Western Wildlife 6:50–60 • 2019
Submitted: 3 July 2019; Accepted: 16 October 2019.

Wildlife Mortalities in Open-Topped Pipes in Central California

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***Abstract*.—Nearly 20 billion birds are killed in the United States each year by a number of anthropogenic causes, but a lesser known threat is open-topped pipes. Open-topped pipes are prevalent across the landscape, as they are used for a multitude of purposes including agriculture, mining, and infrastructure. Birds, herptiles, and small mammals can be attracted to the pipes as sites for nesting or shelter but they soon can become trapped by the smooth interior and small diameter. Cavity-nesting birds are the most likely animals to enter these pipes, potentially due to competition over a decreasing number of tree cavities in their natural habitat. We inspected pipes in several areas in central California including the South Fork Kern River Valley, Ridgecrest, and Fresno. The main goal of this study was to document the prevalence and predominant taxa comprising the wildlife mortalities in pipes, while also examining the influence of pipe dimensions and adjacent landscape types. We found 13.3% of pipes studied caused mortality: the majority of those mortalities were birds and significantly more deaths were in desert landscapes. The results of this study reveal the need for future research and pipe alteration projects to prevent further mortalities, especially in high priority desert shrubland areas.**

Key Words.—birds; cavity-nesting; mortality; desert shrubland; herptiles; mining claim posts; mammals; PVC pipes.

Introduction

It is estimated that up to 20 billion birds are killed in the United States each year due to direct anthropogenic causes, including collisions with vehicles and various manmade structures, poisoning by oil spills and other contaminants, and predation by domestic cats (Loss et al. 2012, 2015). A lesser-known threat to birds are hollow metal or PVC (polyvinyl chloride) pipes or posts, which have the potential to kill a large number of birds annually (Ogden 2013; American Bird Conservancy 2016; Malo et al. 2016). Open-topped pipes, found on farms, ranches, oil production facilities, construction sites, residential areas, and rooftops, serve a variety of purposes including fencing, irrigation, plumbing, ventilation, and mining claim markers. Birds, small mammals, and reptiles enter the pipes to nest or find shelter, but the smooth interior and tight confines of the pipes prevent individuals from escaping, leading to a slow death by stress, dehydration, or starvation (Brattstrom 1995; Hathcock et al. 2014; Malo et al. 2016; Peter Bradley and Jason Williams, unpubl. report). In 2017, the Bureau of Land Management (BLM) estimated that there were 3.6 million mining claims (each with four or more markers) in the western United States, with Nevada having about a third of the claims (1.1 million; Bureau of Land Management [BLM]. 2018. Public Land Statistics 2017. Available from https://www.blm.gov/about/data/public-land-statistics. [Accessed 22 March 2019]). Previously these markers were often made of wood, but in the 1970s they started being replaced by PVC pipes, which were typically hollow and open-topped with about a 10-cm diameter opening (Wilshire et al. 2008). These mining claim markers and other open-topped pipes present a potentially large scale and wide ranging threat to birds in the western United States.

The Nevada Department of Wildlife (NDOW) conducted one of the first studies on bird mortalities in open-topped mining claim markers (Peter Bradley and Jason Williams, unpubl. report). The study began in 1986 after a local chapter of the Sierra Club reported that Mountain Bluebirds (*Sialia currucoides*) were found trapped in mining claim markers. NDOW biologists found 914 dead birds representing 33 species in 7,058 posts in northeast Nevada and estimated that there were 13 dead birds per 100 posts (Peter Bradley and Jason Williams, unpubl. report).

California had an estimated 320,617 mining claims (BLM, *op. cited*) in 2017, which could total to an estimated 1.2 million potential open-topped markers. The issue was first addressed in California in 1990 by LaPre (1990), who reported that 262 dead birds and lizards were found in 820 mining claim posts in the Eastern Mojave National Scenic Area. This study prompted the BLM in California to conduct their own survey of 750 mining claim markers and they found 25% had dead birds and lizards (unpubl. report). Subsequently, California passed legislation that required using solid metal or wooden posts or mounds of stone when marking mines (State of California 1991; Baicich 2012); however, open-topped pipes can still be found in California (e.g., mining claims placed prior to 1991) or pipes that are used for other purposes (irrigation vent pipes, fence posts, rooftop vent pipes).

