Baseline Wildlife Monitoring at I-90 Snoqualmie Pass East, Prior to the Installation of Wildlife Crossing Structures

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16. ABSTRACT

The I-90 Snoqualmie Pass East Project (SPE) is located along a 15-mile stretch of Interstate 90 that passes through the Okanogan-Wenatchee National Forest. The project corridor has been identified as a critical connectivity zone for Pacific Northwest wildlife populations linking natural habitats both to the north and south of the project area. The Washington State Department of Transportation (WSDOT) will help alleviate the effects of increased traffic volume, a wider highway and increased traffic speed by enhancing ecological connectivity at 14 Connectivity Emphasis Areas (CEA) throughout the project area for multiple species and ecological processes.

Wildlife monitoring is needed both prior to and following the installation of project mitigation measures to ensure that efforts to enhance ecological connectivity are achieving their intended goals. WSDOT contracted with Western Transportation Institute (WTI) to conduct pre-construction baseline wildlife monitoring within the I-90 SPE project area from 2008-2012.
This baseline wildlife monitoring report addresses the collection of baseline data related to monitoring objectives. These objectives include: characterizing the rate and location of wildlife-vehicle collisions, assessing the extent of sub-grade and at-grade crossings by wildlife, and assessing species occurrence within the Project Area. This report identifies survey methods and approaches, provides a review of monitoring achievements, and outlines future efforts required to ensure project success.

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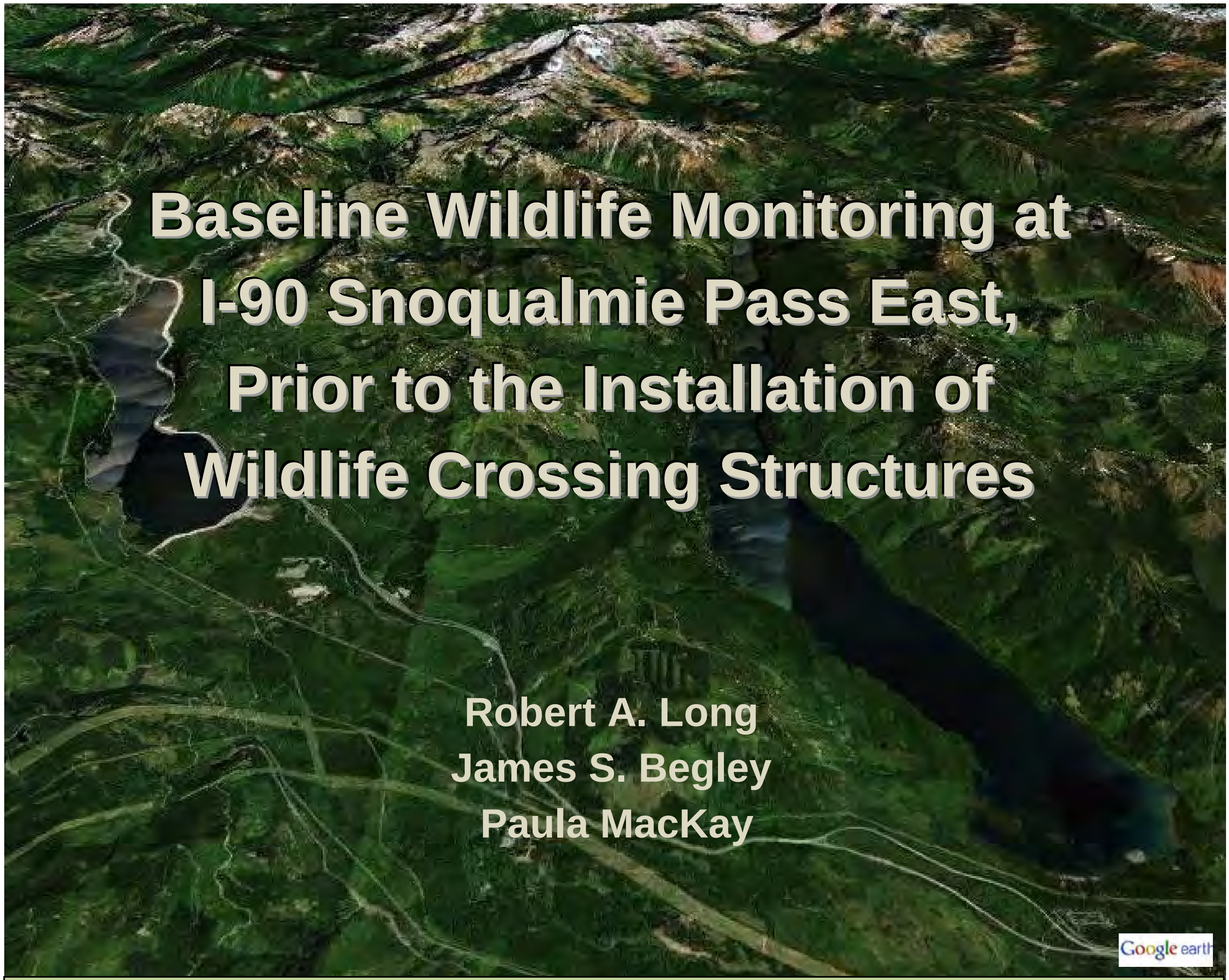

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Chapter 1 – Introduction

Preface

This chapter summarizes the I-90 Snoqualmie Pass East Project, its setting, and our objectives for pre-construction wildlife monitoring. The chapter draws heavily from material previously prepared by Western Transportation Institute and presented in the *I-90 Snoqualmie Pass East Wildlife Monitoring Plan* (Clevenger et al. 2008; also available from the Washington State Department of Transportation [WSDOT]). Please see this plan for further background.

The I-90 Snoqualmie Pass East Project

The I-90 Snoqualmie Pass East (SPE) Project was initiated to fulfill multiple objectives, including reducing avalanche and rock fall impacts on human safety and highway operation, replacing failing concrete pavement, adding lanes to reduce congestion, and improving ecological connectivity across I-90 (WSDOT 2006). To address planning for the ecological connectivity components of the project, WSDOT organized a Multi-Disciplinary Team (MDT) composed of the stakeholder agencies in the Project Area (WSDOT 2006). Recommendations from the MDT were used to inform the ecological connectivity measures that were eventually adopted for the project.

Wildlife crossing structures and associated wildlife exclusion fencing are increasingly being installed along roads and highways in North America and other locations around the world (Clevenger et al. 2009, Gagnon et al. 2011). Such measures are designed to mitigate the effects of highways on wildlife individuals and populations, and have been shown to be effective for a wide variety of species. In 12 years of monitoring 23 wildlife crossing structures at Banff National Park, Alberta, for example, researchers documented large mammals using these structures more than 185,000 times (Clevenger et al. 2009). The I-90 SPE Project proposes to construct more than 20 large (i.e., >120 ft span) wildlife crossing structures—including three major overpasses—along the 15-mile stretch of I-90 between Hyak (west) to Easton (east). In addition, continuous wildlife fencing will be installed throughout most of the Project Area. More details about the I-90 SPE Project are available through WSDOT (WSDOT 2006, 2008).

Project Setting

The I-90 SPE Project is located in the Cascade Mountain Range (Cascades) of Washington. The project comprises a 15-mile segment of I-90 beginning just east of Snoqualmie Pass. The project corridor, which passes through the Okanogan-Wenatchee National Forest, is part of a 100-mile scenic byway known as the Mountains to Sound Greenway—the first stretch of interstate highway in the country to be designated a National Scenic Byway. The corridor also occupies the Upper Yakima River sub-basin east of the Cascade crest. Its topography is mountainous, and it is situated in a rain-shadow that causes highly variable patterns of precipitation ranging from 140 in/year at Snoqualmie Pass to 50 in/year at Easton. The area thus represents an important ecotone between the dry interior and wet coastal zones, and a center of high biodiversity (Hansen et al. 1991).

Landscape Conservation and Biodiversity Values

The I-90 SPE Project Area lies within the boundaries of the Snoqualmie Pass Adaptive Management Area, which was created by the *Northwest Forest Plan* to address concerns regarding the northern spotted owl. The Plan highlights the importance of the Snoqualmie Pass area for maintaining ecological connectivity in the Cascades. Numerous public and private entities have made extensive efforts to improve the ecological conditions in the upper Yakima River watershed, including the development of land management plans that emphasize ecological connectivity, land exchanges, and purchases of private lands for transfer to public ownership.

Value and Threats to Biodiversity

At the landscape scale, the Project Area traverses an extensive network of public lands that provide refuge for wildlife, including the Okanogan-Wenatchee and Mt. Baker-Snoqualmie National Forests, multiple National Forest wilderness areas, and two national parks. The public lands directly abutting the project corridor represent the narrowest band of such lands running north-south in the Washington Cascades. The I-90 SPE corridor has therefore been identified as a critical connectivity zone for Pacific Northwest wildlife populations (e.g., Thomas et al. 1990), potentially providing ecological connectivity between the North and South Cascades (Singleton and Lehmkuhl, 2000). Research by Singleton and Lehmkuhl (2000) further suggested that the Project Area facilitates the local movement of wildlife, and identified three significant north-south linkage zones within the Project Area itself, each with its own distinct species assemblages (WSDOT 2006). Indeed, the USDA Forest Service has identified more than 49 species of amphibians, mammals, and birds that are closely associated with late-successional habitat or old-growth forest in the Project Area.

An estimated 28,000 vehicles pass through the Project Area on the average weekday, with traffic volumes swelling to as many as 58,000 per day on busy weekends and holidays (WSDOT, personal communication, December 2012). Over the course of a day, these volumes average to one vehicle every 3.1 and 1.5 seconds, respectively. Notably, traffic volumes on this section of I-90 are expected to increase at an average of 2 to 3 percent per year—a trend that WSDOT plans to accommodate by widening the highway from four to six lanes.

Roads and highways have been shown to have many negative effects on wildlife and natural communities. The most recent comprehensive review of wildlife-vehicle collision (WVC) databases across the United States estimated that 300,000 WVCs were reported each year, and that the total number of animal-vehicle collisions (AVCs, which include domestic animals and wildlife) was 1–2 million per year (Huijser et al. 2008).

In addition to its direct mortality effects, traffic on roads and highways can also reduce habitat quality in adjacent areas (Reijnen and Foppen 1994, Forman and Deblinger 2000), or result in avoidance by wildlife and therefore affect habitat use and movements (Rowland et al. 2000, Trombulak and Frissell 2000, Sweanor et al. 2000, Chruszcz et al. 2003, Gagnon et al. 2007, Keller and Bender 2007). Forman and Alexander (1998) suggest that avoidance may have the most pervasive effects on wildlife populations. Restriction of movements, especially when they affect dispersal, mating, and migration, can lead to population subdivision and genetic differentiation (e.g., Epps et al. 2005). Increasing traffic volumes along roadways can increase the rates of ungulate-vehicle collisions (e.g., Groot Bruinderink and Hazebroek 1996, Romin and Bissonette 1996).

Ecological Connectivity Objectives

Definitions of Ecological Connectivity

Without mitigation, the combined effects of increased traffic volumes, widening the highway, and a possible resulting increase in traffic speed in the Project Area would undoubtedly serve to further fragment wildlife habitat and populations. Thus, WSDOT determined it necessary to take measures designed to enhance ecological connectivity for multiple species and ecological processes over time (WSDOT 2006, WSDOT 2008). The MDT was charged with developing preferred options for the design and sighting of connectivity measures throughout the Project Area (WSDOT 2006).

As part of its recommendation package, the MDT defined ecological connectivity as:

> *The movement of organisms and the occurrence of ecological processes across an ecosystem over time. Intact ecosystems are structured by dynamic processes that create a shifting mosaic of various habitat patches. The ability of organisms to disperse freely through this mosaic is important to allow genetic exchange, re-colonization of habitats, and maintenance of functioning food webs. Genetic variability is a species' insurance against localized or population level disturbances and ultimately improves an organism's evolutionary potential. The ultimate outcome is natural sustaining populations across an ecosystem over time* (WSDOT 2006).

This definition provided the basis for monitoring and research designed to evaluate whether the project-wide objectives of increasing ecological connectivity in the Project Area were met during the phased reconstruction of the highway.

Project-Wide Objectives

The MDT report identified broad objectives to determine whether project designs would meet the goal of increased ecological connectivity. These objectives can be refined into three major questions:

- Are aquatic and terrestrial habitats sufficiently linked to function properly for the species they support? Habitats of particular importance include old-growth forests, upland forests, wetlands, riparian habitats, streams and unique habitats such as talus.

- Are hydrological processes sufficiently connected to permit the proper function of stream channels, riparian areas, floodplains, channel capacity and movement, wetland flow paths and hydroperiods, and groundwater-surface water interactions?

- Will highway-related wildlife mortality and impediments to movement be reduced sufficiently to provide a moderate to high probability of sustaining local and regional populations of all species, and to reduce risks associated with demographic isolation and limited genetic variability?

Connectivity Emphasis Areas

The MDT also identified “Connectivity Emphasis Areas” (CEAs), defined as areas within the Project Area where there is opportunity to improve connectivity for a unique assemblage of species and/or habitat types. CEA-specific connectivity objectives consist of increasing movement by wildlife and reconnecting plant and animal populations separated by I-90.

Wildlife-Specific Connectivity Objectives

The MDT report identified two broad objectives specific to improving terrestrial species linkages designed to meet ecological connectivity goals (WSDOT 2006). The first objective was to evaluate whether terrestrial habitats are adequately linked to allow for the movement of wildlife between core habitats, to meet the biological needs of wildlife, and to adapt to changing landscape conditions. Of particular importance were unique habitats in the Project Area, such as talus and old-growth forests, in addition to upland forests, wetlands, and riparian habitats. The second objective was to reduce highway-related mortality of wildlife and impediments to their movements, thereby helping to ensure local and regional populations of all native species and reducing risks associated with demographic isolation and limited genetic variability.

Wildlife Monitoring

Wildlife crossing structures and wildlife fencing are costly, and take many years to fund, design, and construct. Wildlife monitoring is required both prior to and following the installation of mitigation measures to ensure that efforts to enhance ecological connectivity are achieving their intended goals. We developed a pre-construction monitoring program—largely for high-mobility mammals—based on WSDOT’s *I-90 Snoqualmie Pass East Wildlife Monitoring Plan* (Clevenger et al. 2008). This program was designed to address the need for monitoring a variety of species at multiple scales, and the data generated were intended to compare with post-construction data in an effort to evaluate long-term structure performance.

Tiered Approach to Pre-Construction Wildlife Monitoring

Due to the landscape context of road systems, and the broad ecological connectivity objectives associated with the I-90 SPE Project in particular, we developed a two-tiered approach to gathering pre-construction, baseline monitoring data for the Project Area.

Tier 1 pre-construction monitoring was designed to help WSDOT answer the most fundamental transportation management questions regarding the ecological connectivity goals of the project (i.e., to address management concerns with regard to the performance of the project's connectivity design measures). Tier 2 pre-construction monitoring efforts are intended to build upon Tier 1 to help WSDOT and other agencies and organizations further assess whether ecological connectivity goals are achieved by having the highway design measures in place.

Pre-construction wildlife monitoring was conducted at multiple spatial scales, including within CEAs, across the Project Area, and throughout the region. Tier 1 monitoring was conducted primarily at the scale of CEAs and the Project Area. Tier 2 monitoring and research encompassed work at specific CEAs, as well as landscape-level and regional studies of wide-ranging mammals. WSDOT was the primary agency responsible for ensuring that Tier 1 monitoring was conducted, while additional public and private partners helped fund and address Tier 2 monitoring efforts.

Pre-Construction Monitoring Objectives

Our Tier 1 pre-construction monitoring objectives included the following:

1. <u>Characterize the locations and rate of wildlife-vehicle collisions</u>.
   Monitoring metric: Incidence of road-killed wildlife in the Project Area. What species are affected by collisions, where are collisions occurring and how frequently?

2. <u>Assess the use of existing sub-grade structures (e.g., culverts, underpasses)</u>.
   Monitoring metric: Use of structures. Do animals use the existing sub-grade structures prior to construction? If so, which species and how frequently?

3. <u>Characterize the rate of at-grade highway crossings by wildlife</u>.
   Monitoring metric: Crossing rates, locations and activity of wildlife in the Project Area. Do animals cross I-90? Which species, where, and with what frequency prior to construction?

4. <u>Assess species occurrence and distribution in the Project Area</u>.
   Monitoring metric: What species are present in the Project Area that might eventually use crossing structures? Assessing occurrence in areas adjacent to crossing structures is important for evaluating the effectiveness of the crossing structures, as expected use of a given structure by a species is contingent on the species occurring there.

Our monitoring methods and protocols were designed primarily for mammals, and generally mid- to large-bodied, high-mobility species. Although we occasionally report results pertaining to birds, our methods were not tailored for this taxonomic group and our results should thus be interpreted accordingly. Other monitoring efforts conducted by faculty and students from Central Washington University were focused on pikas, amphibians, reptiles, and fish.

Our Tier 2 efforts were less constrained. One of these efforts, spearheaded by a Master's student at Montana State University, focused on the presence, movement, and genetic connectivity of flying squirrels within the Project Area. A second Tier 2 project comprised an extensive, multi-partner landscape genetic study of American black bears and American martens.

Organization of this Report

This report is organized into four core chapters (Chapters 2–5). Chapters 2 and 3 primarily address the collection of baseline data relating to the first three Tier 1 monitoring objectives described above: characterizing the rate and location of wildlife-vehicle collisions, and assessing the extent of sub-grade and at-grade crossings by wildlife. Chapters 4 and 5 are focused on the third Tier 1 monitoring objective—assessing species occurrence within the Project Area—but also summarize Tier 2 evaluations of genetic connectivity for flying squirrels and carnivores. The latter two projects were collaborative in nature and funded by multiple partners. Scientific names for all species mentioned in this report are contained in Appendix 1.1, and therefore not included in the report body.

Chapter 2 – Monitoring Wildlife Vehicle Collisions and Live Animal Observations

Introduction

Collisions between vehicles and wildlife can have direct mortality effects on wildlife populations. The most recent comprehensive review of wildlife-vehicle collision (WVC) databases across the United States estimated that 300,000 WVCs were reported each year, and that the total number of animal-vehicle collisions (AVCs, which include domestic animals and wildlife) was 1–2 million per year (Huijser et al. 2008). From 1990–2004, the annual number of WVCs reported increased from 200,000 to 300,000, a change apparently associated with an increase in both vehicle miles driven, and deer population sizes in many regions of the U.S. By 2004 WVCs represented approximately 5% of all reported motor vehicle collisions (Huijser et al. 2008). Further, approximately 89% of all WVCs that occurred from 2001–2005 took place on two-lane roads and highways. Property damage costs associated with WVCs were estimated to be over $8 billion annually (Huijser et al. 2008).

Studies designed specifically to assess species composition of road-killed wildlife suggest that medium-sized mammals (e.g., porcupines, raccoons, skunks, and rabbits and hares) are the most often killed (Barthelmess and Brooks 2010). Most WVCs documented in standard surveys, however, are typically of ungulates (e.g., deer, elk, moose), both because they are large and tend to cause substantial property damage and human injuries (e.g., Nielson et al. 2003, Sullivan and Messmer 2003, Huijser et al. 2008)—and therefore are most likely to be reported—and because they are often migratory (Fryxell et al. 1999), and intersect roads during seasonal shifts between habitats. Further, smaller mammals are more difficult to see, and persist as carcasses for shorter periods than do larger species (Slater 2002, Barthelmess and Brooks 2010).

In addition to its direct mortality effects, traffic on roads and highways can also result in avoidance by wildlife and therefore affect habitat use and movements (Rowland et al. 2000, Trombulak and Frissell 2000, Gagnon et al. 2007, Keller and Bender 2007). Forman and Alexander (1998) suggest that avoidance may have the most pervasive effects on wildlife populations. Restriction of movements, especially when they affect dispersal, mating, and migration, can lead to population subdivision and genetic differentiation (e.g., Epps et al. 2005). Increasing traffic volumes along roadways can increase the rates of ungulate-vehicle collisions (e.g., Groot Bruinderink and Hazebroek 1996, Romin and Bissonette 1996). Alternately, however, some species such as elk may avoid areas near high-traffic roads (e.g., Rowland et al. 2000, Wisdom et al. 2005), leading to reduced road-related mortality when traffic volumes are higher (Gagnon et al. 2007). It is most likely, however, that the relationship between WVCs and highway traffic volumes is quite complex, and related to many variables including animal abundance, mitigation measures, landscape features, traffic volumes, and animal behavior (Seiler 2004, Gagnon et al. 2007). If avoidance effects for many species are positively correlated with traffic volumes, however, such effects could be substantial for wildlife adjacent to I-90 at Snoqualmie Pass East (SPE)—where daily traffic volumes average 28,000 vehicles on the average day, and can increase to as many as 58,000 per day on busy weekends (WSDOT, personal communication, December 2012).

Studies of wildlife mortality along roads and highways typically utilize two sources of data: AVC or WVC reports filed by law enforcement agencies, and Animal Carcass (AC) data collected by state departments of wildlife, natural resources, or transportation (Huijser et al. 2007). In Washington, AVC reports are compiled by the Washington State Patrol, but usually only for collisions involving substantial property damage or loss of human life. Further, while these reports distinguish between domestic animals and non-domestic animals, they generally do not provide species-level information for wildlife. Such limitations severely limit the value of AVC data for the analyses of wildlife mortality on roads.

For approximately 36 years, the Washington Department of Transportation (WSDOT) has collected AC data pertaining to highway and roadway segments in Washington (C. Broadhead, WSDOT, personal communication), including I-90 SPE. Historically, such data were collected on paper forms, focused primarily on ungulates and large carnivores (e.g., bears), and were not accompanied by routine trainings to ensure consistent effort and data accuracy. In 2005, the Western Transportation Institute (WTI) and WSDOT initiated a collaborative pilot program to standardize AC data collection by WSDOT maintenance crews working along I-90 SPE (Ament et al. 2011). This program included the use of computerized, handheld GPS/data entry units (Roadkill Observation Collection System [ROCS]) developed by WTI. In follow-up to this pilot program, WTI launched a full-scale monitoring effort in July 2008 to collect wildlife mortality data (hereafter WVC data, which technically combine WVC and AC data) via the efforts of WSDOT maintenance crew.

It is well-recognized that any given method for collecting WVC data has its limitations. In addition, locations where WVCs occur can differ considerably from locations where live animals congregate and/or cross highways successfully (Alexander et al. 2005, McCoy 2005, Lee 2007, Paul 2007). Thus, in November 2010, WTI and the I-90 Wildlife Bridges Coalition launched I-90 Wildlife Watch to engage motorists to report both live and dead animals sighted along I-90 between North Bend and Easton. This program was developed as a complement to other monitoring efforts in the I-90 SPE Project Area.

Here we address the following objectives related to WVCs and live wildlife in the I-90 SPE region:

1. estimate WVC rates, species composition, and hotspots via two methods—carcass reporting by WSDOT maintenance staff, and citizen reporting via a public website—for the I-90 Snoqualmie Pass East Project Area and an adjacent Control area, to serve as baseline data prior to the installation of crossing structures and wildlife fencing;

2. assess the power of monitoring under different scenarios to detect differences between pre- and post-construction WVC rates (i.e., determine the probability of detecting a given change in WVC rates after the installation of crossing structures and fencing given rates observed before installation);

3. identify live animal hotspots via a citizen reporting method for the I-90 Snoqualmie Pass

East Project Area and an adjacent Control area. Locations where live animals tend to occur may differ from WVC locations, and in such cases may represent places where successful crossings are more likely; and

4. identify landscape features associated with WVCs.

Study Area

The Study Area is described previously in detail (Chapter 1). WVCs and live animal observations were monitored along a 39.3-mile stretch of highway between mile post (MP) 31 (North Bend) on the west side of the Cascade Crest and MP 70.3 (Easton) on the east side of the Crest (Fig. 2.1). Given that one of our main objectives was to provide baseline data for comparison with post-construction WVC rates, we implemented a "before-after-control-impact" (BACI) design (Roedenbeck et al. 2007). Information described in this document constitutes pre-construction baseline data (i.e., the "before" component), with post-construction monitoring to eventually serve as the "after" component.

The 15.3-mile, I-90 SPE Project Area segment between MP 55 (Hyak) and MP 70.3 (Easton)—where planned mitigation activities include the installation of wildlife crossing structures and wildlife fencing—served as the impact component of our study. Our control area was the 24-mile stretch of I-90 between MP 31 (North Bend) and MP 54 (Hyak). Throughout the remainder of this document, we refer to results in terms of the Study Area (i.e., the full 39.3 mile segment), the Project Area (Hyak to Easton), and the Control Area (North Bend to Hyak). Within the Project Area, WSDOT had previously highlighted specific highway segments that were considered to be especially important for connectivity mitigation efforts (WSDOT 2006). Fourteen of these Connectivity Emphasis Areas (CEAs) are used as reference points in our report (Fig. 2.1).

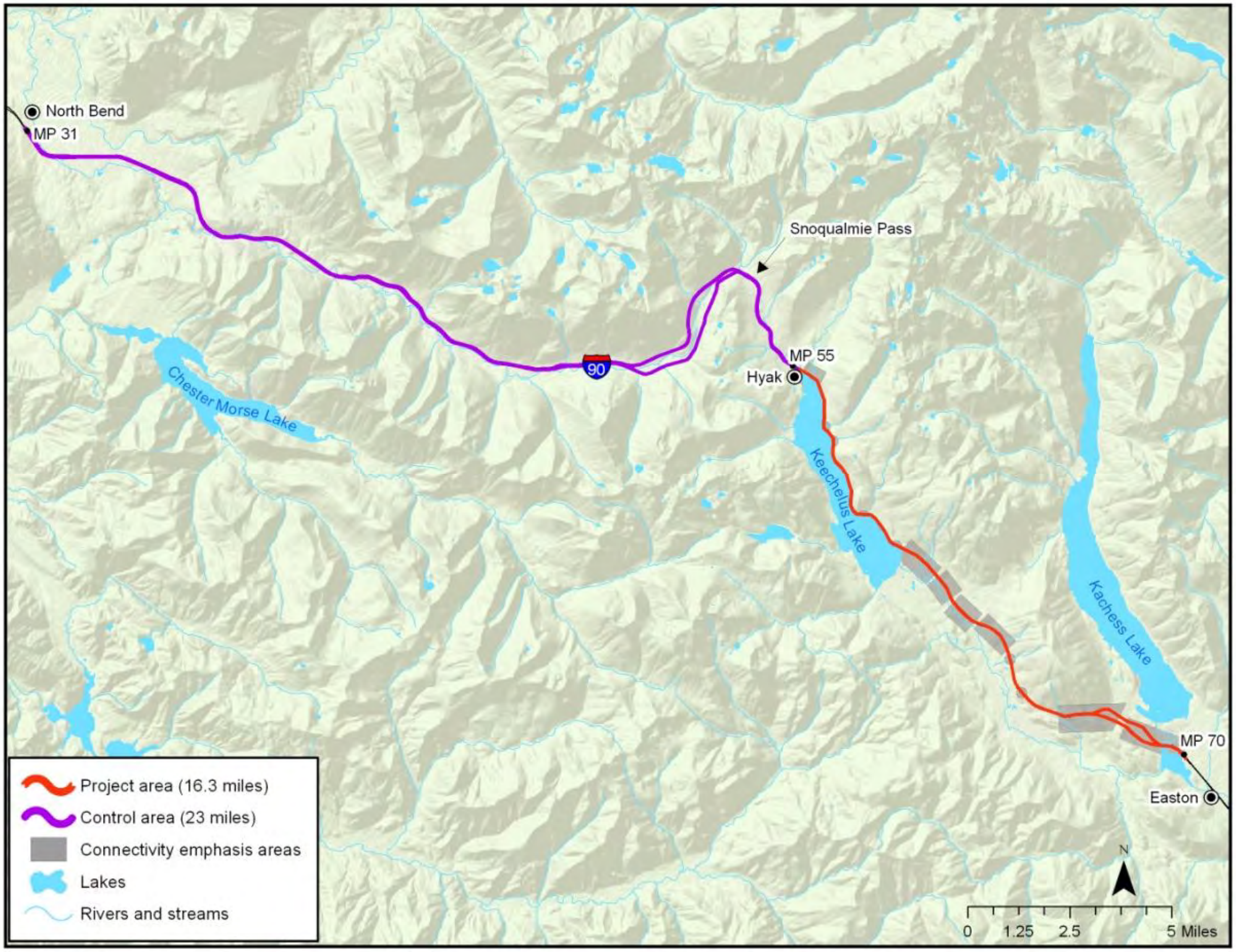


Figure 2.1. Map of Study Area highlighting the Project Area and adjacent Control Area, as well as Connectivity Emphasis Areas (CEAs) and select mileposts.

Methods

Data Collection

We used two sources of WVC data in our analyses: (1) carcass data collected during routine work activities by WSDOT maintenance personnel operating from WSDOT's Hyak facility; and (2) I-90 Wildlife Watch reports from citizens who observed dead animals while traveling through the Study Area.

WSDOT Maintenance Crew Data Collection

In July 2008, WSDOT maintenance personnel were supplied with Trimble Recon GPS XC PDA/GPS units (Trimble Navigation Limited, Corvallis, Oregon) loaded with ROCS software (Ament et al. 2011) (Figs. 2.2). The ROCS system facilitates the entry of geo-referenced locations containing the following information about a given carcass observation:

- date and time of the report;
- species (via a dropdown list);
- number of individuals;
- sex of individual(s);
- whether there was a resulting human injury or death;
- whether there was property damage to a vehicle;
- whether the carcass was removed;
- any additional notes of interest.

After information was entered, the carcass record—accompanied by its spatial coordinates—was uploaded to a database managed by WTI.

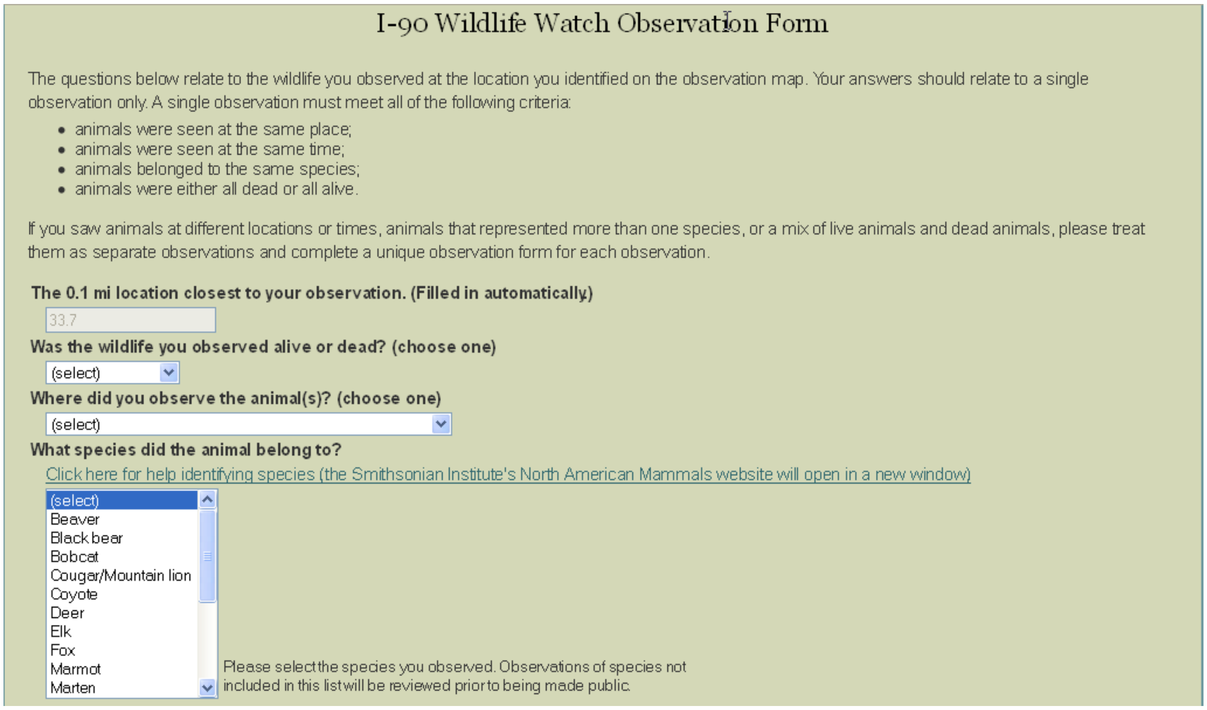
Figure 2.2. Trimble GPS unit (A) and ROCS software (B) used by WDOT maintenance personnel to collect WVC data. (Photos: WTI)

During July 2008, WTI personnel performed a comprehensive training for all WSDOT maintenance personnel who would be using ROCS units. The training included information about the I-90 SPE project, a description of why pre-construction wildlife monitoring was important, and detailed instructions for using the ROCS units, with particular protocols for data collection. Maintenance crews were instructed to record WVC data for all carnivores, as well as for other species larger than a snowshoe hare, as hares, squirrels, and other smaller species were likely to be either difficult to identify or potentially numerous, resulting in inordinate amounts of time and effort to record. Training refreshers have been provided once or twice each year since July 2008.

I-90 Wildlife Watch Data Collection

From its inception, I-90 Wildlife Watch represented an innovative partnership between WTI, the I-90 Wildlife Bridges Coalition, WSDOT, and other agency partners. I-90 Wildlife Watch encouraged motorists to report both dead and live animals along the I-90 corridor via a user-friendly website (www.i90wildlifewatch.org), which included a brief observation form and a locator map to capture sighting information (Fig. 2.3). Website visitors were also able to map sightings reported by other observers. Observers had the option to remain anonymous. GPS coordinates were not collected, as we felt that this information would not be feasible for most motorists to acquire while traveling. Rather, the locator map allowed observers to pinpoint sightings at the resolution of 1/10 mile. As with the WSDOT maintenance crew data collection, only species larger than a snowshoe hare—with the exception of the American mink—were listed on the reporting page. More details about I-90 Wildlife Watch can be found in the first year report (Appendix 2.1).

