Species Composition and Location Relative to Highways of Roadkill in Idaho

Charlotte A. Favre

ABSTRACT

Roads are a ubiquitous feature of the landscape and a significant obstacle for wildlife, most directly through the mortality caused by wildlife-vehicle collisions. This study examines the species composition of two datasets—roadkill reported to the Idaho Dept. Fish and Game and wildlife observations recorded in iNaturalist—to compare the taxa of living wildlife with reported roadkill. Unsurprisingly, roadkill observations are markedly biased to mammals, with 89.3% of roadkill being large or medium sized mammals, while only 6.5% of iNaturalist observations are of these same species, indicating significant underreporting of wildlife-vehicle collisions involving all other wildlife taxa. By far the most common species to be reported as roadkill are white-tailed deer (*Odocoileus virginianus*) and mule deer (*Odocoileus hemionus*). Since 2005, there has been a significant 2.6% a year increase in the proportion of white-tailed deer to mule deer roadkill, adding to the body of evidence that mule deer are in decline in Idaho. The majority of roadkill, 83.5%, occurred within 200 meters of state and interstate highways. Sections of road identified as wildlife linkage zones account for 41.7% of the length of highways but contain 53.9% of highway roadkill, suggesting wildlife are disproportionately killed in these zones. These findings support the installation of wildlife crossing structures in these linkage zones to prevent wildlife-vehicle collisions, re-connect fragmented landscapes, and allow wildlife to exist alongside human society.

KEYWORDS

citizen science, road ecology, landscape connectivity, wildlife movement

INTRODUCTION

Roads have extensive effects on landscapes, particularly on wildlife populations. The United States alone has over 6,300,000 km of public roads; one could drive to within 1 km of 82% of all land in the nation (Smith-Patten et al. 2008). While to the casual observer a road may seem like an inert, passive feature of the constructed landscape, when in actuality roads create a complex spaces where pollutants concentrate, exotic species spread more rapidly, ecosystems and habitats are fragmented, and individual animals are directly killed in conflict with vehicles (Coffin 2007). The phenomenon of roadkill is the purview of the field of "road ecology", an area of study that utilizes the ideas and frameworks of ecology, geology and engineering to examine how transportation infrastructure interacts with and effects surrounding ecosystems (Forman & Alexander 1998). This field arose with the shift in paradigm from making roads inhospitable to permeable to wildlife (Kroll 2015). Millions of vertebrates are killed on the roads, and these collisions negatively impact society; around 26,000 injuries and 200 human deaths per year are attributable to wildlife-vehicle collisions, and the national annual cost of these incidents is $8,388,000,000 (Huijser 2008). This threat to wildlife and drivers has increased over the past few decades, as in the United States from 1990 to 2004 the number of reported collisions involving animals increased by 50% while the number of total collision stayed about the same, indicating that collisions with animals constitute an increasing percentage of all collisions (Huijser 2008). In light of this, attention has been given to determine what variables account for patterns of roadkill and how to counter this phenomenon.

Many environmental factors, species behaviors, and road characteristics determine where wildlife-vehicle collisions will occur. Geography and surrounding vegetation determine where wildlife attempt to cross roads, and roadkill is most commonly found near dense vegetation (Kioko et al. 2015), attributable to the reluctance of many species to move through exposed areas more than necessary. Roads that cross wetlands are particularly dangerous to wildlife, as these habitats often have greater abundances of amphibians and reptiles attempting to cross the roads, and these animals are especially vulnerable to collision due to their slow movement and low visibility to drivers (Ashley & Robinson 1996). While one might think that roads with higher volumes of traffic would have high rates of collisions, such roads often exhibit the opposite pattern, in fact, the Federal Highway Administration found that wildlife-vehicle collisions occur more frequently on

lower volume highways (Huijser 2008). This phenomenon is explained by the "alienating effect" of roads with sufficiently dense traffic, as the sound, light and other stimuli created by so many vehicles makes wildlife too wary to approach the road (Grilo et al. 2015). However, this does not mean that one can simply identify some traffic volume threshold above which wildlife mortalities will surely decline, as the extent to which an animal will experience this alienating effect is determined by the species' behavioral adaptations. Species with strong predator avoidance behavior seem particularly sensitive to increases in vehicles and are therefore more likely to avoid roads with heavy traffic, while other species are not as sensitive and will venture onto busy roads (Grilo et al. 2015). The rate at which wildlife-vehicle collisions will occur is determined by temporal patterns of animal movement; in general, the periods of greatest wildlife collisions will occur when some life cycle stage of the area's wildlife prompts movement of individuals. In the Western United States, fall is the time of most frequent collisions due to migrations and mating behavior causing many species, especially deer, to cross roads more often (Shilling et al. 2018). Examining all these variables allow planners to identify hotspots where roadkills concentrate (Bager & Rosa 2010), which provides guidance as to where mitigation strategies will be most effective if implemented.

To address this problem, over 40 types of roadkill mitigation measures have been developed and implemented across the globe. These include measures to influence driver behavior such as wildlife crossing signs, animal detection systems, and traffic speed and volume reductions. Other methods aim to change animal behavior, by fencing off sections of roads, channeling movement through under-or-over passes, or by scaring wildlife away from roads with reflectors and lights (Glista et al. 2009). With so many mitigation tactics available, it can be difficult to determine how effective a given method is at reducing wildlife-vehicle collisions; transportation agencies will usually choose to implement a cheap method, regardless of whether there exists much evidence as to its effectiveness (Rytwinski et al. 2016), and unfortunately measures are often chosen and implemented based on little more than opinion (Glista et al. 2009). Generally, more expensive crossing structures in conjunction with fencing is most effective (Rytwinski et al. 2016), but since the effectiveness of any method depends on the local environmental conditions and wildlife species of concern, evaluating what mitigation method will be best must also be done on a localized scale.

This study seeks to investigate wildlife-vehicle collisions across Idaho, to determine what species may be being left out of current roadkill mitigation efforts in this state. To investigate this subject, I will identify the species composition of roadkill reported to the Idaho Department of Fish and Game, and compare this species composition to that of living wildlife observed by citizen science programs operating in this area. By examining the differences in taxa of observed wildlife, gaps in roadkill reporting can be determined. As deer are expected to dominate roadkill reports, these species will be further investigated to explore what roadkill data may suggest about the populations of the two deer species in Idaho. Additionally, this study will examine the location of roadkill relative to "wildlife linkage zones" areas identified by Idaho Fish and Game as containing a variety of desirable habitat features, including riparian corridors and canopy cover, that may be used by wildlife to move across the landscape. By examining what species are currently underreported in roadkill and the location of wildlife-vehicle collisions on the landscape, suggestions for the most appropriate roadkill mitigation measures can be formulated.

METHODS

Study Site

This study utilized data collected over the entire state of Idaho. With a land area of 83,569 square miles and a population of around 1.8 million, Idaho is one of the least populous and least densely populated states in the nation (Figure1). Geographically, the landscape can be divided into two general regions: in the south is the Snake River Plain, a lower elevation region dominated by vegetation characteristic of the Intermountain West such as big sagebrush (*Artemisia tridentata*). This region also contains most of the state's population and agriculture. North of these plains, the state is mountainous and mostly forested, and includes much of the federally owned forests in the state (Figure 2). Idaho contains around 5,000 miles of State, Interstate, and US highways (U.S. Census Bureau Geography Department 2019). The state is the site of several seasonal ungulate migrations, including elk, pronghorn and mule deer, and also contains the endangered woodland caribou subspecies (*Rangifer tarandus caribou*) along with many threatened terrestrial vertebrate species (Idaho Department of Fish and Game 2020).

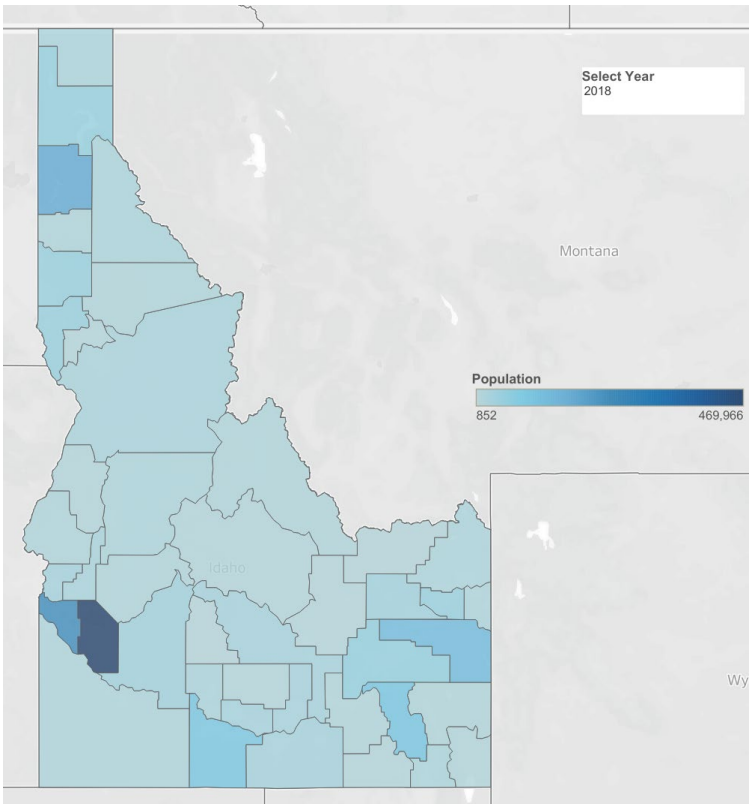


Figure 1. Population density in Idaho. Population is concentrated in Ada County, the seat of the state capital Boise (U.S. Census Bureau 2020).