Across news articles and Audubon newsletters, the prevalence of bird mortalities in open-topped pipes were reported as being quite substantial, although variable. Compared to the news media and gray literature, peer-reviewed scientific research documenting wildlife mortality in open-topped pipes in North America is limited. One of the few studies published was conducted in the mountains of eastern San Bernardino County in California (Brattstrom 1995). In this study, 140 PVC mining claim posts were searched and found to contain the carcasses of birds (19%), lizards (28%), and mammals (4%). Another study, in north central New Mexico on the Los Alamos National Laboratory property, searched open bollard pipes and open pipes on gates and found 19.6% of the 188 pipes had dead birds (Hathcock and Fair 2014). Similar to the study conducted by the NDOW (Peter Bradley and Jason Williams, unpubl. report), both Brattstrom (1995) and Hathcock and Fair (2014) found that a large majority of the dead birds identified in pipes were native cavity-nesting songbirds: Mountain Bluebirds in Nevada, Ash-throated Flycatchers (*Myiarchus cinerascens*) and Cactus Wrens (*Campylorhynchus brunneicapillus*) in California, and Western Bluebirds (*Sialia mexicana*) in New Mexico.

The habitat surrounding open-topped pipes are likely to influence the diversity and abundance of species that are attracted and trapped. Tree cavity shortages limit the numbers of hole-nesting birds an area can support, as several species can compete to use the same sites (Newton 1994). Lower habitat quality and increased competition can drive cavity-nesting birds to occupy manmade holes. In the case of nest boxes, Mänd et al. (2005) found a greater occupancy of nest boxes placed near deciduous habitat where a higher number of cavity-nesting species existed, compared to nest boxes placed near less diverse coniferous habitat. In some cavity nesting species such as bluebirds (*Sialia* spp.), use of artificial cavities is most frequent in areas with perches, wooded pastures, high grass and shrub availability, and sparse ground cover (Munro and Rounds 1985; Hsu and Humpert 1988).

We documented wildlife mortalities in various types of open-topped pipes in several areas in central California: the Kern River Valley, Ridgecrest, and Fresno and King counties. The objective of this study was to quantify the prevalence of wildlife mortalities in open-topped pipes in central California to add to the more extensive work done in Nevada. We examined how several factors may have influenced the prevalence of mortalities in pipes including: (1) taxonomic group (birds, herptiles and mammals); (2) pipe dimensions (height and diameter); and (3) surrounding habitat type (orchard, agriculture, riparian or desert). The results of this study will add to the understanding of the potential threat that open-topped pipes pose to wildlife.

Methods

Study site. —We conducted this study in four areas in central California (Fig. 1). The first area was in the South Fork Kern River Valley on the lands adjacent to Audubon's Kern River Preserve (35.6690N, 118.3050W), California Department of Fish and Wildlife Canebrake Ecological Reserve, and the South Fork Wildlife Area of the U.S. Forest Service. This area encompasses approximately 20 km of contiguous riparian forest (Fig. 1). Kern River Preserve employees have covered most of the open-topped pipes on the preserve itself (unpubl. report), but the surrounding grazing pasture upstream of the Kern River Preserve, and the adjoining South Fork Wildlife Area remained undocumented. The South Fork Kern River Valley is 16 km long and 800 m in elevation and is located at the southern end of the Sierra Nevada, and has been designated as an important area for birds (National Audubon Society [NAS]. 2017. Important bird areas: South Fork Kern River Valley. NAS. Available from https://www.audubon.org/important-bird-areas/south-fork-kern-river-valley. [Accessed 26 November 2017]). The riparian habitat in the SFWA is composed of Fremont Cottonwoods (*Populus fremontii*), Red Willows (*Salix laevigata*), and Goodding's Black Willow (*Salix gooddingii*) as the canopy, and Coyote Willow (*Salix exigua*), Mule Fat (*Baccharis salicifolia*), Stinging Nettle (*Urtica dioica holosericea*), Mugwort (*Artemesia douglasiana*), and a variety of grasses and forbs as the understory (Whitfield et al. 1999). The forest is intermixed with freshwater marshes characterized by cattails (*Typha* spp.) and tules (*Scirpus* spp.; Whitfield et al. 1999). The area supports a diverse range of wildlife species that are potentially at risk of entrapment in pipes, including several small rodents (e.g., *Peromyscus* sp.), fence lizards (*Sceloporus* sp.), and over 339 birds (Hewett 1984). A number of cavity-nesting birds exist in the area, such as flycatchers, bluebirds, woodpeckers, swallows, chickadees, wrens, kestrels, and owls.