In an attempt to quantify the amount of survey effort expended, we explored a data collection approach using recruited volunteers that would permit standardized statistical comparisons of WVC and live animal reporting rates between time periods. More specifically, we recruited several volunteers who drove I-90 on a consistent basis (i.e., 1–2 times per week) to report their wildlife observations. In addition to reporting live and dead wildlife, these volunteers also recorded trips during which they saw no wildlife. Volunteer observations of alive and dead individuals were modeled with a Poisson distribution and used to calculate Bayesian estimates of individual observation rates and associated confidence intervals for volunteers driving the survey route. Estimated rates can potentially be compared with similarly collected, post-construction rates.



I-90 Wildlife Watch Observation Form

The questions below relate to the wildlife you observed at the location you identified on the observation map. Your answers should relate to a single observation only. A single observation must meet all of the following criteria:

- animals were seen at the same place;
- animals were seen at the same time;
- animals belonged to the same species;
- animals were either all dead or all alive.

If you saw animals at different locations or times, animals that represented more than one species, or a mix of live animals and dead animals, please treat them as separate observations and complete a unique observation form for each observation.

The 0.1 mi location closest to your observation. (Filled in automatically)

33.7

Was the wildlife you observed alive or dead? (choose one)

(select)

Where did you observe the animal(s)? (choose one)

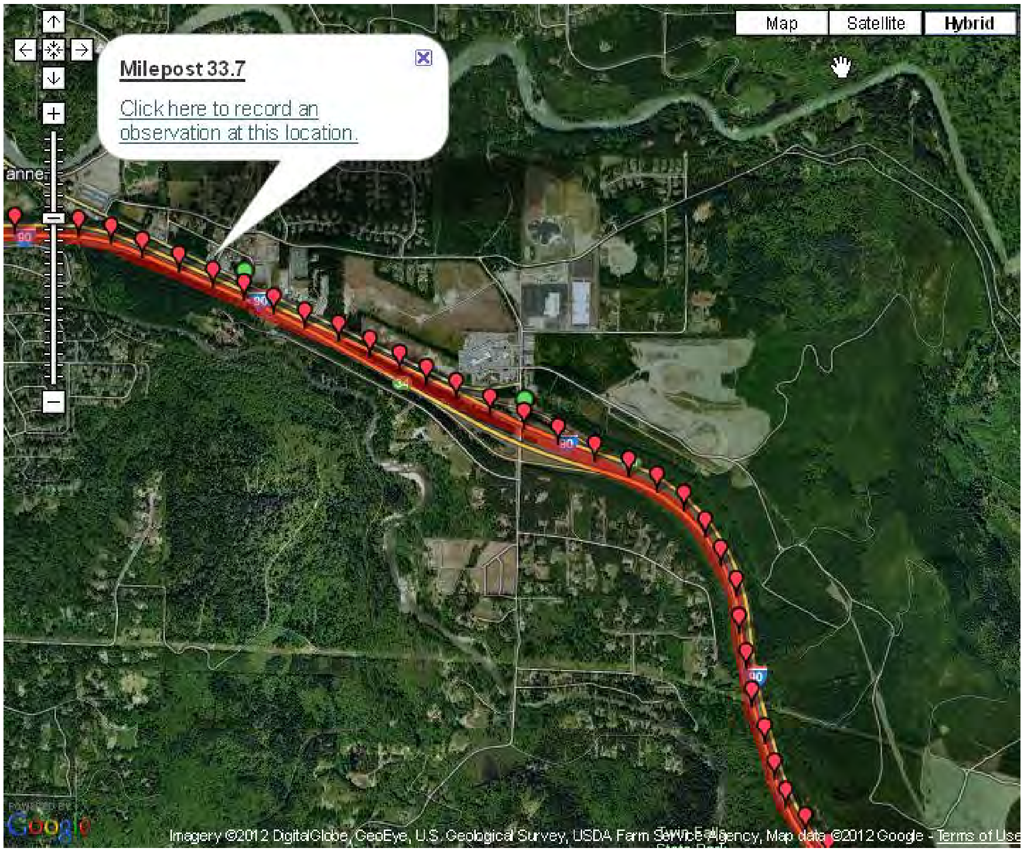
(select)

What species did the animal belong to?

Click here for help identifying species (the Smithsonian Institute's North American Mammals website will open in a new window)

Please select the species you observed. Observations of species not included in this list will be reviewed prior to being made public.

A.



B.

Figure 2.3. Observation form (A) and locator map (B) from the I-90 Wildlife Watch website showing 1/10 mile markers for locations of WVCs and live animal sightings.

Because the success of I-90 Wildlife Watch was dependent on citizen participation, numerous strategies were employed to inform motorists about the launch of the project, and to increase public awareness about the program. We selected a launch date of November 4, 2010, to coincide with "Give Wildlife A Brake" week—a national campaign coordinated by the Humane Society of the United States—and distributed a press release to regional media outlets. The story was picked-up by numerous media outlets, including the Seattle Times. Announcements were also posted on partner websites and blogs, and the program was profiled on various other electronic venues as well (Box 2.1).

Box 2.1. Examples of media promoting I-90 Wildlife Watch

Press release: New project is launched to document wildlife sightings along I-90
November 4, 2010

Drivers encouraged to report wildlife on I-90 over Snoqualmie Pass
Seattle Times, November 4, 2010

New website lets drivers track wildlife along stretch of I-90
Seattle Times, November 6, 2010

I-90 Wildlife Watch
KOMOnews.com (radio), November 6, 2010

New web site tracks I-90 roadkill
TechFlash, November 8, 2010

Heading over I-90 Snoqualmie Pass? Keep your eyes peeled for critters big or small
WSDOT Blog, November 10, 2010

Wildlife sightings wanted from drivers on I-90
Northwest Public Radio, November 22, 2010

Help map wildlife crossings as you drive I-90 east of Snoqualmie in WA
National Geographic Global Action Atlas, March 2011

Watching for wildlife on I-90
Fall City Newsletter, April 2011 (page 4)

I-90 project to ease flow of traffic, wildlife east of Snoqualmie Pass
Seattle Times, July 7, 2011

Volunteers keep eye on wildlife along Interstate 90
Ellensburg Daily Record, July 26, 2011

In early March 2010, we leased a billboard (Fig. 2.4) on the westbound side of I-90 in Cle Elum, approximately 12 miles east of the project area. This high-profile billboard was within easy view of all motorists traveling toward Snoqualmie Pass from eastern Washington, and was displayed for the remainder of the data collection period.

Figure 2.4. A billboard erected on the shoulder of I-90 near Cle Elum. (Photo: P. MacKay/WTI)

Temporal Differences Between Data Collection Approaches

The start dates and duration of data collection differed between our two approaches. Thus, we employed various time periods to describe and compare results from each dataset in the sections below. We encourage readers to pay close attention to figure and table captions to ensure the accurate interpretation of results.

Dealing with Duplicate Reports

We attempted to remove duplicate reports (i.e., two or more reports of the same live or dead individual) from both datasets. We assumed that any two or more (I-90 Wildlife Watch) reports of live individuals were duplicates if their locations were ≤ 0.2 mile apart and they occurred within two hours of each other. Similarly, we assumed reports of dead animals were duplicates if the locations were ≤ 0.2 mile apart and they occurred within 48 hours of each other. Data from WSDOT maintenance personnel were less likely to contain duplicates than I-90 Wildlife Watch data, as WSDOT typically removed carcasses from the roadway.

WVC Rates

In addition to reporting raw WVC and live animal frequencies, we calculated Poisson WVC rates representing WVCs or live animal reports per mile, and exact Poisson confidence intervals following Ulm (1990). Such rates permit comparisons between the Project and Control Areas, as well as with results from studies conducted elsewhere.

Power Analysis

We conducted power analyses to evaluate the capacity of our four-year MC WVC dataset to serve as effective pre-construction baseline data. More specifically, power analyses permitted *a priori* estimates of the probability of detecting a post-construction reduction in WVCs after a specified number of survey years based on the WVC rates observed during our four years of pre-construction monitoring. Further, such analyses allowed us to estimate the number of years of post-construction monitoring that would be required to achieve a specified power.

To conduct power analyses, we contracted J. Buzas (University of Vermont) to develop software programs that compute power and sample sizes for a one-sided hypothesis test comparing the rates of two Poisson distributions (Shiue and Bain 1982, Thode 1997). For all analyses, we used 0.80 as a target power, and set the Type I error rate (α; the risk of detecting a reduction in WVC rates if none actually exists) to 0.05. We excluded I-90 WW data from the power analysis because it is unclear whether I-90 Wildlife Watch will continue into the future or be reinitiated once mitigation efforts are complete.

Hotspot Analysis

We identified relative hotspots for WVCs and live animal locations using kernel estimation. This method evaluates point data and identifies clustering, or dense patterns of spatial locations. Kernel estimation has been used extensively to estimate distributions of animal locations from radio-telemetry data (Worton 1989), and has more recently been employed to characterize clustering of WVCs (Gomes et al. 2009). In our case, such clustering comprised locations of dead animals from data collected by WSDOT maintenance personnel (hereafter “Maintenance Crew” or “MC” data), and both live and dead animals from I-90 Wildlife Watch data (hereafter “I-90 WW” data). Analysis was performed with the spatial analyst toolbox for ArcGIS using the “kernel density” function. Point locations of dead and live animals were represented as point layers in ArcGIS, and the kernel function was performed using an underlying 30-m raster (i.e., grid) layer. Results are, therefore, represented as a density value (i.e., points/mi^2) for each 30-m grid cell.

WVC hotspots are typically defined as locations with the “highest” density of WVCs, and as such identifying what qualifies as “highest” is important. Some studies have used the top 5 percent (i.e., 95th percentile) of density values (Gomes et al. 2009), but such approaches are highly subjective and render comparisons between regions and datasets difficult. Instead, we employed a bandwidth of 500 m to estimate kernels and defined hotspots with a novel method that identified “core areas” from kernel output data (Bingham and Noon 1998). More specifically, this method identifies areas that are disproportionately within an animal’s home range relative to a uniform distribution, and expresses this area as an isopleth (i.e., contour line within which the high-use area or “core” occurs). For our purposes, we considered the area of the core to be analogous to a WVC or live animal hotspot, with the resulting output delineating areas of disproportionate clustering of WVC or live animal observations within the segment of highway being analyzed. Thus, percentiles used to define a hotspot varied among the different subsets of analysis and are identified in figure captions. This method is defensible, repeatable, empirical, and improves on *ad hoc* methods to identify WVC hotspots.

We conducted hotspot analyses separately for the Project and Control Areas. In addition to analyzing hotspots for all WVCs and live animal locations, we also conducted separate analyses for ungulates because deer and elk are often of special concern for transportation planning. To compare hotspots identified from MC data with those identified from I-90 WW results, and for comparisons of WVC and live animal hotspots, we mapped the relevant hotspots and looked for areas of overlap or discordance.

Identifying Landscape Features Associated with WVCs and Live Animal Locations

We identified landscape features associated with the locations of WVCs and live animal reports for deer and elk using maximum entropy habitat modeling with the software package MaxEnt (Phillips et al. 2006). MaxEnt is a method developed for modeling the distribution of species, and uses presence-only data consisting of information related only to sites where animals were reported (i.e., “absences” and “no detections” are not required for the analysis). Presence-only data contrast with presence/absence or presence/no-detection data, which include sites where surveys were conducted but animals were not detected. In species distribution modeling, MaxEnt can be used for prediction (e.g., to estimate where on the landscape a given species would be predicted to occur) and to identify which factors are associated with species occurrence. In our case, we employed MaxEnt to identify landscape features associated with where WVCs and live animal reports occurred along I-90. Although similar modeling methods (e.g., environmental niche factor analysis) have been used for roadkill hotspot analysis (e.g., Gomes et al. 2009), to our knowledge, this is the first time MaxEnt has been used for this purpose.

Inputs required by MaxEnt included a GIS point layer—in our case, representing locations of WVCs or live animal reports—and several underlying GIS raster (i.e., grid) layers representing landscape features suspected of being correlated with WVCs or live animal locations. MaxEnt permits the use of both continuous and categorical landscape layers, making it possible to include variables such as “distance to forest cover” (continuous) and “presence of a median” (categorical) in the same model. We included 3 continuous and 7 categorical landscape features in our analyses (Table 2.1) based on a review of the WVC literature and our own observations within the Project Area. The variable representing the presence of Lake Keechelus was included only in the Project Area analysis. Landscape grids were clipped to a 3-cell- wide path, with the center cell located along the highway midline. We conducted analyses for the Project and Control Areas separately, and for both WVCs and live animal reports. Given sample size constraints, we conducted analyses for only deer and elk. \

We used model selection methods (Burnham and Anderson 2002) and the software ENMTools (Warren et al. 2010) to compare various MaxEnt models containing different combinations of the 10 landscape features, and chose the best model for each species-area combination based on AIC values and Akaike weights (Burnham and Anderson 2002). This method estimates the weight of evidence in favor of a given model being the best model in the candidate set.

Table 2.1. Variables used in the MaxEnt analysis of landscape features associated with locations of wildlife-vehicle collisions.

Variable Name	Description	Type
BRDG	Locations where rivers or roads crossed under highway	Categorical
FORM	Presence of forested medians	Categorical
DTOF	Distance to nearest forest	Continuous
GRAM	Presence of grass medians	Categorical
LAKE	Presence of Lake Keechelus	Categorical
DTOR	Distance to nearest ridge	Continuous
LIGT	Presence of significant highway lighting	Categorical
MMDB	Presence of Jersey barrier	Categorical
SDEN	Stream density (mi/mi^2; calculated from a 900 m radius neighborhood analysis)	Continuous
TOPB	Presence of topographic barrier (e.g., cliff, roadcut)	Categorical

Once a model was selected, we evaluated the performance of the best model using the area under the receiver operating characteristic curve. The area under this curve (AUC) is a threshold-free index of model classification performance and indicates overall ability of the model to accurately predict the data used to create it (Fielding and Bell 1997; Pearce and Ferrier 2000). We also used output from MaxEnt to evaluate how much information each landscape feature contributed to the model, and to explore the response curves associated with each feature.

Results

WVC data were collected by WSDOT maintenance crews from July 2008–June 2012, and by motorists reporting to I-90 Wildlife Watch from November 2010–June 2012. We included the full four years of data for analyses specific to the MC data, but direct WVC rate comparisons between MC and I-90 WW data were limited to data collected during the same time period (i.e., November 2010–June 2012). A report summarizing year 1 results for I-90 Wildlife Watch can be found in Appendix 2.1.

WVC Reports: WSDOT Maintenance Crew Results

During the four year period from July 2008–June 2012, WSDOT maintenance personnel reported 111 WVCs (43 Project Area, 68 Control Area; Table 2.2, Appendix 2.2) representing 10 species. We assigned all deer reports (e.g., deer, mule deer, black-tailed deer) to a single “deer” species category. Most WVCs (79%) reported by maintenance crews were ungulates (i.e., deer, elk), with coyotes, bobcats, and black bears representing the only other species with more than one individual reported (Table 2.2).

Table 2.2. Total number of carcasses reported by WSDOT maintenance crews by species and area, July 2008–June 2012.

Species	Control Area	Project Area	Total
Black Bear	3	1	4
Bobcat	3		3
Coyote	6	3	9
Otter		1	1
Deer	29	26	55
Elk	25	8	33
Beaver	1		1
Canada Goose		1	1
Mallard Duck		1	1
Wild Turkey		1	1
Total	68	43	111

The seasonal distribution of WVCs involving ungulates was irregular. Most WVCs occurred during spring and early summer (April–July), although two additional peaks were also seen in October and December (Fig. 2.5). WVCs of other species appeared to be more evenly distributed throughout the year, but had sufficiently low frequencies to preclude meaningful temporal comparisons (Fig. 2.5).

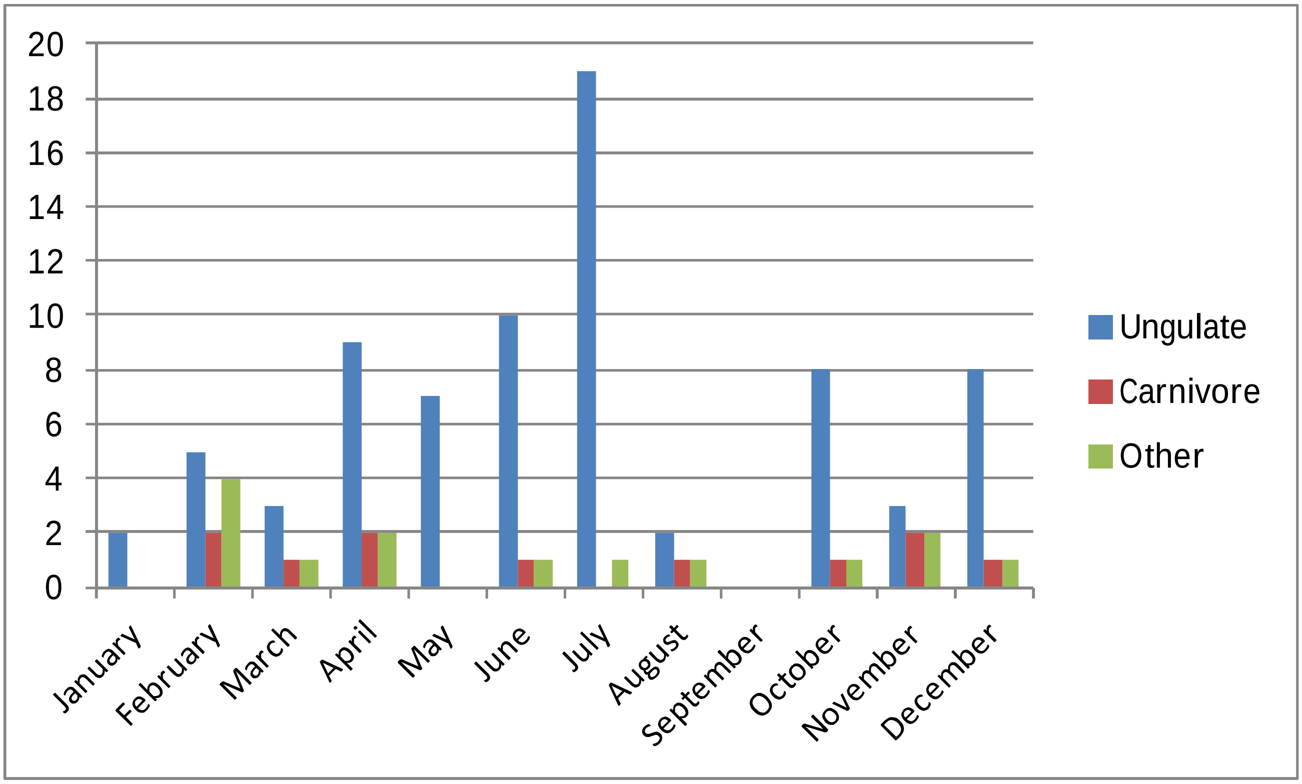


Figure 2.5. Frequency of WVCs reported by WSDOT maintenance personnel, by species group and month, July 2008–June 2011.

Rates of WVCs (i.e., number/length of road) did not differ (based on overlapping 95% confidence intervals) between Project and Control Areas (Fig. 2.6). No difference in WVC rates was detected among years 1–3, but the number of individuals reported per mile in the Control Area was lower in year 4 than in other years, and also lower than in the Project Area during that same year (Fig. 2.7). More ungulates than carnivores were reported based on minimal or no overlap in 95% confidence intervals (Fig. 2.6).

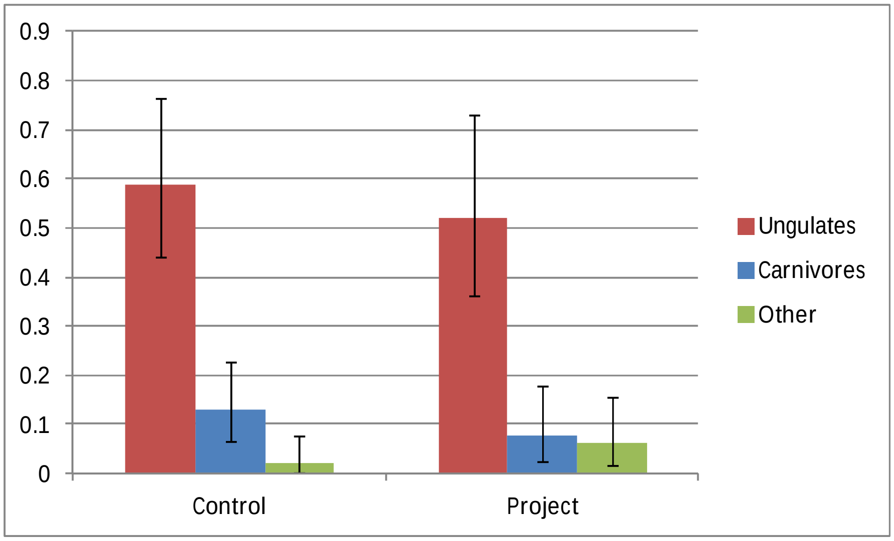


Figure. 2.6. Rates of wildlife-vehicle collisions (number/mile/year, with 95% confidence intervals) reported by WSDOT maintenance personnel, by species group and area, July 2008–June 2011. Sample sizes were 54, 12, and 2 WVCs for ungulates, carnivores, and other species, respectively in the Control Area, and 34, 5, and 4 WVCs respectively in the Project Area

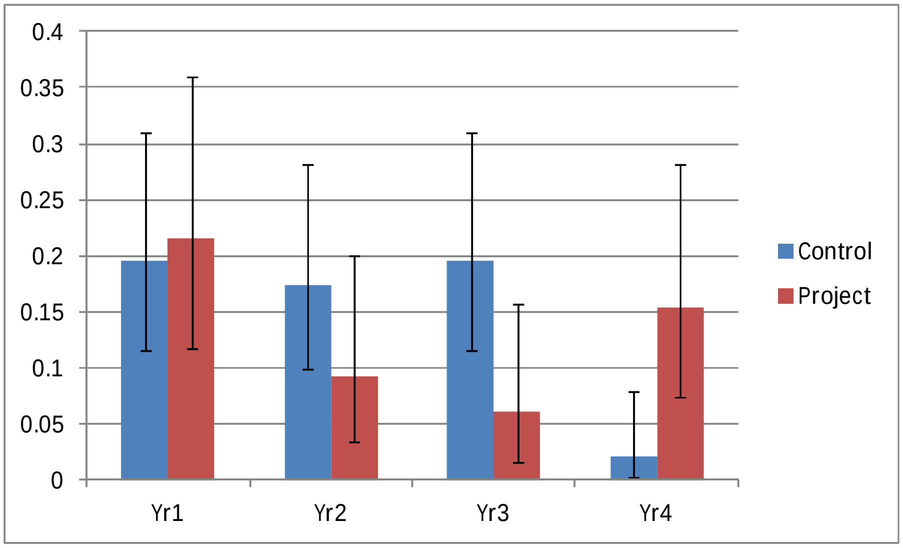


Figure 2.7. Rates of WVCs (number/mile, with 95% confidence intervals) reported by WSDOT maintenance personnel, by year and area, July 2008–June 2011. Sample sizes are shown next to the year and 95% confidence intervals. Sample sizes for years 1–4 were 18, 16, 18, and 2 WVCs respectively for the Control Area, and 14, 6, 4, and 10 WVCs respectively for the Project Area.

WVC Reports: I-90 Wildlife Watch Results

A total of 60 WVCs (18 Project Area, 42 Control Area), representing 14 species or species groups (e.g., raptors) and a number of “unknown” species, were reported on the I-90 Wildlife Watch website from November 2010–October 2011 (Table 2.3, Appendices 2.3, 2.4). Ungulates (n=19) and carnivores (n=17) were reported with similar frequency (Table 2.3). Raptors (n=7) were also frequently reported compared with other mammals and birds.

Table 2.3. Total number of WVCs reported on the I-90 Wildlife Watch website, by species and area, November 2010–October 2011.

Species or Species Group	Control Area	Project Area	Total
Black bear	1		1
Coyote	1	1	2
Fox		1	1
Striped skunk		1	1
Raccoon	9	3	12
Deer	8	4	12
Elk	6	1	7
Virginia opossum		1	1
Porcupine	1	1	2
Raptor	2		2
Hawk	2	1	3
Owl	2		2
Turkey		1	1
Hummingbird		1	1
Unknown	10	2	12
Total	42	18	60

The relatively low frequency of I-90 Wildlife Watch-reported WVCs made it difficult to discern any obvious seasonal patterns to the reports (Fig. 2.8). Fewer WVCs were reported in November–April than in most other months, but small overall sample sizes made valid comparisons impossible.

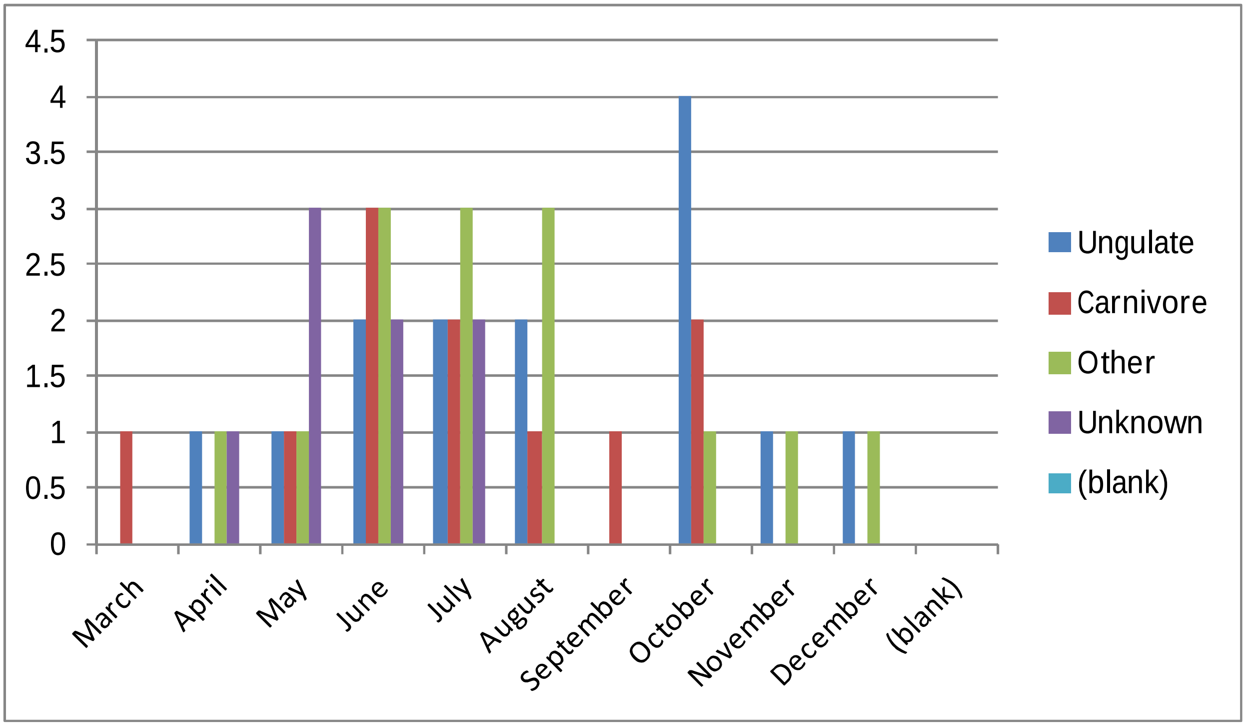


Figure 2.8. Frequency of WVCs reported on the I-90 Wildlife Watch website, by species group and month, November 2010–October 2011.

Rates of WVCs (number/length of road) reported on the I-90 Wildlife Watch website did not differ (based on overlapping 95% confidence intervals) between Project and Control Areas, nor between species groups (Fig. 2.9).

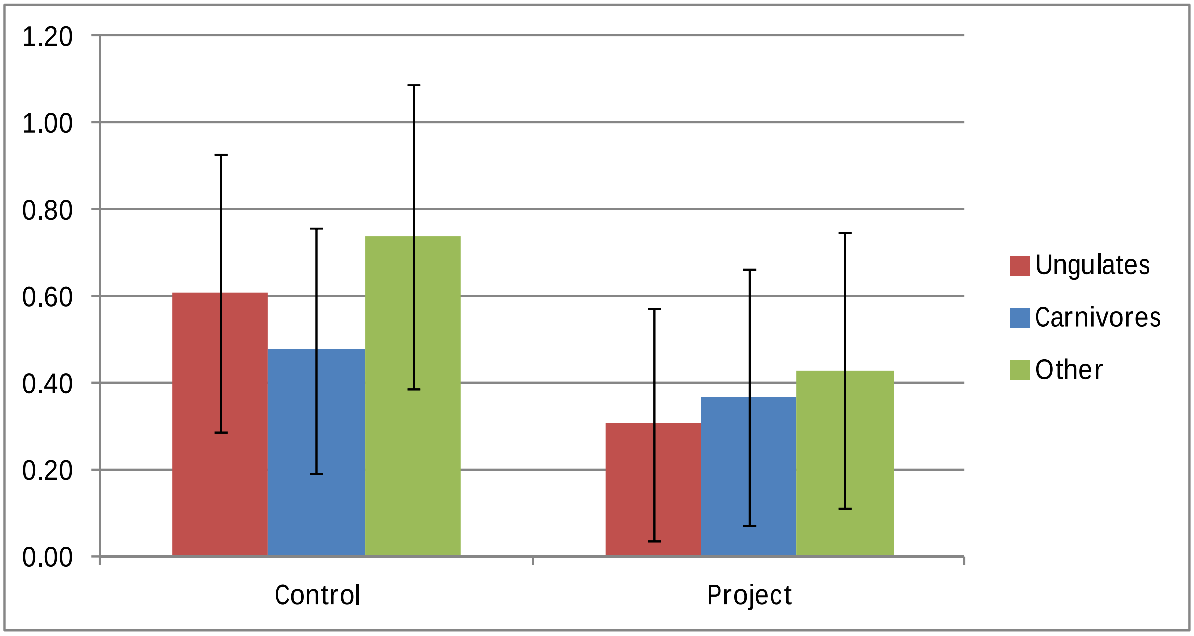


Figure 2.9. Rates of WVCs (number/mile; with 95% confidence intervals) reported on the I-90 Wildlife Watch website, by species group and area, November 2010–June 2012. Sample sizes were 14, 11, and 17 WVCs for ungulates, carnivores, and other species, respectively in the Control Area, and 5, 6, and 7 WVCs respectively in the Project Area.

Direct Comparisons of MC versus Wildlife Watch Methods

We were unable to detect differences (based on overlapping 95% confidence intervals) between rates of WVCs reported by WSDOT maintenance crews and I-90 Wildlife Watch participants during November 2010–June 2012 (Fig. 2.10). Further, we detected no differences in WVC rates between Control and Project Areas for these species groups. In the Control Area, however, I-90 Wildlife Watch participants reported a greater number of "other" species than did WSDOT maintenance crews.

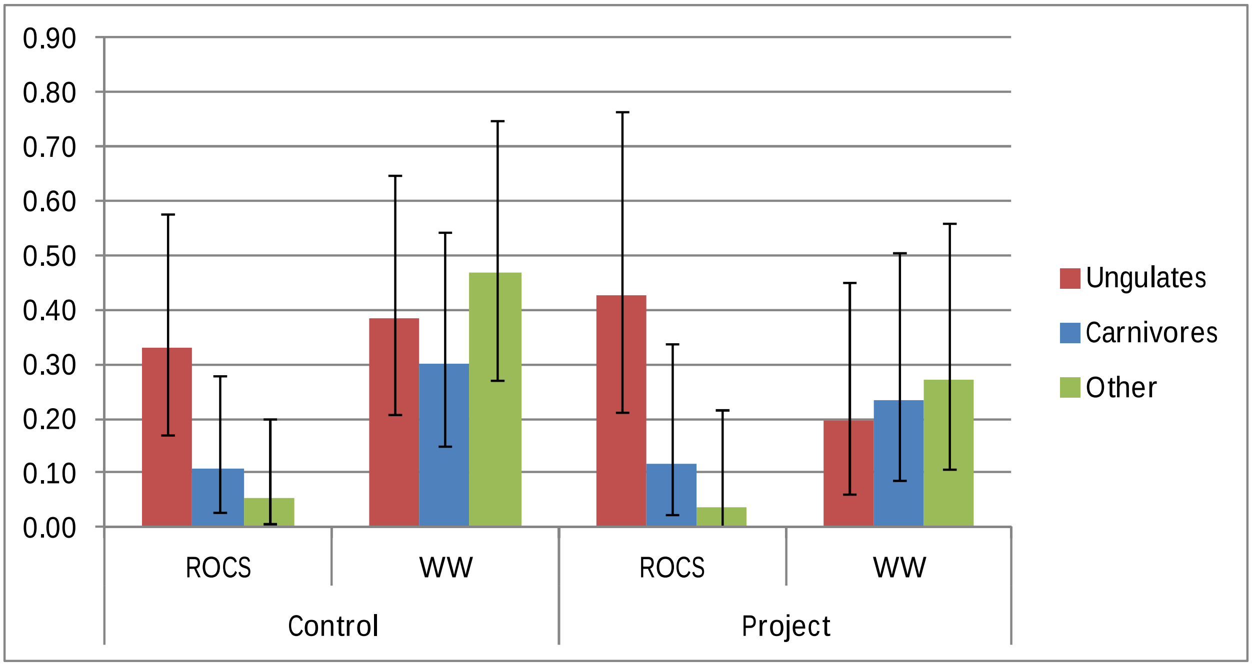


Figure 2.10. ROCS and I-90 WW WVC rates during November 2010–June 2012, with 95% confidence intervals. Sample sizes are reported in Figures 2.6 and 2.9 (above).