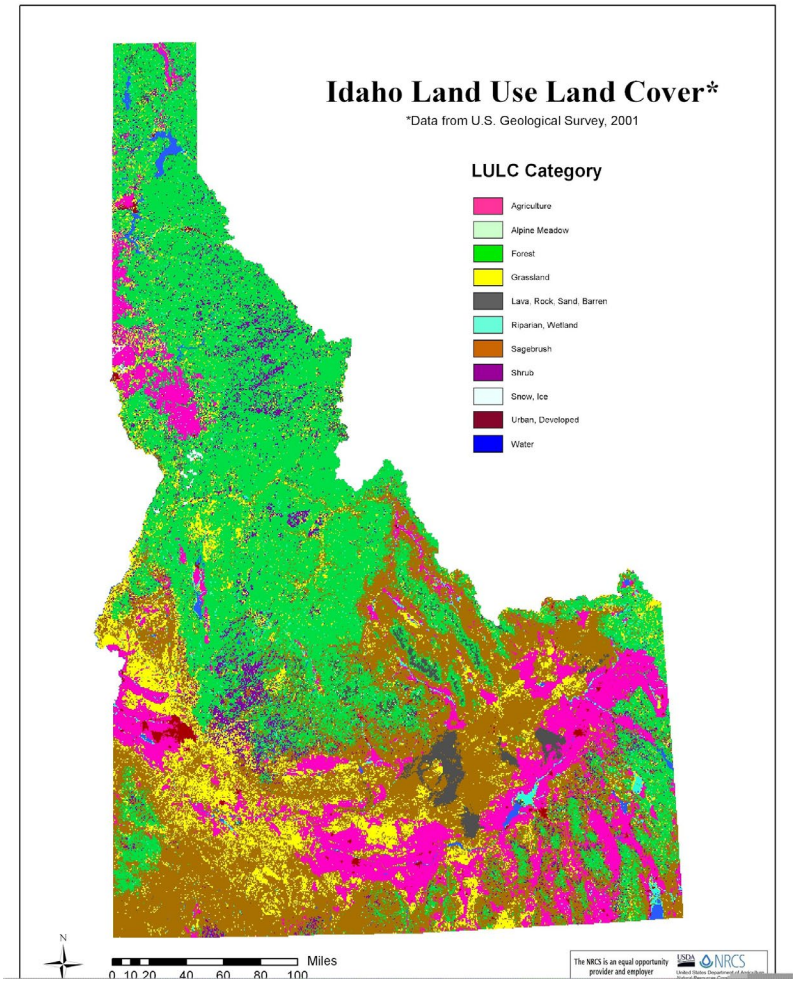


Figure 2. Land use types in Idaho. This shows the general division between lower elevation areas of sagebrush dominant vegetation and agricultural lands, and higher elevation forest lands (Natural Resource Conservation Service 2020).

Data Collection

Roadkill data was collected by the Idaho Department of Fish and Game and downloaded from their Roadkill & Salvage: highway mortality reports database. Three sets of this data were used in this project. To determine the most commonly reported species seen as roadkill, I used a dataset spanning from January 1st 2009 to January 23rd 2020, and totaling at 37,882 observations. To examine the species composition of deer roadkill, I downloaded two datasets, each spanning from January 1st 2005 to December 31st 2019, filtered by deer species. From 2005 to 2019 there were 13,274 reported mule deer (*Odocoileus hemionus*) roadkill, and 14,857 white-tailed deer

(*Odocoileus virginianus*) roadkill. Along with the date of observation and species of animal, this data also information on the roadkill's location, including the latitudinal and longitudinal coordinates, and the county, region, and Game Management Unit the roadkill occurred within. The observations in this dataset are reported to the Department of Fish and Game by members of the public, including by those intending to salvage the roadkill. As such, it is possible that certain non-salvaged individual animals have been reported by multiple people and so are entered more than once into the database.

Observations of living wildlife are from the citizen science website iNaturalist. The data used in this project date from January 1st 2009 to January 23rd 2020. Only research grade observations of wildlife in the taxons Mammalia, Aves, Reptilia and Amphibia for the state of Idaho were included. This excludes observations of captive and cultivated species and ensures accuracy in the species of observations. This dataset totalled 13,486 observations. Observations in iNaturalist include the scientific name, common name and taxon name of the animal, as well as coordinate location and date of observation. As this database records observations and not individual animals, it is possible that a given individual animal could be observed and recorded more than once.

Wildlife Highway Linkages are areas identified by the Idaho Department of Fish and Game as containing important wildlife habitat and which occur nearby and along highways. These zones were determined to be priority areas for wildlife movement based on a series of workshops, held between 2004 and 2008, where the Fish and Game Dept. collaborated with biologists, transportation experts and others to identify zones of high, medium and low priorities for the movement of different species. Each of the 455 linkage zone polygons represents an identified site, and each site has a priority ranking and a list of relevant species. The GIS layer of wildlife linkages is from INSIDE Idaho open data repository. The locations of state and interstate highways were obtained from TIGER/Line Shapefiles for Idaho primary and secondary roads (U.S. Census Bureau Geography Department 2019).

Data Analysis

Species Composition:

I compared the species compositions of roadkill and iNaturalist observations to determine if there are any commonalities or differences in the most often reported species in each datasetI reformatted the roadkill species names to match the common names of iNaturalist observations and joined the data together in R. Analysing the datasets in term of all species present proved to be infeasible, so I filtered for species with at least 50 observations over the 10 year period, and summarize the twenty most common of these species for each datasetI excluded two domestic species, dogs and cats, from the roadkill data, as this project is focused on wildlife and I had filtered domestic species out of the iNaturalist data. Additionally, I determined the species of roadkill that were reported by people intending to salvage them.

Deer Roadkill

I downloaded separate datasets for mule and white-tailed deer, spanning from January 2005, which is the first year white-tailed deer appeared in the roadkill database, to December 2019. In R, I merged these datasets and joined them by year to get the total number of occurrences for each species per year. I used these totals to calculate the proportion of yearly deer roadkill that are white-tailed deer. I graphed the trend in these proportions over time, and performed a linear regression to determine if any trend was significant.

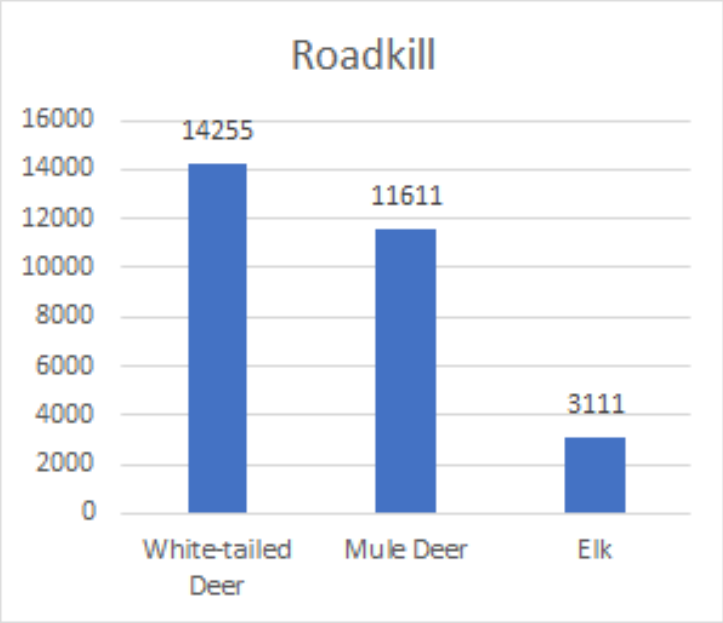
Wildlife Highway Linkages:

Roadkill observations were projected onto a map of highway wildlife linkages and analysed to determine if roadkill occured in a linkage zone or in the surrounding landscape. I created a 200 meter buffer along highways and found the subset of roadkill that occured within this buffer zone. This buffer is to eliminate roadkill that occurred along non-highway roads as well as possible incorrectly reported roadkill locations (in some cases roadkill was reported as being located far outside the Idaho state boundaries, which should not be the case for any observations). I determined the total area, in square kilometers, of the buffer zones, the area of the sections of this buffer zone that also occur within wildlife linkage zones, and the percentage of roadkill that occured within the buffer and linkage zones. Roadkill, wildlife linkages, and highways were projected in Arcmap using the Idaho Transverse Mercator 8478 projection system.

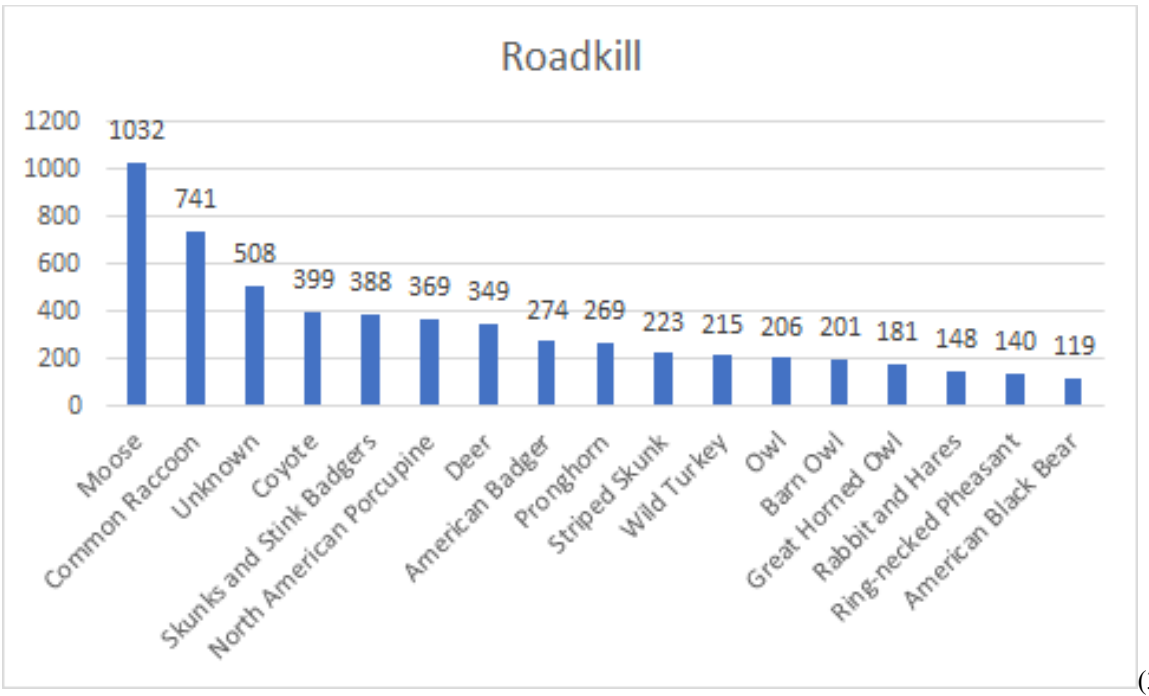
RESULTS

Species Composition

There are 221 unique species names present in the roadkill data, with the most common species to occur as roadkill being white-tailed deer, mule deer, elk, and moose (Figure 3). Of the 37,882 roadill, 33,834 were large and medium sized mammals, making these species account for 89.3% of all recorded roadkill. In iNaturalist there are 509 unique common names for wildlife observations, with the most common species being gopher snakes, canada geese, mallard ducks, and western terrestrial garter snakes (Figure 4). Of the 13,486 observations, 882 were of large and medium sized mammals, meaning these species account for 6.5% of observations. There are 288 species observed as living wildlife that do not appear in roadkill records.



