BioOne RESEARCH EVOLVED

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

Author(s): Jeffrey E. Lovich, Joshua R. Ennen, Sheila Madrak, and Bret Grover
Source: Chelonian Conservation and Biology, 10(1):124-129. 2011.
Published By: Chelonian Research Foundation
DOI: http://dx.doi.org/10.2744/CCB-0864.1
URL: http://www.bioone.org/doi/full/10.2744/CCB-0864.1

BioOne (www.bioone.org) is a nonprofit, online aggregation of core research in the biological, ecological, and environmental sciences. BioOne provides a sustainable online platform for over 170 journals and books published by nonprofit societies, associations, museums, institutions, and presses.

Your use of this PDF, the BioOne Web site, and all posted and associated content indicates your acceptance of BioOne's Terms of Use, available at www.bioone.org/page/terms_of_use.

Usage of BioOne content is strictly limited to personal, educational, and non-commercial use. Commercial inquiries or rights and permissions requests should be directed to the individual publisher as copyright holder.

BioOne sees sustainable scholarly publishing as an inherently collaborative enterprise connecting authors, nonprofit publishers, academic institutions, research libraries, and research funders in the common goal of maximizing access to critical research.

Chelonian Conservation and Biology, 2011, 10(1): 124–129
© 2011 Chelonian Research Foundation

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

JEFFREY E. LOVICH[1], JOSHUA R. ENNEN[1], SHEILA MADRAK[2], AND BRET GROVER[3]

[1]*US Geological Survey, Southwest Biological Science Center, Northern Arizona University, Advanced Research and Development Building, PO Box 5614, Flagstaff, Arizona 86011 USA [jeffrey_lovich@usgs.gov; jennen@usgs.gov];*
[2]*San Diego State University/University of California–Davis, Department of Biology, 5500 Campanile Drive, San Diego, California 92182 USA [svmadrak@gmail.com];*
[3]*Banning Veterinary Hospital, 3559 West Ramsey Street, Suite B, Banning, California 92220 USA [bdgrover13@gmail.com]*

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 Seckendorff 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

