

## Case Study

# Quantifying wildlife use of escape ramps along a fenced highway

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**Abstract:** Wildlife exclusion fencing can significantly reduce wildlife–vehicle collisions. However, some animals breach the fence and become trapped in the highway corridor, thereby increasing risk of a wildlife–vehicle collision. An emerging solution to this problem is the installation of earthen escape ramps (i.e., jumpouts), which allow trapped animals to escape the highway corridor. Few studies have quantified wildlife use of jumpouts, and none have investigated intraspecific differences in use. We used camera traps to document wildlife use of 4 2m-high jumpouts associated with wildlife exclusion fencing along Highway 101 near San Luis Obispo, California, USA, from 2012 to 2017. We surveyed for 7,361 nights across all 4 jumpouts, yielding 1,015 visitation events by 10 different species of large- and medium-sized mammals. Mule deer (*Odocoileus hemionus*) accounted for 895 (88%) detections; they jumped out 20% of the time when detected at the top of the ramp and were never detected using the jumpout to enter the highway corridor. We differentiated male and female deer using the presence of antlers and found that they jumped out at similar rates, but females were detected 6 times more often and were more likely to return to the same jumpout. Two groups of 2–3 deer accounted for ~41% of deer detections, which allowed us to investigate their behavior over time. These results indicate that individual variation could influence jumpout use, which should be considered when quantifying their use. To increase the overall jumpout rate, we recommend a jumpout height between 1.75 and 2 m.

**Key words:** California, escape ramps, jumpouts, mule deer, *Odocoileus hemionus*, road ecology, wildlife corridors, wildlife exclusion fencing, wildlife–vehicle collisions

**ROADS CAN POSE** serious problems for wildlife. By fragmenting habitat, roads can decouple predator–prey dynamics (Clevenger and Waltho 2005) as well as hinder dispersal and recolonization, thereby increasing risk of inbreeding within populations (Spencer et al. 2010, Clevenger and Huijser 2011). Roads also have direct effects on wildlife: an estimated 1,000,000 ver-

tebrates are killed daily on roads in the United States (Forman and Alexander 1998). Indeed, wildlife–vehicle collisions (WVCs) can be a significant mortality source for larger-bodied species, including species of conservation concern. For example, WVCs accounted for 50% of federally endangered Florida panther (*Puma concolor coryi*) mortality and were a serious mortality fac-

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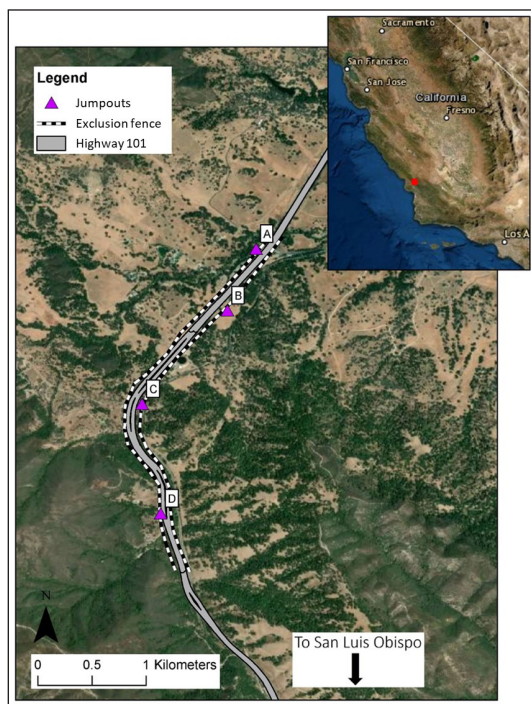
**Figure 1.** Jumpout ramp C (TjCK-N) along Highway 101 in San Luis Obispo County, California, USA (photo courtesy of the authors).

tor for federally endangered Key white-tailed deer (*Odocoileus virginianus clavium*) before infrastructure was built to mitigate WVCs (Evink et al. 1996). In the United States, traffic accidents involving deer (*Odocoileus* spp.) also cause an average of 150–200 human deaths, >29,000 human injuries, and monetary damages >\$6,600 per collision annually (Mastro et al. 2008, Huijser et al. 2009, Stull et al. 2011).

