155
1989	3880	3415	530	165
1990	4685	4160	555	145
1991	4565	4020	550	195
1992	5210	4610	895	220

over the last 10 years (Table 1). The traffic on US 95 tripled in 10 years. On SR 163 traffic nearly quadrupled in 10 years. Traffic on SR 164 and 165 has shown a less dramatic increase but has more than doubled. The traffic on the Loran road is primarily Coast Guard personnel and a few miners and probably has not increased significantly in recent years. It is difficult to assess traffic trends on BC 1 and BC 2 but long-time Searchlight residents have observed that traffic on all of the unpaved roads in the vicinity of Searchlight has increased dramatically in recent years.

Survey Methods. — We selected single large plots rather than multiple small plots on each road. Our rationale in choosing single large plots was that multiple small plots would accentuate the likelihood of encountering large scale patchiness such as might be due to environmental inhomogeneities, such as soil type, previous disturbance, elevation, and drainage or other factors (Schamberger and Turner, 1986; Freilich et al., 2000). The large-scale patchiness would also make selection of control sites problematic, thus we selected sites that would be consistent with a regression analysis by road traffic level.

Each site was surveyed by walking straight line transects parallel to the highways. All plots were surveyed between fall of 1992 and June of 1993. Total survey time for one coverage of a single plot did not exceed 14 calendar days. Plots on US 95 and on SR 163 were surveyed in fall 1992 and again in June 1993 to examine seasonal differences and also to extend the depth of the plots. No rain or severe wind occurred during the survey period for any plot. On the first two sites assessed (US 95 and SR 163) transects were spaced at 10 m intervals out to a distance of more than 1000 m from the highway so that resampling of the data set would enable us to determine an effective sampling interval. At distances greater than 1000 m, and at all other sites, the interval between transects was 100 m. Surveys of the road shoulder were also conducted at the US 95 and SR 163 sites, but not elsewhere. The distance along each transect and the location of all tortoise sign was measured by using a Rolotape™. Tortoise sign included living tortoises, tortoise remains (intact or disarticulated), tortoise burrows, pallets, and shelters, tortoise droppings, uric acid deposits, courtship rings, drinking depressions, egg shell fragments, and tracks. All tortoise sign was identified, coded and mapped (Fig. 2 is a map of the SR 164 site).

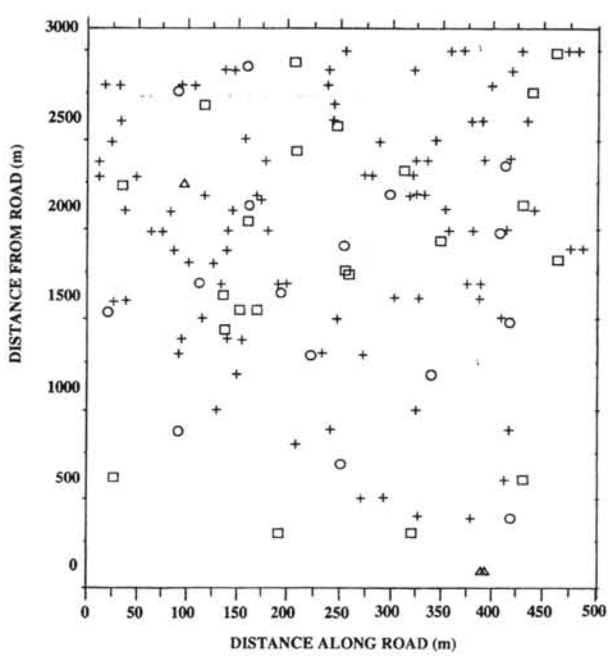

Figure 2. Map of the SR 164 site showing all sign found on transects parallel to the roadway spaced at 100 m intervals. triangle = tortoise shell parts; circle = active burrows, square = inactive burrows; + = scat. Also counted but not found on this plot were live tortoises, bones, courtship rings, pallets, uric acid deposits, and tracks.

Survey Personnel. — Surveys of the first 1000 m at the US 95 and SR 163 sites were conducted by personnel from 7 government, non-governmental, and educational institutions. All other surveys were conducted by RWM.

