METHODS FOR MEASURING THE EFFECTIVENESS OF TORTOISE-PROOF FENCES AND CULVERTS ALONG HIGHWAY 58, CALIFORNIA

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Abstract. Road kills are generally recognized as an important source of depletion to desert tortoise (*Gopherus agassizii*) populations. In 1990, the California Department of Transportation erected a tortoise-proof fence along a portion of State Highway 58 between Barstow and Kramer Junction. The California Energy Commission, responsible for licensing thermal power plants in California, the Bureau of Land Management, and other agencies initiated a study to determine if the fence will reduce tortoise road kills, and if drainage culverts will facilitate tortoise movements from one side of the highway to the other. We are addressing four questions. First, is the fence an effective barrier for preventing road kills? Second, does the fence facilitate "recovery" of the tortoise population near the highway? Third, are culverts effective at facilitating tortoise movements from one side of the highway to the other? And fourth, how do individual tortoises behave when encountering the fence and culverts? Field work began in February 1991. This study is using a combination of strip transects, intensive population surveys, radio-tracking, and automated-sensing using implantable passive integrated transponder (PIT) tags. In this paper, we discuss the methods adopted for the four year project, and the scope of the initial field work.

INTRODUCTION

Study Background

In California, highway traffic has been, and continues to be, an important cause of mortality for the desert tortoise (*Gopherus agassizii*), a California state- and federal-listed threatened species. Nicholson (1978) demonstrated that tortoise population densities were low adjacent to well-used paved roads and highways, but increased at distances up to 1.6 km from the highway. She suggested that causes of the population depression were road kills and illegal collecting. Important factors that apparently affect tortoise densities included traffic volume, highway width, and the length of time the road had been in use. In 1990, Peter Woodman (cited in Boarman 1991) confirmed that substantial tortoise losses did occur, when he located the remains of 42 recently killed tortoises along a portion of California State Highway (Hwy) 58 in San Bernardino County, California.

An additional impact of road- and highway-caused mortality on tortoise populations is that the free movements of individual tortoises are restricted. Highways can have the effect of fragmenting populations into smaller subunits which are at greater risk of suffering local extinctions. In some circumstances, highways can act as barriers to gene flow between populations on either side of the highway. Restriction of gene flow, especially when population numbers are low, can 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 (Nicholson 1978). Because there are numerous 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 facilitate maintenance and recovery of tortoise populations.

In the early 1980s, the California Department of Transportation (Caltrans) initiated a limited experimental research project designed to determine the effectiveness of various types of fences and culverts in protecting tortoise populations along roads and facilitating movements under highways (Fusari 1982). Caltrans constructed a system of fences and culverts in the open desert south of Barstow, California. The tortoise-proof fences were 122-183 m long and were spanned by two or three corrugated steel culverts. The culverts were round, oval, and square, 4-6 m long, and were 1-1.2 m wide and 1 m high with dirt flooring. In addition, small pens enclosed with various fencing material were connected by 1 m long culverts. Fusari (1982) observed several encounters with the fence-culvert system by resident and non-resident tortoises. Several tortoises used the culverts to cross the barrier, and Fusari (1982) suggested that the animals learned to do so after displaying initial hesitancy. The tortoises exhibited no significant preference for a specific culvert type, but expended less effort in attempting to get through 0.10 cm mesh hardware cloth than 5 cm mesh chicken wire fencing. Fusari's project indicated that tortoise-proof fencing and culverts could be effective in preventing tortoises from crossing highways and in focusing their movements under highways through culverts.

In 1990, Caltrans erected tortoise-proof fencing and culverts along Hwy 58 on a portion that was scheduled to be widened from two lanes to a four-lane, divided highway (Fig. 1). Tortoises are known to cross and be killed along Hwy 58 (Boarman 1991), and Bureau of Land Management (BLM) identified this particular portion of highway as important tortoise habitat (U.S. Department of Interior [USDI] 1988a). In 1990, the BLM, California Energy Commission, Caltrans, U.S. Fish and Wildlife Service (USFWS), and California Department of Fish and Game made a commitment to undertake a monitoring project to determine effectiveness of the protective fencing and culverts in contributing toward tortoise population recovery in the area near the fence.

