Measuring the Effectiveness of a Tortoise-Proof Fence and Culverts: Status Report from First Field Season

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Abstract. Road kills are an important source of depletion for desert tortoise populations. In 1990, the California Department of Transportation erected a tortoise-proof fence along State Highway 58 between Barstow and Kramer Junction. The California Energy Commission, responsible for licensing thermal power plants in California, Bureau of Land Management, and other agencies initiated a long-term study to determine if the fence will prevent tortoise road kills, and if drainage culverts will accommodate movements of tortoises from one side of the highway to the other. In this paper, we discuss the process used to select the study site and the results of field work performed to collect baseline data.

A series of transects walked within one mile of the highway indicated that human impacts and relative densities of tortoises varied among potential study sites. These data were used to identify the site of a 1 mi^2 permanent study plot. During baseline work on the study site, 44 tortoises were found, 36 tortoises were affixed with radio transmitters, and 3 were equipped with electronic transponders for remote sensing. The remains of 61 tortoises were located along 66 miles of highway edge; these data will serve as a baseline for future surveys to test if the fence is effective at reducing road kills.

INTRODUCTION

Highway traffic has been, and continues to be, an important cause of mortality for the desert tortoise (*Gopherus agassizii;* Berry and Nicholson 1984a), a species state and federally as listed threatened. In addition to gross mortality, roads and highways impact tortoise populations through restriction of movement. This restriction of movement may result in fragmented populations, which may increase the incidence of local extinctions, or increase the potential for inbreeding and inbreeding depression. Both fragmentation of populations and restricted gene flow are more likely to occur with increases in traffic volume, width of highways, and time (e.g., Nicholson 1978). Because there are many roads and highways throughout desert tortoise habitat, the potential for road kills to affect tortoise populations is great, therefore, the mitigation of road kills could help to facilitate the recovery of tortoise populations.

In 1990, California Department of Transportation (Caltrans) erected tortoise-proof fencing along State Highway (Hwy) 58 in a portion of the highway that was scheduled to be widened from two lanes to a four-lane divided highway (Boarman 1991; Boarman and Sazaki, in press). Culverts for flood protection were also installed. Crushed tortoise carcasses have been found along Hwy 58 (Appendix 1 in Boarman 1991), and Bureau of Land Management (BLM) has identified this particular stretch of highway as important tortoise habitat (Bureau of Land Management 1988; Sievers et al. 1988). In 1990, the BLM, California Energy

Commission, Caltrans, U. S. Fish and Wildlife Service, and the California Department of Fish and Game embarked on a cooperative monitoring project to determine the effectiveness of culverts and protective fencing in contributing to recovery of tortoise populations in the area near the fence (Boarman 1991; Boarman and Sazaki in press).

The Review Board for the project developed four study questions (Boarman and Sazaki, in press) that serve as the focus for the long-term project. (1) Is the fence an effective barrier for preventing road kills? (2) Does the fence facilitate "recovery" of the tortoise population near the highway? (3) Do culverts facilitate movements from one side the highway to theother? (4) How do individual tortoises behave when they encounter the fence and culverts? Here we discuss the results of the process to select a permanent study site, and the baseline data collected to address the above questions (see also Boarman 1992).

The Fence and Culverts

The highway traverses slightly rolling terrain consisting primarily of shadscale scrub and creosote bush scrub communities at elevations of 2245 to 2470 ft. The tortoise-proof portion of the fence consists of 24-inch wide, 1/2-inch hardware cloth sunk generally 6 in beneath ground level. The hardware cloth is attached to a 5-ft high, 5-strand right-of-way fence with three barbed wires on top and two un-barbed wires below. The 156 to 206 ft. long culverts are made of 36 to 60 inch, corrugated metal pipe; 54 inch, reinforced concrete pipe; or 10 ft to 12 ft by 6 ft to 10 ft, reinforced concrete boxes. The culverts cross beneath the entire width of the highway and will eventually connect directly to the fence, thus providing an unobstructed pathway between both sides of the fenced highway (Fig. 1).

Study Site Selection

To evaluate the effect of the fence and culverts on tortoise populations along Hwy 58 we established a long-term study plot, approximately 1 mi^2, that abuts the edge of the tortoise-proof fence. Because the overall success of the project depends on various characteristics of the specific study site, we designed a two-phased process for evaluating and choosing the site. Phase 1 involved selecting eight candidate study sites, and Phase 2 involved final selection from the alternatives identified in Phase 1. The evaluation criteria for each phase were discussed in Boarman (1991) and Boarman and Sazaki (in press) and included: tortoise density, land status, legal and physical accessibility, presence of culverts, location of fence, size of site, proximity to other roads, right-of-way for All-American Pipeline, similarity of habitat, and human damage to habitat.

Initial Survey for Tortoise Signs and Human Impacts

A series of transects were walked at each candidate site to record: 1) signs of tortoise presence for comparing relative tortoise densities and distributions, and 2) evidence of human impacts on each candidate study site. The data were also used to determine if tortoise densities increased with distance from the highway, as reported by Nicholson (1978).

Methods.--Surveys were conducted for tortoise sign and human impacts between March 20 and 31, 1991. The surveys consisted of a series of strip transects, which were each 10-yds wide and ran the width of each site, parallel to the highway. For each site there were four sets of three contiguous transects (Fig. 1). One set began immediately adjacent to the fence or pipeline right-of-way where it abutted the fence, the second was centered 1/4 mile from the fence, the third 1/2 mile, and the fourth ended 1 mile from the fence.