Various strategies have been used to reduce WVCs, usually by attempting to prevent animals from entering the road corridor (Sullivan and Messmer 2003). The most successful strategy has been the installation of wildlife exclusion fencing combined with wildlife crossing infrastructure that directs wildlife over or under the highway (Stull et al. 2011, Rytwinski et al. 2016). In some areas, wildlife exclusion fencing has reduced WVCs involving large mammals by 80–100% (Huijser et al. 2015). However, despite well designed and maintained wildlife exclusion fencing, complete elimination of WVCs is impractical if animals can still enter the highway corridor, such as at the ends of the fence or via ungated access roads within the fence (Clevenger et al. 2001). Moreover, once inside, fencing can trap wildlife in the highway corridor, thereby increasing risk of a WVC or concentrating WVCs in certain areas (Clevenger et al. 2001, Huijser et al. 2016).

One possible solution to this problem is installation of escape ramps (i.e., jumpouts), which typically are earthen mounds that angle up to approximately the height of the wildlife exclusion fence, then abruptly drop off, becoming a continuation of the fence on the non-highway side (Bissonette and Hammer 2000; Figure 1). Jumpouts are designed to encourage animals to walk up the ramp and jump out to the non-road side of the fence while preventing them from accessing the road from the other direction. Few studies have investigated wildlife use of jumpout ramps, and these studies have largely focused on ungulates (Bissonette and Hammer 2000, Gagnon et al. 2013, Siemers et al. 2015).

Important questions remain regarding wildlife use of jumpouts (Huijser et al. 2013). Optimal jumpout height has not been determined and may be species dependent (Huijser et al. 2015), although even within species, sex or age may influence response to the jumpouts (Perre 2015). Most previous studies were <2 years, which may not allow sufficient time to document how species learn to use jumpouts (Clevenger and Huijser 2011). Furthermore, no previous study has accounted for repeat visits by the same individual animals, which could influence apparent rate or probability of use. If individuals of the same species differ in their like-



**Figure 2.** Location of the 4 jumpouts along Highway 101 between San Luis Obispo and Atascadero, California, USA. This portion of the highway bisects the Santa Lucia mountains, an area identified as an important linkage for wildlife connectivity. The wildlife exclusion fence is 4 km long.

likelihood of jumping out, the observed proportion of events resulting in jumping out would not be a reliable indicator of the probability of any individual deer jumping out. Rather, repeated visits by the same individuals would be pseudoreplicates (Hurlbert 1984).

The goal of our study was to quantify wildlife use of jumpouts along a major highway. Although we were interested in all large mammals, we focused on mule deer (*Odocoileus hemionus*; hereafter, deer) because deer are a widespread highway safety concern (Mastro et al. 2008, Huijser et al. 2009, Stull et al. 2011), and preliminary monitoring found them to be common near the highway in our study site (Siepel et al. 2013, Perrine 2015). In addition to documenting the frequency that deer and other wildlife used the jumpouts, we investigated whether deer use of jumpouts varied by sex or age class and estimated the frequency of repeated visits by individual deer. If repeated visits were occurring, we predicted that the probability of jumping out for a given individual or group would increase over time.

## Study area

Our study site was a 4-km portion of US Highway 101 in San Luis Obispo County, California, USA (35.377 N, 120.636 W; elevation range: 170–430 m), a major regional transportation corridor with traffic volumes of up to 4,000 vehicles per hour (Snyder 2014). Just north of the city of San Luis Obispo, the highway crosses through the Santa Lucia Mountains, an area dominated by natural land cover and part of the Los Padres National Forest (Figure 2). This area is part of the California Woodland Chaparral Ecoregion, which is characterized by oak woodland and chaparral with annual and perennial grasslands and relatively small amounts of riparian habitat (deVos et al. 2003, Barbour et al. 2007). The climate is Mediterranean, with hot, dry summers, mild, wet winters, and substantial annual variation in precipitation (Dettinger and Cayan 2014).

Habitat suitability modeling has identified this area as an important movement corridor for deer, puma (*P. concolor*), and American black bear (*Ursus americanus*; bear; Thorne et al. 2006, Thorne and Huber 2011), and field surveys have indicated that this area is a hotspot for roadkills of these taxa (Siepel et al. 2013). To minimize large-mammal roadkills and protect human safety, the California Department of Transportation constructed a 4-km-long wildlife exclusion fence, including 4 jumpout ramps, through the wildlife hotspot in 2012 (Siepel et al. 2013; Figure 2).

