IDAHO TRANSPORTATION DEPARTMENT
RESEARCH REPORT

RP 226

Assessing Feasibility of Mitigating Barn Owl-Vehicle Collisions in Southern Idaho

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16. Abstract

Large numbers of barn owls are killed along roads in southern Idaho. Although barn-owl vehicle collisions are not unique to Idaho, I-84 has among the world's highest rates of vehicle-caused mortality for barn owls. This is concerning because much lower rates have caused local extirpation in some areas. Barn owl populations have declined in portions of their range such that regulatory agencies consider them a species of concern, threatened, or endangered in some states, provinces, and countries. Our research was designed to understand the spatial, road geometric, and biotic (land cover and prey) factors associated with barn owl-vehicle collisions and examine feasibility of mitigation. We also provide a literature review of barn owl road mortality and mitigation approaches from North America and Europe. The greatest rates of mortality along I-84 occurred between Bliss and Hazelton, Idaho. Mortality increased when the highway was close to the Snake River Canyon, close to dairies (agriculture), and farther from water features, and when there were fewer nearby roads, narrower medians, fewer human structures, and a higher percentage of cultivated crops. Owl road kills were higher when plant cover type in the median and right-of-way was grass rather than shrubs. Our research team recommends that mortality hotspots be the focus of initial mitigation. Efforts to reduce barn owl mortality should focus on vegetation management in the right-of-way to promote tall shrubs or scrub vegetation to reduce "huntability" for owls, and keeping grassy areas to very low heights to potentially reduce abundance of small mammals through decreased food and cover for them. There should also be development of barriers (hedges or trees, nets, fences, berms or other) to restrict low flight by owls in mortality hotspots. Reducing wildlife-vehicle collisions involving barn owls is an important step in ensuring persistence of this avian species. In so doing, it would reduce chances that the conservation status of barn owls is elevated, which would bring heightened regulatory challenges to the transportation sector in Idaho.

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APPROXIMATE CONVERSIONS TO SI UNITS					APPROXIMATE CONVERSIONS FROM SI UNITS				
Symbol	When You Know	Multiply By	To Find	Symbol	Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH					LENGTH		
in	inches	25.4		mm	mm	millimeters	0.039	inches	in
ft	feet	0.3048		m	m	meters	3.28	feet	ft
yd	yards	0.914		m	m	meters	1.09	yards	yd
mi	Miles (statute)	1.61		km	km	kilometers	0.621	Miles (statute)	mi
		AREA					AREA		
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ft^2	square feet	0.0929	meters squared	m^2	m^2	meters squared	10.764	square feet	ft^2
yd^2	square yards	0.836	meters squared	m^2	km^2	kilometers squared	0.39	square miles	mi^2
mi^2	square miles	2.59	kilometers squared	km^2	ha	hectares (10,000 m^2)	2.471	acres	ac
ac	acres	0.4046	hectares	ha					
		MASS (weight)					MASS (weight)		
oz	Ounces (avdp)	28.35	grams	g	g	grams	0.0353	Ounces (avdp)	oz
lb	Pounds (avdp)	0.454	kilograms	kg	kg	kilograms	2.205	Pounds (avdp)	lb
T	Short tons (2000 lb)	0.907	megagrams	mg	mg	megagrams (1000 kg)	1.103	short tons	T
		VOLUME					VOLUME		
fl oz	fluid ounces (US)	29.57	milliliters	mL	mL	milliliters	0.034	fluid ounces (US)	fl oz
gal	Gallons (liq)	3.785	liters	liters	liters	liters	0.264	Gallons (liq)	gal
ft^3	cubic feet	0.0283	meters cubed	m^3	m^3	meters cubed	35.315	cubic feet	ft^3
yd^3	cubic yards	0.765	meters cubed	m^3	m^3	meters cubed	1.308	cubic yards	yd^3
Note: Volumes greater than 1000 L shall be shown in m^3									
		TEMPERATURE (exact)					TEMPERATURE (exact)		
^oF	Fahrenheit temperature	5/9 (^oF-32)	Celsius temperature	^oC	^oC	Celsius temperature	9/5 ^oC+32	Fahrenheit temperature	^oF
		ILLUMINATION					ILLUMINATION		
fc	Foot-candles	10.76	lux	lx	lx	lux	0.0929	foot-candles	fc
fl	foot-lamberts	3.426	candela/m^2	cd/cm^2	cd/cm^2	candela/m^2	0.2919	foot-lamberts	fl
		FORCE and PRESSURE or STRESS					FORCE and PRESSURE or STRESS		
lbf	pound-force	4.45	newtons	N	N	newtons	0.225	pound-force	lbf
psi	pound-force per square inch	6.89	kilopascals	kPa	kPa	kilopascals	0.145	pound-force per square inch	psi

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Technical Advisory Committee

Each research project is overseen by a Technical Advisory Committee (TAC), which is led by an ITD project manager. The TAC is responsible for monitoring project progress, reviewing deliverables, ensuring that study objectives are met, and facilitating implementation of research recommendations, as appropriate. ITD's Research Program Manager appreciates the work of the following TAC members in guiding this research study.

ITD Project Manager: Melinda Lowe

TAC Members:
Alissa Salmore, Idaho Transportation Department
Sue Sullivan, Idaho Transportation Department
Ned Parrish, Idaho Transportation Department
Gregg Servheen, Idaho Department of Fish and Game

FHWA-Idaho Advisor: Brent Inghram

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List of Acronyms

[Listed in the order they appear in the text]

IDFG	Idaho Department of Fish and Game
ITD	Idaho Transportation Department
FHWA	Federal Highway Administration
I-84	Interstate 84
WVCs	Wildlife-Vehicle Collisions
ROW	Right-of-way
EB	Eastbound Interstate
WB	Westbound Interstate
WTI	Western Transportation Institute, Montana State University
DOT	Department of Transportation
AIC	Akaike Information Criterion
AI	Abundance Index
CAADT	Commercial Annual Average Daily Traffic

Executive Summary

Barn owls are dying in substantial numbers along Interstate 84 (I-84) in southern Idaho. This was true from 2004 to 2006[1] and continues based on results reported here. Although barn owl- vehicle collisions are not unique to Idaho, I-84 has among the world's highest reported vehicle-caused mortality rate for barn owls (Table 1). The rates are concerning because much lower roadway mortality rates have caused local extirpation of barn owls in some areas. Moreover, barn owl populations have declined in portions of their range such that regulatory agencies consider them a species of concern, threatened, or endangered in some states, provinces, and countries. Reducing wildlife-vehicle collisions (WVCs) involving barn owls in Idaho and elsewhere is an important step in ensuring the persistence of this avian species. In so doing, it would help prevent further elevation of the conservation status of barn owls in Idaho, which would otherwise bring heightened regulatory challenges to its transportation sector.

Table 1. Direct Mortality of Barn Owls along Roads

Rate of Barn Owl Mortality (Owls/100 km/year)	Location	Source
0.7	Germany	Illner[2]
7.0	Switzerland	Bourquin[3]
25.0	France	Massemin and Zorn[4]
43.4	California	Shulz[5]
49.0	Portugal	Gomes et al.[6]
48 – 96	Portugal	Grilo et al.[7]
64.1	Great Britain	Taylor[8]
185.6	California	Moore and Mangel[9]
Up to 260.9	Idaho	Boves and Belthoff[1]

The goal of the research was to explore roadway mortality of barn owls (Figure 1) along portions of I-84 and I-86 in southern Idaho to identify areas of greatest mortality; to assist the Idaho Transportation Department (ITD) in understanding the spatial, road geometric, and biotic (land cover and prey) factors potentially contributing to barn owl-vehicle collisions; and to envision management/mitigation activities that may represent the next steps in reducing WVCs involving barn owls in southern Idaho. The research was conducted on behalf of ITD by a team from Boise State University and the Western Transportation Institute at Montana State University.

Barn Owl Mortality along I-84

Boves and Belthoff conducted standardized road kill surveys for barn owl carcasses along I-84 between Boise and Burley, Idaho from 2004 to 2006, which located 812 dead barn owls.[1] Using a similar approach, between 2013 and 2015, the research team surveyed this same route and expanded the

Figure 1. Photo of Dead Barn Owl Illustrating Direct Mortality along I-84

survey to other portions of I-84 and I-86, and located another 550 dead barn owls. Owl mortality varied by year and was typically greatest during autumn and winter, but it is apparent that barn owl-vehicle collisions continue to occur at high rates along I-84. Indeed, it appears that high rates of barn owl mortality have been occurring along I-84 unabated for more than a decade.

Boves and Belthoff noted that roadway mortality occurred in all regions of I-84 between Boise and Burley, but rates were especially high between Bliss and Hazelton, Idaho.[1] They discussed three particular highway segments with the highest density of barn owl carcasses, which they referred to as mortality hotspots (Figure 2).

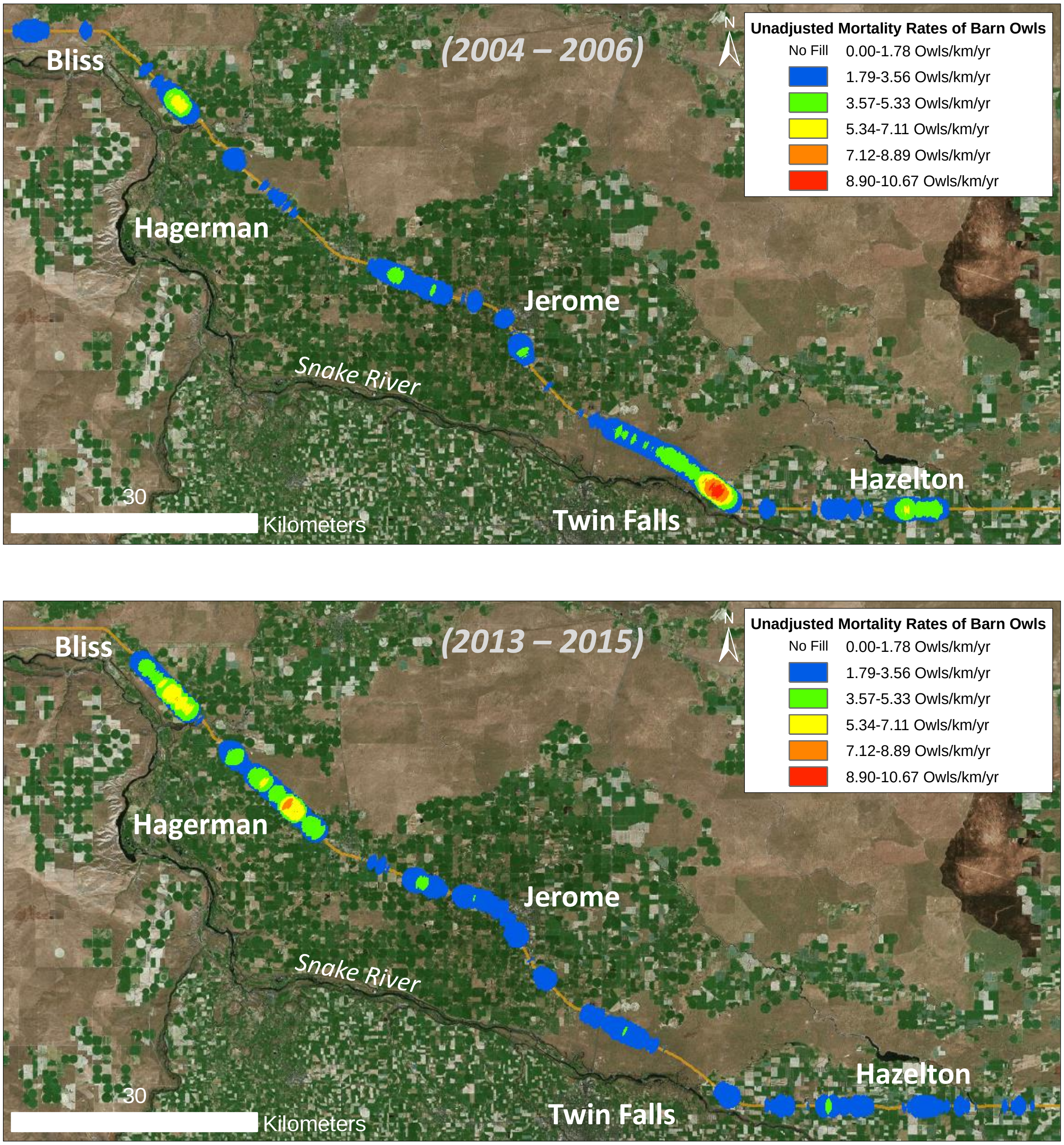

Figure 2. Barn Owl Road Kill Locations and Rates between Bliss and Hazelton, Idaho along I-84

Top: 2004 to 2006. Bottom: 2013 to 2015

The findings from this project show that the largest numbers of barn owl road kills continue to occur in these same regions of I-84 between Bliss and Hazelton, Idaho, although particular segments with the greatest mortality have shifted between the time of previous and current road surveys. Indeed, the rates of mortality in these highway segments remain some of the highest reported worldwide. Reasons for the small shifts in the rate of mortality along I-84 remain unknown. However, given that hundreds of barn owls continue to die in this region of I-84, it could be considered a high priority for potential mitigation. Reducing barn owl mortality in this region would also have a large and immediate effect on the persistence of barn owl populations.

Roads other than I-84/86

With the assistance of citizen science volunteers, the research team also surveyed other major roads in southern Idaho for dead barn owls. These roads included US 20, I-15, US 30, Hwy 34, US 91, and I-84 (Oregon border to Boise, Idaho). The number of barn owl carcasses detected on these roads (n = 14) was quite small in comparison to the numbers detected along the focal interstate (I-84/86), even though there was extensive survey effort along these other roads (see Chapter 7). Thus, I-84 remains the most concerning road of those surveyed for barn owl carcasses, although barn owl mortality is widespread in southern Idaho.

Characteristics of Road Segments

This research examined relationships between barn owl mortality and a suite of spatial, road geometric, and biotic factors along I-84/86. Greater barn owl mortality was associated with decreasing (1) lengths of secondary roads, (2) distances to the Snake River Canyon, (3) distances to the nearest dairy, (4) width of the median, and (5) percentage of human structures near the roadway, and increasing (6) percentage of crop and (7) distance to water features. Barn owl mortality was also greater when plant cover in the (8) median and (9) rights-of-way were grass rather than shrubs.

Characteristics of Mortality Hotspots

Areas like those pictured in Figure 3, with high proportions of cropland near the interstate, narrow median, road segments level with the surrounding landscape, few roads and human structures near the interstate, and no barriers to restrict low flight by owls, are representative of mortality hotspots along I-84.

Figure 3. Photo of I-84 Location within Barn Owl Mortality Hotspot

Reducing Roadway Mortality of Barn Owls

While the published literature is rich with examples of studies that document large numbers of barn owls being killed along roads and some studies that examine spatial, road geometric, and biotic factors associated with road mortality, examples of on-the-ground mitigation and their efficacy in reducing barn owl mortality along roads are rare.

For barn owls, literature mitigation recommendations have centered on several main themes:

- Establishing tall vegetation or other barriers that force owls to fly higher above highways while foraging nearby or crossing.
- Removing rodents or their habitat from the highway ROW.
- Promoting taller shrubs and brambles within the ROW to make it less attractive hunting grounds for barn owls.
- Providing suitable habitat away from roads to provide barn owls the resources they need elsewhere.

In British Columbia, Canada, the South Fraser Perimeter Road near Delta opened in December 2013. The road alignment incorporated barriers to obstruct low flights by barn owls (Figure 4). This is among the only examples of road mitigation in North America related to barn owls.

Figure 4. Photo of Vegetation Designed to Reduce Barn Owl-Vehicle Collisions in British Columbia, Canada

Key Recommendations

Given the high rates of barn owl mortality along I-84, project findings suggest that ITD should consider mitigation that focuses on reducing the potential for barn owl-vehicle collisions. Researchers know from the literature that lower mortality rates than those observed along I-84 have caused local extirpation in other portions of the range of barn owls.[10] The highest priority areas for mitigation are those Boves and Belthoff[1] and the current study identified as mortality hotspots. Specifically, researchers recommend mitigating the hotspots outlined in Chapter 4 (Table 7). There are four priority hotspots with a combined length of 11.8 km (7.3 mi). The individual hotspots range in length from 0.5 km (0.3 mi) to 4.5 km (2.8 mi). In addition to mitigating these hotspots, reducing barn owl-vehicle collisions in the approximately 86-km (52 mi) portion of I-84 between Bliss and Hazelton, Idaho is also warranted, as this section has the highest number of barn owl road kills between Boise and Pocatello. As the effects of road mortality on barn owl populations in southern Idaho are poorly understood, the research team also recommends that ITD continue to partner on research.

Mitigation Recommendation 1: Establish Barriers to Low Flight by Barn Owls

Mortality hotspots along I-84 were generally devoid of low flying obstructions. Given this and other available information, barriers to low flight are probably the most efficacious route to reducing barn owl-vehicle collisions. Options for establishing barriers include vegetation, netting, fences, and earthen berms.

Mitigation Recommendation 2: Vegetation Management

Findings indicated that fewer small mammals were in roadside areas with shrubs, and the literature suggests that taller vegetation (such as brambles and shrubs rather than grass) typically discourages owl foraging. Thus, ITD should encourage taller shrubs rather than grass in the median and ROW in areas of high barn owl mortality. Alternatively, keeping grassy areas very short by frequent mowing to reduce food and cover for small mammals may also be effective but would require regular maintenance.

Monitoring

Monitoring effectiveness of any mitigation that ITD undertakes is critical. Because there is seasonal and annual variation in barn owl road mortality, monitoring schedules and duration should take this variability into account with a multiple year schedule.[(1, this study)]

Research Recommendation

Detailed risk assessments about the likelihood of barn owl population declines are not currently possible because barn owl populations are not regularly monitored in southern Idaho. Studies of occupancy, demography, movements, interactions with roads, and other factors affecting mortality are needed to fully understand population consequences of barn owl mortality along I-84/86 and to evaluate the effectiveness of any mitigation implemented. Thus, the research team recommends that ITD continue to work with partners such as Idaho Department of Fish and Game, U.S. Fish and Wildlife Service, U.S. Bureau of Land Management, universities, NGOs, and others to develop the needed understanding of barn owl population dynamics.

Chapter 1
Introduction

Purpose of the Project

Barn owls (*Tyto alba*) are killed in large numbers along major roads in southern Idaho. Indeed hundreds of barn owls are killed annually along Interstate 84 (I-84) between Boise (Ada County) and Burley (Cassia County), Idaho.[1] Along this interstate highway, barn owl carcasses are recorded four times as often as skunks (*Mephitis* spp.) and eight times as often as badgers (*Taxidea taxus*), which themselves are common victims of roadway mortality.[1] Although barn owl-vehicle collisions are not unique to Idaho, I-84 has among the world's highest vehicle-caused mortality rate for barn owls (Table 1). The rates are concerning, as much lower roadway mortality rates have caused local extirpation of barn owls in some areas.[10] Reducing wildlife-vehicle collisions (WVCs) involving barn owls in Idaho and elsewhere is important for motorist safety and would be an important step in ensuring the persistence of this avian species.

Table 2. Rates of Direct Mortality of Barn Owls along Roads

Rate of Barn Owl Mortality (Owls/100 km/year)	Location	Source
0.7	Germany	Illner[2]
7.0	Switzerland	Bourquin[3]
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48 – 96	Portugal	Grilo et al.[7]
64.1	Great Britain	Taylor[8]
185.6	California	Moore and Mangel[9]
Up to 260.9	Idaho	Boves and Belthoff[1]

The goal of this research was to explore roadway mortality of barn owls (Figure 5) along portions of I-84 and I-86 in southern Idaho to identify areas of greatest mortality (hotspots); to assist the Idaho Transportation Department (ITD) in understanding the spatial, road geometric, and biotic (land cover and prey) factors potentially contributing to barn owl-vehicle collisions; and to envision management/mitigation activities that may represent the next steps in reducing WVCs involving barn owls in southern Idaho. The research was conducted on behalf of ITD by a team from Boise State University and the Western Transportation Institute at Montana State University.

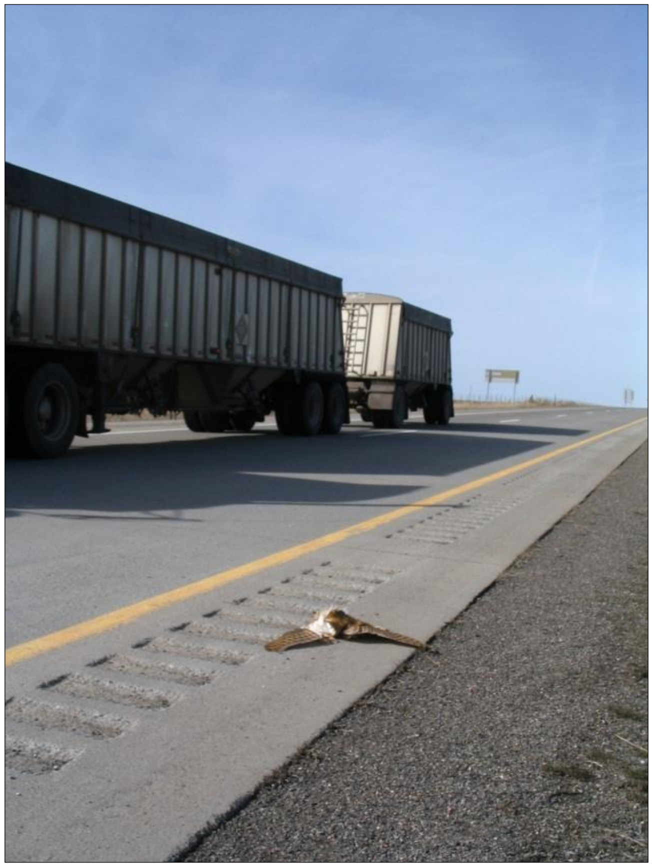


Figure 5. Photo of Road-killed Barn Owl along I-84 in southern Idaho

Project Objectives

The project had four main objectives:

1. Identify locations of barn owl-vehicle collisions along I-84 and I-86.
2. Examine spatial, geometric, and biotic characteristics of barn owl collision locations to shed light on features of the roadways and surrounding landscape that may provide clues about why and how barn owls are being killed.
3. Establish public-private partnerships among transportation agencies, natural resource agencies, university researchers, and citizen scientists to work on owl-vehicle collision data collection, research, and, ultimately, mitigation.
4. Assess feasibility of potential mitigation strategies that may reduce owl-vehicle collisions and reduce driver risk of collision with barn owls.

To accomplish these project objectives, the research team:

1. Conducted road kill surveys for dead barn owls along I-84/86.
2. Performed small mammal abundance surveys to understand relative abundance of potential owl prey.

3. Quantified spatial, road geometric, and other biotic factors along the focal highway and assessed these factors to examine their relationship with number of dead barn owls per survey within 1-km segments of highway.
4. Partnered with agencies and citizen scientists to record owl mortality data on major roads outside of the focal study area to determine the nature and extent of barn owl road mortality in portions of southern Idaho.
5. Reviewed the published literature about potential mitigation approaches and assessed feasibility of approaches for southern Idaho.

Throughout this report, we use the following terminology:

- **Right-of-way** (ROW) – the ROW describes the area inside of fences that bound the interstate highway. In the project area in southern Idaho, these roadside areas are typically vegetated with grass, shrubs, or mixed grass and shrubs. Papers in the primary literature related to barn owl mortality along roads often refer to these areas as roadside 'verges.' EB ROW refers to that section of roadside vegetation inside of the fence adjacent to eastbound traffic lanes. WB ROW refers to the section of roadside vegetation inside of the fence adjacent to westbound traffic lanes.
- **Median** – this is the vegetated area between east- and westbound traffic lanes.
- **Eastbound Lanes** – corresponds to *ascending* mileposts along interstate alignment.
- **Westbound Lanes** – corresponds to *descending* mileposts along interstate alignment.

General methods are summarized below. In some cases more detailed methods are provided in Appendix A.

Methodology

Study Area

Project research was conducted in southern Idaho and draws upon locations of more than 1300 road-killed barn owls recorded between 2004 and 2015. Between October 2013 and May 2015, the research team completed road kill surveys along a 365-km (226 mi) stretch of I-84/86 running east-west between Boise (Ada County, 43°37'N, 116°12'W) and Pocatello, Idaho (Bannock County, 42°52'N, 112°26'W). Surveys completed prior to October 2013 were along I-84 and primarily between Boise and Burley, Idaho (Cassia County, 42°32'N, 113°47'W). These portions of I-84/86 are in ITD's Districts 3, 4 and 5 (Figure 6).

I-84/86 is a major interstate highway with multiple lanes in each direction and with a median separating the eastbound and westbound lanes in most locations. Median width varies from 13 to 100 m (43 to 328 ft), and the eastbound and westbound ROW range from approximately 7 to 82 m (23 to 269 ft) wide. Elevation along I-84/86 ranges from approximately 800 m (2600 ft) near Glenns Ferry, Idaho to 1,365 m (4500 ft) near Pocatello, Idaho. The speed limit was 121 km/h (75 mi/h) for cars and 105 km/h (65 mi/h) for trucks throughout much of the period of the study but was raised to 129 km/h (80 mi/h) and 113 km/h (70 mi/h), respectively in July 2014.

The study area in southern Idaho is characterized by shrub steppe, disturbed grasslands, and agricultural lands. The Snake River Canyon, which is among the widest and deepest canyons in the United States, runs in proximity to the I-84/86 corridor at times and provides ample nest and roost sites for barn owls,

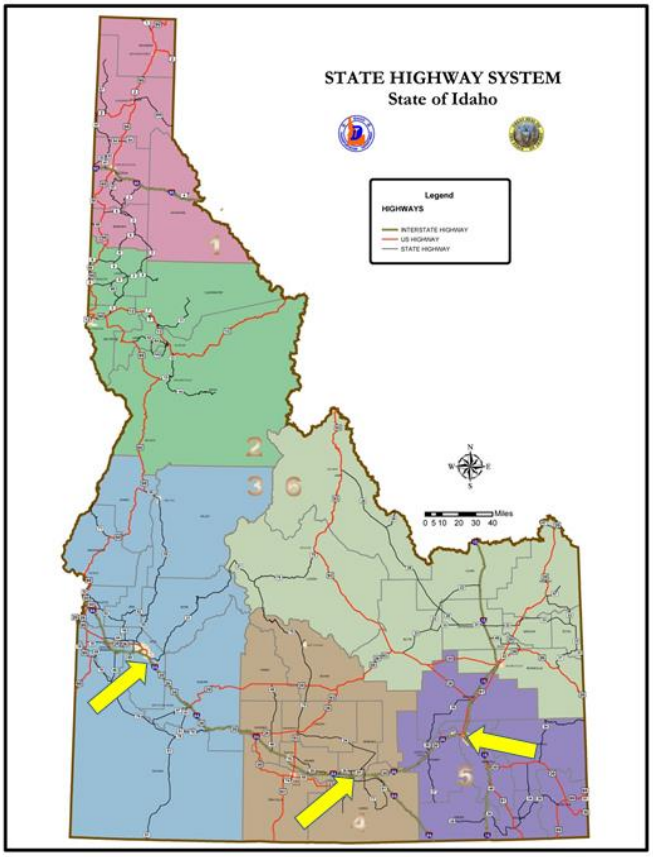


Figure 6. Map of I-84/86 in southern Idaho within ITD Districts 3, 4, and 5

From East to West, Arrows Show Locations of Boise, Burley, and Pocatello

in addition to those that occur in trees and human structures. Boves and Belthoff provide a detailed description of the focal highway and study area.[1]

Road Kill Surveys

The research team performed *standardized* road surveys to locate dead barn owls along I-84/86 twice per month (roughly every two weeks) for 12 months (October 2013 to September 2014) between Boise and Pocatello, Idaho. Additional a*d hoc* surveys occurred in March and April 2014, February 2015, and May 2015. Standardized surveys and ad hoc surveys were identical except that standardized surveys occurred consecutively at regular intervals. Researchers ultimately combined observations from these surveys with previously collected datasets (Boves and Belthoff[1], and unpubl. data) from between Boise and Burley, Idaho, which together summed to 73 road surveys. These surveys provided locations of 1,335 dead barn owls for analysis.

Driving surveys for road-killed barn owls occurred during daylight hours and started in Boise between 0700 and 0800 h. The time to complete a survey depended on the number of owl carcasses detected and processed, but surveys typically ended between 1800 and 2000 h. The team conducted road kill surveys from a full-size pickup truck while traveling at ~88 km/h (55 mph). Two observers (including the driver) scanned the roadsides for dead barn owls and recorded carcass locations using a handheld GPS. They stopped at the locations of all barn owl carcasses and removed them from the roadway to avoid double-counting in subsequent surveys. These surveys helped meet objective #1 “Identify locations of barn owl-vehicle collisions along I-84 and I-86.”

Small Mammal Abundance Survey

Barn owls inhabit open areas where they prey primarily on small rodents, and vegetation along roads likely provides habitat for owl prey. However, little is known about how small mammals occur along interstate highways in Idaho, so the research team sought to estimate small mammal abundance along focal portions of I-84 to help determine if owls were being killed in areas with the greatest prey. These methods were most appropriate for detecting rodents, which comprise the main portion of barn owl diet. Using a combination of camera and track traps[11-22] (Figures 7, 8, 9), the research team quantified small mammal abundance at 120 randomly selected sites along a 289-km (180 mi) section of I-84 between Boise and Burley, Idaho (Figure 10). This section fell within the limits of the barn owl road

Figure 7. Photo of Trail Camera Positioned on a Track Trap to Determine Small Mammal Abundance

mortality survey**.** Between December 2013 and July 2014 there were 18 trap nights (6 traps for 3 nights) at each of the 120 trapping sites including in the EB and WB ROW and median at each site. Appendix A contains further methodological details related to small mammal trapping.

Figure 8. Photograph of Track Trap Showing Footprints Used to Determine Small Mammal Presence

Figure 9. Photo from a Camera Trap Showing Presence of Deer Mice (*Peromyscus maniculatus*)

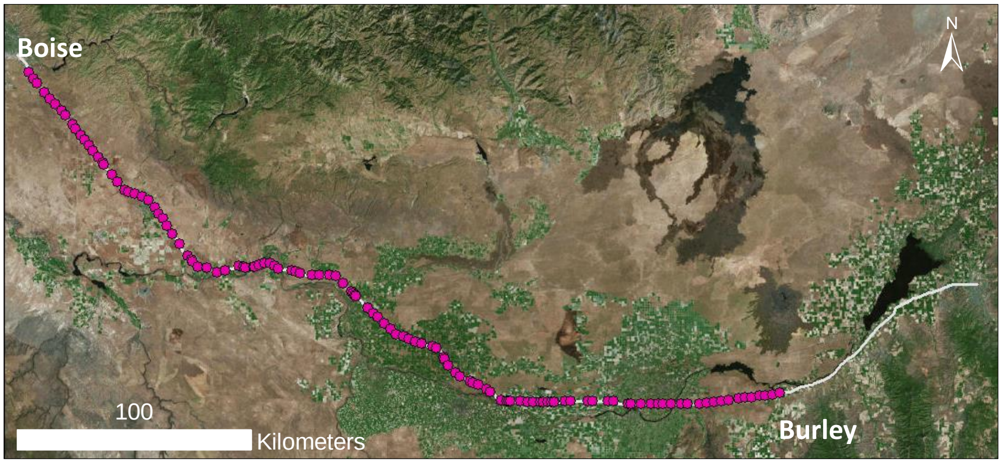


Figure 10. Small Mammal Trapping Locations (n = 120) along I-84 between Boise and Burley, Idaho

Small Mammal Abundance Index and Barn Owl Mortality

Researchers were able to decipher species of rodent from both camera and track traps. However, the traps did not allow for identification of individuals, which requires methods such as capture/handling/marking. Thus, the team could not employ capture-recapture (CR) methods to determine the relative abundance of small mammals among sites. Instead, the survey produced occupancy data from which a ***small mammal abundance index*** was calculated. Researchers calculated the index by scoring the number of traps that captured any small mammal species over the three nights of trapping. The index ranged from 0, when there were no small mammals at any trap, to 6 when all six traps at a trapping location had signs. The small mammal abundance index ultimately was one of the biotic factors examined in relation to barn owl mortality locations. The findings also provide a summary of plant cover type factors related to variation in small mammal abundance among the sampling sites.