(3a.)



(3b.)

Figure 3. Roadkill Observations. The 20 most common wildlife species reported as roadkill in Idaho from January 1, 2009 to January 23, 2020. Medium-sized ungulate roadkill (3a.) far outnumber any other species (3b.).

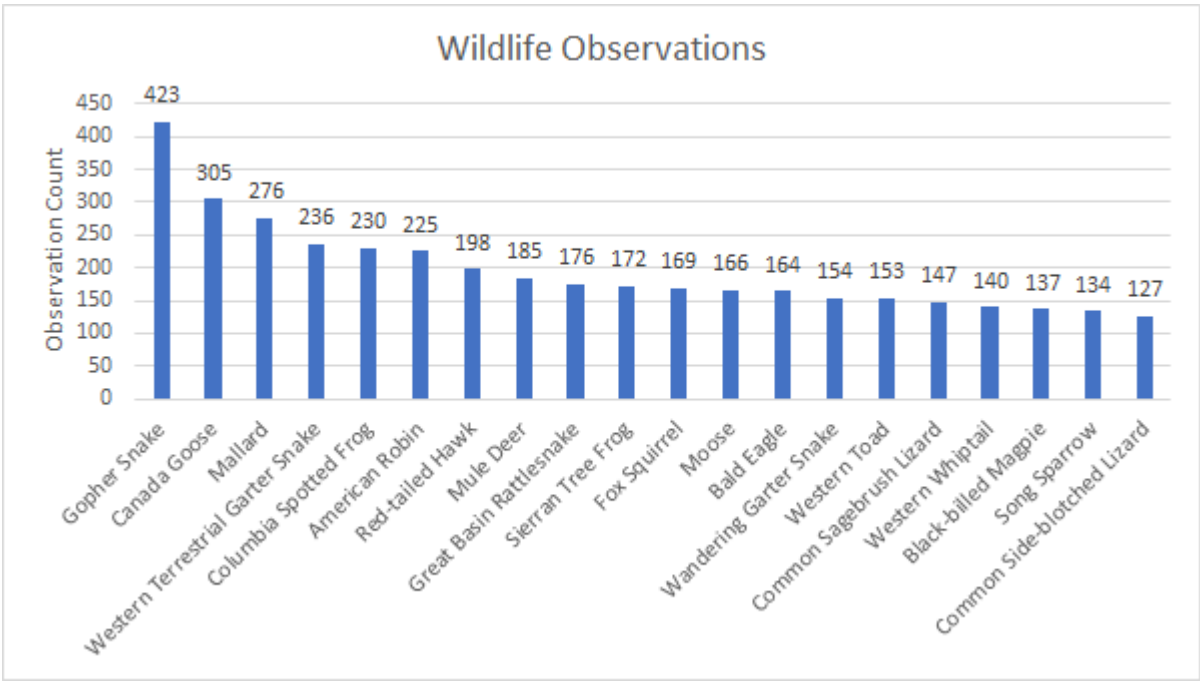
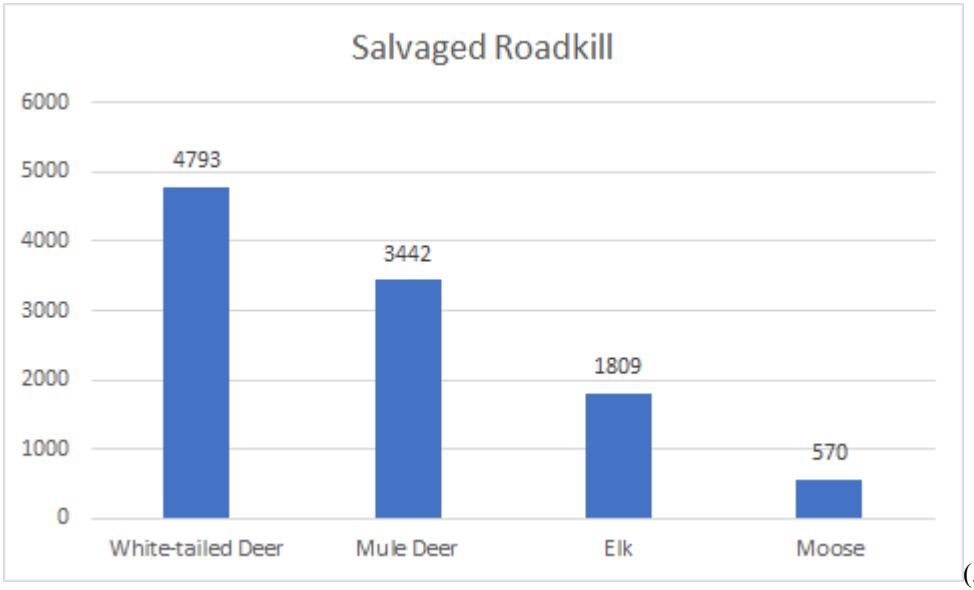
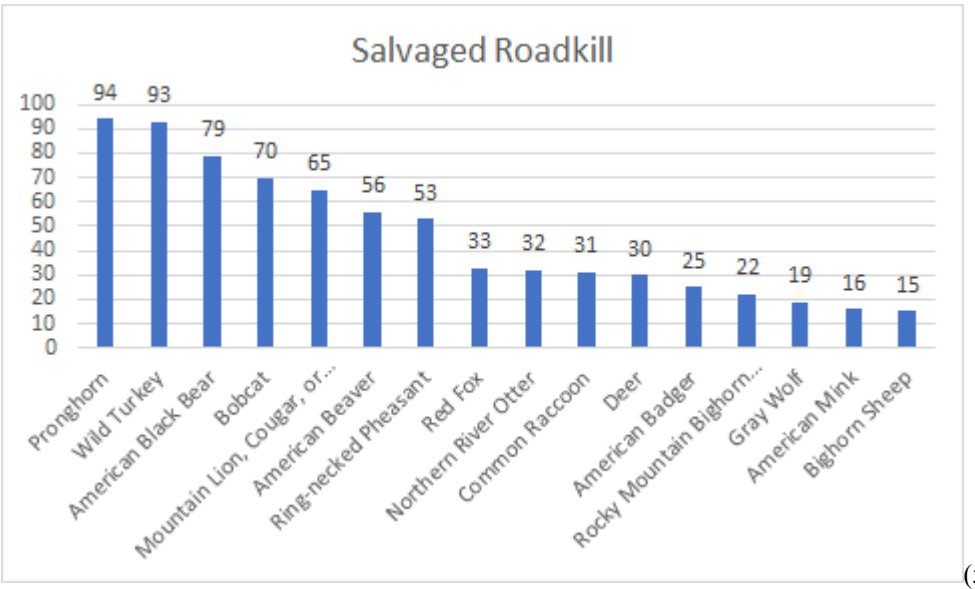


Figure 4. Wildlife observations in iNaturalist. The 20 species with the greatest number of observations in iNaturalist from January 2009 to January 23, 2020.

Only two species, mule deer and moose, appear in both the top 15 most commonly reported roadkill and observed wildlife. Of the 37,882 reported roadkill, 11,433 were salvaged by the reporter. These consist of 50 unique species, with the most common being ungulates (Figure 5).



(5a.)



(5b.)

Figure 5. Salvaged roadkill. The species of the most commonly salvaged roadkill from January 1, 2009 to January 23, 2020, divided into medium and large ungulates (5a.) and all other species (5b.).

Deer Roadkill

White-tailed deer first appeared in the roadkill record in 2005. From then to 2019 there were 13,274 mule deer and 14,857 white-tailed deer roadkill (Figure 5). This relationship was analysed with a linear regression (Table 1).

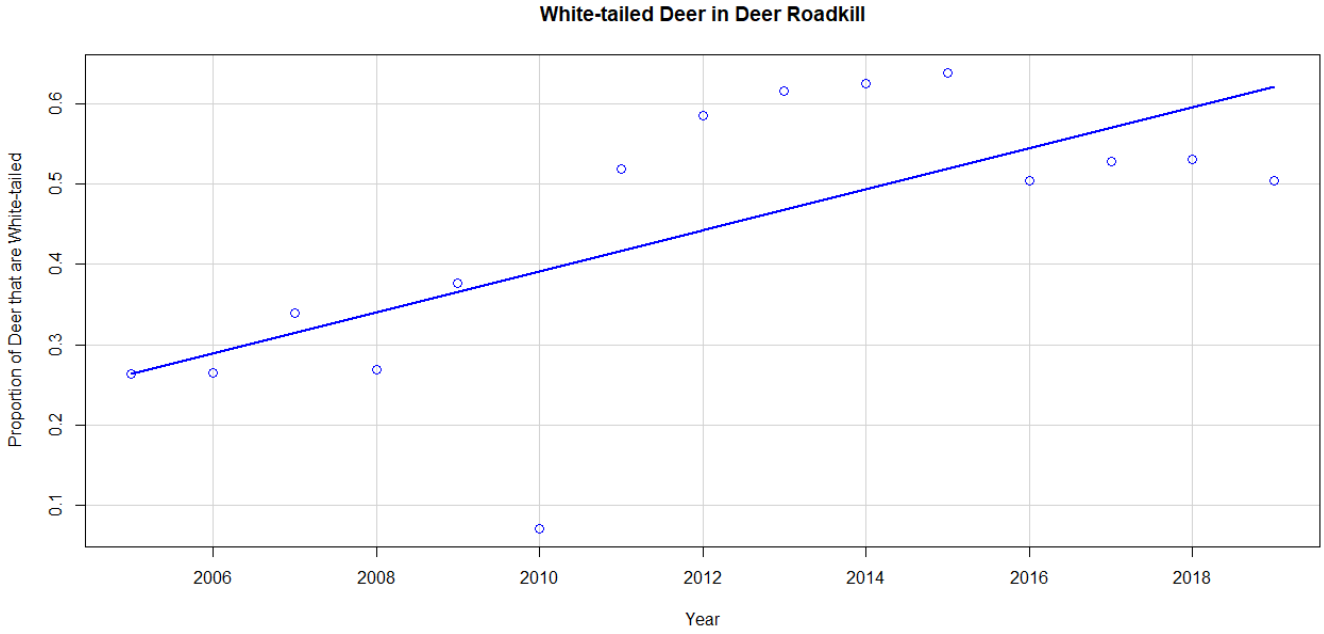


Figure 6. The proportion of white-tailed deer in deer roadkill. On average, white-tailed deer have comprised an increasing proportion of deer roadkill since 2005.