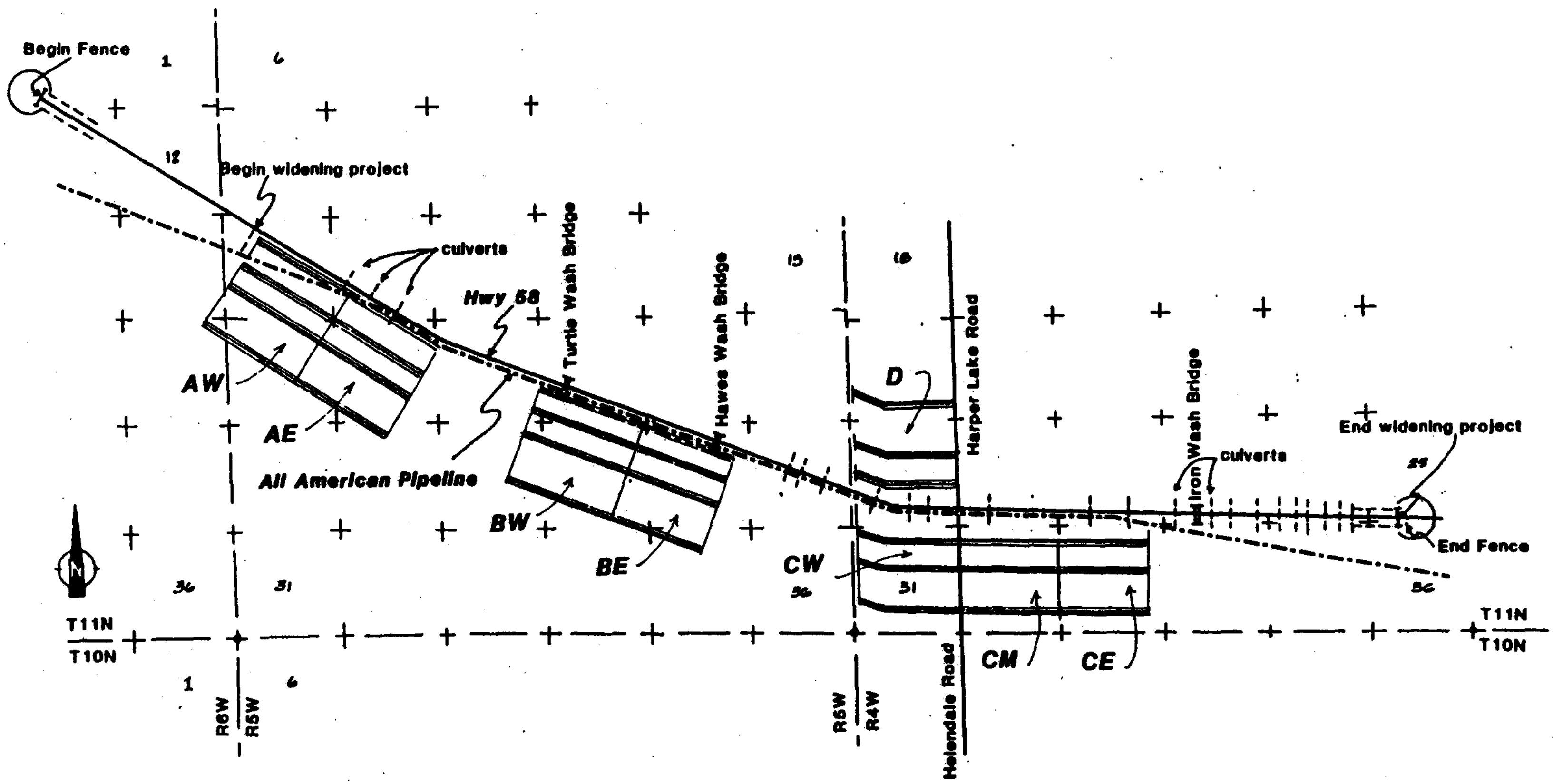

Figure 1. Map showing potential study sites that were surveyed by strip transects for estimates of tortoise density and human impacts.

For tortoise population density, the exact location and characteristics of all tortoise sign (i.e., live animals, shells, tracks, individual or groups of scats, burrows, and pallets) were recorded. Human impacts were evaluated by noting all roads, trails, graded areas, structures, sheep scat, individual tire tracks, campsites, garbage, shooting areas or targets, balloons, and mining pits or markers present on each transect.

For determining if there were significant differences ($P = 0.05$) among candidate study sites, the total number of tortoise sign along each transect were square-root transformed. The data were entered into a one-factor analysis of variance (ANOVA) with study area being the between groups effect. Pair-wise comparisons among means were made, post-hoc, using the Fisher's Protected Least Significant Difference test. A Kendall Partial Rank-order Correlation Coefficient was estimated to test for an east-west gradient in tortoise sign among sites. This analysis assumes that differences in total corrected sign counts (independent observations of scats, tracks, and burrows) accurately corresponded to relative differences in tortoise density.

Results.--The one-factor ANOVA of the transformed data showed a significant difference among sites ($F = 2.544$, df = 7, 88, $p=0.020$; Table 1). Post-hoc analyses indicated that the sites roughly fell into three groups: site AE with the lowest count, site CE with the highest, and all others in between. The seven sites that were south of the highway showed a nearly significant increase in tortoise sign from west to east (= 1.925, $p = 0.0543$, $n = 7$).

Discussion.--The density of tortoise signs did differ among sites, with a possible increase in densities from west to east. The highest density area, which was significantly higher than the others, was on the eastern-most site. The lowest density was near the west end of the study area.

Table 1. Mean number of tortoise sign found along each 1-mile long transect within each study area. Study areas are arrayed from west to east (with exception of D which was directly north of area CW). N for each area is 12.

Study Area	TCS	Standard Error
AW	2.5	0.74
AE	1.5	0.36
BW	4.1	0.93
BE	3.1	0.66
CW	4.3	0.96
CM	3.6	0.70
CE	7.1	0.23
D	4.9	0.01

Selection Process

To help select the study site, we used the method of Decision Analysis under uncertainty, which was developed by Raiffa (1968) for business management and adapted for wildlife management by Maguire (1986). Decision Analysis provides a framework for evaluating alternative choices in the face of a myriad of uncertainties that affect the outcomes of each alternative decision. The selection of the best available study site is essential for the success of the long-term project, but was dependent on several criteria (listed above), several of which involved uncertain impacts or intensities. It was necessary to consider several factors which often contradicted each other and made the selection process more complicated. The criteria considered were discussed in detail in Boarman (1991) and Boarman and Sazaki (in press). The stability of the land status was one uncertain factor. The extent of habitat heterogeneity and human impacts to the habitat and their respective impact on the outcome of the study were also uncertain. The extent and effects of the other criteria were more certain.

In the final analysis, three factors were most important in selecting the site: presence of culverts, human impacts, and land status. The site (CE) with the most tortoises had the most tenuous land status and the highest potential human impacts. The best sites (AW, BW, and BE)with intermediate tortoise densities had no culverts. Site AE, with the lowest human impacts and most stable land ownership and management status, had significantly fewer tortoises than any other site.

The selected study plot is a combination of study sites AE and AW (Fig. 2). It contains three culverts (two round corrugated metal ones and one large, double, concrete box culvert), has a relatively low level of human impacts, exhibits moderately heterogeneous habitat, is sufficiently large to contain a 1 mi^2 study plot with room for expansion, and is easily accessible for field workers. The All-American Pipeline does skirt the edge of the fence at the northeast end of the site, which may confound the study, but this was also true of all other marginally acceptable sites. The site includes a portion of the low density site AE, but was extended as far as was possible into site AW, which had an intermediate tortoise density. If feasible, the boundaries of the plot will be extended in the future to incorporate more of the higher density tortoise habitat and is less confounded by the All-American pipeline.