In addition to the South Fork Kern River Valley, we inspected pipes in nearby areas with similar landscapes and characteristics, including near Ridgecrest (35.9749N, 117.3540W) within Kern County and Sanger (36.7080N, 119.5560W) within Fresno County, and near Riverdale (36.3008N, 119.7829W) within Kings County (Fig. 1). We examined mining claim markers on BLM land north of Ridgecrest and west of the China Lake Naval Air Weapons Station. The area is situated at the edge of the Mojave Desert and the foothills of the Sierra Nevada and is characterized as high desert shrubland with rocky hills. We found pipes near Riverdale that were situated in agricultural fields and in small, neighborhood orchards and vineyards in Sanger. These two cities lie within the San Joaquin Valley and have relatively flat landscapes. Their semi-arid climates include hot, dry summers and mild, rainy winters (Tucker 2013). A number of cavity nesting birds, as well as small mammals, reptiles, and amphibians inhabit these areas.

Data collection. —We collected data from the middle of May through August 2017. We conducted weekly roadside surveys in search of pipes. We planned the general survey locations in advance to contact any known landowners for permission to access their properties. When a pipe was spotted, we pulled over and initially documented what the pipe was being used for, assigned it a number, and used a GPS unit (Garmin GPSMAP 76CSx, Garmin Ltd., Olathe, Kansas) to mark location

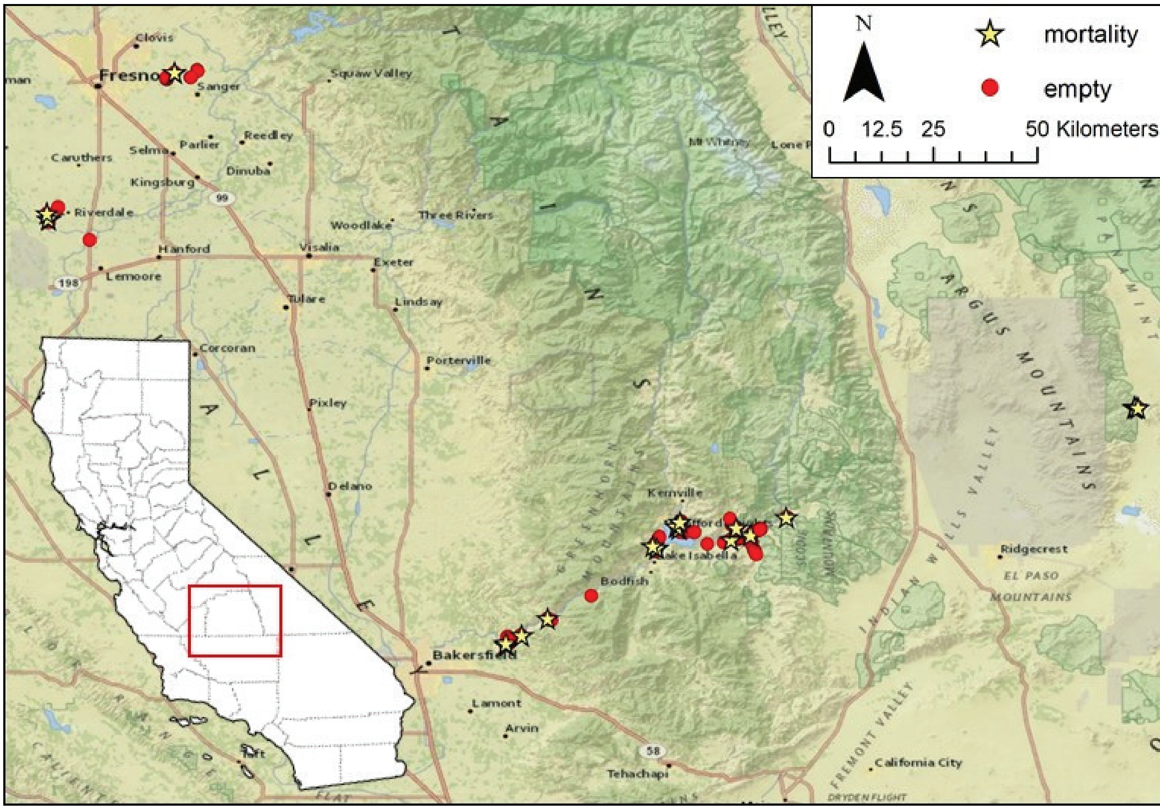

Figure 1. The locations of the pipes checked May-August 2017 in the Kern River Valley and Ridgecrest in Kern County, Sanger in Fresno County, and near Riverdale in Kings County, California, representing those empty and those with wildlife mortalities.