A review board, consisting of agency, academic, and private biologists, was convened and charged with developing and overseeing a 3-4 year monitoring program (Boarman 1991). Here we describe the four study questions recommended by the board, the method for selecting a study site, and techniques for collecting essential baseline data. The results of the site-selection process and baseline inventories are reported in Boarman et al. (in press) and Boarman (1992).

Study Questions

The project research addresses four questions:

1. Is the fence an effective barrier for preventing road kills? To address this question we must determine whether fewer tortoises are killed along the fenced portion of Hwy 58, than along similar unfenced highway segments.

2. Does the fence facilitate "recovery" of the tortoise population near the highway? This question requires that we document changes in numbers and distributions of tortoises living in close proximity to the highway immediately after the fence is constructed and into the future. This question will likely take many years to answer.

3. Are culverts effective at facilitating tortoise movements from one side of the highway to the other? To address this question we will monitor tortoise movements through the culverts and their movements to and around the opposite side of the highway.

4. How do individual tortoises behave when they encounter the fence and culverts? This question concerns tortoise behavior on contact with a fence or culvert and how movement patterns change as a result of the presence of the fence and culverts. One concern is to determine if the fence represents a hazard in terms of increasing predation or causing injury to tortoises.

Site Selection

General Study Area

The primary study site will be along the portion of Hwy 58 that has been equipped on both sides with a tortoise-proof fence (Fig. 1). This area begins 5.8 km east of Kramer Junction, San Bernardino County, and extends east for a total of 24.8 km. The highway traverses slightly rolling terrain consisting primarily of shadscale scrub and creosote bush scrub communities at elevations of 684 to 753 m. The fencing consists of 61 cm wide, 1.3 cm mesh hardware cloth installed generally 15 cm beneath ground level, and is attached to a five-strand wire fence with the top three strands barbed and the bottom two strands barbless. The 48-63 m long culverts are made of 0.9-1.5 m corrugated metal pipe, 1.37 m reinforced concrete pipe, or 3-3.6 m x 1.8-3 m reinforced concrete boxes. The culverts cross beneath the entire width of the highway and connect directly to the fence, thus providing an unobstructed pathway between both sides of the fenced highway (Fig. 2).

Phase One Criteria

Candidates for the principle study site were screened using a two phased process. For the first phase, the entire portion of highway was evaluated using seven criteria:

1. Tortoise Presence - The site should contain the highest possible densities for a good sample size. This was a high priority.