Analysis. — All statistical analysis, except fitting curves, used STATVIEW software (Abacus Concepts). Curves were fitted using SIGMAPLOT (SPSS Science). The distribution of types of sign was addressed by analysis of variance (ANOVA) to compare mean distances of different types of sign from the road on 500 m wide plots that were 1000 m deep with the 10 m transect intervals (i.e., on US 95 and SR 163 only). χ^2-tests were used to examine distribution of total sign (close to or far from the road) on subsets of the plots ranging from 300 m to 3000 m deep. Analysis of the 10 m transect data sets from the US 95 and SR 163 plots was used to determine appropriate sampling (transect) interval. The 10 m interval data sets were resampled at increasing intervals: 10, 20, 50, 80, 100, 120, 150, 180, and 200 m. The total sign count was correlated with distance from the road for each sampling interval. The data from 100 m transect spacings were fitted to 3 parameter sigmoid curves. We defined the distance from the road at 90% of the value of the asymptote for total sign as the magnitude of the impact.

RESULTS

Distribution of Different Types of Sign. — We found 467 total sign and 9 sign types on the 500 m wide x 1000 m deep plot at the US 95 study site. Four carcasses or parts of carcasses were found on the road shoulder. Analysis of variance showed that there were significant inhomogeneities of mean distances from the road of sign types ($F = 4.58$, $p < 0.001$) on the plot. Subsequent analysis showed that all tortoise remains pooled (scattered parts, whole skeletons, single bones, but excluding the carcasses on the shoulder), as well as inactive burrows, were closer to the road than those sign associated with live tortoises, i.e., live tortoises, active burrows, and scat (Scheffe F-test, $p < 0.05$). However, tortoise remains (skeletons, scattered parts) constituted only 2.3% of the data (11 sign), while scat made up 82%, active burrows 6.6%, and inactive burrows 6.1%.

On the 500 m x 1000 m plot at the SR 163 study site 185 total sign and 8 sign types were found. Two carcasses were found on the shoulder of the road. Results of the ANOVA on distance from the road of different sign types was similar to the US 95 plot. Significant inhomogeneities were found ($F = 4.88$, $p < 0.0001$). Tortoise remains were found closer to the road than were live tortoise sign (Scheffe F-test, $p < 0.05$), but again tortoise parts constituted a very small portion of the total data (2%), while live tortoises, scat, and burrows together made up more than 92%. The remaining sign were made up of temporary shelters, tracks, courtship rings, and uric acid deposits. On this plot inactive burrows were not significantly closer to the road than were active burrows.

The distribution of total sign on the US 95 and SR 163 plots was examined using χ^2 on subdivisions of the plots that extended 300, 600, and 1000 m from the road. In each case the plot was split into equal halves (close to and far from the road) and the total sign counted in each half. The mean of the two counts (i.e., an even distribution) was used as the expected value for the χ^2-test. Table 2 shows the total count and χ^2 values for the different sized subdivisions of the two high-density data plots. On the US 95 plot, χ^2 showed that sign were not randomly distributed and that the reduction in sign close to the road was detectable on the 600 and 1000 m plots. On the SR 163 plot, however, the reduction of sign close to the road was detectable only on plots of at least 1000 m ($p < 0.05$).

Sign distribution on study plots on all seven roads was evaluated using χ^2-tests on 100 m spaced transects (Table 2). The overall sign count was necessarily much lower than on the plots with 10 m transect spacing. On only two of these plots (BC 2 and US 95) did χ^2 tests show a non-random distribution of tortoise sign relative to the road on 1000 m deep plots. Even the 1600 m (1 mile) plots did not, in all cases, show a decrease in sign count close to the road. On larger plots (2000 m and 3000 m deep), however, χ^2 tests showed a clear decrease in tortoise sign adjacent to the road on all plots except the Loran Road. The Loran Road, which carries only approximately 25 cars per day, showed no area of reduced sign count close to the road.

Table 2. χ^2 values for tortoise sign close to vs. far from the road on plots of various depths along seven roads in the Piute Valley. χ^2 values were calculated conservatively using the mean of sign counts on the half of the plot near the road and the half far from the road as the expected value. Each plot was divided exactly in half for each exercise so that on a 1000 m deep plot the sign count close to the road was all sign encountered on transects spaced 100 m apart within the first 500 m of the road. On several roads the shorter plots (1000 m and 1600 m) did not reveal a difference in sign count between close to and far from the road, while on the deeper plots the reduction in sign count closer to the road was clear.