coordinates. We checked an average of 41 pipes during a full day of search effort. Most pipes were gate markers or fence posts, but we also surveyed irrigation pipes, livestock corrals, signposts, BLM mining claim markers, and lone pipes that appeared to serve no function. Of the 295 pipes inspected, 256 (87%) pipes were made of metal and only 39 (13%) were of plastic material.

We documented several factors about each pipe and its location in order to assess how they might affect wildlife mortalities. The diameter and length of each pipe were measured with a measuring tape (length was taken from the ground to the top of the pipe that was above ground and thus did not include the portion below ground) and classified position as upright, horizontal, or leaning. The majority of the pipes were positioned upright (277) with only 12 leaning and six horizontal; therefore, we did not include this characteristic in our analyses. We also described the habitat and vegetation components surrounding each pipe based on general visual observations, noting whether the pipe was near roads, buildings, cow pastures, forests, or orchards and then used this information to categorize each pipe into a habitat type category.

The contents of each pipe were searched for any signs of wildlife, dead or alive, using a 700+ lumen flashlight. The flashlight allowed us to identify the presence or absence of an animal, as well as categorize what taxa it belonged to and the number of individuals inside of a single pipe. The presence of trash and debris was also noted, as this could potentially affect our ability to accurately estimate taxa or number of individuals.

Data analysis.—Because we did not necessarily predict a linear relationship of pipe diameter and height with wildlife mortality, we grouped the data by pipe diameter and height into interval categories depending on the range of values obtained. We expected that the pipe frequencies would not be equal across categories, but we tried to make it so that each category contained an adequate number of pipes so a pattern of wildlife mortality could be detected during analyses. We ended up using three diameter intervals of 2.5–8.33 cm (small), 8.34–14.16 cm (intermediate), and ≥ 14.17 cm (large), and the numbers of pipes that fell within each category were fairly equal (Table 1). The height variable, however, was more uniform (most pipes were 120–160 cm tall), therefore we only split height into two categories, 12.7–120.9 cm (short) and 121.0 cm and taller (tall); and there were far fewer pipes in the short height category than the tall category (Table 2).

In addition, we grouped the habitat descriptions into landcover categories using available types within the study areas. These categories included: urban, agriculture, orchard, riparian/temperate forest, and desert shrubland; however, only two pipes could be classified as urban, so that category was removed from the analysis. We defined agriculture as a crop field, cow pasture, or otherwise open, grassy area. An orchard contained uniform rows of trees or vineyards. We defined riparian/temperate forest by groupings of trees > 5 m tall, an understory of shrubs or saplings, and possible water bodies. Desert shrubland

Table 1. The number of pipes in each diameter category (cm) comparing those empty and those with wildlife mortalities measured May-August 2017 in the Kern River Valley and Ridgecrest in Kern County, Sanger in Fresno County, and near Riverdale in Kings County, California.

	Mortality			
Diameter (cm)	No	Yes	% Yes	Total
Small (2.50–8.33)	75	5	6.67	80
Intermediate (8.34–14.16)	97	22	22.60	119
Large (≥ 14.17)	84	12	14.20	96
Total	256	39	13.22	295

was an open, rocky area with sparse vegetation in the form of short shrubs. These habitat types followed a gradient of human disturbance, with agriculture and orchard sites considered highly impacted by humans, while forest and desert sites were considered to have less human influence. We placed pipes located in areas with characteristics that fell into multiple categories in the habitat type that was most dominant and influential. For example, we classified a roadside pipe near both a pasture and a riparian forest in the riparian/temperate forest category, as the presence of trees was deemed more influential on the types of species that might use the area (e.g., cavity nesting bird species). The numbers of pipes inspected in each habitat category were fairly evenly distributed with 76 pipes in orchards, 73 in agriculture, 59 in riparian/forests, and 87 in desert areas.

