Turtles, Culverts, and Alternative Energy Development: An Unreported but Potentially Significant Mortality Threat to the Desert Tortoise (Gopherus agassizii)

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ABSTRACT. — Culverts are often used to increase the permeability of roaded landscapes for wildlife, including turtles. Although the benefits of culverts as safe passages for turtles are well documented, under some conditions culverts can entrap them and cause mortality. Here we report a culvert-related mortality in the federally threatened desert tortoise (Gopherus agassizii) at a wind energy facility in California and offer simple recommendations to mitigate the negative effects of culverts for wildlife in general.

Utility-scale renewable energy development, particularly wind and solar, is rapidly expanding in the desert Southwest United States. This is especially true for California, which has a goal for increasing renewable energy generated electricity from 11% currently to 33% by 2020 (California Energy Commission 2007). Large networks of roads and drainage culverts are often associated with these developments that degrade wildlife habitat (Kuvlesky et al. 2007). Roads are known to be barriers to wildlife movements and sources of significant mortality (Ashley and Robinson 1996; Forman and Alexander 1998; Andrews et al. 2008; Hagood and Bartles 2008), especially for reptiles (Dodd 1989; Rosen and Lowe 1994). Turtles, including the desert tortoise (Gopherus agassizii; Von Seekendorff Hoff and Marlow 2002), are especially vulnerable to road mortality because of their inability to cross roadways quickly (Fowle 1996). Additionally, females of many species cross roadways while searching for nest sites (Haxton 2000; Gibbs and Steen 2005; Steen et al. 2006) and have an affinity for nesting on road shoulders (Aresco 2005). As a result, road mortality is a significant factor contributing to the decline of turtles (Gibbs and Shriver 2002), in part because of the disproportionate mortality of females (Steen and Gibbs 2004).

Numerous methods have been proposed to mitigate the negative effects of roads, including wildlife overpasses, underpasses, and fences (Forman and Alexander 1998). Culverts, designed primarily as conduits for streams and stormwater runoff, are ubiquitous features of most roadways that can function secondarily as wildlife passages for some species by increasing the “permeability” of the road and reducing mortality (Yanes et al. 1995; Andrews et al. 2008). However, the overall effectiveness of culverts has received little attention (Fowle 1996; Spellerberg 1998) despite their potential importance from a conservation perspective. The paucity of before and after mortality studies following the installation of wildlife-crossing structures further complicates an evaluation of their effectiveness (Glista et al. 2009). Here we report a negative effect of culverts on the desert tortoise, a federally protected species north and west of the Colorado River. In addition, we review the scant peer-reviewed literature on the use of culverts by turtles (including tortoises) and make recommendations to minimize a largely unrecognized negative effect.

We have been studying a population of G. agassizii at a wind energy facility near Palm Springs, California, since 1995 (for a site description, see Lovich and Daniels 2000). During various phases of the project tortoises were marked (n = 160), and some were outfitted with radio transmitters to study movements and reproductive ecology (Lovich et al. 1999). In 2009 a large male tortoise (33.9-cm carapace length) was outfitted with a radio transmitter and tracked at biweekly intervals from 22 April to 14 July 2009 and generally monthly thereafter. Starting on 19 May, the tortoise began using a corrugated steel culvert (about 60 cm in diameter), designed for stormwater runoff, as a burrow surrogate. Since the bottom of the culvert was half filled with sand and sediment, it had an entrance that mimicked the half-moon shape of a natural tortoise burrow. The outlet of the culvert was completely buried under eroded sediment and vegetation. The tortoise used this same culvert (and another that was nearby) intermittently until 26 September. From 25 October 2009 through 6 February 2010, the tortoise used the first culvert as a brumation site.