Quantification of Spatial, Road Geometric, and Biotic Factors

In addition to determining small mammal abundance index at each of the 120 trapping locations, the research team quantified a suite of spatial, road geometric and other biotic variables (Table 3) at each using a combination of manual measurements, existing data provided by ITD and other agencies, and information from land cover databases. Team members used ArcMap 10.2 (ESRI 2014) to help characterize these features. Scale-dependent variables were also assessed at three different scales that corresponded to highway segment lengths of 1, 3, and 5 km (0.6, 1.8 and 3 mi): 1-km (area = 100 ha/247 acres), 3-km (area = 900 ha/2224 acres), and 5-km (area = 2,500 ha/6177 acres) segments centered on the 120 small mammal trapping sites. These scales reflect the typical foraging trip of a barn owl (1 km/0.6 mi) and the approximate maximum nightly movements of barn owls (5 km/3 mi).[23] Ultimately, the research team determined the best scale for each variable by assessing its individual relationship with barn owl mortality. Appendix A contains detailed methods concerning quantification of the spatial, road geometric, and biotic factors at sampling sites along I-84/86.

Table 3. Spatial, Road Geometric, and Biotic Variables Measured along I-84/86

Variable	Description	Units
Spatial		
Elevation	Average calculated by measuring elevation every 100-m within buffer	m
Distance to Nearest Agricultural Field (min, avg, center)	Average and minimum distance to nearest agricultural field calculated by measuring every 100-m within buffer; Center measured from center of buffer	km
Distance to Snake River Canyon (min, avg, center)	Average and minimum distance to Snake River Canyon calculated by measuring every 100-m within buffer; Center measured from center of buffer	km
Distance to Nearest Bridge/Overpass (min, avg, center)	Average and minimum distance to nearest bridge or overpass calculated by measuring every 100-m within buffer; Center measured from center of buffer	km
Distance to Nearest Water Feature (min, avg, center)	Average and minimum distance to nearest water feature (stream, river, canal, lake, reservoir, or other water feature) calculated by measuring every 100-m within buffer; Center measured from center of buffer	km
Distance to Nearest Dairy (min, avg, center)	Average and minimum distance to nearest commercial dairy calculated by measuring every 100-m within buffer; Center measured from center of buffer	km
Number of Dairies	Number of dairies within buffer	#
Cumulative Length of Water Features	Cumulative length of water features within buffer	km
Cumulative Length of Roads other than I-84	Cumulative length of roads within buffer	km
Road Geometric		
Embankment/Excavation	Road surface relative to surrounding landscape scored: -2 (excavated > 5 m), -1 (excavated 1 - 4 m), 0 (level), 1 (embanked 1 - 4m), 2 (embanked > 5 m), measured every 100-m within buffer and averaged	Index
Homogeneity of Slope	Standard deviation of slope calculated from a Digital Elevation Model (DEM) in GIS	%
Cumulative Length of Obstructions	Start/End of obstructions (trees, structures, excavated portions of highway, others to potentially block low flight of owls, ≥ 5 m tall and within 30 m of highway); cumulative length within buffer and summed for EB/WB/Median	km
Cumulative Length of Power Lines	Start/End of power lines; cumulative length within buffer and summed for EB/WB/Median	km
Pavement Type	Extracted from ITD GIS layer; Flexible, Rigid	Nominal
AADT	Average Annual Daily Traffic extracted from ITD GIS layer	No.
CAADT	Commercial Average Annual Daily Traffic extracted from ITD GIS layer	#

Variable	Description	Units
PAADT	Passenger Average Annual Daily Traffic extracted from ITD GIS layer	#
Traffic Lanes EB/WB	Extracted from ITD GIS layer	#
Total Number of Traffic Lanes	Extracted from ITD GIS layer	#
Traffic Speed	Extracted from ITD GIS layer	km/h
Width of EB/WB ROW	Average calculated by measuring every 100-m within buffer	m
Width of Median	Measured at center of buffer	m
Pavement Condition	Extracted from ITD GIS layer; Good, Fair, or Poor calculated by measuring every 100-m within buffer	Nominal
Shoulder Type EB/WB	Extracted from ITD GIS layer; Surfaced with bituminous material, Surfaced with tied PCC, Surfaced with PCC measuring every 100-m within buffer	Nominal
Left/Right Unpaved Shoulder Width EB/WB	Extracted from ITD GIS layer measuring every 100-m within buffer	m
Left/Right Paved Shoulder Width EB/WB	Extracted from ITD GIS layer measuring every 100-m within buffer	m
Total Lane Width EB/WB	Extracted from ITD GIS layer measuring every 100-m within buffer	m
Total Road Width EB/WB	Extracted from ITD GIS layer measuring every 100-m within buffer	m
Biotic		
Small Mammal Abundance Index	Calculated from camera and track trapping at 120 locations	Index
Habitat in the EB/WB ROW	Mode calculated from measurements every 100-m within buffer; Grass (G), Mixed (M), Shrub (S)	Nominal
Habitat in the Median	Mode calculated from measurements every 100-m within buffer; Grass (G), Mixed (M), Shrub (S)	Nominal
Habitat Change Past Fence EB/WB ROW	Percentage of 'Yes' values calculated from measurements every 100-m within buffer (see text)	%
Percentage of Crop	Percentage of crop within buffer calculated from National Land Cover Database (NLCD2011)	%
Percentage of Shrub	Percentage of shrub within buffer calculated from National Land Cover Database (NLCD2011)	%
Percentage of Human Structures	Percentage of human structures within buffer; Manually digitized using GIS	%
Percentage of Developed	Total percentage of development within buffer calculated from National Land Cover Database (NLCD2011)	%
Percentage of Open Water	Percentage of open water within buffer calculated from National Land Cover Database (NLCD2011)	%

Statistical Analysis

After assessing variables for redundancy, multicollinearity, best scale, and model parsimony, the research team ultimately produced a final variable set for analysis that included 14 variables. These included 4 spatial, 5 road geometric, and 5 biotic variables. Researchers assessed all possible combinations of variables using Poisson Regression within an Akaike Information Criterion $(AIC)_c$ information theoretic model selection framework [24] to determine top competing models for explaining the relationship between number of dead barn owls in 1-km (0.6 mi) segments centered on small mammal trapping locations and the spatial, geometric, and biotic features using the statistical software JMP 12.0 (SAS Institute, Cary, North Carolina) and R (R Core Team 2013).

Road Kill Hotspots

The research team had locations of road-killed barn owls along I-84 collected during previous studies (2004 to 2006)[1], and from road kill surveys for barn owls conducted during the current study (2013 to 2015). As a result, the research team was interested in examining if and how areas of peak mortality (i.e., hotspots) had changed over time. Using a density gradient analysis, Boves and Belthoff reported three hotspots each 3 to 4 km (1.8 to 2.5 mi) in length near the towns of Hagerman, Kimberly, and Hazelton, Idaho.[1] The research team used a similar approach for analysis of data collected during the 2013 to 2015 period and compared areas of peak mortality to determine changes between time periods. They also combined data from all survey time periods to produce maps of long-term mortality hotspots.

Citizen Science Component

To help collect data on roadways that extended beyond the focal route and to potentially expand the reach of the standardized surveys to secondary roads in southern Idaho that are under ITD's jurisdiction, the research team recruited qualified citizen scientists (e.g., members of Master Naturalist programs, Audubon Society affiliates) from southern Idaho. These volunteers were briefly trained by project personnel to identify barn owl carcasses. Each volunteer (or volunteer team) committed to driving one or more routes at least four times within a year (spring 2014 to spring 2015). For safety reasons, volunteers were instructed to never stop on the highway or inspect a carcass unless accompanied by project personnel with the appropriate authorization to stop their vehicle and handle owl carcasses.

For each survey, volunteers recorded their route, date, and search time in an Excel spreadsheet provided by the project team, and volunteers sent their data to the project team as soon as possible after completing their surveys. Volunteers also recorded the location of each barn owl carcass they detected, entered their findings into the Idaho Department of Fish and Game Roadkill and Salvage website (https://fishandgame.idaho.gov/species/roadkill), and sent the carcass data to the research team.

Mitigation Options

The researchers performed a literature search related to mitigation for roadway mortality of barn owls and summarized literature examples. They also assessed the feasibility of mitigation in southern Idaho and along I-84/86 to make recommendations to ITD.

Organization of Report

In the text that follows, the research team:

- Provides a literature review about barn owl life history and roadway mortality in the United States, Europe, and elsewhere (Chapter 2).
- Summarizes what is currently known about barn owl roadway mortality in Idaho (Chapter 3).
- Describes results of 2013 to 2015 road kill surveys and compares mortality hotspots for barn owls between the current and previous studies to determine if areas of concern have remained constant (Chapter 4).
- Describes findings of research on abundance and distribution of small mammals (barn owl prey) along I-84 (Chapter 5).
- Examines spatial, road geometric, and biotic factors related to barn owl-vehicle collisions along I-84/86 (Chapter 6).
- Based on work by citizen scientists, describes observations of barn owl mortality along major roads in southern Idaho outside of the focal I-84/86 highway corridor (Chapter 7).
- Reviews literature about mitigation approaches related to reducing barn owl mortality along roads (Chapter 8).
- Makes recommendations for mitigation along I-84 and further research (Chapter 9).

Appendices A through D contain detailed descriptions of methods, results of an online survey of state Departments of Transportation referencing the potential for barn owl-vehicle collisions throughout the United States, characteristics of 120 sites used to model barn owl mortality sites, and a copy of training materials and instructions for citizen scientists, respectively.

Chapter 2
Literature Review

Overview and Synopsis

Barn owls are killed by vehicles along roads in Europe, North America, and elsewhere. The rate at which they are killed is at times described as remarkable and alarming. This is of concern because barn owl populations have declined in portions of their range such that regulatory agencies consider them a species of concern, threatened, or endangered in some states, provinces, and countries.

Below is a brief summary of important points about barn owl-vehicle collisions gleaned from published literature from North America, Europe, and elsewhere. A detailed literature review follows this synopsis.

- Barn owl roadway mortality is reported from the U.S., Canada, and numerous countries in Europe.
- Traffic-caused deaths of owls have increased over time concomitant with increased development of road networks.
- Peaks in mortality often occur in autumn and winter, but vehicular traffic kills barn owls along roads throughout the year.
- Immature birds and females are sometimes more numerous victims than adults and males.
- Although barn owls are killed along many types of roads, they are more likely to be seen alive than dead along secondary roads but more likely to be observed dead along major roads.
- Barn owls disappear from previously occupied areas after new roads are constructed.
- Based on previous studies, general attributes of roads associated with barn owl mortality include:
    - Wide ROW that contain open habitat without tall shrubs.
    - ROW that provide suitable habitat for rodents.
    - Stream crossings and other linear features.
    - Level with surrounding landscapes or especially embanked roads.
- On-the-ground mitigation for barn owl-vehicle collisions has been much less common than the number of studies that suggest owl mortality from collisions is an issue of concern.
- Mitigation approaches discussed in the literature have centered on:
    - Establishing tall vegetation near roads to force owls to fly higher.
    - Reducing suitable habitat for rodents along roads.
    - Reducing “huntability” of roadsides for barn owls by promoting taller or less suitable vegetation cover types.
    - Establishing (or restoring) suitable owl habitat away from highways.

Barn Owl Life History

Marti et al. and numerous other authors have extensively reviewed barn owl life history and population dynamics. This section offers a brief summary of key features of the natural history of barn owls as referenced in Marti et al.[23]

Barn owls occur throughout much of the United States (Figure 11) where they occupy a wide variety of open habitats in both urban and rural settings. They inhabit farmlands, grasslands, prairies, and deserts and fly slowly at night or dusk with slow wing beats and a looping, buoyant flight. Barn owls nest in a

Figure 11. Map of Barn Owl Distribution in North and South America

(from Cornell Lab of Ornithology)

wide variety of cavities including in trees, cliffs, caves, riverbanks, church steeples, barn lofts, haystacks, and nest boxes. They breed in their first year of life and are usually monogamous. Barn owls can breed year-round in lower latitudes, but in higher latitudes a single clutch in spring is typical. Eggs are laid in early to mid-March depending on latitude; clutch size ranges up to about 10 although typically averages near six; young fledge after spending 8 to 10 weeks in the nest; and both parents feed young until the latter are independent. Fledglings normally remain dependent upon the adults for three to five weeks after attaining the ability to fly, which is followed by dispersal by young in late summer and early autumn. Young of the year usually settle into ultimate breeding areas by winter. Life expectancy is on the order of two to four years, but high first-year mortality characterizes barn owls. Mean age at death of 572 barn owls banded across North America and reported to the Bird Banding Laboratory (U.S. Geological Survey) was 20.9 months.[23]

Barn owls typically prey on small mammals, including voles (*Microtus* spp.), mice (*Peromyscus* spp., and others), pocket mice, rats, moles and shrews. Bats, leporids, birds, reptiles, amphibians, and arthropods are taken but usually in much smaller numbers compared to rodents. Barn owls typically hunt at night and usually with low flights at 1.5 to 4.5 m (5 to 15 ft) above the ground, although they occasionally hunt from perches or hover above prey before pouncing. They detect prey with excellent low-light vision and hearing; indeed the ability of barn owls to locate prey by sound is cited as the most accurate of any animal tested, which allows capture of prey hidden by vegetation or snow. The owls generally swallow prey whole, and fur, feathers, and bones that the owls cannot digest are cast as pellets; the number of castings per individual is typically about two per day. Analysis of pellets to determine barn owl diet is common, and researchers have used this approach to examine the diet of barn owls throughout the cosmopolitan distribution of barn owls.

Barn owls are medium-sized owls with a heart-shaped face, no ear tufts, and dark eyes (Figure 12). They are sexually dimorphic in size with females typically larger than males. The owls are 32 to 40 cm in length, have a wingspan of 100 to 125 cm (40 to 50 in), and weigh approximately 400 to 700 g (14 to

Figure 12. Barn Owl Nestlings within Nest Box near I-84 in southern Idaho

24oz). Female plumage is richer in color and more spotted than that of males. Adults typically only defend the area immediately around their nest; thus, two or more barn owl pairs may nest near one another and forage in similar areas. Although they will occasionally change nest sites, individuals often nest in the same location as long as they live. Barn owls are generally non-migratory, but juveniles can disperse long distances, sometimes on the order of thousands of kilometers. Dispersal distances for individuals banded as nestlings in Utah[23] ranged from 1 to 1,267 km (mean = 102.9 ± 162.0 (SD) km/63 ± 100 mi); females banded as nestlings bred at distances 61.4 ± 52.0 km (38 ± 52 mi) from their natal site, which was significantly farther than males (35.7 ± 36.6 km/22 ± 22 mi). Thus, dispersal in barn owls is similar to that of many avian species in that it is female-biased. Based on radio-tracking studies, home range size is roughly 300 to 750 ha (741 to 1853 acres), and individuals can make foraging movements up to 5 km (3 mi), although the distance is usually much shorter (<1 to 2 km/0.6 to 1.2 mi).

Barn owls are not well adapted to cold climates and require roosts in sheltered places that provide thermal protection during cold weather. Severe winter weather (e.g., low temperatures and increased snow cover) kills barn owls in both the northern U.S. and Europe and may significantly reduce population size. The cold makes increased food intake essential while deep snow makes prey capture difficult or impossible. Voles, the primary prey of many northern barn owl populations, tunnel under snow and are thus protected from predation when the ground is snow covered.

Taxonomy

Although authorities differ on the number and distinctions for classification of subspecies, *Tyto alba pratincola* is often recognized as the North American subspecies of barn owl, whereas Europe has two subspecies: *Tyto alba alba and Tyto alba guttata*. Recently, distance-based DNA barcoding of mitochondrial *cox1* gene sequences suggested sufficient sequence variation to conclude that new world and old world barn owls are separate species.[25] Previous work by others had a similar conclusion. While not yet adopted by the naming bodies of the International Ornithologists' Union (IOC: http://www.worldbirdnames.org/) or the American Ornithologists' Union (AOU: http://checklist.aou.org/), some authors already use the proposed taxonomy of *Tyto furcata* for new world barn owls and *Tyto alba* for old world barn owls.[26]

Conservation Status of Barn Owls in United States and Canada

In the United States and its territories, barn owls are federally protected by the Migratory Bird Treaty Act (50 CFR 10.13). This law prohibits the hunting, taking, capturing or killing of most species of non-game birds. At least six states (Connecticut, Illinois, Indiana, Iowa, Michigan, and Ohio) currently list barn owls as threatened or endangered. Numerous others consider barn owls as a species of special concern or of similar special designation.

Idaho

The Idaho Department of Fish and Game (IDFG) does not list barn owls among the species of greatest conservation need in their upcoming 2015 State Wildlife Action Plan (under preparation, R. Dixon, IDFG, pers. comm.). However, IDFG will likely assign a statewide conservation status of S4 (*Apparently secure: uncommon but not rare; some cause for long-term concern due to declines or other factors*), which would represent an elevation from the previous status of S5 (*Secure: common, widespread, and abundant*).

Canada

In Canada, the distribution of barn owls is generally restricted to southwestern British Columbia and southern Ontario. Because of threats to its habitat, a likely population decline, and the species' small population size, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assessed the eastern population as **Endangered** and recently revised the status of the western population from Special Concern to **Threatened**.[27] Elsewhere in Canada, barn owls are vagrant or accidental in the Maritime Provinces; barn owls are not known to have bred successfully in Manitoba, although there are occasional observations; and barn owls occur accidentally in Alberta and Saskatchewan where two and 11 records, respectively, are apparently known.[27]

Barn Owls and Roads

Roads have direct and indirect effects on wildlife, including barn owls. This section summarizes some existing literature about road effects related to barn owls.

Roads Affect Barn Owl Persistence and Reproductive Success

Hindmarch et al. examined how changes to landscape attributes influenced persistence and current occupancy of barn owls at roosting and nesting sites.[28] The Fraser Valley of British Columbia, Canada experienced considerable agricultural development between the early 1990s and 2008. Over this span, grasslands decreased by 53 percent, urban areas increased by 133 percent, length of secondary roads increased by 18 percent, and the volume of highway traffic increased by 33 percent.[28] More than 30 percent of the sites barn owls occupied in the early 1990s were not occupied in 2007 to 2008. The main variables that predicted continued use and current occupancy were traffic exposure and length of highways. Barn owls were most likely to persist at sites with smaller increases in traffic exposure, and currently occupied sites contained fewer kilometers of highway within a 1-km (0.6 mi) radius than unoccupied sites. Barn owls are less likely to persist in areas with high traffic exposure and less likely to occupy sites close to highways.[28]

Martin et al. examined how barn owl reproductive success in the Everglades Agricultural Area of Florida related to sugarcane agricultural practices.[29] These owls initiated nests before the onset of harvest, but most fields adjacent to nest boxes were harvested at some point during owl nesting attempts. Nest survivorship, as well as survivorship of individual nestlings within broods, was lower after harvest. Declines were likely the result of associated declines in the abundance of rodents, i.e., the primary food source of barn owls.[29] Nestlings in nests surrounded by harvested fields were generally lighter before fledging than young in nests surrounded by standing sugarcane and the latter’s associated dense rodent populations. Of particular note is that Martin et al. mentioned that vehicle strikes are a significant source of barn owl mortality based on personal observation, but they provided no further data. However, because of this mortality factor, they analyzed whether the presence of at least one major road within 1.5 km (1 mi) of each nest box influenced nest survival. Roads indeed affected reproductive success, as the odds of daily nest survival when no roads were present were 1.75 times those when roads were present. The authors suggested that some nestling mortality may have been linked to mortality of their parents that occurred along roads.[29]

Traffic Noise

How traffic noise specifically affects barn owls has not been well studied. However, an increasing number and variety of studies indicate that noise, and traffic noise specifically, can directly or indirectly affect birds or degrade the quality of their habitat.[30-35, but see 36] Traffic noise also reduces effectiveness of mammalian acoustical predators.[37] As barn owls hunt by sound as well as by sight, and they depend strongly on hearing for intra-specific communication, studies of potential effects of road noise on barn owls are needed.

Road Lighting and Headlights

If and how sources of anthropogenic light affect roadway mortality of barns owls also has not been systematically studied. Some barn owls swoop towards a moving light, and this might account for a number of nocturnal casualties.[38] When barn owls confront bright lights while foraging they can become disoriented, perhaps as a result of temporary blindness.[5] Then, they often move away from the light source continuing in their path, but they will occasionally fly directly toward the light source.[5] Taylor[8] also mentioned that barn owls may be “dazzled and confused by headlights at night.” Although not demonstrated, barn owls in noisy environments may depend more on their vision to successfully hunt prey.[39] Thus, near major roads the headlights of regularly passing vehicles could contribute to reduced hunting efficiency in owls.

Direct Mortality

Perhaps the most obvious effect of roads on barn owls is direct mortality by vehicle collision (Figure 13). Vehicle collisions cause barn owl mortality in Europe, North America, and elsewhere. Indeed, vehicle-caused mortality can be the major mortality factor in barn owls as it accounts for as much as 56 to 70 percent.[8,40,41,42,43] Moreover, barn owls are frequently the most common species recorded when studies focus on multiple species of birds in road casualty studies.[1,6,9,10] Major road deaths have more impact on barn owls than any other animal in England because of the rarity of barn owls and the frequency with which they are killed.[10]

Road deaths of barn owls may be a combination of purely accidental deaths of birds moving across the countryside and deaths of birds fatally attracted to hunt within road verges (vegetated roadsides). [10] Ramsden[10] explained, “In the nesting season (March to August) in England, all adult barn owls whose nest site is within 0.5 km (0.3 mi) of a major road are almost certain to be killed, and those within 1 km (0.6 mi) are highly likely to be killed. Outside of the nesting season, adult barn owls whose main roost site is within 0.5 km (0.3 mi) of a major road are almost certain to be killed, birds within 2 to 3 km (1.2 to 1.8 mi) are highly likely to be killed, but birds beyond 5 km (3 mi) are most unlikely to be affected. During the period when young barn owls are dispersing from nest sites (August to November), roughly 40 percent of birds dispersing from within 1 km (0.6 mi) of a major road will be killed, about 20 percent of birds dispersing from 12 km (7 mi) will be killed, but birds dispersing from 25 km (15 mi) are less likely to be affected."

Figure 13. Photo of Dead Barn Owl along I-84 Illustrating Direct Mortality along Roads

Roadway Mortality of Barn Owls – Europe

Barn owl roadway mortality is known from numerous countries in Europe and has been the subject of research for decades there. Barn owls are a Schedule 1 species in the United Kingdom under the Wildlife and Countryside Act of 1981. Schedule 1 species are protected throughout the year with special penalties. Similar protection is generally afforded in other European countries. Here we summarize findings from European research on barn owl roadway mortality.

United Kingdom

Hodson and Snow reported on a survey/questionnaire administered in 1960 and 1961 to discover how many birds are killed in one year on the roads of Britain.(44) There were 76 returns of the questionnaire, and these described 5,269 birds of 80 species killed along roads. Interestingly, there were only two barn owls (0.0004 %) listed in the data, while there were 2,365 (44.9 %) house sparrows (*Passer domesticus*).

Glue reported recovery details for five British birds of prey banded in large numbers, including barn owls, and compared the relative importance of mortality factors for the 1910 to 1954 and 1955 to 1969 time periods.(45) Approximately 10 percent of 1,696 total recoveries during the period 1910 to 1969 concerned birds dead on the surface or at the side of roads, while a similar proportion of owls were found dead on railway lines or engines. The number of barn owls recovered on railways remained steady over time, but the number of road recoveries increased by more than four-fold.[45] Observers who were able to note the manner in which owls were killed at night mentioned birds that were hit while rising from road surfaces, birds flying directly into moving vehicles (shattering the windshield in one instance), and birds struck a glancing blow while flying low across the road.[45]

Percival reviewed mortality causes for barn owls from British Trust for Ornithology (BTO) banding data for the entire United Kingdom from observations that spanned 1944 to 1998.[46] One of the most interesting aspects was an increase in the proportion of traffic deaths in both first-year and adult age classes of barn owls.[46] The contribution of road mortality to the annual death rate of barn owls rose as follows: 14/27 percent (adult/juvenile) between 1944 and 1964, 33/34 percent between 1965 and 1970, 40/41 percent between 1971 and 1976, 38/40 percent between 1977 and 1982, 48/29 percent during 1983 and 1985, and 32/49 from 1986 to 1988.

Post-mortem analysis of 55 free-living barn owls submitted to the Animal Health Laboratory at the Royal College of Surgeons of England helped elucidate factors that contributed to disease, reproductive failure, or death.[47] In addition to detecting disease, parasitism, and starvation as causes of barn owl death, more than 50 percent (28 of 55) of the owls submitted for examination had traumatic injuries that appeared to be the result of traffic accidents, as in most cases the birds were found on or near a road. Injuries ranged from subcutaneous bruising and ruptured organs (usually liver) to extensive fractures and crushing of the head or body. The author discussed the implications of these results in relation to declining populations of barn owls in the United Kingdom.[47]

Shawyer collected information about causes of barn owl mortality from a wide cross-section of the public, including from farmers, landowners, and other country people who would have an equal chance of finding a dead barn owl on their farm as they would on the highway, for example.[43] He also contacted taxidermists, public officials, birdwatchers, and ornithologists. He ultimately obtained 726 records from Britain and 50 records from Ireland. Even though the information originated from a wide cross-section of individuals, by far the most significant single cause of death for barn owls was road-traffic accidents, which accounted for 52 percent of all mortality in Britain and 49 percent in Ireland.[43] Shawyer estimated that 3,000 to 5,000 barn owls are killed every year on Britain's roads, which is the equivalent of about one individual per brood. He described that whenever major roads are constructed through traditional barn owl habitat in Britain, they have a devastating effect on local populations. Owls are forced to fly over the road to maintain the old limits of their home ranges. To find sufficient food they are also tempted to hunt on the grassy roadsides which soon attract small mammal communities. "Both of these activities expose barn owls, more than any other British Bird to the hazard of fast moving traffic."[43] Thus, Shawyer found "soon after major road schemes are completed in areas where barn owls are present, mortality increases with the result that local populations are rapidly depleted and within a few years the area within about 2 km (1.2 mi) of the new road no longer supports breeding barn owls."[43]

Vehicle collisions are one source of owl mortality in Scotland.[8] Starvation was cited as the main cause of death for barn owls in Scotland, although road collisions were not uncommon. Taylor thought that collisions may have been the immediate cause of death, but he felt the ultimate cause was something else, as many road kill victims were in poor body condition.(8) He argued that such lightweight individuals may have been less able to avoid vehicles as they crossed roads while moving among foraging patches or they may have been forced “through lack of alternatives” to hunt roadsides where they were more vulnerable. Thus, Taylor felt that food shortages were important in roadway mortality such that habitat quality, natural prey abundance, and weather *ultimately* were responsible. Other studies have disagreed with Taylor as seemingly healthy birds were killed in large numbers near roads, or it is possible that different ultimate factors operate in different portions of the barn owl range.(1,10)

Based on post-mortem analysis of 1,101 barn owl carcasses submitted by the public, 477 (44.7 percent) were road casualties.(48) The proportion of deaths attributed to road traffic increased from 6 percent during 1910 to 1954 and 15 percent in 1955 to 1969, to 35 percent in 1963 to 1970 and 50 percent in 1991 to 1996.(48) Over the same period the barn owl population declined by an estimated 70 percent.(43)

In one of the most comprehensive (15 years) studies to date on barn owls and roads, Ramsden found road casualties were the most common cause of mortality of barn owls in their first year of life, and the same was true for adult barn owls.(10) Moreover, barn owl roost sites occupied prior to the opening of a new 22-km (14 mi) long dual carriageway in southern England were no longer occupied three years later; the new road was the main cause of extirpation.(10) Similarly, there were no barn owls roosting within 5 km (3 mi) of a 14-km (9 mi) section of a different motorway, whereas barn owls roosted and nested within two nearby non-motorway control areas. The presence of the motorway was responsible for the lack of barn owls.(10) Minor roads were unlikely to have a negative effect on barn owl populations, as barn owls were 57 times more likely to be reported as seen alive than found dead. In contrast, along major roads, barn owls were three times more likely to be reported as found dead than observed alive. Importantly, barn owls that reached major roads were those that survived exposure to other common hazards; thus, major roads kill barn owls that would otherwise have survived, i.e., rather than roads killing weak or inferior individuals.(10) Of 62 barn owls that encountered a major road, 72 percent were killed during the encounter. Major roads caused the complete extirpation of breeding barn owls within 0.5 to 2.5 km (0.3 to 1.5 mi) and some depletion within 2.5 to 8 km (1.5 to 5 mi). Only at distances >25 km (15 mi) from the road did barn owl populations not feel the impact of vehicular mortality.(10)

Switzerland

For traffic casualties of birds of prey recorded between 1964 and 1981 in Switzerland, there were 80 owls, of which 55 percent were barn owls.(3) The rate of barn owl mortality was ~7.0/100 km (60 mi)/year. Mortality of owls peaked in January through February perhaps because the density of voles remained high (250 to 400/ha or 250 to 400/2.5 acres) in the embankments and the median strip and roadside vegetation may have been free of snow earlier than surrounding habitat.(3) The attraction of raptors to highways was a consequence of two factors: (1) occupation by small mammals (mainly voles) of the embankments, median strip, and unmaintained zones behind the game fences, and (2) presence of a large number of artificial perches, mainly metallic game fence posts, which were used frequently by birds of prey when searching the grass for food.(3)

Germany

Road mortality appears to be a major factor in the decline of barn owl populations in Germany.[2] Of the 151 owls found dead in a 125-km^2 (48 mi^2) area between 1974 and 1986, barn owls numbered 74 (49 percent). Of these barn owls, 30 percent were dead on roads. The researcher suggested that traffic speed rather than traffic density was the major factor in traffic-caused fatalities of owls because roads with traffic speeds greater than 80 km/h (50 mi/h) had 21 times the number of owls killed as roads with traffic speeds of less than 80 km/h (50 mi/h)[2]. Mortality was estimated to 0.7 barn owls deaths/100 km (62 mi) road/year, and mortality at this rate kills an estimated 10 to 15 percent of the local population each year.[2]

Spain

Fajardo examined non-natural causes of mortality of barn owls in central Spain and compared 1990 through 1999 results with those obtained a decade earlier (1983 to 1989).[49] Road surveys were conducted by vehicle every three months at constant speed (70 km/h or 43 mi/h), and these surveys covered 26,700 km (16,590 mi) in seven years for the 1980s surveys and 38,300 km (23,800 mi) in 10 years for the 1990s. There were dead barn owls from shooting, nest robbing, electrocution, accidental trapping in buildings, trapping, collisions, starvation, and other causes. The percentage of road-killed barn owls increased from 36.5 percent to 79.5 percent of dead birds between the 1980s and 1990s. These increases were associated with concomitant reductions in the percentage of birds that were shot and from nest robbing. The reductions in shooting and nest robbing were discussed in relation to improved adherence to European Union regulations and increased funding for environmental education in Spain, whereas the increases in the percentage of road-killed owls were consistent with expansion of the road network within Spain.