Baseline Inventories

Once the study plot was identified, it was prepared in the same manner as the permanent study plots established by the BLM for tracking tortoise population changes (Berry 1984b). The plot was surveyed for live tortoises, and radio transmitters were attached to 36 of them. Passive Integrated Transponders (PIT tags) were attached to three individuals.

Study Plot Location and Characteristics

The study plot is located on the south side of Hwy 58, approximately 7 miles east of Kramer Junction, San Bernardino Co., California (Fig. 2). It consists primarily of rolling hills to the north and relatively flat areas to the south. Vegetation is primarily an association of creosote bush (*Larrea tridentata*), burrobush (*Ambrosia dumosa*), Mojave saltbush (*Atriplex spinifera*), and Anderson thronbush (*Lycium andersonii*). Creosote is predominant in the northern portion of the study plot and saltbush dominates in the south. A small dry lake bed occurs at the southeast corner of the plot. The plot's substrate primarily consists of coarse sand or gravel with patches of cobblestone in the north and sandy loam in the south.

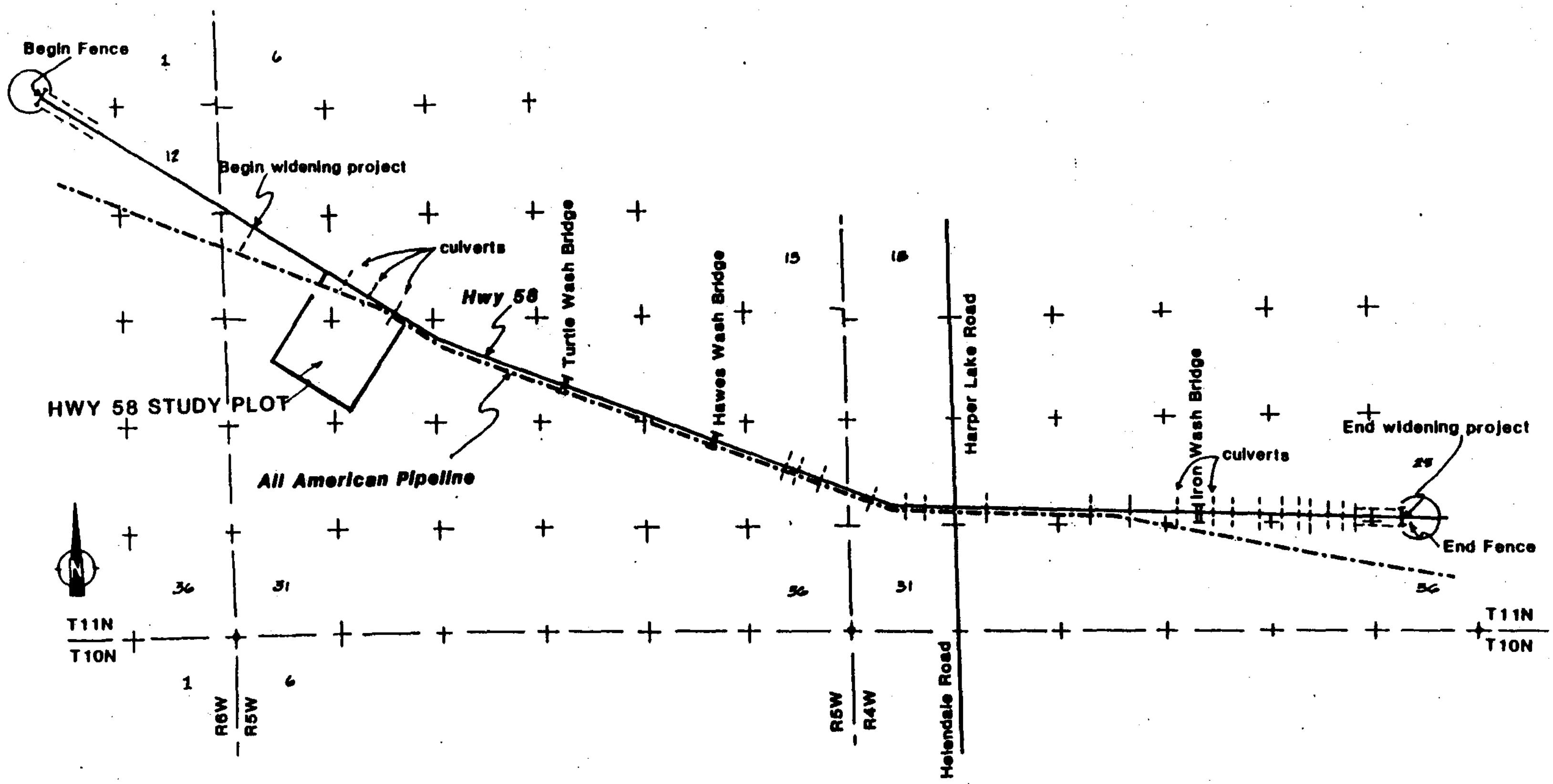

Figure 2. Map of general location of study plot.

Table 2. Size-age class distribution of live tortoise found on the study plot in spring, 1991.

Size-age Class	Unidentified Sex	Males	Females	Total	Percent
Juvenile 1	2			2	4.2
Juvenile 2	2			2	4.2
Immature 1	10			13	27.6
Immature 2	12			12	25.5
Subadult		3	0	3	6.4
Adult 1		1	9	10	21.3
Adult 2		4	1	5	10.6

Site Surveying and Marking

On May 3, 1991, the 1 mi^2 study plot was surveyed and a grid system established that was identical to that used at other BLM permanent study plots (Fig. 3). The northeastboundary of the site was along the highway barrier fence with the sides running at 90° angles southwest for one mile. The plot was surveyed relative to the legal cadastral survey for the area using range poles and reflecting prisms, which reflect infrared light back to the instrument giving a very accurate, distinct measure. A compass bearing, corrected for declination and accurate to 0.25°, was used as a reference angle. A total of 100 quadrats, which were each 528 ft X 528 ft, were surveyed and marked. For marking each quadrat, a four-foot length of 3/8-in rebar was placed in each corner. Ten-ft long 1/2-in diameter, Schedule 125 PVC pipe was placed over each rebar. The quadrats were numbered from 00 in the NW corner of each cadastral section (Fig. 7) and the quadrat number was written on the pole at the northwest corner of each quadrat. An additional five off-plot quadrats were established in the northwest corner where tortoise densities were higher.

Tortoise Surveys

Between April 27 and June 19, 1991, all quadrats were searched at least twice for tortoises. Each quadrat was searched methodically, using a standard pattern of parallel transects as described in Berry (1984b). The experienced field workers first walked the 10-yard wide contiguous transects in one direction then covered the entire plot again by walking similar transects at a 90° angle to the first ones. Every effort was made to rotate search times. However, 60-80% of the quadrats were searched before noon because mornings are usually more successful than afternoons for locating tortoises. All tortoises were marked (Berry 1984b), weighed, sexed, measured, and photographed, and observed for health status using methods described in BLM (1991).