Reports of Live Animals

I-90 Wildlife Watch also facilitated reports of live animals observed within the Study Area, with participants having reported 482 live animals during November 2010–June 2012 (Table 2.4). Most reports (82%) pertained to ungulates, especially elk, which were often reported in herds. The average number of individual elk observed per elk report was 3.2, whereas the average number of deer observed per deer report was 1.4. Carnivores were reported infrequently, with black bears and coyotes reported most often. Rates of live animal reports were similar between the Control and Project Areas (Fig. 2.11).

Table 2.4. Live animals reported on the I-90 Wildlife Watch website, by species and area, November 2010–June 2012.

Species or Species Group	Control	Project	Total
Black bear	7	3	10
Bobcat	1		1
Cougar/Mountain lion	3		3
Coyote	5	1	6
Fox	1	3	4
Otter		4	4
Raccoon	2		2
Deer	51	59	110
Elk	176	111	287
Moose	1		1
Hare		1	1
Mouse	1		1
Woodrat		1	1
Raptor (general)	2		2
Eagle		4	4
Hawk	9		9
Osprey		1	1
Vulture	5		5
Owl	1		1
Goose		14	14
Raven		2	2
Crow		3	3
Turkey	4	5	9
Bluebird	1		1
Grand Total	**270**	**212**	**482**

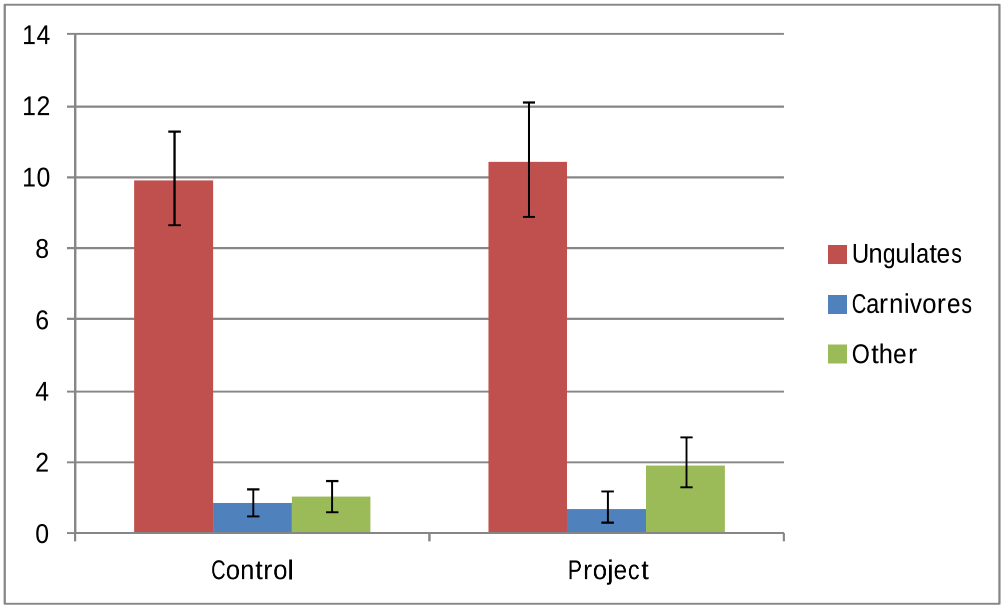


Figure 2.11. Rates of live animals (number/mile; with 95% confidence intervals) reported on the I-90 Wildlife Watch website, by species group and area, November 2010–June 2012. Sample sizes were 228, 19, and 23 WVCs for ungulates, carnivores, and other species, respectively in the Control Area, and 170, 11, and 31 WVCs respectively in the Project Area.

I-90 Wildlife Watch Volunteer Reporting Rates

Seven volunteers drove a combined total of 22,859 miles within the survey area, contributing 73 reports totaling 100 individual animals (live=65, dead=35). After removing miles driven in poor visibility (n=5,402) and live bird sightings (n=19), Bayesian estimates of reporting rates over the entire Study Area for live and dead individuals were 0.003 individuals/mile driven (95% credible interval = 0.002–0.003) and 0.002 individuals/mile driven (95% credible interval = 0.001–0.003), respectively. Such relatively small numbers of individuals observed per mile driven preclude further meaningful analysis between Project and Control Areas, however, it is likely that this approach could be effective in other regions where WVC rates are higher.

Power Analysis

Based on the observed, four-year total of 34 ungulate WVCs detected in the Project Area with MC data, we estimated an occurrence rate of 8.5 WVCs/year. Using this value as the annual pre-construction rate for ungulate WVCs, we further estimated that 3.5 years of post-construction monitoring by WSDOT maintenance crews would be required to detect a 50% reduction in ungulate WVCs. Larger reductions would be detectable with fewer years of post-construction monitoring data, and more years would be required to detect smaller reductions (Fig. 2.12). Given the higher annual rate of ungulate WVCs in the Control Area versus the Project Area (i.e., 13.5 WVCs/year versus 8.5 WVCs/year), fewer years of post-construction monitoring would be required to detect a statistical reduction in WVCs in this area (Fig. 2.13).

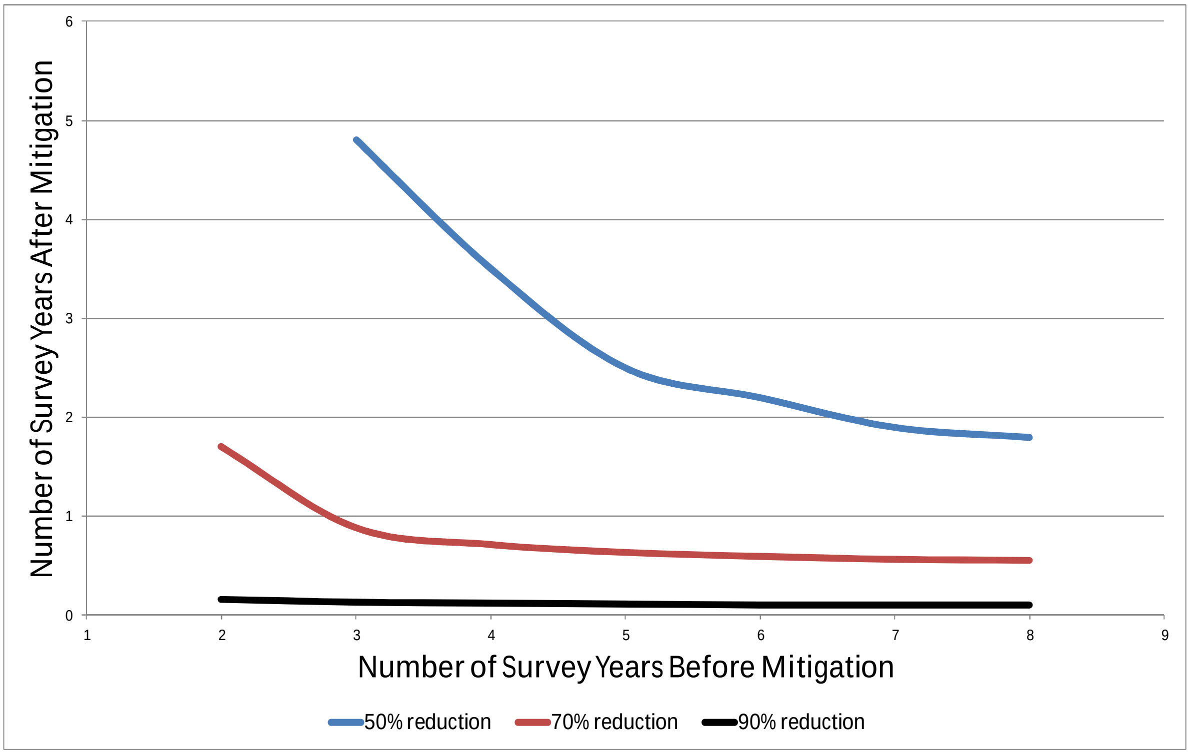


Figure 2.12. Power curves indicating the estimated number of years of monitoring that must be conducted before and after mitigation in the Project Area to detect 50%, 70%, and 90% reductions in WVCs with a power of 0.8.

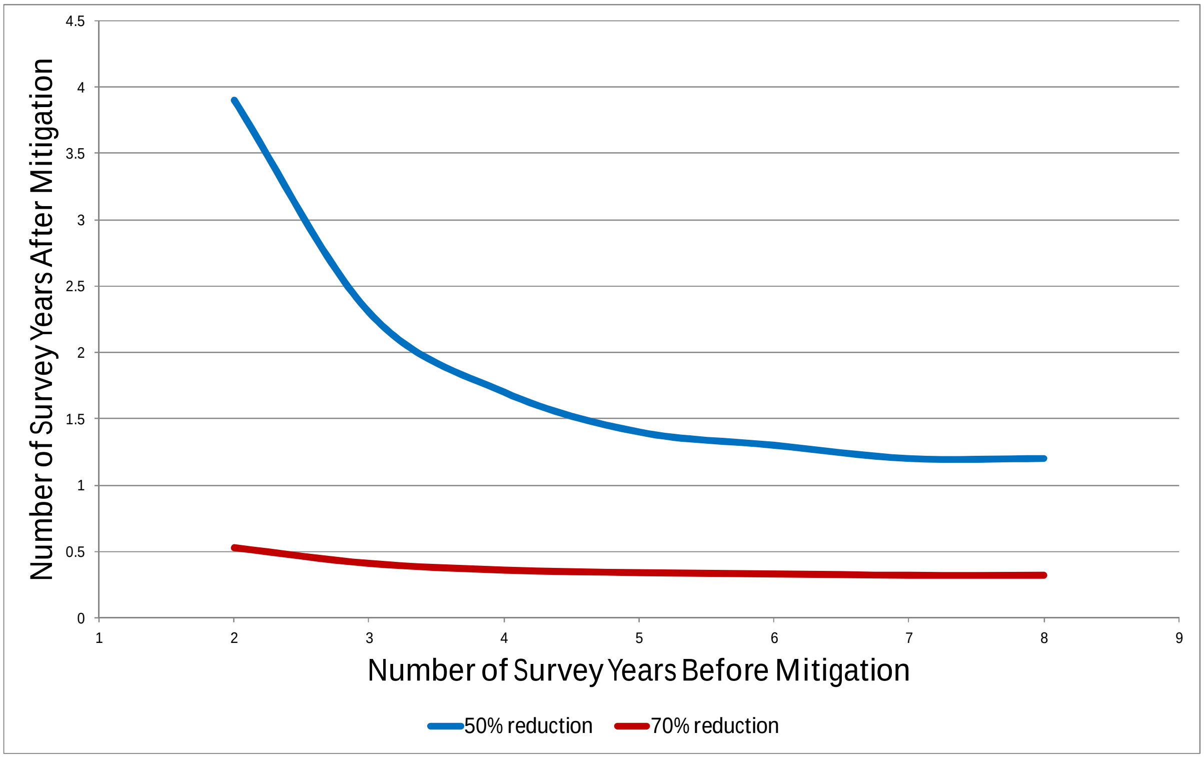


Figure 2.13. Power curves indicating the estimated number of years of monitoring that must be conducted to detect 50% and 70% reductions in WVCs with a power of 0.8 between the period before and after mitigation efforts in the Control Area.

We also estimated year-specific power curves for detecting 30%, 50%, and 70% reductions in ungulate WVCs based on 1, 2, 3, 4, and 5 years of post-construction monitoring, assuming 4 years of pre-construction monitoring with annual rates of 8.5 and 13.5 ungulate WVCs/year in the Project and Control Areas, respectively (Fig. 2.14, 2.15). Almost no amount of post-construction monitoring will permit the detection of a relatively small (i.e., 30%) reduction in WVCs. However, 3–4 years would likely provide sufficient power to detect >50% reductions in WVCs.

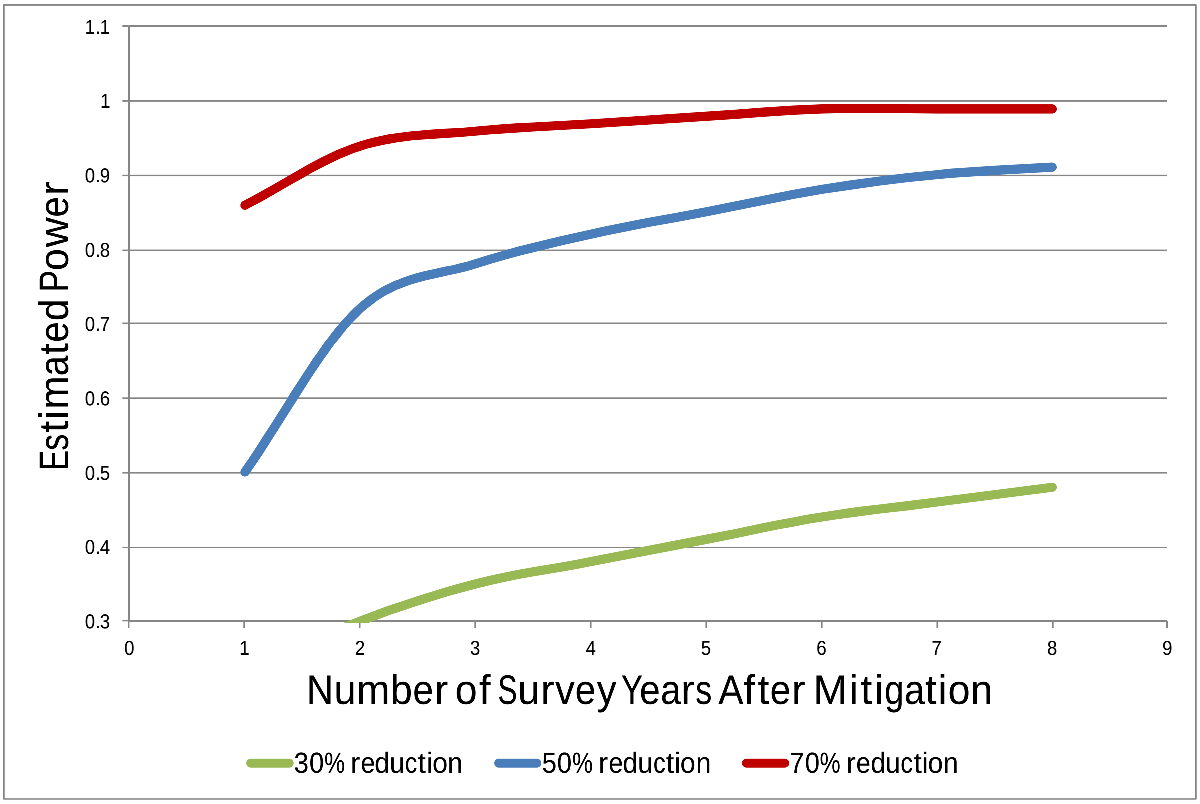


Figure 2.14. Curves indicating the power achieved and the associated number of years after mitigation required to detect 30%, 50%, and 70% reductions in WVCs within the Project Area, assuming four years of pre-mitigation monitoring.

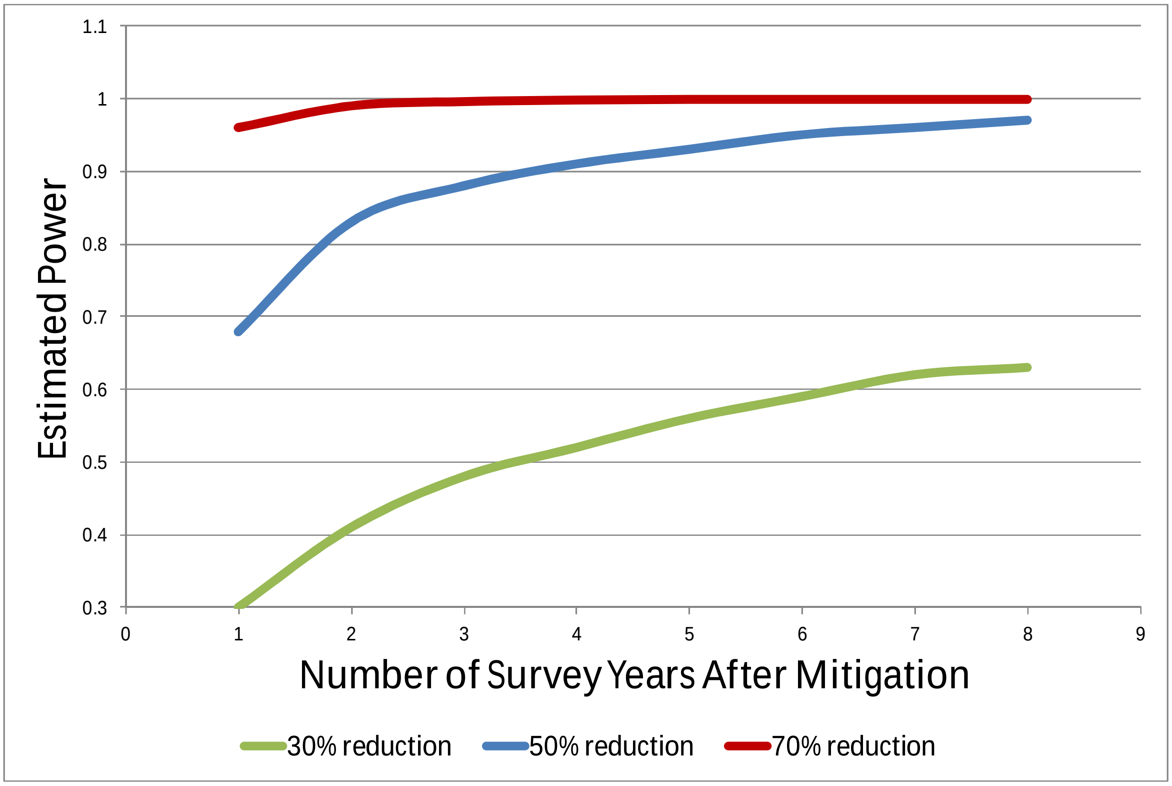


Figure 2.15. Curves indicating the power achieved and the associated number of years required to detect 30%, 50%, and 70% reductions in WVCs within the Control Area, assuming four years of pre-mitigation monitoring.

Hotspot Analyses

We identified WVC hotspots for ungulates from MC data collected during July 2008–June 2012 within the following CEAs in the Project Area: Gold Creek (MP 55.2), Price/Noble Creek (MP 61.6), and at the border of Swamp Creek and Toll Creek (MP 63.3)(Fig. 2.16). There were no ungulate-specific WVC hotspots identified using I-90 WW data in the Project Area. One non-ungulate WVC hotspot (composed of one coyote and one bobcat) was identified from MC data, at the Townsend Creek CEA (MP 70) (Fig. 2.17). In addition, a major, non-ungulate hotspot was identified with I-90 WW data, adjacent to Easton Lake in the Kachess River CEA (MP 70). This latter hotspot comprised one report each of a coyote, a skunk, and a Virginia opossum.[1]

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[1] This location is further east than would be expected to encounter a Virginia opossum. This is an instance where it was necessary to simply report what was entered into the I-90 Wildlife Watch website, as accuracy-checking of citizen reports was not possible. This also highlights why caution must be practiced when interpreting these data.

Figure 2.16. Ungulate WVC hotspots in the Project Area, identified via data collected by WSDOT maintenance crews. Hotspots were derived from n=34 WVCs with hotspots defined as the 46% kernel isopleth (see Methods for details).

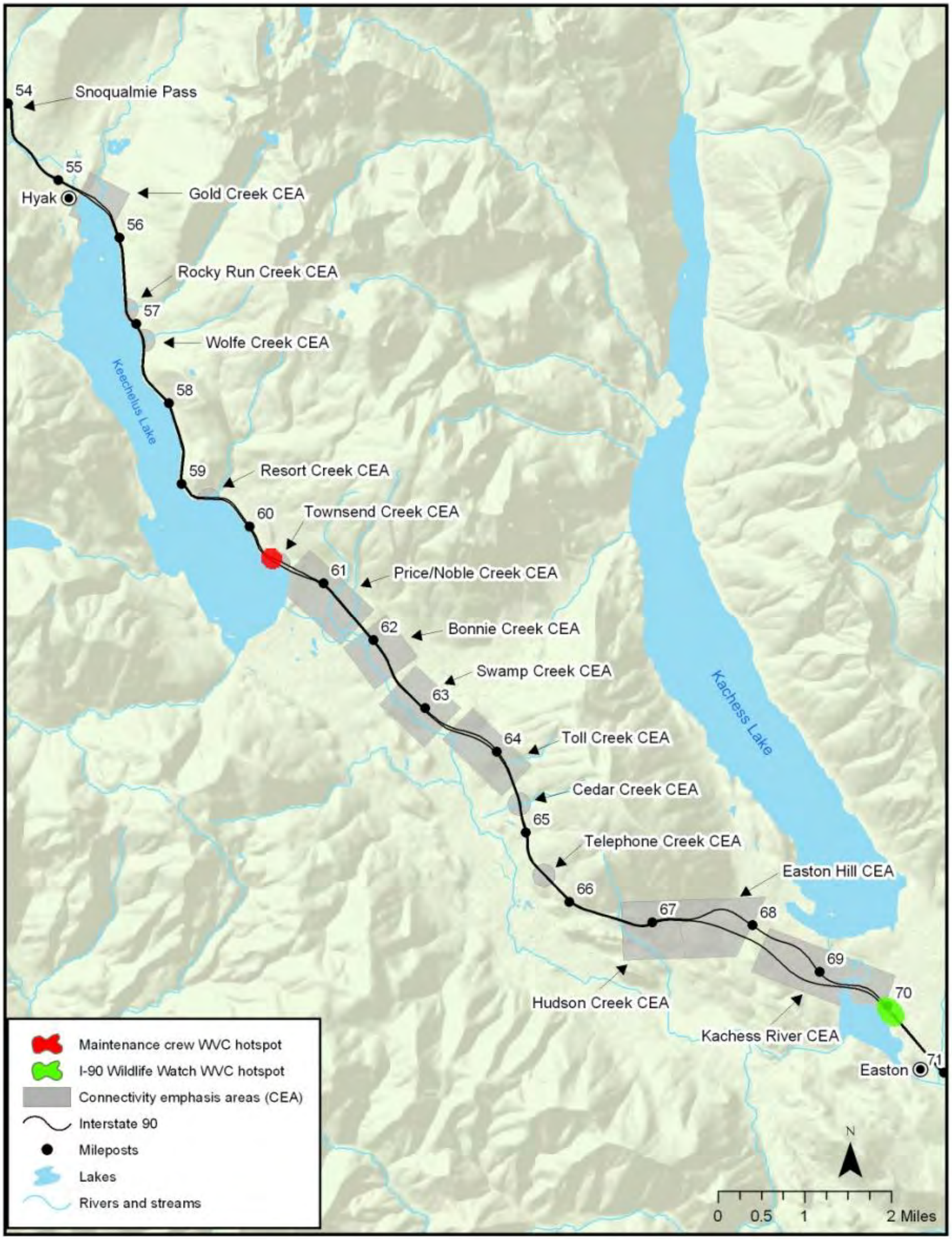

Figure 2.17. Non-ungulate WVC hotspots in the Project Area, identified via data collected by WSDOT maintenance crews and I-90 Wildlife Watch participants. Hotspots were derived from n=6 WVCs with hotspots defined as the 72% kernel isopleth (see Methods for details).

MC data were used to identify a single ungulate WVC hotspot in the Control Area at MP 34.9, east of North Bend (Fig. 2.18). Three minor ungulate WVC hotspots were identified from I-90 WW data, at MPs 31, 32.1, and 39.7 (Fig. 2.18).

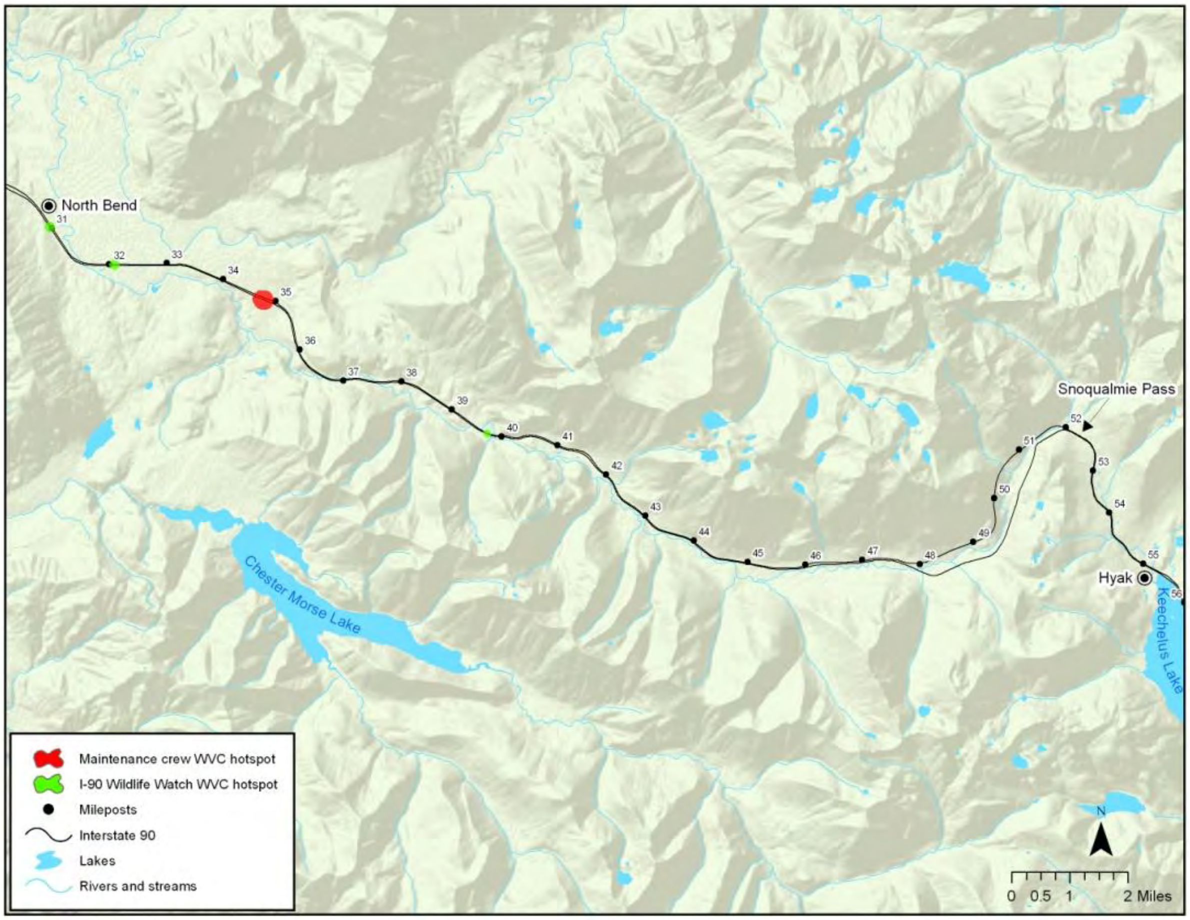

Figure 2.18. Ungulate wildlife-vehicle collision hotspots in the Control Area identified via analysis of data collected by WSDOT maintenance crews and I-90 Wildlife Watch participants. Hotspots were derived from n=54 WVCs with hotspots defined as the 49% kernel isopleth (see Methods for details).

Also in the Control Area, non-ungulate WVC hotspots were detected with MC data at MPs 36 (2 coyotes, 1 bobcat) and 48.3 (2 black bears), and with I-90 WW data at MPs 31 and 31.3 (4 raccoons, 1 coyote)(Fig. 2.19).

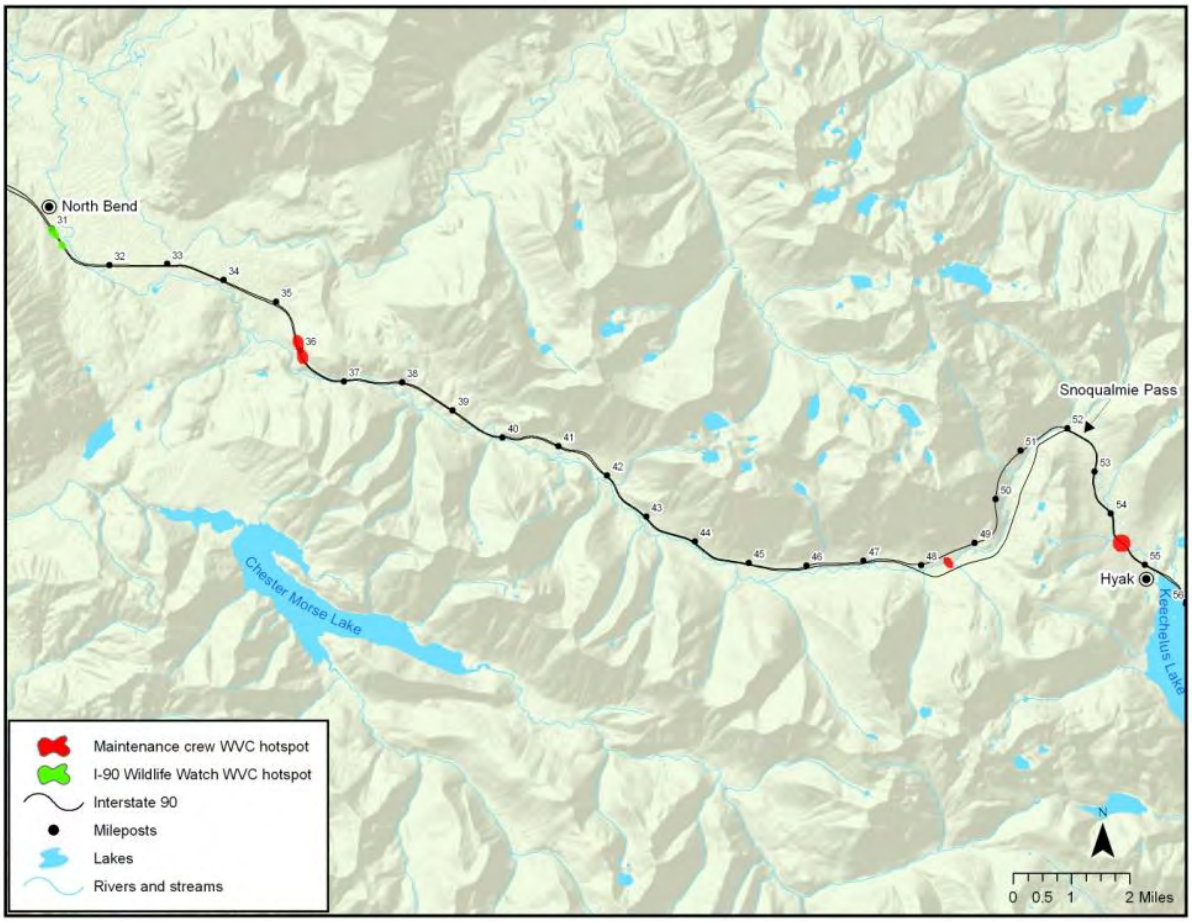

Figure 2.19. Non-ungulate WVC hotspots in the Control Area, identified via data collected by WSDOT maintenance crews and I-90 Wildlife Watch participants. Hotspots were derived from n=13 WVCs with hotspots defined as the 57% kernel isopleth (see Methods for details).

Comparisons of Live and Dead Animal Hotspot Locations

When ungulate WVC hotspots from both MC and I-90 WW data from within the Project Area were combined and compared with live ungulate hotspots derived from I-90 WW data, only two locations showed hotspot overlap—Noble Creek (MP 61.6) within the Price/Noble Creek CEA, and a location just west of the Hudson Creek CEA (MP 66.4)(Fig. 2.20).

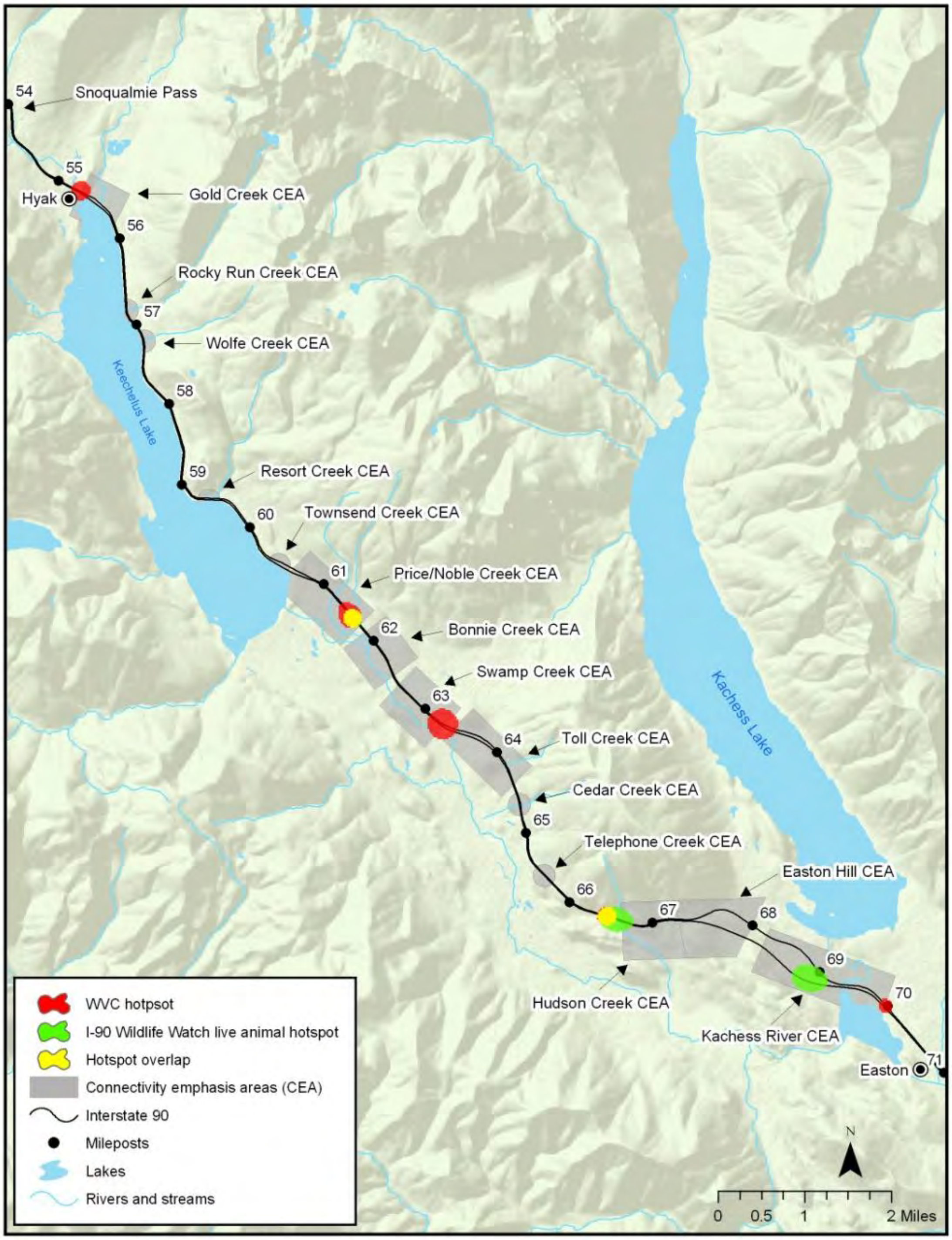

Figure 2.20. Ungulate WVC hotspots and live ungulate hotspots in the Project Area, identified via data collected by WSDOT maintenance crews and I-90 Wildlife Watch participants. WVC hotspots were derived from n=39 WVCs with hotspots defined as the 46% kernel isopleth, and live hotspots were derived from n=74 observations with hotspots defined as the 58% kernel isopleth (see Methods for details).