Fajardo et al. also analyzed patterns of dispersal, survival and mortality of rehabilitated barn owls in Spain. Released birds included both wild birds after recovery from injuries and captive-bred/released individuals. Collisions with vehicles and starvation were the most frequently reported causes of death for 41 released birds that later died (51.2 and 26.8 percent, respectively).[50]

The Netherlands

For 18 years, de Bruijn examined the ecology, behavior and demography of barn owl populations in two adjacent areas in the eastern part of The Netherlands.[42] One of these areas (Liemers) had a higher density of main roads than the other and also contained all of the dual carriageway/motorways (i.e., major roads) present (approximately 27 km in length). Barn owls were more common victims of traffic in Liemers than Achterhoek (51 percent of mortality versus 33 percent, respectively). Liemers was a “sink” area where barn owl mortality exceeded productivity and the population declined in spite of the immigration of birds from adjacent areas.[42] An expansion of the main road network and the resulting “heavy losses” of barn owls from roadway collisions was the putative cause of decline. [42] Road traffic mortality now forms the main cause of death in Dutch barn owls. One potential reason is that roadside vegetation appears to afford suitable habitat for small rodents, and the rich prey supply entices barn owls to hunt along roads, with the result that many of them die as traffic victims.[42]

France

There were 187 dead owls along a 150 km (93 mi) of highway in northeastern France between 1990 and 1994, and barn owls (n = 148) were the most frequently killed species.[4,51] Most mortality occurred along embanked highway segments that crossed open fields and lacked hedges on either side. Two maxima in the mortality were evident: the first corresponded to immature birds in autumn, and the second corresponded to mature birds in late winter.[51] While traffic intensity did not differ seasonally, peak traffic intensity was nearest the onset of owl activity during these times. Immature birds and females were killed more frequently than adults and males, respectively. Except for mature females, which showed decreased body condition compared with live birds, barn owls killed on roads in northeastern France were in good body condition.[51] Massemin et al. concluded that mortality of barn owls on motorways in autumn and winter was probably related to "the concomitance between the peak of traffic and the onset of hunting activity and the large number and dispersal of immature birds during this period." [51]

Lode' examined road mortality of vertebrates along 68 km (42 mi) of a recently constructed section of the A83 motorway in western France. Weekly surveys for road-killed animals occurred for 7.5 months between April and November 1995. During the 33 weekly surveys, there were 2,266 road-killed animals representing 97 species (14.5 animals/100 km or 62 mi/day).[52] Road-killed animals increased as a function of traffic intensity. They were mainly mammals (43 percent) and mainly rodents, but predators (Falconiformes, Strigiformes, and Carnivora) constituted 21.7 percent of vertebrates. Barn owls were 8.1 percent of the dead animals and 30.7 percent of birds (184 of 304 of the owls found dead). Opening of a new motorway clearly resulted in immediate demographic depletion and effective population isolation; thus, any construction of a new roadway demands studies on migrations and population exchanges to preserve local populations and to minimize the impact on ecosystem equilibrium.[52]

Baudvin summarized collections of road-killed raptors that occurred between 1992 and 2001 from more than 300 km (186 mi) of a motorway in northeastern France. [53] He reported 677 diurnal raptors and 2,667 owls as road kill. Of the owls found dead along the motorway, barn owls (n = 1,731, 64.9 percent of owls and 51.8 percent of all raptors) were the most frequently collected of any species. Almost 68 percent of the dead barn owls were located near cereal fields, with 17.2 percent and 15.1 percent from forests and meadows, respectively. Most dead barn owls (63.5 percent) were from sections of the motorway that were level or higher than the surroundings compared with lower. The author considered 76 percent of the areas with dead barn owls to be rich with voles based on the biotope of "rich grass" rather than bushes or stones, which he considered poor for voles. Possible approaches to mitigation included decreasing the suitability of roadsides as habitat for rodents and establishing or improving habitat for barn owls elsewhere.[53]

Recently a capture-recapture analysis on four motorways in France to evaluate factors affecting persistence of bird carcasses (Passeriformes and Strigiformes) found that surveys by automobile were as efficient as surveys on foot in detecting carcasses on the pavement, but less efficient for carcasses on the verge.[54] Persistence probability was higher for large (owls) and old (i.e., those without eyes or plumage brightness) carcasses. Importantly, barn owls were the most frequently encountered dead bird along these roadways (n = 63 dead individuals), whereas European robins (*Erithacus rubecula*, n = 52 carcasses) were the most common passerine.[54]

Portugal

Gomes et al. surveyed 311 km (193 mi) of road in southern Portugal over a two-year period to record the occurrence of dead barn owls, tawny owls (*Strix aluco*), and little owls (*Athene noctua*) and compared different approaches for identifying mortality hotspots.[6] They located 539 vehicle-killed owls, of which 52 percent were barn owls. The mortality index for barn owls was 0.49 fatalities/km (0.6 mi)/year. There was significant spatial autocorrelation in the distribution of fatalities for all three species of owl, which means that fatalities occurred in clusters rather than being randomly distributed along the road. Three especially dense hotspots were identified for barn owls. The proportion of pine tree habitat and of urban area were negatively associated with the occurrence of barn owl fatalities while presence of permanent water bodies (i.e., ponds and reservoirs) near the road was significantly associated with fatalities.[6] Variables describing high road-kill segments that were most different from mean road conditions were mean altitude, the presence of fences, and the proportion of shrub and pine tree habitats. The authors discussed the possibility that because barn owls hunt using low level flights, presence of any structure near the road that could prevent low-altitude continuous flight may reduce the frequency of road kill events. This may explain why the presence of fences was associated with lower fatalities in their models.[6]

Canary Islands

Barn owls comprised 181 of the 2,611 birds of prey admitted to a wildlife rehabilitation center in Tenerife, Canary Islands between 1998 and 2007.[55] Of these, *collision* (vehicle collision, tower collision, and other collisions) accounted for 113 (62.4 percent) cases. Barn owl admissions occurred steadily throughout all months of the year, whereas admissions of other raptors were concentrated in the species' fledging periods. Collision also was the primary cause of admission to the center, representing 42.2 percent of total admissions.[55] Thus, barn owls are susceptible to road mortality even on an island where almost 50 percent of the land is under local nature protection laws.

North America

Roadway mortality of barn owls is less well studied in North America than in Europe but is documented in a variety of published research notes and studies.

Utah

Smith et al. studied a colony of nesting barn owls in an abandoned steel mill in central Utah and observed 11 nesting attempts.[56] Three owls from this colony, one adult male and two newly fledged juveniles, were found dead on nearby highways. The adult died 0.9 miles (1.4 km) from its roosting site. The juveniles, both of which had been banded in June 1969, were found in August and September 1969 alongside an interstate highway 3.6 miles (5.8 km) northwest of the colony.[56]

There were 98 dead barn owls found during the particularly severe winter of 1981 to 1982.[57] While mean winter temperatures were only a few degrees lower than normal, there was a severe two-week period during which the mean daily temperature was -9.7°C (14°F). At the same time, snow cover was 20 to 25 cm (8 to 10 in) deep, which presumably interfered with the owls' ability to capture their most important prey (*Microtus* spp.). A large proportion of the dead owls (77 of 98, 78.6 percent) had empty stomachs and low body weight so apparently died from starvation. The remaining 21 dead owls were found as road kill, and their body mass was much greater than the starved birds.[57] Moreover, there was a 40 percent decline in breeding attempts in the season after the major die-off associated with auto and weather-related mortality in northern Utah.

New Jersey

A 10-year study in southern New Jersey examined road-killed raptors every weekday (November to April) from 1980 to 1990 along a 145-km (90 mi) route between the North Cape May Ferry Terminal and Atlantic City in southern New Jersey.[58] The route included two county roads, a state road, the Garden State Parkway, and the Atlantic City Expressway. There were 250 road-killed raptors representing six owl and six hawk species.[58] Owls predominated (88 % of all raptors) with northern saw-whet owls (*Aegolius acadicus*) and eastern screech-owls (*Megascops asio*) being most numerous. A single barn owl was among the dead raptors recorded. The authors concluded that southern New Jersey, especially the southern Cape May peninsula, hosts a large number of wintering and migrating saw-whet owls and resident screech-owls, and collisions with automobiles kill a significant number.[58] They do not mention local population size of barn owls, so it is not clear if the lower number of dead barn owls is because barn owls are rare or for some other reason.

Hawaii

Barn owls were introduced from California into Hawaii in 1958 for rodent control, and they now occupy the six main Hawaiian Islands. Despite that they are not native, barn owls suffer road mortality in Hawaii much as they do in native portions of their range. Of 81 barn owls evaluated for cause of death between 1992 and 1994, the most common cause (50 percent) was trauma apparently by vehicular collisions.[59] Others reported similar findings of dead owls caused by vehicle collisions in Hawaii.[60,61]

Kansas

Rivers described a 61-mile (98.2 km) trip between Meade and Greensburg, Kansas along U.S. Highway 54 during which time he encountered 9 dead barn owls, which was an average of 1 individual every 6.8 miles (10.9 km).[62] Several raptor species, including red-tailed hawks (*Buteo jamaicensis*) and northern harriers (*Circus cyaneus*), were encountered often along the same stretch of highway, yet there were no road-killed individuals of those species. Rivers[62] surmised that most road mortality probably occurred at night when the barn owls were active.

California

Robertson recorded number and species of dead birds along a 31-mile (49.9 km) rural mail route (9 miles [14.5 km] along pavement and the rest on oiled dirt roads) that he traveled in in Orange County, California 287 times from November 1927 to October 1928.[63] A small number of barn owls (n = 3) was among the 136 individuals of 27 species recorded as road kill.

Collisions with moving vehicles along roads and freeways are the major cause of death in barn owls in California.[5] Shulz reported that 64 percent of 25 leg-banded barn owls later recovered died as a result of vehicle collision. Moreover, he documented 912 barn owls killed from collisions along highways in the central valley of California between 1980 and 1985. The author surveyed 24,542 miles (39,500 km) of highway roads during this span and found 0.27 dead barn owls/mile/year (0.43/km/year). There were more dead barn owls during peak agricultural activity (harvest and plowing) and on stretches of highways with roadside vegetation in the center divider as well as off the road's shoulder in the ROW. The author noted that high roadway mortality in barn owls in California is likely a function of the owl's behavior and the high rodent densities in roadside vegetation.[5]

Moore and Mangel conducted weekly roadkill surveys along 236 km (147 mi) of Interstate 5 and Highway 113 near Sacramento, California from May to November 1995.[9] Prior to the start of systematic surveys, the authors removed 50 dead barn owls from these road segments. They recorded 283 individuals of 13 species. Barn owls (n = 227) outnumbered all other species and represented 80.2 percent of the total dead birds detected. The estimated mortality rate was 185.6 owls/100 km (62 mi)/year. For barn owls, the sex ratio of dead birds was skewed toward females (74 percent of collected barn owls) and young of the year (61 percent). Moore and Mangel[9] discussed the smaller size of males potentially may assist them in avoiding traffic collisions or that there may be more females in the local population related to female-biased dispersal into the study population which inhabits ideal habitat. The abundance of young birds among the dead also may have reflected age structure in the population or indicated that young are more susceptible to collisions. Barn owl carcasses were over-represented in pasture/open habitats, which the authors suggested indicates increased presence of barn owls in pasture/open lands compared to rotated crop land. The highest proportion of owl carcasses occurred in areas where there was an abundance of riparian habitat in proximity to the pasture/open habitats.

Idaho

Boves and Belthoff surveyed a 248-km (154 mi) stretch of Interstate highway (I-84) in southern Idaho using systematic searches every two weeks over a two-year period between July 2004 and June 2006.[1] As their results are directly relevant to the current research, we summarize them separately in Chapter 3.

Other States Based on Online Survey Results

Based on an online survey that the research team administered to state DOTs in October 2013 (Appendix B), respondents reported that barn owls are also killed along roads in Arizona, California, Florida, Georgia, Illinois, Indiana, Iowa, Nevada, Ohio, Oklahoma, Oregon, Utah, and Washington, although the published literature does not include descriptions of reports in most of these states. In addition, this list is not comprehensive as only about one-half of all states participated in the survey (Appendix B).

Canada

In 1987 and between 1995 and 2005, there were surveys of road-killed owls of 10 different species along highways and secondary roads in the lower mainland and Central Fraser Valley of British Columbia.(64) The two most common road-killed species were barn owls (n = 542, 56.9 percent) and northern saw-whet owls (n = 278, 29.2 percent). Mortality of both species was generally greatest in winter months, although sampling effort was somewhat lower between May and September. As populations of barn owls in British Columbia are in decline, the large numbers of dead barn owls on the road were described as remarkable and alarming.(64) More owls were killed in areas with agriculture and old barns than when the surrounding habitat was largely dominated by woodlands, riparian areas, and forested slopes.

Although annual avian road kill is estimated to be in the millions in the United States, Europe, and the United Kingdom, no rate estimates existed for Canada. Thus, values for avian mortality derived from North American studies were used to estimate annual mortality for Canadian road networks.(65) Because owls are particularly susceptible to collisions with vehicles, researchers used rates of collisions, scavenger bias, and search bias(1,9) to estimate the number of road-killed barn owls in this species' last remaining range within Canada. This is of particular relevance as barn owls are on the IUCN red list and are federally listed as threatened in Canada (Committee on the Status of Endangered Wildlife in Canada 2010, International Union for the Conservation of Nature 2012). In sum, seven Canadian studies found 2,834 individuals dead on roads, representing 80 species and 14 orders of birds.(65) The unadjusted number of barn owls killed annually on four-lane roads during the breeding and fledging season within the range of barn owls in southern British Columbia was estimated at 244 and, when adjusted for scavenging and observer bias, the estimate increased to 851.(65) In southern British Columbia, the population size for barn owls is estimated to be only 250 to 1,000 breeding pairs (Committee on the Status of Endangered Wildlife in Canada 2010). Thus, loss of as few as 244 (unadjusted estimate) to as many as 851 (adjusted) barn owls per year from vehicle collisions is a substantial threat to persistence of the British Columbia barn owl population.(65)

Behavior of Barn Owls near Roads

Shawyer described barn owl behavior near roads as follows: "With their low-level hunting barn owls inevitably fall victim [to road mortality]. High-sided lorries (trucks) present a particular problem to owls flying along verges because they are sucked into the slipstream almost as easily as a sheet of tissue paper and are often killed or injured by a following vehicle. Collisions also occur, again most often with high lorries as barn owls are flying across roads usually where there is a low gate or gap in the hedge."(43) Post-mortem investigations by a veterinarian showed that most barn owl road casualties suffered right wing fractures, indicating that most collisions are the result of owls emerging suddenly into the path of traffic from the nearside verge and that birds emerging from the offside verge were usually able to avoid the hazard by rising above the traffic. "Barn owls are not only killed while hunting but are killed while apparently sitting motionless in the road."[43] Shawyer believed the latter situations arise when "birds may have been stunned from a previous but non-fatal collision or were attempting to 'still-hunt' using the open road to catch small mammals moving across the tarmac."[43]

Radio-tagged barn owls in Scotland had long stretches of roadside grass along quiet minor roads immediately adjacent to their nest sites.[8] Usually only a strip of a meter (3 ft) or so wide was cut short; otherwise the remaining areas of the wide vegetated roadsides were long vegetation with high densities of rodents. Despite these areas of rich prey along minor roads, radio-marked owls apparently never hunted these areas of grass.[8]

Grilo et al. investigated how barn owls in Portugal responded in their spatial behavior towards a highway and its traffic at different spatial resolutions (home range location, movement directionality and locations/crossings/road-kills).[7] Specifically, they assessed 1) how highways affected home-range location and size in the immediate vicinity of a major road, 2) which road-related features influenced habitat selection, 3) the role of different road-related features on movement properties, and 4) characteristics associated with crossing events and road kills. Between April 2008 and September 2009 they marked 11 adult barn owls with radio-transmitters near their individual nests. Four were ultimately killed on the highway, and another four disappeared from the study area. The authors obtained sufficient radio locations to quantify home ranges of five barn owls, which averaged 763 ± 650 ha (1885 ± 1606 acres) in size. They noted that "while barn owls established home ranges mostly in the vicinity of the highway, they included highways in areas of their home ranges with a lower probability of use." The researchers obtained 2,027 locations from the radio-tagged barn owls, of which 258 independent locations were used in habitat selection analyses. Barn owl presence was negatively related to the distance to streams. Importantly, an interaction between distance to highway and traffic volume was observed, indicating that barn owls tended to avoid the highway when traffic intensity increased. Radio-tagged owls made 721 movements towards the highway and 736 away from the highway. Traffic intensity had no effect on the overall directionality, but barn owls tended to avoid moving toward the highway when they were in proximity to it. When considering only those movements in the vicinity of the highway, movements toward the highway seemed to be explained primarily by a high percentage of suitable vegetation in the roadsides, e.g., herbaceous cover for barn owls, and where the highway crossed streams.[7]

Six of the marked barn owls crossed roadways 29 times during 1175 hours of monitoring.[7] This equates to highway crossing at a rate of 0.30 times per day assuming a 12-hour activity period. The probability (risk) of being road-killed per crossing event was 0.009. The likelihood of highway crossing for barn owls was higher at road sections that were above grade, with wide road verges, and a higher proportion of herbaceous cover in the verge.[7] Barn owl crossings tended to be at locations with low volume of lighter (smaller) vehicles. From data on 11 dead barn owls found between 2003 and 2009 in the vicinity of the 5 barn owl home ranges mapped, owls tended to be killed on highway sections where they preferred to cross but when traffic was high.[7]

In summary, Grilo et al. discussed that if there is available habitat, barn owls do not avoid locating their home ranges in the vicinity of highways. Highways did not appear to be barriers to movement, but they may have acted as artificial home range boundaries instead. Traffic intensity affected barn owl habitat use but did not appear to influence the decision to move across or move next to the highway. Within their home ranges, barn owls moved closer to highways when in proximity to streams and in places where verges offered suitable habitat. Barn owls were particularly vulnerable to mortality when crossing highways even though they crossed with low frequency. Thus, some highway sections may be functioning as attractive sinks, especially those with suitable verges (wide with herbaceous cover) and those at which barn owls tend to cross (i.e., above-grade sections).(7) Owls also tended to cross when light-vehicle traffic was low. The authors translated their observed crossing and mortality rates into a potential mortality rate of 48 to 96 barn owls per 100 km (62 mi) per year.

Factors Contributing to Roadway Mortality of Barn Owls

The volume of traffic, speed of vehicles, individual configuration of roads, and road density are among the most frequently mentioned factors affecting bird mortality on roads.(66-69) Considering major roads, Ramsden suggested barn owl kill-risk factors in the following *descending order of importance* and provided an estimated importance score for each (in parentheses below): (10)

- Presence/absence of continuous low flight obstructions (10).
- Elevation of the carriageway (sunken or level/embanked) (4).
- Presence/absence of rough grass verges (3).
- Traffic density (2).
- Traffic speed (2).
- Vehicle size (2).
- Number of traffic lanes (1).

Spatial factors such as distance to streams and other linear features are also important in some cases.(1,7,43) Mortality rates are particularly high on highways that are even with or elevated compared to the rest of the surrounding landscape.(10,52,70) The proportion of birds killed, including barn owls, and amphibians increased dramatically when roads were embanked compared with sunken or ground-level.(52)

Biotic features such as vegetation cover type near roads, prey abundance, and relative occupancy of owls certainly play a role in mortality rates, as well in determining the likelihood of barn owl vehicle collisions.

Mitigation Recommendations

The primary literature is rich with examples of studies that document large numbers of barn owls being killed along roads, and there are some studies that examine spatial, geometric, and biotic factors associated with road mortality. However, examples of on-the-ground mitigation and their actual efficacy in reducing barn owl mortality along roads are woefully missing. Although millions of birds and a large portion of the barn owl population may be lost each year, Bishop and Brogan pointed out that there have been no mitigation measures for birds incorporated into road construction in Canada (but see Chapter 8 for a recent project in British Columbia).[65] Indeed, while not referencing mitigation to reduce bird mortality *per se*, Lesbarreres and Fahrig noted that "up to now, road mitigation research has mostly languished in a backwater where studies lack scientific rigor, are reported in obscure outlets and are ignored by the larger research community and the road planning community."[71]

For barn owls, mitigation ideas have generally centered on a few main themes: (1) establishing tall vegetation or other screen/barriers that force owls to fly higher above highways while foraging or crossing, (2) removing rodents or their habitat from highway roadsides to make these areas less attractive hunting grounds for barn owls, and (3) allowing taller vegetation to remain near roads to reduce the attractiveness of these areas to owls, because taller vegetation makes owl hunting more difficult and could decrease use of such areas. Some have also suggested (4) providing suitable habitat away from roads to provide barn owls the resources they need elsewhere. Chapter 8 includes examples of comments about mitigation that are representative of those previous authors.

Chapter 3
Barn Owl-Vehicle Collisions in Idaho

This chapter summarizes previously known information about barn owl-vehicle collisions in Idaho along I-84. The information that follows is based on studies by Boves and Belthoff.(1)

Road-killed Animals along I-84

Boves and Belthoff surveyed a 248-km (154 mi) stretch of I-84 in southern Idaho between Boise (Ada County) and Burley (Cassia Country) for road kill using systematic searches every two weeks over a two-year period between July 2004 and June 2006.(1) Barn owls (n = 812) were 33 percent of the 2,528 dead animals recorded and outnumbered the next most common species (skunks, *Mephitis* spp.) by 4:1 (Table 4). Many of these dead owls had obvious signs of blunt force trauma consistent with vehicle collisions, including broken necks and wings.(1)

Table 4. Number of Road-killed Barn Owls (*Tyto alba*) and Other Wildlife along I-84

(from Boves and Belthoff(1))[1]

Table 1. Summary of the 20 most common animals (of 2,528 total individuals) recorded as victims of roadway mortality from July 2004–June 2006 along a 248-km stretch of I-84 in southern Idaho, USA. Mortality rates are unadjusted and indicate number of individuals/km/yr.

Species	No.	Proportion	Mortality rate
Tyto alba	812	0.33	1.64
Mephitis mephitis	232	0.09	0.47
Taxidea taxus	143	0.06	0.29
Canis latrans	136	0.06	0.27
Lepus townsendii or californicus	110	0.05	0.22
Felis silvestris catus	102	0.04	0.21
Columbia livia	80	0.03	0.16
Marmota flaviventris	79	0.03	0.16
Bubo virginianus	57	0.02	0.12
Odocoileus hemionus or virginianus	65	0.03	0.13
Vulpes vulpes	43	0.02	0.09
Pica pica	32	0.01	0.07
Canis lupus familiaris	32	0.01	0.07
Procyon lotor	31	0.01	0.06
Spermophilus spp.	21	0.01	0.04
Sylvilagus audubonii	19	0.01	0.04
Phasianus colchicus	17	0.01	0.03
Order Passeriformes	17	0.01	0.03
Buteo jamaicensis	13	0.01	0.03

[1] Tables and figures as they appear in Boves and Belthoff(1) are used in accordance with Copyright Transfer Agreements between those authors, the Journal of Wildlife Management, and Wiley Publications.

High Mortality Zones (Hotspots)

Although barn owl mortality occurred throughout most regions of I-84 that Boves and Belthoff[1] surveyed, there were three areas of especially high mortality (Table 5, Figure 14). These mortality hotspots were near Hagerman, Kimberly, and Hazelton, Idaho and averaged 3.3 km (2 mi) in length. Barn owls were also killed more often on portions of the roadway closer to the Snake River canyon, perhaps because of the availability of nest and roost sites.

Table 5. Characteristics of Three Areas of Peak Barn Owl Mortality along I-84

(from Boves and Belthoff[1])

Table 4. Spatial characteristics of 3 peak barn owl road mortality zones along I-84 in southern Idaho, USA from July 2004–June 2006.

Zone	Location	Length of zone (km)	No. of owls detected	% of total route	% of total mortality	Land cover (5-km radius from zone center)	Distance to Snake River canyon (km)
1	8 km N of Hagerman, ID	2.9	44	1.2	5.4	78% Agriculture, 20% Shrub-steppe, 2% Other	3.0
2	8 km NE of Kimberly, ID	3.0	71	1.2	8.7	55% Agriculture, 42% Shrub-steppe, 3% Other	1.5
3	2.5 km SE of Hazelton, ID	4.0	49	1.6	6.0	85% Agriculture, 12% Shrub-steppe, 3% Other	7.5

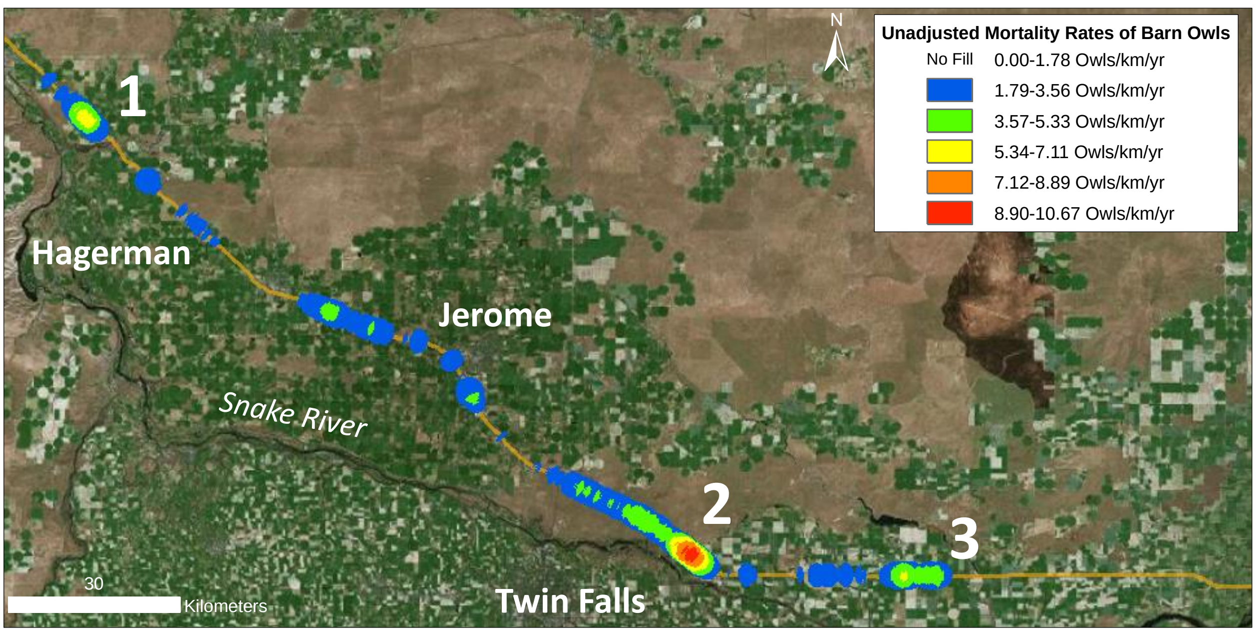


Figure 14. Density Map of Barn Owl Mortality Locations along 1-84 between Hagerman and near Burley

Three Peak Mortality Areas and the Relative Location of the Snake River are Shown (adapted from Boves and Belthoff[1])

Sex and Age Classes of Road-killed Barn Owls

Females and juveniles, which represent individuals more likely to disperse long distances, were killed more frequently than males and adults (Figure 15).

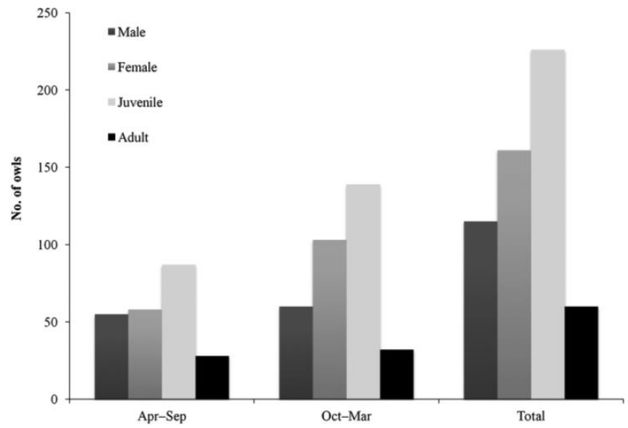


Figure 2. Influence of age, sex, and season on roadway mortality of barn owls along I-84 in southern Idaho, USA, July 2004–June 2006.

Figure 15. Age and Sex Classes of Road-killed Barn Owls

(from Boves and Belthoff[1])

Plant Cover Type

There were 488 of 812 (60 percent) dead barn owls adjacent to agricultural lands.[1] This was significantly greater than expected given the distribution of land cover types (agricultural lands and grassland/shrub steppe) in the study area.

Annual and Seasonal Variation of Road-killed Barn Owls

There was marked seasonal as well as annual variation in the deaths of barn owls (Figure 16). Owl mortality peaked in autumn/winter and was substantially greater in the second year of the Boves and Belthoff study, perhaps because of environmental conditions that affected prey abundance and/or owl reproduction (Figure 15). Necropsied owls often had rodents in their stomachs, so there was little or no evidence that dead birds had starved.[1]

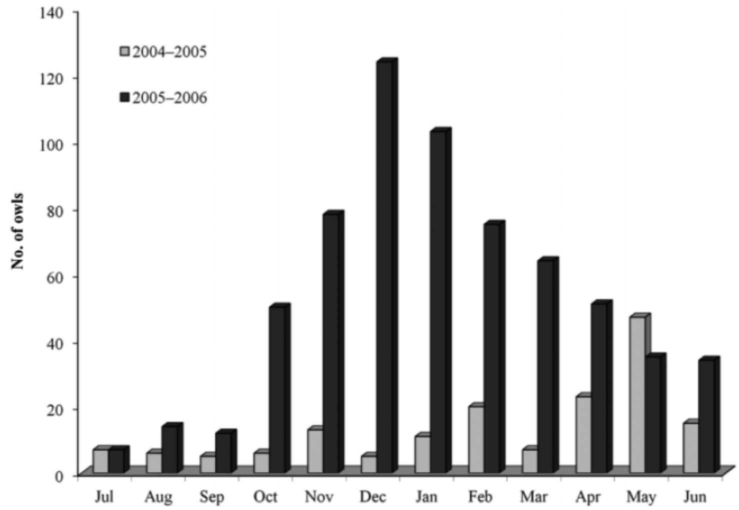


Figure 4. Monthly and annual variation of unadjusted barn owl mortality along I-84 in southern Idaho, USA, July 2004–June 2006.