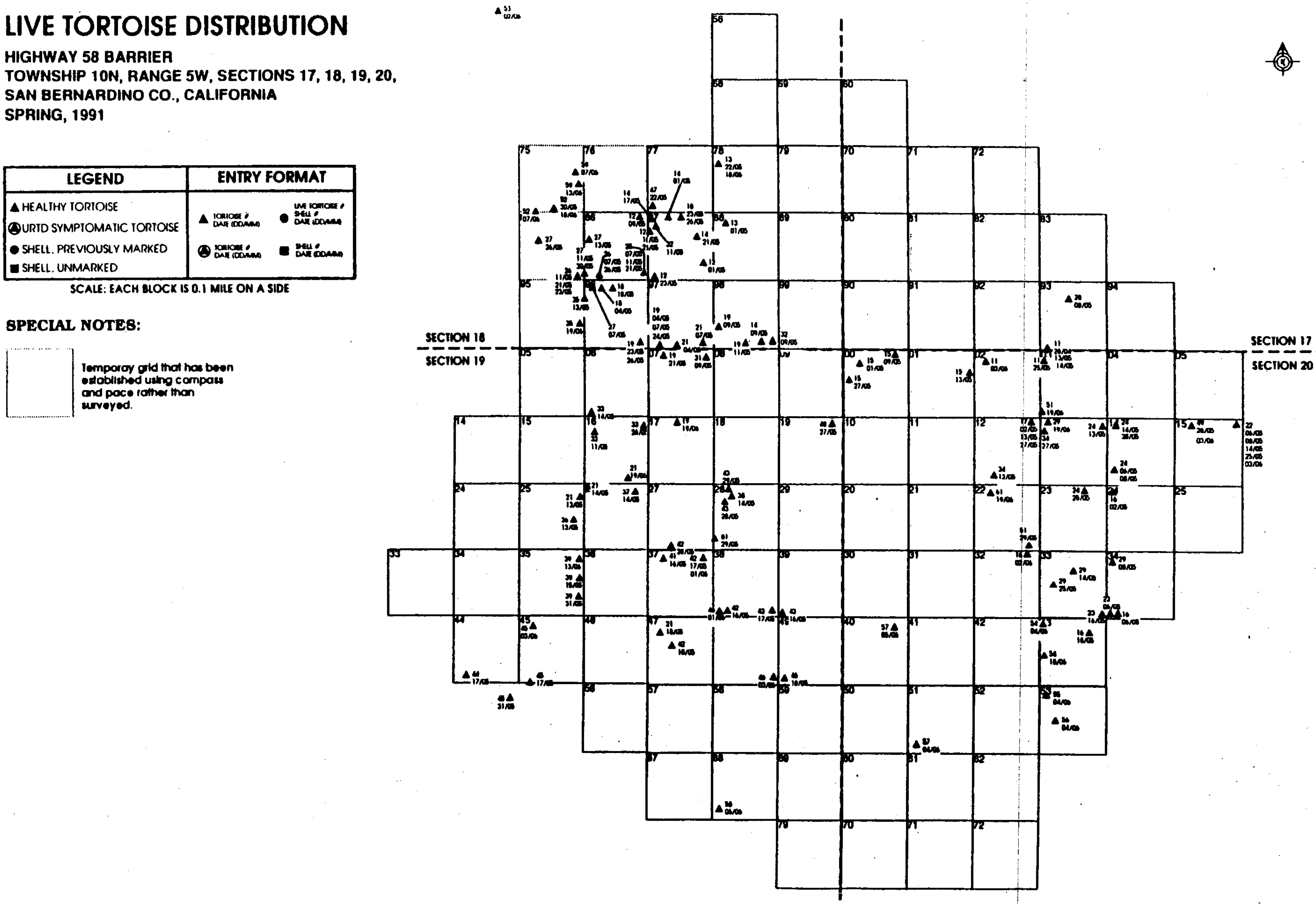

Figure 3. Map showing the layout and numbering system of plot grids and showing all individual tortoise sightings within or near the study site in spring of 1991.