Locations for other live ungulate hotspots differed from those of WVC hotspots (Fig. 2.20), and non-ungulate WVC hotspots differed in location from live non-ungulate hotspots within the Project Area (Fig. 2.21).

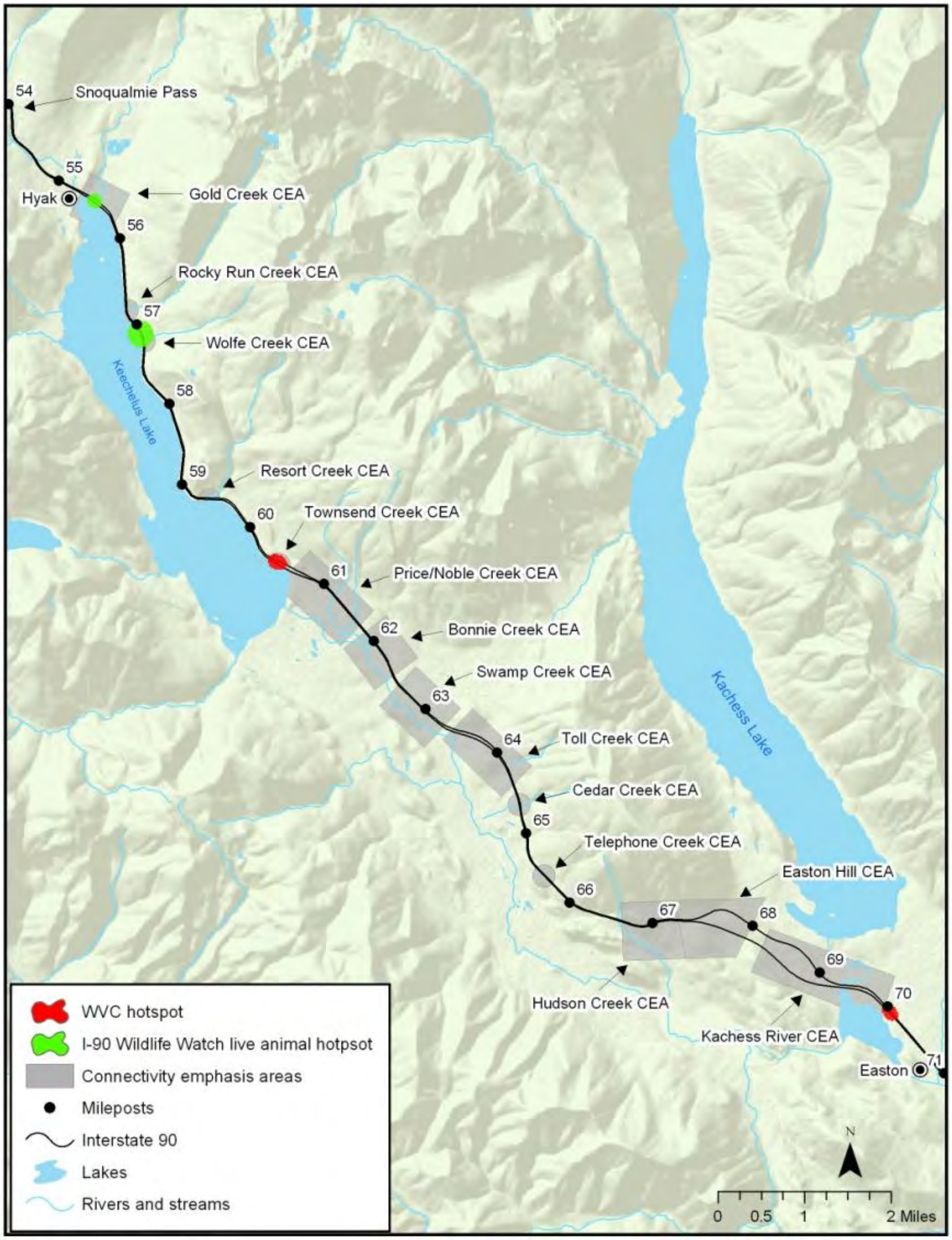

Figure 2.21. Non-ungulate WVC hotspots and live non-unglulate hotspots in the Project Area, identified via data collected by WSDOT maintenance crews and I-90 Wildlife Watch participants. WVC hotspots were derived from n=16 WVCs with hotspots defined as the 72% kernel isopleth, and live hotspots were derived from n=11 observations with hotspots defined as the 63% kernel isopleth (see Methods for details).

In the Control Area, there was no overlap in live and dead hotspot locations for ungulates nor non-ungulates (Figs. 2.22, 2.23).

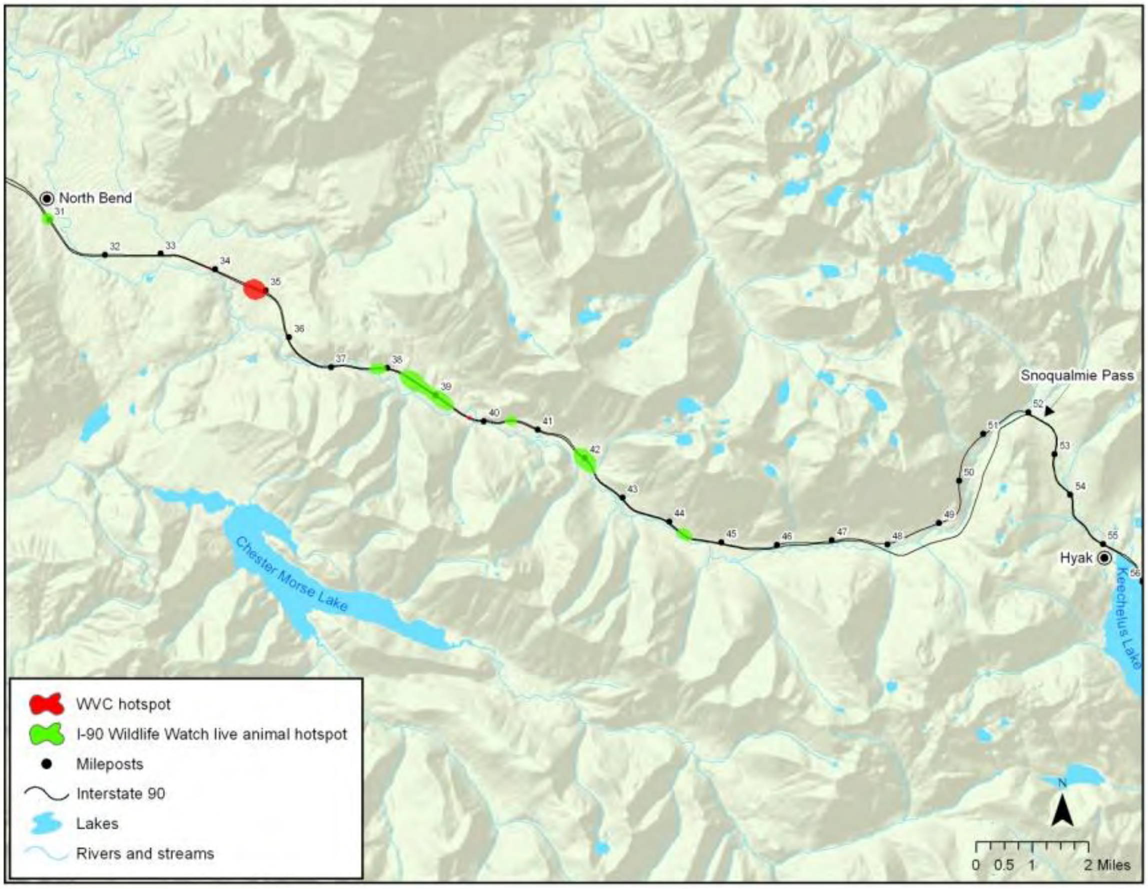

Figure 2.22. Ungulate WVC hotspots and live animal locations in the Control Area, identified via data collected by WSDOT maintenance crews and I-90 Wildlife Watch participants. WVC hotspots were derived from n=107 WVCs with hotspots defined as the 44% kernel isopleth, and live hotspots were derived from n=95 observations with hotspots defined as the 48% kernel isopleth (see Methods for details).

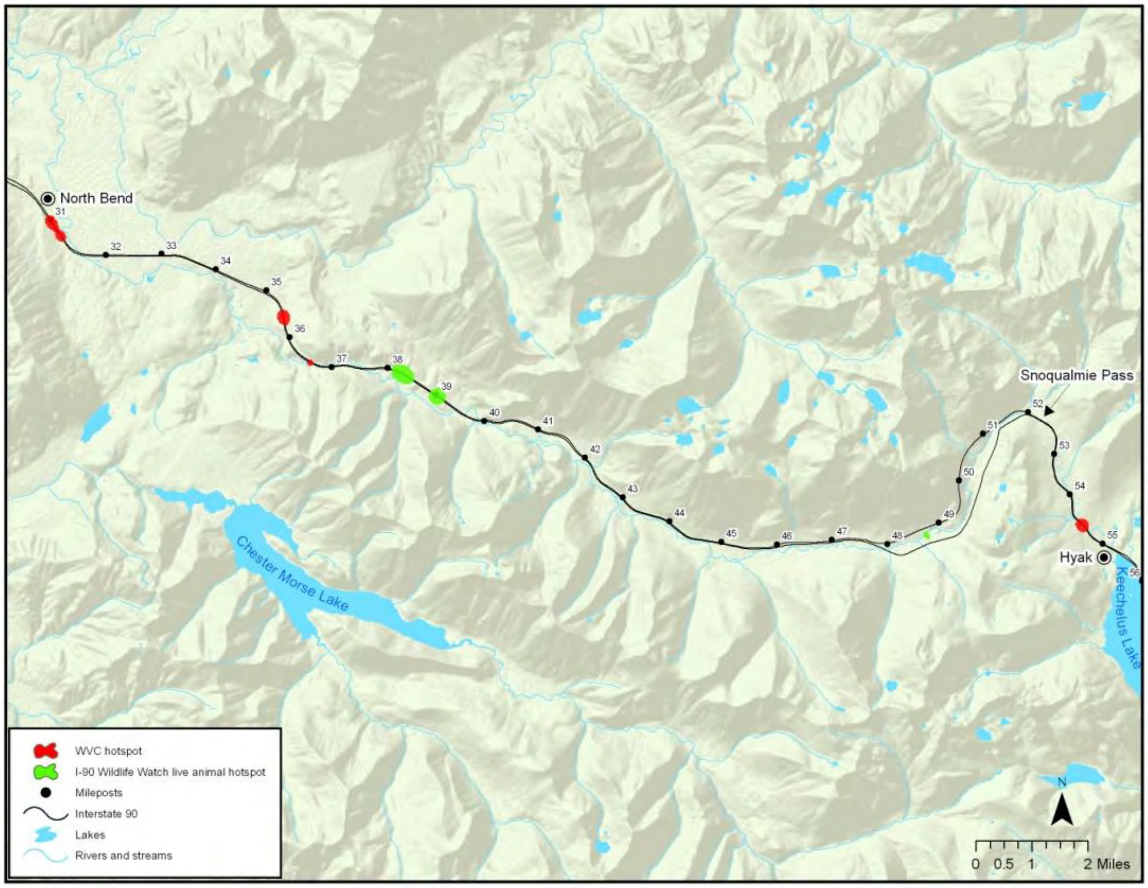

Figure 2.23. Non-ungulate WVC hotspots and live animal locations in the Control Area, identified via data collected by WSDOT maintenance crews and I-90 Wildlife Watch participants. WVC hotspots were derived from n=30 WVCs with hotspots defined as the 73% kernel isopleth, and live hotspots were derived from n=20 observations with hotspots defined as the 52% kernel isopleth (see Methods for details).

Landscape Features Associated with WVCs and Live Animal Locations

The best models for predicting deer or elk WVCs from landscape characteristics that we developed using the MaxEnt modeling approach performed relatively poorly for predicting the actual location of WVCs based on AUC values. This outcome may have resulted from actual weak relationships between the landscape features we measured and the location of deer or elk WVCs, or could have been a result of relatively small sample sizes leading to low model power. Despite the overall weak predictive power of the models, MaxEnt was able to identify some features that were most related to WVC presence.

Deer WVCs

Our MaxEnt analysis suggested that, of the landscape features evaluated (Table 2.1), stream density had the strongest relationship with deer WVC locations in the Project Area. In the Control Area, distance-to-nearest ridge was identified as having the most relationship with deer WVC locations. In both cases the relationship was positive, meaning that in the Project Area higher stream densities were associated with locations of WVCs (Fig. 2.24), and in the Control Area WVCs tended to be located further from ridges (Fig. 2.25). The Project and Control Area models had AUC values of 0.65 and 0.61 respectively (where 0.5 is prediction no better than chance, and 1.0 indicates perfect predictive performance).

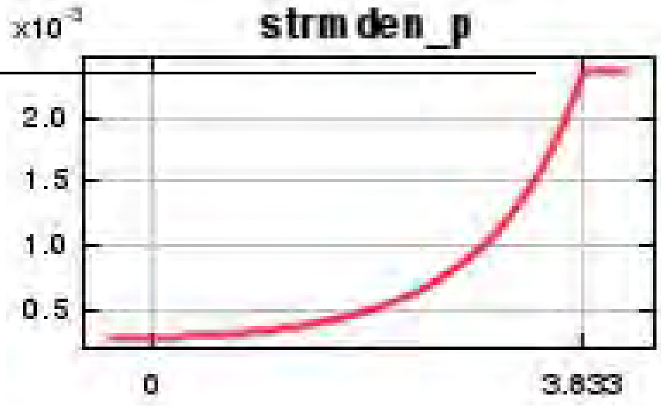

Figure 2.24. Response curve output from MaxEnt analysis showing positive association between deer WVC locations and stream density in the Project Area. The Y-axis represents increasing likelihood of a WVC, and the X-axis is stream density.

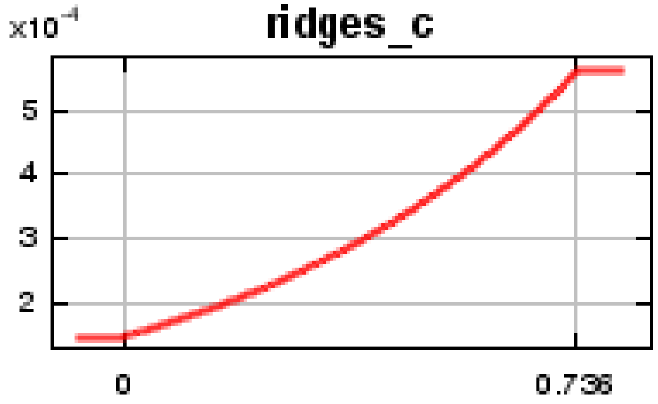

Figure 2.25. Response curve output from MaxEnt analysis showing positive association between deer WVC locations and distance-to-nearest-ridge in the Control Area. The Y-axis represents increasing likelihood of a WVC, and the X-axis is distance-to-ridge.

<u>Elk WVCs</u>

Landscape features relating to the location of elk WVCs in the Project and Control Areas tended to be different than those identified for deer. In the Project Area, elk WVCs were positively associated with areas farther from forest patches (Fig. 2.26), but in the Control Area, WVCs were most associated with areas lacking Jersey barriers along the highway or in the median (Fig. 2.27). Again, the model was only moderately predictive (AUC = 0.66).

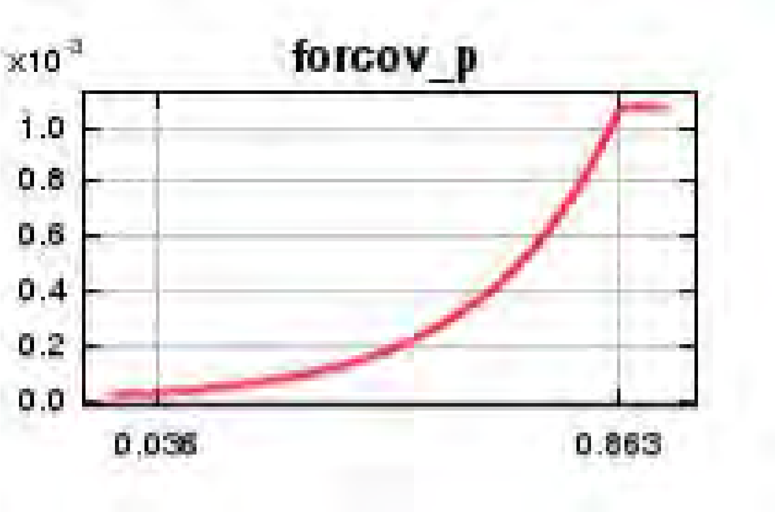

Figure 2.26. Response chart output from MaxEnt analysis showing positive association between elk WVC locations and areas further from the nearest forested patch in the Project Area. The Y-axis represents increasing likelihood of a WVC, and the X-axis is distance-to-forested patch.

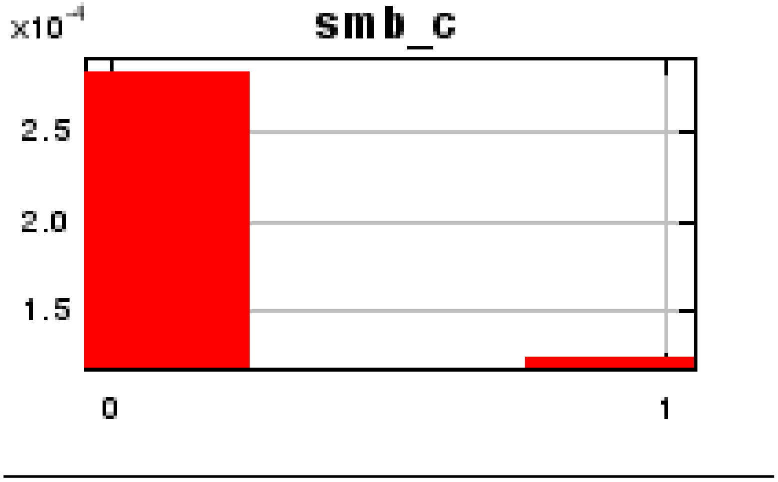

Figure 2.27. Response chart output from MaxEnt analysis showing the negative association between elk WVC locations and the presence of Jersey barriers in the Control Area. The Y-axis represents increasing likelihood of a WVC, and the X-axis is whether a Jersey barrier is absent (0) or present (1).

Discussion

Species Diversity, Seasonal Trends, and Rates for WVCs and Live Animal Observations

The types and number of species involved in WVCs reported in the two datasets (MC and I-90 WW) were similar. Both datasets contained elk, deer, black bears, and coyotes. Only MC data included bobcats, and single reports of a beaver, a Canada goose and a mallard were also unique. In contrast, I-90 WW data contained a large number of unique species, including multiple reports of raccoons and raptors (hawks, owls, and generic reports of "raptor"), two reports of porcupines, and single reports of a fox, a skunk, an opossum, and a hummingbird. Although caution is advised when considering these results given the relatively small number of reports involved and the caveats of citizen-generated data, the higher rate of WVCs involving raccoons and raptors reported by I-90 Wildlife Watch participants versus WSDOT maintenance crew is noteworthy nonetheless, as it may represent more sensitivity of this method to detections of smaller species.

As a proportion of total reports, MC data contained a higher percentage of ungulates than non-ungulates (Figs. 2.5, 2.6), which was not the case for I-90 WW data (Figs. 2.8, 2.9). This may be the result of WSDOT maintenance crews having had less of a search image for the smaller carcasses that characterize most non-ungulate WVCs, or having been less likely to record these types of WVCs. Further, during certain times of the year, high workloads may have made it more difficult for WSDOT crews to devote time to carcass detection and recording. As deer and elk carcasses have the most potential to hinder traffic flow, these species may have been prioritized for removal. Finally, although WSDOT maintenance crews were collecting WVC data prior to our 2007 collaboration, such data were limited only to ungulates. Therefore, crews may have been conditioned to search for and record only ungulate carcasses during our collaborative project as well.

The temporal patterns of WVC reports were generally similar between data collection methods, with most reports occurring during late spring and summer, and another pulse of reports in the fall. These trends coincide with the relatively snow-free periods of the region, when ungulates tend to become more active and move into areas of higher elevation (e.g., the I-90 Snoqualmie Pass East region), and when young animals disperse from natal territories. Singleton and Lehmkuhl (2000) documented similar patterns for deer and elk in this region, and other studies suggest that WVCs follow seasonal trends coinciding with major breeding and movement periods that often center on spring and fall. (Groot Bruinderink and Hazebroek 1996, Hubbard et al. 2000, Clevenger et al. 2003, Saeki and MacDonald 2003). Notably—albeit difficult to interpret—neither method reported any ungulate WVCs during September.

Based on overlapping 95% confidence intervals, there was no decline in WVC rates reported by maintenance crews from year 1 to year 4 (Fig. 2.7), except in the Control Area between years 3 and 4. It should, however, be noted that within-year sample sizes were small overall, and that detecting differences between rates generated from small sample sizes requires very substantial effects. This is also the case for detecting differences between Control and Project Areas, and rates associated with different species groups. Without additional data on wildlife population trends, or other more intensive studies, it is difficult to speculate as to why there was an apparent decline in WVCs between years 3 and 4 in the Control Area. This issue again highlights the need for long-term, consistent datasets that permit multiple variables and hypotheses to be explored with high statistical power. Assuming 3–4 years of I-90 WW data are eventually collected, stronger comparisons among years, areas, and species groups will be possible using both MC and I-90 WW data.

Documented ungulate WVC rates of 0.5–0.6 collisions/mile/year in our Study Area were generally lower, and in some cases substantially lower, than those observed in other parts of Washington and in other states. A review by Huijser et al. (2009) reported overall WVC rates ranging from 0.66 ungulate WVCs/mile on Highway 93 in Kootenay National Park (BC, Canada) to 5.79 ungulate WVCs/mile on I-90 near Bozeman Pass (MT, USA). A study of WVCs along the TransCanada Highway throughout the Bow Valley (Alberta, Canada) reported rates of 0.5–6.8 ungulate WVCs/mile, with rates across all highway subsections averaging about 2–3 ungulate WVCs/mile (Lee et al. 2012). In Washington, an analysis by Wang et al. (2010) estimated WVC rates for white-tailed and mule deer to range from about 1 WVC/mile on US-101 to >25 WVC/mile on State Route 970, with rates on most routes ranging from ~5–10 WVCs/mile. This latter study, however, included locations throughout Washington, many of which contained much higher quality ungulate habitat and therefore higher ungulate densities. In contrast, data collected in the I-90 SPE region from 1990–1998 (Singleton and Lehmkuhl 2000) yielded WVC rates of 1 deer/mile/year and 0.5 elk/mile/year, which were similar to the 0.5–0.6 ungulate collisions/mile/year that we observed.

Relatively low WVC rates in our Study Area may have been a function of low overall habitat quality for ungulates, and the fact that ungulates in this mountainous area migrate to lower elevation habitats during winter. In addition, our relatively low WVC rates could indicate high levels of highway avoidance by wildlife. Other studies suggest that WVC rates are generally higher on lower volume roads (Huijser et al. 2008), and Gagnon et al. (2007) documented wildlife avoidance of a highway in Arizona when traffic volumes were highest (e.g., an increase in traffic volume from 0–1,500 vehicles/hour correlated with a 20% decrease in highway crossings by elk). Effects in the latter study, however, did not appear to be permanent, with elk returning to areas near the highway during periods with lower traffic volumes. Gagnon et al. (2007) speculated that the higher elk WVC rates observed during weekdays, which typically exhibited lower traffic volumes than weekends, resulted from greater elk activity along the highway during these periods. In the case of I-90 SPE, traffic volumes were routinely 2,000–2,500 vehicles/hour, with average volumes of >500 vehicles/hour during all but 6 hours of the day (Fig. 2.28). Resulting avoidance effects may translate to fewer WVCs.

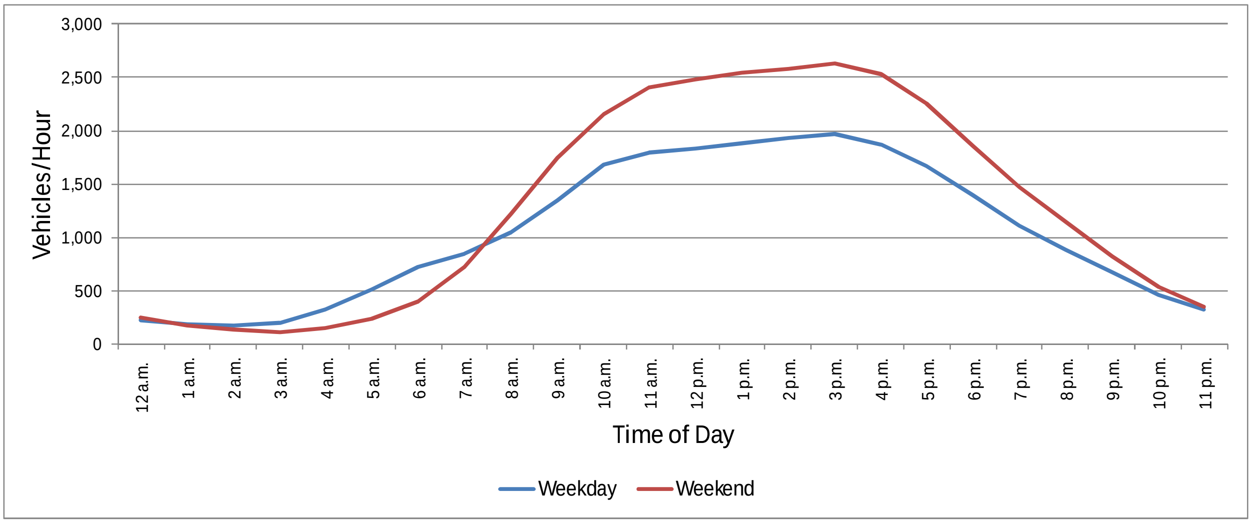

Figure 2.28. Average number of vehicles traveling on I-90 by hour, recorded in 2011 (excluding June–July) at milepost 52.2 near Snoqualmie Pass. Data extracted from the WSDOT Data Warehouse.

Hotspots

Hotspot analyses are intended to highlight locations where a disproportionate number of WVCs or live animal reports occur. Where data are sparse, few hotspots can be identified unless reports are highly clustered, and identified hotspots can comprise relatively few reports, despite being defined as hotspots. More hotspots were identified with MC data than I-90 WW data, which is to be expected given the longer duration of MC data collection and thus the greater number of reports used to generate hotspots (i.e., 111 reports for MC-generated hotspots versus 60 reports for I-90 WW-generated hotspots). Longer-term datasets (or higher intensity surveys) for both data collection methods would provide more accurate hotspot estimates and yield better options for comparing these methods.

WVC hotspot locations differed according to which method was used to gather the data. It is difficult to say why this may have been the case. Perhaps WSDOT maintenance crews, who were able to travel along the shoulder and stop to investigate carcasses along the roadway, were more effective at detecting carcasses in certain locations than were citizens traveling at high speeds and unable to stop. Another hypothesis is that maintenance crews, whose responsibilities included locating and removing debris (e.g., tire remnants) from travel lanes, had less of a search image for small and midsized carcasses located off of the main roadway. Reciprocally, it should be noted that motorists, given the speed at which they were traveling and their inability to stop, may have been prone to error in pinpointing exact carcass locations, or may have been less able to focus on detecting carcasses at certain locations along the highway (e.g. curves).

Interestingly, when MC and I-90 WW ungulate WVC data were combined, major WVC hotspots generally corresponded with locations highlighted as high-density roadkill sites by Singleton and Lehmkuhl (2000)—specifically at MP 55–55.3 near the northern tip of Keechelus Lake, and at MP 60.5–62 from the Keechelus Lake dam to Price/Noble Creeks.

Locations of live animal hotspots and WVC hotspots tended to differ. This result was not surprising, and has been documented and discussed elsewhere (Clevenger et al. 2002). Live animal hotspots without corresponding WVC hotspots may represent places where wildlife (e.g., elk) congregated but were discouraged from crossing because of landscape or highway features (e.g., Jersey barriers), or where crossing efforts were relatively successful. Indeed, modeling of landscape features related to WVC hotspots (see below) suggest that for elk, the presence of Jersey barriers was associated with fewer WVCs. Further research, however, would be required to effectively evaluate these hypotheses.

Most WVC and live animal hotspots in the Project Area occurred within CEAs that will be mitigated with crossing structures as part of the I-90 SPE project. One live animal/WVC hotspot overlap area near MP 66.5, however, is largely outside of planned CEAs. Treating this location with effective wildlife fencing (Clevenger et al. 2001) may be important for reducing or eliminating WVCs there in the future.

Landscape Features Associated with WVCs and Live Animal Locations

Relatively poor predictive performance for both the deer and elk models across the Study Area (i.e., AUC values of only 0.60–0.75) makes the interpretation of relationships between WVCs and landscape features tenuous, and although relationships between WVCs and landscape features were identified by MaxEnt, such relationships were likely weak. Higher densities of streams and areas located away from ridges (e.g., valley bottoms) were associated with deer WVCs in the Project and Control Areas, respectively. Others studies have identified similar relationships between deer WVCs and riparian areas and gullies (Finder et al. 1999, Crooks et al. 2008). In Colorado, Crooks et al. (2008) identified "midslope drainages" and areas closer to streams as having higher counts of animal-vehicle collisions. They speculate that such areas are conducive to animal movements and may, therefore, be predisposed to higher WVC activity.

In contrast to the results of the analysis for deer, elk WVCs appeared to be more related to open areas (i.e., locations farther from forest cover) in the Project Area, or areas with fewer Jersey barriers in the Control Area. The relationship with open areas is somewhat counter to results from other studies (e.g., Crooks et al. 2008) that have identified areas with higher percent forest cover or shorter distances to forest patches as being more associated with ungulate WVC locations. Such contrasts may, however, be the result of differences in regional land-use trends and study scale, or could represent complex interactions of multiple variables such as forest cover and vehicle sight distances. Jersey barriers (and especially those with vertical reflectors on top) may present enough of an additional disincentive—beyond the high-traffic volume roadway itself—to crossing by elk that they choose to attempt crossing elsewhere.

While local landscape features themselves have been shown to affect the location of WVCs, it may often be that factors related to the road segment (e.g., speed limit; Seiler 2004, Ng et al. 2008), the larger region (e.g., road density; Wang et al. 2010), or other specific habitat-driven choices (Roger and Ramp 2009) have the most effect on the location of WVCs).

Biases in Reporting

Both methods we employed for collecting WVC and live animal occurrence data were inevitably subject to biases. Indeed, efforts to collect WVC data and estimate accurate WVC rates are known to be fraught with bias issues, such as spatial inaccuracy of report locations (Gunson et al. 2009), incorrect species identification, and duplicate reporting, or from underreporting of WVCs related to carcasses being removed from the highway (Slater 2002) or injured animals dying elsewhere (Hesse 2006).

We attempted to include various protocols and standards in an effort to address, or at least minimize, some of these issues. For example, maintenance crews were equipped with ROCS GPS devices to ensure spatial accuracy of reports. We also conducted regular ROCS trainings for maintenance crews, during which we described species that might be encountered in the Study Area. The I-90 Wildlife Watch website included a detailed locator map to help address spatial accuracy issues, and provided species photos and links to natural history information to help maximize the accuracy of species identification. Despite these efforts, the website did not require that users include contact information, and it was therefore typically impossible to verify reports of sightings. On the roadway, 1/10 mile marker posts were present throughout most of our Study Area, and ostensibly made it easier for motorists to note their sighting locations and plot them with accuracy later. We screened I-90 WW data to identify and remove duplicate reports.

Concerns about underreporting of WVCs as a result of degraded /removed carcasses or injured animals leaving the roadway are more difficult to address. One study in Wales estimated that only 6–8% of all actual WVCs might typically be recorded in WVC studies (Slater 2002), and Hesse (2006) concluded that for every reported WVC, three went unreported. Our two data collection methods—i.e., WSDOT maintenance crews and I-90 Wildlife Watch—were intended to complement one another and reduce the chances that a given carcass would be missed. For I-90 Wildlife Watch, we conducted extensive outreach (e.g., billboards, radio advertisements, posters) in an attempt to increase citizen participation, and therefore maximize the probability of capturing WVC data. Similarly, our regular ROCS trainings for maintenance crews encouraged them to routinely look for and report WVCs. While such measures could not ensure that every WVC was recorded, they at least provided some consistency in survey effort. It will be important to parallel this consistency when collecting post-construction WVC data for comparison with pre-construction data.