	Coefficients	Estimate Std. Error,	t value,	Pr(>|t|)
(Intercept)	-51.017972	15.437544	-3.305	0.00569
Year	0.025577	0.007673	3.333	0.00539
Residual standard error: 0.1284 on 13 degrees of freedom				
Multiple R-squared: 0.4608, Adjusted R-squared: 0.4194				
F-statistic: 11.11 on 1 and 13 DF, p-value: 0.005389**				

Table 1. The results of linear regression of the change in white-tailed deer roadkill over time.

Most relevant to this study there is an average 2.56% increase in the proportion of white-tailed deer each year, and this trend is significant, with a p-value of 0.005389.

Wildlife Highway Linkages

Of the 37,882 total roadkill observations reported (Figure 6), 31,632 occurred within 200 meters of state and interstate highways. Of these incidents, 17,054 occurred within the wildlife linkage zones (Figure 7). This means 83.5% of roadkill occured on highways, and 53.9% of highway roadkill, or in other words 45.0% of all roadkill, occurred within wildlife linkage zones.

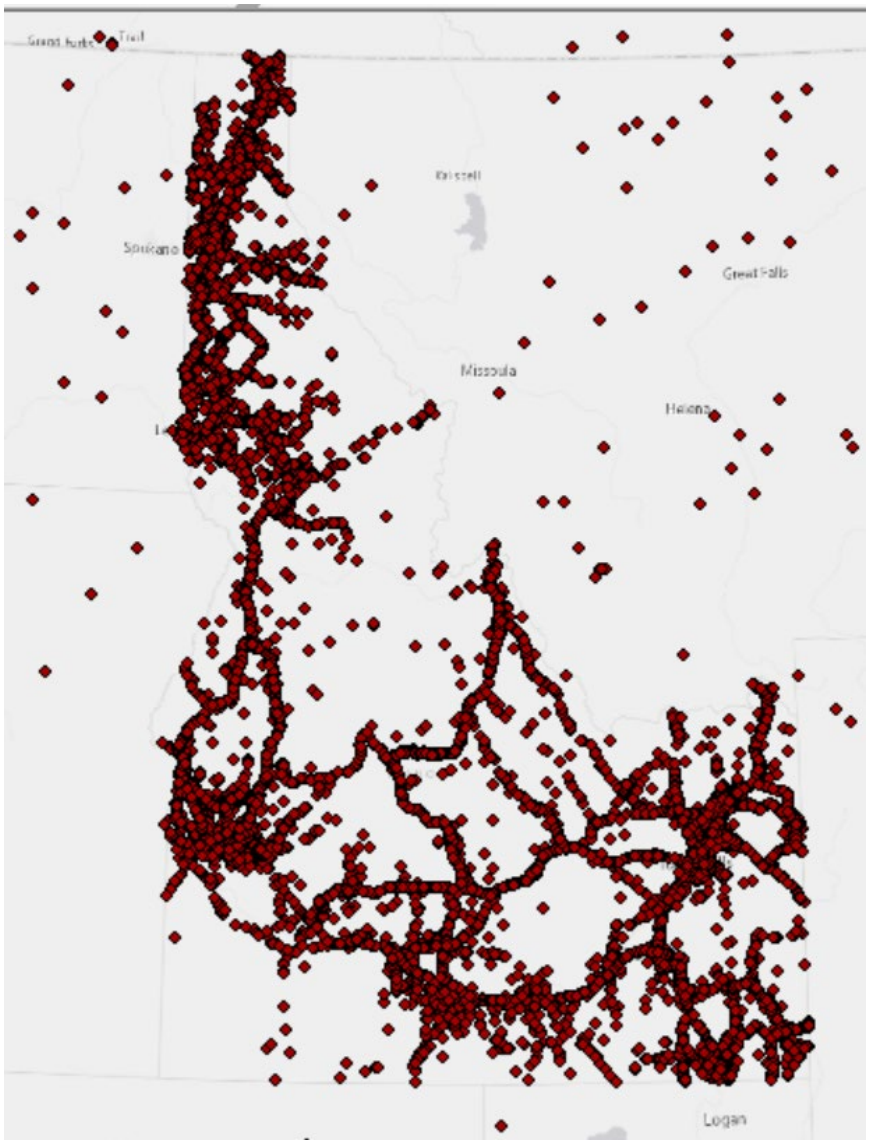
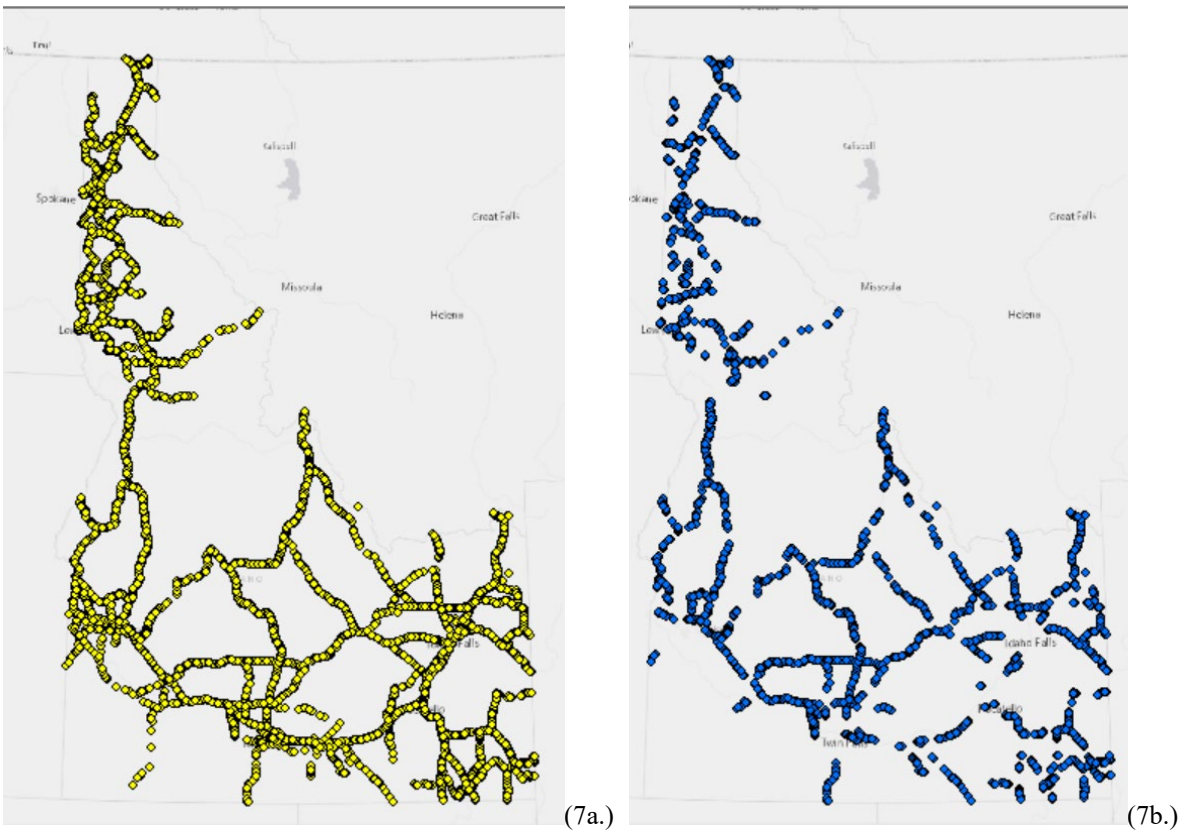


Figure 6. All roadkill observations. Data points located outside of Idaho are likely errors in the reported coordinates.



(7a.) (7b.)

Figure 7. Highway roadkill observations. All roadkill occurring within 200 meters of the state and interstate highway system (7a). Roadkill occurring both within 200 meters of highways and in wildlife linkage zones (7b).

A 200 meter buffer around all highways has a total area of 5933.2 square kilometers, and the overlap of wildlife linkage zones in this buffer has a total area of 2472.8 square kilometers (Figure 8); therefore these linkage zones contain 41.7% of the total highway buffer area.

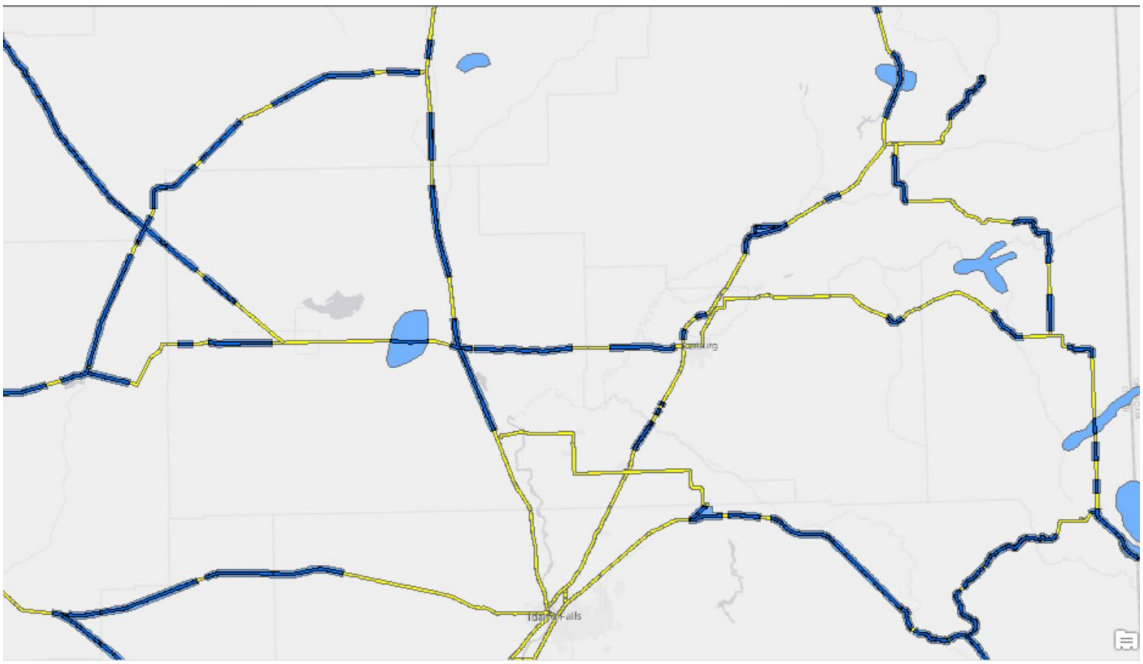


Figure 8. Highway buffers and linkage zones. A zoomed-in image of the buffer around highways in yellow, and wildlife linkage zones in dark blue. The light blue areas are wildlife linkage zones that do not overlap with highways. This map extends to the entirety of the state.