Figure 16. Graph of Monthly and Annual Barn Owl Road Mortality

(from Boves and Belthoff[1])

Naïve vs. Adjusted Estimates of Mortality

Experiments to determine detection rates during road surveys (detection bias) and the rate at which scavengers removed carcasses from roadways (removal bias) showed road surveys likely failed to count large numbers of vehicle-killed barn owls.[1] After adjusting for detection and removal bias, adjusted mortality estimates for vehicle-killed barn owls were at least 2 to 4 times higher than naïve estimates and therefore ranged as high as 599 barn owls/100 km (62 mi)/year along focal portions of I-84.[1]

Effect of Roadway Mortality on Persistence of Barn Owl Populations near I-84

Demographic modeling suggested that the barn owl population in the Snake River plain of southern Idaho has potential to decline under the observed levels of roadway mortality along I-84.[1] Boves and Belthoff provide the following description related to this conclusion: [1:1389 – 1390]

> *"In a study in central California, Moore and Mangel (1996) theorized that if greater than 27 percent of juvenile barn owl mortality was a result of traffic collisions, the population would be in decline. No published information exists regarding Idaho's barn owl population; therefore, we used life history and demographic data from other locations in combination with this threshold to determine the level of productivity necessary for the southern Idaho owl population to sustain the rate of roadway mortality that we observed (assuming a closed population). Our data indicated that 562 to 1,171 juvenile owls died along this roadway per year. Using the juvenile mortality threshold of 0.27, 2,037 to 4,222 juvenile owls would need to fledge annually to*

maintain the local population. Barn owls will typically travel 1 to 3 km (with a maximum of 5 km) from their roosting or nesting sites to hunt (Colvin 1984, Hegdal and Blaskiewicz 1984, Taylor 1994). Assuming an average foraging distance of 2.5 km, the effective area of our study was 1,240 km^2. Thus, 1.6 to 3.4 young/km^2/year must be produced for this population to remain stable ($\lambda > 1$). Barn owls are not typically territorial, and breeding densities vary worldwide, often based on available nesting sites and prey abundance (Smith and Hopkins 1937, Smith et al. 1974, Baudvin 1975). Previous studies report breeding densities at 3.6 pairs/10 km^2 in Spain (Martinez and Lopez 1999) and 2.2 to 5.1 pairs/10 km^2 in Scotland (Taylor et al. 1988). Assuming breeding densities of Spain, each barn owl pair in our study area would need to fledge 4.6 to 9.5 young/year to maintain $\lambda > 1$. In a long-term study in nearby Utah, barn owls had a nesting success rate of 71 percent and produced an average of 5.1 young/successful nest, with very few birds laying second clutches after initial failures (Marti 1994). This results in an average of 3.6 fledglings produced/pair/year, which is well below the minimum productivity likely required for the southern Idaho barn owl population to persist without substantial immigration or decreases in roadway mortality. Thus, barn owl populations in the Snake River plain of southern Idaho have potential to decline under the level of roadway mortality we observed. Grajera et al. (1992) and Ramsden (2003) reported local extirpations along highways with much lower roadway mortality rates, and in milder climates, than those of Idaho."

Chapter 4
Barn Owl Road Kill Survey Results and Hotspots (2013 – 2015)

Overview

The research team performed systematic and ad hoc surveys along I-84 between Boise and Pocatello, Idaho in a manner similar to Boves and Belthoff.[1] The objective was to document the locations of road-killed barn owls and to determine if and how the locations of peak mortality (i.e., hotspots) may have changed. Information in this chapter relates to objectives 1, 2, and 4 which were to:

- Determine locations of barn owl-vehicle collisions along I-84 and I-86.
- Examine spatial, geometric, and biotic characteristics of barn owl collision locations to shed light on features of the roadways and surrounding landscape that may provide clues about why and how barn owls are being killed.
- Assess feasibility of potential mitigation strategies that may reduce owl-vehicle collisions and reduce driver risk.

The following sections:

- Summarize barn owl road kill data collected from 2013 to 2015 as part of the current research.
- Provide density maps for barn owl road mortality based on surveys between 2004 to 2006 and 2013 to 2015 surveys.
- Graphically assess changes in areas of greatest mortality along the I-84/86.

Findings

Barn Owl Road Kill Data (2013 – 2015)

Researchers completed 24 standardized road surveys along I-84/86 between October 2013 and September 2014 and recorded 106 dead barn owls between Boise and Pocatello, Idaho. As in Boves and Belthoff, there was temporal variation in number of dead owls with the largest number of carcasses in winter months (December through February; Figure 17). Additional ad hoc road surveys conducted between March 2013 and May 2015 located 444 dead barn owls along I-84/86 (Table 6).

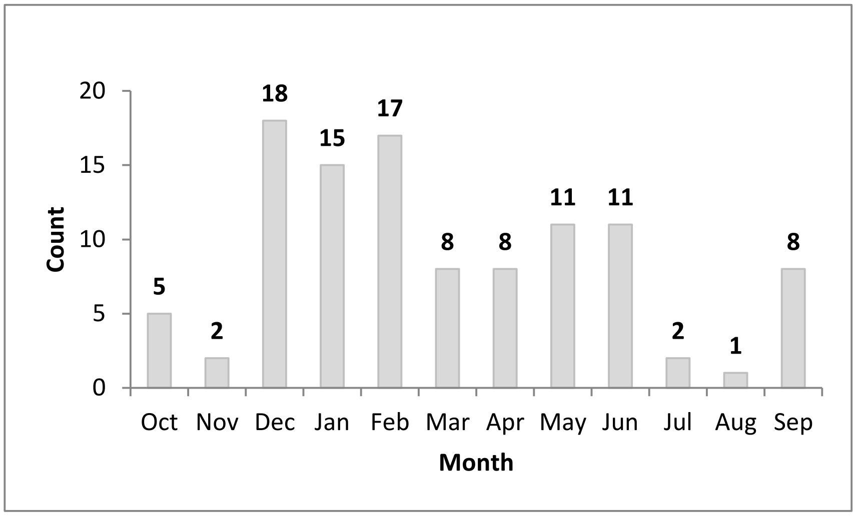


Figure 17. Graph of Road-killed Barn Owls per Month during *Standardized* Surveys

(October 2013 to September 2014)

Table 6. Road-killed Barn Owls Recorded during *Ad Hoc* Surveys

Month/Year	Survey Route	Number of Barn Owls
March 2013	Boise to Wendell, I-84	123
March 2013	Boise to Pocatello, I-84/86	230
February 2015	Boise to Pocatello, I-84/86	29
May 2015	Boise to Pocatello, I-84/86	62
	Total	444

Density Maps of Barn Owl Mortality along I-84/86

From road kill survey data, the research team used ArcMap to produce point density maps of barn owl carcass locations along I-84/86. Team members did so for the years 2004 to 2006 (adapted from Boves and Belthoff[(1)]), 2013 to 2015 (the current study period), and for these two study periods combined (Figures 18, 19, 20, 21). While barn owl mortality along I-84/86 continues to be widespread, these road kill surveys and those of Boves and Belthoff were consistent in identifying a zone with the greatest mortality in the region between Bliss and Hazelton, Idaho (Figures 19 and 21).

The magnitude of barn owl mortality has decreased somewhat in the hotspot regions that Boves and Belthoff described as #2 and #3, although barn owl carcasses continue to be recorded in these locations (Figure 19). The hotspot #1 described by Boves and Belthoff has expanded such that it now appears with two components (Figure 19).

Boves and Belthoff surveyed for barn owl carcasses only along I-84 between Boise and Burley (approx. 240 km/150 mi).[(1)] The current project extended road kill surveys along sections of I-84 east of Burley and along I-86 to Pocatello. While the research team detected owl carcasses along these additional highway sections, they were not as large in number as in the area of highest mortality between Bliss and Hazelton along I-84.

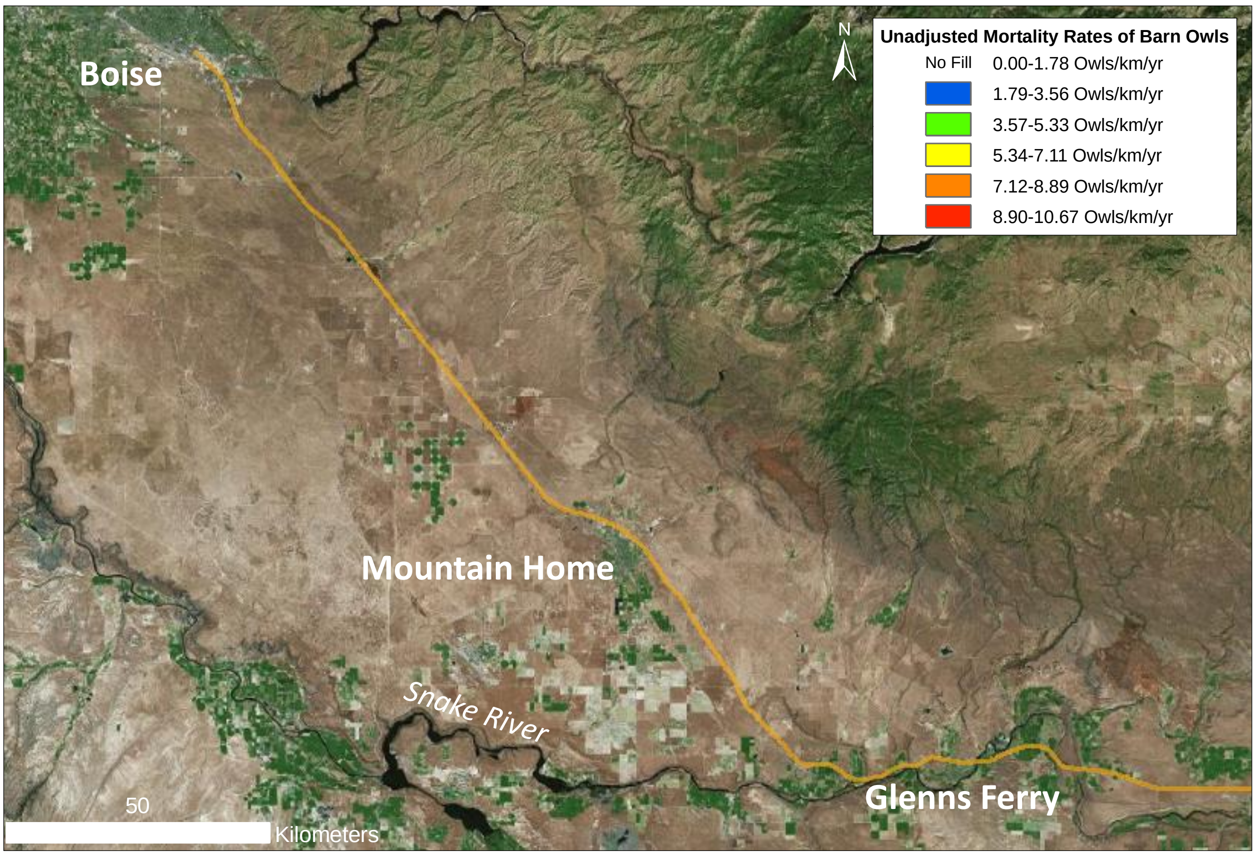


Figure 18. Point Density Estimates of Barn Owl Road Kills along I-84 Between Boise and Glenns Ferry, Idaho

Note: this map is similar for 2004 – 2006, for 2013 – 2015, and for these time periods combined, so only one figure is shown. Owl mortality occurred between Boise and Glenns Ferry during these time periods but at low rates (0 – 1.78 owls/km/year), so no fill is shown as in subsequent figures.

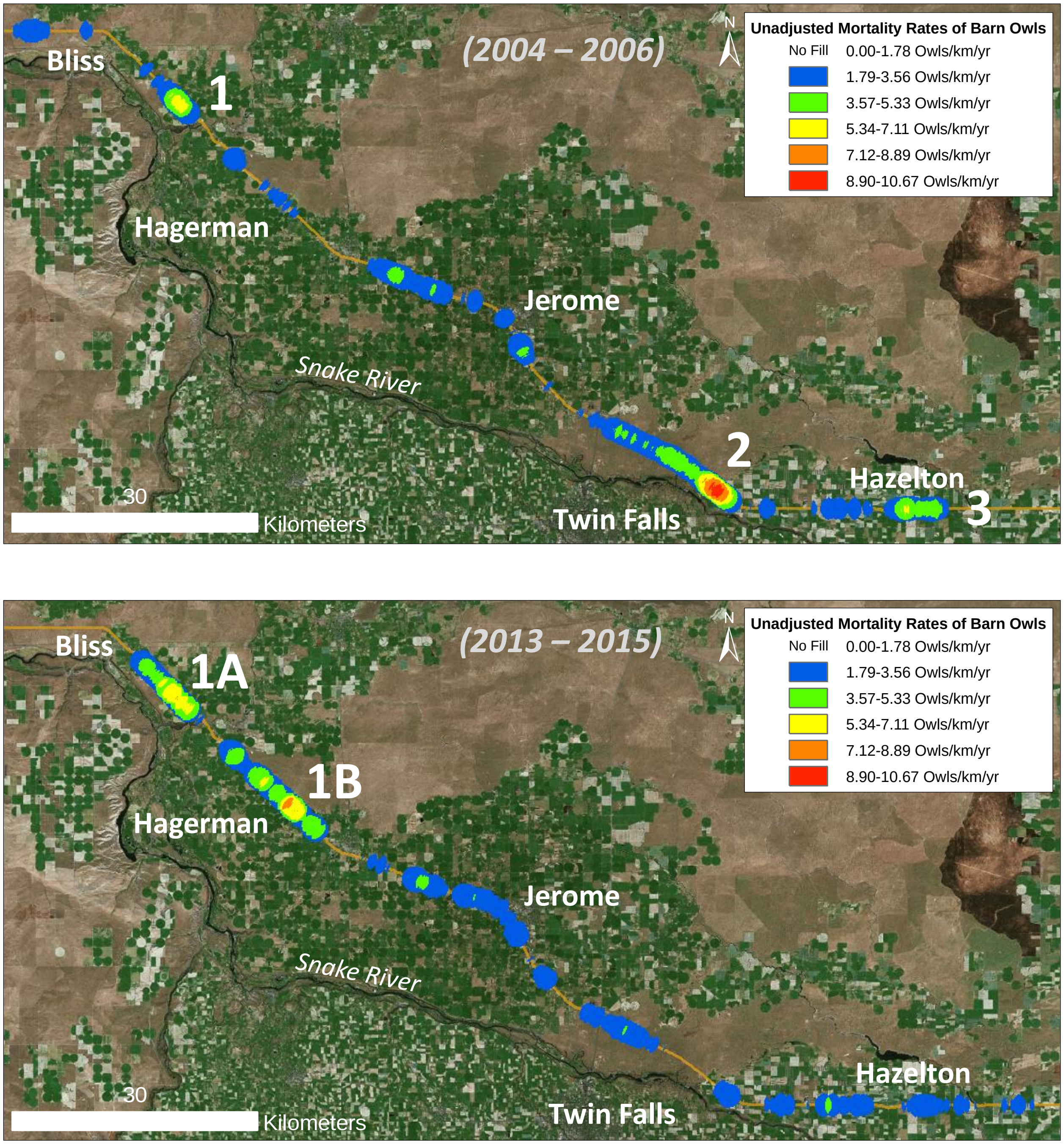
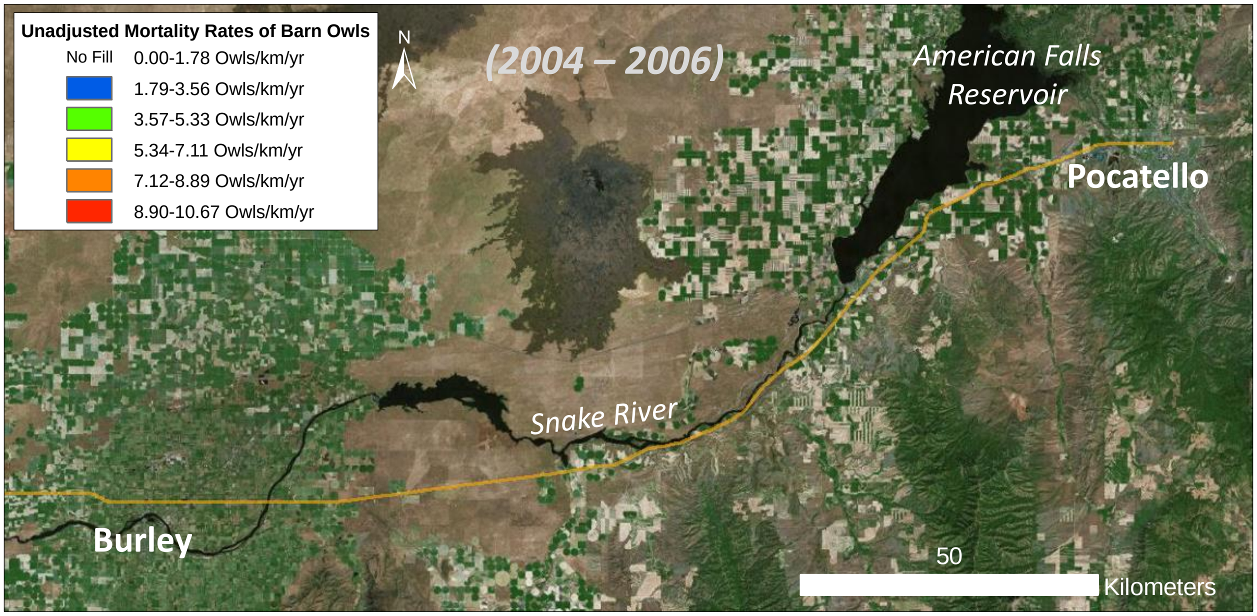


Figure 19. Barn Owl Carcass Locations Between Bliss and Hazelton, Idaho along I-84

Top: Years 2004 to 2006; Bottom: Years 2013 to 2015



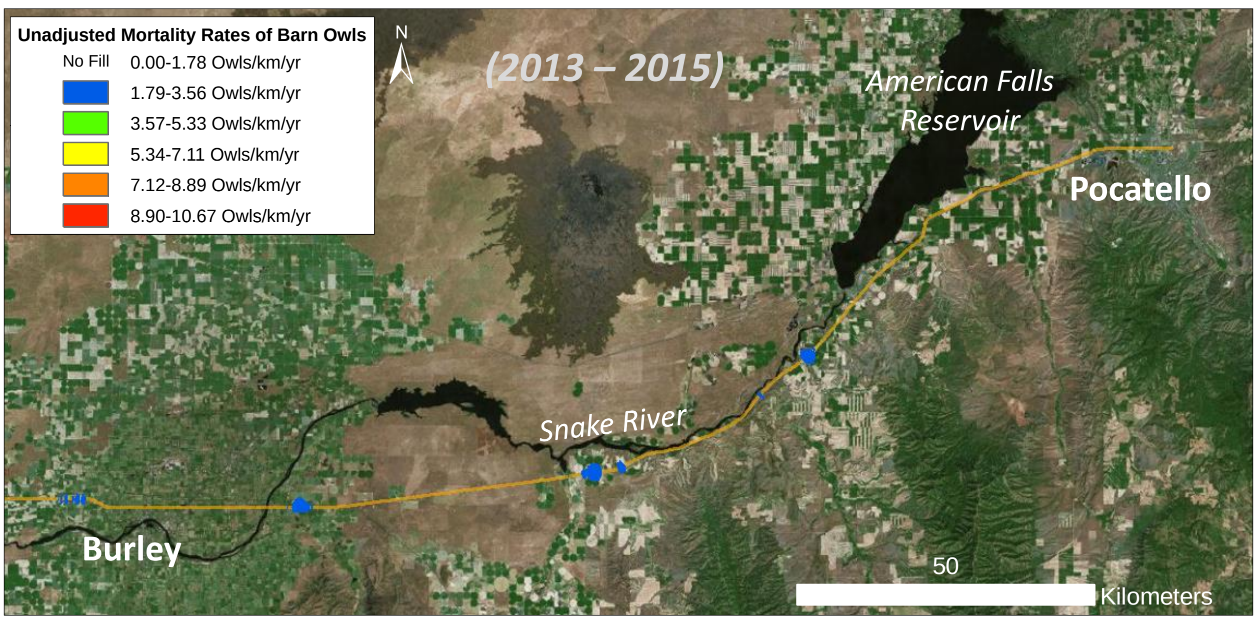
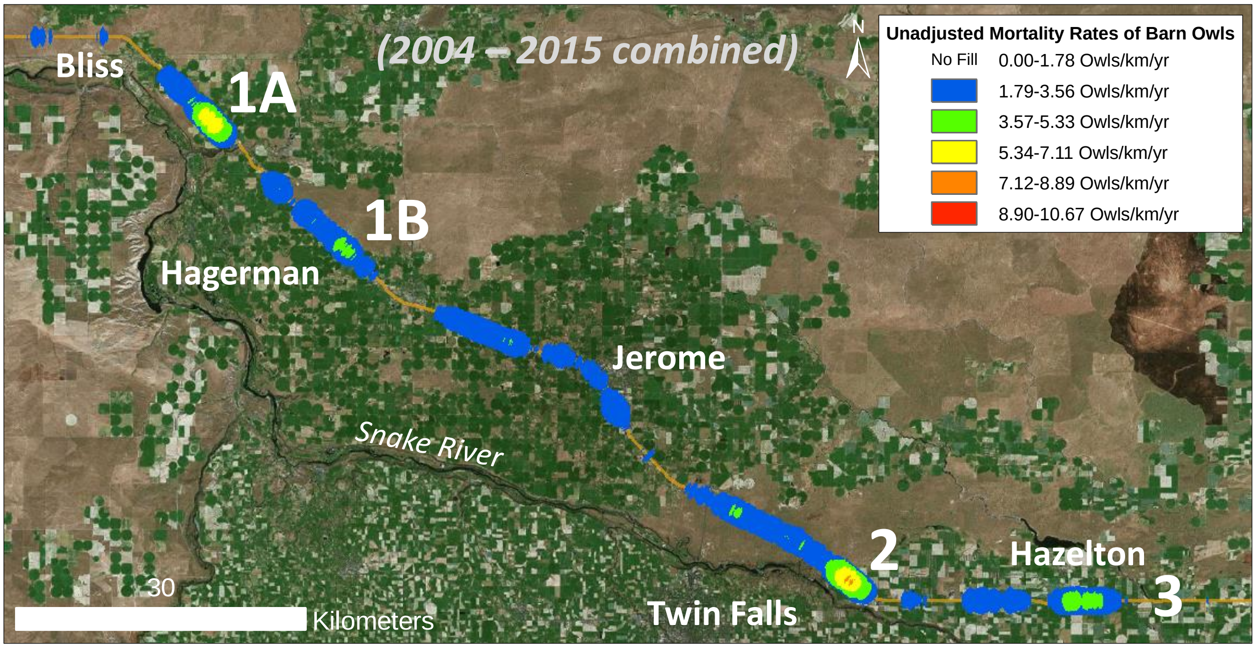


Figure 20. Barn Owl Carcass Locations between Burley and Pocatello, Idaho along I-84/86

Top: Years 2004 to 2006; Bottom: Years 2013 to 2015



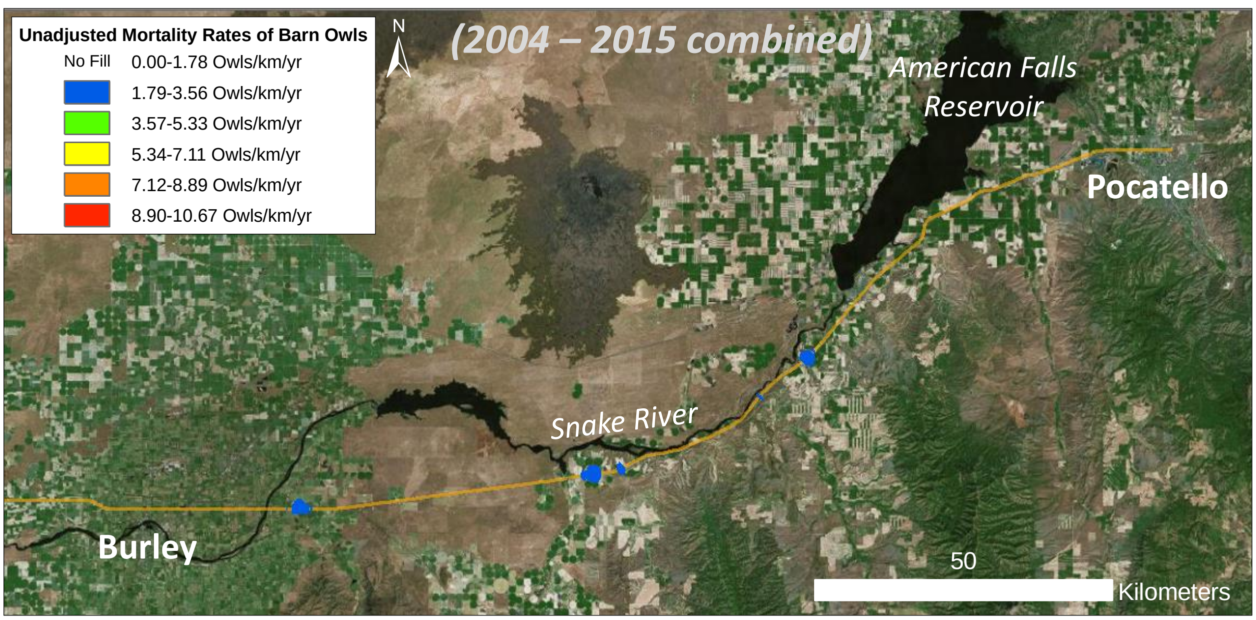


Figure 21. Barn Owl Mortality Locations using Combined Years (2004 to 2006 and 2013 to 2015) Road Kill Survey Data

The areas of greatest barn owl mortality (those identified as yellow or above in previous maps corresponding to mortality rates of 5.24 – 10.67 owls/km /year [9 – 19 owls/mi/year]) identified in 2004 to 2006 occurred between mileposts 144 and 191 and accounted for approximately 15 percent of road kills in the 236-km (146 mi) length of I-84 between Boise and Burley, Idaho (Table 7). The hotspots identified for 2013 to 2015 (1A and 1B) occurred between mileposts 143 and 154 and accounted for 79 of 550 barn owl carcasses (14.4 percent) detected in the 365 km (227 mi) between Boise and Pocatello, Idaho (Table 7). When pooling data from all survey years, the areas with barn owl mortality rates greater than 5.24 owls/km/year or 9 owls/mi/year (hotspots) were between mileposts 143 and 191 and accounted for approximately 19 percent of all barn owl mortality (250 of 1335). Mortality of barn owls occurs in the areas leading into and out of these hotspots as well as in other areas of the surveyed portions of I-84/86 but at somewhat lower rates (Figures 18, 19, 20, 21).

Table 7. Characteristics of Areas of Greatest Barn Owl Mortality along I-84

Zone	Location	Approximate Mileposts	Length of Zone (km)	No. of Owl Carcasses	% of Total Route	% of Total Carcasses
Years: 2004 – 2006						
1	8 km N of Hagerman, ID	144 to 145	1.8	27	0.8	3.4
2	8 km NE of Kimberly, ID	179 to 181	3.3	76	1.4	9.7
3	2.5 km SE of Hazelton, ID	190 to 191	0.5	14	0.2	1.8
Years: 2013 – 2015						
1A	8 km N of Hagerman, ID	143 to 145	3.5	38	1.0	6.9
1B	6 km NW of Wendell, ID	150 to 154	4.5	41	1.2	7.5
Years: 2004 – 2015 Combined (Locations Recommended for Mitigation)						
1/1A	8 km N of Hagerman, ID	143 to 145	3.5	83	1.0	6.2
1B	6 km NW of Wendell, ID	150 to 154	4.5	64	1.2	4.8
2	8 km NE of Kimberly, ID	179 to 181	3.3	87	0.9	6.5
3	2.5 km SE of Hazelton, ID	190 to 191	0.5	16	0.1	1.2

Photos of High Mortality Zones

Below are photographs of I-84 from specific areas of high barn owl mortality in Zones 1, 2, and 3, respectively. Areas of high mortality generally were in agricultural settings, with narrow medians between east and westbound traffic lanes, with few roads and human structures in the vicinity, no low flight barriers, and with the highway level with surrounding landscapes (Figures 22, 23, 24).

Figure 22. Photos of High Mortality Areas for Barn Owls, I-84 between Bliss and Tuttle, Idaho

Top: East view from eastbound shoulder; Bottom: West view from eastbound shoulder.

Figure 23. Photos of High Mortality Areas for Barn Owls, I-84 north of Kimberly, Idaho

Top: East view from eastbound shoulder; Bottom: North view from eastbound lanes.

Figure 24. Photos of High Mortality Area for Barn Owls, I-84 near Hazelton, Idaho

Top: East view from eastbound lanes; Bottom: North view from eastbound lanes.

Chapter 5
Small Mammal Abundance Survey along Interstate 84/86, Idaho

Overview

Barn owls inhabit open habitats where they prey primarily on small mammals, and vegetation along roads likely provides habitat for owl prey. Little is known about how small mammals occur along interstate highways in Idaho and how these areas represent potential foraging habitat for barn owls. Thus, the research team sought to determine small mammal abundance along focal portions of I-84 to help understand if owls were being killed in areas with the greatest abundance. Using a combination of camera and track traps, the research team trapped 120 locations along I-84 for three nights each to quantify abundance. This allowed inclusion of a small mammal abundance index as one of the biotic factors to ultimately achieve objective 2 "*Examine spatial, road geometric, and biotic characteristics of barn owl collision locations to shed light on features of the roadways and surrounding landscape that may provide clues about why and how barn owls are being killed.*" The team also characterized small mammal habitat along I-84.

Findings related to the following are described below:

- Numbers and species of small mammals (rodents) detected during camera and trap trapping at n = 120 sampling sites.
- Calculation of the small mammal abundance index for each of the 120 sampling sites.
- Small mammal (rodent) abundance and plant cover type in the median and ROW.

Findings

Number of Small Mammals Detected

The track traps and camera traps recorded 3,108 observations, from which we were able to identify five species of small mammals, all of which were rodents. These were *Peromyscus maniculatus* (deer mouse, 82.3 percent), *Dipodomys ordii* (Ord's kangaroo rat, 0.2 percent, Figure 25), *Rattus norvegicus* (Norway rat, 0.5 percent), *Microtus* spp. (vole, 0.2 percent), and *Urocitellus* spp. (ground squirrel, 0.3 percent). For the remaining 516 observations, the species of small mammals that marked the track traps or were captured in camera trap photographs could not be identified. For both camera and track traps, deer mice were the most commonly recorded small mammal species with 79.4 and 81.2 percent of total observations, respectively.