## Methods

### Data collection

At each jumpout, we documented wildlife activity using a Reconyx HC600 Hyperfire camera (Reconyx, Holmen, Wisconsin, USA) with a passive infrared trigger and infrared flash. Cameras were deployed continuously from July 2012 through August 2017. We installed each camera on the highway side of the wildlife exclusion fence, aimed at the top of the jumpout and programmed to take 3 photographs per trigger, 1 second apart, retriggering immediately if additional motion was detected. We checked each camera every 3–5 weeks to change data cards, replace batteries as needed, and ensure the camera was functioning properly.

### Data analysis

Our sampling unit was detection events, which we defined as the detection of 1 or more

**Table 1.** Number (%) of mule deer (*Odocoileus hemionus*) detection events at 4 jumpouts from August 2012 to August 2017 along Highway 101 near San Luis Obispo, California, USA.

Site	Number of deer events	Outcome <sup>a</sup>				
		No jumpout	Jumpout	No reverse	Reverse	Unclear
A (Hwy 58-S)	553	410 (74%)	109 (20%)	29 (5%)	0	5 (1%)
B (Hwy 58-N)	157	33 (21%)	6 (4%)	118 (75%)	0	0
C (TjCk-N)	102	23 (23%)	2 (2%)	77 (75%)	0	0
D (Wat-Dist)	83	6 (7%)	2 (2%)	75 (90%)	0	0
Total	895	472 (53%)	119 (13%)	299 (33%)	0	5 (1%)

<sup>a</sup> Four different outcomes relative to the wildlife exclusion fence: “no jumpout” means approached from inside and stayed inside (i.e., did not jump out), “jumpout” means approached from inside and went outside (jumped out), “no reverse” means approached the jumpout from outside and stayed outside, “reverse” means approached the jumpout from outside and jumped in, and “unclear” means the event started on the inside (on top of the jumpout ramp) but the outcome was ambiguous.

individuals of the same species at a jumpout. A single detection event could range from 3 photos (1 trigger) to hundreds of photos. To account for potential dependence between events, we set a 15-minute buffer period before photographs of the same species at the same site was considered a new event. We chose 15 minutes as a compromise between 10 and 30 minutes used in previous camera trap studies (Ridout and Linkie 2009, Martinig and Bélanger-Smith 2016). For each event, we recorded the site, date, start and end times, species, number of individuals involved, and the number of juvenile and adult individuals; for deer, we further documented the number of antlered and non-antlered adults. Male deer bear antlers during most of the year but shed them in January or early February and start to re-grow them in late spring (California Department of Fish and Wildlife 2018). Therefore, we excluded February, March, and April when comparing sexes because the odds of misidentification were relatively high during those months. We attempted to identify individual deer using antler points and ear notches but were unable to confidently determine if every detection was a new individual/group or not.

We assigned each event one of the following 4 outcomes based on the location of the animals at the start and end of the event: (1) the animals approached from outside the wildlife exclusion fence and remained outside; (2) the animals approached from outside and went inside (i.e., they scaled the jumpout wall to enter the fenced high-

way corridor, known as reversing the jumpout); (3) the animals approached the ramp from inside the fence and remained inside (i.e., they did not jump out but rather returned back down the ramp toward the highway); and/or (4) the animals approached the ramp from inside and went outside (i.e., they jumped out). We counted multiple individuals of the same species traveling together as 1 detection event because their activity was likely interdependent (Allen et al. 2013). We recorded all events consisting of large and medium-sized mammals. We also detected birds, reptiles, rodents, rabbits (Leporidae), domestic cats (*Felis catus*), dogs (*Canis familiaris*), and humans at the jumpouts, but we did not include them in analyses.

## Results

We surveyed 7,361 nights across all 4 jumpouts. The cameras were fully operational for 7,132 (97%) of these nights (Supplemental Table 1), during which we documented 1,012 wildlife detection events by 10 large and medium-sized mammal species (Supplemental Table 2). Deer were the most frequently detected species, with 895 detections (88% of the total), followed by gray foxes (*Urocyon cinereoargenteus*; 57 detections), and raccoons (*Procyon lotor*; 12 detections). Gray foxes were the only species to reverse the jumpout but did so only 3 times. Each of the remaining species (bear, bobcat [*Lynx rufus*], coyote [*C. latrans*], opossum [*Didelphis virginiana*], red fox [*Vulpes vulpes*], and



**Figure 3.** A mule deer (*Odocoileus hemionus*) doe using the Hwy-58-N (B) jumpout to escape the Highway 101 corridor near San Luis Obispo, California, USA, in August 2012 (photo courtesy of the authors).