We used a series of Chi-square tests to compare the frequency of the response variable wildlife mortality in a pipe (yes or no) across our three categorical independent variables including pipe diameter, pipe height, and habitat type. We also calculated the effect sizes using Cramer's V for each analysis which allowed us to determine the strength of association of any significant results (Cohen 1988). We used SPSS (IBM Corporation) for all statistical analyses with $\alpha = 0.05$.

Results

We inspected 339 pipes, 295 of which we were able to determine if there were wildlife mortalities. We excluded the additional 44 pipes from the analysis because it could not be determined with confidence whether the pipes contained wildlife. This was due to trash and/or debris obstructing the view inside the pipes.

Of the 295 pipes we inspected, 39 (13.3%) contained dead wildlife. Twenty-one pipes (7.1%) contained signs of birds, specifically passerines, including full carcasses, feathers, and a nest with a cracked egg (Appendix Fig. 1). Although most birds could not be identified to species, two feathers were confirmed as belonging to a Western Bluebird and a Western Meadowlark (*Sturnella neglecta*). We detected herptiles in five pipes (1.7%), including five Western Fence Lizards (*Sceloporus occidentalis*), a Western Toad (*Anaxyrus boreas*), and a Great Basin Gopher Snake (*Pituophis catenifer deserticola*; Appendix Fig. 2). We found mammals in nine pipes (3.1%), all of which were mice (*Peromyscus* spp.; Appendix Fig. 3). Four pipes (1.4%) held unknown carcasses that we could not identify beyond vertebrate status, including a spine, skulls, and other assorted bones.

Pipe diameter category significantly influenced the frequency of wildlife mortality in pipes ($X^2 = 6.309$, df = 2, $P = 0.043$) but the strength of this association was weak (Cramer's V = 0.146; Cohen 1988). There were more deaths in pipes with an intermediate-sized diameter (8.34–14.16 cm) than the small or large pipes (Table 1). There was no significant difference in the number of pipes with wildlife mortality of differing heights ($X^2 = 1.338$, df = 1, $P = 0.223$; Table 2). Habitat type had a significant influence on the number of pipes with wildlife mortality ($X^2 = 10.598$, df = 3, $P = 0.014$) and the effect was moderate (Cramer's V = 0.190; Cohen 1988). Specifically, pipes in desert landscapes had more wildlife deaths than those in orchard, agricultural, or forested areas (Fig. 2).

Discussion

We found that just over a tenth of pipes inspected in our central California study area had wildlife mortalities, with birds being the greatest represented taxonomic group (7.1%), followed by mammals (3.1%) and herptiles (1.7%). These results are lower than previous studies conducted in California in San Bernardino County (LaPre 1990; Brattstrom 1995), in particular the number of pipes with herptiles (e.g., Brattstrom 1995 found 28% of pipes inspected had

Table 2. The number of pipes in each height category (cm) comparing those empty and those with wildlife mortalities measured May-August 2017 in the Kern River Valley and Ridgecrest in Kern County, Sanger in Fresno County, and near Riverdale in Kings County, California.

	Mortality			
Height (cm)	No	Yes	% Yes	Total
Short (12.70–120.9)	82	9	9.89	91
Tall (≥ 121.0)	174	30	14.70	204
Total	256	39	13.22	295

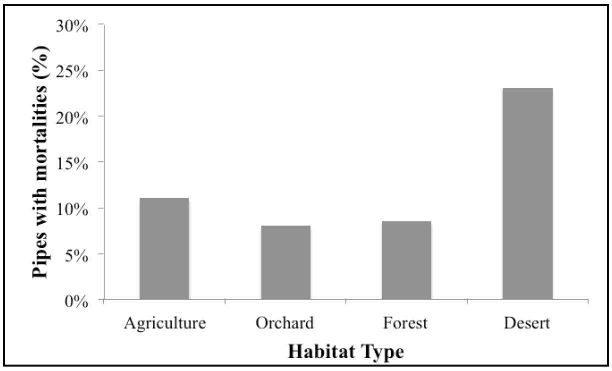

Figure 2. The percentage of pipes with wildlife mortalities in four habitat types observed May-August 2017 in the Kern River Valley and Ridgecrest in Kern County, Sanger in Fresno County, and near Riverdale in Kings County, California. The total number of pipes inspected in each habitat were 73 in agriculture, 76 in orchard, 59 in forest/riparian, and 87 in desert.

lizards). This difference may be due to differences in habitat types as well as distribution and abundance of species in Kern, Kings, and Fresno counties compared to San Bernardino.