Figure 25. Photos of *Peromyscus maniculatus* (above) and *Dipodomys ordii (below)* recorded at Camera Traps along I-84

Small Mammal Abundance Index

The small mammal abundance index averaged 4.8 ± 1.5 (SD) at the 120 trapping sites and ranged from 0-6 (Figure 26). Only 3 sites (2.5 percent) lacked rodents (i.e., index = 0), whereas 53 sites (44.2 percent) had the greatest index value of 6. Thus, species that contribute to the rodent prey of barn owls were generally abundant at the 120 trapping sites along I-84 (Figure 27).

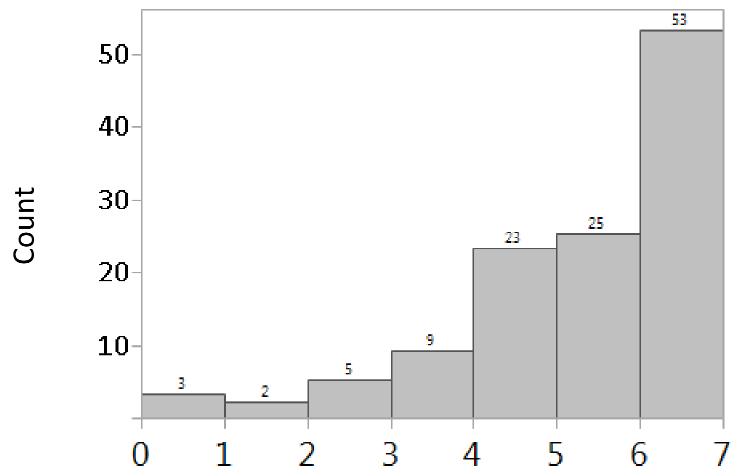


Figure 26. Frequency Histogram of Small Mammal Abundance Index at 120 Sites along I-84

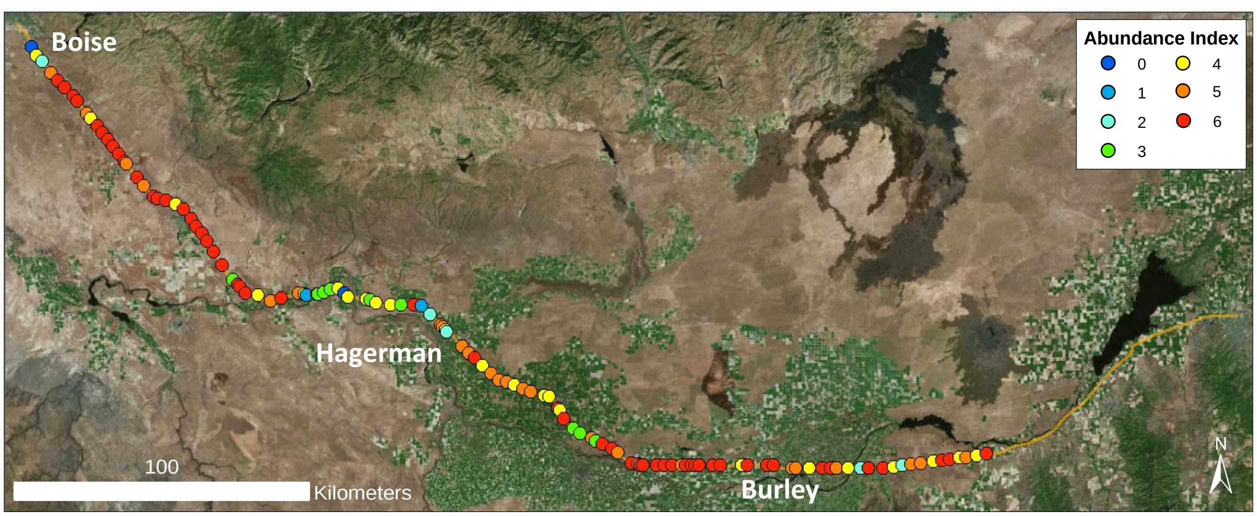


Figure 27. Small Mammal Abundance Index at 120 Sampling Locations along I-84

Plant Cover Type

Among the 120 randomly placed small mammal trapping sites along I-84, there were 86 (71.7 percent) that had grass plant cover type in the ROW, 29 (24.2 percent) with mixed grass/shrubs, and 5 (4.1 percent) with shrub plant cover type. These same sites had grass (n = 104, 86.7 percent), mixed grass/shrubs (n = 12, 10.0 percent), and shrub (n = 4, 3.3 percent) plant cover type in the median.

The small mammal abundance index was highest when the median and/or the ROW had grass plant cover type (Figure 28). Shrub-covered sites had lower average small mammal abundance than grass for both the median and the ROW.

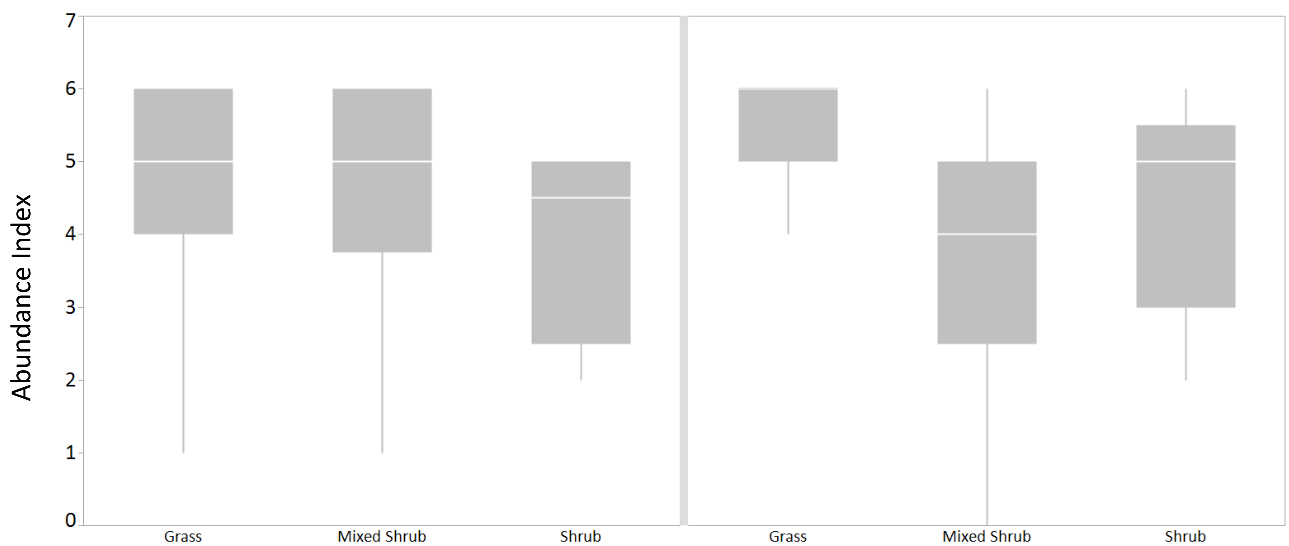


Figure 28. Box Plots of Small Mammal Abundance Index in Relation to Plant Cover Type in the Median (left) and ROW (right) at 120 Sampling Sites along I-84

Conclusions

Camera and track traps produced data from which the research team estimated an index of small mammal abundance along I-84. Deer mice were especially plentiful, and they were the most common rodent detected and identified. The small mammal abundance index value varied among the 120 sampling sites, although almost half of the sites had the highest index value. Sites with grass cover type in either or both the median and ROW tended to have higher small mammal abundance indices. Barn owls prey on deer mice and other small mammals, so owl prey appears to be available in many sites along I-84. This is especially true in those areas that have grass in the ROW and/or median.

Chapter 6
Spatial, Geometric, and Biotic Features Associated with Barn Owl-Vehicle Collisions

Overview

The main objective of this research was to discover which features contribute to barn owl mortality along the I-84/86 corridor in southern Idaho. To do so the research team measured spatial, geometric, and biotic features at 120 sample sites along the focal interstate highway. Researchers first evaluated the scale at which each variable most closely related to barn owl mortality locations. Using Generalized Linear Models, they then examined the relationship between these variables and the number of dead barn owls/km/survey using a model selection framework. The top competing model explaining barn owl mortality contained nine variables: length of secondary roads, percentage of human structures, percentage of cultivated crops, distance to Snake River Canyon, distance to nearest dairy, width of highway median, distance to nearest water feature, and plant cover type in the median and ROW. Using the density maps described in Chapter 4, the research team then examined how these characteristics differed in locations judged as mortality hotspots and those with lower barn owl mortality.

Information in this chapter thus relates to objective 2, which was to examine spatial, geometric, and biotic characteristics of barn owl collision locations to shed light on features of the roadways and surrounding landscape that may provide clues about why and how barn owls are being killed.

This chapter summarizes our findings related to:

- Number of dead barn owls in the 120 sampling sites used for analysis.
- Assessment of best scale for scale-dependent variables.
- Variable reduction and selection for final modeling.
- Analysis of final set of spatial, geometric, and biotic factors related to barn owl road kill locations.
- Spatial, geometric, and biotic characteristics of mortality hotspots.

Findings

Characteristics of 120 Sample Sites

For the 120 1-km (0.6 mi) segments, the number of dead barn owls per segment averaged 5.0 ± 6.1 (SD) and ranged from 0 to 25 (Figure 29). This equated to an average of 0.1 ± 0.1 (SD) dead barns owls per km (0.6 mi) per survey along the 120 segments characterized for spatial, geometric, and biotic variables. Spatial, geometric, and biotic characteristics of the 120 segments are summarized in Appendix C.

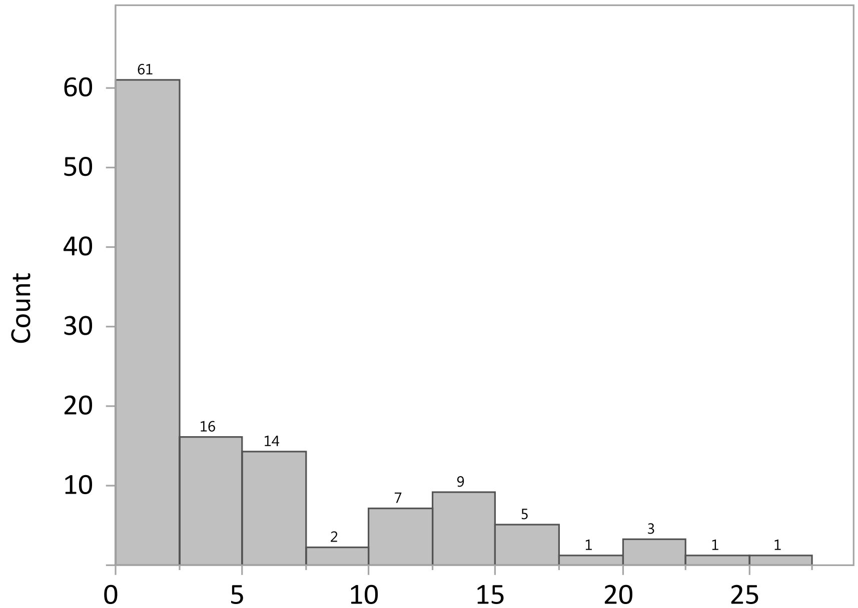


Figure 29. Frequency Histogram of Number of Dead Barn Owls/1-km Segment (n = 120 segments)

Assessing Scale

The scale at which each variable performed optimally had to be determined. The twenty-three variables that were scale-dependent were measured at each of three scales (1-, 3-, and 5-km buffer [0.6-, 1.8- and 3-mi]). The AIC_c values of a given variable were then compared at each of these three scales, in which the lowest AIC_c indicated the best scale for the variable. The final list of fourteen variables include a number in front of the name of the variable indicating which scale was the best for that given variable (e.g., 1RdLength indicates the 1-km scale was the best for the variable road length). Variables that were not scale-dependent do not have a number associated with their name.

Variable Reduction and Final Variable Set

Ultimately, researchers removed the variables presented in Table 8 from analysis because of multicollinearity, redundancy, lack of data variability within the feature, and model parsimony. That left 14 variables for final data analysis. Among these 14 final variables were four spatial, five geometric, and five biotic variables (Table 9).

Table 8. Variables Removed for Statistical Analysis

Variable	Reason for Removal
Spatial	
Elevation	Model parsimony
Distance to Nearest Agricultural Field (min, avg, center)	Avg lower AICc than min and center (935.17 vs. 981. 98 vs. 995.86); Correlated with ***Percentage of Crop*** (-0.68); higher AICc (935.17 vs. 809.59)
Distance to Snake River Canyon (min, center)	Avg lower AICc than min and center (879.87 vs. 881.61 vs. 879.99)
Distance to Nearest Bridge (min, avg, center)	Captured in ***Cumulative Length of Obstructions*** variable
Distance to Nearest Water Feature (avg, center)	Min lower AICc than avg and center (998.53 vs. 1002.80 vs. 1009.45)
Distance to Nearest Dairy (avg, center)	Min lower AICc than avg and center (803.63 vs. 804.11 vs. 813.38)
Number of Dairies	***Distance to Nearest Dairy (min)*** had lower AICc (803.63 vs. 962.64) so chosen as dairy measurement
Cumulative Length of Water Features	***Distance to Nearest Water Feature (min)*** lower AICc (998.53 vs. 1007.54) so chosen as water measurement
Geometric	
Embankment/Excavations	Correlated with ***Cumulative Length of Obstructions*** (-0.82); higher AICc (956.11 vs. 975.64), so selected ***Cumulative Length of Obstructions***
Cumulative Length of Power Lines	Model parsimony
AADT	Correlated with ***CAADT*** (0.72) and PAADT (0.99); CAADT lowest AICc (955.04)
PAADT	Correlated with ***CAADT*** (0.60) and AADT (0.99); CAADT lowest AICc (955.04)
Number of Traffic Lanes EB/WB	No variability
Total Number of Traffic Lanes	No variability
Traffic Speed	No variability
Width of EB/WB ROW	EB and WB correlated (0.87); WB lower AICc (789.08 vs. 873.90); WB correlated with ***Percentage of Crop*** (-0.60); Lower AICc (789.08 vs. 809.59) but kept ***Percentage of Crop***
Pavement Condition	Model parsimony
Shoulder Type EB/WB	Model parsimony
Left/Right Unpaved Shoulder Width EB/WB	No variability

Variable	Reason for Removal
Geometric Continued	
Left/Right Paved Shoulder Width EB/WB	No variability
Total Lane Width EB/WB	No variability
Total Road Width EB/WB	No variability
Biotic	
Habitat Change Past Fence EB/WB ROW	EB and WB correlated (0.90); EB lower AICc (790.82 vs. 799.60); Correlated with ***Percentage of Crop*** (0.74); lower AICc (790.82 vs. 809.59) but kept ***Percentage of Crop***; Correlated with ***Distance to Snake River Canyon (avg)*** (-0.76); lower AICc (790.82 vs. 879.99) but kept ***Distance to Snake River Canyon (avg)***
Percentage of Shrub	Correlated with ***Percentage of Crop*** (-0.98); higher AICc (809.59 vs. 830.59)
Percentage of Developed	Correlated with ***Percentage of Human Structures*** (0.70); higher AICc (1002.59 vs. 1016.83)
Percentage of Open Water	Correlated with ***Homogeneity of Slope*** (0.68); ***Distance to Nearest Water Feature (min)*** chosen as water measurement

[1]Bolded variable names are those that appear in Table 9 as final variables remaining for modeling.

Table 9. Final Spatial, Geometric, and Biotic Variables for Modeling

Symbol	Variable Description	Scale	Range
Spatial			
5DistSRC_avg	Average distance to Snake River Canyon measured every 100 m within 2.5 km buffer	km	0.4 to 48.3
3DistWat_min	Minimum distance to nearest water feature measured every 100 m within 1.5 km buffer	km	0.1 to 3.9
3DistDairy_min	Minimum distance to nearest dairy measured every 100 m within 2.5 km buffer	km	0.9 to 33
1RdLength	Total length of secondary roads within 0.5 km buffer	km	2.5 to 18.8
Geometric			
CAADT	Commercial Vehicle Average Annual Daily Traffic measured at center of buffer	vehicles/year	2100 to 5300
PvmntType	Pavement Type measured at center of buffer	nominal	flexible or rigid
1Slope	Standard deviation of slope within 0.5 km buffer	%	2.4 to 22.1
5Ob	Cumulative length of obstructions in 2.5 km buffer	km	0 to 10
WofM	Width of the median measured at center of buffer	m	13 to 100
Biotic			
AI	Small mammal abundance index measured from center of buffer	--	0 to 6
3CovTypeROW	Mode of plant cover type in ROW measured every 100 m within 0.5 km buffer	nominal	mixed, grass, or shrub
5CovTypeM	Mode of plant cover type in median measured every 100 m within 2.5 km buffer	nominal	mixed, grass, or shrub
5Crop	Total % crop land within 2.5 km buffer	%	0 to 87.3
1HS	Total % human structures within 0.5 km buffer	%	0 to 46.3

Model Selection and Top Models

Using Generalized Linear Models (Poisson distribution, Log link function, and log transformed number of surveys as the offset), the research team evaluated candidate models for their ability to describe information in the number of dead barn owls in 1-km (0.6 mi) road segments centered on the 120 sampling sites. There were three models within 2 AIC of the top model (Table 10). However, these included a single variable in addition to all variables in the top model or lacked a single variable compared to the top model, so they were judged as non-informative.(72) The top competing model contained 9 variables (Table 10) and had AIC_c substantially lower than either the null model (1016.502) or the global model (601.724), which indicates it is a better model than one with no predictor variables (intercept only) or one containing all 14 predictor variables, respectively.

Table 10. Top Competing Model and Others within 2 AIC

#	Model[1]	k	AIC_C	ΔAIC_C	w_i
1	3CovTypeROW, 5CovTypeM, 1RdLength, 1HS, 5Crop, 3DistDairy_min, 5DistSRC_avg, 3DistWat_min, WofM	11	592.128	0	0.1127
2	3CovTypeROW, 5CovTypeM, 1RdLength, 1HS, 3DistDairy_min, 5DistSRC_avg, 3DistWat_min, WofM	10	593.085	0.957	0.0698
3	3CovTypeROW, 5CovTypeM, Pavement Type, 1RdLength, 1HS, 5Crop, 3DistDairy_min, 5DistSRC_avg, 3DistWat_min, WofM	12	593.448	1.32	0.0582
4	3CovTypeROW, 5CovTypeM, 1RdLength, 1HS, 5Crop, 1Slope, 3DistDairy_min, 5DistSRC_avg, 3DistWat_min, WofM	12	593.719	1.591	0.0508

[1]Only models within 2 AIC of the top model are shown among all combinations of variables evaluated.

Five of the variables in the top model (length of secondary roads, distance to Snake River Canyon, distance to nearest dairy, human structures, and width of median) had negative parameter estimates, which indicates an inverse relationship with number of dead barn owls/1-km (0.6 mi)segment/survey (Table 11, Figure 30). In contrast, number of dead barn owls/1-km (0.6 mi) segment/survey increased with increasing cultivated crops and larger distances to nearest water feature (Table 11, Figure 30). For the two categorical variables (plant cover type in the median and plant cover type in the ROW), number of dead barn owls/1-km (0.6 mi) segment/survey was highest when there was grass cover type (Table 11, Figure 30). Moreover, all of the highest mortality segments had grass rather shrubs or mixed cover types in the median and ROW.

Table 11. Parameter Estimates for Variables in Top Model

Term	Estimate	Std Error	Lower CL	Upper CL
Intercept	-8.441	2243.726	-250.438	-2.076
3CovTypeROW [G]	0.762	0.341	0.242	1.724
3CovTypeROW [M]	0.601	0.376	-0.018	1.598
5CovTypeM [G]	6.334	2243.726	-0.142	248.271
5CovTypeM [M]	5.161	2243.726	-1.335	247.055
1RdLength	-0.045	0.016	-0.077	-0.015
1HS	-0.047	0.016	-0.081	-0.018
5Crop	0.005	0.003	-0.000	0.011
3DistDairy_min	-0.063	0.012	-0.086	-0.040
5DistSRC_avg	-0.031	0.007	-0.044	-0.018
3DistWat_min	0.510	0.110	0.293	0.725
WofM	-0.016	0.006	-0.029	-0.004

Source	FDR LogWorth	FDR P-Value
3DistDairy_min	6.409	0.00000
5CovTypeM	5.946	0.00000
5DistSRC_avg	5.543	0.00000
3DistWat_min	4.908	0.00001
1HS	2.706	0.00197
1RdLength	2.374	0.00422
3CovTypeROW	2.181	0.00660
WofM	1.961	0.01094
5Crop	1.193	0.06405

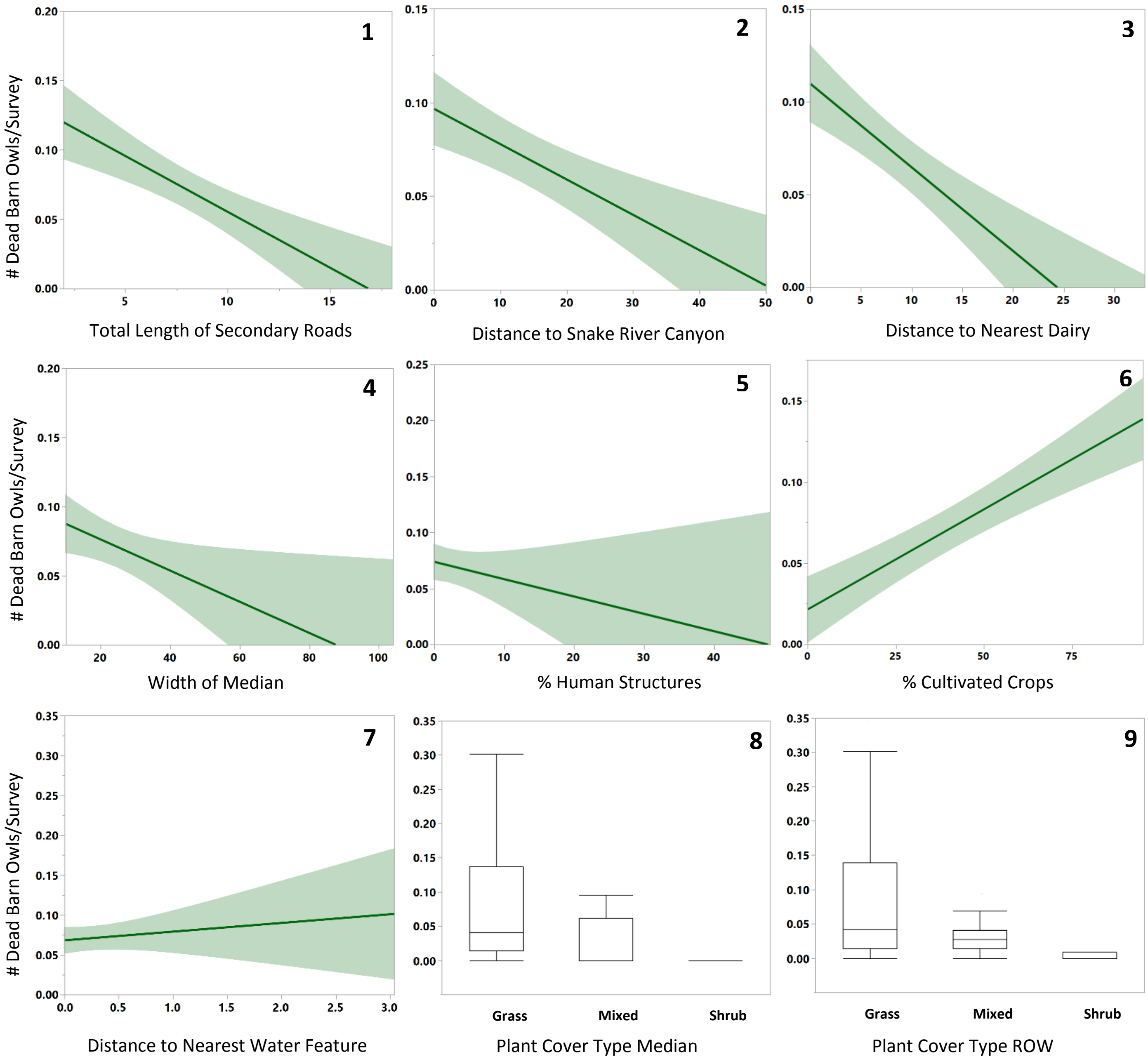


Figure 30. Model Based Relationships Between Number of Road-killed Barn Owls per Survey in 1-km Segments along I-84/86

(for Variables in Top Model)

Spatial, Geometric, and Biotic Characteristics of Mortality Hotspots

Based on the point density estimate maps produced in Chapter 4, there were n = 6 sampling sites that ultimately fell into an areas classified as a mortality hotspot (i.e., > 5.34 owls/km/year or 9 owls/mi/year, coded as yellow, orange or red in Figures 18 through 21) and n = 114 sites outside of the hotspots. The research team then examined characteristics of the two types of sites for the 14 spatial, geometric, and biotic variables selected for final modeling.

For the spatial variables, sites in mortality hotspots had low values for Distance from the Snake River (5DistSRC_avg), Distance from Nearest Dairy (3DistDairy_min), Cumulative Road Length (1RdLength) and Distance to Nearest Water Feature (3DistWat_min) relative to many of the sites not within hotspots (Figure 31).

For the geometric variables, mortality hotspots did not have the highest levels of commercial traffic (CAADT), but they generally had low slopes (1Slope), fewer km of obstructions to low flight (5Ob), narrow medians (WofM) and flexible rather than rigid pavement type (Figure 32).

Among the biotic variables, sampling sites in hotspot locations had small mammal abundance index (AI) values that were 2 to 6, as none of the hotspot sites lacked rodents (index = 0), whereas there were sites outside that had index values = 0 or 1 (Figure 33). Hotspot sites had grass rather than shrubs or mixed shrubs and grass (Figure 33) in both the ROW (3CovTypeROW) and median (5CovTypeM) and high percentages of crops. Hotspots typically had small percentages of human structures (1HS) (Figure 33).

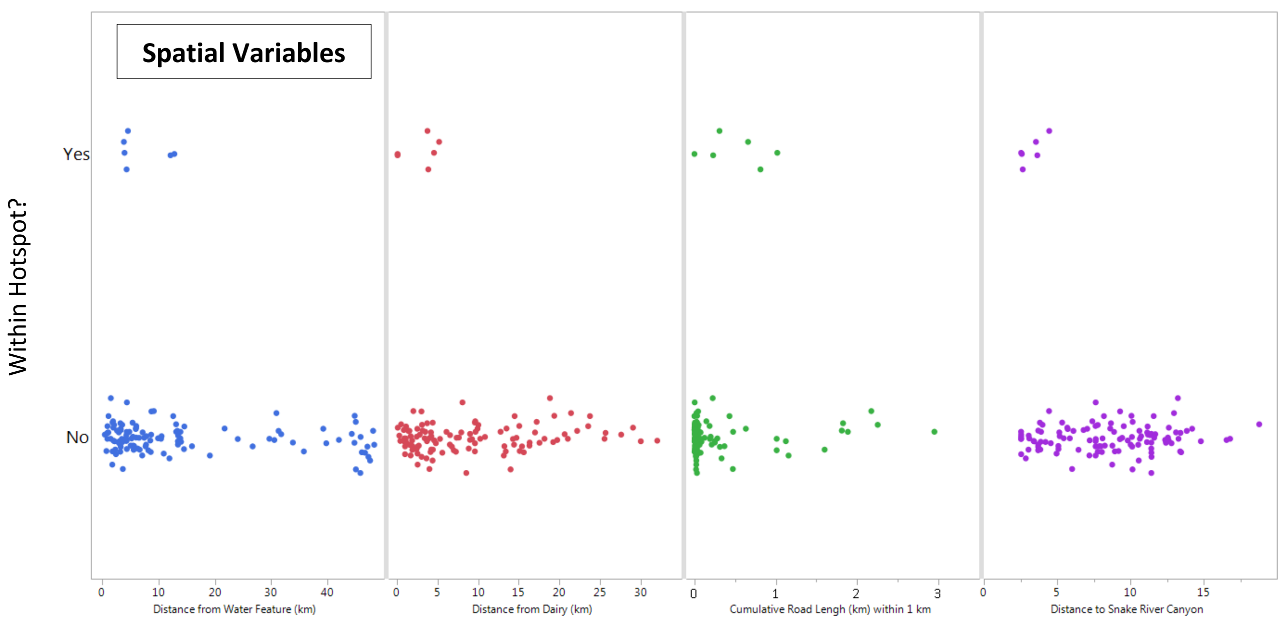


Figure 31. Scatterplot of Spatial Characteristics of Sampling Sites along I-84 within Barn Owl Mortality Hotspots (n = 6) Relative to Others (n = 114)

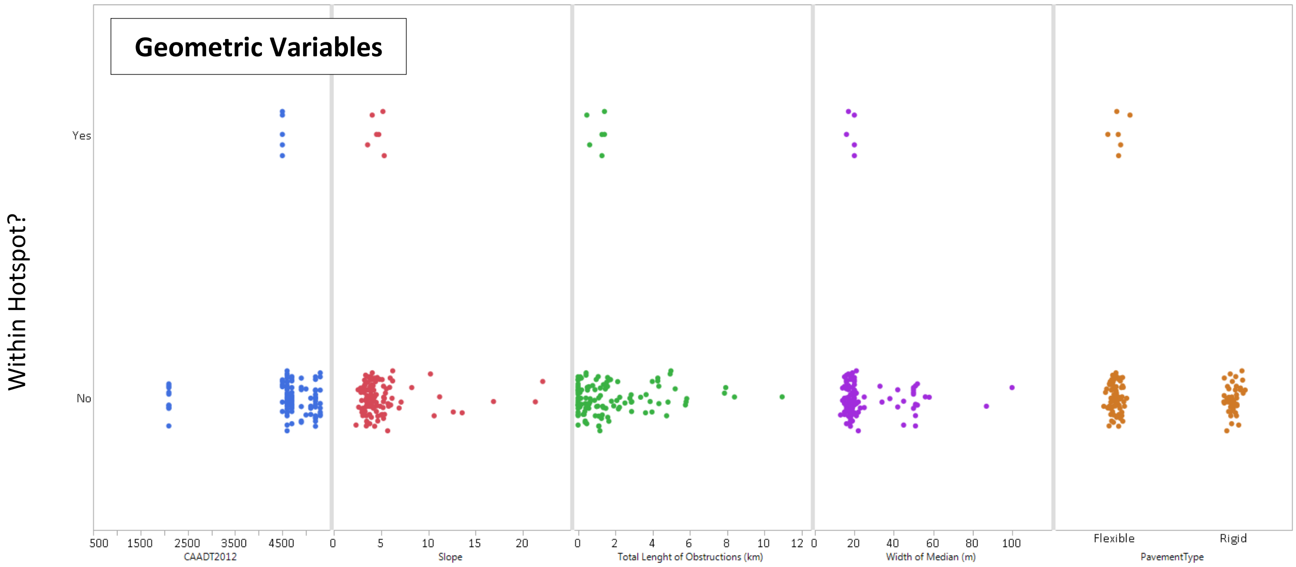


Figure 32. Scatterplot of Geometric Characteristics of Sampling Sites along I-84 within Barn Owl Mortality Hotspots (n = 6) Relative to Others (n = 114)

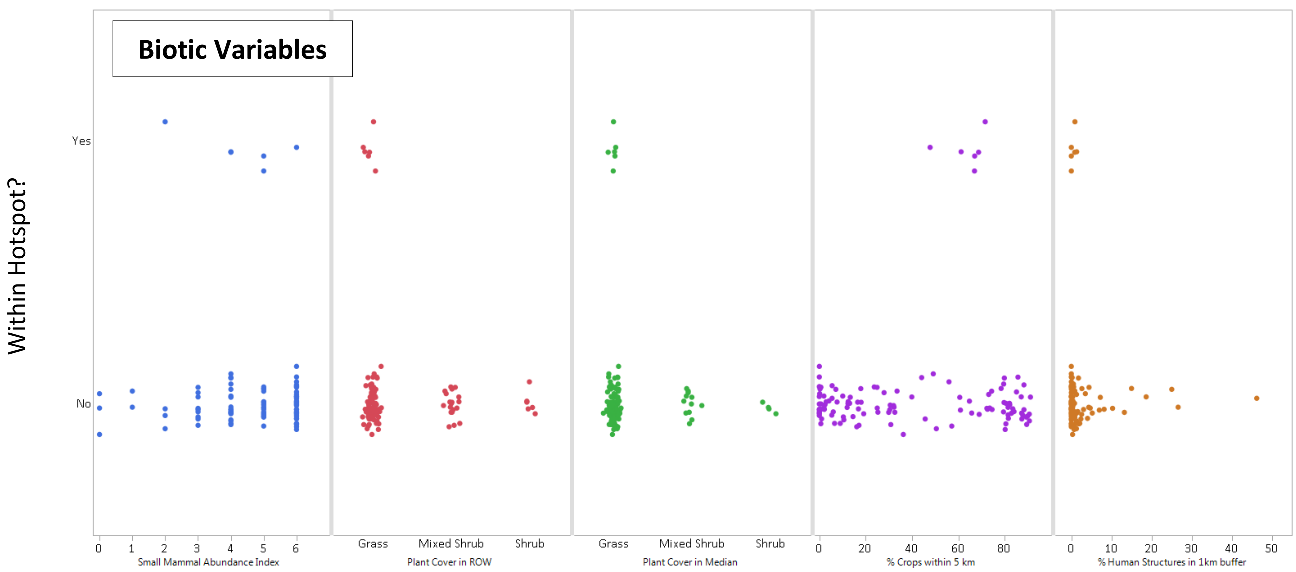


Figure 33. Scatterplot of Biotic Characteristics of Sampling Sites along I-84 within Barn Owl Mortality Hotspots (n = 6) Relative to Others (n = 114)

Conclusions

After assessing a suite of spatial, road geometric, and biotic features potentially associated with barn owl-vehicle collisions, research findings indicated that barn owl carcasses along I-84/86 increased with percentage of cultivated crops and distance from water features, and as length of secondary roads, distance to Snake River Canyon, distance to nearest dairy, width of the median, and percentage of human structures decreased. Barn owl mortality was also higher when there was grass in the median and ROW when compared with sites where plant cover type was shrubs, and this could reflect the suitability of grassy areas for both small mammals and owl hunting and the lack of “huntability” in areas with taller shrubs.