Road	Plot Depth (m)	Total sign Close to road	Total sign Far from road	χ^2	p
US 95	1000	15	39	10.65	<0.005
	1600	25	50	8.33	<0.005
	3000	42	130	45.02	<0.005
	4000	119	172	9.65	<0.005
SR 163	1000	10	11	.048	NS
	1600	13	28	5.48	<0.025
	3000	36	104	33.03	<0.005
	4000	61	170	51.43	<0.005
SR 164	1000	10	10	0	NS
	1600	13	28	5.48	<0.025
	3000	27	108	48.6	0.0005
SR 165	1000	1	6	1.76	NS
	1600	5	9	1.14	NS
	3000	12	49	11.22	<0.005
Loran	1000	25	24	.01	NS
BC 1	1000	2	5	1.28	NS
	1600	4	15	6.37	<0.025
	3000	7	23	8.54	<0.005
BC 2	1000	2	22	16.67	<0.005
	1600	7	63	44.8	<0.005
	3000	57	115	19.6	<0.005

Effects of Time of Year. — The total sign count on a 500 m section of the US 95 site (2900 to 3400 m from the road) differed enormously between November 1992 and June 1993. The first survey, conducted after a relatively wet year found 77 total sign, while the second survey, conducted in June of a drier year found only 34 sign. The same person (RWM) conducted both surveys. Although the pattern of increasing sign count with increasing distance from the road was clear in both data sets, these results suggest that time of year of the survey, as well as environmental conditions such as drought, do affect gross sign count. This may limit the applicability of the techniques discussed here where sign count is very low, and may affect the consistency of survey results in the same place from year to year.

Effective Sampling Interval. — Data from the US 95 and SR 163 plots were resampled at increasing transect intervals (from 10 to 200 m). Linear regressions of total sign on

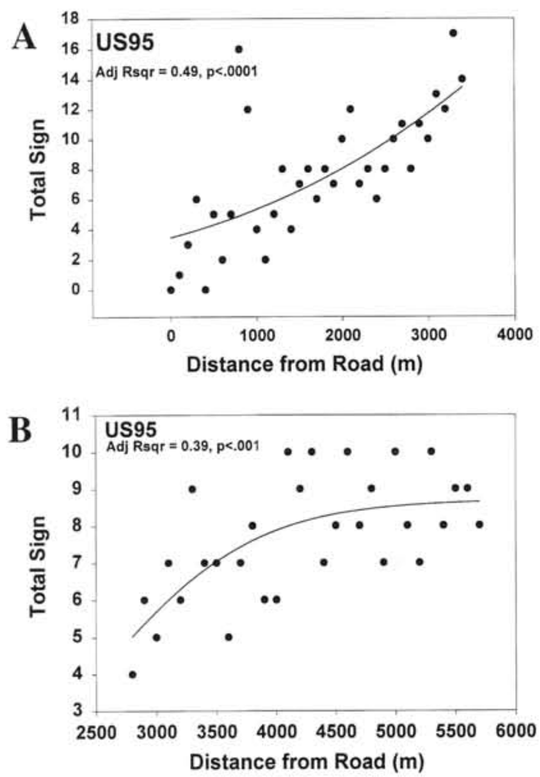

Figure 3. Total sign count for 500 m long transects at 100 m intervals along US 95. **(A)** Data collected in the fall of 1992 from the roadway out to 3400 m from the road. A 3-parameter sigmoid curve fit did not have a significant asymptote. **(B)** Data collected in the spring of 1993 from 2800 to 5900 m from the road. There was a lower total sign count than in the previous fall, but a 3-parameter sigmoid curve did show a significant asymptote.

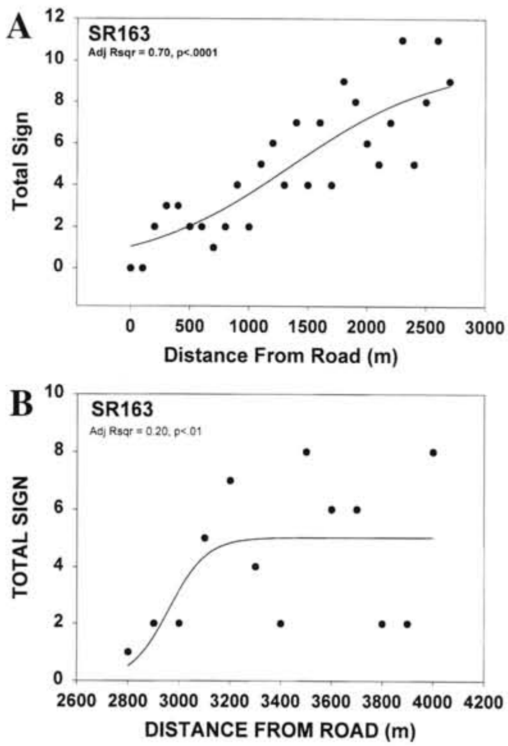

Figure 4. Total sign count for 500 m long transects at 100 m intervals along SR 163. **(A)** Data collected in the fall of 1992 from the roadway out to 3400 m from the road. A 3-parameter sigmoid curve fit did not have a significant asymptote. **(B)** Data collected in the spring of 1993 from 2800 to 4000 m from the road. There was a lower total sign count than in the previous fall, but a 3-parameter sigmoid curve did show a significant asymptote.