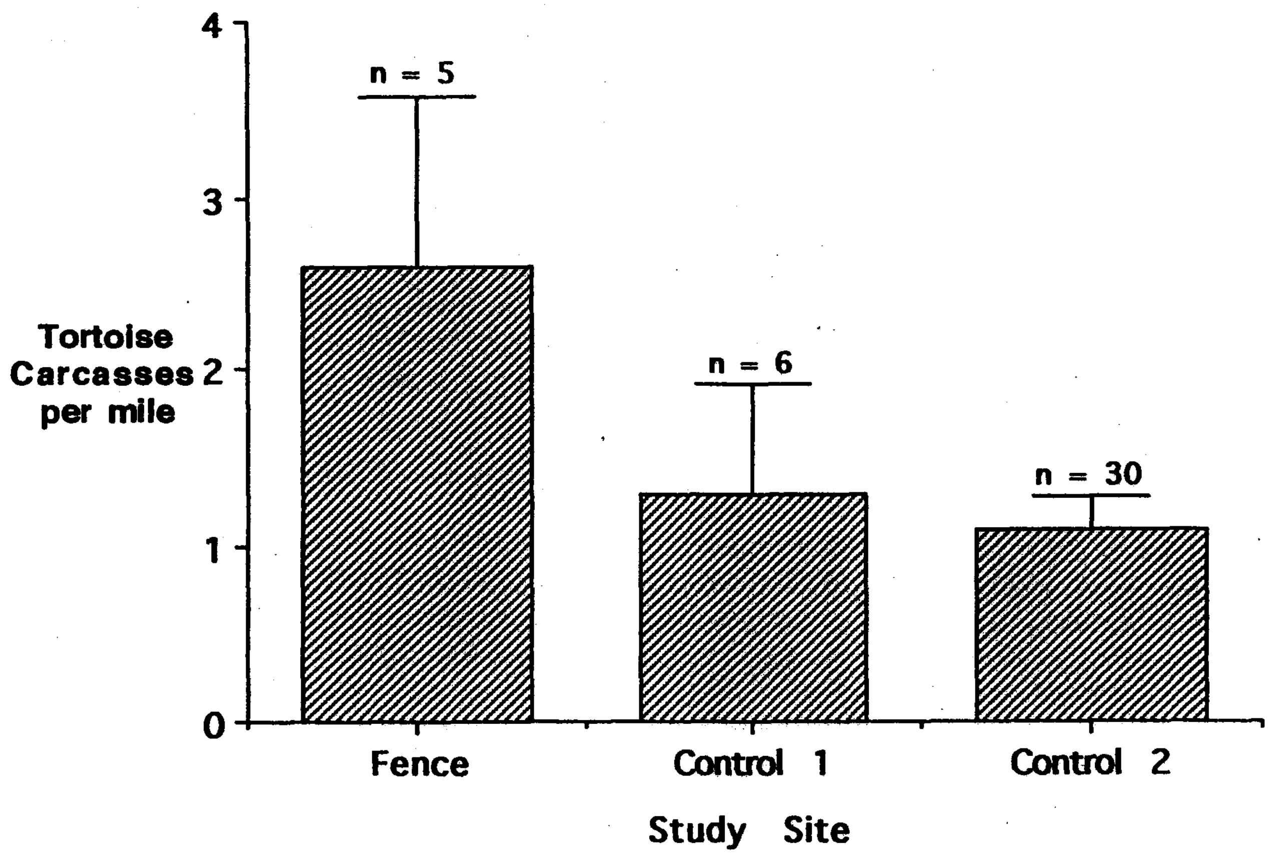

Figure 7. Mean (+ 1 SE) number of shells found per mile along highway edges.

In all, 47 tortoises were located, 44 of which were on the actual study plot (Table 2). Of those 47, 10 were adult females, 8 adult males, and 29 were too young to determine sex correctly. Four animals had wet "beaks" or noses, both of which are possible signs of Upper Respiratory Tract Disease. Three of them were of normal weight for their sex and size, while the fourth was somewhat lighter than expected. Locations of each individual sighting of live tortoises are shown in Fig. 3 and locations of the 65 tortoise carcasses found are shown in Fig. 4.

High-band VHS radio transmitters, made by AVM Instrument Company, Ltd., were attached to 36 animals. Twenty-one were stage two side-car transmitters with removable base plates, five were stage one side-car transmitters also with removable base plates, and 10 were solar-assisted transmitters. The removable base plates allow for easy removal of the transmitters for periodic servicing or replacement. The base plates of the larger two transmitter-types were attached to the 1st left costal scute and the antenna's were run through short sections of PVC tubing epoxied individually to the scutes. The solar-assisted transmitters were attached to the 5th vertebral scute with the flexible antenna in a near-vertical position. Three transmitters became detached from the tortoises, probably due to inadequate mixing or malfunctioning of the epoxy. Two of the transmitters were subsequently re-attached.

PIT tags were attached to three tortoises with 5-min Devcon epoxy. For the adults, the PIT tags were attached to the 10th left marginal scute, oriented parallel to the ground with the most sensitive end of the transducer pointed toward the rear of the animal. For small tortoises where the PIT tag would overlap marginal scutes if attached there, the tags were placed on the pygal scute.

Human Impacts

Several human impacts were present on the site (Fig. 5). The majority of the plot lies south of the All-American and Mojave gas pipelines, but the pipeline right-of-way runs directly through the north-east end, mostly parallel to the barrier fence. Five lightly traveled, dirt access roads run through the plot, although none were known to be used by anyone not associated with this project. A helicopter and patrol plane flew low over the plot on daily inspections of the pipeline. The plot has been subjected to sheep grazing in the past; dry sheep manure was found within 10 of the plot's 100 quadrats. Several mining pits and balloon remains were found scattered throughout the plot. Evidence of shooting included shotgun shells and clay pigeons in two quadrats. Beer cans and a few broken bottles were found within tossing distance of the highway although there were also many scattered throughout the plot. Campsites with old fire pits were found on four quadrats.

Highway Sweeps For Road Kills

The Highway Sweeps project is designed to determine if the barrier fence effectively prevents road kills. A series of transects were walked along the edges of two highways in San Bernardino Co., California. All desert tortoise carcasses or shell fragments found were mapped, recorded, and collected. We compared the results among two controls and the treatment (fenced) site. The first year of the four-year project was intended to: a) test the data collection methods, b) remove old shells and fragments, and c) compare the three study sites. Using the same methods, the sites will be resurveyed in summers of 1992 through 1994.

CARCASS DISTRIBUTION

HIGHWAY 58 BARRIER
TOWNSHIP 10N, RANGE 5W, SECTIONS 17, 18, 19, 20,
SAN BERNARDINO CO., CALIFORNIA
SPRING, 1991

LEGEND	ENTRY FORMAT
▲ HEALTHY TORTOISE	▲ TORTOISE # DATE (DD/MM)
Ⓐ URTD SYMPTOMATIC TORTOISE	Ⓐ TORTOISE # DATE (DD/MM)
● SHELL, PREVIOUSLY MARKED	● LIVE TORTOISE # SHELL # DATE (DD/MM)
■ SHELL, UNMARKED	■ SHELL # DATE (DD/MM)

SCALE: EACH BLOCK IS 0.1 MILE ON A SIDE

SPECIAL NOTES:

Temporary grid that has been established using compass and pace rather than surveyed.