Some portions of I-84 had barn owl mortality rates of > 5.34 owls/km/year (9 owls/mi/year), which the research team categorized as mortality hotspots. Barn owl mortality hotspots were situated close to the Snake River Canyon, which offers potential barn owl nesting and roosting sites and may operate as a dispersal corridor for owls,[(1)] near dairies, away from water features, and in areas with few secondary roads. The hotspots had low slopes (level terrain), few kilometers of obstructions to low flight, narrow medians, and flexible rather than rigid pavement type. The hotspots were not necessarily in regions of I-84 with the greatest traffic volume (CAADT). Finally, hotspots had moderate to high small mammal abundance, grass plant cover types, and a high percentage of crops and a low percentage of human structures surrounding them. In general, hotspots were in rural areas dominated by various forms of agriculture including dairies and crop production. Thus, the surrounding landscape, as well as road geometric and biotic (prey, cover types, and plant height) factors, all appear to have some influence on owl mortality hotspots.

These findings are similar to those of Boves and Belthoff in that those authors found mortality was highest in areas close to the Snake River Canyon and in agricultural settings.[(1)] However, Belthoff and Boves examined only those two aspects of mortality areas. Our research extends understanding of barn owl mortality along I-84 by describing a suite of other spatial, road geometric, and biotic factors related to barn owl mortality and characteristics of mortality hotspots.

Chapter 7
Citizen Science Components: Major Roads Other than I-84/86

Overview

The main objective for this portion of the study was to establish public-private partnerships among transportation agencies, natural resource agencies, university researchers, and citizen scientists to work on owl-vehicle collision data collection, research, and, ultimately, mitigation. Citizen science has become increasingly popular in recent years, and is being used in a number of scientific disciplines, including ecology.[73,74,75] For this research, citizen scientists helped in expanding the number of roads surveyed for locations of dead barn owls. Other meaningful relationships were also established during the study, with collaboration between ITD, Boise State University, IDFG, and WTI.

Findings

A total of 10 teams (1 or 2 people) responded to requests for volunteers for this study and agreed to participate. Of these 10 teams, six were ultimately able to participate. Each team completed between two and 65 survey routes between March 12, 2014 and June 13, 2015. There were a total of 10 different survey routes, varying in length between about 24 and 224 miles, some of which were adjacent to each other or overlapping (Figure 34).

Most of the surveys completed by volunteers were on different highways or different sections of the

Figure 34. Routes Citizen Scientists Surveyed in Southern Idaho

Red: carcasses found outside of standardized survey route. Yellow: carcasses citizen scientists found along standardized survey route.
(Google Earth)

interstates than the standardized surveys and ad hoc surveys described earlier. However, some volunteers also did surveys while driving the routes of the standardized surveys. Of the routes that were different than the standardized surveys, a total of 109 one-way surveys were completed, including one survey that covered four different highways/interstates in a loop. Volunteers surveyed approximately 6,000 miles total, giving nearly 110 hours of effort. Despite this enormous survey effort, only nine barn owl road kills were reported (Table 12).

Table 12. Supplementary Survey Routes Citizen Scientists Completed

Highway/ Interstate	Road segment	Estimated number of miles (1 direction)	Number of surveys on route (1 direction)	Estimated total number of hours driving survey route	Number of road-killed barn owls reported
I-84	Boise to OR-ID border	54	3	NA[1]	3
US 20/ Hwy 33	Idaho Falls (US 20, exit 310) to Driggs (Hwy 33, M.P. 141)	70	22	33.48	0
I-15	Idaho Falls to MT-ID border	77	13	16.50	1
I-15	Idaho Falls (exits 116 & 119) to Sage Junction (exit 143)	24 - 27	10	3.27	1
I-15	Idaho Falls (exits 116 & 119) to Roberts (exit 135)	16 - 19	4	1.15	0
I-15	Idaho Falls (exit 118) to UT-ID border	118	5	11.25	0
I-15	Idaho Falls (Exits 112-119) to Pocatello (exits 69-72)	44 - 47	32	20.15	4
I-15 - loop[2]	Exit 36 to exit 47	11	1	0.25	0
US 30 - loop[2]	Intersection of US 30 & I-15 (exit 47) to intersection of US 30 and Hwy 34	27	1	1.75	0
Hwy 34 - loop[2]	Intersection of US 30 & Hwy 34 to intersection of Hwy 34 & US 91	43	1	1.0	0
US 91 - loop[2]	Intersection of Hwy 34 & US 91 to Preston (intersection of US 91 and I-15, exit 36)	33	1	1.0	0

Highway/ Interstate	Road segment	Estimated number of miles (1 direction)	Number of surveys on route (1 direction)	Estimated total number of hours driving survey route	Number of road-killed barn owls reported
US 91	Idaho Falls to Chubbuck (intersection of US 91 & I-86, exit 61)	45	19	17.93	0

[1]Complete survey route was from I-84 at the beginning of I-86 to the Oregon-Idaho border; time to complete the section reported here is not available.

[2]Though presented by highway in this table, these four road segments were driven as one survey route.

For the two routes that were the same as the standardized surveys, volunteers completed a total of 16 one-way surveys. They surveyed approximately 1,840 miles in total, giving about 23 hours of effort. In these surveys, they reported 46 barn owl road kills (Table 13).

Table 13. Survey Routes Completed by Citizen Scientists that Overlapped Standardized Routes

Highway/ Interstate	Road segment	Estimated number of miles (1 direction)	Number of surveys on route (1 direction)	Estimated total number of hours driving survey route	Number of road-killed barn owls reported
I-84	Beginning of I-86 (exit 222) to Boise (exit 52)	169	7	14.67[1]	35
I-86	Beginning of I-86 to intersection with I-15	73	9	7.83	11

[1]Four of the surveys were from I-84 at the beginning of I-86 to Boise (reported here), while three were from I-84 at the beginning of I-86 to the Oregon-Idaho border; time to complete the portion of the three surveys to the OR-ID border reported here was estimated based on averages of the other four.

Conclusions

The research team established partnerships among ITD, IDFG (road kill website), universities (Boise State University and Montana State University) and the public (citizen scientists). Citizen scientists not only supplemented data for this research, but they also added data to the IDFG Roadkill and Salvage database.

Of the nine barn owl carcasses that volunteers located along supplemental routes, three were found on I-84 outside of the standardized survey routes between Boise and the Idaho-Oregon border. The remaining carcasses were along I-15, where the volunteers focused a large part of their survey efforts.

Volunteers found far fewer barn owl carcasses on the non-focal highways, especially when considering that many more total miles were surveyed along the non-focal highways. This indicates that the pattern of high mortality along I-84 and I-86 as compared to other highways and interstates in the area is not just an artifact of the survey methodology. Rather, it likely reflects the reality that there is a much higher mortality rate in the focal area.

In line with the objectives, the project team established partnerships and working relationships through this study that are now solidly in place and that may facilitate possible future research on mitigation.

Chapter 8
Mitigation Recommendations from the Literature

Mitigation Recommendations Appearing in the Literature

The published literature is rich with examples of studies that document large numbers of barn owls being killed along roads, as well as some studies that examine spatial, geometric, and biotic factors associated with road mortality. However, examples of on-the-ground mitigation and their efficacy in reducing barn owl mortality along roads are missing. Indeed, birds present several road mortality mitigation challenges compared to other vertebrates.(76) Although millions of birds and a large portion of the barn owl population may be lost each year, Bishop and Brogan pointed out that there have been no mitigation measures for birds incorporated into road construction in Canada (but see recent mitigation example from British Columbia, this chapter).(65) Indeed, while not referencing mitigation to reduce bird mortality *per se*, Lesbarreres and Fahrig reported that "up to now, road mitigation research has mostly languished in a backwater where studies lack scientific rigor, are reported in obscure outlets and are ignored by the larger research community and the road planning community."(71)

For barn owls, mitigation recommendations have centered on several main themes, including:

- Establishing tall vegetation or other barriers that force owls to fly higher above highways while crossing.
- Removal of small mammals or their habitat from highway ROW to make these areas less attractive hunting grounds for barn owls.
- Providing suitable habitat away from roads to provide barn owls the resources they need elsewhere.

Table 14 provides a summary of mitigation recommendations that appear in the literature followed by some expanded comments contained within each reference.

Expanded Literature Descriptions

Vegetation Management to Reduce Rodents and/or Discourage Owl Hunting

de Bruijn suggested regular grass cutting to reduce vole populations along stretches of metalled (paved) roads that are known to bring about high rates of traffic mortality of barn owls.(42) He suggested this could also be achieved by planting trees and by creating high shrubs along these stretches.

Mead indicated that both minor and major roads are lethal for owls attracted to small mammals along the grass edges.(77) He noted "The management of these edges to discourage owls from hunting is crucial. It seems that allowing rank vegetation to grow thickly is a possible strategy, but more work needs to be done."

Table 14. Summary of Mitigation Recommendations that Appear in the Literature

1. Vegetation Management to Reduce Rodents and/or Discourage Owl Hunting		
Regular grass cutting to reduce voles	The Netherlands	de Bruijn[42]
Allow rank vegetation to grow thickly (e.g., brambles) to reduce prey and discourage hunting	Great Britain	Mead[77]
Allow bramble or gorse to spread across entire width of ROW to reduce voles and discourage owl hunting	Great Britain	Ramsden[10]
Stop systematic mowing so that brambles, thorns, and broom will take over grassy areas and discourage owl hunting	France	Baudvin[53]
Reduce prey near roads by changing vegetation or removing it by plowing	Portugal	Grilo et al.[7]
2. Barriers to Flight		
Allow hedges to grow high on roadsides to force owls to flying higher above road	Great Britain	Shawyer[43]
Create continuous 2-3 m hedges immediately next to roads to force owls to fly higher	Great Britain	Ramsden[10]
Regardless of whether trees or shrubs are used, any continuous low-flight obstruction (e.g., fence) would force birds to fly higher over roads and reduce mortality	Great Britain	Ramsden[10]
Forcing barn owls to fly high by minimum hedgerow height or narrow band of trees of at least 4 m	Canada/Great Britain	Garland[78] cited in Preston and Powers[64]
Diversion poles or short fences along highway medians and ROW		Jacobson[79]
3. Create Suitable Habitat Elsewhere		
Reduce owl prey in areas of highway or *enhance it elsewhere*	Portugal	Gomes et al.[6]
Establish complementary corridors of suitable grassland outside the ROW parallel to road exclusion fence on both sides	Portugal	Grilo et al.[7]
4. Reduce Traffic Speed		
Speed rather than density of traffic important for owl mortality, so reduce traffic speed	Germany	Illner[2]
Over 100 times as many barn owls killed on major roads with high vehicle speeds, so reduced speeds potentially could save owls	England	Ramsden[10]

Ramsden stated that "there can be little doubt that the creation of continuous 2–3 m (6–10 ft) hedges immediately next to the metalled surface of all major roads in Britain would drastically reduce barn owl road mortality, but safety considerations, current landscape policies and the conservation of other wildlife mean that the scope for creation is limited."[10] Reducing the availability of small mammals on road verges has been suggested, but Ramsden noted it is generally impractical and undesirable for a variety of reasons. For instance, even where major roads have no verges, or verges without rough grass, barn owls are killed.(10) In some areas, dense ground cover such as bramble or gorse has been allowed to spread across the entire width of the verge, which has greatly reduced barn owl access to small mammals; in areas where the loss of verge grassland is acceptable, such ground cover would reduce the attractiveness of the verge to barn owls and may reduce mortality.(10) Ramsden concluded that further research is needed to determine the effectiveness of such measures but feels current indications are that it would be much less effective than the creation of low-flight prevention barriers/screens.

Baudvin made recommendations to Societé des Autoroutes Paris Rhin Rhone (SAPRR) in France to address the high mortality of raptors along the motorway, and the recommendations are "being realized."(53) His recommendations were (1) areas showing a high rate of mortality will no longer be systematically mown so that vegetation will grow naturally (brambles, thorns, and broom) and (2) low bushes will be planted which would decrease vole availability and thus the number of their predators. Along with these attempts aimed at reducing mortality, Baudvin described other measures to simultaneously "help the birth rate: erection of nest boxes, making breeding sites safe from predators or weather conditions." He described that helping to increase the birth rate of focal raptors is a "way to counterbalance the excessive roadway caused mortality."(53)

Grilo et al. recommended exploring the response of individuals to a reduction in prey alongside verges and raising the height of roadside verges in road sections with mortality; reducing prey near such road sections could be done by changing the vegetation next to road verges (e.g., plowing).(7)

Barriers to Flight

Shawyer mentioned that it is difficult to tackle the problem of high road mortality of barn owls but stated "some success has been achieved by allowing hedges to grow high on roadsides where barn owls have habitually crossed. This forces them to fly higher above the road thus avoiding collision with cars and lorries."(43:196)

Preston and Powers discussed a number of potential mitigation efforts that they feel could be employed to reduce the incidence of barn owl collisions with vehicles in British Columbia.(64) They noted that each will almost certainly require cooperation among federal, provincial, and municipal governments, as well as with private landowners. Below is excerpted from Preston and Powers and their discussion of mitigation approaches for roads in British Columbia:

> "*1) Roadside vegetation mowing: In the United Kingdom, Garland (2002) assessed the possibility of mowing roadside vegetation to reduce small mammal populations, and hence, barn owl foraging and subsequent vehicular collisions. The project was based on one mowing per year, which in turn reduced field vole (Microtus agrestis) abundance by 40 percent, but increased wood mouse (Apodemus sylvaticus) abundance by 14 percent. Although it was initially anticipated that roadside verges would only have to be mowed once every three years, Garland (2002) later concluded that they would have to be mown more often, which was considered neither economically feasible nor desirable. As an alternative to mowing, Ramsden (2003) suggested*

> *creating high density prey areas to draw birds away from roadways. This approach appears ecologically counter-intuitive for two reasons: 1) adults would likely dominate the better areas and juveniles would be forced to hunt roadside verges and suffer higher mortality rates; and 2) a higher prey base would support higher numbers of barn owls but not diminish the probability of roadside foragers being hit.*
>
> *2) Planting dense shrubbery: Baudvin (1997) suggested that by planting dense shrubs along roadside verges, access to small mammals by barn owls would be greatly reduced. However, the general thought to reduce wildlife mortality on roads is to reduce vegetative cover. Ramsden (2003) agreed that although barn owl mortality may be reduced, this method would likely have consequences for many other species.*
>
> *3) Forcing barn owls to fly high: In France, road mortality of barn owls was always lower when the road was sunken rather than level or raised (Massemin and Zorn 1998), and in the United Kingdom when a hedgerow (a narrow band of tall trees or shrubs) was present (Garland 2002). Garland (2002) recommended a minimum hedgerow height of 4 m (13 ft), which we assume is meant to be above the height of the road surface. Ramsden (2003) acknowledged that regardless of whether trees or shrubs are used, any continuous low-flight obstruction (e.g., fence) would force birds to fly higher over roads and reduce mortality, regardless of prey availability, how often the roadway was used by the owl, or how many vehicles there were. For much of the Central Fraser Valley, we urge a note of caution with this method because Highway 1 is a divided highway, which may result in birds dropping down to forage in the median, and possibly becoming trapped or confused with no readily accessible escape route."* [64:20-21]

Several species of owls, particularly barn owls, great horned owls, and short-eared owls (*Asio flammeus*) forage near roads at about the same height as vehicle windshields and are therefore common victims of vehicle collisions.[79] Jacobson suggested that "a low fence or fence material such as plastic construction fence or closely spaced, frangible reflective highway markers may be effective if installed along highway verges and medians."[79]

Create Suitable Habitat Elsewhere

Gomes et al. stated that in addition to the relatively good habitat provided adjacent to most roads, hunting issues seem to be the principal cause of road casualties in Strigiformes.[6] Consequently, "mitigation measures must focus on reducing owl prey in areas of highways or enhancing it elsewhere."

Grilo et al. suggested complementary corridors of suitable grassland with the same verge width should be left beyond the road verge, parallel to the road exclusion fencing on both sides.[7]

Traffic Speed

Because there appears to be a relationship between traffic speed and the rate of barn owl-vehicle collisions, it is possible that reduced speed limits may modulate rates of owl mortality. For instance, with car speeds regularly greater than 80 km/h (50 mph) , about 21 times as many owls (including barn owls) were killed by cars as on the other roads, and speed of vehicles rather than density of vehicles seemed to be the more important factor.[2] There were 111 times as many barn owls killed on major roads (e.g., motorways, dual carriageways and modern A roads) with high vehicle speeds as compared to minor roads with lower speeds.[10] It is plausible, therefore, that reducing speed limits would help reduce the number of owl casualties. A reduction in speed limits might be especially productive during those seasons when mortality is greatest (winter).

British Columbia Example of Barn Owl Mitigation along Highway

As part of the current research, the principal investigator toured project sites and conferenced with project biologists involved in a barn owl roadway mitigation project near Vancouver, British Columbia, Canada. This project is among the few mitigation projects aimed at reducing roadway mortality of barn owls in North America.

The South Fraser Perimeter Road (SFPR) is a new four-lane, 80 km/h (50 mph) highway that extends 40 km (50 mi) along the south side of the Fraser River in British Columbia near Ladner and Delta (Figure 35). This new alignment was completed in December 2013. As the SFPR was to traverse sensitive environmental areas for fisheries and wildlife, the BC Ministry of Transportation pursued mitigation measures. These included building more than 40 environmental areas, 25 wildlife crossings and one bumble bee habitat, to help berry farmers with pollination.

Figure 35. Map of Gateway Projects near Vancouver, British Columbia including the South Fraser Bypass Road (SFBR)

(map produced by University of British Columbia Geography)

Because the SFPR traversed agricultural areas important to barn owls, there were conservation actions related to this species (Figures 36, 37, 38). Among the mitigation activities implemented were:

- Planting of hedgerows (cedars).
- Tall fencing near overpasses.

These are designed to encourage barn owls to fly above the highway. The mitigation projects are still too new to understand their efficacy, and follow-up monitoring for dead barn owls is occurring along SFPR.

Figure 36. Photos of SFPR near Vancouver, BC Illustrating Coniferous Trees Planted to Reduce Barn Owl-Vehicle Collisions

Figure 37. Photo of Vegetation (Cedars) Designed to Reduce Barn Owl-Vehicle Collisions along SFPR in British Columbia

Figure 38. Photo of Chain-Link Fencing (indicated with arrow) to Prevent Low Flight by Barn Owls near an Overpass along SFPR

Chapter 9
Conclusions and Recommendations

Conclusions

Barn owl-vehicle collisions continue to occur in high numbers along I-84/86, as they did in 2004 to 2006.(1) During the initial study, as many as 105 dead barn owls were detected in a single road survey conducted between Boise and Burley, Idaho.(1) In the current study, the research team found up to 230 dead owls between Boise and Pocatello during a single road survey. While mortality occurs in many portions of I-84/86 between Boise and Pocatello, there are areas where the rate of barn owl-vehicle collisions is especially high (hotspots). The areas identified as hotspots are generally similar between the 2004 to 2006 surveys and the 2013 to 2015 road surveys conducted as part of this study, although there have been some expansions and contractions. Despite different survey frequency, traffic patterns, and traffic speeds in some cases, surveys of other roads in southern Idaho performed by citizen science partners also documented dead barn owls. However, numbers were lower than those recorded along I-84/86, and they were especially lower than rates the research team documented in the hotspots. Nonetheless, results indicated that barn owl-vehicle collisions are widespread in southern Idaho, but the most pressing problem with barn owl-vehicle collisions appears to occur along I-84 among those roads surveyed.

A number of portions of I-84 had barn owl mortality rates >5.34 owls/km/year (9 owls/mi/year), which the research team categorized as mortality hotspots. After assessing a suite of spatial, road geometric, and biotic features potentially associated with barn owl-vehicle collisions, results indicated that barn owl mortality hotspots were situated close to the Snake River Canyon and near dairies, perhaps because of the abundance of roost and nest sites. However, it is interesting to note that barn owl mortality hotspots were located away from water features. While the Snake River Canyon is a water feature, in contrast to the distance to water features parameter in this study, the distance to the Snake River Canyon parameter represents areas of high barn owl density and movement, as its unusually high canyon walls provide an abundance of roost and nest sites and the canyon may act as a possible dispersal corridor.

Barn owl mortality hotspots were located in areas with few km of secondary roads and only a small number of human structures nearby. This may be explained by dilution of road mortality where there are more secondary roads, however, the research team believes it is likely the result of more suitable habitat where there are fewer secondary roads. The hotspots also had flat slopes (level terrain), few km of obstructions to low flight, narrow medians, and they were in regions where the predominant pavement type in the vicinity was flexible rather than rigid. The hotspots were not necessarily in regions of I-84 with the greatest commercial truck traffic volume. Finally, hotspots had moderate to high small mammal abundance, grass plant cover types in the ROW and median, and a high percentage of crops in areas surrounding the road. This may reflect the suitability of grassy areas and croplands for both small mammals and owl hunting and the lower capability of owls to hunt in areas with taller shrubs. This may also partially explain some of the seasonality seen in barn owl mortalities (increase in autumn and winter). It is likely that crops provide good habitat for small mammals and good hunting for barn owls for a large portion of spring and fall, but in autumn and winter, small mammal populations in fields may be greatly reduced and barn owls may choose other suitable areas to hunt, including grassy ROW and medians.

High numbers of dead barn owls across two multi-year studies about a decade apart indicate that the high mortality rate is not a one-time occurrence. Rather, barn owl-vehicle collisions continue along this interstate. Furthermore, the fact that collision hotspots have remained similar over this duration indicates that these specific road segments are the areas of greatest concern. Targeting these areas for mitigation would have the largest impact in reducing barn owl-vehicle collisions and reducing the negative effects on the barn owl population in southern Idaho.

Recommendations

The authors recommend that ITD consider implementing mitigation along I-84 and supporting further research about barn owls and effective highway mitigation approaches. Mitigation actions to reduce barn owl mortality along I-84/86 are warranted given project findings. These actions have the potential to be most efficacious if they focus on developing screens/barriers to restrict low flight of owls and promoting shrubs or other taller vegetation rather than grass as roadside vegetation. The highest priority locations for mitigation would be the mortality hotspots that this research and that of Boves and Belthoff outlined.(1) The research team also recommends that ITD work cooperatively with other agencies to more fully understand the impacts of the substantial barn owl mortality along I-84 and to acquire, enhance, or protect areas that contain suitable habitat for barn owls as one means to offset road mortality.

1. Mitigation

Locations

The highest priority locations for mitigation are I-84 between Bliss and Hazelton (Figures 19 and 21). While barn owls are also killed between Boise and Glenns Ferry (Figure 18), and between Burley and Pocatello (Figures 20 and 21), findings show that the portion of I-84 between Bliss and Hazelton is most problematic. Mortality hotspots and the areas near them in this portion of I-84 are therefore recommended for mitigation.

Specifically, researchers recommend mitigating the hotspots outlined in Chapter 4 (Table 7). There are four priority hotspots ranging in length from 0.5 km (0.3 mi) to 4.5 km (2.8 mi). These four hotspots are a combined length of 11.8 km (7.3 mi). The areas surrounding these hotspots also kill owls, so extending mitigation beyond the immediate boundaries of each hotspot will be useful.

North of Hagerman – M.P. 143.0 – 145.0

The research team recommends that the section of I-84 just north of Hagerman (M.P. 143 – 145) be considered high priority for mitigation. This hotspot was identified in both studies (2004 – 2006 and 2013 – 2015) as well as when the data from both studies were combined (Figures 19 and 21).

Southeast of Hazelton – M.P. 190.0 – 191.0

A second high priority location recommended for mitigation is the mortality hotspot along I-84 southeast of Hazelton (M.P. 190 – 191, Figures 19 and 21). This section is only 0.5 km (0.3 mi) long but accounts for 1.2 percent of the total barn owl carcasses in the combined data set (2004 – 2006 and 2013 – 2015).

Wendell M.P. 150.09 – 154.0 & Kimberly M.P. 179.0 – 181.0

The team also recommends mitigation at the hotspots along I-84 near Wendell (M.P. 150 – 154) and Kimberly (M.P. 179 – 181; Figures 19 and 21). While each of these were hotspots in only one of the studies (2013 – 2015 and 2004 – 2006, respectively), both were hotspots in the combined data set, and in the combined data they represented a substantial portion of the total carcasses observed (6.5 % and 4.8 %, respectively).

Specific Mitigation Recommendations

Though the literature is lacking in formal studies on the efficacy of mitigation for barn owl-vehicle collisions, there is information available on measures that have been implemented or are hypothesized to be effective. The following recommendations are based on suggestions in the literature, authors' knowledge of other mitigation projects (e.g., South Fraser Perimeter Road in British Columbia), and the results of this study.

Mitigation Recommendation 1: Establish Barriers to Low Flight by Barn Owls

Mortality hotspots along I-84 are generally devoid of low flying obstructions. Given this and other available information, the research team hypothesizes that barriers to low flight are the most efficacious route to reducing barn owl-vehicle collisions. However, specific rates of reduction remain to be determined because no previous studies are available from which to estimate effects. The Barn Owl Trust (Devon, England) website describes major roads in England where tall vegetation screens potentially reduced number of dead owls to zero however (http://www.barnowltrust.org.uk/hazards-solutions/barn-owls-major-roads/).

Low flight barriers should be developed on both sides of the interstate and as close to the paved traffic lanes as safety consideration will allow. In high mortality areas where medians are wide, low flight barriers may also be considered in the median. The barriers should extend at least 4 m (13 ft) above the road surface. However, 5 m (16 ft) would be preferable to promote the highest flight and clearance above semi-trucks.

Barriers to low flight can be constructed in a variety of ways, and with a variety of materials. Each of these has advantages and disadvantages that may vary by location. Below are some options that the authors believe have the potential to be effective along I-84.

Establish Barriers to Low Flight by Barn Owls

Vegetation in the Form of Hedges or Trees:

Advantages:

- More visually acceptable to motorists than nets, fencing or berms.
- Once established, little maintenance or cost is required.
- Implementation costs anticipated to be moderate compared to other recommendations.
- Ecologically, would provide diversity and habitat for other species, especially if using native species (but see related disadvantage below).

Disadvantages/Challenges:

- Requires establishment period.
- Potential need for irrigation in high-desert climate of southern Idaho.
- Would need to be planted outside of the Interstate's clear zone (recovery area for errant vehicles), which may reduce the effectiveness of barrier.
- Potential to alter the habitat near the road, creating more perching opportunities for raptors, and possibly attracting other species of wildlife to highway.

Bird Netting:

Advantages:

- Benefit is anticipated to be immediate.
- May be more visually acceptable to motorists than fencing.
- Likely provides fewer perches for owls and other raptors as compared to fencing and vegetation.

Disadvantages/Challenges:

- Potential for entanglement of owls or other wildlife.
- Potential to act as undesirable barrier to other wildlife.
- Possible secondary mortality.
- Implementation and maintenance costs are unknown but may be higher than other recommendations.

Fences (snow, exclusionary, pole barriers or other)[80]

Advantages:

- Benefit is anticipated to be immediate.
- Snow fence may reduce blowing snow and dirt across interstate.

Disadvantages/Challenges:

- Potential to provide added perches near the interstate for owls and other birds, which might contribute to increased interactions with traffic.
- Potential to act as undesirable barrier to other wildlife. This could likely be remedied by constructing gaps within fence sections.
- Possible secondary mortality.
- Implementation costs are unknown but could be high considering amount of material and installation costs.

Earthen Berms Combined with other Barrier Recommendations:

Advantages:

- Benefit is anticipated to be immediate (unless combined with hedges or trees).
- Once established, little maintenance or cost required.

Disadvantages/Challenges:

- Would require erosion control maintenance until stabilized.
- Potential to act as undesirable barrier to other wildlife unless constructed with gradual slope.
- Location and configuration of the berm would need to meet highway safety requirements, which could make the barrier less effective.
- Potential motorist safety consideration depending on construction.

When constructing many of the low flight barrier options, it is necessary to minimize secondary mortality and possible undesirable barrier effects to other wildlife. The barrier needs to be visible to both diurnal and nocturnal species most likely to encounter them. Structures should be equipped with Flash Tape or a similar material to deter birds, and escapes should be provided for animals that may become entrapped within ROW between mitigation structures. Biologists, ecologists and/or engineers with knowledge of the species concerned and knowledge of best practices should be consulted to ensure proper design.

