Highway Mortality in Desert Tortoises and Small Vertebrates: Success of Barrier Fences and Culverts[1]

by

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Highway traffic is an important cause of mortality for many species of animals (Bennett 1991), including the desert tortoise (*Gopherus agassizii*), a species state- and federally-listed as threatened (USFWS 1990). Besides direct mortality and facilitating illegal collections, roads and highways impact tortoise populations through restriction of movement. The restriction of movement may result in fragmenting populations, thereby increasing the probability of local extinctions and the potential for inbreeding and inbreeding depression (Opdam 1988, Frankham 1995). Fragmentation of populations and restriction of gene flow may increase with increases in traffic volume, width of highways, and time (Oxley et al. 1974, Nicholson 1978, Sargeant 1981). Because there are many roads and highways throughout the habitat of the desert tortoise, the potential for road kills to affect tortoise populations is high. Consequently, reducing road kills could help to facilitate recovery of tortoise populations. Barrier fences are a potential mitigation, but they also increase population fragmentation. Culverts beneath the roadway may reduce fragmentation by facilitating movements of tortoises between both sides of the road.

Herein we discuss a scientific research project designed to learn the effectiveness of a highway barrier fence built to aid in the recovery of desert tortoise populations along California State Highway 58 (Hwy 58) in the western Mojave Desert of California. We characterize the extent of road kills for several species of small terrestrial vertebrates; the demographic impact highway mortality has had on surrounding tortoise populations, the effectiveness of the barrier fence at reducing mortality along the highway, and the use of culverts by tortoises and other small vertebrates.

Background.--In 1990, California Department of Transportation (Caltrans) erected tortoise-barrier fencing along a section of State Highway (Hwy) 58, San Bernardino County, that was scheduled for widening from two lanes to a four-lane divided highway (Boarman and Sazaki 1994). Culverts for flood protection were also installed. The Bureau of Land Management, 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 learn the effectiveness of protective fencing and culverts in contributing to recovery of tortoise populations in the area near the fence

(Boarman and Sazaki 1994). In 1992, the Nevada Department of Transportation and Federal Highways Administration, and in 1993, the National Biological Service, joined the partnership.

The Review Board for the project, a team of experts in tortoise ecology and management, developed four study questions that served as the focus for the long-term project (Boarman and Sazaki 1994). (1) Is the fence an effective barrier for reducing road kills? (2) Does the fence facilitate "recovery" of the tortoise population near the highway? (3) Do culverts facilitate movements from one side of the highway to the other? (4) How do individual tortoises behave when they encounter the fence and culverts? In this paper we discuss results from the first five years of field work (1991 - 1995).

Characteristics of Fence and Culverts.--The two highways studied traverse relatively flat terrain consisting primarily of Mojave saltbush-allscale scrub and creosote bush scrub communities (USFWS 1994) at elevations of 684 to 915 m. The 24-km long fence runs east from a point approximately 6 km east of Kramer Junction parallel to Hwy 58, which had an average daily traffic of 8500 vehicles (California Dept. Transportation 1993). It consists of 60-cm wide, 1.3-cm mesh, galvanized steel, hardware cloth that is buried to 15 cm beneath ground level and extends 45 cm above the ground (Boarman and Sazaki in press). The fence is supported by a six-strand wire fence; the top three strands are barbed to inhibit access by humans and livestock, and the three bottom strands are unbarbed to allow easy installation of the hardware cloth and to allow medium-sized mammals to climb over without being injured. The bottom two strands are placed beneath the top of the hardware cloth to provide structural support to the cloth. The wires are attached to the cloth by steel rings. The fence is held up by 2-m t-bars spaced approximately 3-m apart.

Gates, which are required to allow access to private property along the highway edge, were also designed as barriers to tortoises. The same hardware cloth that is used on the fence is separately attached to the lower part of the gate. To prevent tortoises from escaping under the gates, the gates are hung close to the ground and flush to 20 cm X 20 cm wood beams that are buried between gate-posts.

Twenty-four culverts that span the entire width of the highway are in place and all are designed for rainwater runoff. In August 1992, the fence on Hwy 58 was attached in funnel fashion to storm-drain culverts to facilitate movements by tortoises under the highway. The culverts are made of 0.9-m to 1.5-m diameter corrugated steel pipe; 1.4-m diameter reinforced concrete pipe; or 3-m to 3.6-m by 1.8-m to 3-m, reinforced concrete boxes. The culverts are 33 to 66 m long. Three bridges, spanning natural washes, also exist along the highway. A 1.6 km^2 permanent study plot was established on the south side of Highway 58, approximately 11 km east of Kramer Junction. It consists primarily of rolling hills to the north and relatively flat areas to the south. Perennial vegetation is mainly an association of Mojave saltbush (*Atriplex spinifera*), shadscale (*A. confertifolia*) bur sage (*Ambrosia dumosa*), and creosote bush (*L. tridentata*). Elevation ranges from 742 to 757 m.