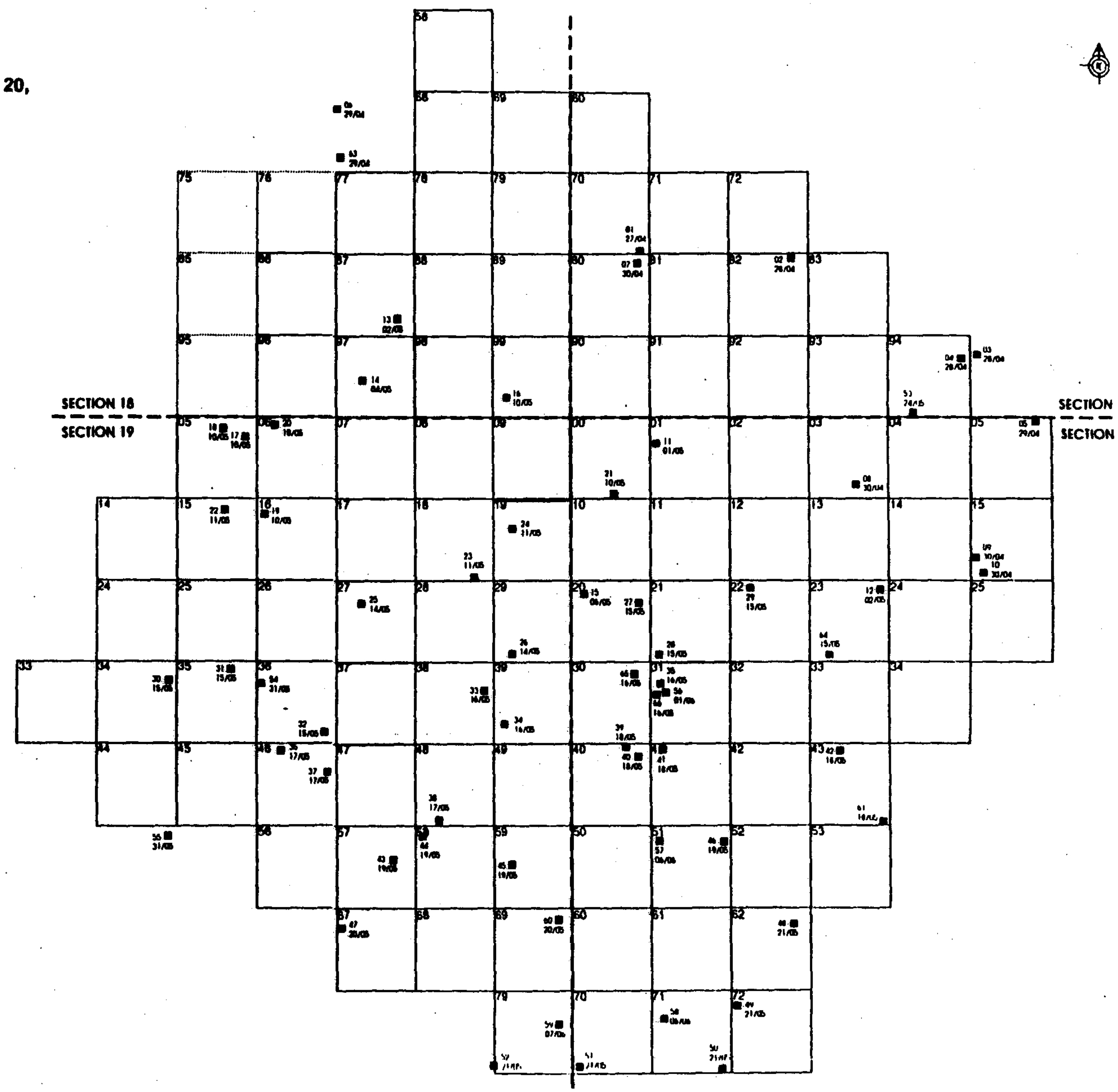

Figure 4. Map of all locations of all tortoise carcasses found within or near the study site in spring of 1991.

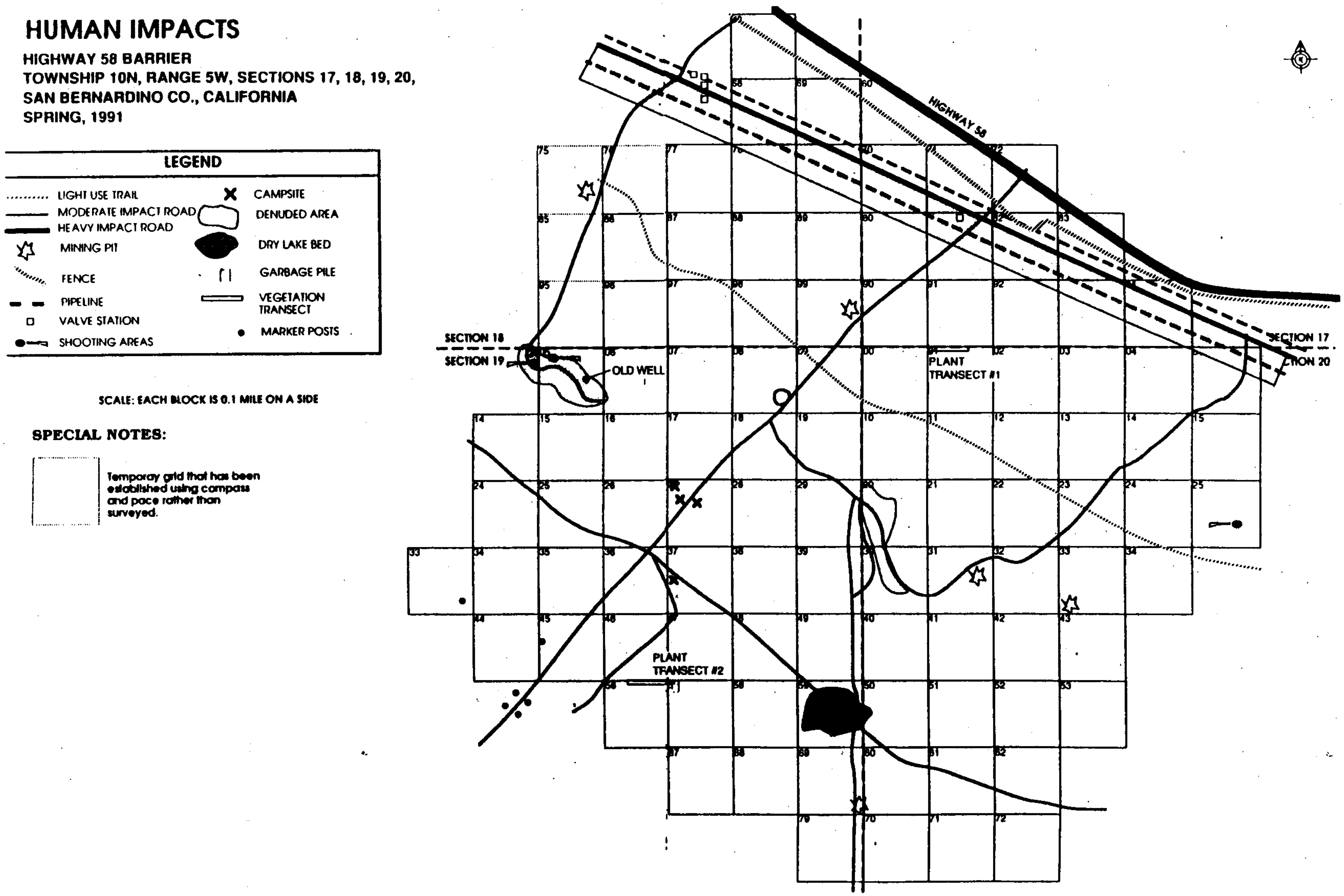

Figure 5. Map of major human impacts recorded on the study plot in spring of 1991.

METHODS

Between February 22 and March 12, 1991, 66 1-mi transects were surveyed along both edges of Hwy 58 and Hwy 395, east and south of Kramer Junction, San Bernardino Co., California (Fig. 6). The general study area was subdivided into three sites: Treatment, Control 1, and Control 2. The Treatment site consisted of both sides of Highway 58 where the tortoise-proof fence was in place. It began approximately 3.6 miles east of Kramer Junction and extended east for 15 miles (30 1-mile transects). Control 1 was along a nearby section of Hwy 58 without a tortoise-proof fence. It began at the western-most end of the Treatment site and ran west along both sides of the highway for three miles (6 1-mile transects). Control 2 was along an unfenced section of Hwy 395. It began 7.7 mi south of Kramer Jct and ran south for 15 miles along both sides of the highway (30 1-mile transects).