Recommendations for Future Monitoring

This chapter documents the results of four years of WVC and live animal monitoring conducted via two methods along 39 miles of I-90 near Snoqualmie Pass. Our primary objective was to collect baseline data prior to the installation of wildlife crossing structures and wildlife fencing such that the performance of these mitigation measures can ultimately be evaluated. Our data and results will be suitable for comparison with post-mitigation data and rates, assuming methods and efforts to collect post-mitigation data are similar to those described herein. The following recommendations should help to guide future monitoring efforts such that the performance of mitigation efforts can be most effectively evaluated:

- Identifying the effects of mitigation efforts in the face of other potential concurrent changes in wildlife populations requires that a BACI design be implemented. Maintaining monitoring efforts in both the Project and Control Areas is, therefore, essential.

- For accurate pre-post comparisons, pre-construction monitoring should be conducted immediately prior to the installation of crossing structures and wildlife fencing, and post-construction monitoring should begin immediately following the installation of the structures and fencing. Large temporal gaps in monitoring between pre- and post-construction monitoring efforts make comparisons less reliable, as it becomes more likely that other factors beyond mitigation efforts (e.g., changes in wildlife densities) influence WVC rates as well. Observed WVC rates to-date in both the Project and Control Areas suggest that at least 6–8 years of a combination of pre- and post-construction monitoring should be conducted. Ideally, the number of monitoring years pre- and post-construction should be close to equal. Fewer years of monitoring during the pre-construction window will require an increased number of years of monitoring post-construction to detect a given reduction in WVCs, with a given power. Thus, continuation of WVC monitoring—or at the very least initiating WVC monitoring again 3–4 years prior to final construction and the installation of wildlife fencing—will make the detection of actual reductions in

WVCs after construction much more probable.

- Despite multiple years of data collection, the relatively small sample sizes observed for WVCs during our monitoring efforts resulted in relatively low power to detect differences (1) between Maintenance Crew and I-90 Wildlife Watch results; (2) between Control and Project Areas, and; (3) among survey years. In the case of WVC studies, sample size is the result of both sufficient survey effort and total actual numbers of WVCs. We made substantial efforts to encourage consistent participation in WVC reporting by both the WSDOT maintenance crews and members of the public. Future monitoring efforts should include regular refreshers and reminders for WSDOT crews, as well as increased outreach and publicizing of the I-90 Wildlife Watch program. Such efforts will help to ensure that sample sizes are as large as possible, and will maximize consistency between pre- and post-construction monitoring, thus making results from pre- and post-construction monitoring efforts more comparable.

Chapter 3 – Monitoring the Pre-Construction Crossing Activity of High-Mobility Species

Introduction

Evaluating the performance of mitigation efforts aimed at reducing wildlife-vehicle collisions (WVCs) on highways and increasing cross-highway connectivity for wildlife and natural communities requires first assessing pre-mitigation frequencies of WVCs and existing levels of connectivity across the highway of interest. Such baseline data can then be compared with post-mitigation data. Chapter 2 described pre-mitigation frequencies and patterns of WVCs and live animal distributions in the I-90 Snoqualmie Pass East (SPE) Project Area. Here, we summarize our efforts to document at-grade and sub-grade highway crossing frequencies for high-mobility mammals in the Project Area, and the results of these monitoring efforts.

We quantified sub-grade crossing activity using remote cameras deployed in many of the I-90 SPE Project Area's larger culverts, and in underpasses formed by highway bridges. These structures were designed and installed decades ago, with the specific purpose of facilitating the movement of water beneath the highway. Although they were not originally installed with the intention of providing crossing opportunities for wildlife, few long-term and intensive studies have been conducted to assess whether and to what extent such structures are indeed used by wildlife.

At-grade crossing activity is difficult to quantify, especially across very large stretches of highway. Radio- or GPS-collar technology has proven useful for such applications (e.g., Dodd et al. 2007, Gagnon et al. 2007), but collaring projects are expensive, can have negative consequences for study animals (Cattet et al. 2008), and typically permit data to be collected on relatively few individuals. Track beds installed parallel and adjacent to the highway (Hardy et al. 2007, Hardy and Huijser 2007) can be effective for evaluating relatively short stretches of highway, but they are labor intensive to install and maintain—especially when right-of-way access is limited, topography is a constraint (e.g., when the highway runs along cliffs and steep slopes), and climate is particularly challenging (e.g., in areas characterized by high precipitation, cold weather, snow, and ice). Such conditions were all present within the I-90 SPE Project Area.

Snow tracking can yield reliable crossing and occurrence data, even under difficult topographical scenarios, and has been applied previously within the Project Area (Singleton and Lehmkuhl 2000). This method also has substantial limitations in the I-90 SPE corridor, however. First, snow tracking allows for the detection only of species that are present and active when snow cover is consistent, and thus largely precludes monitoring ungulates at higher elevations and bears during hibernation periods. Further, the window of opportunity for tracking is small; conducting surveys too soon after a snowfall provides insufficient time for animals to become active and deposit tracks, but waiting too long can result in poor snow conditions as temperatures warm or cool. Also, rapid warming or rain following a snow event can quickly render the snow surface unsuitable for tracking. Finally, snow tracking is ineffective for monitoring wildlife during periods lacking snowfall. Despite these limitations, we chose snow tracking as the best available method for collecting at-grade crossing data in the Project Area. We nonetheless suggest that snow tracking results be interpreted carefully, and that they be considered indices to crossing rates and behaviors for those few species detected as opposed to actual estimates of crossing rates for all species that might be present.

We specifically focused our monitoring efforts on medium- to large-bodied, high-mobility mammals (e.g., animals larger than a snowshoe hare). This was primarily due to the fact that remote cameras and camera deployment configurations for larger bodied mammals differ from those that are most effective for surveying small mammals, birds, or aquatic species (e.g., fish, amphibians). Further, snow tracking protocols for small mammals differ markedly from those optimized for larger mammals. Finally, other research projects being carried out by biologists at Central Washington University were already addressing one small mammal of conservation concern (i.e., pikas), as well as amphibians, reptiles, and fish.

We address the following objectives related to sub-grade and at-grade crossing activity by high-mobility mammals in the I-90 SPE Project Area:

1. estimate rates, species composition, and timing of sub-grade crossings through existing large culverts and underpasses, and over existing bridges using remote camera methods;

2. estimate rates and species composition of at-grade crossings during winter within select stretches of I-90 using snow tracking methods.

Study Area

The Study Area is described in detail in Chapter 1. We monitored large culverts and underpasses along the entire 15-mile extent of the I-90 SPE Project Area, from MP 55.1 (Hyak) to MP 70.3 (Easton)(Fig. 3.1). Within the Project Area, WSDOT had previously highlighted specific highway segments that were considered to be especially important for connectivity mitigation efforts (WSDOT 2006). Fourteen of these Connectivity Emphasis Areas (CEAs) are used as reference points in our report (Fig. 3.1). We use “Project Area” when referring to the I-90 SPE project extent, and “Study Area” to more generally describe the region where our monitoring efforts took place. For the purposes of our structure monitoring efforts, these areas are identical.

Figure 3.1. Map of our Study Area, highlighting Connectivity Emphasis Areas (CEAs), select mileposts, and locations of monitored structures.

Methods

Identification of Structures for Monitoring

In late 2007, we obtained multiple, georeferenced databases of known storm water culverts from WSDOT, which were combined into a master database of 349 culverts. In addition to locations, this database contained attributes including culvert type (e.g., corrugated metal pipe, concrete box) and size. Preliminary field visits to select culverts suggested that this database was both incomplete and, in some cases, inaccurate, with regards to both culvert type and size. We acquired a second database from the USDA Forest Service (P. Singleton, USDA Forest Service, unpublished data) that included sites monitored as part of a study conducted from 1998–2000 (Singleton and Lehmkuhl 2000). From both databases, we selected a subset of culverts to evaluate in terms of the likelihood of their being used by medium- to large-bodied mammals to cross under I-90. We based our assessment primarily on whether the structures: (1) were large relative to all available culverts (i.e., ≥4 ft x 4ft for rectangular structures or ≥4 ft in diameter for cylindrical structures); (2) were likely to be water-free during some periods of the year based on the size of the creek they drained and whether they emptied into a lake; (3) had flat bases; and (4) were located in areas deemed to have high potential for wildlife access and movement based on previous assessments (Singleton and Lehmkuhl 2000, WSDOT 2006).

In addition to culverts, we evaluated all underpasses that could potentially provide crossing opportunities for medium-to-large mammals, as well as bridges crossing over the highway that could potentially be used by wildlife.

Remote Camera Deployment and Maintenance

We used remote digital cameras to monitor wildlife crossings through culverts and bridges. Over five-plus years, we employed all models of Reconyx remote cameras (Holmen, Wisconsin), including Silent Image, Rapidfire, and Hyperfire models from both the “professional” and “outdoor” series (Fig. 3.2). These cameras were triggered to take photographs when they detected the movement of objects (i.e., animals) whose temperature differs from the ambient air temperature. While most photos are instigated by warm-blooded mammals or birds, other objects, such as snow, ice chunks, or blowing vegetation, occasionally caused “false” triggers. With sufficient light (e.g., daytime in open habitats), most camera models recorded color photos without infrared illumination. When light was limited, however, (e.g., inside culverts, nighttime, under heavy tree canopy), infrared emitters were used to illuminate subjects and a black and white image was recorded. We used standard camera models that featured high-output infrared emitters that glowed red to the human eye, as well as “stealth” or “covert” models whose infrared emitters were undetectable to humans and some wildlife. We opted for deploying covert models in locations where passersby might be more likely to occur to minimize the risk of theft and vandalism.

Figure 3.2. Three Reconyx-brand digital remote cameras used to monitor culverts, underpasses, and bridges. Silent Image, Rapid Fire, and Hyperfire models are shown from left to right. (Photo: R. Long/WTI)

We programmed cameras with the highest sensor-sensitivity setting, and to take 10 successive photos during each trigger event, with no pause between events. This combination of settings maximized our chances of detecting individuals of all sizes, and also ensured that we would record as many images as possible from each trigger event. Cameras were powered with rechargeable NiMH C-cell batteries, and equipped with 1–2 GB compact flash or SD media cards.

We deployed a single camera at each culvert. At larger underpasses, we deployed a camera at each potential crossing location (e.g., under bridges spanning creeks, where either bank of the creek could be accessed by wildlife, we deployed a camera on each bank). We initially deployed cameras on trees outside of culverts, with the camera and sensor aimed at the culvert entrance. After experiencing high numbers of false detections triggered by vegetation, however, as well as detections of birds and rodents using culvert entrances as perching locations or habitat, we moved cameras to the inside the culverts and faced them towards the center. Locating cameras inside of culverts also eliminated the need to continually adjust the height of camera units to adjust for changing snow levels, and eliminated exposure to rain, sleet, snow, and sun. We removed cameras from culverts and directed them at culvert entrances during some spring thaw periods, when high water levels inside the culverts threatened to submerge the cameras.

We attached cameras to cement culverts by affixing a custom-made bracket to the wall with expansion bolts, and attaching a Reconyx security box to the bracket (Fig. 3.3). We then inserted the camera into the bracket, and locked the security box to avert camera theft.

Figure 3.3. Remote camera deployed on culvert wall in a locked, metal security box. (Photo: R. Long/WTI)

For monitoring larger underpasses, we enclosed cameras in faux utility boxes that were locked to the ground (Figs. 3.4).

Figure 3.4. “Faux” electrical housing containing remote camera deployed at the Sparks Road Bridge South. Various images show housing (A), aim of camera (B), view from under the bridge with arrow pointing to camera box (C), and sample photo of WTI field vehicle (D). (Photos: R. Long /WTI)

We generally checked cameras at 2–3 week intervals. During checks, we inserted fully charged batteries if necessary and replaced the memory card. We also recorded the battery level, the amount of memory remaining on the card, and whether the camera was intact and appeared to be operating. Upon arrival and departure, we recorded a test photo and the time the photo was taken, permitting us to later evaluate whether the camera was functioning correctly and whether the time—automatically imprinted on each image—was accurate.

Supplemental Camera Surveys

In addition to our long-term monitoring efforts at culverts, we conducted a limited number of short-term camera surveys at select sites. During summer and fall of 2009, we deployed a single camera on each of two paved bridges crossing I-90 at the Stampede Pass Road and Cabin Creek Road exits (Exits 62 and 63), respectively, to quantify the use of these "overpasses" by wildlife. We also deployed a second camera in the Swamp Creek East culvert—at eight feet across, one of our widest culverts—during summer and fall 2010 and 2011, in an effort to assess how often crossings would have been undetected by a single camera and whether small animals (e.g., mink, weasels) were missed more often than larger animals (e.g., raccoons).

Photo Analysis

We reviewed all photos for detections of wildlife, humans, or vehicles, and recorded the following data: date of detection, time of detection, number of photos associated with a given detection occasion, species, a confidence rating for species identification, number of individuals, direction of travel, and outcome (i.e., crossed through structure, entered structure but aborted crossing, visited entry to structure only, unable to ascertain whether crossing occurred). Unless individuals could be distinguished with confidence, multiple detections of the same species within 15 minutes were recorded as the same detection "event." We also evaluated water levels in culverts by reviewing photos once per month and assigning relative height values ranging from 0–5, with "0" indicating dry and "5" indicating very high flow.

We recorded a "crossing" whenever a camera detected an individual moving in one direction through a structure and there was no indication that it turned and failed to complete the crossing. "Aborted" crossings were recorded when an animal entered a structure with the apparent intention to cross but then turned and failed to complete the crossing. We also noted "visits," or detection events during which an animal visited a structure but exhibited no crossing behavior. The latter were primarily captured by cameras deployed outside of culverts, and at underpasses where cameras were able to detect individuals in the vicinity of the structure.

In addition to reporting the *frequencies* of crossings, aborted crossings, and visits, we calculated associated *rates* based on the frequency of detections at a site divided by the number of "camera nights" at that site, with a "camera night" defined as a full 24-hour survey period during which the camera was functional and capable of collecting detection data. This enabled standardization among sites with different levels of survey effort due to variation in dates of camera deployment and removal, or inoperative cameras.

Finally, we used the VLOOKUP function in MS Excel, along with the time of detection and a table of sunrise/sunset times for Roslyn, WA (U.S. Naval Observatory 2008–2012), to classify detections and crossings as having occurred during day, night, crepuscular dawn, or crepuscular dusk, with "crepuscular" being defined as within 1 hour of sunrise or sunset. In order to evaluate the timing of crossings by species-of-interest, we calculated an index of timing selection for each species. This index represents the proportion of total crossings for a given species detected during day, night, or dawn/dusk crepuscular periods, divided by the proportion of time each period represents of a 24-hour day. For example, we defined crepuscular as 1 hour before and after sunrise and sunset, so "crepuscular dawn" represents 2/24 = 0.083 of a 24-hour day, and "day" represents (on average over a year) 5/24 = 0.208 of a 24-hour day. Thus, index values greater than or less than 1.0 reflect the detection of more or fewer crossings, respectively, than would have been expected due to chance during a given time period.

Snow Track Monitoring of At-Grade Crossings

We conducted snow tracking surveys in an attempt to identify at-grade wildlife crossing locations and to evaluate the behavior of animals in close proximity to I-90. We identified three sets of paired survey transects (i.e., on either side of the highway)(Fig. 3.5) that: (1) collectively encompassed as much of the Project Area as possible; (2) included shoulders that could be safely traveled by researchers without their encountering cliffs or steep drop-offs; and (3) could be feasibly surveyed in a single day. The Swamp-Bonnie-Price Creek Transect extended 2.3 mi from Keechelus Dam to Exit 62 (Stampede Pass), the Toll-Swamp Creek Transect extended 1.6 mi from Exit 62 to Exit 63 (Cabin Creek), and the Easton Hill Transects extended 1.75 mi along both divided highway segments and bounded the large island between the eastbound (EB) and westbound (WB) lanes (Fig. 3.5).

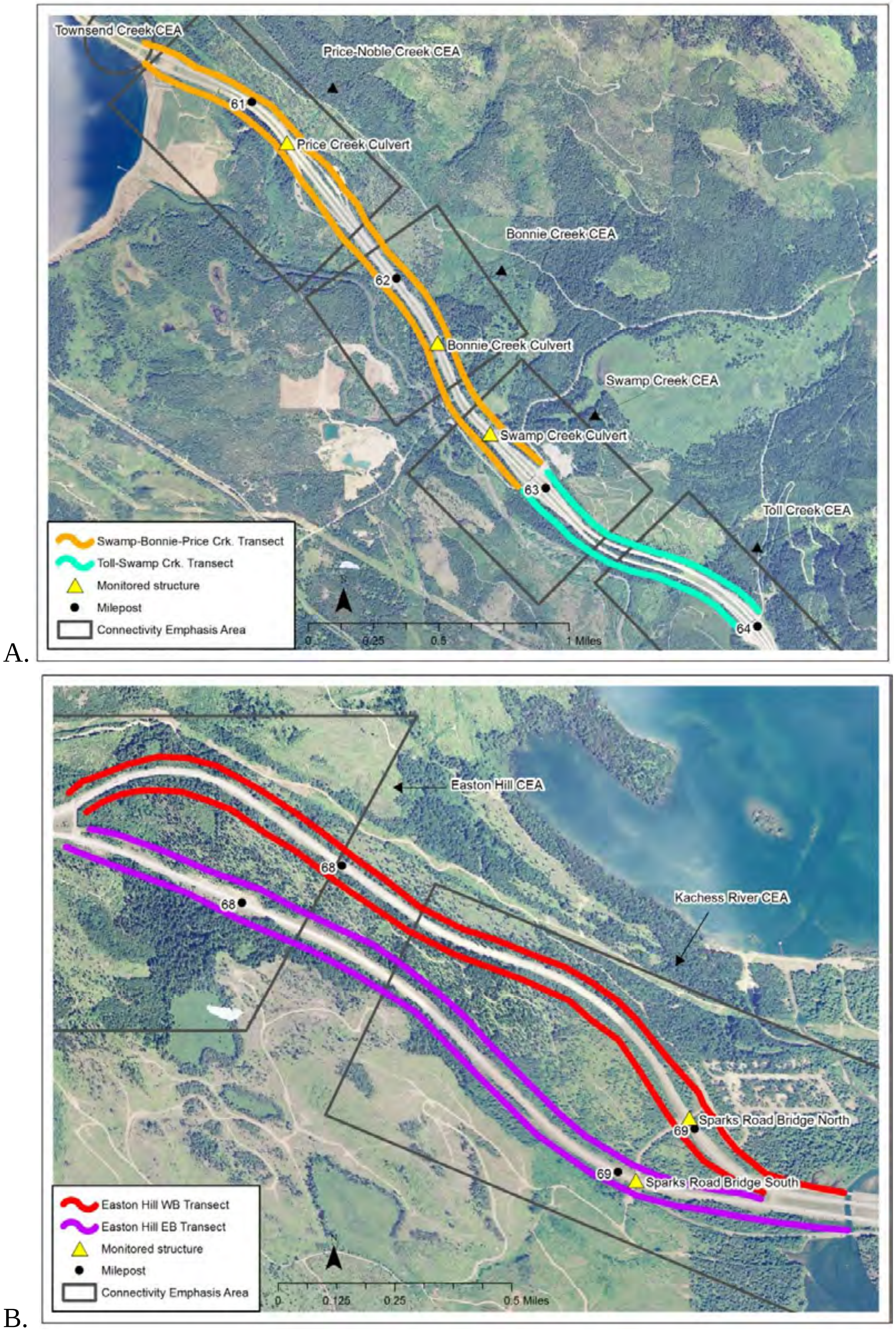

Figure 3.5. Transects used for snow tracking along I-90 including (A) Swamp-Bonnie-Price Creek and Toll-Swamp Creek Transects, and (B) Easton Hill WB and EB Transects.

We conducted snow tracking surveys by snowshoeing or skiing parallel to the highway immediately outside the plow zone (Fig. 3.6). Surveys were initiated 24–72 hours after a track-obliterating snow event (i.e., when new snowfall covered any previously existing tracks). Whenever possible, two researchers surveyed the north and south sides of the highway simultaneously—communicating by radio or cell phone—and completed transects in a single day. We recorded standard information during surveys, including the transect name, date, begin and end times, number of hours since last snowfall, and current snow conditions. When tracks were located, we recorded the name of the species that deposited them, our confidence in species identification, snow track quality, GPS coordinates for the beginning and end points of the observation, direction of travel, and if and how the tracks interacted with the highway (Table 3.1). A single animal could have more than one road encounter, but each was recorded as a unique observation. All animals larger than a snowshoe hare were recorded. Periodically, tracks were also documented by photograph or sketch.

Table 3.1. Highway encounter categories for tracks found along snow tracking transects.

Encounter Type	Definition
None	Tracks had no apparent interaction with the highway
Parallel	Track trail paralleled the highway
Turned back	Track trail approached the highway but then turned away from it
Entered roadway	Track trail entered the highway but then turned back
Unconfirmed crossing	Track trail entered the highway but no similar tracks were located on the opposite side
Confirmed crossing	Track trail entered the highway and similar tracks were located on the opposite side

Figure 3.6. Researcher snow-tracking along I-90. (Photo: P. MacKay/WTI)

Results

Identification of Structures for Monitoring

We visited 18 of the 21 structures targeted for potential monitoring—safety concerns precluded access to 2 structures, and a third could not be located. Because these latter three structures were adjacent to Lake Keechelus, they presumably had a lower likelihood of being used by wildlife during much of the year. Further, records suggested that one of the three was a small culvert, and would therefore be low-priority for the purposes of our monitoring. Of the 18 structures that we did visit and evaluate, 8 culverts were ultimately selected for monitoring (Fig. 3.1). Those not selected were: (1) likely too small to permit crossings by mid- to large-bodied mammals; (2) cylindrical metal structures that might have had a lower likelihood of use given their curved floor; or (3) apparently prone to large flows of water during much of the year.

We also selected three *de facto* underpasses for monitoring because we felt they represented potential crossing opportunities for medium-to-large mammals. The first was formed by a bridge spanning Gold Creek, and the other two by county road bridges spanning West Sparks Road. The Gold Creek underpass comprised two structures for our monitoring purposes, as each stream bank could have been used independently by wildlife. A double culvert at Swamp Creek was characterized as two structures for the same reason. In total, then, we targeted 12 structures (Table 3.2, Fig. 3.1; Appendix 3.1) for intensive camera-based monitoring.

We later deployed cameras at two bridges spanning the highway (Fig. 3.7), at exits 62 (Stampede Pass Road) and 63 (Cabin Creek Road), in an effort to detect crossings at these locations. Because we monitored these locations for only three and six months, respectively, we evaluated data from these locations separately from long-term camera site data.

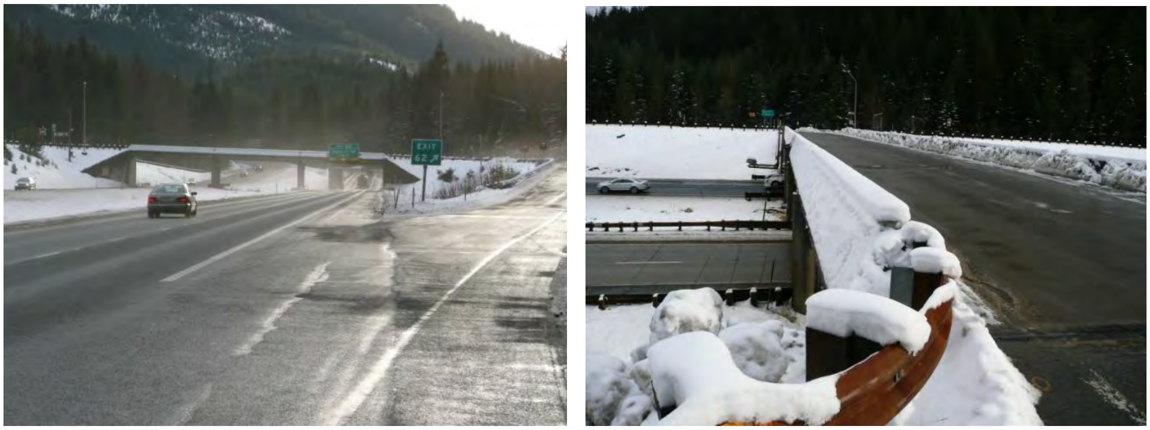

Figure 3.7. Paved bridges that were monitored by remote cameras at Exit 62 and Exit 63. (Photo: J. Begley/WTI)

Table 3.2 High-priority structures for wildlife monitoring. Monitoring end date for all structures was June 2012.

Structure Name`	Milepost	Type	Culvert or bridge length[1] (ft)	Height (ft)	Span (ft)	Openness[2] ([span x height] / highway width)	Monitoring Begin Date
Gold Creek Bridge Northeast	55.49	Underpass formed by bridge	41	22[3]	138	22.6[4]	October 2008
Gold Creek Bridge Northwest	55.5	Underpass formed by bridge	41	22[2]	126	20.6[3]	November 2008
Price Creek Culvert	61.35	Concrete box	272	10	10	0.11	April 2008
Bonnie Creek Culvert	62.4	Concrete tube (eastbound), concrete box (westbound)	187	6	6	0.06	April 2008
Swamp Creek Culverts (2)	62.71	Dual concrete double-boxes	201	6	8	0.07	April 2008
Cedar Creek Culvert	64.67	Concrete box	155	4	4	0.03	April 2008
Unnamed Creek Culvert	65.1	Concrete box with round metal insert on south side	145	4	4	0.03	April 2008
Telephone Creek Culvert	65.57	Concrete box	170	6	4	0.04	April 2008
Hudson Creek Culvert	66.6	Corrugated metal pipe	165	4	4	0.03	May 2008
Sparks Road Bridge North	69.04	Underpass formed by bridge	52	18	28	2.9	May 2008
Sparks Road Bridge South	69.04	Underpass formed by bridge	41	18	28	3.7	May 2008

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[1] Length is the measurement perpendicular to vehicle flow, and represents the distance an animal must traverse to cross from one side of the highway to the other.

[2] Openness ratios are controversial, and have been inappropriately used as one-size-fits-all metrics to evaluate structure suitability (Clevenger and Huijser 2009). We include openness ratios here (calculated using meters) simply to provide some context for the structure's shape and dimensions and for comparison with other studies. Ratios are calculated using meter units, so conversion from feet is required.

[3] This height value is a maximum, when Gold Creek was sufficiently low that large animals could have effectively walked down the middle of the creek versus along the steep rip-rapped stream banks.

[4] This openness value is a maximum, when Gold Creek's bridge's height above the creek was at a maximum (see above).

Monitoring Summary and Camera Performance

We monitored 12 structures from April 2008–June 2012 (Table 3.2). Start and end dates varied by structure, but all structures were monitored for 1200–1932 consecutive days, from October 2008–June 2012 (Fig. 3.8). During this period, cameras were operational for 1049–1527 camera nights (Fig. 3.8), yielding a total of 16,543 camera nights. The percentage of nonfunctional camera nights ranged from 0–14.2% (mean=6.4%), with functionality having been compromised by malfunction, theft, weather issues (e.g., snow obscuring the sensor or lens), or logistical constraints associated with camera re-deployment.

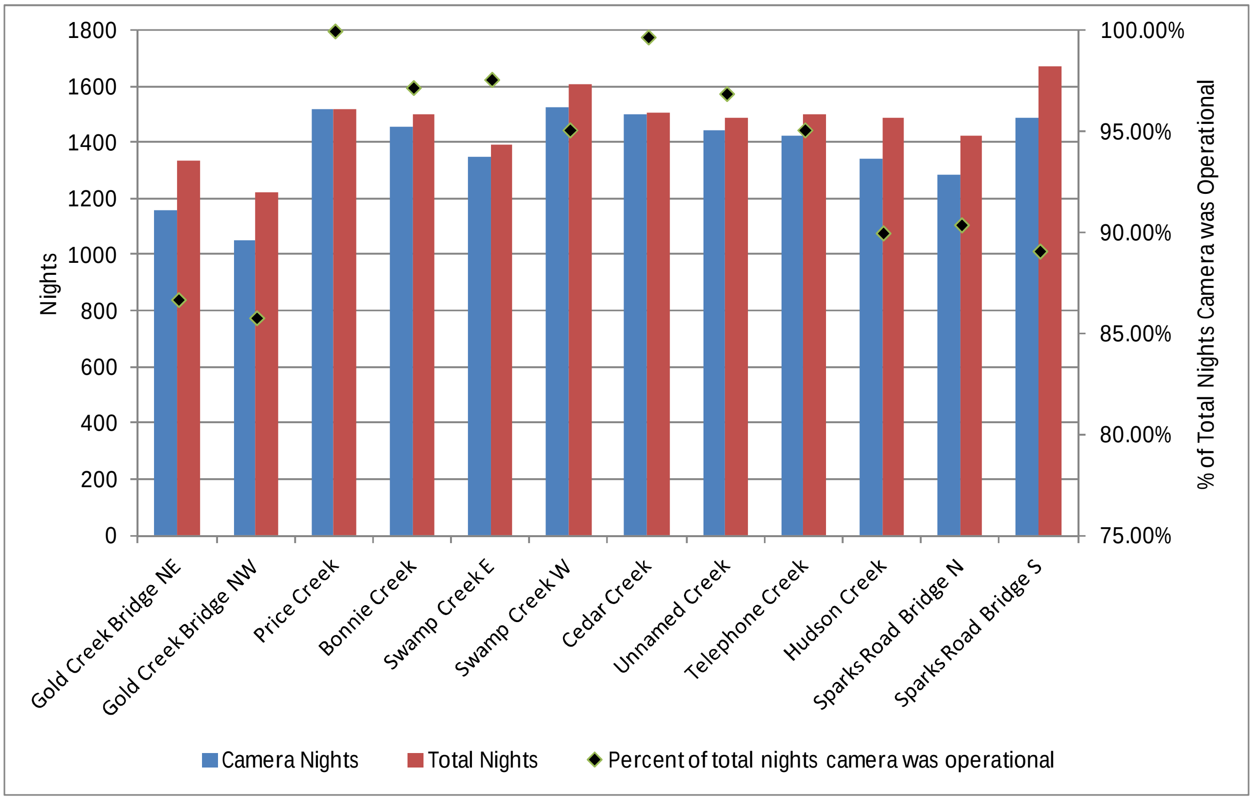


Figure. 3.8. Camera performance metrics, including the total number of nights that cameras were deployed, nights they were operational (Camera Nights), and percentage of total nights they were operational.

Species-Specific Crossing Results from Long-Term Camera-Monitored Sites

We detected 18 animal species, as well as individuals from four large groups of species (i.e., bats, small mammals, birds, squirrels; Table 3.3) that weren't individually identified, at the 12 long-term monitoring sites. We routinely detected birds, squirrels, bats, and various other small mammals (e.g., mice, voles, chipmunks, woodrats), but did not differentiate between detections and crossings for these species for multiple reasons. First, we presume that small animals were photographed unreliably with our camera setup, which was optimized to maximize detections of larger wildlife across the entire width of the culvert or bridge. Second, it was often difficult to assign a crossing status (i.e., crossed or not) to those small animals that were detected. Finally, many small animals occurred very frequently in photographs, and may have been using culverts as habitat—thus rendering the interpretation of crossing behavior and the assessment of crossing rates for these species problematic.

Table 3.3. Species (or species groups) detected by remote cameras at long-term monitoring sites.

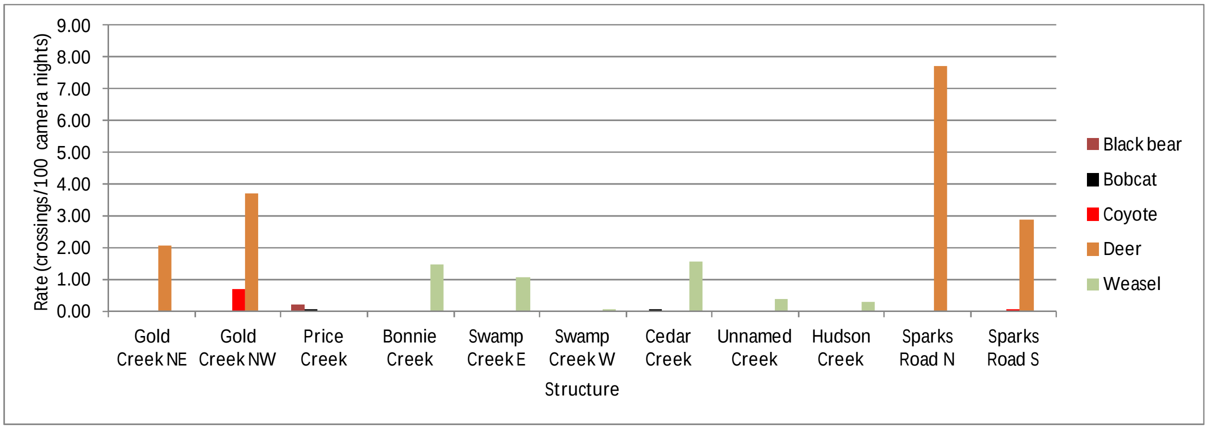
Species
American black bear
American mink
Bat (includes multiple species)
Beaver
Bird (includes all species smaller than waterfowl)
Bushy-tailed woodrat
Bobcat
Canada goose
Coyote
Deer (includes both mule and black-tailed)
Domestic dog
Domestic cat
Douglas' squirrel
Elk
Mountain beaver
Northern flying squirrel
Northern raccoon
Northern river otter
Small mammal (includes mice, voles, shrews and chipmunks)
Snowshoe hare
Waterfowl
Weasel (includes both long- and short-tailed)

We focused our crossings analysis on a subset of species (i.e., “species-of-interest”) comprising medium- to large-bodied mammals, and defined as (1) all carnivores and (2) other mammals larger than a snowshoe hare. The final wildlife crossings dataset totaled 605 individual animals representing 9 species-of-interest (Table 3.4, Appendix 3.2).