Road kills.--Surveys were conducted each July from 1992 to 1994 along the edge of 24 km of highway from the median strip to the outer edge (desert side) of the graded shoulder Boarman et al. 1993). We recorded the identity (to species, family, order, or class) and locations of all animal carcasses. A total of 1080 carcasses, representing 31 species of reptiles, mammals, and birds, were found. Thirty-six tortoise carcasses were found, representing an average of 1 tortoise killed every 2.4 km per year. This is a low estimate because many carcasses disappear after several days to weeks (pers. obs.), some animals are able to move off the highway after being struck and before dying, and some carcasses or fragments are probably missed by field workers.

Two aspects of tortoise behavior places them under risks of highway mortality. Most of a tortoise's activity occurs within the same general area, defined as their home range. Home range size (minimum convex polygon) for adult Desert tortoises ranges between about 12 and 72 ha (O'Connor et al. 1994), with males generally having larger home ranges than females. If those home ranges are near a highway, the animals are likely to encounter the highway edge, which may have preferred food plants or water, or cross the road surface in search of food, water, minerals, or mating opportunities (Boarman and Sazaki in press). Furthermore, significantly more immature and subadult males than expected by chance dispersed distances of 1 to 26 km or more in a given season. This dispersal places those age classes under greater risks of mortality (Sazaki et al. 1993). In support of this, 36% of the road killed tortoises identifiable to age class were subadults, which was significantly more than expected based on their proportional representation in the study population (20%).

Impact of Mortality on Tortoise Populations.--Highways have a measurable impact on surrounding populations. We conducted transects looking for signs of tortoise activity (scat, burrows, tracks, live tortoises), which is an index of population density, at the edge of the highway, 0.4 km, 0.8 km, and 1.6 km from the highway edge (Boarman et al. 1993). There were significantly more signs of tortoises 0.8 and 1.6 km from the highway than at the edge or 0.4 km away. Thus, there was a zone of reduced tortoise numbers within 0.4 to 0.8 km of the highway. Similar results were obtained by Nicholson (1978), Hoff and Marlow (unpubl.), Karl (1989), and LaRue (1993). The population sink is probably caused by vehicle mortality, but we cannot rule out the effects of illegal collecting, vibration and noise, and habitat degradation, all of which probably decrease with distance from the highway.

Reduction in Road Kills by Fence.--We searched for vertebrate carcasses along 24 km section of fenced highway at the same time we did so along the 24 km of unfenced highway, described above. We found 88% fewer vertebrate carcasses and 93% fewer tortoise carcasses along the fenced section of highway. These differences were highly significant and indicate that the fence was very successful at reducing road mortality. However, in 1995, several tortoises were killed along the fenced section of Hwy. 58, all within 0.5 km of gaps in the fence. As most of the gaps were due to poor maintenance, these observations indicate that proper maintenance of the fence is critical to success of the fence.

Effect of Fence on Tortoise Population.--To determine if the fence aids in the recovery of tortoise populations near the highway, in 1991 and 1995, we surveyed the population on a 1.9 km^2 study plot (Boarman et al. 1993). These surveys will provide estimates of population density and distribution with respect to the highway. The data have not yet been analyzed, but we do not expect significant results now because we predict a slow population-level response by the long-lived animals. Additional follow-up surveys are planned every four years. So far we have marked 171 tortoises on or near the study plot.

Use of Culverts by Tortoises and Other Vertebrates.--Because the fence is likely to increase the fragmenting effects of the highway, it is hoped that tortoises and other animals will make use of storm-drain culverts placed beneath the highway. To monitor use of the culverts by tortoises, we attached Passive Integrated Transponder (PIT) tags to the carapace of each tortoise found. We developed an automated reading system to record the passages of tortoise through three culvert systems (Boarman et al. in prep.). Reading units were placed at both ends of each culvert to record tortoise identity, time, and date. During the first six months of operation, two tortoises passed through the culverts ten times. By checking for tracks in sand traps placed at the entrance of several culverts, we also noted use by several other small to medium-sized vertebrates (e.g.,

Coyote, *Canis latrans*, kit fox, *Vulpes macrotis*, jackrabbit, *Lepus californicus*, ground squirrels, *Ammospermophilus* sp., kangaroo rats, *Dipodomys* sp., snakes, and lizards).

Conclusions.--Our results indicate that, when new or properly maintained, the barrier fence was effective a greatly reducing highway mortality in several species of vertebrates, including the threatened desert tortoise. However, tortoises can escape from relatively small gaps that may result from improperly installed or maintained fences and gates. Tortoises and other vertebrates also used culverts, but we cannot yet determine if the use will reduce the fragmenting effects of the fence and highway. Their use is expected to increase with time as more animals settle near and discover the culverts.

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