Each transect was 10-yd wide and centered 5 yd from the paved roadway. The field worker walked parallel to the highway, at the center of the transect, and scanned the ground for any tortoise remains or signs. If several fragments were found in a cluster less than 7 yd in diameter, we assumed they were from a single animal. A unique carcass number was assigned and the location along the transect was noted and mapped. The physical conditions of the highway edge, including shoulder width, were recorded.

To test for significant differences among the mean number of shells found per mile in each of the three sites, we used a Kruskal-Wallis analysis of variance by ranks test, corrected for ties.

RESULTS

Fragments from 61 tortoises were located; most of the carcasses consisted of a few small fragments. Although the Treatment site was 15-miles long, yielding 30 1-mile transects (15 on each side of the highway), we could only use five of the transects for the analysis. The four transects at both ends of the site were removed to avoid the possible confounding effect of tortoises entering the transect from the non-fenced areas; fragments from seven tortoises were located in these four transects and these shells were not used in further analyses. An additional 21 transects were removed because they were partially or completely obliterated by heavy construction activities associated with widening of the highway. The five remaining transectscontained relatively normal highway-edge habitat, similar to that along the two control sites, and were used for analysis of mean number of shells found per mile.

The mean number of shells found per mile in the Treatment site (2.6 ± 0.980) was roughly twice that found in each of the Control sites (1.3 ± 0.615 and 1.1 ± 0.182; Fig. 7). However, the variance among transects within each site was so great that there was no significant difference among sites (Kruskal-Wallis $H_c = 2.277$, df = 2, $p = 0.3202$).

Width of the highway shoulder in the Treatment site ranged from 6.5 to 131 ft., but 22 of the 30 transects were nearly entirely obliterated by construction. The average shoulder width for the relatively unimpacted transects within the Treatment site was 6.5 ft. The average width of the shoulder along Control 1 was 9.8 ft and for Control 2 was 6.5 ft.

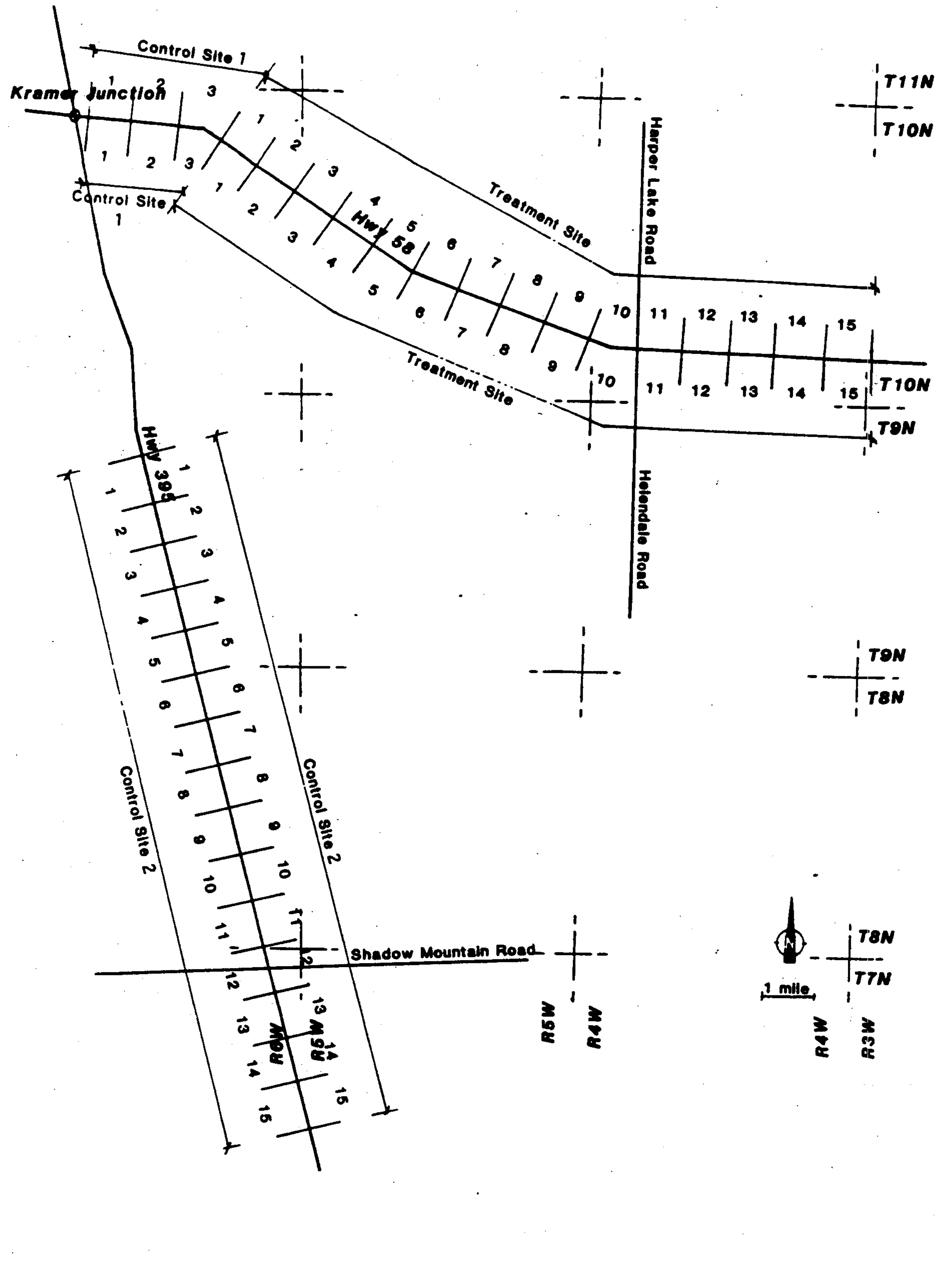

Figure 6. Map showing locations of transects for sweeps of highway edges to search for road killed tortoises.

DISCUSSION

The remains from a total of 61 tortoises were found. All shells found in the surveys were highly fragmented, which is consistent with the hypothesis that the animals were killed by motor vehicles while crossing the road. Additionally, all shell fragments showed evidence of being from dead tortoises exposed to weathering for at least one year prior to being collected (Woodman and Berry 1984). The tortoise-proof fence on Hwy 58 was erected by Caltrans in spring of 1990, so all dead tortoises found most likely died before the fence was in place. Therefore, we assume the sample from the Treatment site largely represents animals killed before the barrier fence was in place.