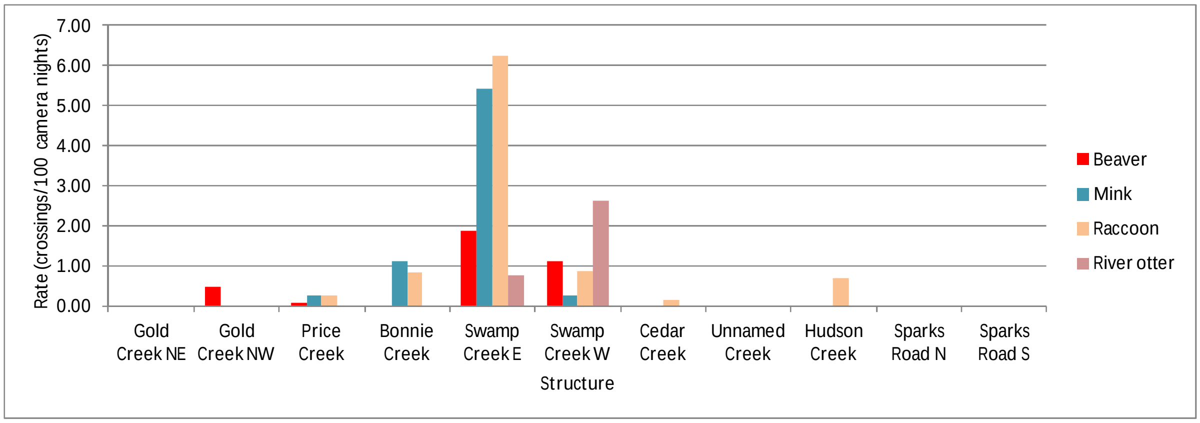
Table 3.4. Crossings data for all "species-of-interest" (as defined in this report), including crossing frequency and (below frequency in parentheses) crossing rate, expressed as crossings/100 camera nights.

Species	Gold Creek NE	Gold Creek NW	Price Creek	Bonnie Creek	Swamp Creek E	Swamp Creek W	Cedar Creek	Unnamed Creek	Telephone Creek	Hudson Creek	Sparks N	Sparks S	Total
Black bear			3 (0.20)										3 (0.20)
Bobcat			1 (0.07)				1 (0.07)						2 (0.13)
Coyote		7 (0.67)										1 (0.07)	8 (0.73)
Mink			4 (0.26)	16 (1.10)	73 (5.42)	4 (0.26)							97 (7.04)
Raccoon			4 (0.26)	12 (0.82)	84 (6.24)	13 (0.85)	2 (0.13)			9 (0.67)			124 (8.98)
River otter					10 (0.74)	40 (2.62)							50 (3.36)
Weasel				21 (1.44)	14 (1.04)	1 (0.07)	23 (1.53)	5 (0.35)		4 (0.30)			68 (4.72)
Deer	24 (2.07)	39 (3.72)									99 (7.70)	43 (2.89)	205 (16.37)
Beaver		5 (0.48)	1 (0.07)		25 (1.86)	18 (1.11)							49 (3.51)
Total	24 (2.07)	51 (4.86)	13 (0.86)	49 (3.36)	206 (15.29)	76 (4.91)	26 (1.73)	5 (0.35)	0 (0)	13 (0.97)	99 (7.70)	44 (2.96)	606 (45.06)

Species-specific use of the culverts and bridges varied considerably. Deer and coyotes were never detected using culverts, but crossed only under the bridges (Fig. 3.9). Other terrestrial species-of-interest (e.g., raccoons, river otters, weasels) were documented using one or more of the Price Creek, Bonnie Creek, Swamp Creek, Cedar Creek, and Hudson Creek Culverts, but were *not* detected crossing under bridges (Fig. 3.9). In the case of smaller species such as weasels, this may have been due in part to our camera configurations under the bridges, which were necessarily designed to capture images across a wide area and therefore may have missed small animals. Aquatic animals (e.g., beavers, mink, river otters) and raccoons crossed most often through the Swamp Creek Culverts, although mink and raccoons were detected crossing through other culverts as well (Fig. 3.9). Beavers were also detected crossing under the Gold Creek Bridge. Notably, no elk crossings were detected, despite their presence at or near many of the structures (see below and Chapter 4). Further, we detected no crossings by species-of-interest at the Telephone Creek Culvert, and Unnamed Creek had the second-fewest crossings (i.e., 0.35 crossings/100 camera nights), with all documented crossings associated with weasels.



A.



B.

Figure 3.9. Species-specific crossing rates (crossings/100 camera nights) for (A) terrestrial and (B) aquatic (or semi-aquatic, in the case of raccoons) species.

<u>Timing of Crossings</u>

We observed species-specific differences in the time of day when crossings tended to occur. Deer crossed during all periods of the day, with more crossings during crepuscular periods than would be expected by chance (Fig. 3.10). River otters and mink crossed primarily during the day, while raccoons, coyotes, and beavers crossed disproportionately at night (Fig. 3.10). Weasels crossed with similar frequency during day and night (Fig. 3.10). Black bears and bobcats were detected too infrequently to allow for a meaningful comparison of timing of crossings. Notably, deer were the only species that crossed disproportionately during crepuscular periods (Fig. 3.10).

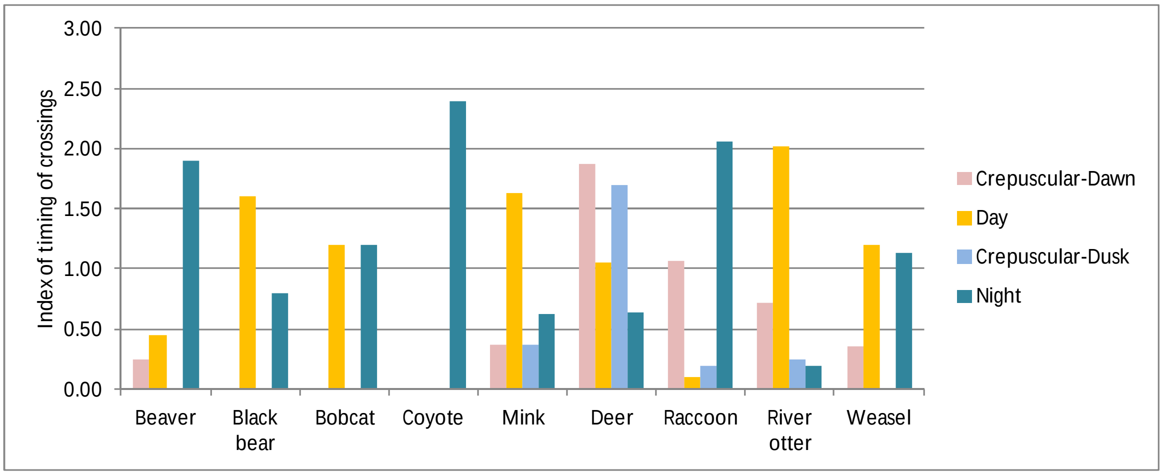
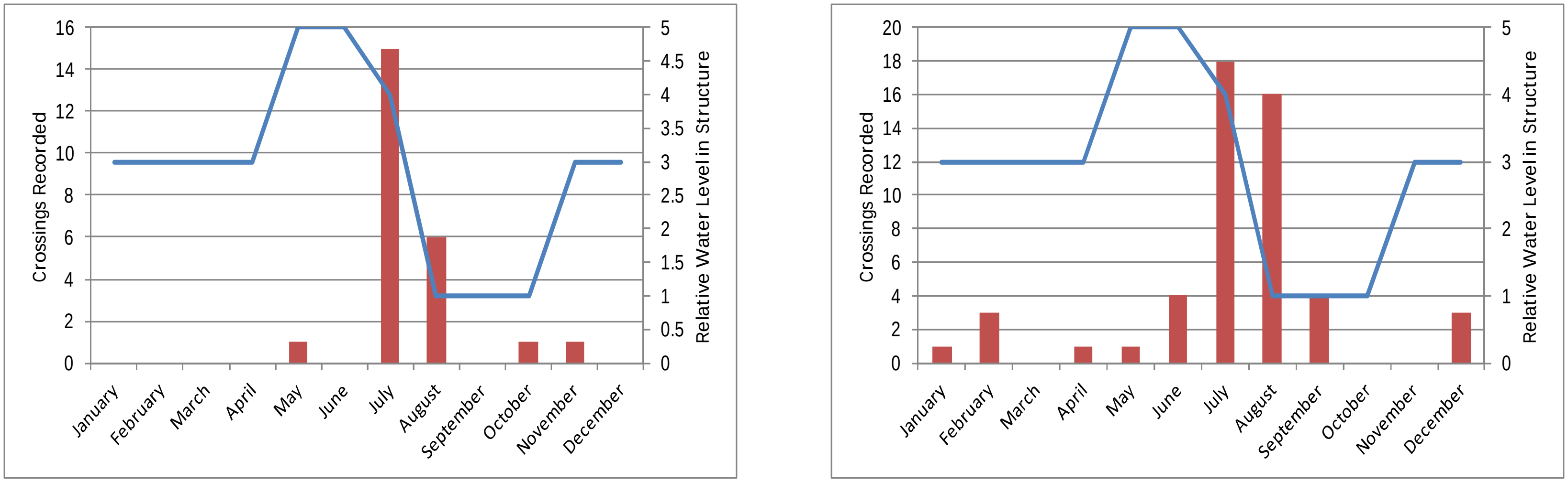


Figure 3.10. Index of the timing of crossings by species-of-interest using the 12 crossing structures monitored with remote cameras. Index of timing values greater than or less than 1.0 reflect the detection of more or fewer crossings, respectively, than would have been expected due to chance during a given time period.

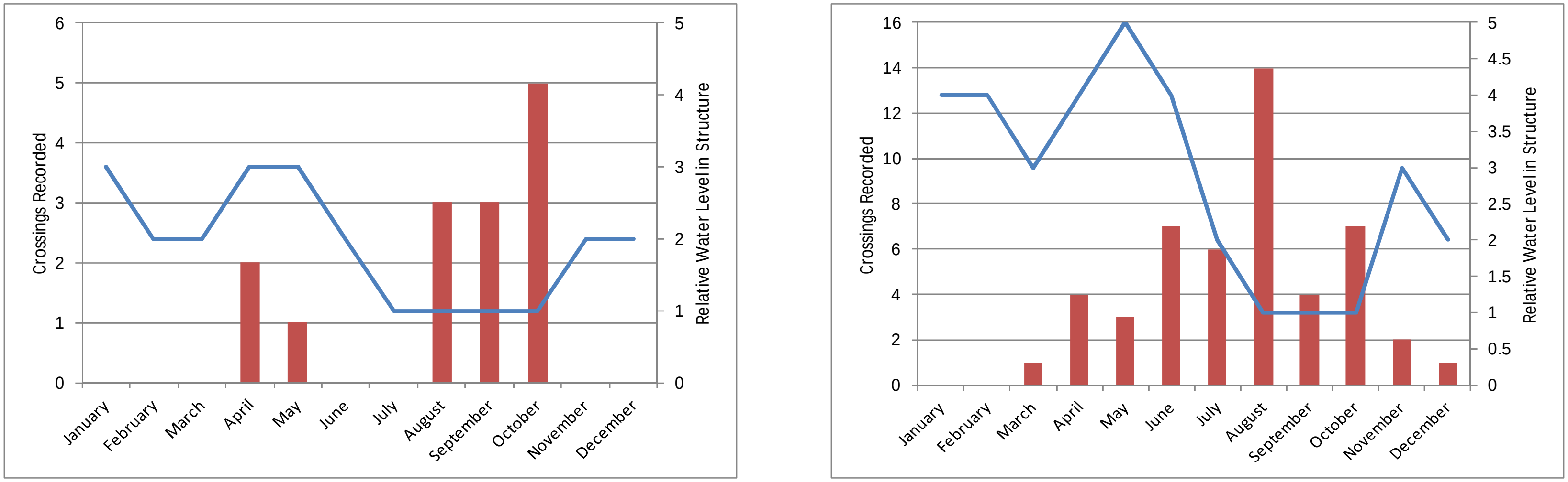
<u>Seasonal Patterns of Crossings</u>

We observed clear seasonal patterns in crossing activity at most structures, with few if any crossings detected during January–March and most crossings detected during May–November (Fig. 3.11–3.13). There were a number of clear exceptions, however, specifically at Cedar Creek. We detected crossing activity by weasels at this culvert all through the winter months, and no crossing activity by any species-of-interest during June–July. Swamp Creek E, as well, had low but relatively consistent crossing activity throughout all months but December (during which we detected only a single crossing, by a raccoon), with most winter activity attributed to mink and raccoons. Water levels in most culverts tended to be highest during spring runoff (i.e., March–May), and generally corresponded to periods where fewer crossings were observed (Fig. Fig. 3.11–3.13)–with the exception of Swamp Creek E, where crossings of primarily aquatic species were detected.



Gold Creek NE

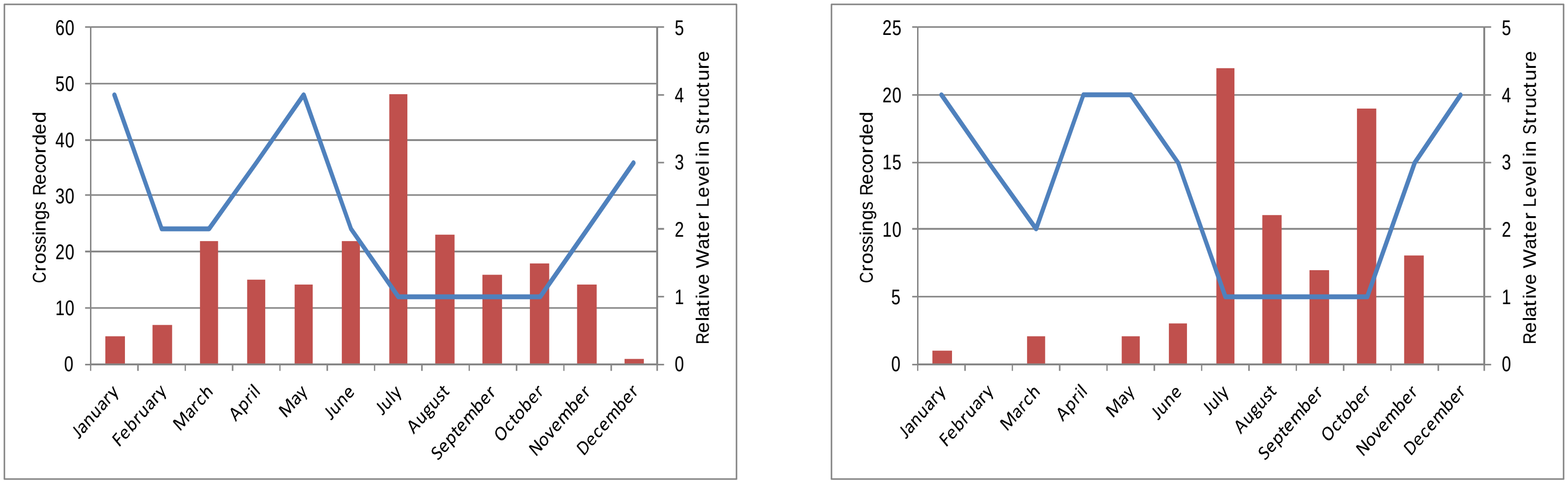
Gold Creek NW



Price Creek

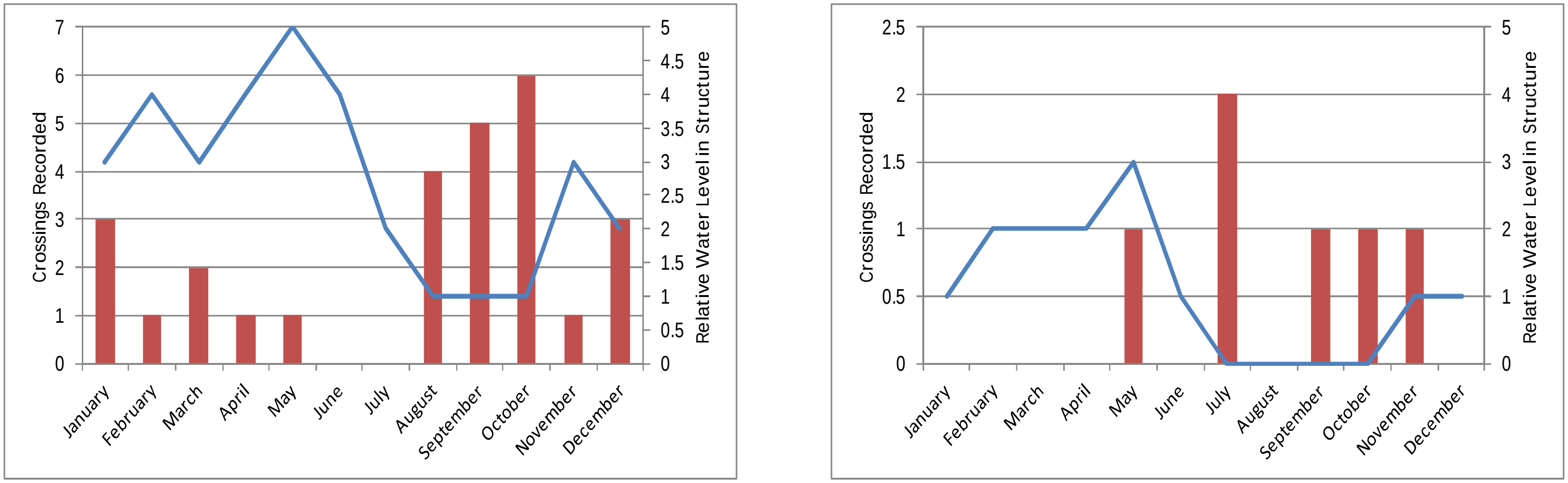
Bonnie Creek

Figure 3.11. Detection frequencies by month and relative water levels for Gold Creek NE, Gold Creek NW, Price Creek, and Bonnie Creek structures.



Swamp Creek East

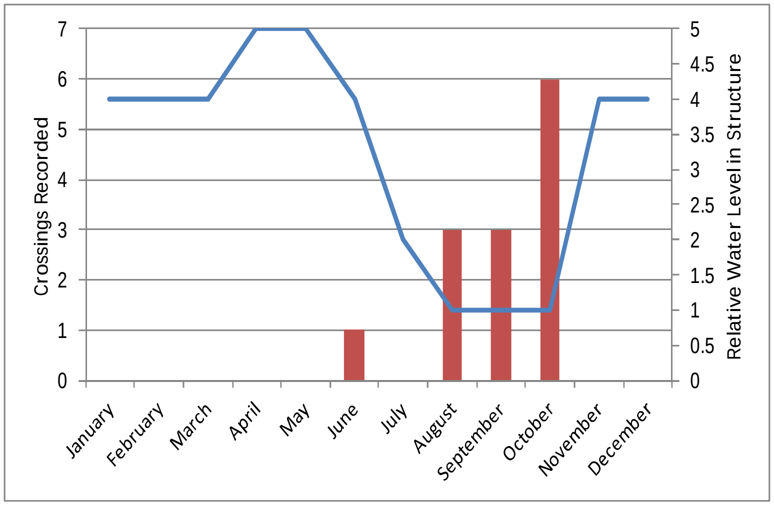
Swamp Creek West



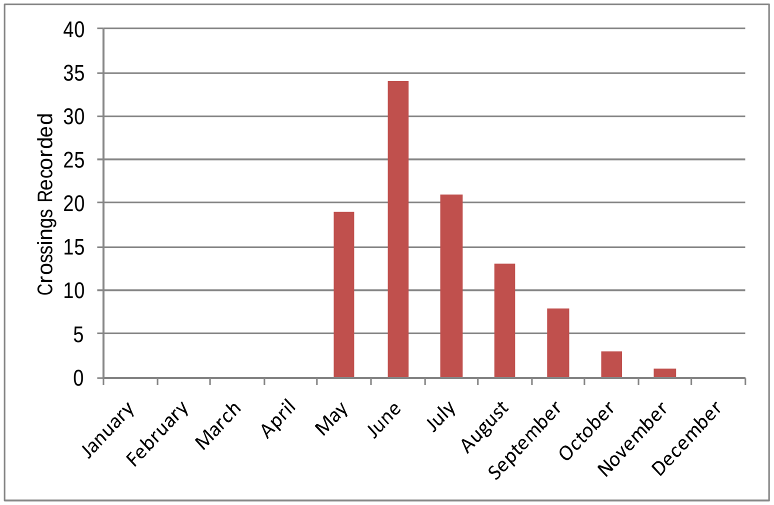
Cedar Creek

Unnamed Creek

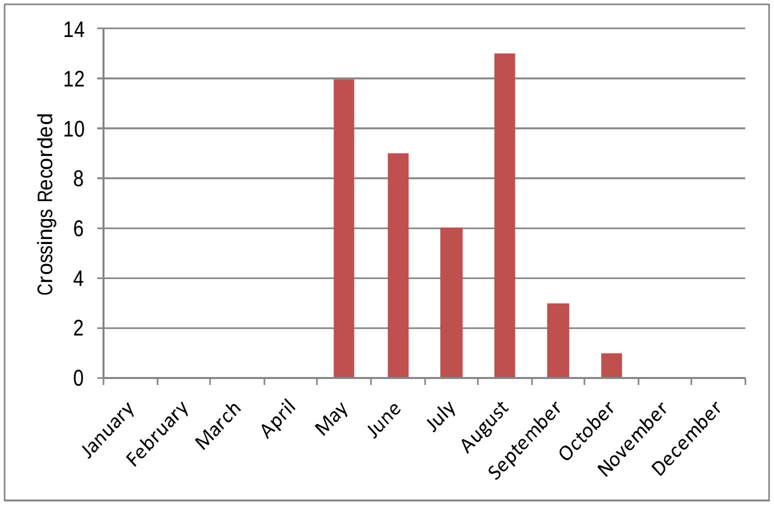
Figure 3.12. Detection frequencies by month and relative water levels for Gold Creek NE, Gold Creek NW, Price Creek, and Bonnie Creek structures.



Hudson Creek



Sparks Road N



Sparks Road S

Figure 3.13. Detection frequencies by month and relative water levels for Hudson Creek, Sparks Road N, and Sparks Road S structures. No water levels are reported for Sparks Road structures because they span roads not creeks.

Crossings by Humans and Domestic Animals

We also detected crossings by non-wildlife species, including humans, domestic dogs, and domestic cats, through various structures (Table 3.5). Most such detections occurred beneath the Gold Creek and Sparks Road Bridges, with those humans who were detected at culverts primarily comprising fish and amphibian researchers versus members of the general public. On busy days, we detected crossings by dozens of automobiles and trucks, as well as all-terrain vehicles (ATVs), at the Sparks Road structures. Motorized vehicle detections were not analyzed due to the impracticality of, and lack of utility in, reviewing such a high volume of photographs.

Table 3.5. Crossings by humans and domestic animals, including crossing frequency and crossing rate (below frequency in parentheses) expressed as crossings/100 camera nights.

Type	Gold Creek NE	Gold Creek NW	Price Creek	Swamp Creek E	Swamp Creek W	Unnamed Creek	Sparks Road N	Sparks Road S
Human	363 (31.3)	127 (12.1)	165 (10.9)	109 (8.1)	69 (4.5)	9 (0.6)	407 (31.6)	415 (27.9)
Human with dog	66 (5.7)	8 (0.8)					144 (11.2)	168 (11.3)
Bicyclist							157 (12.2)	192 (12.9)
Domestic dog	1 (0.1)							7 (0.5)
Domestic cat								1 (0.1)
Total	430 (37.1)	136 (12.9)	165 (10.9)	109 (8.1)	69 (4.5)	9 (0.6)	708 (55.0)	783 (52.7)

Aborted Crossing Attempts

We detected only 33 aborted crossing attempts across all 12 structures during the monitoring period (Fig. 3.14), with the species detected generally mirroring those that were detected making successful crossings at the various structures. Deer were most often associated with aborted crossings, and such activity was especially prevalent at the Sparks Road Bridges—where only deer were documented exhibiting this behavior.

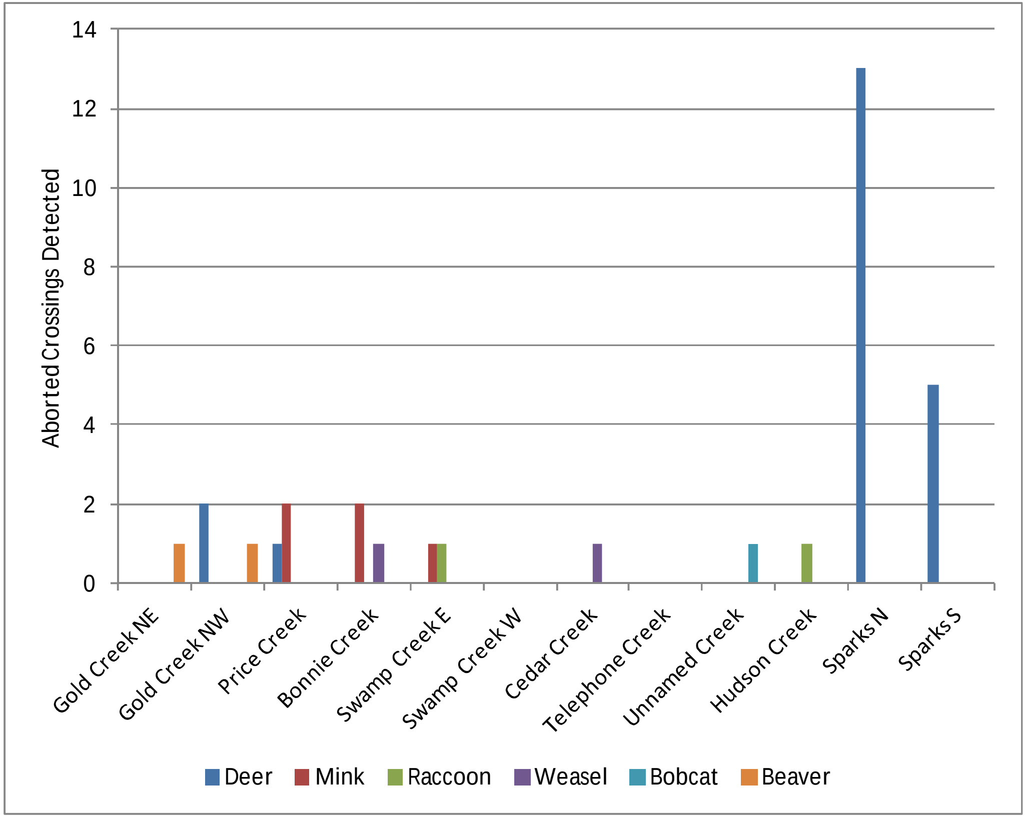


Figure 3.14. Frequency of aborted crossings by species-of-interest and structure. Aborted crossings were defined as an individual being detected by remote camera, but turning around before a crossing was completed and exiting the same way it entered.

Species Occurrence at Structures

In some cases, we recorded the occurrence of species outside of structures, with no crossing event recorded. For example, during initial monitoring efforts in 2008—when cameras were deployed outside of culverts—or when cameras were moved from the inside to the outside of culverts during periods of high water runoff, we routinely detected birds, squirrels, and other small mammals near culvert entrances. Further, cameras deployed in faux electrical boxes at the four bridge locations also occasionally detected animals (e.g., deer, elk) that did not cross under the bridges. Because camera deployment efforts outside of structures was uneven, both in time and across structures, it would be misleading to report detection totals or even rates. Table 3.6, however, summarizes all species detections at structures, whether the detection comprised a "visit only" occurrence outside of the structure or a crossing through the structure. Note that we also discuss species detections in Chapter 4, which highlights occurrence data throughout the Project Area—both along I-90 and in abutting habitats.

Table 3.6. Species-specific detections at all monitored culverts and bridges. "X" indicates that the species or group was detecte either outside of the structure or crossing through the structure. Species/group names are alphabetical.

Species	Gold Creek NE	Gold Creek NW	Price Creek	Bonnie Creek	Swamp Creek E	Swamp Creek W	Cedar Creek	Telephone Creek	Unnamed Creek	Hudson Creek	Sparks Road N	Sparks Road S
Bat			X	X	X	X				X		
Beaver	X	X	X		X	X						
Bicyclist											X	X
Bird (non-waterfowl)[6]	X	X	X	X	X	X	X	X	X		X	X
Black bear			X									
Bobcat			X				X		X			
Coyote		X										X
Deer	X	X	X								X	X
Domestic dog	X											X
Domestic cat												X
Elk											X	X
Flying squirrel			X									
Human	X	X	X	X	X	X	X		X	X	X	X
Human with dog	X	X									X	X
Mink			X	X	X	X						
Mountain beaver			X				X		X		X	
Raccoon			X	X	X	X	X			X	X	X
River otter					X	X						
Small mammal			X	X	X		X		X	X	X	X
Snowshoe hare									X	X		
Squirrel			X	X	X	X	X	X	X	X		
Vehicle											X	X
Waterfowl	X	X				X						
Weasel				X	X	X	X		X	X		
Woodrat					X		X		X			

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[6] Most "non-waterfowl" bird detections were American dippers, which were detected in most culverts and nested consistently in the Swamp Creek culvert.

Cameras Deployed on "Overpasses"

We deployed a single remote camera under the guardrail on each of the paved Exit 62 (Stampede Pass Road) and 63 (Cabin Creek Road) bridges during May–August 2009 and May–November 2009, respectively. These two-lane bridges permit vehicles to cross over I-90 and could serve as "overpasses" for wildlife. We detected only crossings by vehicles, with no wildlife detections during the survey period. Further, high vehicle use of these bridges resulted in remote camera memory cards quickly filling to capacity during relatively short survey periods. The lack of detections and memory card issues led us to remove these cameras prior to winter 2009.

Estimating Detection Omission Rates with Two Cameras

During May–November 2010, and again during May–November 2011, we deployed a second camera in the Swamp Creek E Culvert in an attempt to estimate detection omission rates for the primary camera. This culvert, with a span of 8 feet, had the second longest culvert span after Price Creek (at 10 feet). Omission rates for the primary camera varied from zero omissions for river otters to 0.33 for beavers (Table 3.7).

Table 3.7. Omissions and omission rate by primary camera at the Swamp Creek E Culvert, from May–November, 2010 and 2011.

	Raccoon	Beaver	River otter	Mink	Weasel
Crossings omitted	8	3	0	7	2
Crossings detected	28	6	3	34	6
Crossings through culvert	36	9	3	41	8
Omission rate	0.22	0.33	0.00	0.17	0.25

Monitoring At-Grade Crossings

Snow Tracking

We monitored the weather for snow tracking opportunities during three winters: 2008–2009, 2009–2010, and 2010–2011. Only during the winter of 2008–2009, however, were we able to collect survey data. During the other two winters, weather patterns in the Project Area were inconsistent with those required for conducting effective track surveys along the highway. For example, track-obliterating snow events occurred too close together in time, resulting in insufficient time between storms for tracks to accumulate; rapid warming or rain-on-snow events followed too closely on the heels of track-obliterating storms to allow for quality track accumulation or tracking; and long periods characterized by no or very light snowfalls resulted in insufficient snow for track registration. Although tracking to establish presence would have been possible during some periods, our interest was in estimating or indexing track rate, which required us to know which tracks were recent and how long they had had to accumulate between track-obliterating snow events (Kauhala and Helle 2000).

During January–April 2009, we conducted four surveys along the Easton Hill EB and WB Transects, and five surveys along each of the Swamp-Toll Creek and Swamp-Bonnie-Price Creek Transects. Of our species-of-interest, we detected only bobcats and coyotes (Fig. 3.15) adjacent to or crossing the highway (Table 3.8, Figs. 3.16–3.18). We detected coyote and bobcat tracks, and confirmed coyote crossings, along all transects. Bobcats were detected less often than coyotes, and we confirmed only a single crossing by a bobcat—along the Toll-Swamp Creek Transect (Table 3.8, Figs. 3.16–3.18).

Figure 3.15. Coyote tracks leading up to the shoulder of I-90, with a semi-trailer truck in the background. (Photo: R. Long/WTI)

Table 3.8. Number of detections and rate of detections (number/survey/mile) within various encounter classifications along four snow track survey transects conducted during winter 2008–2009.