DISCUSSION

We must understand the phenomenon of wildlife-vehicle collisions if we are to make our roads safer for humans and wildlife. As expected, the current roadkill data collected by the Idaho Fish and Game department is heavily biased toward large ungulates. The ratio of white-tailed deer to mule deer roadkill has significantly increased in the last 15 years, at an average rate of about 2.6% a year. This indicates either white-tailed deer populations are increasing, or mule deer populations are declining. Of roadkill that occured along highways, 53.9% occurred in wildlife linkage zones, suggesting it is more likely that wildlife-vehicle collisions occur in these areas. I will first consider the data I used, what biases it contains, and what it may reveal about the wildlife most impacted by vehicle collisions in Idaho. I will then focus on deer collisions in particular and what they might suggest about a particular species population dynamic. By examining the species composition and location of roadkill, I will suggest mitigation strategies best suited for reducing roadkill in Idaho.

What Animals Appear as Roadkill?

Unsurprisingly, this data clearly demonstrates the bias toward large ungulates roadkill present in many data collection platforms. Nationally, deer are the most frequently reported roadkill, this is partially because since deer are large enough to cause considerable damage to vehicle when struck, collisions involving deer are more likely to be recorded by drivers making of insurance claims as well as highway patrol officers accident reports (Shilling et al. 2015) Additionally, as migratory animals, deer must cross roads often. In comparing the iNaturalist and roadkill data, it is apparent that reptiles, amphibians, small mammals, and birds are largely absent in the roadkill records, despite accounting for over 93% of all observations in iNaturalist. While this could be because such animals are less likely to be involved in vehicle collisions, it is far more likely that such collisions go unnoticed and unreported (Ruiz-Capillas et al. 2015). In part, this is because small carcasses do not attract attention from passing motorists, but it is also influenced by the often short retention time of small carcasses; scavengers have been found to remove small bird roadkills in just half an hour (Slater 2002), reducing the chance of the public encountering these species as roadkill at all. Studies conducted into these missing small vertebrate mortalities have estimated that around 80 million (Boves & Belthoff 2012) to as many as 240 million (Schwartz et al. 2019) birds are killed in vehicle collisions in the United States each year, with young birds dispensing from nest sites being particularly vulnerable. Small mammals and herpetofauna roadkill are similarly understudied. The dearth of robust data for these taxa can make it difficult to adequately protect such animals from vehicle collisions, as they will respond to environmental features differently than large mammals (Cleavenger et al. 2003). Ultimately, this means opportunistically collected roadkill data cannot answer many questions about the significance of collisions on many wildlife species, and data collected systematically by researchers must still be used to explore such questions.

It is worth noting that of the five species of birds which appear in the 20 species most reported as roadkill, three are owls. Owls are not legally salvageable species, meaning no part of their carcasses can be taken for use, reducing any bias motorists might have toward reporting them, and are the observations of them alive are not proportional to their presence as roadkill. Barn owls for example, which are one of the most common and widespread owl species (Boves & Belthoff 2012), were recorded in iNaturalist 14 times while appearing as roadkill 201 times over the same

period. This incongruity suggests that owls may be more susceptible to vehicle collisions than other bird species, a finding that is consistent with other studies into owl road mortality. There are several proposed reasons for this vulnerability; barns owls may fly at vehicle-level when patrolling their territory (Grilo et al. 2014), and many species of owls have been observed eating carrion (Kapfer et al. 2011). Additionally, wildlife-vehicle collisions are more likely to occur in the low-visibility conditions of dusk and night, further increasing their risk to nocturnal and crepuscular wildlife (Huijser 2008). Some researchers have gone as far to contend that vehicle collisions are one of the greatest causes of owl mortalities (Gagné et al. 2015). This illustrates the compounding consequence of wildlife-vehicle collisions: if owls are being attracted to roadkill, then reducing vehicle collisions with other species could have a ripple effect, reducing mortality of scavenging birds such as owls.

Deer Roadkill in Idaho

Given the dominance of two deer species in roadkill, examining this data may reveal something about the population dynamics of these two species. Before making any conclusions, the validity of using roadkill data to monitor wildlife populations must be considered. There are some caveats to this approach; previous studies using roadkill to determine population dynamics have been conducted over small geographic areas, such as a single city, and use exceptionally well documented road mortality data (Baker et al. 2004). While there is still uncertainty about using roadkill counts to estimate population numbers, differences in roadkill counts between study sites have been found to accurately reflect differences in population sizes between the sites (Gehrt 2002). Most relevant to the data used in this study, changes in roadkill counts have been found to parallel changes in species abundance (Schwartz et al. 2019). There has been a significant change in the proportion of white-tailed deer to mule deer in roadkill, with white-tailed deer comprising an increasingly larger proportion of all deer roadkill. From roadkill alone however, I cannot determine whether this change is being driven by an increase in the white-tailed deer population, a decrease in the mule deer population, or a combination of both.

This shift in deer species roadkill supports the hypothesis that mule deer are in decline in Idaho, and across the western United States. Although precise population estimates are hard to determine, mule deer fawn recruitment has been generally declining since the 1970s (with some

regional exceptions, such as Arizona) while white-tailed deer populations have not shown the same decline in fawn recruitment (Carpenter 1998). While the exact dynamics between these two deer species are difficult to untangle, white-tailed deer seem to outcompete mule deer when the species come into direct competition over resources (Weiglus 2017). This is particularly evident in landscapes that have been converted to agriculture, and points to mule deer requiring greater expanses of native vegetation for adequate forage (Carpenter 1998). Along with the decades-old issue of land use change, newer research suggests that a warming climate favours white-tailed deer by expanding the northern range of habitat suitable for this species (Dawe & Boutin 2016), further raising concern for mule deer in the future. In 2004 the Idaho Department of Fish and Game launched their Mule Deer Initiative to address this species's decline, and wildlife-vehicle collisions were identified as a significant contributor to the problem (Idaho Dept. Fish and Game 2012). Although both species are killed on roads, as has been demonstrated with vulnerable and endangered species such as the florida panther, the consequences of these mortalities is greater for species with already smaller or declining populations.

Roadkill in the Landscape

The majority of roadkill, around 83.5% in total, was reported along state and interstate highways. This is an expected finding, as the higher speed limits and traffic volumes of major roads make them more dangerous to wildlife (Zimmerman et al. 2017, Grilo et al. 2015). Idaho is a sparsely populated state, and it is likely that most roads do not reach traffic volumes high enough to deter those species that display avoidance behavior at very high traffic volumes, such as deer and rabbits, (D'Amico et al. 2017), but still have enough traffic to make collisions with wildlife common. While non-highway roads can also be significant sources of wildlife mortality (Huijer et al. 2008), evaluations of roadkill are focused on providing solutions for the particular roads in question, and since effective mitigation is expensive (Rytwinksi et al. 2016), such measures are only feasible for roads with justifiably high enough traffic volumes.

Wildlife linkage zones were identified by a collaboration of biologists, transportation specialists and Fish and Game officials in 2007 as part of an effort to increase habitat connectivity across Idaho. The zones are characterised by a variety of features, including riparian and fish corridors, secure core habitats, hiding cover and other characteristics important to threatened and

endangered species (Idaho Dept. of Fish and Game and Dept. of Transportation 2007). As such, not every linkage zone is utilized by every species, and not every linkage zone lies near or across roads. While admittedly not tested for significance, it is still worth considering that while wildlife linkage zones overlap with around 42% of the total length of highways, they contain nearly 54% of roadkill observations. This suggests that these areas are more likely to be the location of wildlife-vehicle collisions. Such a result is logical, since wildlife generally avoid moving through open terrain if possible, areas with greater vegetative cover or other features will be more likely to have wildlife in them; such is the reason why protected parklands exhibit higher rates of roadkill than the surrounding landscape (Garriga et al. 2012). Identifying these higher mortality zones allows examination of reasonable mitigation options.

This leads into possible mitigation options appropriate to the conditions present along highways of Idaho. The state has already had success with one wildlife-vehicle collisions mitigation project: the Highway 21 underpass, located in the Boise Mountains of western Idaho, was completed in 2011 and in the spring after it's construction only one deer collision was reported, down from the 75-200 such collisions reported in previous years (Nokkentved 2011). This is a promising start to roadkill mitigation in the state. Given the underreporting of small animal roadkill, future mitigation should be designed to accommodate such wildlife, rather than just deer and other large mammals. Such measures could include vegetated overpass structures, or less expensive underpasses designed to avoid flooding or other conditions that prevent less mobile wildlife from being able to use them effectively (Rytwinksi et al. 2016), in combination with wildlife fencing, appropriately placed as to not create additional danger to crossing animals (Kreling et al. 2019). Fortunately, small animals such as herpetofauna will make use of passage structures so long as these structures allow for their movement (McGregor et al. 2015). The initial price of passage structures can be daunting to local governments, but in the long run they are necessary to significantly reduce collisions (Rytwinksi et al. 2016) and should be treated as infrastructure investments.