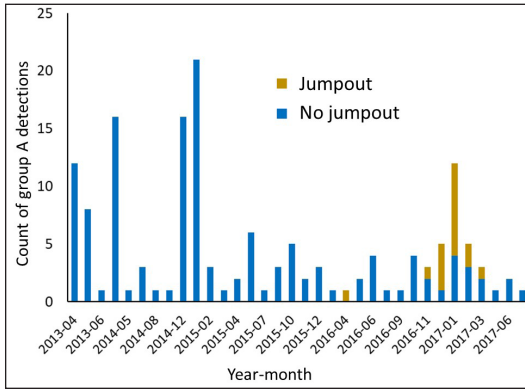
striped skunk [*Mephitis mephitis*]) were detected <10 times. We detected bear at the top of the jumpout 4 times, which resulted in 1 successful jumpout. We never detected puma, feral pig (*Sus scrofa*), or badger (*Taxidea taxus*) on or adjacent to a jumpout despite evidence they occurred in our study area (Siepel et al. 2013, Jensen 2018).

Deer activity was relatively consistent across years. On average, there were 14–20 deer events per month from 2012 to 2016 and 4 events per month in 2017. Most (83%) deer activity occurred during the dry season (May to October; Sommer et al. 2007). In 33% of the 895 deer events, the deer were first detected at the base of the jumpout outside the wildlife exclusion fence, and they never jumped up onto the ramp and into the highway corridor (Table 1). In the remaining 596 events, the deer were first detected on the ramp inside the wildlife exclusion fence. For 5 of these events, it was unclear if the deer jumped out or not, so we excluded those from further analysis. Of the remaining 591 events, deer jumped out in 119 (20%) of them, exiting the highway corridor (Table 1; Figure 3).

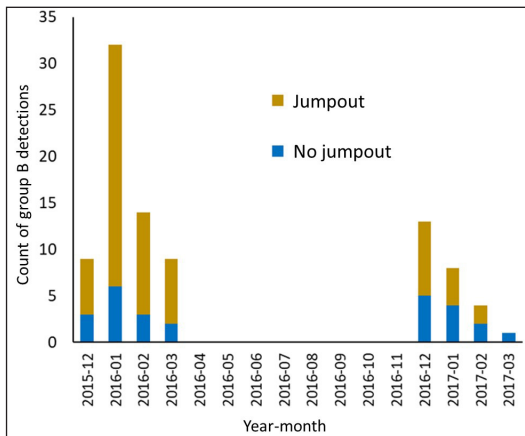
Male deer were detected 64 times and jumped out 14 (22%) times, whereas female deer were detected 408 times and jumped out 97 (24%) times (Supplemental Table 3). Male deer appeared to be relatively less likely to be detected multiple times, and when they were, a female

was usually present as well (Supplemental Table 4). Anecdotally, male deer also appeared to spend less time at the top of the jumpout and therefore were potentially less hesitant to jump out. Juvenile deer were present in 142 (24%) of the 591 events that began on the ramp, and 47 of these events (33%) resulted in jumping out. However, 43 of the 47 events where a juvenile deer jumped out were likely the same individual (from group B; see below), which precluded statistical comparison of jumpout rates between groups of deer with and without juveniles.

We could confidently differentiate antlered deer, but not non-antlered adults or juveniles. However, it was evident that some groups returned to the jumpout on a regular basis based on unique physical traits (i.e., notches in ears) and knowledge of deer habitual behavior. We estimated that 2 groups, each containing 2–3 deer, accounted for 41% of deer detection events: a group of 3 adult females (group A) accounted for ~153 events (26% of the total), and a single doe and her trailing fawn (group B) accounted for 89 events (15% of the total; Supplemental Table 4). The repeated detections of these individuals may indicate how deer respond to the jumpouts over time. Group A did not jump out for the first 107 times they were detected on the ramp, then did so 36 months after their first visit (Figure 4). They then visited the ramp 12 times without



**Figure 4.** Outcome of detections of group A, consisting of 3 mule deer (*Odocoileus hemionus*) does, at Hwy58-S (A) jumpout along Highway 101 near San Luis Obispo, California, USA, from 2013 to 2017 by month. Blue bars are events when they did not jump out, and gold bars are events when they did. Months with no detections not shown for clarity.