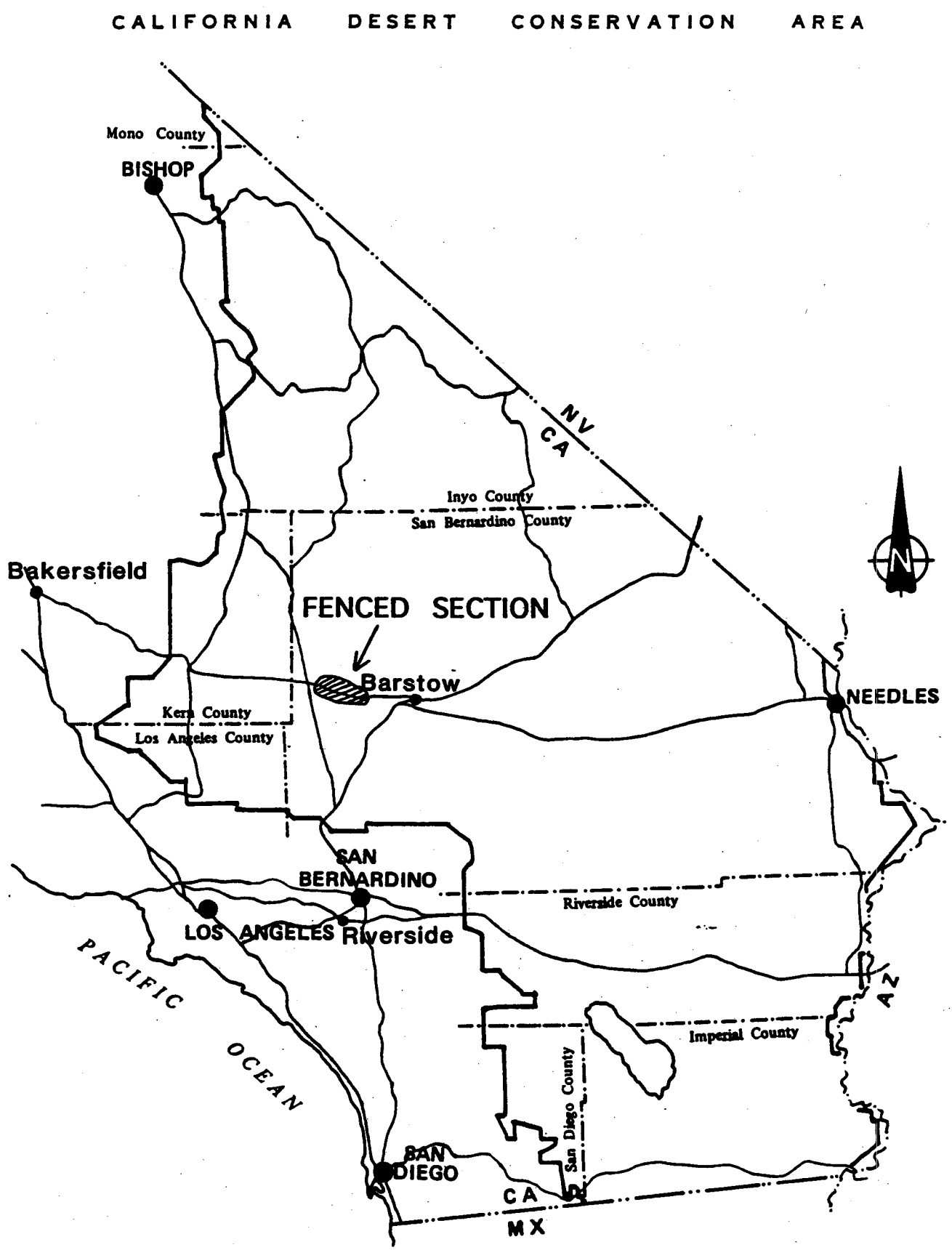

Figure 1. Location of fenced portion of Hwy 58, San Bernardino County, California.