We found differences in habitat types in our study with the largest proportion of wildlife deaths in the pipes found in the desert shrubland landscape type, which may in part be explained by the observed scarce vegetation and therefore potential lack of natural cavities in those areas. Orchards and riparian/temperate forests provide trees for nesting and roosting that may be preferred over man-made holes. Agricultural areas are similarly open landscapes with a lack of trees and natural cavities or shelter, but desert shrubland represents a more natural habitat type and may have more native species. In contrast, the Nevada Department of Wildlife found a positive relationship between the distances to Pinon-Juniper Woodlands with bird mortality in open-topped pipes; however, mortalities were also found in Sagebrush Steppe and Salt Desert Shrub landcover (Peter Bradley and Jason Williams, unpubl. report). It is likely that across species these relationships will vary as some species will prefer to use natural areas, whereas others may also use disturbed areas and perhaps even expand into disturbed areas because of human structures (e.g., Dunning and Bowers 1990) and in some cases can benefit from new nesting structures (Morelli et al. 2014). We did not systematically survey the presence of natural cavities across our sites in this study, and thus cannot quantify what options were available for cavity nesting birds; however, future studies should consider this variable to test if entrapment in pipes is greater in areas with fewer natural cavities.

The structure, dimensions, and type of some pipes may be more hazardous for certain wildlife species than others. Overall, we found that intermediate-sized diameter (8.34–14.16 cm) pipes were more likely to have wildlife mortalities. This may simply be due to easier access; however, it was more difficult to clearly see to the bottom of pipes with smaller diameters so this may have also played a role in this relationship. For mammals, we found that four of the nine pipes we inspected that caused mice mortalities were irrigation pipes dispersed throughout a Sequoia National Forest campsite. We found the remains of several mice in each individual pipe, along with a western toad and a bird. We did not find a distinct pattern for herptiles, but Brattstrom (1995) found all pipes with lizards were perforated posts. Although we only examined very few horizontal pipes, one could predict that wildlife may have an easier time escaping compared to vertical pipes. Nevertheless, Brattstrom (1995) discovered a dead Desert Cottontail (*Sylvilagus audubonii*) in a post laying on the ground, and an Audubon employee found over 200 birds in a fallen irrigation standpipe on the Kern River Preserve (Audubon, unpubl. report), but in the latter case the pipe was previously upright.

The areas with the most mortalities for wildlife in our study was located on BLM land near Ridgecrest, where six out of 11 pipes (54.5%) contained at least one bird. These pipes were previously used as mining claim markers and were dispersed along the crest of a rocky hill far from any urban structures. A BLM employee estimated that at least half of the several dozen mining claim markers he had capped in the surrounding area contained dead birds (Robert Enriquez, pers. comm.). Nationwide, BLM registered 3.6 million mining claims in 2017 (BLM 2018, *op. cited*), which could represent millions of death traps for wildlife. Moreover, mining claim markers are only a small subset of the open-topped pipes used for a variety of other purposes. Comparing the extent of mortality across pipes of different uses and structures, such as mining claim markers, gate markers, vent pipes on buildings and irrigation pipes, would be interesting for a future study.

This study was limited to presence or absence of wildlife mortalities in pipes because pipes were inspected with a flashlight and contents were not removed. We were only able to count the actual number of individuals within a few pipes, so it is unknown if pipes contained one or more individuals. The data likely underestimate the number of pipes with wildlife mortalities, as well. Even though pipes obscured by trash and debris were removed from the analysis, we could have easily overlooked carcasses in seemingly empty pipes. Hathcock and Fair (2014) also used a flashlight to inspect bollards and gate markers except for the few that were removable. Their findings were fairly similar, with positive detections in 11% of gate markers and 27% of bollards. Malo et al. (2016) were much more thorough when investigating uncapped tubular poles along the Madrid-Levante high-speed railway line in central Spain. They examined poles using flashlights and a borescope and extracted carcasses with wire hooks that were later identified. Their findings were significantly higher, with one or more bird remains found in 70 out of 96 poles (72.9%) for a total of 162 carcasses.