In mid-February, storms brought significant rain to southern California. As a result, large amounts of sediment were carried into the culvert, entombing the brumating tortoise in a wet slurry of sand and silt. Late on 26 March, during our regularly scheduled monthly visit to the site to collect data, we found the culvert completely filled from top to bottom with moist loamy soil. Although attenuated due to being surrounded by metal, the radio signal clearly indicated that the tortoise was buried deep in the culvert. The following morning, a total of 5 people, including 3 employees from the wind energy facility, began the process of digging with a pick and shovels to remove the overburden from the point where the tortoise was thought to be located based on radio signal strength. The top of the culvert at this point...
was approximately 0.6 m below the dirt road bed. An oxygen-acetylene torch was then used to cut the top of the culvert away in an area adjacent to the putative location of the tortoise. Removal of a portion of the culvert revealed that sediment filled the entire inside diameter with no visible air space (Fig. 1).

After removing 2 more sections from the top of the culvert to allow a person to get inside, more dirt was carefully removed until the rear carapace of the tortoise was visible (Fig. 2), fully 3 m from the point where it entered the culvert.

The animal was completely encased in tightly packed sediment as if set in concrete (Fig. 2). Since the tortoise was likely overwintering and inactive during the time the sediment was deposited (Ernst and Lovich 2009), motor functions were inhibited, preventing it from digging out while the slurry accumulated. Careful excavation eventually allowed the tortoise to be freed 7 hours after work began.
started. The head was fully retracted inside the shell, and
the cavity in front of the nose was tightly packed with dirt
that had to be scraped away to free the tortoise
completely. The eyes of the tortoise appeared cloudy on
removal, but otherwise the individual appeared alert and
exhibited locomotion and behavior typical of a healthy
tortoise. During the following month of April, the tortoise
was located several times and appeared normal in all
regards, including responding to visual stimuli.

However, 18 days after excavation from the culvert,
the tortoise was found dead in a nearby burrow. The shell
and limbs were in good condition, but the tortoise had
been dead for an undetermined period of time. Its right
eye was desiccated and filled with maggots, and there was
some crusting around the nares from possible exudate or
dried mud. A necropsy revealed that the heart had
hemorrhaging in the right ventricle and some necrotic
areas in the left ventricle. The lungs were firm and
consolidated with caudal areas having multifocal coalesc-
ing white regions. The colon was full of plant material
that was wet and had been recently consumed. No other
abnormalities were noted grossly. The likely cause of
death was pneumonia caused by being fully immersed in
mud. The animal was eating prior to death, consistent
with normal behavior as noted previously. Although this
is the first case of culvert-related mortality documented at
our study site during 6 field seasons spanning 15 years,
we have observed other tortoises use culverts on several
occasions.

This situation underscores a previously unrecognized
threat that culverts present to desert tortoises and other
wildlife that use culverts for shelter or other purposes,
such as nesting. Desert tortoises at our study site have
been documented to routinely use culverts and other
human structures associated with wind energy develop-
ment (Lovich and Daniels 2000). Desert tortoises in other
parts of the California desert are known to use culverts as
passages under roads (Boarman 1995; Boarman and
Sazaki 1996), sometimes spending the night inside
(Boarman et al. 1998). When used in conjunction with
culverts, barrier fences effectively reduce mortality and
facilitate movements under busy roadways for desert
tortoises (Boarman et al. 1997), Hermann’s tortoise
(Testudo hermanni; Guyot 1995), and other species of
reptiles and amphibians (Dodd et al. 2004). However, in
some instances, desert tortoises may not be able to
excavate themselves if entombed and will experience
physiological stress that results in a slow death. Although

Figure 2. Posterior carapace of a desert tortoise trapped in a steel culvert where it was overwintering near Palm Springs, California. A large volume of tightly compacted dirt was removed to expose and extricate the tortoise.
most studies on entombment of tortoises (*Gopherus polyphemus*; Landers and Buckner 1981; Diemer and Moler 1982; Mendonça et al. 2007) have shown little negative effects, some have reported mortalities (Burke 1989; Wester 2004). The reported mortalities could be a result of hypoxia and hypercarbia, especially in clay-laden soils (Ultsch and Anderson 1986, 1988). However, the entombment described in this paper is not characteristic of the circumstances described in the previously mentioned studies for *G. polyphemus* (i.e., burrow collapse), where tortoises had air pockets and space immediately around them.