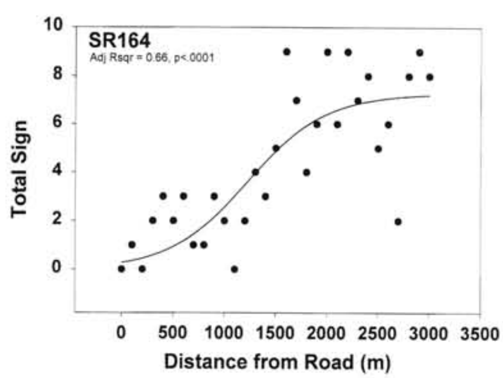

Figure 5. Total sign count at distance from the roadway for SR 164.

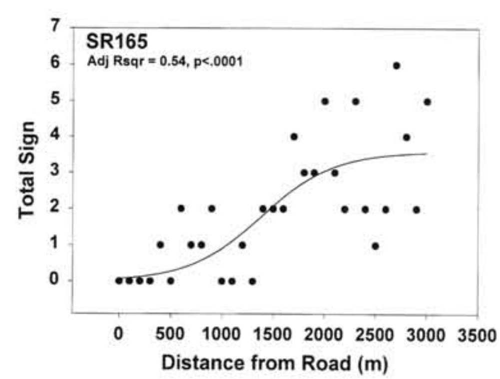

Figure 6. Total sign count at distance from the roadway for SR 165.

distance from the road for each resampled data set were used to evaluate efficient transect spacing. For these two plots, total sign count was significantly correlated ($p < 0.05$) with distance from the road for all transect spacings below 120 m. Thus we chose to use 100 m transect spacing for the remainder of the study in order to assure a reasonable probability of detecting any trend in tortoise sign density that might exist. Transects spaced even more closely might be necessary to determine impact when sign density is even lower or where the impact is small.

Magnitude of the Impact Zone. — The total sign count data for transects spaced at 100 m intervals were fitted to a 3-parameter sigmoid curve:

$$y = a/(1+ e^{-(x-x_0)/b})$$

where $\mathbf{y}$ = total sign count, $\mathbf{x}$ = distance from the road, $\boldsymbol{a}$ = the fitted asymptote, and $\mathbf{x_0}$ = the distance from the road at the inflection point for the curve for each road. Total sign count from all roads, except Loran Road, fitted well to 3-parameter sigmoid curves with significant asymptotes and inflection points. The magnitude of the impact was defined as the distance from the road at 90% of the asymptote for the fitted curve.

For the US 95 site, the November 1992 survey data (up to 3400 m from the road) showed a significant increase in total sign with distance from the road, but the curve did not level off (Fig. 3a) and could not be fitted to a significant asymptote. The site was resurveyed in June 1993 (2800 m to

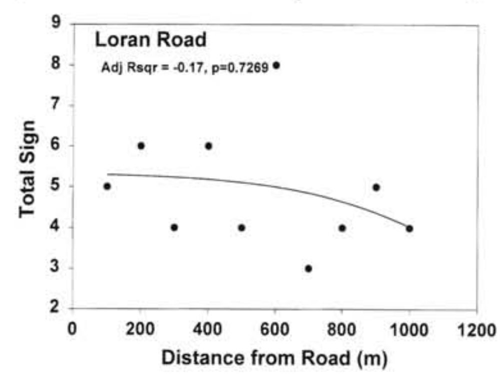

Figure 7. Total sign count at distance from the roadway for Loran Road. There was no significant correlation between distance from the road and total sign count.

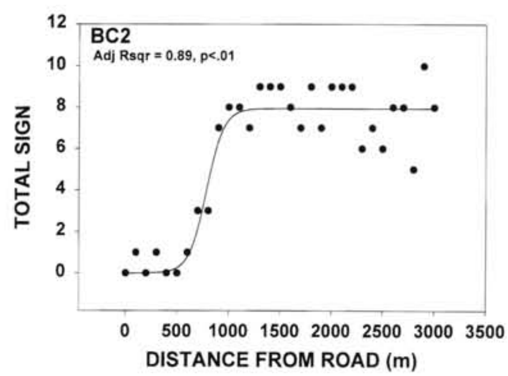

Figure 8. Total sign count at distance from the roadway for BC 2.