Location and Roadkill data

This project was originally going to be conducted in California, but obtaining roadkill data for that state proved to be a formidable obstacle. The most complete database of roadkill in

California is not run by a government agency, instead it is an independent project run by the UC Davis road ecology center. For Idaho, on the other hand, this data is immediately accessible by any member of the public. A notable difference in laws regarding roadkill exist between these states: Idaho allows certain species of roadkill to be salvaged, while California does not. In Idaho, specific species of big game, upland game, upland game birds, furbearers, and nongame unprotected wildlife may be collected if killed in collisions, either for edible flesh or for the sale of non-edible parts. Doing so requires the salvager to report the roadill within 24 hours and to obtain a salvage permit within 72 hours (Idaho Department of Fish and Game 2012). Examining the salvaged roadkill illustrates that while four most salvaged species are also the most commonly reported roadkill, the majority of roadkill is not reported by people intending to salvage it. While it is beyond the scope of this project to make any connections between the legality of roadkill salvage and the incentive of a state government to more closely monitor roadkill, it is not unreasonable to consider that these laws may increase public awareness and willingness to engage in citizen science roadkill reporting.

Limitations and Future Directions

This project has led me to the same conclusion as many roadkill studies: to accurately analyze wildlife-vehicle collisions, a standardized system of data collection across municipalities and states is needed. As it stands, the incomplete nature of data makes coming to decisive conclusions difficult and not realistic. Another critical aspect of roadkill data is it's accessibility- the reason I chose Idaho as a study site is because the Idaho Fish and Game Department both records roadkill and is transparent with its data and allows for public access. Not every state even collects data on roadkill, such as California, and not all that do allow the public to access this data.

This study is a precursory look into roadkill in Idaho, and every finding prompts new avenues of research. A possible future study would be to map wildlife migrations to identify where these migrations cross roads. The Fish and Game department has, in their GIS data repository, the locations of summer and winter ranges for mule deer, and if the migration corridors of mule and white-tailed deer could be determined, the potential for greatly reducing wildlife-vehicle collisions exists. Additionally, breaking down linkage zones by target taxa could be useful for examining collisions involving less reported wildlife such as reptiles and amphibians. It would also be

interesting to examine the relationship between a region's hunting and roadkill salvage laws and culture to its efforts to mitigate roadkill.

Broader Implications

The goal of every study into road ecology is to help illuminate how to avoid the problems caused by our transportation infrastructure. To this end, my findings are encouraging: identifying that roadkill is more likely to occur in wildlife linkage zones is a jumping-off point for more in depth analysis that could identify the precise locations where installing wildlife passage structures will have the greatest benefit to both animals and humans. Beyond the specifics of Idaho, roadkill is an issue well-suited to citizen science data collection- it is an easily observable and common problem, yet much of this phenomenon continues to go unrecorded and unremarked upon by governments across the country. Landscape connectivity is vital for the continued existence of many wildlife, and will only become more important as climate change forces species to move to new habitats. Unlike many environmental issues, roadkill is both easy to understand and not particularly difficult to prevent, making it an ideal arena for the effective combination of citizen science and standardized data collection to inform policy decisions. With more standardized and comprehensive data collection and greater government transparency into wildlife-vehicle mitigation projects, reducing the harm our roads cause to wildlife is easily within our reach.

Acknowledgements

I extend my thanks to the Idaho Department of Fish and Game for providing the data used in this study, and the Berkeley Geospatial Innovation Facility for assistance with the mapping section of this project, with special thanks o Tina, Sam, Jessica and the rest of the ESPM 175 team for supporting me through this process.

REFERENCES

Ashley, P., & Robinson, J. T. 1996. Road mortality of amphibians, reptiles and other wildlife on the Long Point Causeway, Lake Erie, Ontario. Canadian Field Naturalist, 110(3), 403-412.

Baker, P. J., Harris, S., Robertson, C. P. J. , Saunders, G. & White, P. C. L. 2004. Is it possible to monitor mammal population changes from counts of road traffic casualties? An analysis using Bristol's red foxes Vulpes vulpes as an example. Mammal Review 34:115-130.

Bager, A., & Rosa, C. A. d. 2010. Priority ranking of road sites for mitigating wildlife roadkill. Biota Neotropica, 10(4), 149-153.

Boves,T. J. & Belthoff J.R. 2012. Roadway Mortality of Barn Owls in Idaho, USA. The Journal of Wildlife Management 76:1381-1392.

Carpenter, L. H. 1998. Deer in the West. Proceeding from 1997 Elk/Deer Workshop. Wildlife Management Institute.

Clevenger, A. P., Chruszcz, B., & Gunson, K. E. 2003. Spatial patterns and factors influencing small vertebrate fauna road-kill aggregations. Biological Conservation, 109(1), 15-26.

Coffin, A. W. 2007. From roadkill to road ecology: A review of the ecological effects of roads. Journal of Transport Geography, 15(5), 396-406.

D'Amico, M., S. Périquet, J. Román, E. Revilla, and M. Hayward. 2016. Road avoidance responses determine the impact of heterogeneous road networks at a regional scale. Journal of Applied Ecology 53:181-190.

Forman, R. T. T., & Alexander, L. E. 1998. Roads and their major ecological effects. Annual Review of Ecology and Systematics*, 29*(1), 207-231.

Gagné, S. A., Bates, J. L., & Bierregaard, R.O. 2015. The effects of road and landscape characteristics on the likelihood of a Barred Owl (Strix varia)-vehicle collision. Urban Ecosystems 18:1007–1020.

Garriga, N., Santos, X., Montori, A., Richter-Boix, A., Franch, M., & Llorente, G. 2012. Are protected areas truly protected? the impact of road traffic on vertebrate fauna. Biodiversity and Conservation, *21*(11), 2761-2774. doi:10.1007/s10531-012-0332-0

Gehrt, S.D. 2002. Evaluation of Spotlight and Road-Kill Surveys as Indicators of Local Raccoon Abundance. Wildlife Society Bulletin 30:449-456.

Glista, D. J., DeVault, T. L., & DeWoody, J. A. 2009. A review of mitigation measures for reducing wildlife mortality on roadways. Landscape and Urban Planning, *91*(1), 1-7. doi:10.1016/j.landurbplan.2008.11.001

Grilo, C., Ferreira, F. Z., & Revilla, E. 2015. No evidence of a threshold in traffic volume affecting road-kill mortality at a large spatio-temporal scale. Environmental Impact Assessment Review, 55, 54-58.

Huijser, M. P. 2008. Wildlife-vehicle collision reduction study: Report to Congress: McLean, VA: U.S. Dept. of Transportation, Federal Highway Administration.

Idaho Department of Fish and Game & Idaho Transportation Department- Districts 3, 4, and 5 Fish and Wildlife Linkage Project GIS Layers Final Report. 2007. Prepared by Geodata Services, Inc. Missoula, Montana.

Idaho Department of Fish and Game. 2012. Roadkill & Salvage.

Idaho Department of Fish and Game. 2018. Mule Deer Initiative

Idaho Department of Fish and Game. 2020.Species Conservation Status.

iNaturalist Observations. 2020, January 23.

INSIDE Idaho ArcGIS Hub. 2019. Highway Wildlife Linkages. University of Idaho

Kapfer, J. M., Gammon, D.E., & Groves, J. D. 2011. Carrion-feeding by Barred Owls (Strix varia). The Wilson Journal of Ornithology 123:646-649.

Kioko, J., Kiffner, C., Jenkins, N., & Collinson, W. 2015. Wildlife roadkill patterns on a major highway in northern tanzania. African Zoology, *50*(1), 17-22.

Kreling, S. E. S., K. M. Gaynor, and C. A. C. Coon. 2019. Roadkill distribution at the wildland-urban interface. The Journal of Wildlife Management 83:1427-1436.

Kroll, G. 2015. An environmental history of roadkill: Road ecology and the making of the permeable highway. Environmental History*, 20*(1), 4-28. doi:10.1093/envhis/emu129

McGregor, M. E., S. K. Wilson, & D. N. Jones. 2015. Vegetated fauna overpass enhances habitat connectivity for forest dwelling herpetofauna. Global Ecology and Conservation 4:221-231.

Natural Resources Conservation Service. 2020 . https://www.nrcs.usda.gov/wps/portal/nrcs/detail/id/technical/?cid=nrcs144p2_048092.

Nokkentved, N. 2011. Highway 21 Wildlife Underpass is Working. Idaho Dept. of Fish and Game

Roadkills. 2020. https://idfg.idaho.gov/species/roadkill/list.

Ruiz-Capillas, P., Mata, C., & Malo, J. 2015. How many rodents die on the road? biological and methodological implications from a small mammals' roadkill assessment on a spanish motorway. Ecological Research, 30(3), 417-427.

Rytwinski, T, Soanes, K., Jaeger, J. A. G., Fahrig, L., Findlay, C. S., & Houlahan, J. 2016. How effective is road mitigation at reducing road-kill? A meta-analysis. PLoS ONE, 11(11), 166941.

Schwartz, A. L. W., F. M. Shilling, & S. E. Perkins. 2020. The value of monitoring wildlife roadkill. European Journal of Wildlife Research 66:.

Shilling, F. M., and D. P. Waetjen. 2015. Wildlife-vehicle collision hotspots at US highway extents: scale and data source effects. Nature Conservation 11:41-60.

Shilling, F., Denney, C., Waetjen, D., Herrold, K., Farman, P., & Perez, P. 2018. Impact of Wildlife-Vehicle Conflict on California drivers and Animals. In UC Davis Road Ecology Center.

Smith-Patten, B., & Patten, M. 2008. Diversity, seasonality, and context of mammalian roadkills in the southern great plains. Environmental Management, 41(6), 844-852.

Slater, F. M. 2002. An assessment of wildlife road casualties - the potential discrepancy between numbers counted and numbers killed. Web Ecology 3:33-42.

U.S. Census Bureau Geography Department. 2019.TIGER/Line® Shapefiles: Roads.

U.S. Census Bureau QuickFacts: Idaho. 2020. https://www.census.gov/quickfacts/ID.

Wielgus, R. B. 2017. Resource competition and apparent competition in declining mule deer (Odocoileus hemionus). Canadian Journal of Zoology 95:499–504.

Zimmermann Teixeira, F., A. Kindel, S. M. Hartz, S. Mitchell, L. Fahrig, & M. Cadotte. 2017. When road-kill hotspots do not indicate the best sites for road-kill mitigation. Journal of Applied Ecology 54:1544-1551.