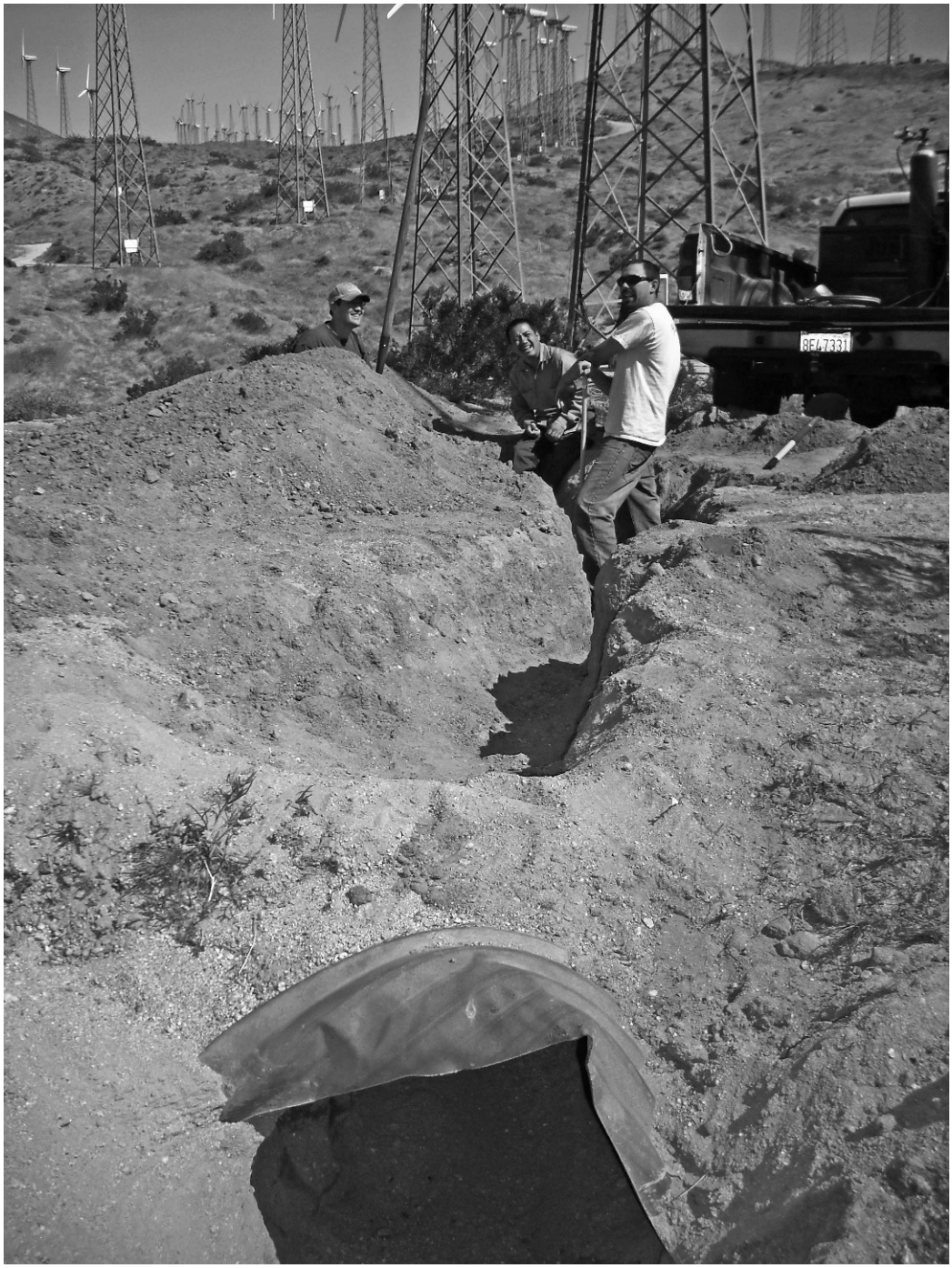

Figure 1. Excavation of the culvert to rescue a trapped desert tortoise. Note the partially excavated entrance used by the tortoise in the foreground.

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

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.

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 coalescing 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 development (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

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, excluder 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

ANDREWS, K.M., GIBBONS, J.W., AND JOCHIMSEN, D.M. 2008. Ecological effects of roads on amphibians and reptiles: a literature review. In: Mitchell, J.C., Jung Brown, R.E., and Bartholomew, B.E. (Eds.). Urban Herpetology. Herpetological Conservation 3. Salt Lake City, UT: Society for the Study of Amphibian and Reptiles, pp. 121–143.

ARESCO, M.J. 2005. The effect of sex-specific terrestrial movements and roads on the sex ratio of freshwater turtles. Biological Conservation 123:37–44.

ASHLEY, E.P. AND ROBINSON, J.T. 1996. Road mortality of amphibians, reptiles and other wildlife on the Long Point Causeway, Lake Erie, Ontario. Canadian Field Naturalist 110: 403–412.

BOARMAN, W. 1995. Reduction in mortalities of desert tortoises and other vertebrates along a fenced highway. In: Behler, J.J., Das, I., Fertard, B., Pritchard, P., Branch, B. Durrel, L., and Fretey, J. (Eds.). Proceedings of the International Congress of Chelonian Conservation. Gonfaron, France: Editions Soptom, 250 pp.

BOARMAN, W.I., BEIGEL, M.L., GOODLETT, G.C., AND SAZAKI, M. 1998. A passive integrated transponder system for tracking animal movements. Wildlife Society Bulletin 26:886–891.

BOARMAN, W.I. AND SAZAKI, M. 1996. Highway mortality in desert tortoises and small vertebrates: success of barrier fences and culverts. In: Evink, G.J., Garrett, P., Zeigler, D., and Berry, J. (Eds.). Trends in addressing transportation related wildlife mortality: Proceedings of the Transportation Related Wildlife Mortality Seminar, Orlando, FL: Environmental Management Office, Department of Transportation, pp. 169–173.