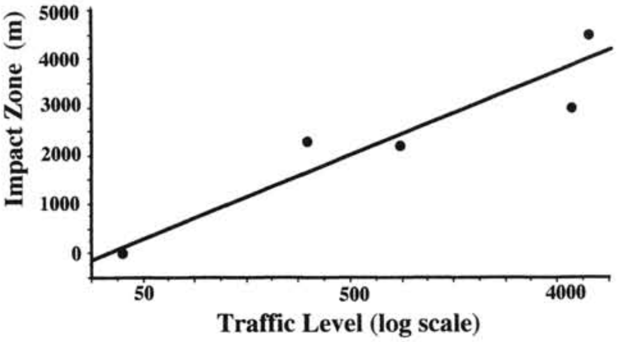

Figure 9. Linear regression for Impact Zone on the log of average daily traffic (ADT) for the five roads with known traffic levels. The good linear fit (adj. $r^2 = 0.92$) suggests that impacts may increase at traffic levels higher than 5000 vehicles per day. Data are needed for roads with higher traffic levels and with documented lower traffic levels to ascertain the shape of the curve and the total extent of roadway traffic impacts on desert tortoise populations.

5800 m from the road). Although the sign count was much lower in the overlapping survey area (2800–3400 m) in the second survey, the upward trend was very similar. The curve for the plot more distant from the road did level off with a significant asymptote (Fig. 3b). The distance from the road at 90% of the asymptote for the fitted curve was 4250 m.

For the SR 163 site, like the US 95 site, the November 1992 survey data did not extend far enough from the road to show a significant leveling off of total sign (Fig. 4a) and could not be fitted to a significant asymptote. The site was surveyed again in June 1993, and again, although the sign count was much lower in the overlapping survey area in the second survey, the upward trend was very similar. The curve for the plot more distant from the road did level off with a significant asymptote (Fig. 4b). The distance from the road at 90% of the asymptote for the fitted curve was 2650 m.

For the other sites the distance from the road at 90% of the asymptote for the fitted curves were as follows: SR 164 = 2150 m (Fig. 5); SR 165 = 2250 m (Fig. 6); Loran Road = no trend (Fig. 7); BC 1 = 1389 m; and BC 2 = 1090 m (Fig. 8).

Linear regression of impact zone (defined as the distance from the road at 90% of the asymptote of the fitted 3-parameter sigmoid curve) on the log of average daily traffic level for the five roads with known traffic levels showed a strong positive correlation (adjusted $r^2 = 0.92$, $p < 0.01$). Higher traffic levels were associated with reduction in total sign count at greater distances from the road than were low traffic levels (Fig. 9).

DISCUSSION

Distribution of Different Types of Sign. — The analysis of distribution of different types of sign on the US 95 and SR 163 plots suggested that type of sign would probably not provide a robust assessment of highway impacts in all cases or when sign is sparse.

The smaller plot sizes and lower data densities did not reveal significantly lower sign counts close to the roads. However, increasing the size of plots at some sites was sufficient to improve resolution. These data indicate that it might be necessary to use very large plots (greater than 1000 m deep and possibly much greater than 500 m along the road) to assess population impacts of roads, especially if sign density is low.

Effects of Time of Year. — Surveys conducted in the fall of a wet year found more sign than those conducted in June of a drier year. This suggests that surveys after a wet period may be more efficient than after a dry period in detecting trends in areas where tortoise density is low. However, our data on all seven roads indicate that effective assessments of highway impacts can be made at any time of year so long as surveys are completed quickly, so that weather and tortoise activity do not change the distribution of sign on a plot during the survey period.

Effective Sampling Interval. — Overall, the 500 m long transects spaced at 100 m intervals used in this study provide a robust methodology for detecting impacts of highway traffic in the environments we sampled. In habitats that are less suitable for tortoises, where densities are lower, longer transects may be required. If management decisions are required for a finer distance resolution than 100 m then the distance between transects may need to be smaller. The parallel transect orientation also supports methods required by the USFWS in determining the zone of influence of impacts of construction activities on tortoises (U.S. Fish and Wildlife Service, 1992).