Solutions for decreasing open-topped pipe mortalities include filling, crimping, capping, or removing unused pipes, which for mining claim markers in California and Nevada is now required by law (State of California 1991; State of Nevada 2009). In the case of PVC pipes used for mining claims, capping pipes with plastic caps has been shown to not be effective as they are often not monitored once installed and often fall off due to desert weather wear (Peter Bradley and Jason Williams, unpubl. report). Removal of unused pipes or replacing them with other mine markers (wooden posts or rock piles) is obviously the most effective permanent solution. Taking into account labor and material costs, capping existing poles in the field is much more costly than sealing them in the factory in the first place (Malo et al. 2016) or using alternatives that are not open-topped. Solutions for other types of open-topped pipes vary and include securing metal caps for chain link fence posts, filling pipes that cannot be removed with sand or concrete, and covering rooftop and heating vents with galvanized hardware cloth held in place by stainless steel pipe clamps or gutter guard leaf filters (Southern Sierra Research Station. Avian Mortality Epidemic - Death Pipes. Available from http://www.southernsierraresearch.org/Information/DeathPipes/ [Accessed 26 November 2017]). Nevertheless, pipes may still need to be monitored, as installments such as hardware cloth can fall off. One specialized solution that appears very effective has been developed to reduce the entrapment of raptor and other bird species in vault toilets (e.g., pit toilets; Teton Raptor Center. Poo-poo Project. https://tetonraptorcenter.org/our-work/poo-poo-project/ [Accessed 13 December 2017]). Raptors enter the vault toilets through ventilation pipes and the Teton Raptor Center created a stainless-steel screen that secures to the top of the pipe, preventing entry by birds while allowing for ventilation. With the increasing awareness of the issue and solutions being implemented, future research will be able to test the long-term effectiveness of these variety of solutions.

Our study provides insight into the severity of bird and wildlife mortality caused by open-topped pipes in central California. The extent to which these pipes are having a population level effect is unknown (Loss et al. 2015), but the presence of open-topped pipes in areas where threatened or endangered wildlife exists could be of conservation concern. This issue can be invisible to the general public, as wildlife trapped in pipes die completely unnoticed in these hidden locations compared to birds colliding with windows or dead animals brought home by cats. Raising awareness is vital, and a larger dataset of mortalities could attract funding for projects to remove unused pipes and securely close off others. Quantifying the number of potentially threatening pipes that exist would also shed light on the scope of this issue and garner support. Furthermore, open-topped pipes are not the only source of entrapment, as several other human-made structures endanger wildlife such as uncovered trenches dug into the ground (Germano et al. 1993, Germano 1995, Simpson et al. 2011) and oil pits (U.S. Fish and Wildlife Service 2013). Collaboration across federal, state and local natural resource agencies, agricultural workers, landowners, and the public is necessary for successful solutions and preventative measures to be implemented to lessen the impacts of wildlife entrapment and mortality.

Acknowledgments.—This study was initiated due to the previous work conducted by Jeff King and Sean Rowe at the Kern River Preserve of Audubon California, which helped raised awareness of the dangers of open-topped pipes to wildlife. We also appreciate advice received from Chuck Hathcock regarding his own study on open-topped pipes. We would like to thank Bruce Hafenfeld and Reed Tollefson for permission to inspect pipes on their properties, as well as Robert Enriquez for leading us to mining claim markers on Bureau of Land Management (BLM) land. We would also like to thank Ana Davidson, Leigh Douglas, Chad Moura, Molly Parren, and Trinity Smith for helpful suggestions on a previous version of this manuscript, and Christy Klinger and MacKenzie Jeffress for providing an internal Nevada Department of Wildlife (NDOW) report.

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Appendix Figure 1. The contents of a gate marker with (Top) a Western Bluebird (*Sialia mexicana*) and (Bottom) a mining claim marker with an unidentified bird. (Photographed by Michelle Harris).

Appendix Figure 2. The contents of three metal livestock corral pipes revealing (Top and Bottom Left) two living Western Fence Lizards (*Sceleporus occidentalis*) and (Bottom Right) a Great Basin Gopher Snake (*Pituophis catenifer deserticola*). (Photographed by Michelle Harris).

Appendix Figure 3. The contents of an irrigation pipe revealing several deer mice (*Peromyscus* sp.). (Photographed by Michelle Harris).