BOARMAN, W.I., SAZAKI, M., AND JENNINGS, W.B. 1997. The effect of roads, barrier fences, and culverts on desert tortoise populations in California, USA. In: Van Abbema, J. (Ed.). Proceedings: Conservation, Restoration, and Management of Tortoises and Turtles: an International Conference. Purchase: New York Turtle and Tortoise Society, pp. 54–58.

BURKE, R.L. 1989. Gopherus polyphemus: mortality. Herpetological Review 20:54.

CALIFORNIA ENERGY COMMISSION. 2007. Integrated energy policy report. Sacramento, California. pp. 34. http://www.energy.ca.gov/2007publications/CEC-100-2007-008/CEC-100-2007-008-CMF-ES.PDF

DIEMER, J.E. AND MOLER, P.E. 1982. Gopher tortoise response to site preparation in northern Florida. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 36:634–637.

DOAK, D., KAREIVA, P., AND KLEPETKA, B. 1994. Modeling population viability for the desert tortoise in the western Mojave Desert. Ecological Applications 4:446–460.

DODD, C.K., JR. 1989. Reptiles on highways in north-central Alabama, USA. Journal of Herpetology 23:197–200.

DODD, C.K., JR., BARICHEVICH, W.J., AND SMITH, L.L. 2004. Effectiveness of a barrier wall and culverts in reducing wildlife mortality on a heavily traveled highway in Florida. Biological Conservation 118:619–631.

ERNST, C.H. AND LOVICH, J.E. 2009. Turtles of the United States and Canada. Second edition. Baltimore: Johns Hopkins Univ. Press, 827 pp.

FORMAN, R.T.T. AND ALEXANDER, L.E. 1998. Roads and their major ecological effects. Annual Review of Ecology Systematics 29:207–231.

FOWLE, S.C. 1996. Effects of roadkill mortality on the western painted turtle (*Chrysemys picta bellii*) in the Mission Valley, western Montana. In: Evink, G., Ziegler, D., Garrett, P., and J Berry (Eds.). Highways and Movement of Wildlife: Improving Habitat Connections and Wildlife Passageways Across Highway Corridors. Proceedings of the Florida Department of Transportation/Federal Highway Administration Transportation-Related Wildlife Mortality Seminar. Orlando, FL: US Department of Transportation, Federal Highway Administration, pp. 205–223.

GIBBS, J.P. AND SHRIVER, W.G. 2002. Estimating the effects of road mortality on turtle populations. Conservation Biology 16:1647–1652.

GIBBS, J.P. AND STEEN, D.A. 2005. Trends in sex ratios of turtles in the United States: implications of road mortality. Conservation Biology 19:552–556.

GLISTA, D.J., DEVAULT, T.L., AND WOODY, J.A. 2009. A review of mitigation measures for reducing wildlife mortality on roadways. Landscape and Urban Planning 91:1–7.

GUYOT, G. 1995. Etat d'une population de tortues d'Hermann apres perturbation du site par al construction d'une autoroute. In: Behler, J.J., Das, I., Fertard, B., Pritchard, P., Branch, B., Durrell, L., and Fretey, J. (Eds.). Proceedings of the International Congress of Chelonian Conservation. Gonfaron, France: Editions Soptom, pp. 184–186.

HAGOOD, S. AND BARTLES, J.J. 2008. Use of existing culverts by eastern box turtles (*Terrapene c. carolina*) to safely navigate roads. In: Mitchell, J.C., Jung Brown, R.E., and Bartholomew, B. (Eds.). Urban Herpetology. Herpetological Conservation 3:169–170. Salt Lake City, UT: Society for the Study of Amphibians and Reptiles.

HAXTON, T. 2000. Road mortality of snapping turtles, *Chelydra serpentina*, in central Ontario during their nesting period. Canadian Field Naturalist 114:106–110.

KUVLESKY, W.P., JR., BRENNAN, L.A., MORRISON, M.L., BOYDSTON, K.K., BALLARD, B.M., AND BRYANT, F.C. 2007. Wind energy development and wildlife conservation: challenges and opportunities. Journal of Wildlife Management. 71:2487–2498.