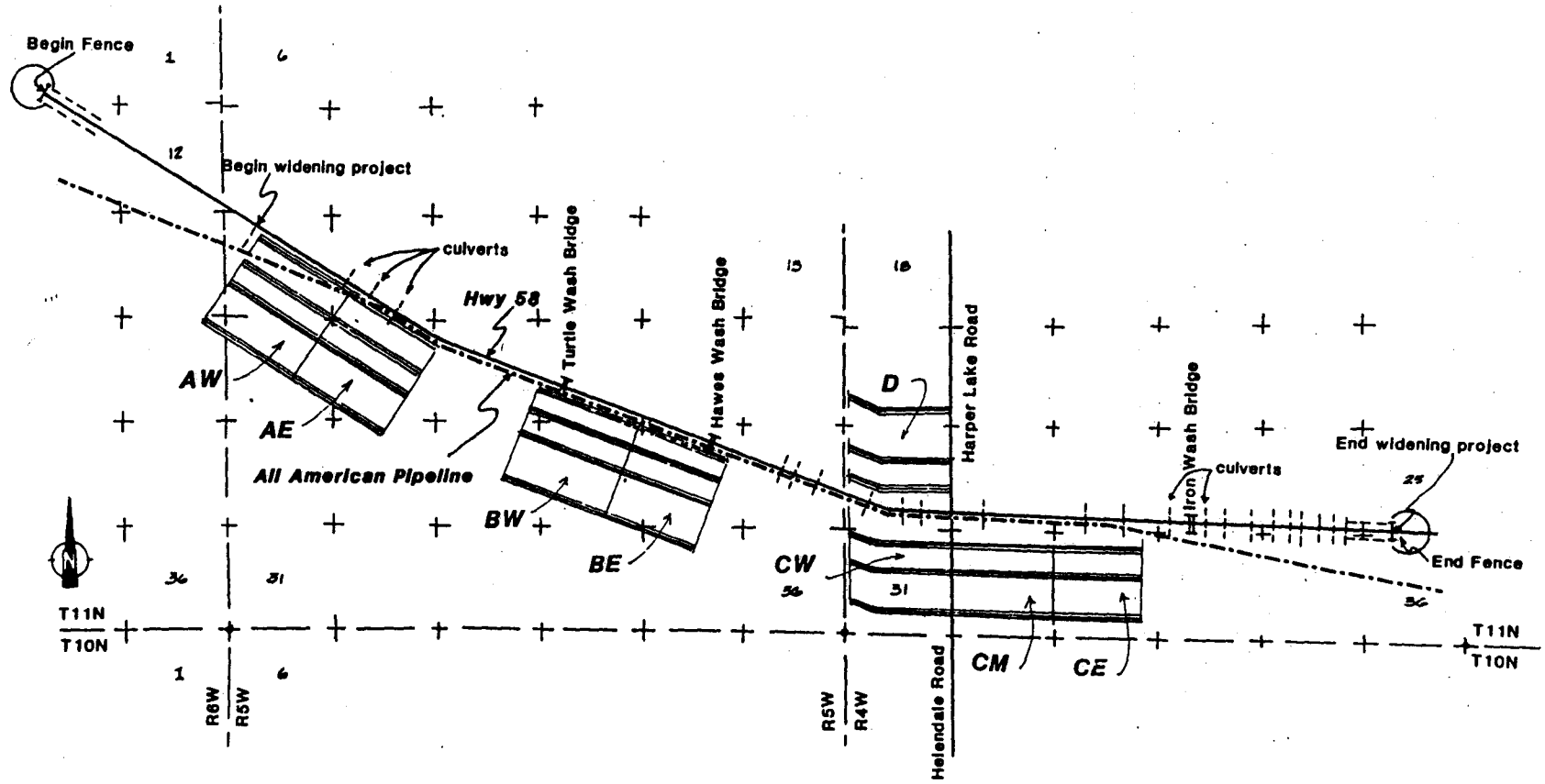

Figure 2. Map of general location of project showing study areas from which the 260 ha study site was selected. Study areas were general locations for strip transect surveys conducted in spring 1991, San Bernardino County, California.

2. South Side of Highway - The north side of the highway is largely unacceptable because of the presence of railroad tracks within 80 to 1078 m of the highway for most of the area. Railroads may be a source of mortality and an obstacle to tortoise movements. Any such limitation to movement or unnatural source of mortality may compromise the experiments.

3. Land Status/Legal Accessibility - The land must be accessible legally and physically, and the potential for disturbance of the site must be low over the course of the study. We considered existing and future rights-of-way, plans for frontage roads, and land tenure adjustment status (USDI 1988b).

4. Presence of Culverts - At least one planned culvert should be within the bounds of the study site.

5. End of Fence - To avoid edge effects, the site should not be at either end of the fence.

6. Size of Site - The site should include a minimum of 1.6 km of fenceline along one edge.

7. Proximity to Other Roads - The study sites should not include other heavily traveled roads (to avoid increased mortality to tortoises).

Sites that minimally satisfied these criteria are highlighted in Figure 2. These sites were first subjected to the initial field surveys described below and then to the second phase of evaluations.

Initial Field Survey for Phase One

In late winter 1991, initial surveys of each potential study site were conducted. The surveys consisted of a series of strip transects, each 10 m wide, oriented along the width of each site, parallel to the highway. For each site there were four sets of three contiguous transects. One set began immediately at the fence edge, the second was centered 0.4 km from the fence, the third at 0.8 km, and the fourth ended 1.6 km from the fence (Fig. 2).