APPENDIX

All Roadkill Observations:

Species Common Name	Count
Accipiters	3
American Badger	274
American Beaver	100
American Bison	1
American Black Bear	119
American Black Duck	1
American Crow	12
American Goldfinch	1
American Kestrel	6
American Marten	19
American Mink	26
American Pipit	1
American Robin	54
American White Pelican	3
American Wigeon	1
Animal	30
Bald Eagle	23
Barn Owl	201
Barn Swallow	4
Barred Owl	3
Barrow's Goldeneye	1
Bats	8
Bear	1
Belding's Ground Squirrel	1
Belted Kingfisher	5
Bighorn Sheep	19
Bird	34

Bird Hawks	1
Black-billed Magpie	14
Black-headed Grosbeak	2
Black-tailed Jack Rabbit	9
Black Bear	5
Bobcat	87
Brewer's Blackbird	42
Brewer's Sparrow	10
Broad-winged Hawk	1
Brown-headed Cowbird	9
Bullock's Oriole	4
Burrowing Owl	9
Bushy-tailed Woodrat	1
California Bighorn Sheep	1
California Gull	13
California Quail	8
Canada Goose	54
Cassin's Finch	5
Castoridae	1
Cedar Waxwing	7
Chipmunk	1
Chipping Sparrow	16
Chukar	5
Cinnamon Teal	3
Cliff Swallow	9
Columbian Ground Squirrel	2
Common Gartersnake	1
Common Goldeneye	1
Common Loon	1
Common Nighthawk	5
Common Poorwill	4

Common Raccoon	741
Common Raven	10
Common Whitetail	4
Cooper's Hawk	2
Coyote	399
Dabbling Ducks	1
Dark-eyed Junco	6
Dasymutilla	1
Deer	349
Deer Mouse	10
Domestic Cat	787
Domestic Cattle	32
Domestic Dog	149
Dusky Grouse	10
Eastern Cottontail	1
Eastern Fox Squirrel	20
Eastern Gray Squirrel	4
Eastern Kingbird	2
Elk	3111
Ermine	1
Eurasian Collared-Dove	2
European Starling	34
Evening Grosbeak	1
Fisher	1
Golden-mantled Ground Squirrel	2
Golden Eagle	38
Gophersnake	12
Gray Catbird	2
Gray Jay	1
Gray Partridge	12
Gray Wolf	31

Great Blue Heron	6
Great Gray Owl	19
Great Horned Owl	181
Greater Sage-Grouse	38
Green-tailed Towhee	3
Grizzly Bear	1
Gulls	10
Hairy Woodpecker	1
Hoary Bat	1
Horned Lark	3
Horse	6
House Sparrow	4
House Wren	11
Idaho Pocket Gopher	1
Idaho Point-headed Grasshopper	2
Killdeer	5
Lazuli Bunting	1
Least Chipmunk	1
Lesser Scaup	1
Lincoln's Sparrow	3
Little Brown Myotis	2
Long-eared Owl	5
Long-tailed Weasel	14
Mallard	30
Mammal	45
Meadow Vole	1
Merganser	1
Moose	1032
Mountain Bluebird	4
Mountain Chickadee	1
Mountain Cottontail	34

Mountain Goat	2
Mountain Lion	88
Mountain Plover	1
Mourning Dove	11
Mule Deer	11611
Muskrat	21
Mustela sp	6
North American Porcupine	369
Northern Bobwhite	1
Northern Flicker	15
Northern Harrier	5
Northern Pike	1
Northern Pocket Gopher	1
Northern River Otter	39
Northern Saw-whet Owl	6
Northern Shrike	1
Osprey	2
Owl	206
Painted Turtle	5
Peregrine Falcon	1
Phasianus	5
Pine Siskin	4
Prairie Falcon	2
Prairie Rattlesnake	1
Pronghorn	269
Pygmy Rabbit	2
Quail	8
Rabbit and Hares	148
Racer	3
Red-naped Sapsucker	1
Red-tailed Hawk	33

Red-winged Blackbird	7
Red Crossbill	4
Red Fox	96
Red Squirrel	39
Reptile	2
Ring-billed Gull	13
Ring-necked Pheasant	140
Rock Dove	6
Rocky Mountain Bighorn Sheep	34
Rodents	22
Rough-legged Hawk	8
Rubber Boa	1
Ruffed Grouse	28
Rufous Hummingbird	1
Sage Thrasher	3
Sandhill Crane	5
Savannah Sparrow	6
Sharp-shinned Hawk	2
Sharp-tailed Grouse	3
Short-eared Owl	52
Skunks and Stink Badgers	388
Snowshoe Hare	10
Snowy Owl	2
Song Sparrow	8
Sora	5
Sparrows	10
Squirrel, Woodchuck, Marmot	1
Striped Skunk	223
Striped Skunk	5
Swainson's Hawk	25
Swan	1

Terrestrial Gartersnake	7
Tree Swallow	6
True Foxes	87
True Owl	1
Trumpeter Swan	10
Turkey Vulture	4
Uinta Ground Squirrel	46
Duck	9
Flycatcher	1
Squirrel	3
Unknown	508
Vesper Sparrow	11
Virginia Opossum	2
Warbling Vireo	1
Water Vole	3
Western Groundsnake	1
Western Jumping Mouse	3
Western Kingbird	1
Western Meadowlark	20
Western Rattlesnake	5
Western Screech-Owl	4
Western Spotted Skunk	1
Western Tanager	6
Western Tiger Salamander	10
Western Toad	4
Western Wood-Pewee	1
White-crowned Sparrow	25
White-tailed Deer	14255
White-tailed Jack Rabbit	14
Wild Turkey	215
Wilson's Snipe	2

Wolverine	2
Woodchuck	2
Yellow-bellied Marmot	42
Yellow-headed Blackbird	2
Yellow-pine Chipmunk	6
Yellow-rumped Warbler	4
Yellow Warbler	14

All Observations made in iNaturalist:

Species Common Name	Count
Accipiters	1
American Avocet	22
American Badger	16
American Barn Swallow	3
American Beaver	31
American Bison	3
American Bittern	1
American Black-crowned Night-Heron	1
American Black Bear	33
American Bullfrog	78
American Coot	79
American Crow	88
American Dipper	20
American Elk	16
American Golden-Plover	3
American Goldfinch	66
American Green-winged Teal	2
American Kestrel	87
American Marten	2
American Mink	15

American Pika	61
American Pipit	16
American Pronghorn	4
American Red Squirrel	93
American Redstart	1
American Robin	225
American Tree Sparrow	6
American White Pelican	59
American Wigeon	68
Anna's Hummingbird	4
Audubon's Warbler	23
Baird's Sandpiper	2
Bald Eagle	164
Bank Swallow	9
Barn Owl	14
Barn Swallow	38
Barred Owl	19
Barrow's Goldeneye	18
Belted Kingfisher	39
Bewick's Wren	16
Big Brown Bat	1
Bighorn Sheep	40
Black-backed Woodpecker	3
Black-bellied Plover	3
Black-billed Magpie	137
Black-capped Ã— Mountain Chickadee	1
Black-capped Chickadee	110
Black-chinned Hummingbird	46
Black-crowned Night-Heron	18
Black-headed Grosbeak	34
Black-necked Stilt	22

Black-tailed Jackrabbit	11
Black-throated Gray Warbler	2
Black-throated Sparrow	4
Black Rosy-Finch	2
Black Scoter	3
Black Swan	1
Black Swift	2
Black Tern	1
Blotched Tiger Salamander	1
Blue-gray Gnatcatcher	4
Blue-winged Teal	8
Blue Jay	22
Bobcat	6
Bobolink	6
Bohemian Waxwing	15
Bonaparte's Gull	2
Boreal Chorus Frog	38
Boreal Toad	16
Brant	1
Brewer's Blackbird	43
Brewer's Sparrow	11
Broad-tailed Hummingbird	17
Broad-winged Hawk	1
Brown-headed Cowbird	31
Brown Creeper	15
Bufflehead	56
Bullock's Oriole	38
Burrowing Owl	28
Bushtit	4
Bushy-tailed Woodrat	1
Cackling Goose	7

California Gull	35
California Quail	106
California Scrub-Jay	1
Calliope Hummingbird	41
Canada Goose	305
Canada Jay	13
Canvasback	14
Canyon Wren	10
Caspian Tern	6
Cassia Crossbill	13
Cassiar Junco	2
Cassin's Finch	32
Cassin's Vireo	5
Cedar Waxwing	83
Chestnut-backed Chickadee	10
Chestnut-sided Warbler	2
Chinese Ring-necked Pheasant	1
Chipping Sparrow	41
Chorus Frogs	1
Chukar	20
Cinnamon Teal	27
Clark's Grebe	18
Clark's Nutcracker	27
Clay-colored Sparrow	1
Cliff Swallow	21
Coeur d'Alene Salamander	12
Columbia Spotted Frog	230
Columbian Ground Squirrel	42
Columbian Sharp-tailed Grouse	4
Common Garter Snake	41
Common Goldeneye	58

Common Grackle	2
Common Loon	25
Common Merganser	88
Common Merganser (North American)	5
Common Nighthawk	16
Common Poorwill	2
Common Raccoon	24
Common Raven	23
Common Redpoll	9
Common Sagebrush Lizard	147
Common Side-blotched Lizard	127
Common Slider	4
Common Yellowthroat	11
Cooper's Hawk	51
Cordilleran Flycatcher	7
Coyote	39
Dark-eyed Junco	102
Deer Mouse	8
Desert Collared Lizard	17
Desert Horned Lizard	30
Desert Nightsnake	2
Desert Striped Whipsnake	1
Domestic Cat	7
Domestic Cattle	1
Domestic Chicken	1
Domestic Dog	1
Domestic Duck	20
Domestic Muscovy Duck	2
Domestic Rabbit	6
Domestic Swan Goose	5
Domestic Turkey	1

Double-crested Cormorant	64
Downy Woodpecker	69
Dunlin	4
Dusky Flycatcher	6
Dusky Grouse	23
Eared Grebe	17
Eastern Cottontail	13
Eastern Gray Squirrel	1
Eastern Kingbird	43
Eastern Long-toed Salamander	1
Eastern Phoebe	2
Empidonax Flycatchers	6
Eurasian Collared-Dove	83
Eurasian Collared-Dove (Eurasian)	1
Eurasian Wigeon	5
European Starling	105
Evening Grosbeak	40
Feral Pigeon	23
Ferruginous Hawk	13
Fisher	1
Flammulated Owl	1
Forster's Tern	2
Fox Sparrow	3
Fox Squirrel	169
Franklin's Gull	12
Gadwall	32
Gambel's Quail	1
Gambel's White-crowned Sparrow	3
Garter Snakes	4
Glaucous Gull	3
Golden-crowned Kinglet	17