LANDERS, J.L. AND BUCKNER, J.L. 1981. The gopher tortoise: effects of forest management and critical aspects of its ecology. Southlands Experimental and Forest Technical Notes 56:1–7.

LOVICH, J.E. AND DANIELS, R. 2000. Environmental characteristics of desert tortoise (*Gopherus agassizii*) burrow locations in an altered industrial landscape. Chelonian Conservation and Biology 3:714–721.

LOVICH, J.E., MEDICA, P., AVERY, H., MEYER, K., BOWSER, G., AND BROWN, A. 1999. Studies of reproductive output of the desert tortoise at Joshua Tree National Park, the Mojave National Preserve, and comparative sites. Park Science 19:22–24.

MENDONÇA, M., BEAUMAN, R., AND BALBACH, H. 2007. Burrow collapse as a potential stressor on the gopher tortoise (*Gopherus polyphemus*). TR-07-33. Champaign, IL: US Army Engineer Research and Development Center/Construction Engineering Research Laboratory. 55 pp.

PATRICK, D.A., SCHALK, C.M., GIBBS, J.P., AND WOLTZ, H.W. 2010. Effective culvert placement and design to facilitate passage of amphibians across roads. Journal of Herpetology 44:618–626.

REES, M., ROE, J.H., AND GEORGES, A. 2009. Life in the suburbs: behavior and survival of a freshwater turtle in response to drought and urbanization. Biological Conservation 142:3172–3181.

ROSEN, P.C. AND LOWE, C.H. 1994. Highway mortality of snakes in the Sonoran Desert of southern Arizona. Biological Conservation 68:143–148.

RUBY, D.E., SPOTILA, J.R., MARTIN, S.K., AND KEMP, S.J. 1994. Behavioral responses to barriers by desert tortoises: implications for wildlife management. Herpetological Monographs 8: 144–160.

SPELLERBERG, I.F. 1998. Ecological effects of roads and traffic: a literature review. Global Ecology and Biogeography Letters 7:317–333.

STEEN, D.A., ARESCO, M.J., BEILKE, S.G., COMPTON, B.W., CONDON, E.P., DODD, C.K., JR., FORRESTER, H., GIBBONS, J.W., GREENE, J.L., JOHNSON, G., LANGEN, T.A., OLDHAM, M.J., OXIER, D.N., SAUMURE, R.A., SCHUELER, F.W., SLEEMAN, J.M., SMITH, L.L., TUCKER, J.K., AND GIBBS, J.P. 2006. Relative vulnerability of female turtles to road mortality. Animal Conservation 9:269–273.

STEEN, D.A. AND GIBBS, J.P. 2004. Effects of roads on the structure of freshwater turtle populations. Conservation Biology 18:1143–1148.

ULTSCH, G.R. AND ANDERSON, J.F. 1986. The respiratory microenvironment within the burrows of gopher tortoise (*Gopherus polyphemus*). Copeia 1986:787–795.

ULTSCH, G.R. AND ANDERSON, J.F. 1988. Gas exchange during hypoxia and hypercarbia of terrestrial turtles: a comparison of

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

VON SECKENDORFF HOFF, K. AND MARLOW, R.W. 2002. Impacts of vehicle road traffic on desert tortoise populations with consideration of conservation of tortoise habitat in southern Nevada. Chelonian Conservation and Biology 4:449–456.

WESTER, E.E. 2004. Impact of natural gas pipeline operation and maintenance on long-term population viability of the threatened gopher tortoise (*Gopherus polyphemus*). Report to Florida Gas Transmission Company. Auburn, AL: Southern Ecosystems Research.

WILSHIRE, H. AND PROSE, D. 1987. Wind energy development in California, USA. Environmental Management 11:13–20.

WOLTZ, H.W., GIBBS, J.P., AND DUCEY, P.K. 2008. Road crossing structures for amphibians and reptiles: informing design through behavioral analysis. Biological Conservation 141: 2745–2750.

YANES, M., VELASCO, J.M., AND SUAREZ, F. 1995. Permeability of roads and railways to vertebrates: the importance of culverts. Biological Conservation 71:217–222.

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