	Easton Hill WB (n=4 surveys)		Easton Hill EB (n=4 surveys)		Toll/Swamp (n=5 surveys)		Swamp/Bonnie/Price (n=5 surveys)		
Encounter Type	Coyote	Bobcat	Coyote	Bobcat	Coyote	Bobcat	Coyote	Bobcat	Total
Confirmed Crossing	8 (1.14)	0 (0)	3 (0.44)	0 (0)	7 (0.87)	1 (0.12)	5 (0.43)	0 (0)	24 (3.01)
Unconfirmed Crossing	0 (0)	0 (0)	0 (0)	0 (0)	3 (0.37)	0 (0)	3 (0.26)	2 (0.17)	8 (0.80)
Back	2 (0.28)	0 (0)	2 (0.29)	0 (0)	5 (0.62)	1 (0.12)	4 (0.34)	2 (0.17)	16 (1.85)
Enter	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (0.08)	0 (0)	1 (0.08)
Parallel	4 (0.57)	0 (0)	1 (0.14)	1 (0.14)	9 (1.12)	2 (0.25)	3 (0.26)	2 (0.17)	22 (2.67)
Unknown	0 (0)	0 (0)	0 (0)	0 (0)	1 (0.12)	0 (0)	0 (0)	0 (0)	2 (0.12)
Total	14 (8)	0 (0)	6 (3.52)	1 (0.58)	25 (15.62)	4 (2.5)	16 (6.95)	6 (2.60)	73 (8.56)

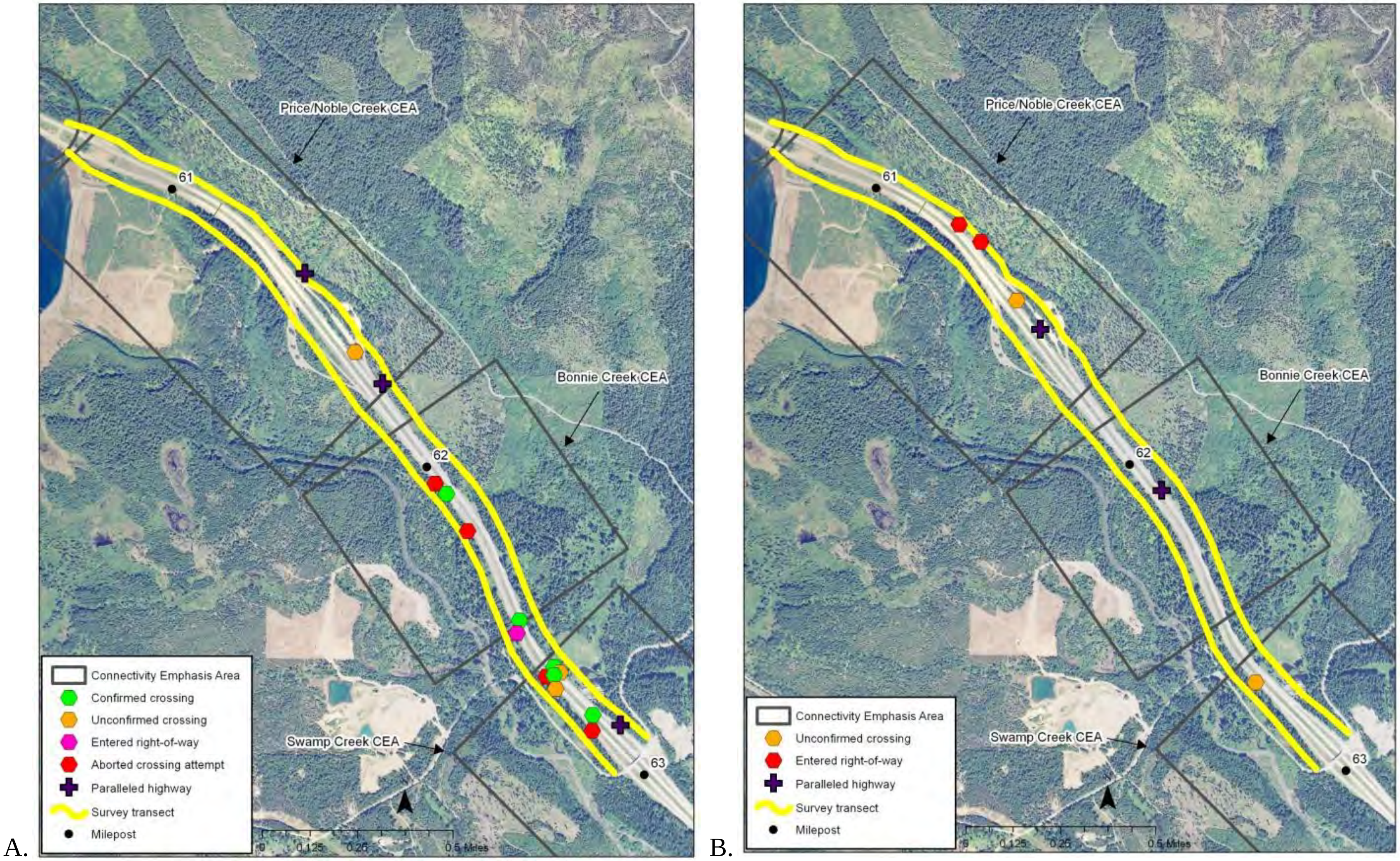
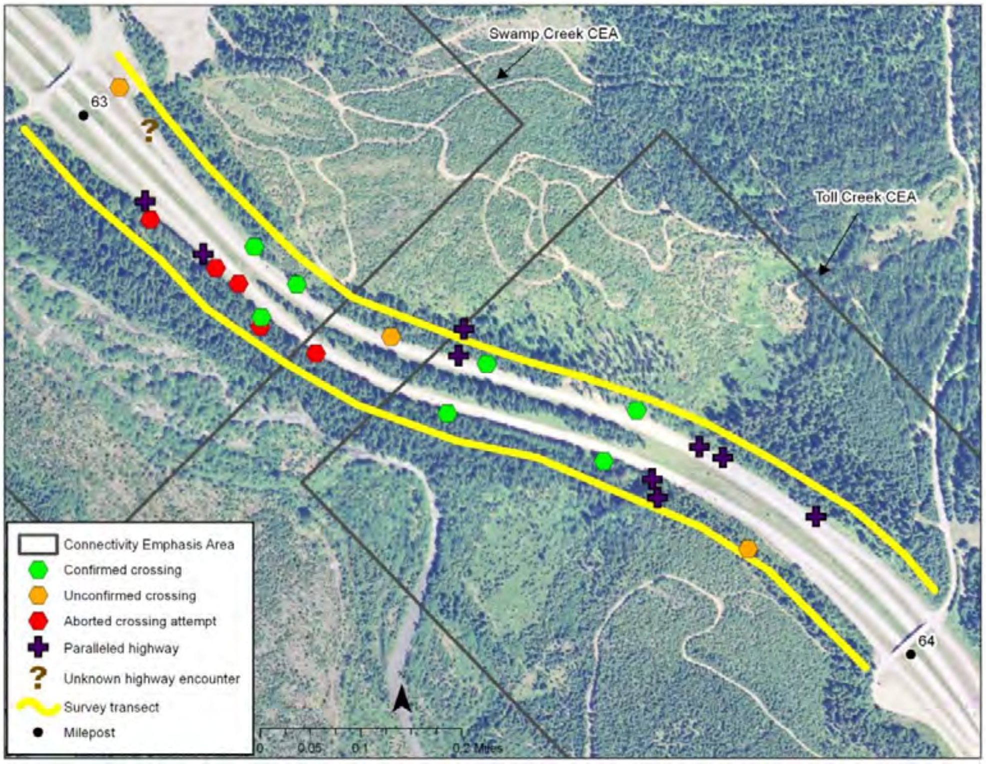
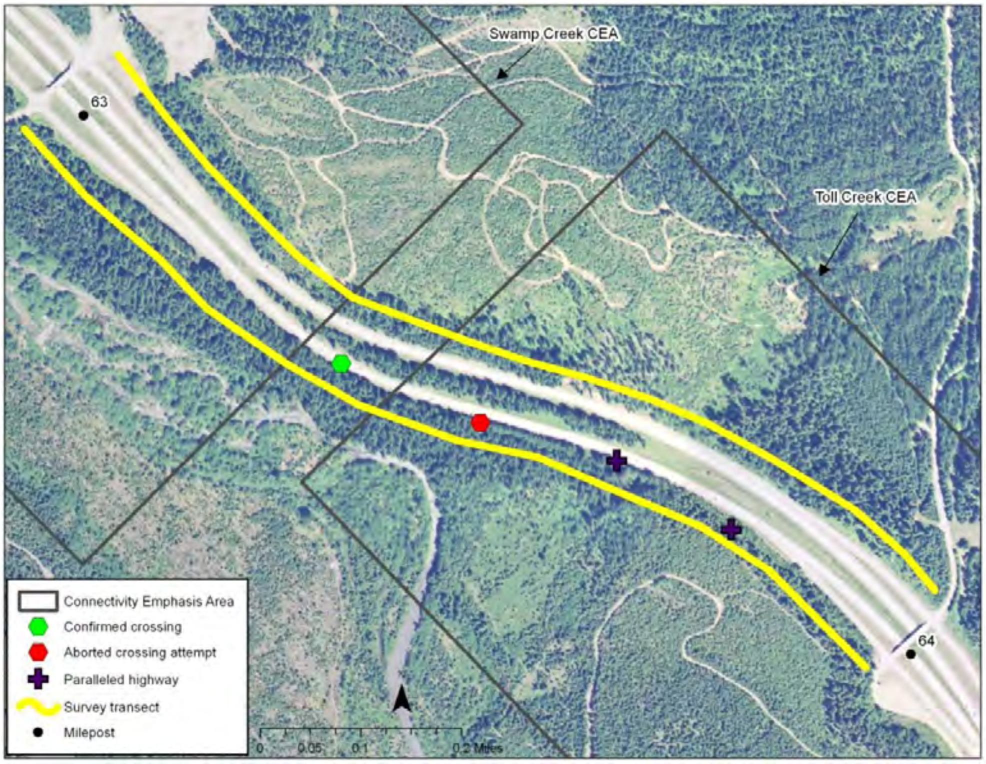


Figure 3.16. Winter 2008–2009 snow track detections, including encounter type, along the Swamp-Bonnie-Price Creek Transect for (A) coyotes and (B) bobcats.



A.



B.

Figure 3.17. Winter 2008–2009 snow track detections, including encounter type, along the Toll-Swamp Creek Transect for (A) coyotes and (B) bobcats.

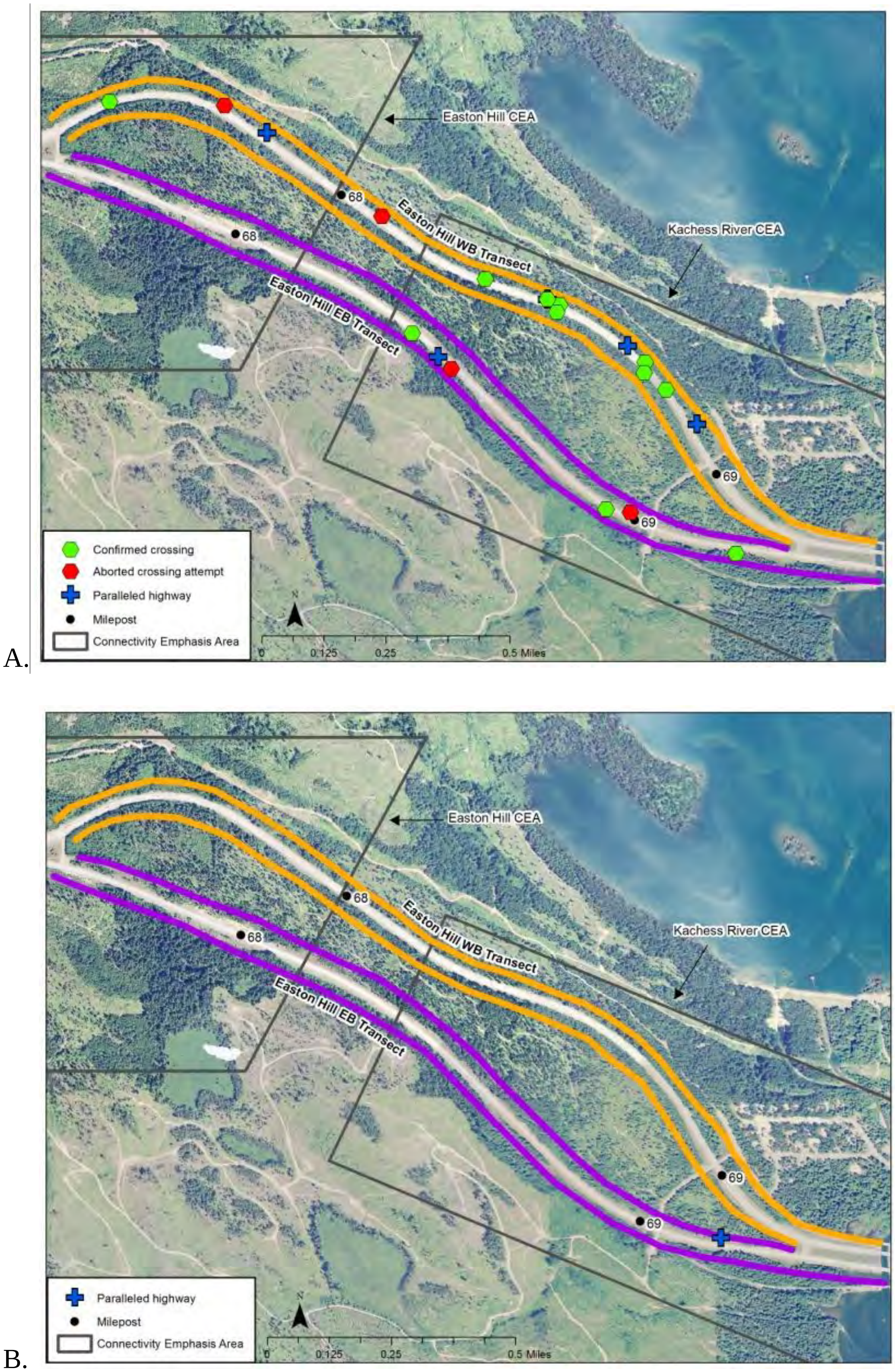


Figure 3.18. Winter 2008–2009 snow track detections, including encounter type, along the Easton Hill WB and EB Transects for (A) coyotes and (B) bobcats.

Use of Time-Lapse Cameras for Assessing At-Grade Crossings

To complement snow tracking as a means for assessing at-grade crossing rates, we explored the use of time-lapse remote cameras along select stretches of I-90. Time-lapse cameras capture images at predetermined time intervals, regardless of whether there is a moving object in the frame. The advantage of such cameras is that they can monitor very large areas (e.g., up to hundreds of meters, depending on the size of the target animals[s]) since they don't rely on a sensor mechanism to trigger the shutter. Although researchers must ultimately review photos to detect wildlife, this process can be automated to some extent using software "scan" functions that identify pixel-by-pixel changes between successive photos, effectively allowing the detection of movement across many frames. One substantial limitation of this method, however, especially for monitoring night-active species, is its inability to record photos during periods of darkness, as the cameras lack a flash.

In the spring and summer of 2012, we deployed two Plotwatcher Pro (Day 6 Outdoors) time-lapse cameras (at various locations along the highway shoulder and median in an attempt to evaluate whether they would be effective at monitoring select stretches of highway during daylight hours. We attempted to locate cameras in areas with overhead lighting to maximize the potential for capturing photos after dark. Although the cameras generally performed well (Fig. 3.19), the nearly constant movement of traffic within the photo frame made the use of scanning software problematic. Thus, we needed to review all photos manually, resulting in very large processing times. We decided that this limitation (which could potentially be addressed with future software advances or more sophisticated camera/software combinations)—combined with minimal nighttime application (which could also be addressed with new technology)—rendered this method inappropriate for our monitoring purposes at this time.

Figure 3.19. One frame of a multi-frame time-lapse sequence taken by a camera deployed in the highway median. (Photo: WTI)

Discussion

Camera Performance

Reconyx-brand remote cameras performed extremely well for us, especially given their year-round exposure to changing temperatures and dampness within the culverts. Many of the individual camera units were continuously operational for more than three years, and we sent cameras back to the factory for maintenance only 11 times. Indeed, due to the consistency with which cameras performed, the percent of operational nights (i.e., camera functional nights/total nights deployed) averaged a very high 93.6% (range 86%–100%). Although we did not rigorously test other camera brands, our experience is similar to comprehensive testing efforts (e.g., chasingame.com) that have suggested that the Reconyx cameras are unparalleled in terms of ruggedness and dependability.

Sub-Grade Crossing Rates and Species Composition

Comparisons of crossing rates and species compositions among regions and across studies should be undertaken with caution. Although there may be utility in comparing raw crossing rates for assessments of population connectivity or gene flow, it would be inappropriate to attempt a quantitative comparison of structure performance by simply comparing crossing rates. For instance, crossing rates may be linked to local densities of the species-of-interest (Clevenger 2011), which may or may not be similar between regions and are often unknown. Nonetheless, for the purposes of providing some context for the crossing frequencies we observed, here we provide a very brief comparison of our results to those of several other road monitoring projects.

Singleton and Lehmkuhl (2000) previously monitored 29 structures from Snoqualmie Pass to Cle Elum, including some of the same structures we monitored for this project. Overall, they detected fewer crossings of many of the same species documented by our monitoring efforts (i.e., deer, raccoons, weasels, river otters), but the structures they monitored included a much greater number of small- and medium-sized culverts (i.e., <44 in diameter) than did our effort, and they also employed film-based remote cameras—which were generally slower to respond and had lower image capacities than digital cameras. Both factors may help explain the disparity in crossing rates between our respective monitoring efforts.

As described above, we detected sub-grade highway crossings by a number of species, including several carnivore species and deer. The crossing rates that we observed in our Study Area, however were generally lower than those that have been observed in other regions with structures of roughly similar design, size, and intended purpose (i.e., to facilitate the flow of water), and without accompanying wildlife fencing. For example, over approximately five months, Huisjer et al. (2008) documented 100 deer crossings under four bridges along State Highway 75 in Idaho (i.e., approximately 20 crossings per month). In contrast, we recorded a total of 212 deer crossings beneath the four bridges in our Study Area over the entire approximately four-year monitoring period (i.e., 4–5 crossings per month).

We detected deer crossings only through the largest of the four structures we monitored—all bridges—and no elk crossings were observed at any structure, despite documented elk presence in the vicinity of the Gold Creek and Sparks Road Bridges (Chapter 4). The performance of structures for the passage of wildlife, especially elk and deer, has been strongly linked with the design characteristics and dimensions of the given structures (e.g., noise, height, span, length, openness [a metric calculated as {Span x Height}/Length; Reed and Ward 1985])(Clevenger and Waltho 2005, 2010; Gagnon et al. 2011). Ungulates have been shown to be reluctant to cross through underpasses with narrow spans and short heights (Reed et al. 1975; Yanes et al. 1995; Rosell et al. 1997), with suggested configurations for elk in the range of 23–33 ft wide and 11.5–13 ft high (A. Clevenger, unpublished data). In general, ungulates and large carnivores tend to favor structures that are high, wide, and short in length (Clevenger and Waltho 2005). Huisjer et al. (2008) detected no elk crossings under a bridge with openness ratios of 0.6–2.7 and a height of approximately 6.5 ft, despite the presence of elk near the bridge entrance. Further, studies in Utah documented few ungulate crossings through bridges and culverts not originally designed for wildlife—especially when fencing was not used (Cramer 2012).

Of the 12 structures we monitored, 8 were culverts ≤10 ft x 10 ft, and with low openness ratios of only 0.03–0.11. Four of these culverts (Cedar Creek, Unnamed Creek, Telephone Creek, and Hudson Creek) also featured 4–5 ft drops to the streambed where they opened on the south side of the highway, requiring crossing individuals to either jump down or laterally to the adjacent cutslope. The other four structures—all bridges—had spans, heights, and lengths ranging from 28–138 ft, 10–18 ft, and 40–52 ft, respectively, and openness ratios[7] of 2.9–22.6[8]. The size and openness ratios of all 12 structures we monitored were presumably suboptimal for elk, which never used these structures for crossing.

Relatively high human use of the Sparks Road structures (which averaged 16 human detections per month), in addition to consistent vehicle use, may have negatively influenced structure use by wildlife (e.g., Clevenger and Waltho 2000). Indeed, although aborted crossings were relatively rare in our dataset, 55% of those recorded (all deer) were at Sparks Road. Both Sparks Road bridges featured minimal shielding (Appendix 3.1), and therefore exposed any animals present to substantial auditory and visual stimuli—effects that may have been amplified given that semi-trailer trucks are common on I-90 at this location. Interestingly, Gagnon et al. (2007) estimated that semi-trailer trucks were four times more likely to cause flight behavior by elk, and although this finding was relevant primarily when traffic volumes were intermittent, it suggests that semi-trailer truck traffic may affect elk behavior.

Large carnivores are typically thought to avoid using underpasses that are relatively long and low (Hunt et al. 1987; Beier & Loe 1992; Foster & Humphrey 1995, Clevenger and Waltho 2010). Structure use by carnivores has also been related to road and landscape factors, such as distance to cover, and topography adjacent to structures (Yanes, Velasco & Suárez (1995) and Rodríguez, Crema & Delibes (1996), Clevenger et al. 2001, Clevenger and Waltho 2005, Gagnon et al. 2011). Regardless of cover and topography, we experienced very low overall crossing rates

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[7] As mentioned in the caption for Table 3.2, openness ratios are controversial, and have been inappropriately used as one-size-fits-all metrics to evaluate structure suitability (Clevenger and Huijser 2009). We include openness values in this section (calculated using meters) simply to provide some context for the structure's shape and dimensions.

[8] This openness ratio is a maximum, when Gold Creek is sufficiently low that larger animals can effectively walk down the middle of the creek, where the height is maximized, and when using rip-rap along the banks is unnecessary. Often, however, wildlife wishing to use this structure to cross would be confined to much lower, and narrower, rip-rap walkways on either side of the creek.

for carnivores. Despite the presence of black bears, bobcats, coyotes, and cougars throughout the Study Area, we detected crossings of only three black bears, 2 bobcats, and 2 coyotes during our extensive monitoring period.

Given the relatively low observed crossing rates, and the relative paucity of wildlife-vehicle collisions (WVCs) for carnivores (Chapter 2), it may be that I-90 had sufficiently high volumes to create an avoidance response in many species. Traffic volumes have been shown to affect use of areas adjacent to roads for many species (e.g., mule deer [Sawyer, Kauffman and Nielson 2009], elk [Rowland et al. 2000], wolves [Whittington et al. 2004], and grizzly bears [Wielgus et al. 2002; Apps et al. 2004, Northrup et al. 2012]), and even if densities of carnivores were substantial in the Snoqualmie Pass region, it may be that reluctance to approach the highway resulted in relatively few crossings and WVCs.

During our monitoring those non-ungulate species with the highest crossing rates—raccoons, mink, weasels, river otters, and beavers—were observed crossing through structures only 1–2.7 times per month. For these species that were observed somewhat regularly, all but the weasels crossed almost exclusively through the two Swamp Creek culverts. These culverts, and the Gold Creek bridges, were the only structures that included a significant water component adjacent to their mouth or entrance. In the case of the Swamp Creek culverts, a small pond and wetland system was present immediately adjacent to the north entrance, and fed directly into the dual culverts. The Gold Creek bridges, on the other hand, spanned a large, deep creek, and the cameras used to monitor this structure were primarily focused on the banks of the creek. Although five beaver crossings were detected there, the lack of other aquatic species such as mink and river otters may have largely been a consequence of small body size and/or full immersion in the creek while crossing, either of which would have generally precluded detection by the cameras there.

To help put the crossing rates that we observed into perspective, crossing rates reported from a mitigated highway stretch in Arizona equipped with both crossing structures (i.e., underpasses and overpasses) and associated wildlife fencing, and designed specifically for use by wildlife, reported maximum monthly crossing rates of 44 elk crossings, 11 deer crossings, 1.8 raccoon crossings, and 0.5 coyote crossings (Gagnon et al. 2011). This can be compared with maximum monthly crossing rates observed in our study of 0 elk crossings, 1.6 deer crossings, 2.3 raccoon crossings, and 0.2 coyote crossings. As part of the largest and most successful program to implement highway mitigation strategies in North America, Clevenger et al. (2009) documented average monthly crossing rates by deer and elk of 11.0 and 37.2 crossings (max=53.7–131.5 crossings), respectively, at 23 structures (a mix of both under- and overpasses) in Banff National Park from 1996–2009. Further, monthly crossing rates for coyotes and black bears were 2.1 (max=5.3) and 0.35 (max=1.53) respectively. These rates are all substantially higher than rates we recorded for similar species.

Undetected Sub-Grade Crossings

Despite our use of high-quality remote cameras, logistical constraints related to camera location and setup presumably resulted in some undetected crossings at all structures. This was most likely to be true for smaller species (e.g., weasels) and at larger structures (e.g., Gold Creek and Sparks Road bridges), where cameras were necessarily deployed to maximize the width of the detection area. In such cases, when the camera is facing a large, unbounded area, crossing animals may be able to slip through “blind spots” in the sensor area, either along the edges of the structure or below the sensor. Further, irregular surfaces within structures, such as the large rip-rap at Gold Creek, can create spaces that effectively permit smaller species to pass undetected.

Our two-camera test at Swamp Creek East Culvert yielded detection omission rates of 0–0.33. Omission rates for the primary camera, which was deployed in what was assumed to be an optimal location, ranged from zero for river otters, to 0.33 for beavers. This culvert, which had a span of eight feet, was wide enough to have some sensor blind spots. We suspect that similar omissions occurred at our Price Creek culvert, which spanned 10 feet, and at all four bridges, which had even larger spans and, in the case of Gold Creek, rip-rap surfaces. Alternately, we presume that crossings by mammals of all sizes were consistently recorded at the smaller, four-foot culverts because the cameras were deployed low on the wall and had a narrower maximum detection area.

At-Grade Crossings

Our detection of only coyotes and bobcats during snow tracking surveys was not surprising. We did not expect to detect ungulates, as deer and elk would generally be found at lower elevations during winter, and bears were in hibernation. Although martens were present within the larger Project Area (see Chapter 4), their status in most locations immediately adjacent to the highway was questionable (see Chapter 4). And while cougars were also known to occur within the Project Area (e.g., White et al. 2011; Chapter 4), their densities were inherently low enough to have made detection by relatively few snow tracking surveys unlikely. Wolverines, Canada lynx, and mountain goats, although potentially detectable within the Project Area, generally had distributions further to the north.

Singleton and Lehmkuhl (2000) conducted snow tracking during two winters within the same Study Area as our monitoring, collecting data from a much larger number of surveys than our single-season effort. Of wildlife species detected within the same Study Area as ours, 69% were of coyotes, 24% were of bobcats, and 6% were of ungulates (10 elk, 1 deer), as compared with 85% coyote and 15% bobcat detections in our case. Elk were present during early-spring in the easternmost portion of the Project Area, which may explain the elk detections by Singleton and Lehmkuhl (2000), who surveyed as late as March 20 and whose elk detections all occurred along their easternmost transects. Although our single season of snow tracking did not detect elk or deer, this may have been a function of our small sample size.

Monitoring at-grade crossings of wildlife continues to be problematic. Snow tracking can provide information about winter-active species, but only during one season and in locations where snow conditions permit. As we experienced, these limitations often make this method prohibitive. Track beds installed along the highway shoulder, or in the median, were deemed infeasible given the steep topography and minimal medians along most stretches of I-90 through the Project Area, and combined with relatively short snow-free seasons. We evaluated time-lapse cameras for monitoring at-grade crossings, but concluded that the inability to monitor at night, combined with the time-intensive nature of manually reviewing photos, also precluded the use of this method for large-scale, at-grade monitoring. This method, however, may be useful for monitoring specific highway stretches where daylight monitoring is sufficient and where vehicle detections could be minimized (i.e., where the direction of the camera is oriented parallel with the highway shoulder or median). Lastly, radio- and GPS-collar approaches were considered, but for our purposes, the constraints outweighed the advantages of applying this method, except in the case of flying squirrels (see Chapter 5).

Recommendations for Future Monitoring

This chapter documents the results of over four years of monitoring in the I-90 SPE Project Area. Our primary objective was to collect baseline data prior to the installation of wildlife crossing structures and wildlife fencing such that the performance of these mitigation measures can ultimately be evaluated. Our data and results will be suitable for comparison with post-mitigation data and rates, assuming methods and efforts to collect post-mitigation data are similar to those described herein. The following recommendations should help to guide future monitoring efforts such that the performance of mitigation efforts can be most effectively evaluated:

- We suggest that the monitoring of newly installed crossing structures begin as soon as possible following their completion. Restricting human access to the structures wherever possible would be preferable, to minimize both the potential for remote camera theft and disturbance to wildlife that might attempt to cross.

- We also strongly suggest that remote camera monitoring be initiated whenever possible, prior to the installation of wildlife fencing. This isn’t to say that the installation of fencing should be postponed to enable pre-fence monitoring, but rather that monitoring should begin even if a gap between structure completion and fence installation is necessary. Valuable data concerning the performance of structures with and without fencing are difficult to collect, and the opportunity to monitor newly installed structures both pre- and post-fencing presents a unique opportunity.

- We suggest that remote camera monitoring at crossing structures continue for at least 5–10 years after project completion, as other studies strongly suggest that rates of passage increase continually over time as animals habituate and adapt to structures (Clevenger et al. 2009, Gagnon et al. 2011).

- When possible, we suggest that multiple remote cameras be deployed at each structure to enable the estimation of omission rates and to maximize detections of crossings.

- Despite its limitations and our minimal success with snow tracking, we suggest that snow track surveys be conducted when feasible following crossing structure construction—both before and after the installation of wildlife fencing. Although relevant data can only be collected for winter-active species, snow tracking currently remains the only cost-effective method suitable for detecting at-grade crossing behavior for multiple species over large areas. Such data will be important for evaluating structure performance.

Chapter 4 – Species Occurrence and Genetic Sampling

Introduction

This chapter describes species occurrence and genetic data collected along I-90 and throughout the greater I-90 Snoqualmie Pass East (SPE) Project Area. We report detections from surveys conducted by WTI as part of its Tier 1 monitoring (see Chapter 1) of the I-90 corridor (e.g., snow tracking, small mammal sampling), and also from surveys conducted as part of a larger, cooperative effort to collect genetic information about American black bears and American martens in the North Cascades Ecosystem.

Baseline species occurrence and detection data are important to collect prior to the installation of crossing structures and wildlife fencing. If such pre-construction data are available, post-construction use of wildlife crossing structures can be evaluated within the context of the species expected to use them. For instance, if no bobcats were detected within a given region prior to crossing structure construction, there would be little expectation that crossing structures installed within that region should receive use by bobcats. Reciprocally, pre-construction occurrence data provides information about where species of interest may *not* have occurred prior to construction. These same locations could thus be surveyed post-construction to evaluate colonization of new areas—possibly as a result of the mitigation efforts. Such post-construction surveys may need to be conducted many years after structures have been installed, to allow suitable time for species dispersal and recolonization.

To collect species detection data, we used a suite of noninvasive survey methods (Long et al. 2008) that did not require the capture, handling, or sedation of study animals (MacKay et al. 2008). In addition to minimizing risk to wildlife and researchers alike, such methods—including remote cameras, hair-snagging, scat collection, and track surveys—permit efficient surveys across large areas, and are effective for even low-density, secretive species such as carnivores. In addition, hair-snagging methods (Kendall and McKelvey 2008) provide an effective means for colleting genetic samples, which can then be combined with cutting-edge landscape genetic approaches (Holderegger and Wagner 2008) to evaluate possible landscape barriers to animal movement and the effects of such barriers on the genetic structure of wildlife populations.

In 2008, WTI launched the highly collaborative Cascades Carnivore Connectivity Project (www.cascadesconnetivity.org) to explore barriers to the movement of carnivores using noninvasive genetic methods. Black bears and martens were selected as study-wide focal species, as these two species have very different movement capabilities and habitat requirements. Our goal was to obtain DNA from a spatially well-distributed sample of individuals across the North Cascades Ecosystem (i.e., from I-90 north to the Canadian border), and we exploited the synergy between noninvasive sampling and landscape genetics with the intent of investigating barrier effects at a very large scale. We include DNA sampling results from black bears and martens in this report, as well as some preliminary landscape genetic analyses for the subset of locations within the greater I-90 SPE Project Area.

Finally, we report on two additional survey projects. The first was a live-trapping effort for small mammals (i.e., chipmunks, rodents and shrews) designed to collect occurrence information and genetic samples from within select Project Area Connectivity Emphasis Areas (CEAs). The second was a track survey of the eastern shoreline of Lake Keechelus, conducted as part of an assessment of whether wildlife fencing would be essential to eventual crossing structure performance in this portion of the Project Area.

In summary, the objectives of the above-described survey efforts were to:

1. gather baseline DNA information for black bears and martens within the greater I-90 SPE Project Area;

2. map occurrences of large, high-mobility mammals across the Project Area;

3. collect genetic information, as well as data pertaining to baseline occurrence and relative abundance, for small mammals at select locations within the Project Area; and

4. assess wildlife access to I-90 and the need for fencing along the eastern shore of Lake Keechelus.

Study Area

The Study Area is described in detail in Chapter 1. We conducted occurrence surveys along the 15-mile extent of the I-90 SPE Project Area, from MP 55.1 (Hyak) to MP 70.3 (Easton)(see Fig. 4.4 below). We surveyed at varying distances from the actual highway corridor, depending on the species group of interest. Survey grids for small mammals, for example, were located ¼–½ mi from the highway, whereas black bears were surveyed both close to and many miles away from the highway corridor.

Methods

Carnivore Genetic Analysis

During 2008–2012, we collected genetic material (i.e., DNA) and occurrence data from black bears and martens using a suite of noninvasive hair and scat collection methods. These methods are described in detail in Long et al. (2008).

A general rule of thumb suggests that DNA be collected from a minimum of 20–30 individuals from each side of a putative barrier to test for barrier effects (D. Paetkau [Wildlife Genetics International] and S. Kalinowski [Montana State University], personal communications). To maximize sampling efficiency, we mapped a tessellation of hexagonal sample units across the greater I-90 SPE Project Area. Each hexagon comprised 2500 ha, an area slightly smaller than the average home range of a female black bear in this region (Lyons et al. 2003). By focusing a discrete and predefined amount of survey effort on each sample unit and then shifting efforts to a new unit, we were able to efficiently collect DNA samples from as many individuals as possible while minimizing redundant sampling and associated field and laboratory costs.

For bears, we deployed two barbed wire corral-type hair snares (Kendall and McKelvey 2008) within each sample unit. Corrals comprised a single strand of barbed wire stretched around four or more trees at a height of 45–50 cm, with one liter of liquid scent lure (i.e., cattle blood and fish oil) poured onto a pile of woody debris in the center of the corral (Fig. 4.1). Corrals were revisited at 14 days and (1) removed if a sufficient sample was present or (2) rebaited and left for another 14 days if no sample was present. We attempted to locate corrals approximately 2.5–3.0 km apart within a given sample unit.

We collected hair samples from martens with gun cleaning brushes attached to a tree-mounted enclosure that was baited with chicken and scent lure (Fig. 4.2). We placed marten devices selectively—usually in groups of two or three spaced at approximately 100 m intervals—in presumed marten habitat (i.e., mature forest). After conducting unsuccessful marten surveys during the summer of 2008, we shifted to sampling in winter—when this species appeared to be more generally attracted to survey stations (R. Long, unpublished data).