**Figure 5.** Outcome of detections of group B, consisting of a mule deer (*Odocoileus hemionus*) doe and a juvenile, at Hwy58-S (A) jumpout along Highway 101 near San Luis Obispo, California, USA, from 2015 to 2017 by month. Blue bars are events when they did not jump out, and gold bars are events when they did.

jumping out, then jumped out again in November 2016. After that, they jumped out in 15 (47%) of the remaining 32 times they were detected on the ramp. In total, they jumped out 17/153 (11%) times (Supplemental Table 4). In comparison, group B did not jump out the first 2 times they were detected on the ramp, but then jumped out the next 3 times (Figure 5). Notably, these first 5 events consisted of only the doe, then the fawn appeared in the sixth detection. The pair did not jump out the first time they were both detected at the jumpout but then jumped out together in the following 7 events. Of their remaining

76 detections, they jumped out 52 times (68%), but there was no clear change in this rate over time. In total, they jumped out 64/89 (72%) times. Importantly, when we excluded these 2 groups (242 events), the overall jumpout rate was 11%.

## Discussion

Combined with wildlife exclusion fencing, jumpouts are a promising advance in reducing WVCs, but their performance has remained poorly documented. Our study was initially designed to document jumpout use by large mammals, specifically deer, bears, and pumas (Siepel et al. 2013). However, we documented only 5 bear events and no pumas. Pumas and bears were undoubtedly less abundant than deer in our area, but we detected both species at under-crossings nearby, sometimes within a few hundred meters of the jumpouts (Jensen 2018). Few large carnivore detections could be explained by differences in behavior near highways; deer tend to be less likely than large carnivores to use culverts (Mastro et al. 2008, Clevenger and Barrueto 2014, Kintsch et al. 2019, Bhardwaj et al. 2020), making it more likely that they would attempt to cross the highway at grade and therefore encounter the jumpouts. In addition, deer often travel parallel to roads before attempting to cross (Puglisi et al. 1974), whereas bears and pumas may not exhibit this behavior, reducing their chances of encountering a jumpout.

The height of a jumpout is critical to its success; the drop-off must be low enough that animals on the ramp feel comfortable jumping out, yet the wall must be high enough to discourage wildlife from jumping in and entering the highway corridor (Clevenger and Huijser 2011). Across 5 years of nearly continuous monitoring at 4 sites, we never detected a large mammal using the jumpout to enter the highway corridor, although gray foxes and domestic cats did so occasionally. Most notably, we detected deer 299 times at the base of the ramp, and in none of these events did they jump up onto the ramp itself. To our knowledge, only 2 prior studies have reported ungulates reversing jumpouts, and in both studies the frequency of incidents was very low. Desert bighorn sheep (*Ovis canadensis nelsonii*; bighorn sheep) in Arizona, USA, reversed 1.83-m-high jumpouts in 44 (3%) of 1,312 detections on the outside of the fence (Gagnon et al. 2013). Mule deer in Colorado, USA, reversed the



**Figure 6.** A mule deer (*Odocoileus hemionus*) doe and yearling (group B) bedded down at the top of the Hwy58-S (A) jumpout along Highway 101 near San Luis Obispo, California, USA, in December 2014 (photo courtesy of the authors).

jumpout in 27 (0.9%) of 2,965 detection events, using jumpouts ranging from 1.4–2.0 m in height (Siemers et al. 2015). The Arizona Department of Transportation (2013) recommended a jumpout height of 1.7–1.8 m, and Huijser et al. (2015) suggested jumpouts 1.5–2.1 m high may be best for deer, elk (*Cervus canadensis*), and bighorn sheep. The jumpouts in our study were 2 m, which was high enough to prevent large mammals from entering the highway corridor, yet perhaps too high to encourage jumping out by most individuals. The optimal height may be species dependent, as different species have different jumping and climbing capabilities (Goldingay et al. 2018).