Mitigation Recommendation 2: Vegetation Management

Results from this study show that fewer rodents are found in areas with shrubs in the ROW. Taller vegetation approximately ≥ 1 m (3 ft) has potential to discourage owl foraging as well, so researchers recommend encouraging taller shrubs rather than short grass in the median and ROW. This may be done in two primary ways. The first method is to prevent the loss of shrubs in areas where they currently occur. Maintenance procedures affecting vegetation, such as mowing schedules and methods, can be modified to encourage shrubs and taller vegetation. Second, the research team recommends restoring native shrubs or planting suitable taller 'scrub' vegetation in areas of high barn owl mortality where disturbed shorter grasslands currently occur in the median and ROW. A key would be for shrubs to have sufficient density to minimize open patches for owl hunting. In contrast, it might be possible to reduce rodent abundance in some areas by very frequent mowing to keep vegetation heights at very low levels that reduce cover and forage for any small mammals.

Vegetation Management: Convert Grass Dominated Areas to Taller Woody Vegetation:

Advantages:

- More visually acceptable to motorists than nets, fencing or berms.
- Once established, little maintenance or cost is required.
- Implementation costs anticipated to be lower than other recommendations.

Disadvantages/Challenges:

- Requires establishment period.
- Possibility of increasing fire fuel potential. (Recommend creating a "no-fuel" buffer area immediately adjacent to the roadway).
- Potential to alter the habitat near the road, creating more perching opportunities and possibly attracting other species of wildlife to highway.

Mitigation Recommendation 3: Establish Barriers to Low Flight by Barn Owls and Vegetation Management

The most effective mitigation strategy may be a combination of low flight barriers and vegetation management described above. The effectiveness of barriers mentioned above would be enhanced by ensuring that the areas between the barriers and traffic lanes are not suitable for owl foraging. This could be accomplished by combining barriers at a safe distance with taller scrub vegetation next to traffic lanes. Alternatively, these areas could be frequently mown to very short heights to reduce suitability for small mammals.

On roads in Great Britain, the Barn Owl Trust (http://www.barnowltrust.org.uk/hazards-solutions/barn-owls-major-roads/) recommends that branches from 'vegetation screens' be allowed to extend to within 1 m (3 ft) of traffic lanes to more fully discourage owls from using roadsides and to force them to fly up and over traffic lanes. It is likely that this would increase the efficacy of barriers to low flight constructed by vegetation along I-84 as well, should safety considerations allow.

Alternative Recommendation: Installing Wildlife Warning Signs to Promote Reduced Speeds

High traffic speeds likely contribute to barn owl-vehicle collisions. If barriers to low flight or vegetation management fail to quell rates of barn owl mortality along I-84, the research team suggests considering installing warning signs to encourage reduced speed limits along I-84.

It is understood that posted speed limits on I-84 are determined by traffic studies, which evaluate factors such as roadway geometrics, prevailing speed and driver's expectation, and that any change to the posted speed would require legislative or policy changes not currently reflected in the traffic speed studies. Given the infeasibility of lowering the speed limit along any portion of I-84 via permanent regulatory signs, the research team suggests installing warning signs as an alternative.

Studies evaluating the effectiveness of warning signs in reducing wildlife mortality are limited, but warning signs are only effective if they modify driver behavior. Research suggests that increased effectiveness can be achieved by restricting the time and location at which the signs are visible. These locations should be limited to only the hotspots. Specifying time and location reduces the driver's tendency to ignore the warnings.(81) Since most owl mortality occurs in the fall and winter, suggesting lower speed limits especially during this time of year may be most effective in reducing barn owl mortality. Additionally, since barn owls are nocturnal the signs could be designed to be employed only when barn owls are active. Finally, a public education/information program to accompany the warning signs could increase awareness and improve the potential for drivers to modify their behavior accordingly.

Supplemental Recommendation: Consider Promoting Barn Owl Habitat Projects

The literature suggests that some negative effects of roads on barn owls persist even many kilometers away from the road.(10) Thus, the research team recommends that ITD work to acquire, enhance, and/or protect important barn owl habitat away from roads. ITD may work cooperatively with land management agencies, municipalities, and private land owners to provide and/or protect habitat for barn owls away from major roads (e.g., I-84). One example of this is nest box programs that provide replacement habitat for barn owls.

Monitoring

Follow-up monitoring of mitigation actions is critical to determine their efficacy and to ensure that barn owl mortality hotspots simply do not shift to other locations after being effectively reduced in mitigation sites. As barn owl-vehicle collisions vary seasonally and annually, an appropriate schedule of multi-year monitoring would be needed to account for such potential variability.(1, this study)

2. Research

Mitigation Experiment

Because there is sparse information from previous mitigation projects related to the efficacy of alternate methods of reducing barn owl-vehicle collisions, the research team recommends that ITD consider implementing mitigation in the form of experiments where feasible. Such experiments could be designed to incorporate a number of mitigation approaches (e.g., vegetation management that promotes tall vegetation in the ROW or increases mowing to keep grass at very short heights, and barriers to low flight of different designs and distances from traffic lanes) with the objective of determining the relative effectiveness of each. Ultimately it could form the basis for a demonstration project centered on reducing barn owl interactions with roads.

Research Barn Owl Population Dynamics

Detailed risk assessments about the likelihood of barn owl population declines are not currently possible for Idaho because barn owl populations are not regularly monitored. Studies of occupancy, demography, movements, interactions with roads, and other factors affecting mortality are needed to fully understand population consequences of the substantial mortality along I-84/86 and to understand the effectiveness of any mitigation implemented. The research team recommends that ITD continue to work with partners such as Idaho Department of Fish and Game, U.S. Fish and Wildlife Service, U.S. Bureau of Land Management, universities, NGOs, and others to develop the needed understanding of barn owl population dynamics.

Research and Development

There are several technologies that are in development or are thought to be effective in deterring owls from the ROW; however, none have been thoroughly tested and some still need development. ITD may consider investing in research and development for one or more of these technologies. For example, laser bird deterrents have promise if they can be safely deployed near roads, but the response of barn owls to such devices is currently unknown. Also, noises and other sounds used at airports and in agricultural settings may help deter owls from roads, but their effectiveness is not known.

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Appendix A
Detailed Methods

Spatial, Geometric, and Biotic Variable Characterization

The research team used ArcMap 10.2 (ESRI 2014) to help characterize spatial, geometric, and biotic variables (Table 3 in Chapter 1) at 120 highway segments centered on small mammal trapping locations. Researchers quantified numerous scale-dependent variables within square buffers that contained highway segments of 1, 3, and 5 km (0.6, 1.8, and 3 mi): 1-km (area = 100 ha/247 acres), 3-km (area = 900 ha/2224 acres), and 5-km (area = 2,500 ha/6177 acres) centered on the 120 small mammal trapping sites (Figure 39).

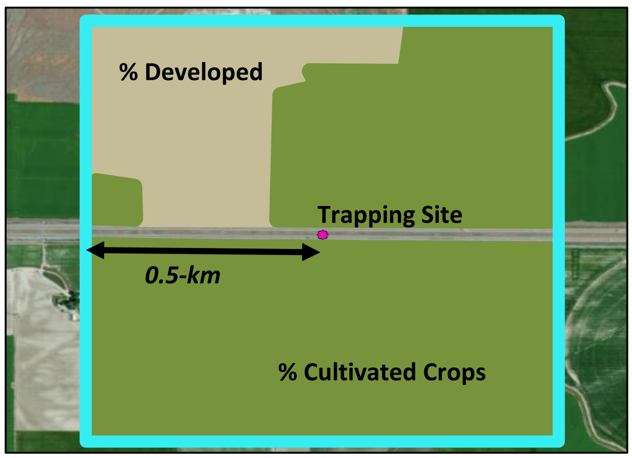

Figure 39. Characterization of I-84 Segments Showing 0.5-km Square Buffer (1-km Sides)

Researchers determined the percentage of each land cover category for the 120 highway locations within each buffer size from the most recent National Land Cover Database (NLCD2011) raster layer. They also used NLCD2011 to calculate the minimum, maximum, and average distance from the nearest agricultural field. They used 100-m (328 ft) increments along the length of a given buffer (Figure 40) to calculate average distances at each of the three scales.

ITD provided GIS data layers that summarized 2012 passenger vehicle average annual daily traffic, commercial vehicle average annual daily traffic, total average annual daily traffic, pavement type, pavement condition, speed limit, shoulder type EB/WB, left/right unpaved shoulder width EB/WB, left/right paved shoulder width EB/WB, total lane width EB/WB, and total road width EB/WB. These data were extracted to each of the small mammal sites (center of the buffer). ITD also provided a layer that contained all roads surrounding the I-84/86 corridor from which the research team calculated cumulative length of secondary roads within each of the buffers.

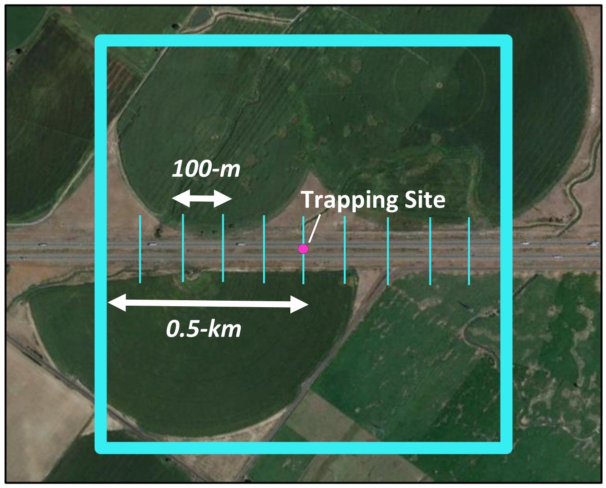

Figure 40. GIS Image Displaying 100-m Increments within a 0.5 km Square Buffer (1-km Sides) Used to Calculate Average Distance

Idaho State Department of Agriculture (ISDA) provided a GIS layer of all registered dairies within the state of Idaho from which the researchers determined total number of dairies within each buffer and the minimum, maximum, and average distance from a given buffer to the nearest dairy. They also obtained a water feature layer from Idaho Department of Water Resources (IDWR) based on the most recent data (1996), from which they calculated minimum, maximum, and average distance to the nearest water feature from a given buffer (calculated using the 100-m [328 ft] increments), average distance to Snake River Canyon (calculated using the 100-m method), and the total length of water features. Slope was calculated using a digital elevation model (DEM) provided by the United States Geological Survey (USGS) EarthExplorer database. The team used standard deviation of the slope for a given buffer as a measure of landscape heterogeneity (standard deviation measures the amount of variation or dispersion in a dataset).

Using Google Earth (2014) researchers manually measured several variables at 100-m (328 ft) increments along the focal interstate between Boise and Pocatello, including width of the ROW EB/WB, number of traffic lanes EB/WB, total number of traffic lanes, habitat in the EB/WB ROW, plant cover type in the median and EB/WB ROW (Figure 41), habitat change past the fence adjacent to the highway EB/WB (yes or no, Figure 42), and embankments/excavations (Figure 43). They then averaged in each buffer for width of the verge EB/WB. We scored the mode for habitat in the EB/WB verge and for habitat in the median. For habitat change past the fence EB/WB (yes or no), they calculated the total percentage of 'yes' values for each buffer. They quantified embankments/excavations using a scale of -2 to 2 at each 100-m segment (-2 = excavated > 5 m, -1 = excavated 1 – 4 m, 0 = flat, 1 = embanked 1 – 4 m, 2 = embanked > 5 m) and averaged values for a given buffer.

Figure 41. Photo of Portion of I-84 Right-of-way with Grass Plant Cover Type

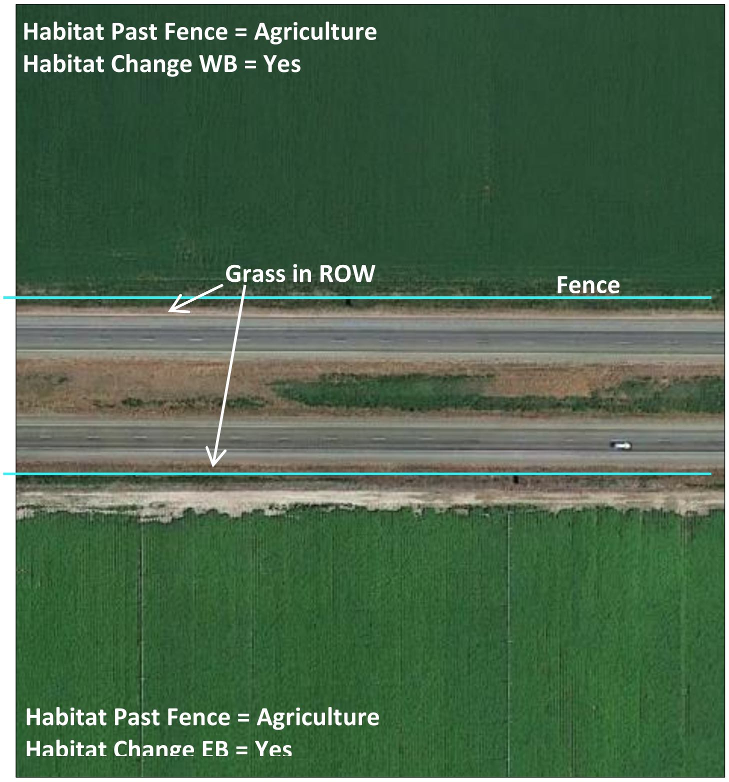

Figure 42. Measurement of Habitat Change Past the ROW Fence

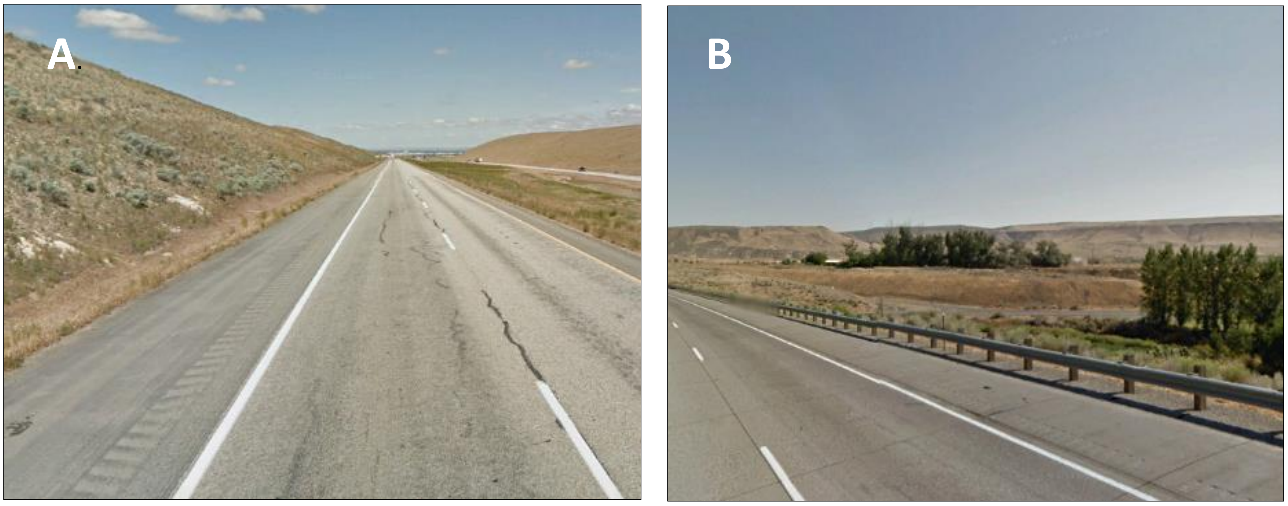

Figure 43. Photos of Segments of I-84 Illustrating (a.) Excavated (sunken) and (b.) Embanked Portions

(Google Earth Imagery)

Using Google Earth (2014), researchers measured obstructions, power lines, and the width of the median manually. Obstructions were measured by marking the start and end points of an obstruction producing a series of line segments along both sides of the highway. They operationally defined an obstruction as anything that may block the flight of an owl (i.e., trees, housing structures, excavated portions of the road, which were at least 5 m (16 ft) in height and within 30 m (98 ft) of the road surface). They used ArcMap 10.2 IESRI 2014) to calculate total length of these obstructions. Power lines were measured using this same method resulting in total length of power lines for each buffer. Width of the median was measured at each of the small mammal trapping sites (center of the buffer). Human structures were digitized using ArcMap 10.2 (ESRI 2014) from which they calculated the percentage of human structures within a buffer.

Small Mammal Abundance Survey

Camera and Track Traps

The research team conducted a small mammal abundance survey along I-84 using a combination of camera and track trapping methods.

Camera Traps

Researchers used trail cameras (M-990i and M80 Moultrie Digital Game Cameras, motion triggered, infrared capable for night photography) to record small mammal occurrence at sites along I-84. At trapping sites they mounted each camera onto a 122-cm (48 in) piece of rebar using small pieces of wood as mounts and positioned cameras 1.5 m (5 ft) in front of a bait station with the bait station at the center of focus (Figure 44). They baited traps nightly using a mixture of rolled oats and peanut butter. The cameras captured images of small mammals present at the bait station onto digital SD cards, which

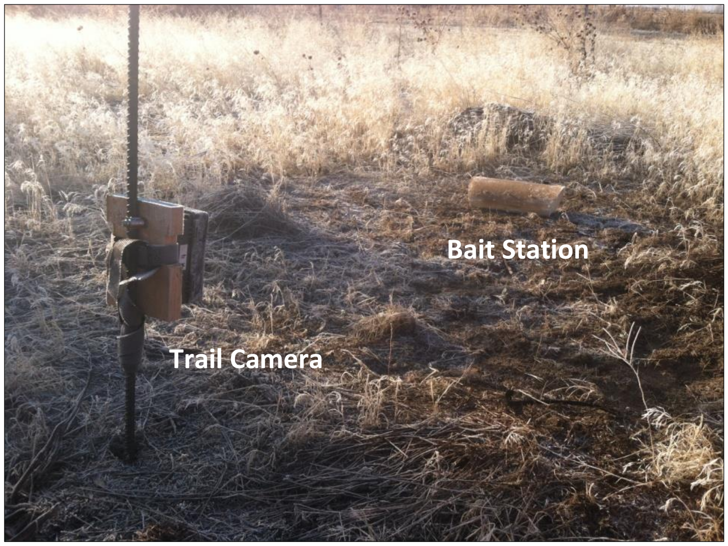

Figure 44. Camera Trap Showing Trail Camera and Bait Station

they retrieved daily and downloaded upon return to the laboratory. Motion activated camera traps were set to take pictures when triggered and then delay for 30 seconds before taking additional pictures if triggered again. Thus, they often obtained multiple pictures of the same individual small mammal at a trap but counted them as the same individual. They considered images taken more than 15 minutes apart as new detections.

Track Traps

Researchers constructed track traps similar to Mabee[13] using 10 cm (4 in) PVC tubing flattened on the bottom so that openings on each side were 7.5 cm (3 in). They then fitted each trap with a removable track plate (23 x 7 cm/9 x 3 in) that had felt pads (7 x 5 cm/3 x 2 in) at each end, which we inked with a mixture of lampblack and mineral oil. The track plate was also fitted with index paper (12.7 x 7 cm/5 x 3 in); small mammals that walked across the ink left their tracks on the index paper (Figure 45), which

Figure 45. Track Trap (left) and Track Plate (right) showing Rodent Footprints

they used to identify species of small mammal and determine an index of abundance for the track traps. The team baited the traps with rolled oats and peanut butter and replaced the track plates on a nightly basis. For track traps, a single print from a particular species counted as a unique detection.

Researchers also conducted trapping with traditional Sherman live traps (7.62 x 7.62 x 25.4 cm/3 x 3 x 10 in) along I-84 to collect footprints from known species of small mammals to compare to the tracks collected using the track traps. After capture in a live trap, they temporarily transferred mice and other small rodents to a small plastic arena where they walked on ink pads and paper to leave tracks.

Trapping Sites

To obtain sufficient geographic coverage, the research team randomly selected 120 small mammal trapping locations (Figure 46) along I-84, which were trapped between December 2013 and July 2014 to determine small mammal occurrence. They trapped these sites using a combination of camera sites and track trap sites (Figure 47).

Figure 46. Map of Small Mammal Trapping Locations (n = 120) along I-84 between Boise and Burley, Idaho

Each camera survey site consisted of two cameras with bait stations placed in the EB ROW and two cameras on the WB ROW (Figure 47). The research team generally could not use cameras to record rodent abundance in the median because of the large number of false triggers produced from passing cars, which was not an issue in the ROW because they angled cameras away from the road surface. Instead, the median at each trapping site was surveyed using track traps. At track trap sites the team used two track traps in the EB ROW, two in the WB ROW, and two in the median (Figure 47). Thus, a total of six traps were at each survey location with a distance of approximately 20 m (66 ft) between each trap laterally but variable distances between each pair of traps depending on the span of highway lanes at the trapping location. Each location was trapped for 3 consecutive nights.

Figure 47. Schematic Illustrating 'Camera' Trapping Sites (left) and Track Traps Sites (right)

(TT) Track Trap; (Cam) Trail Camera; (EB ROW) Eastbound Right-of way; (WB ROW) Westbound Right-of-way

Camera and Track Trap Comparison Study

Because researchers employed a mixture of track traps and camera traps, they evaluated how results from camera trapping and track traps compared using a separate experiment. In winter 2013/2014 they conducted a comparison experiment using 56 traps placed at 14 different sites. For each camera trap, they placed a track plate in its bait station; this essentially made it a simultaneous track trap and camera trap. They then compared trapping results from each method conducted at the same site. They obtained 140 comparisons (Table 15) and found no significant difference between methods (McNemar's Test: X^2 = 8.0, P = 0.004). Cohen's kappa was 0.76, which indicates congruence between methods.

Table 15. Comparing Camera and Track Traps

Yes = rodent detected, No = rodent not detected

		Track Trap	
		Yes	**No**
Camera Trap	**Yes**	86	13
	No	2	39

Appendix B
Survey of State DOTs Concerning Barn Owl-Vehicle Collisions

(December 2013)

Introduction

The geographic range of the barn owl spans across most of the continental United States and into portions of Canada. The research team sought to gain insight into if and how other departments of transportation (DOT) address barn owl road mortality in their jurisdictions. The goal was to obtain participation from at least one representative from every state.

Methods

Researchers developed a short survey using a web-based tool, www.surveymonkey.com (see below). The survey was anonymous and voluntary and was exempt from University Institutional Review Board (IRB) approval.

Ned Parrish, Idaho Transportation Department Research Program Manager, emailed the survey invitation to 49 other state DOT research program managers via the American Association of State Highway Transportation Officials (AASHTO) network. Directing invitations to research program managers helped ensure surveys were distributed to the most appropriate personnel in each agency. Mr. Parrish sent the initial invitation on October 8, 2013 and a reminder email on October 22, 2013. The survey was open for a total of three weeks and closed on October 29, 2013.

The research team downloaded the raw survey results from www.surveymonkey.com and analyzed them. For those states with multiple respondents, researchers aggregated results into a single response per agency because they were interested in responses at the state level rather than at the level of individual personnel. In all but two cases, this amounted to using content-rich responses in place of those with no data. That is, when faced with multiple responses per DOT, they used data from respondents who shared information versus those that provided no data or who indicated they did not have the knowledge required to fill out the survey. In two cases, they combined multiple content-rich responses from the same agency into a single response. In some cases, they also edited the name of states from certain responses to provide anonymity.

DOT experience with owl mortality and mitigation

The Idaho Transportation Department, in collaboration with Boise State University and the Western Transportation Institute-Montana State University, is researching the feasibility of mitigation to reduce barn owl mortality because of vehicle collision. We hope to gain insight from all 50 states. This survey is voluntary and no personally identifiable information will be used.

Barn owls (Tyto alba) are one of the most widespread of all owls and occur in almost all U.S. states. However, despite being common in some areas and often nesting close to human habitations, their secretive nature and nocturnal habit often render them inconspicuous to most people. Barn owls are sometimes called "monkey-faced owls" because of their white, heart-shaped faces and dark eyes, which is unlike many other owls. Barn owls occupy a broad range of open habitats, including within both urban and rural landscapes. They hunt on the wing, from a perch, from hovers, stoops, and in open fields, wetlands, and grasslands. They are particularly abundant in agricultural areas where they are prolific rodent predators. A breeding pair and their young can eat thousands of voles per year. Barn Owls nest in a wide variety of natural and man-made cavities in trees, cliffs, caves, riverbanks, church steeples, barn lofts, haystacks, and nest boxes. But, in many portions of their range, including throughout much of Europe, they are killed in high numbers near major roads. This is the case in Idaho. We are seeking information on the extent to which barn owls are killed along roadways in other states.



***1. In what state do you work?**

State: [ ]

2. Are barn owls present in your state?

- ( ) Yes
- ( ) No

Page 1

DOT experience with owl mortality and mitigation

3. Please list any BIRD species for which your agency has a program to reduce mortality caused by vehicles.

4. To the best of your knowledge, have there ever been barn owl mortalities because of vehicles in your state? Please choose the option that best fits your situation.

- ◯ Yes, regularly
- ◯ Yes, but infrequently
- ◯ No, never
- ◯ I have no idea

5. Please check all that apply. Barn owl mortalities caused by vehicles are officially reported in your state by:

- ☐ Transportation department personnel
- ☐ State or federal fish and game personnel
- ☐ Members of the public
- ☐ To the best of my knowledge, there is no official reporting

6. If there is a roadkill reporting website in your state, please provide the URL.

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DOT experience with owl mortality and mitigation

7. Please check the characteristics of roads on which barn owl-vehicle collisions typically occur in your state. Please check all that apply:

- ☐ Two-lane, unpaved
- ☐ Two-lane, paved
- ☐ Four-lane
- ☐ Six-lane or more
- ☐ Mainly passenger cars, including pick up trucks and passengers vans
- ☐ Light volume of commerical trucks, not including pick up trucks or passenger vans
- ☐ High volume of commercial trucks, not including pick up trucks or passenger vans

8. For those roadways in your state with barn owl-vehicle collisions, please list road name, if possible, and include whether the road is an interstate, US highway, or state highway:

9. Please list/describe the transportation department district(s) of your state with barn owl-vehicle collisions:

10. Is reducing barn owl-vehicle collisions part of your agency's comprehensive program to reduce potential environmental impacts of roadways OR to improve motorist safety?

- ◯ Yes
- ◯ Not yet but we are moving in that direction
- ◯ No

11. Why not?

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DOT experience with owl mortality and mitigation

12. Please describe any mitigations that have been SUCCESSFUL or UNSUCCESSFUL in reducing owl-vehicle collisions within your state.

13. Please provide contact information for the most appropriate person in your agency for more information about this topic.

Name:

Title/Section:

Email Address:

Phone Number:

Survey almost completed!

Thank you for taking our survey.

Please click "Done" to submit.

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Results

The research team anticipated one respondent per DOT; however, zero to four personnel responded per agency for a total of 44 respondents (Table 16). The completion rate for finishing the survey once it was started was 55 percent.

Representatives from 26 US states responded to the survey, yielding a 53 percent response rate of the target audience (i.e., 26/49, all 50 state DOTs besides Idaho). One representative of a Canadian provincial DOT also learned about and participated in the survey. A total of 27 DOTs from the US and Canada are therefore represented in these survey results (Table 16). The team also received the following (excerpted) email correspondence from Indiana DOT and Department of Natural Resources on October 9, 2013, *"We occasionally encounter a road-killed barn owl, but not very often. Our population is small (maybe 40-50 pairs) and they tend to nest in rural areas most likely along county roads and not adjacent to highways. I'm not aware of any mitigation projects for raptor mortality along highways in Indiana*." Note that aside from the preceding quote, Indiana is not represented in the survey results. A representative from Missouri DOT who was not the survey respondent from Missouri contacted the research team by telephone and indicated that Missouri DOT shares data layers with Missouri Department of Conservation. It was noted that of 96 records of barn owls in the data that span 1980s to 2000s, there was one record that was listed as "dead on road."

Respondents of 26 DOTs (n = 27) affirmed that barn owls are present in their state/province. One respondent indicated that that barn owls were not present in his/her state, but an internet search showed that the state indeed has a Barn Owl Conservation Initiative.

Table 16. Number of Survey Respondents by State/Province DOT

US State	# Respondents
Alabama	
Alaska	
Arizona	1
Arkansas	
California	1
Colorado	1
Connecticut	
Delaware	
Florida	2
Georgia	4
Hawaii	
Idaho	NA; agency conducting the survey
Illinois	4
Indiana	*
Iowa	2
Kansas	1
Kentucky	
Louisiana	
Maine	
Maryland	
Massachusetts	
Michigan	1
Minnesota	
Mississippi	1
Missouri	1
Montana	
Nebraska	1
Nevada	1
New Hampshire	
New Jersey	4
New Mexico	1
New York	
North Carolina	
North Dakota	
Ohio	1
Oklahoma	2
Oregon	3
Pennsylvania	1
Rhode Island	
South Carolina	2
South Dakota	
Tennessee	
Texas	1
Utah	3
Vermont	
Virginia	1
Washington	1
West Virginia	
Wisconsin	1
Wyoming	1
subtotal	43
Canadian Province DOT	
British Columbia	1
subtotal	1
TOTAL	44

**Indiana (IN) DOT enlisted the aid of IN Department of Natural Resources to describe IN's situation (via email).*

None of the 27 DOTs represented have programs to reduce any bird species mortality caused by vehicles. In response to the question, “To the best of your knowledge, have there ever been barn owl mortalities because of vehicles in your state?,” 13 respondents (48 %) answered affirmatively (Figure 48).

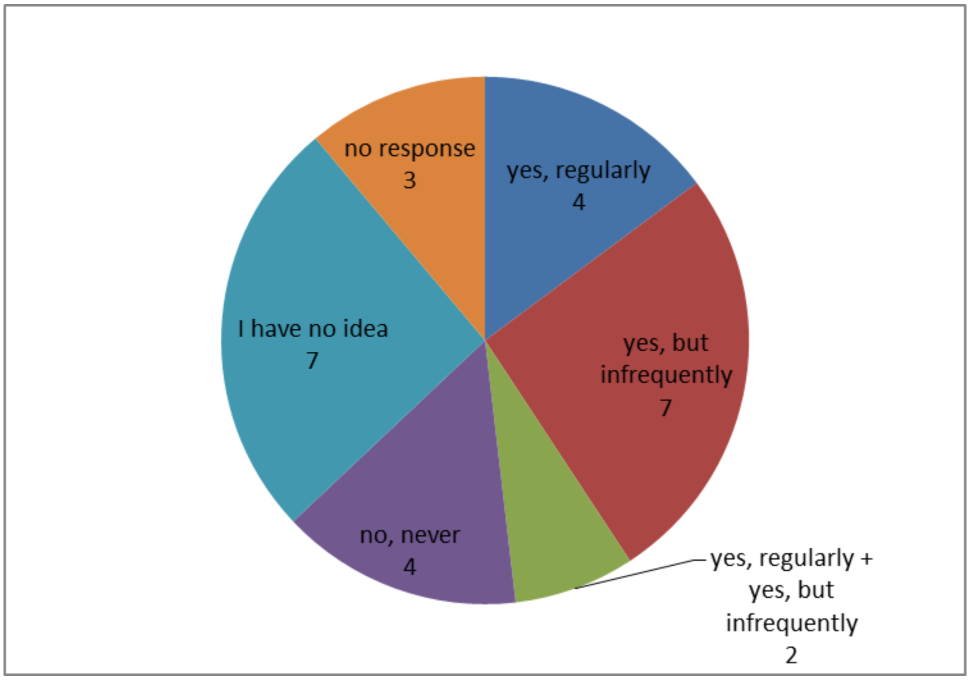

Figure 48. Relative Options Selected Regarding Occurrence of Barn Owl Mortalities Because of Vehicles in Respondents’ State/Province; (n=27)

Of the 13 DOTs that indicated they have barn owl mortalities caused by vehicles, 10 selected the option “To the best of my knowledge, there is no official reporting.” However, some of these also selected one or more other options (i.e., transportation department personnel, state or federal fish and game personnel, members of the public). Four respondents provided emails or URLs for reporting road kill in their state/province (Table 17; References). It remains unclear if other states have official reporting of barn owl mortalities caused by vehicles.