On most currently operating utility-scale renewable energy facilities like our study site, road traffic is limited compared to public highways and roads, where wildlife passages are beneficial and often essential to prevent excess mortality (Rees et al. 2009). However, the beneficial effects of culverts as safe passages for wildlife are tempered by the possibility that they can entrap and potentially kill animals like desert tortoises under some circumstances. This is important because even a slight increase in adult desert tortoise mortality, especially females, is detrimental to populations (Doak et al. 1994). Therefore, species that often use wildlife passages and culverts for an extended period of time (i.e., brumation sites, nesting sites, and refugia) and not just in an ephemeral fashion (i.e., as a corridor for dispersal) could be negatively impacted. Female tortoises at our study site frequently nest inside their burrows (23 out of 24 nests in 2000; Lovich et al., unpubl. data), so entire clutches could be entombed during spring or summer floods if females nest in culverts. During the excavation of the tortoise, we found multiple hatched snake eggs, so the nests of other species are affected as well.

We believe that the negative effects of culverts can be largely mitigated by adopting several best management practices. First, utility-scale renewable energy developments and road construction projects could install larger-diameter culverts to lessen the possibility of blockage with sedimentation and debris. Erosion is a major problem at wind energy facilities in California because of the presence of compacted roads that create large amounts of runoff during rain storms (Wilshire and Prose 1987). Various species of reptiles and amphibians are known to respond differently to assorted barrier fence and culvert lengths, heights, diameters, placements, and designs (Woltz et al. 2008; Patrick et al. 2010), so preconstruction planning should target the needs of local fauna. The use of larger concrete box culverts or corrugated steel culverts with a diameter of 1 m or greater should be considered since desert tortoises are known to willingly enter such structures in preference to smaller tunnels (Ruby et al. 1994). Although implementing these recommendations on existing facilities could be a costly process and not feasible in some cases, the alternative would be frequent inspections of smaller culverts to prevent blockage and entrapment. As noted by Glista et al. (2009), preconstruction planning is likely to be more economical than retrofitting existing road networks. Furthermore, exclude devices (e.g., wire mesh, rebar, and so on) on the entrances of smaller culverts could be considered to prevent desert tortoises and other sensitive species from entering culverts and potentially becoming entrapped. However, properly designed fencing (Ruby et al. 1994) may be required to prevent blocked culverts from forcing desert tortoises onto the road (Yanes et al. 1995).

Although our account of entrapment may be an isolated example, future road design should consider the effectiveness of culverts for facilitating safe passage of wildlife, and existing structures should be evaluated for their efficacy as both wildlife conduits and refugia.

**ACKNOWLEDGMENTS**

We thank Rowland Griese and other maintenance staff of the wind energy facility, especially Cha Yang, Elbert Yang, and Isaac Carrera of Green Energy Maintenance Corporation, for their assistance excavating the tortoise on their day off. Earlier versions of this manuscript benefited from comments offered by Kimberly Andrews and Whit Gibbons and review by John Roe. Research was permitted by the California Department of Fish and Game, the Bureau of Land Management, and the US Fish and Wildlife Service, the latter under permit number TE-198910-0. Institutional Animal Care and Use Committee certification for the project was provided by Northern Arizona University with assistance from Tom Greene and Crystal Redding. Research was supported by funding to the senior author from the California Energy Commission, Public Interest Energy Research (PIER) Program, and the Bureau of Land Management, California Desert District, Palm Springs-South Coast Resource Area. We thank John Mathias and James Gannon, respectively, for their assistance with these 2 grants.

**LITERATURE CITED**


a fossorial species (*Gopherus polyphemus*) with a sympatric nonfossorial species (*Terrapene carolina*). Physiological Zoology 64:142–152.


*Received: 25 May 2010
Revised and Accepted: 17 November 2010*