Magnitude of the Impact Zone. — The results of this study demonstrate that there is a detectable impact of vehicle road traffic on the abundance of tortoise sign adjacent to roads and highways with traffic levels from 220 to over 5000 vehicles per day. The extent of the detectable impact was positively correlated with the measured traffic level. The higher the traffic levels (between 220 and 5000 average daily traffic), the greater the distance from the road the impact is detectable. These results are similar to those of Fahrig et al. (1995), who found that the number of dead frogs and toads on roads increased as traffic increased and the density of adjacent populations decreased, and Fowle (1996), who found that population density of painted turtles (*Chrysemys picta*) increased with distance from a highway.

One new result of this study is the finding that reductions in tortoise sign are easily detectable more than 4000 m from the roadway (Figs. 3, 9). With only a few points with known traffic levels it is not clear whether even higher traffic volume will result in detectable impacts to tortoise populations farther from the road. The best fit to existing data is linear and does not level off, but additional data on roads with greater traffic volume is needed to clarify the issue. There is also evidence from the unpaved utility access roads (BC 1 and BC 2) that even lower traffic levels may have a significant detectable impact. Further examination of population impacts of lower traffic roads is needed.

All of our study sites are relatively free from other obvious human impacts and are indistinguishable from habitat supporting moderate to high tortoise population densities at greater distances from the highways and roads. The smaller numbers of tortoise sign over the area surveyed

Table 3. Land area with reduction of tortoise sign count adjacent to 7 roads within conserved tortoise habitat defined in the Clark County Habitat Conservation Plan (RECON, 1991) and Intensively Managed Areas (IMAs) delineated in the Clark County Multiple Species Habitat Conservation Plan (RECON, 2000). Distance from the road is for one side only. Total impacted area considers whether one or both sides of the road is through conserved tortoise habitat. Total impacted area amounts to more than half of the area considered to be conserved.

Road	Distance through conserved tortoise habitat (km)	Detectable reduction distance from the road (km)	Total impacted area both sides of of the road (ha)
US 95	61.60	4.25	51,414
SR 163	22.08	3.15	13,606
SR 164	27.84	2.15	11,842
SR 165	21.28	2.25	9,323
Loran		0	0
BC 1	41.60	1.39	11,087
BC 2	23.20	1.09	5,115
TOTAL			102,387

adjacent to the road demonstrates a clear negative impact of the road on tortoise populations. Further, since in all other regards this area appears to be generally suitable tortoise habitat, except for the presence of the highway, it is clear that the highway has significantly degraded the capacity of this habitat to support viable tortoise populations.

Both US 95 and SR 163 have roughly equivalent traffic levels though SR 163 has experienced a more dramatic increase in traffic over the last 10 years than has US 95. The numbers of mortalities immediately adjacent to the road and the slope of the regressions of total sign on distance from the road are all roughly equivalent at both sites. The distance from the road at which the impact is detectable on US 95 is 4250 m and on SR 163 it is considerably less at 2650 m. This difference undoubtedly reflects the recent increase in traffic. The SR 163 tortoise population probably has not stabilized under the recently increased mortality pressure resulting from the traffic increase.

Impacts to Conserved Tortoise Habitat. — Clark County's Short-Term Habitat Conservation Plan required that 400,000 acres of tortoise habitat be "conserved" in the Piute and Eldorado valleys of southern Nevada. The definition of "conserved" consisted of significant land use changes including the removal of livestock grazing and some restriction of off-highway vehicle (OHV) racing, but it did not address the direct mortality of tortoises on roadways. The seven roads evaluated for this study are the major roadways through that "conserved" habitat and represent a significant degradation of the suitability of 102,387 ha (see Table 3), representing more than 260,000 of the 400,000 acres of the area intended to be preserved for desert tortoises.

The most direct mitigation of this impact is to prevent access to the roadway by tortoises. Clark County has chosen to restore habitat quality adjacent to roadways by installing fences or barriers or using other mechanisms to reduce tortoise-vehicle encounters as part of the mitigation for its Multiple Species Habitat Conservation Plan (RECON, 2000). Although there is abundant reason to believe that the installation of fences and other barriers along roadways will do much to reduce direct tortoise mortalities, the effects of fragmentation caused by those roads and fences on the desert tortoise population as a whole has yet to be addressed.

The tortoise habitat in the Piute and Eldorado valleys is fragmented by the impacts of US 95 running north to south the entire length of the "conserved habitat" and by the other roads and highways so that the effective size of contiguous habitat blocks is quite small. We expect that the prevention of direct mortalities on roadways will be an important step, but not the last step, in mitigating the effects of roadway traffic on tortoise populations.

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