Table 18 lists various road and traffic characteristics associated with barn owl collisions and the number of DOTs that selected each type. “Two-lane paved,” and “four-lane paved” were the most frequent responses for type of road along which barn owl mortality occurred (Table 18). Of the small number of responses concerning traffic type, respondents most frequently selected “High volume of commercial trucks, not including pick-up trucks or passenger vans” (Table 18). The Appendix lists road names and districts with known barn owl-vehicle collisions.

Table 17. Methods of Reporting Vehicle-caused Barn Owl Mortalities by State/Province

DOT	Method(s) of Reporting
Arizona	No official reporting
British Columbia	Transportation department personnel; (provided URL – see References)
California	Members of the public + No official reporting; (provided URL – see References)
Florida	Members of the public; (provided URL – see References)
Georgia	No official reporting
Iowa	Transportation department personnel + State or federal fish and game personnel + Members of the public + No official reporting
Illinois	No official reporting
Nevada	Transportation department personnel + State or federal fish and game personnel
Ohio	No official reporting
Oklahoma	No official reporting
Oregon	Transportation department personnel + No official reporting
Utah	State or federal fish and game personnel + No official reporting; (provided URL – see References)
Washington	No official reporting

Note: Idaho Department of Fish and Game hosts a website that allows transportation department personnel, fish and game department personnel, and members of the public to officially report barn owl and other road kill sightings.

Table 18. Characteristics of Roads and Traffic for Barn Owl Mortality Locations

(n = 10 after aggregating multiple responses from two states)

Characteristic	# of DOT
Two lane, unpaved	1
Two-lane, paved	9
Four-lane, paved	8
Six lane or more	3
Mainly passenger cars, including pick-up trucks and passengers vans	1
Light volume of commercial trucks, not including pick-up trucks or passenger vans	1
High volume of commercial trucks, not including pick -up trucks or passenger vans	2

Two of the 13 DOTs that indicated they have barn owl mortalities caused by vehicles reported that reducing such collisions is part of their agency's comprehensive program to reduce potential environmental impacts of roadways or to improve motorist safety. The other eleven provided explanations for why this is not the case in their agency (Table 19).

Table 19. Respondent Explanations for not Reducing Barn Owl-Vehicle Collisions as part of a Comprehensive Program to Reduce Environmental Impacts and Improve Motorist Safety

(Responses were not edited except for spacing between words and letter case)

It has not been an issue brought to our attention. Mortality can be assumed because BAOW's are in our state and we have highways, but the issue has not risen to a level that requires mitigation. We do have a comprehensive program to prevent impacts to all nesting birds and raptors for construction projects. However, cliff swallows and burrowing owls are usually the species targeted to prevent impacts.
Barn owl mortality is not considered to be either a safety problem or a problem for the species' population. Also the barn owl is not a listed species nor does it appear on the most recent Department of Fish and Wildlife Special Animals List.
Barn owls are not common in our state and barn owl road mortality is even less common. Efforts to reduce wildlife mortality on operational roadways focus primarily on White-tailed Deer. A few other species such as Black Bear, Gopher Tortoise, and Diamondback Terrapin receive some consideration in some areas. There are few, if any, efforts mitigate road mortality for birds of any kind on operational roadways. At this time, there is no apparent impetus to change this.
Because our state wildlife and animal diversity program is under-staffed and under-budgeted, and (as far as I know) this is the first time anyone in our state has looked at our data to see what proportion of barn owl mortality is from car collisions. For the 47 barn owls where cause of mortality is known, 18 were caused by vehicle collision.
It does not occur that frequently because there are few barn owls in our state (it is listed state endangered).

Our state has been focused on reducing wildlife-vehicle collisions over the past 10 years, but is primarily focused on large bodied species that pose a significant safety risk to the motorist. In the future, smaller species can be addressed, but at this time they are not a primary focus of mitigation efforts.
Not widely considered a problem
They are not listed as threatened or endangered.
We are working to reduce wildlife-vehicle collisions around the state but nothing specifically planned for barn owls. Most of our work is focused on terrestrial species, primarily big game.....
To my knowledge, barn owl collisions are not a huge problem in our state.
Not a priority. At this time it's difficult to fund even the highest priority corrections for wildlife-vehicle problem areas.

Two respondents provided some insights into successful mitigation efforts for reducing owl-vehicle collisions (Table 20).

Table 20. Respondent Descriptions of Successful Mitigation Efforts for Reducing Owl-Vehicle Collisions

(Responses were not edited)

The bird protection initiatives involved a vegetated flyover to encourage birds to gain elevation before flying over a highway. Please note, barn owls may not have been a target species for the mitigation.
Surveying, avoiding nests/cavity trees, timing of construction, coordination with state and federal wildlife agencies to develop and implement avoidance, minimization, and conservation measures to reduce bird-vehicle collisions in Florida. Other measures include maintaining or providing buffer zones, consideration of placement of staging areas and use of equipment, and construction monitoring. Unsuccessful mitigations unknown at this time, but most of the listed successful conservation measures were implemented for other owl species (such as the burrowing owl) and raptor species (such as bald eagle, Audubon's crested caracara, Everglades snail kite, Southeast American kestrel, peregrine falcon, etc. Some of these also included monetary contributions to a wildlife conservation fund (i.e., for bald eagle permit, Audubon crested caracara compensatory mitigation).

Conclusions

Results from this survey indicate that barn owl-vehicle collisions are not limited to the state of Idaho. Agencies from the Midwest, Southeast, and across the West reported such collisions; however, the number of dead owls does not appear to match what has been recorded in Idaho. Results suggest that owl-vehicle collisions typically occur on two- and four-lane paved roads. Reporting of owl-vehicle collisions across the US is sporadic and not standardized but several states/provinces have attempted to formalize data collection via road kill reporting websites and email addresses.

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Appendix. Roads and Districts with Known Barn Owl-Vehicle Collisions

(Responses not edited)

DOT	Road(s) with Barn Owl-Vehicle Collisions	District(s) with Barn Owl-Vehicle Collisions
British Columbia	Provincial highway	District 1 - Lower Mainland (Vancouver, BC)
California	Many Roads including Interstate 5, Interstate 505, Interstate 80, and State Route 99. Since data collection is haphazard this is not a statistically usable list.	District 11 San Diego Area, District 9 Eastern Sierra Nevada, District 3 North to Central Inland, District 4 San Francisco Bay Area, District 10 Central inland, District 6 San Joaquin Valley
Florida	My office does not have any known or documented occurrences of barn owl-vehicles in Florida but we are aware barn owl-vehicle collisions do happen and are not usually reported by the public. Barn owls are located mostly in South and Central Florida so we assume potential roads with barn owl-vehicle collisions may include I-75 (Interstate), US Highway 441 (Paynes Prairie area), US Highway 27 (Everglades area), and possibly state and local highways.	Based on responses to Item 7, it is possible that barn owl-vehicle collisions are more likely to occur in FDOT Districts 1, 4, 6, and Florida Turnpike Enterprise. Potential minimal involvement in Districts 2, 3, and 5.
Iowa	State Hwy 2, Taylor Co.; Co. J46, Appanoose Co. State Hwy.5, Monroe Co.; St. Hwy. 71, Audubon Co. State Hwy. 30, Tama Co.; St. Hwy 137, Monroe Co.	Iowa DNR has records of road-killed barn owls from at least twelve counties, mostly in western & SE Iowa.
Illinois	Unknown.	Districts 7, 8, and 9 (Edwards, Franklin [this county unconfirmed], and Randolph Counties had roadkilled barn owls in 2013).
Nevada	Interstate 80, US Highways 50, 93, 95, and State Routes 208, 225, 360, 305, 376.	Nevada has three districts. District I, II, and III. The boundaries do not follow county lines or roadways, but are split by southern (District I), western (District II), and eastern (District III) regions for the most part. Please contact Nevada Department of Transportation for detailed map if needed.
Oklahoma	State Highway	Western part of the state
Oregon	US, Interstate 84 and OR routes	All in Eastern Oregon
Utah		All districts I suspect would have barn owl vehicle collisions.
Washington	US012	South Central Region is the only one I know of that has frequent collisions but all regions have some level of collisions between vehicles and barn owls. I suspect that other eastern Washington regions may have frequent collisions but I don't know for certain.

Appendix C
Characteristics of Sampling Sites along I-84

Summary statistics for 120 sampling sites are provided below for spatial (Table 21), geometric (Table 22, Figure 49) and biotic (Table 23, Figure 50) variables that the research team measured to examine their potential relationship with barn owl mortality along I-84 and I-86 in southern Idaho.

Table 21. Spatial Characteristics of 120 Sampling Sites along I-84

Variable	No Buffer $\bar{x}$ ± SD (min – max)	1-km Segment Buffered $\bar{x}$ ± SD (min – max)	3-km Segment Buffer $\bar{x}$ ± SD (min – max)	5-km Segment Buffer $\bar{x}$ ± SD (min – max)
Elevation (m)	–	1068 ± 170 (765 – 1365)	1068 ± 168 (768 – 1360)	1067 ± 168 (768 – 1357)
Minimum Distance to Agricultural Field (km)	–	0.37 ± 0.71 (0.0 – 3.90)	0.21 ± 0.47 (0.0 – 3.19)	0.12 ± 0.29 (0.0 – 2.0)
Average Distance to Agricultural Field (km)	–	0.51 ± 0.79 (0.01 – 3.94)	0.53 ± 0.71 (0.02 – 3.77)	0.52 ± 0.64 (0.02 – 3.33)
Center Distance to Agricultural Field (km)	0.51 ± 0.82 (0.00 – 3.92)	–	–	–
Minimum Distance to Snake River Canyon (km)	–	13.49 ± 14.94 (0.10 – 48.44)	12.95 ± 14.96 (0.00 – 48.12)	12.49 ± 14.94 (0.00 – 47.82)
Average Distance to Snake River Canyon (km)	–	13.79 ± 14.91 (0.40 – 48.61)	13.76 ± 14.92 (0.45 – 48.44)	13.74 ± 14.92 (0.46 – 48.26)
Center Distance to Snake River Canyon (km)	13.78 ± 14.91 (0.46 – 48.62)	–	–	–
Minimum Distance to Bridge/Overpass (km)	–	1.23 ± 1.32 (0.00 – 6.46)	0.48 ± 0.94 (0.00 – 5.08)	0.18 ± 0.57 (0.00 – 3.70)
Average Distance to Bridge/Overpass (km)	–	1.80 ± 1.35 (0.20 – 6.93)	1.71 ± 1.15 (0.42 – 6.26)	1.63 ± 0.99 (0.50 – 5.57)
Center Distance to Bridge/Overpass (km)	1.83 ± 1.41 (0.00 – 7.14)	–	–	–
Minimum Distance to Nearest Water Feature (km)	–	0.53 ± 0.79 (0.00 – 4.03)	0.24 ± 0.53 (0.00 – 2.95)	0.13 ± 0.36 (0.00 – 2.24)
Average Distance to Nearest Water Feature (km)	–	0.80 ± 0.83 (0.05 – 4.42)	0.78 ± 0.74 (0.08 – 3.94)	0.76 ± 0.67 (0.16 – 3.59)
Center Distance to Nearest Water Feature (km)	0.83 ± 0.86 (0.00 – 4.69)	–	–	–
Minimum Distance to Nearest Dairy (km)	–	9.47 ± 7.90 (0.32 – 33.21)	8.69 ± 7.74 (0.10 – 32.00)	8.01 ± 7.53 (0.10 – 30.80)
Average Distance to Nearest Dairy (km)	–	9.94 ± 7.94 (0.66 – 33.87)	9.93 ± 7.92 (0.73 – 33.56)	9.95 ± 7.86 (0.87 – 32.99)
Center Distance to Nearest Dairy (km)	9.93 ± 7.95 (0.62 – 33.88)	–	–	–

Variable	No Buffer $\bar{x}$ ± SD (min – max)	1-km Segment Buffered $\bar{x}$ ± SD (min – max)	3-km Segment Buffer $\bar{x}$ ± SD (min – max)	5-km Segment Buffer $\bar{x}$ ± SD (min – max)
Center Distance to Nearest Dairy (km)	9.93 ± 7.95 (0.62 – 33.88)	–	–	–
Cumulative Length of Water Features (km)	–	0.61 ± 0.76 (0.00 – 2.68)	5.77 ± 4.18 (0.00 – 14.71)	16.11 ± 9.57 (0.00 – 35.43)
Cumulative Length of Roads other than I-84/86 (km)	–	8.09 ± 3.82 (2.54 – 18.79)	37.71 ± 18.13 (8.59 – 99.82)	84.78 ± 42.35 (15.78 – 250.69)

Table 22. Geometric Characteristics of 120 Sampling Sites along I-84/86

Variable	No Buffer $\bar{x}$ ± SD (min – max)	1-km Segment Buffer $\bar{x}$ ± SD (min – max)	3-km Segment Buffer $\bar{x}$ ± SD (min – max)	5-km Buffer $\bar{x}$ ± SD (min – max)
Embankment/Excavations EB	–	0.56 ± 0.52 (-1.55 – 1.09)	0.51 ± 0.44 (-1.65 – 1.13)	0.50 ± 0.39 (-1.24 – 1.25)
Embankment/Excavations WB	–	0.68 ± 0.58 (-2.00 – 1.36)	0.51 ± 0.44 (-1.65 – 1.13)	0.64 ± 0.41 (-1.06 – 1.20)
Homogeneity of Slope (5)	–	4.95 ± 3.05 (2.35 – 22.09)	5.95 ± 3.92 (2.50 – 24.32)	7.04 ± 4.66 (2.62 – 23.36)
Cumulative Length of Obstructions (km)	–	0.27 ± 0.47 (0.00 – 2.53)	0.93 ± 1.27 (0.00 – 7.64)	1.68 ± 2.04 (0.00 – 10.96)
Cumulative Length of Power Lines (km)	–	0.55 ± 0.69 (0.00 – 2.54)	1.65 ± 1.72 (0.00 – 6.10)	2.81 ± 2.62 (0.00 – 9.00)
AADT	–	15635 ± 3947 (6400 – 21500)	15635 ± 3947 (6400 – 21500)	15635 ± 3947 (6400 – 21500)
CAADT	–	4584 ± 837 (2100 – 5300)	4584 ± 837 (2100 – 5300)	4584 ± 837 (2100 – 5300)
PAADT	–	11051 ± 3391 (4300 – 16300	11051 ± 3391 (4300 – 16300	11051 ± 3391 (4300 – 16300
Traffic Speed Passenger Vehicles (km/h)	–	121 ± 0 (121 – 121)	121 ± 0 (121 – 121)	121 ± 0 (121 – 121)
Traffic Speed Commercial Vehicles (km/h)	–	105 ± 0 (105 – 105)	105 ± 0 (105 – 105)	105 ± 0 (105 – 105)
Width of EB ROW (m)	–	22.1 ± 8.8 (7.0 – 53.3)	26.5 ± 12.7 (8.7 – 82.1)	25.8 ± 10.5 (10.0 – 65.6)
Width of WB ROW (m)	–	22.6 ± 9.4 (8.0 – 66.3)	27.2 ± 12.9 (9.2 – 82.1)	26.8 ± 10.3 (10.0 – 59.0)
Width of Median (m)	24.9 ± 15.0 (13.0 – 100.0)	–	–	–
Left/Right Unpaved Shoulder Width EB and WB (m)	0 ± 0 (0 – 0)	0 ± 0 (0 – 0)	0 ± 0 (0 – 0)	0 ± 0 (0 – 0)
Left Paved Shoulder Width EB and WB (m)	1.22 ± 0 (1.22 – 1.22)	1.22 ± 0 (1.22 – 1.22)	1.22 ± 0 (1.22 – 1.22)	1.22 ± 0 (1.22 – 1.22)
Right Paved Shoulder Width EB and WB (m)	3.05 ± 0 (3.05 – 3.05)	–	–	–
Total Lane Width EB and WB (m)	7.3 ± 0 (7.3 – 7.3)	–	–	–
Total Road Width EB and WB (m)	11.6 ± 0 (11.6 – 11.6)	–	–	–
Total Width of ROW (m)	97.6 29.3 (58 – 218)	–	–	–

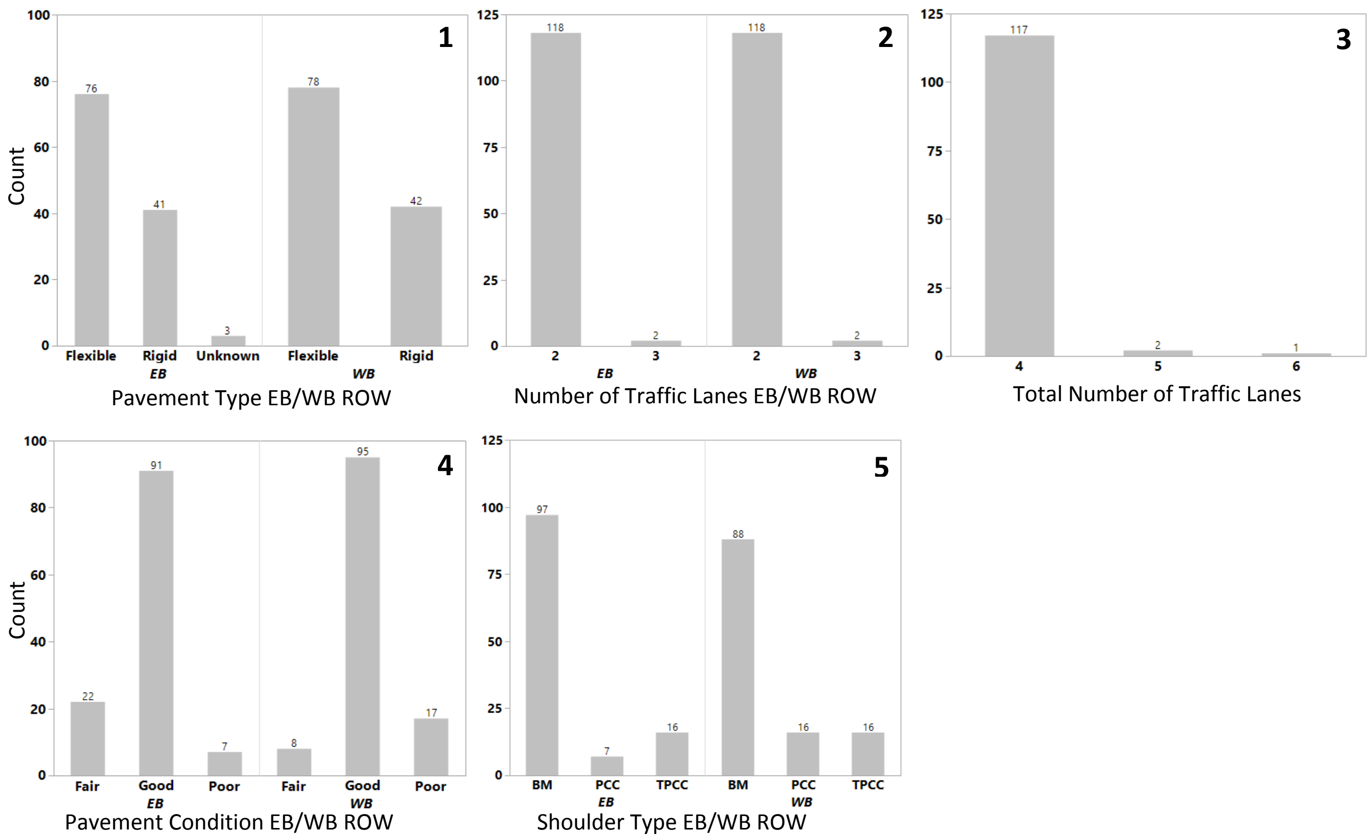

Figure 49. Frequency of Pavement Type, Traffic Lanes, Pavement Condition, and Shoulder Type at Sampling Sites

(count is on y-axis with percentage of 120 sites above bars)

BM = Surfaced with Bituminous Material; PCC = Surfaced with PCC; TPCC = Surfaced with Tied PCC

Table 23. Biotic Variable Characteristics of 120 Sampling Sites along I-84/86

Variable	No Buffer $\bar{x}$ ± SD (min – max)	1-km Buffer $\bar{x}$ ± SD (min – max)	3-km Buffer $\bar{x}$ ± SD (min – max)	5-km Buffer $\bar{x}$ ± SD (min – max)
Small Mammal Abundance Index	4.78 ± 1.47 (0 – 6)	–	–	–
Habitat Change Past Fence EB ROW	–	65.9 ± 43.7 (0 – 100)	64.2 ± 42.8 (0 – 100)	64.1 ± 42.5 (0 – 100)
Habitat Change Past Fence WB ROW	–	64.8 ± 46.1 (0 – 100)	65.0 ± 43.8 (0 – 100)	64.5± 43.5 (0 – 100)
Percentage of Crop	–	39.6 ± 35.5 (0.0 – 87.3)	40.2 ± 35.6 (0.0 – 91.9)	39.9 ± 33.8 (0.0 – 91.1)
Percentage of Shrub	–	41.7 ± 38.2 (0.0 – 92.2)	47.4 ± 38.5 (0.0 – 96.0)	49.2 ± 37.0 (0.0 – 97.6)
Percentage of Human Structures	–	2.1 ± 5.9 (0.0 – 46.3)	2.7 ± 6.1 (0.0 – 41.9)	2.5 ± 4.8 (0.0 – 32.5)
Percentage of Developed	–	18.2 ± 8.3 (7.8 – 58.2)	11.5 ± 9.5 (4.0 – 56.4)	9.9 ± 7.7 (2.4 – 47.4)
Percentage of Open Water	–	0.5 ± 2.0 (0.0 – 16.1)	0.9 ± 2.3 (0.0 – 12.4)	1.1 ± 2.1 (0.0 – 10.3)

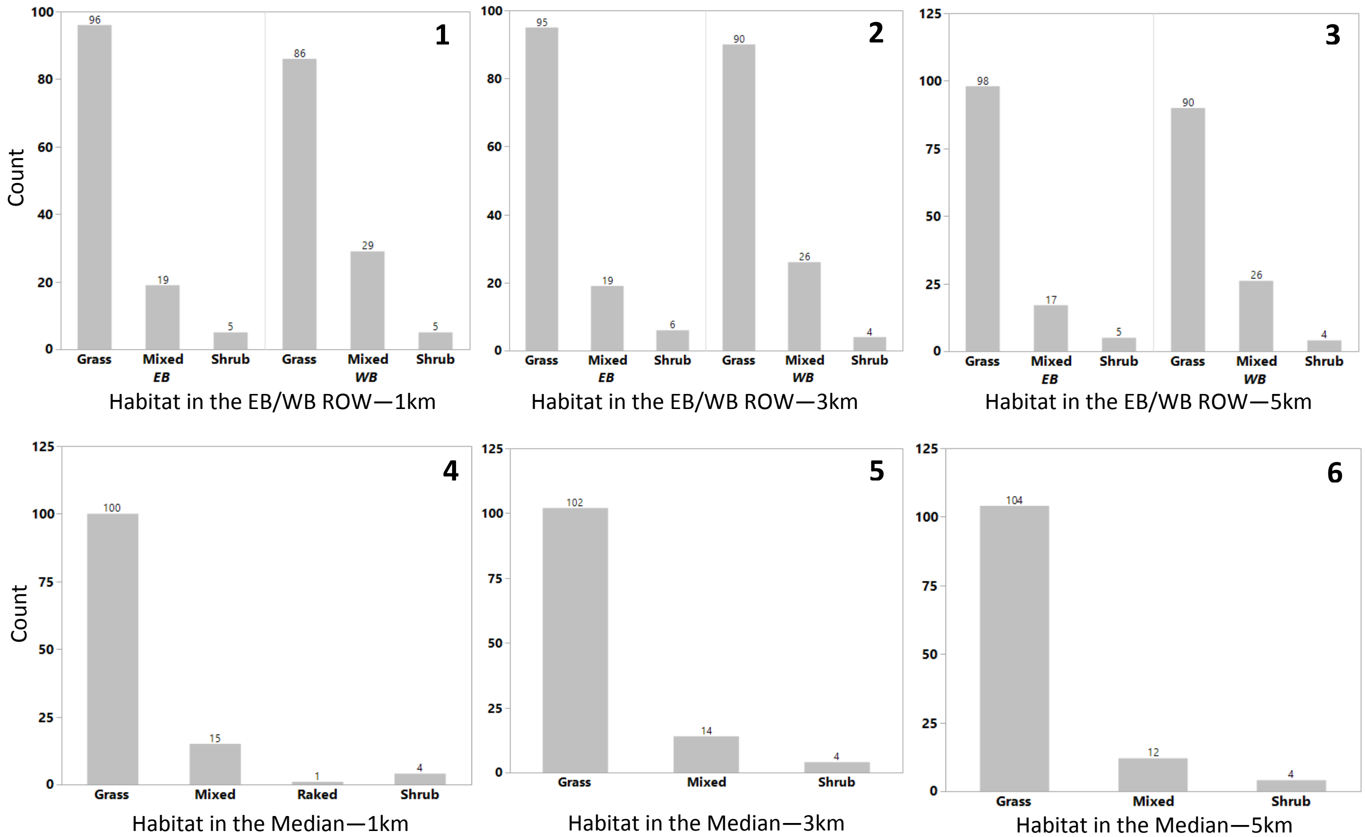

Figure 50. Plant Cover Type in the EB and WB ROW and Median at 1 km, 3 km, and 5 km Scales

(count is on y-axis with percentage of 120 sites above bars)

Appendix D
Training Packet Provided to Citizen Scientists

Spring 2014

The Idaho Barn Owl Roadkill Survey is a joint effort by Boise State University, Montana State University, Idaho Transportation Department, Idaho Fish and Game Department (IDFG) and citizen scientists like you.

Thank you for volunteering your time and energy to help us learn more about where Barn Owls are being roadkilled in Southern Idaho.

This packet contains some background information and instructions on how to conduct and report your surveys. Angela Kociolek at angela.kociolek@coe.montana.edu (406.994.6547) is the point of contact for data reporting and any questions you may have.

Background

Overview and purpose

Dr. Thomas G. Barnes/USFWS Digital Library

Barn Owls are frequently killed by vehicles along roads in North America and Europe. This is of concern because Barn Owl populations have declined in portions of their range such that 21 natural resource agencies in the U.S. consider them a species of concern, threatened, or endangered.

Between July 2004 and June 2006, Boise State University researchers surveyed a 248-km stretch of Interstate-84 (I-84) in southern Idaho using systematic searches every two weeks (Boves and Belthoff 2012). They recorded the highest rate of Barn Owl road mortality in the world and estimated that as many as 599 Barn Owls were being roadkilled per 100 km of I-84 per year. Demographic modeling suggested that the Barn Owl population in the Snake River plain of southern Idaho has potential to decline under the level of roadway mortality observed.

Currently, researchers are conducting systematic searches along I-84 and I-86 (between Boise and the juncture with I-86, and then I-86 from that confluence to Pocatello). **Citizen scientists will aid in *expanding* the number of roads surveyed for Barn Owl roadkills.** Ultimately, information from all surveys will be analyzed in conjunction with other variables to determine what actions have the potential to reduce Barn Owl road mortality.

Fast Barn Owl Facts

- In the U.S. and its territories, Barn Owls are federally protected by the Migratory Bird Treaty Act (50 CFR 10.13).
- Barn owls are medium-sized owls (32–40 cm in length, have a wingspan of 100-125 cm, and weigh approximately 400 - 700 g).
- They have a heart-shaped face, no ear tufts, and dark eyes.
- Female plumage is more colorful and spotted than that of males.
- Barn Owls occur throughout much of the U.S. where they occupy a wide variety of open habitats in both urban and rural settings.
- They are common in farmlands, grasslands, prairies, and deserts and fly slowly at night or dusk with slow wing beats and a looping, buoyant flight.

Identification Tips

Compiled by Alissa Salmore/ITD

3

Data Reporting Instructions

There are **three main things to remember** during the course of this project.

1. **Safety first!**
    a. First and foremost, if you are the driver, please focus on driving safely.
    b. Match your speed with the flow of traffic. Avoid driving erratically.
    c. If you see an owl carcass, **do not stop**. Just note the nearest mile marker* (in 1/10^{ths}, if possible) and record the information when it is safe to do so.

2. **Do <u>not</u> collect bird carcasses.**
    a. It is illegal to collect bird carcasses without a permit.
    b. The researchers' collecting permit does not cover you.
    c. It is illegal to stop on the interstate except in emergencies.

3. **Do submit data promptly after every time you travel your assigned route.**
    a. ***If*** you saw owl roadkill, then create a Trip Roadkill Report once you have completed that particular trip:
        i. Go to https://fishandgame.idaho.gov/species/roadkill to report your sightings. Items marked with a red asterisk (*) are mandatory. Please also select "Species details" in order to enter a count for the number of carcasses you observed. Be sure to click "Save" after each record.

        > ❖ **Tip!** To start, click "Report roadkill" > For species, type "barn owl" in the rectangular box and Enter > Select "Barn Owl (Tyto alba)" from list

        ii. Then go to https://fishandgame.idaho.gov/species/roadkill/list to export the sightings you just entered for that *particular* trip.

        > ❖ **Tip!** Fill in "Species," "Highway," "Start Date," AND "End Date." > Click blue "Filter" button > Scroll down past the map and your list of sightings for that particular trip > Click orange "CSV" button > Download the file to your computer

        iii. Save yourTrip Roadkill Report (.csv) export file as: last name_hwy_mm.dd.yyyy (e.g., kociolek_US20_03.12.2014)
        iv. Email your Trip Roadkill Report along with your Driving Log
    b. ***Whether or not*** you saw owl roadkill, send an updated copy of your Driving Log** to angela.kociolek@coe.montana.edu

*Note: 1/10 mile marker delineator posts are set at 580 ft. spacing on generally flat and straight roadways, but are adjusted for shorter spacing on vertical and horizontal curves (and can be set as close as 50 ft. apart).

The **Driving Log is a spreadsheet included with this packet. Detailed instructions are in the file. Please maintain this log for the duration of the project.

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Select Reading List

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