Had the wildlife exclusion fence worked perfectly, we would not have detected any deer on top of the jumpout ramps. We did not expect this, and indeed, deer did find their way into the highway corridor somehow and accessed all 4 jumpouts. The overall rate at which deer jumped out when detected on the ramp was fairly low (approximately 20% of total events). This percentage is similar to a study in Canada that documented successful “escapes” by deer (19%), elk (67%), and coyotes (25%); however, there were only 33 total detections across those

3 species (Clevenger et al. 2002). Slightly lower rates were reported for deer (13%) and elk (9%) in Colorado (Kintch et al. 2019). In contrast, deer jumped out 51.5% ( $n = 2,588$ ) of the time in a different part of Colorado (Siemers et al. 2015), and bighorn sheep jumped out 95.5% ( $n = 337$ ) of the time in Arizona (Gagnon et al. 2013).

We found no evidence for sex-based differences in jumpout rate among deer, although we detected far fewer visitation events by male deer compared to females. Except during the mating season, male and female deer generally segregate from each other, probably due to sex-specific strategies to maximize fitness (Main and Coblentz 1996). Specifically, female deer with fawns in our study area may have been selecting areas close to roads because they provide refugia from predators. This human shield effect has been documented in other ungulates, including pregnant cow moose (*Alces alces*) in Yellowstone (Berger 2007), and non-migratory elk (Hebblewhite and Merrill 2009).

Our results highlight the importance of long-term monitoring, given the variance in behavior between the 2 groups of deer, which accounted for ~41% of deer detections. The behavior of

group A suggests that these deer learned to use the jumpout or eventually became comfortable with jumping out. A shorter study might have erroneously concluded that these deer never jumped out (i.e., based on the first 3 years of data) or frequently jumped out (i.e., based only on the last 10 months of data). In contrast, group B appeared to consist of local residents returning regularly to the same jumpout and incorporating it into their daily movement patterns, including foraging at the top of the jumpout and occasionally bedding down there (Figure 6). To group B, the raised ramp was likely more than just a way to escape the highway corridor; it also provided food, enhanced visibility in all directions, and the option to return down the ramp or jump out. Ultimately, quantifying a generalized probability of jumping out depends on the assumption that each event is independent—an assumption that our data show not to be valid.

Our study is subject to 2 considerations. First, our small sample size ( $n = 4$  sites) and 62% of the deer detection events occurring at one site (Table 1) precluded us from making comparisons between sites. Future research on jumpouts would ideally be able to test the effects of various factors on their use, including height, nearby vegetation cover, and distance from the end of the fence. Second, although our observation that 5 individuals represented 41% of the detection events is important, our results suggest that the relatively high jumpout rate (72%) of group B likely skewed the overall jumpout rate, and 11% is likely more representative of the population than 20%. However, these results highlight the importance of accounting for individual (or group) differences in behavior when quantifying activity.

### Management implications

Our study added to the growing literature documenting that jumpouts can effectively provide escape opportunities for deer and other medium-to-large mammals. We recommend that jumpouts be incorporated into wildlife exclusion fencing that guides wildlife to alternative crossings such as underpasses. Our data indicated that a jumpout height of 2 m effectively deters medium-to-large mammals from jumping up onto the ramp and entering the highway corridor. Further reduction of this height (but not to less than 1.75 m; Huijser et al. 2015) may increase

the probability of wildlife jumping out without increasing the probability of their jumping in. Likewise, animals detected on the ramp may not always have the intention of jumping out to escape the highway corridor, and a low rate of jumping out may not indicate that the ramp is unsuitable for jumping out. Although we were unable to quantify repeat visits by all deer, we are confident that several deer accounted for a significant portion of detections—a previously unexplored aspect of jumpout research. We recommend post-construction monitoring for at least 3 years to account for acclimation and temporal variability in use. More research is needed to better identify what factors contribute to successful jumpouts for deer and other large mammals, and we encourage researchers to mark or otherwise account for repeated visits by the same individuals whenever possible. Marked animals would better allow researchers to differentiate local residents from individuals passing through the site, and global positioning system tags would probably provide the best data on individual differences in fine-scale spatial decision making near highway corridors.

### Supplemental material

Supplemental material can be viewed at <https://digitalcommons.usu.edu/hwi/vol16/iss1/13>.

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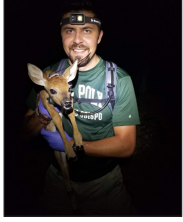
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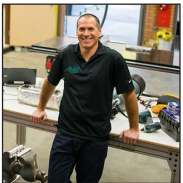


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