This is the first detailed study of the rate of tortoise deaths along roads. The only other data available are from Woodman (unpubl. data; see Appendix 1, Boarman,1991). In 1990, he found fragments from 58 tortoises along 17 miles (3.4/mi) of highway right-of-way along the same general stretch of Hwy 58 as covered by our study; 42 of which were considered to be dead for 4 years or less. It is difficult to infer from Woodman's or our data the full impact vehicular traffic has on desert tortoise populations. Nicholson (1978), showed a significant decline in tortoise densities near highways, indicating that highways cause population-level impacts. This relationship was corroborated by our study (Boarman 1991). Detailed and long-term studies on the movements of tortoises near highways are needed to evaluate the causes for the declines noted by Nicholson (1978) and the full impacts of vehicular traffic on individual tortoises and tortoise populations.

Future Plans

The project will run for at least three more field seasons and likely for several years at a less intense rate. The primary activities for spring 1992 were to map home ranges of animals with radio transmitters, attach PIT tags to most animals on the plot, and perform a sweep of highway edges for tortoise carcasses. During the winter of 1992-1993 we plan to deploy the automated-sensing of tortoise use of culverts, which will remain operational for at least 2 years. Spring of 1993 will primarily consist of a resurvey of the tortoise population, some radio-tracking and behavioral observations, sweeps of highway edges, servicing and replacement of transmitters, and reading and maintenance of the automated-sensing apparatus. We will also conduct a survey of the north side of the highway to search for and mark tortoises that have used the culverts, or may use them in the future. Work in the spring of 1994 will emphasize radio-tracking, culverts, population surveys, and a sweep of highway edges. Funds provided by Nevada Department of Transportation and Federal Highways Administration will help to develop the automated-sensing system and to conduct some of the field work in 1993 and 1994.

The Review Board has identified and prioritized several additional tasks that would significantly improve the study. In approximate order of importance, the additional tasks are to: 1) enlarge the study plot to increase sample sizes; 2) establish a new study site with a bridge for determining if tortoises cross under bridges; 3) conduct transects along Hwy 395 to determine densities and distribution of tortoises to validate use of Hwy 395 as a control for thehighway sweeps; 4) extend the study beyond 1994; 5) establish a control plot along Hwy 395; 6)place more transmitters on animals; and 7) place transponders on other animal species to determine if they use culverts.

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LITERATURE CITED

Berry, K. H. 1984a. Appendix 1. A description of forty-seven study sites for the desert tortoise in California, Nevada, Utah, and Mexico. pp. A1-1 to A1-40. In: K. H. Berry, (ed.), The status of the desert tortoise (*Gopherus agassizii*) in the United States. Desert Tortoise Council Report to the U. S. Fish and Wildlife Service on Order No. 11310-0083-81.

Berry, K. H. 1984b. Appendix 2. A description and comparison of field methods used in studying and censusing desert tortoises. pp. A2-1 to A2-33. In: K. H. Berry, (ed.), The status of the desert tortoise (*Gopherus agassizii*) in the United States. Desert Tortoise Council Report to the U. S. Fish and Wildlife Service on Order No. 11310-0083-81.

Berry, K. H. 1990. The status of the desert tortoise in California in 1989. Draft report submitted to U. S. Fish and Wildlife Service. Bureau of Land Management, Riverside, California.

Berry, K. H. and L. L. Nicholson. 1984a. Chap. 3. A summary of human activities and their impacts on desert tortoise populations and habitat in California. Pp. In: K. H. Berry (ed.), Chap. 3. The status of the desert tortoise (*Gopherus agassizii*) in the United States. Desert Tortoise Council Report to the U. S. Fish and Wildlife Service on Order No. 11310-0083-81.

Berry, K. H. and L. L. Nicholson. 1984b. Chap. 5. Attributes of populations at twenty-seven sites in California. Pp. In: K. H. Berry (ed.), The status of the desert tortoise (*Gopherus agassizii*) in the United States. Desert Tortoise Council Report to the U. S. Fish and Wildlife Service on Order No. 11310-0083-81.

Berry, K. H. and F. B. Turner. 1984. Notes on the behavior and habitat preferences of juvenile desert tortoises (*Gopherus agassizii*). Proceedings of the Desert Tortoise Council Symposium 1984:111-130.

Boarman, W. I. 1991. Effectiveness of fences and culverts for protecting desert tor toises along California State Highway 58: final report on study design. Report to California Energy Commission. Bureau of Land Management, Riverside, California.

Boarman, W. I. 1992. Effectiveness of fences and culverts for protecting desert tor toises along California State Highway 58: summary of initial field season. Report to California Energy Commission. Bureau of Land Management, Riverside, California.

Boarman, W. I. and M. Sazaki. in press. Measuring the effectiveness of tortoise-proof fences and culverts along Highway 58, California. Proceedings of the 1991 Desert Tortoise Council Symposium.

Bureau of Land Management. 1988. Western Mojave Land Tenure Adjustment Project. Final Environmental Impact Statement/Report. Bureau of Land Management, Department of the Air Force, County of San Bernardino.

Bureau of Land Management. 1991. Statement of work for establishing a new long-term desert tortoise study plot along State Highway 58. Solicitation No. B950-RFP1-0017. Bureau of Land Management, Sacramento, California.

Fusari, M. 1982. Feasibility of a highway crossing system for desert tortoises. Report to Caltrans, July 15, 1982, Report No. FHWA/CA/TP-81/1. Sacramento, California.

Maguire, L. A. 1986. Using decision analysis to manage endangered species populations. Journal of Environmental Management 22:345-360.

Nicholson, L. 1978. The effects of roads on desert tortoise populations. Proceedings of the Desert Tortoise Council Symposium 1978:127-129.

Raiffa, H. 1968. Decision analysis: Introductory lectures on choices under uncertainty. Reading: Addison-Wesley.

Sievers, A., J. B. Aardahl, K. B. Berry, L. D. Burge, L. D. Foreman, G. E. Moncsko and J. A. St. Amant. 1988. Recommendations for management of the desert tortoise in the California desert. Submitted by the California Desert Tortoise Workgroup to the Bureau of Land Management, California Desert District Office, Riverside.

Woodman, A. P., and K. H. Berry. 1984. Appendix 6. A description of carcass deterioration for the desert tortoise and a preliminary analysis of disintegration rates at two sites in the Mojave desert, California. Pp. In: K. H. Berry (ed.), The status of the desert tortoise (*Gopherus agassizii*) in the United States. Desert Tortoise Council Report to the U. S. Fish and Wildlife Service on Order No. 11310-0083-81.