Golden-crowned Sparrow	1
Golden-mantled Ground Squirrel	52
Golden Eagle	32
Golden Pheasant	1
Gopher Snake	423
Grasshopper Sparrow	4
Gray-crowned Rosy-Finch	4
Gray-headed Junco	1
Gray Catbird	15
Gray Flycatcher	6
Gray Partridge	15
Gray Wolf	13
Great-tailed Grackle	5
Great Basin Fence Lizard	8
Great Basin Gopher Snake	94
Great Basin Rattlesnake	176
Great Basin Skink	5
Great Basin Spadefoot	19
Great Basin Whiptail	3
Great Blue Heron	101
Great Egret	17
Great Egret (American)	1
Great Gray Owl	19
Great Horned Owl	124
Greater Sage-Grouse	16
Greater Sandhill Crane	2
Greater Scaup	4
Greater White-fronted Goose	20
Greater Yellowlegs	7
Green-tailed Towhee	11
Green-winged Teal	14

Green Heron	1
Greylag Ã— Swan Goose	2
Grizzly Bear	1
Gyrfalcon	1
Hairy Woodpecker	30
Hammond's Flycatcher	5
Harlan's Hawk	3
Harlequin Duck	5
Harris's Sparrow	5
Hermit Thrush	12
Herring Gull	12
Hoary Bat	4
HolbÃ¸ll's Red-necked Grebe	1
Hooded Merganser	52
Hooded Warbler	1
Horned Grebe	14
Horned Lark	33
House Finch	114
House Mouse	3
House Sparrow	87
House Wren	27
Iceland Gull	1
Iceland Gull (Thayer's)	4
Idaho Giant Salamander	13
Idaho Ground Squirrel	4
Indian Peafowl	1
Indigo Bunting	1
Juniper Titmouse	4
Killdeer	127
Lark Sparrow	13
Lazuli Bunting	47

Least Chipmunk	17
Least Sandpiper	4
Lesser Black-backed Gull	7
Lesser Canada Goose	4
Lesser Goldfinch	54
Lesser Sandhill Crane	1
Lesser Scaup	27
Lesser Snow Goose	1
Lesser Yellowlegs	5
Lewis's Woodpecker	17
Lincoln's Sparrow	7
Little Brown Bat	2
Loggerhead Shrike	6
Long-billed Curlew	20
Long-billed Dowitcher	8
Long-eared Owl	5
Long-nosed Leopard Lizard	38
Long-nosed Snake	1
Long-tailed Duck	2
Long-tailed Shrews	1
Long-tailed Weasel	13
Long-toed Salamander	59
MacGillivray's Warbler	8
Mallard	276
Marbled Godwit	1
Marsh Wren	5
Masked Shrew	1
Meadow Vole	1
Merlin	26
Merlin (Taiga)	2
Merriam's Turkey	1

Merrill's Song Sparrow	2
Mew Gull	1
Miller's Myotis	4
Moffitt's Canada Goose	6
Montana Oregon Junco	3
Moose	166
Mountain Bluebird	61
Mountain Chickadee	42
Mountain Cottontail	33
Mountain Goat	11
Mountain Lion	6
Mountain White-crowned Sparrow	2
Mourning Dove	60
Mouse-eared Bats	1
Mule Deer	185
Muskrat	28
Mute Swan	9
Nashville Warbler	10
Nevada Side-blotched Lizard	6
Nevada Spotted Towhee	1
North American Barn Owl	2
North American Mountain Lion	1
North American Porcupine	23
North American Racer	35
North American River Otter	7
Northeastern Great Blue Heron	1
Northern Alligator Lizard	15
Northern American Kestrel	9
Northern Bald Eagle	3
Northern Barred Owl	1
Northern Blue Jay	1

Northern Desert Horned Lizard	3
Northern Flicker	109
Northern Flying Squirrel	2
Northern Goshawk	7
Northern Harrier	50
Northern Hawk Owl	6
Northern Leopard Frog	92
Northern Mallard	1
Northern Mockingbird	1
Northern Pacific Rattlesnake	14
Northern Pintail	15
Northern Pocket Gopher	3
Northern Pygmy-Owl	6
Northern Pygmy-Owl (Rocky Mts.)	1
Northern Rough-winged Swallow	14
Northern Rubber Boa	55
Northern Sagebrush Lizard	8
Northern Saw-whet Owl	13
Northern Shoveler	36
Northern Shrike	8
Northern Shrike (American)	1
Northern Waterthrush	2
Northwestern Fence Lizard	1
Northwestern Ringneck Snake	2
Olive-sided Flycatcher	7
Orange-crowned Warbler	9
Ord's Kangaroo Rat	5
Osprey	125
Osprey (carolinensis)	6
Ovenbird	1
Pacific Loon	3

Pacific Marten	1
Pacific White-fronted Goose	1
Pacific Wren	9
Painted Turtle	26
Pallid Bat	5
Pectoral Sandpiper	5
Peregrine Falcon	7
Pied-billed Grebe	15
Pileated Woodpecker	31
Pine Grosbeak	11
Pine Siskin	43
Pink-sided Junco	3
Pinyon Jay	1
Piute Ground Squirrel	14
Plains Bison	1
Plumbeous Vireo	1
Prairie Falcon	19
Prairie Rattlesnake	6
Pronghorn	63
Pygmy Nuthatch	6
Pygmy Short-horned Lizard	23
Red-breasted Merganser	9
Red-breasted Nuthatch	75
Red-breasted Sapsucker	2
Red-eared Slider	6
Red-eyed Vireo	2
Red-flanked Bluetail	4
Red-legged Partridge	1
Red-naped Sapsucker	24
Red-necked Grebe	21
Red-necked Phalarope	5

Red-shafted Flicker	27
Red-tailed Chipmunk	3
Red-tailed Hawk	198
Red-winged Blackbird	120
Red Crossbill	12
Red Fox	34
Redhead	23
Regal Ringneck Snake	1
Ring-billed Gull	101
Ring-necked Duck	50
Ring-necked Pheasant	30
Ringneck Snake	1
Rock Pigeon	21
Rock Wren	31
Rocky Mountain Bighorn Sheep	7
Rocky Mountain Mule Deer	17
Rocky Mountain Tailed Frog	50
Rocky Mountains Hairy Woodpecker	1
Rose-breasted Grosbeak	2
Ross's Goose	3
Rough-legged Hawk	19
Rough-skinned Newt	74
Ruby-crowned Kinglet	28
Ruddy Duck	12
Ruddy Turnstone	1
Ruffed Grouse	33
Rufous Hummingbird	29
Sabine's Gull	1
Sage Thrasher	13
Sagebrush Sparrow	7
Sanderling	3

Sandhill Crane	75
Savannah Sparrow	25
Say's Phoebe	23
Scissor-tailed Flycatcher	1
Semipalmated Plover	4
Semipalmated Sandpiper	1
Shanks, Tattlers, and Allies	2
Sharp-shinned Hawk	22
Sharp-tailed Grouse	3
Short-billed Dowitcher	1
Short-eared Owl	16
Sierran Tree Frog	172
Silver-haired Bat	7
Skilton's Skink	1
Small Cackling Goose	1
Snow Bunting	3
Snow Goose	29
Snowshoe Hare	16
Snowy Egret	3
Snowy Owl	2
Snowy Plover	1
Solitary Sandpiper	4
Song Sparrow	134
Sora	3
Southwestern Common Raven	1
Spotted Sandpiper	28
Spotted Towhee	28
Spruce Grouse	14
Steller's Jay	26
Stilt Sandpiper	2
Stoat	5

Striped Skunk	16
Striped Whipsnake	45
Surf Scoter	3
Swainson's Hawk	109
Swainson's Thrush	3
Swans	1
Taverner's Cackling Goose	1
Tennessee Warbler	1
Townsend's Big-eared Bat	2
Townsend's Solitaire	37
Townsend's Warbler	9
Tree Swallow	50
Trumpeter Swan	50
Tundra Swan	14
Tundra Swan (Whistling)	1
Turkey Vulture	50
Uinta Ground Squirrel	9
Valley Garter Snake	34
Varied Thrush	17
Vaux's Swift	2
Vesper Sparrow	15
Violet-green Swallow	32
Virginia's Warbler	1
Virginia Rail	4
Wandering Garter Snake	154
Wapiti	56
Warbling Vireo	9
Wasatch Mountain Fox	1
Western Ã— Clark's Grebe	1
Western Bluebird	20
Western Bobcat	1

Western Burrowing Owl	1
Western Fence Lizard	120
Western Grebe	60
Western Groundsnake	6
Western Jumping Mouse	3
Western Kingbird	57
Western Meadowlark	39
Western Mourning Dove	1
Western Painted Turtle	38
Western Rattlesnake	14
Western Red-tailed Hawk	28
Western Robin	1
Western Sandpiper	8
Western Screech-Owl	23
Western Skink	24
Western Tanager	63
Western Terrestrial Garter Snake	236
Western Tiger Salamander	37
Western Toad	153
Western Whiptail	140
Western Wood-Pewee	23
Western Yellow-bellied Racer	64
Whimbrel	1
White-breasted Nuthatch	15
White-crowned Sparrow	80
White-faced Ibis	12
White-headed Woodpecker	7
White-tailed Antelope Squirrel	5
White-tailed Deer	73
White-tailed Jackrabbit	1
White-throated Sparrow	7

White-throated Swift	1
White-winged Crossbill	1
White-winged Dove	2
White-winged Scoter	1
Wild Turkey	87
Willet	5
Willet (Western)	1
Williamson's Sapsucker	8
Willow Flycatcher	11
Wilson's Phalarope	4
Wilson's Snipe	22
Wilson's Warbler	13
Wolverine	1
Wood Duck	81
Woodhouse's Scrub-Jay	5
Woodhouse's Toad	10
Yellow-bellied Marmot	62
Yellow-breasted Chat	9
Yellow-headed Blackbird	72
Yellow-pine Chipmunk	14
Yellow-rumped Warbler	46
Yellow-shafted Ã— Red-shafted Flicker	6
Yellow Warbler	47