Transects provided information for evaluating and ranking each potential study site. For tortoise population density, the following data were collected: exact location and characteristics of all tortoise sign (i.e., live animals, shells, tracks, scats, burrows, and pallets). For every live tortoise found, surveyors were to record carapace length, scars and other damage, and evidence of Upper Respiratory Tract Disease. The aspect, height, length, and width of each burrow were measured. Habitat condition on potential study sites was evaluated by taking note of all roads, trails, graded areas, structures, sheep scat, sheep beds, individual tire tracks, campsites, garbage, and other impacts. For this last purpose, each potential site was to be scouted to identify these and other sources of degradation. Habitat similarity within each site was evaluated by inspecting aerial photographs, 35 mm slides taken along the transects, and by noting the dominant plant species composition along the survey transects. All potential access roads and nearest gates along the fence were located on USGS topographical maps (7.5 min quads) and Caltrans project plans. The results of these transects are presented in Boarman et al. (in press) and Boarman (1992).

Phase Two Criteria

The second phase of site selection involved a more intensive analysis of each potential site selected in Phase One. This phase used information developed, in part, from the initial field surveys described above. Sites were ranked using the following nine criteria and the highest ranked site was to be selected as the principle study site for the project:

1. Tortoise Population - High tortoise densities were preferred. Data from the initial surveys were used to evaluate this criterion.

2. Land Status/Legal accessibility - The land must be accessible, and the potential for disturbance of the site must be low over the course of the study. We considered existing and future rights-of-way, plans for frontage roads, and land tenure adjustment status (USDI 1988b).

3. Culverts - Preferably one culvert, and no bridges, should be present within the bounds of the study site. The culvert should be as near to the center of the site as possible.

4. The Right-of-Way for All-American Pipeline - This approximately 30 m wide corridor, which had little vegetation cover, should not lie close to the fence edge because it could reduce direct tortoise-fence encounters and contribute to increased predation, thus confounding the results of some experiments.

5. Physical Accessibility - The site should be accessible to field workers (e.g., near an existing gate or lightly traveled dirt road).

6. Size of Site - An area of approximately 260 ha or more was desired to maximize sample size and not limit natural movements of tortoises.

7. Proximity to Other Roads - Preference was given to sites at relatively greater distances from heavily traveled secondary highways and dirt roads.

8. Similarity of Habitat - A site consisting of only one habitat type was preferred over more heterogenous sites.

9. Human Impacts to Habitat - We expected prior damage to habitat at all sites from off-road vehicles, grazing, grading, mining and other human activities. However, denuded and fragmented areas, which may alter the natural population dynamics, should be avoided. Location of disturbed areas was determined during initial site surveys.

The process and results of site selection are discussed in detail in Boarman et al. (in press) and Boarman (1992).

Baseline Inventories

Once the specific study site was identified, baseline inventories of tortoises were made to identify and mark all study animals and to obtain an accurate estimate of population distribution and density, which are essential for the experiments described below. The site was prepared by establishing a grid of 100 quadrats, each of which were 2.6 ha. The grid was staked with permanent markers and removable PVC pipe. The coordinate location on the grid of each stake were marked clearly on the given stake. The grid is essential for compilation of tortoise locational and movement data.

An intensive inventory of all tortoises and tortoise sign was conducted. The purpose of this inventory was to locate as many resident tortoises as possible, with particular emphasis on juvenile tortoises. Contiguous transects, about 3 m wide, were walked in one direction for the first survey of the plot, followed by contiguous transects that were perpendicular to the first set of transects for the second survey of the plot. In this way, the site was surveyed thoroughly. The exact location of live tortoises was noted. Each live tortoise was marked and recorded in the manner described in Berry (1984) for the permanent BLM desert tortoise study plots. Each tortoise was photographed for purposes of identification and to record injuries, anomalies, and general condition.

For the purpose of tracking movements of individual tortoises, passive integrated transponder (PIT) tags and radio transmitters were placed on some tortoises. A PIT tag, which will individually identify each tortoise, was attached to the shell of three tortoises. Radio transmitters were attached to 37 tortoises selected to approximate the sex and size-class distribution of the local population.

Handling procedures for all aspects of the baseline survey work followed protocols and standards set by the BLM and FWS (Berry 1990a; Berry and Turner 1984). Results of the baseline inventories can be found in Boarman et al. (in press) and Boarman (1992).

Study Design

The extent and complexity of the studies proposed herein will depend on the level of funding available. The study design to answer each of the four questions described previously follows.

Question 1 - Is the fence an effective barrier for preventing road kills?

In spring 1991 and 1992, a field worker walked both sides of the 24 km portion of fenced Hwy 58 to record, map, and remove all tortoise carcasses along the highway edge. Unfenced control sites were established and surveyed along Hwy 58 and along Hwy 395 south of Kramer Junction. Both areas will be resurveyed in

summers of 1993 and 1994, after highway construction along Hwy 58 has ended. The construction is within an area fenced off to tortoises, so no construction-related mortality is expected. Carcasses will be evaluated for time-since-death, using the methods described in Woodman and Berry (1984). The frequency of carcasses found along Hwy 58 will be compared with that along Hwy 395 and with data collected in 1990 along Hwy 58 by Peter Woodman (Boarman 1991). Using the Kruskal-Wallis Analysis of Variance by Ranks test, we will infer that the fence reduces tortoise road kills if significantly fewer carcasses are found along Hwy 58 in 1993 and 1994 than along Hwy 58 in 1990 and the control site over the entire period. Results of the initial surveys, which were conducted in 1991, are in Boarman et al. (in press) and Boarman (1992).

Question 2 - Does the fence facilitate "recovery" of the tortoise population near the highway?

The 1991 baseline inventory provided information on the spatial distribution of tortoises with respect to the highway shortly after the fence was erected. Because tortoise density increased with distance from the highway (Boarman et al. in press; Boarman 1992), we predict that tortoises will begin to spend more time nearer to the fence.

To identify if resettlement of the area near the highway occurs, we will conduct two separate experiments: A) An extensive survey of the study site will be conducted in 1994 or 1995 and approximately every four years thereafter. Data from other permanent BLM tortoise study plots (Berry 1990b) will be used as controls; B) Fifty tortoises will be equipped with radio transmitters. These tortoises will be located numerous times each season to determine their home ranges and detect any evidence of dispersal or long-distance movements. Success of the fence in facilitating tortoise population recovery along the highway will be inferred, if the relationship between tortoise density and distance from the highway becomes weaker over time, or if the areas of activity of individual, radio-equipped tortoises move closer to the fence over the course of the study.

Question 3 - Are the culverts effective at facilitating tortoise movements from one side of the highway to the other?

This question requires two separate approaches: individual-level and population-level responses to the culverts. At the individual-level, in spring 1991 and 1992 we attached a PIT tag to most tortoises found on or near the study plot. In winter 1993, we will place automated sensors at both ends of all four culverts located within the plot. During 1993-1995, and perhaps beyond, the automated sensors will record the identity of each tortoise walking past the electronic recorder as well as the date, time, and probably ambient temperature. If the tortoise walks completely through the culvert, the sensor at the other end will again record the same information. The technique will allow us to determine if the animal crossed beneath the highway, when it crossed, and how long it took to do so. We will also know if tortoises use the culverts as burrows or pallets. Success of the culverts in facilitating movement across the highway will be signified by use of the culverts by study animals.

At the population-level, we must determine if tortoises exhibit permanent, or long-term, dispersal from one side of the highway to the other. To accomplish this, we will conduct extensive surveys on the opposite side of the highway to locate marked animals from our primary study population between 1993 and 1995. Any tortoise found will be marked, equipped with a PIT tag, and the data recorded on standard BLM study plot data sheets (Berry 1990b). This process will allow us to identify north-to-south dispersal through the culverts. Radio-equipped animals will facilitate locating individuals that disperse to the opposite side of the highway.

Question 4 - How do individual tortoises behave when they encounter the fence and culverts?

To determine what effect the fence and culverts have on individual tortoise behavior and survival, from 1991 to 1994 we will search the vicinity of the fence and follow individual tortoises as they approach the fence or culverts. Specific behaviors exhibited by the animals are being noted carefully and the direction of travel taken before and after contacts with the fence or culverts are being recorded. We are particularly interested in behavioral changes over time, that is, if tortoises develop a conditioned response to fences as barriers and culverts as non-barriers. Tracking of individual tortoises will be facilitated by the radio-transmitters.

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