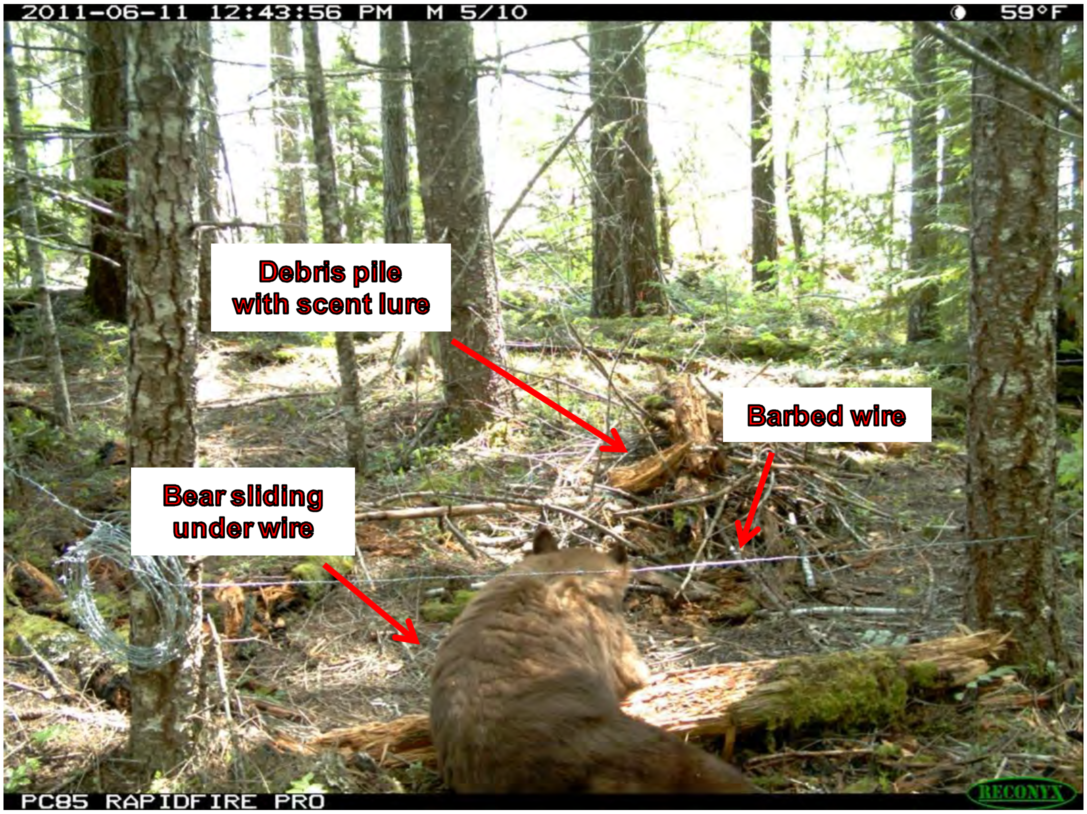

Figure 4.1. Corral-type hair snagging station for bears showing barbed wire and debris pile, with black bear sliding under the wire. (Photo: WTI)

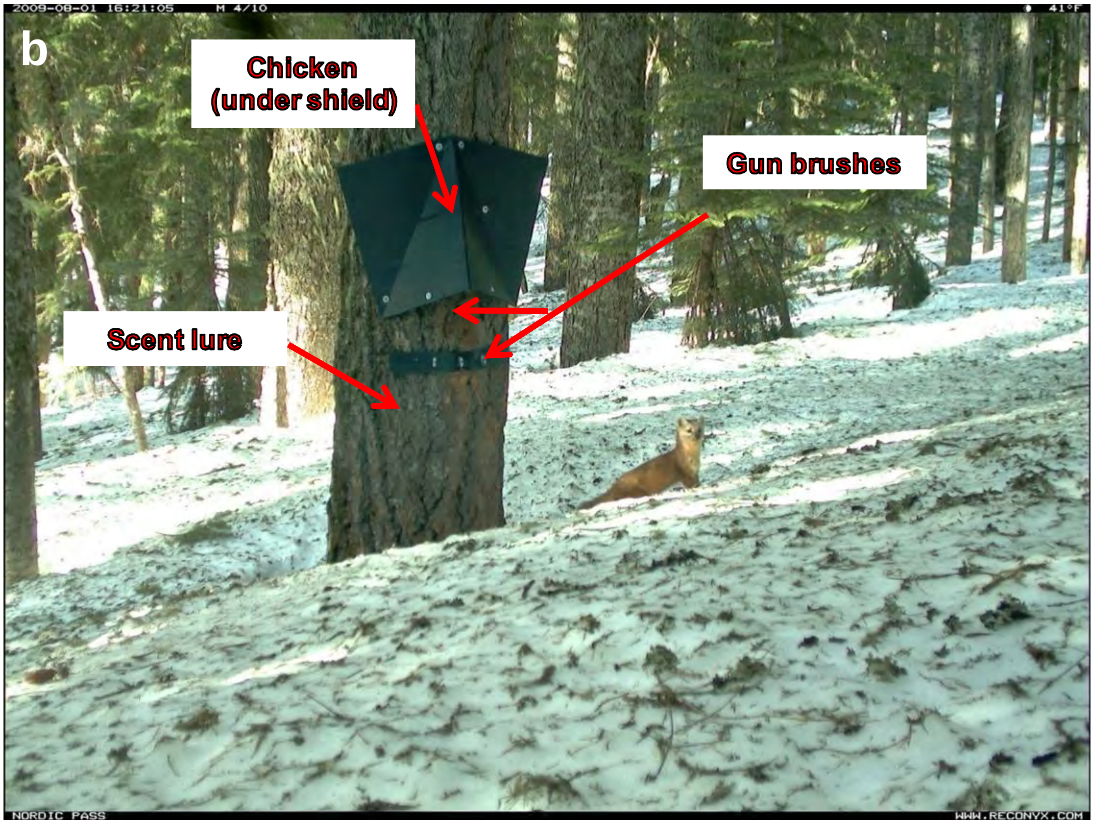

Figure 4.2. Cubby-type hair snagging station for martens showing scent lure and chicken bait locations and gun brushes, with marten at base of tree. (Photo: WTI)

Hairs collected on a given barb or gun cleaning brush were assigned unique sample numbers, placed in paper envelopes, and stored with desiccant. A subsample of hair samples from each site, selected based on the presence of follicles and the number of actual hairs, was sent to Wildlife Genetics International (Nelson, BC) for analysis. Subsampling helped to increase the likelihood that sufficient DNA was obtained from as many samples as possible (Kendall and McKelvey 2008).

During summer/fall 2008, we employed two scat detection dog survey teams (Working Dogs for Conservation, Three Forks, MT) to conduct 15 pilot surveys in the greater I-90 SPE Project Area. Each survey was carried out by a professional handler, an orienteer, and a dog, with the latter trained to detect scats from target species—as well as from other rare carnivores (e.g., wolves, grizzly bears, wolverines, cougars, and fishers)—and to alert the dog handler to the specific location of each scat (Fig. 4.3). DNA from scat samples was extracted and analyzed by Wildlife Genetics International using standard methods.

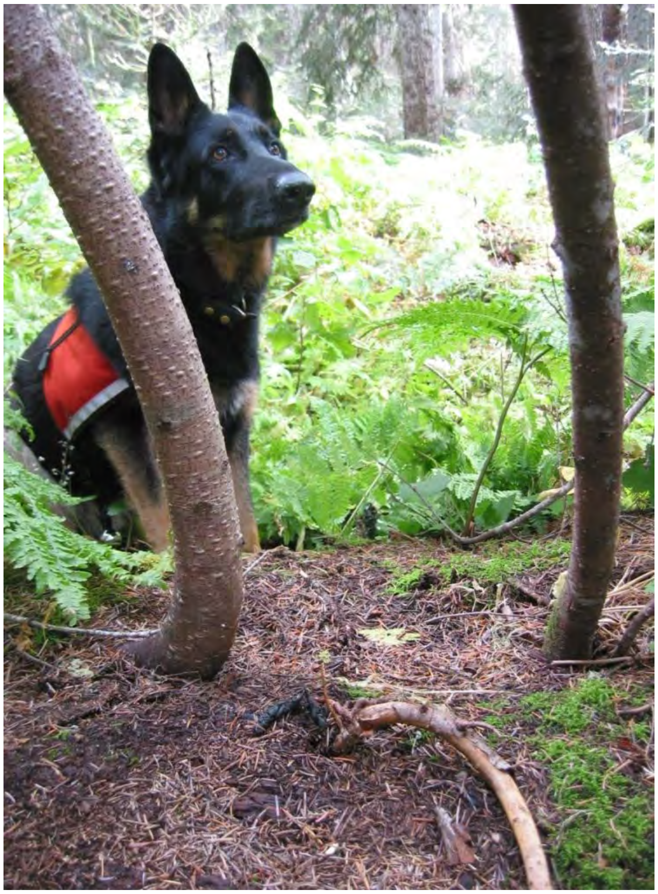

Figure. 4.3. A scat detection dog alerts her handler to a marten scat (foreground). (Photo: P. MacKay/WTI)

We deployed digital remote cameras (Reconyx, Inc.; see full description and photos in Chapter 3) at a subset of survey stations to: (1) collect additional species detection data; (2) gather information about animal behavior and interactions with hair sampling devices, and; (3) attain photos for outreach and educational purposes. We also opportunistically deployed remote cameras, both with and without scent lure, throughout the five-year study.

DNA Genotyping and Sex Determination

DNA was extracted from black bear hair and scat samples and amplified by Wildlife Genetics International using standard procedures. Six microsatellite loci were analyzed from each successfully extracted and amplified sample to determine individual identity. Further, as many as 14 additional loci were analyzed from each individual to enable the assessment of gene flow and barrier effects. Mixed samples (i.e., samples with hair from >1 bear) were reliably identified by evidence of ≥3 alleles at ≥1 locus (Roon et al. 2005a). Sex was determined by the amelogenin marker, which varies in length by sex (Ennis and Gallagher 1994). A similar approach was taken for marten genotyping, but with a single run of 12 loci (versus 6 for bears) analyzed for each sample. Sex determination for martens was accomplished by analyzing an intron in the ZFX and ZFY genes, whose length is sex-specific (D. Paetkau, Wildlife Genetics International, personal communication).

Landscape Genetic Analysis

We used a Bayesian model-based clustering method (STRUCTURE 2.2; Pritchard et al. 2000) to infer numbers of populations and assign individuals to populations based only on multi-locus genotype data and without knowledge of sample origin. We also used a method that employs both genotype data and sample location to assess population membership (Geneland 3.1; Guillot et al. 2005). We will apply other methods for detecting barrier effects in future analyses, especially in places where there may be gradients of connectivity as opposed to a complete barrier. Such methods will include evaluating the correlation between measures of genetic distance (Legendre and Legendre 1998) and landscape distance—a process called causal modeling (Cushman et al. 2006)—to test whether subtle genetic structuring is primarily a result of isolation due to barrier effects of the highway versus distance, elevation, or habitat.

Species Occurrence

Species occurrence data were collected from 2008–2012. We mapped species occurrences by combining detection results from:

- genetic surveys;
- remote camera surveys and monitoring;
- snow tracking (Chapter 3);
- incidental tracks deposited at survey devices;
- track surveys conducted at Keechelus Lake (see below).

Note that we did not include data from wildlife-vehicle collision monitoring nor live animal monitoring (Chapter 2) in our occurrence maps, as it was generally not possible to confirm species identities or locations for those data.

Small Mammal Surveys

We conducted small mammal surveys from September 15 –October 17, 2008. We deployed Sherman live traps (3 x 3.75 x 9”) using a 5 x 5 trapping grid configuration (i.e., 25 trapping stations) with 20-m spacing. We paired grids on both sides of I-90 in the following CEAs: Gold Creek, Price-Noble Creek, Swamp Creek, Toll Creek, Hudson Creek, and Easton Hill/Kachess River (Fig. 4.4). We baited traps with a mixture of peanut butter, oats, and molasses, and placed polyester filling in each trap to provide warmth to animals and to help reduce the risk of hypothermia.

We began trapping at the Gold and Price-Noble Creek CEAs, and then moved eastward to subsequent grids until finishing at the Easton Hill/Kachess River CEA. Initially, we monitored four grids (two CEAs) per week, but we reduced this to two grids (one CEA) per week after the first week due to time constraints. We opened traps on Monday of each week and checked them daily through Friday, resulting in a total of four trap nights per grid. We closed all traps on weekends.

We identified each trapped animal to species, and recorded sex and weight. We also temporarily marked each individual using a thick, black felt-tipped pen to allow the identification of recaptured animals. Northwestern (Keen's) deermice were differentiated from common (North American) deermice by tail length; the tail of a Northwestern deermouse is generally >103 mm in length, whereas that of a deermouse is usually <103 mm (key provided by John Lehmkuhl, USDA Forest Service). To be conservative, we identified any individuals with tails <103 mm in length as deermice, and others as Northwestern deermice. We collected DNA from each individual by rubbing a swab inside the cheek to obtain epithelial cells, and then stored swabs in paper envelopes containing desiccant for future DNA analysis.

Keechelus Lake Survey

We surveyed for wildlife tracks along the south side of the eastbound lanes of I-90 between mileposts 55.1–56.6, 59.2 –60.0, and 60.4–60.8 during three visits (10/5/09, 10/15/09, 10/28/09), with the objective of detecting any tracks that approached the roadway from the lakeside. We also surveyed portions of the lakebed and along the western lakeshore. These areas are available to terrestrial wildlife traveling from the west during periods of lake drawdown, and could potentially provide highway access. We recorded and followed all tracks until we could ascertain whether or not the animal encountered the highway. After each assessment, we returned to our previous survey route and continued to survey until we reached our predetermined route destination.

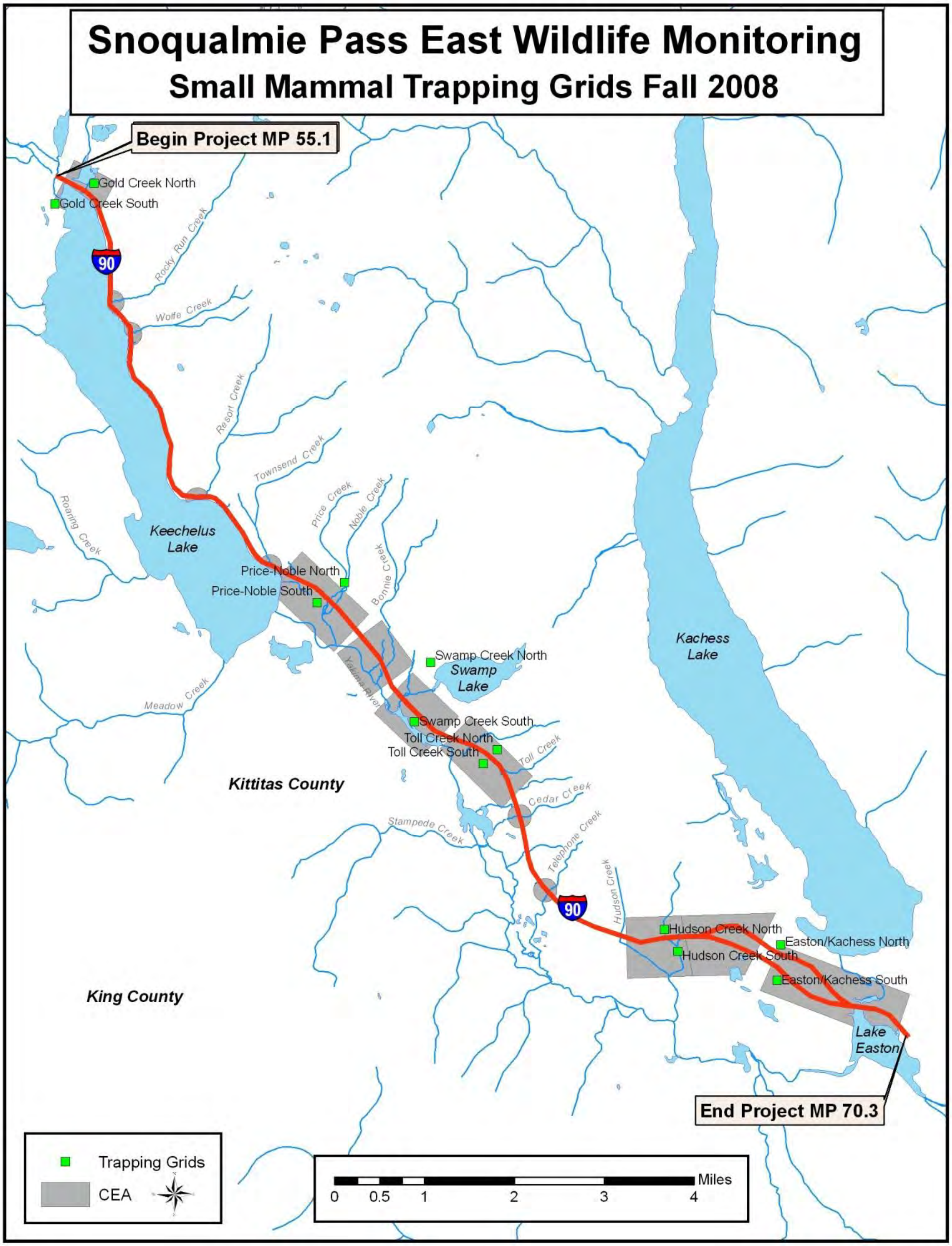

Figure 4.4. Locations of small mammal trapping grids.

Results and Discussion

Carnivore Genetic Sampling and Landscape Genetic Analysis

With DNA methods, we identified 77 individual black bears within the greater I-90 SPE Project Area (Appendix 4.1), including 38 females, 38 males, and one individual of undetermined sex. Both sides of the highway were almost equally represented in our dataset, with 36 and 41 individuals identified on the north and south sides, respectively. We were able to successfully identify at least 17 of 20 loci for 74 of the 77 individuals (Appendix 4.2), and this subset was used for landscape genetic assessments.

We identified 18 individual martens within the greater I-90 SPE Project Area (Appendix 4.3), including 4 females and 14 males. Only one individual—a male—was identified south of I-90. We were able to successfully identify at least 10 of 12 loci for all individuals (Appendix 4.4), so all individuals were used for landscape genetic assessments.

Detection dogs were successful at locating black bear scats in the steep, difficult terrain characteristic of the North Cascades. We collected 37 black bear scats, with 6 of these contributing to the pool of 77 black bear individuals mentioned above. Relatively poor success in genetic testing led us to conclude that black bear scats were an inadequate source of DNA for conducting landscape genetic analyses, thus this method was discontinued in subsequent years.

Detection dogs contributed to the collection of only three marten scats. This small number of samples may have reflected the dogs’ lack of experience with martens, the challenges associated with detecting small scats in a steep and thickly vegetated landscape, limited marten presence, or a combination of these factors.

Our preliminary landscape genetic analyses for black bears did not indicate that I-90 was a strong movement barrier for this species. The ability to detect movement barriers among populations, assuming such barriers exist, depends greatly on the extent of the barrier. As mentioned in the “Methods” section above, we intend to conduct further analyses to explore additional, highway-related connectivity issues for black bears (e.g., partial barriers, localized constraints to movement, intact linkages).

Landscape genetic analyses for martens were not complete at the time of this report, however, because we were able to only collect a single marten DNA sample from south of I-90, evaluating any barrier effects of the highway will not be possible. Future analyses will, instead, focus on other landscape features that might cause genetic clustering for this species.

Species Occurrence

Using the suite of methods described above, we detected 18 individual species and 7 additional species groups (i.e., bats, birds, deer, small mammals, squirrels, weasels, waterfowl) in the greater I-90 SPE Project Area (Table 4.1). Most were detected via DNA testing or remote camera surveys (Fig. 4.5), but incidental tracks at survey stations (Fig. 4.6), snow tracks along I-90 (See Chapter 3), and tracks recorded during Lake Keechelus surveys were also informative.

Table 4.1. Species (or species groups) detected by remote cameras, DNA extracted from hair or scat, and tracks within the greater I-90 SPE Project Area.

Species
American black bear
American marten
American mink
Bat (includes multiple species)
Beaver
Bird (includes all species smaller than waterfowl)
Bushy-tailed woodrat
Cougar
Bobcat
Canada goose
Coyote
Deer (includes both mule and black-tailed)
Domestic dog
Domestic cat
Elk
Gray wolf[9]
Mountain beaver
Northern flying squirrel
Northern raccoon
Northern river otter
Small mammal (includes mice, voles, shrews and chipmunks)
Snowshoe hare
Squirrel (includes multiple species)
Waterfowl (includes multiple species)
Weasel (includes both long- and short-tailed)

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[9] This detection was recorded by remote cameras in the Swauk-Teanaway region as part of a targeted effort to detect a new pack of gray wolves. Our photos helped to confirm the pack's presence.

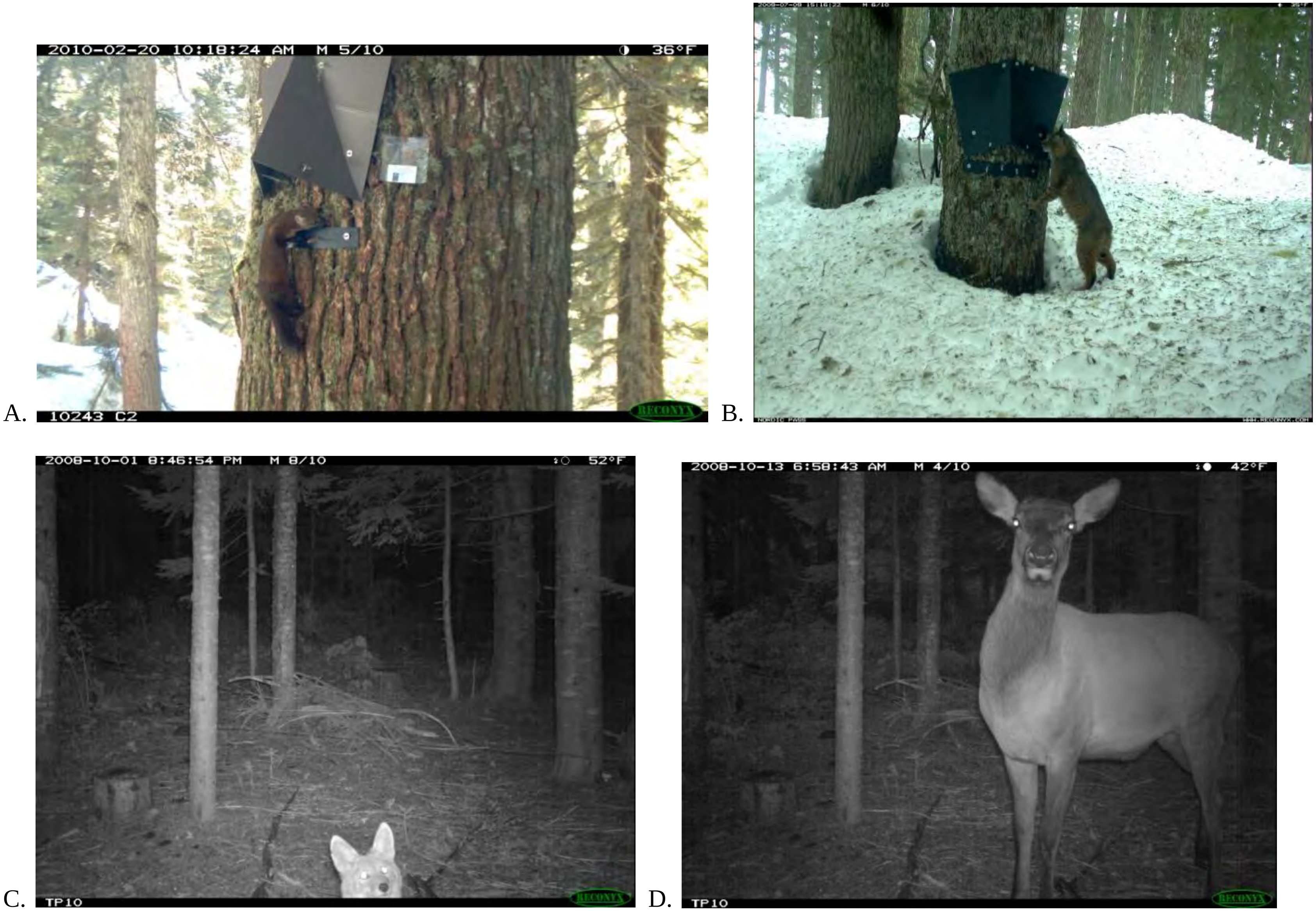


Figure 4.5. Photos of (A) marten, (B) bobcat, (C) coyote, and (D) elk captured at remote camera/hair-snagging stations. (Photos: WTI)

Figure 4.6. Marten tracks photographed just south of I-90 near Snoqualmie Pass. (Photo: R. Long/WTI)

Defining species distributions based on detection-nondetection data requires surveying: (1) a large enough area to be relevant (i.e., the extent); (2) evenly enough to ensure few unsampled regions (i.e., evenness), and; (3) a substantial enough number of sufficiently small areas within the extent to maintain resolution (i.e., the grain) (Long and Zielinski 2008). Most importantly, an adequate amount of survey effort must be expended at each location to ensure, with some *a priori* level of confidence, that false-negative errors are minimized. Our surveys were not designed to meet these criteria, and therefore should not be considered the basis for a distribution map.

Because we used specific protocols and minimum deployment times for surveys of black bears and martens, we report locations where these species were not detected in addition to detection locations (Figs. 4.7, 4.8). Although the former locations should not be strictly interpreted as “absences”— the species may have been present but undetected—they do represent “nondetections.” In contrast, the detections presented for coyotes, bobcats, cougars, deer, and elk (Figs. 4.9–4.13should be interpreted as “presence-only” data, as we did not specifically target these species with our survey methods and protocols.

Although black bears and martens were detected on both sides of I-90, fewer detections (per unit of effort) occurred south of the highway than north (R. Long, unpublished data). This was especially true for martens, which were rarely detected south of the highway despite substantial survey effort (Fig. 4.8). We speculate that this trend may have been due to the logging-induced fragmentation of forest stands in this area, as martens elsewhere have been shown to prefer contiguous, mature forest stands with large diameter trees (Slauson et al. 2007). Future analyses of these data may further help to explain the apparent dearth of marten and bear detections south of I-90.

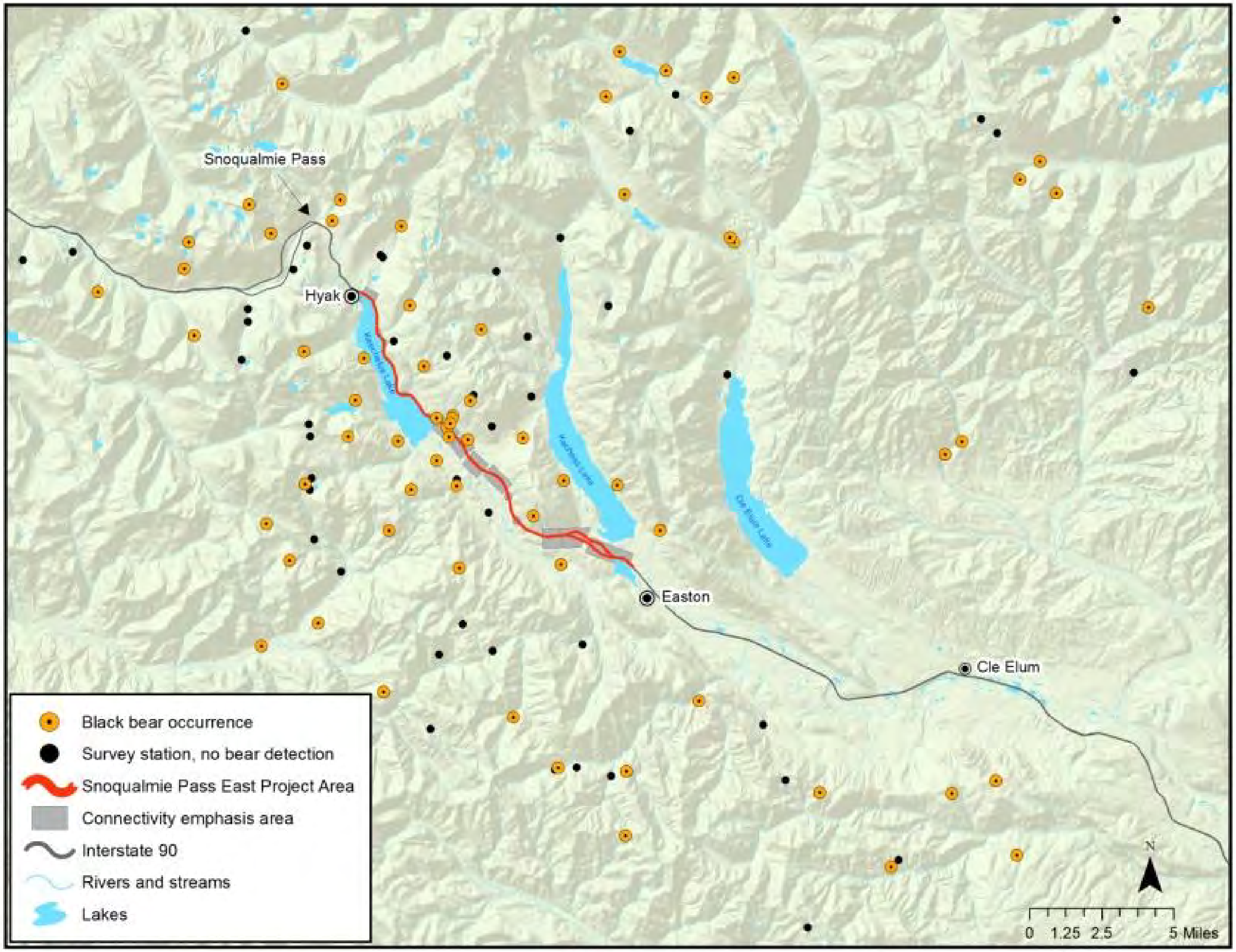


Figure 4.7. Locations where black bears were detected via the genetic analysis of hair or scat samples, or remote camera photographs. Hair-snagging survey locations yielding nondetections are also shown.

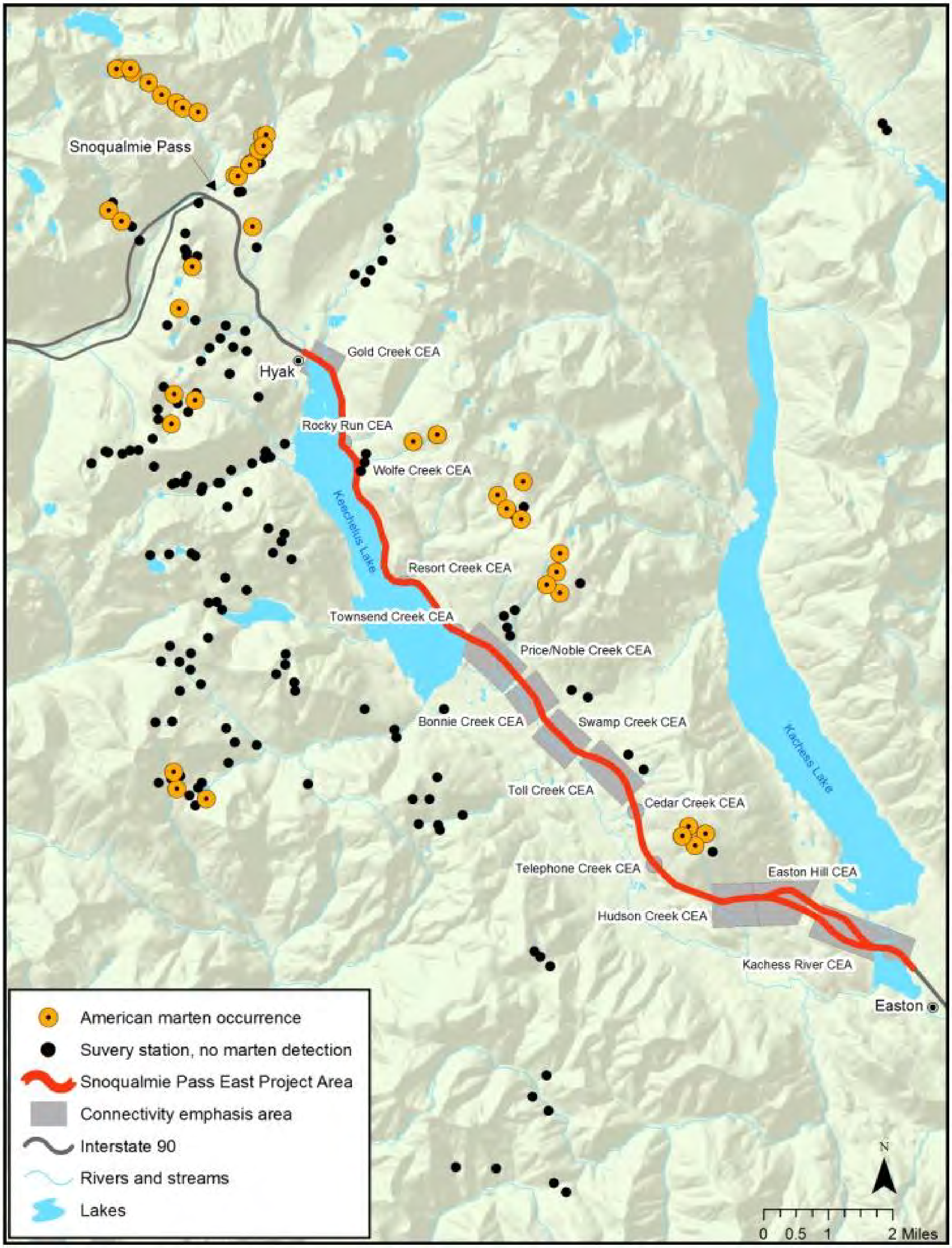


Figure 4.8. Locations where martens were detected via the genetic analysis of hair samples, remote camera photographs, or snow tracks at hair-snagging stations. Hair-snagging survey locations yielding nondetections are also shown.

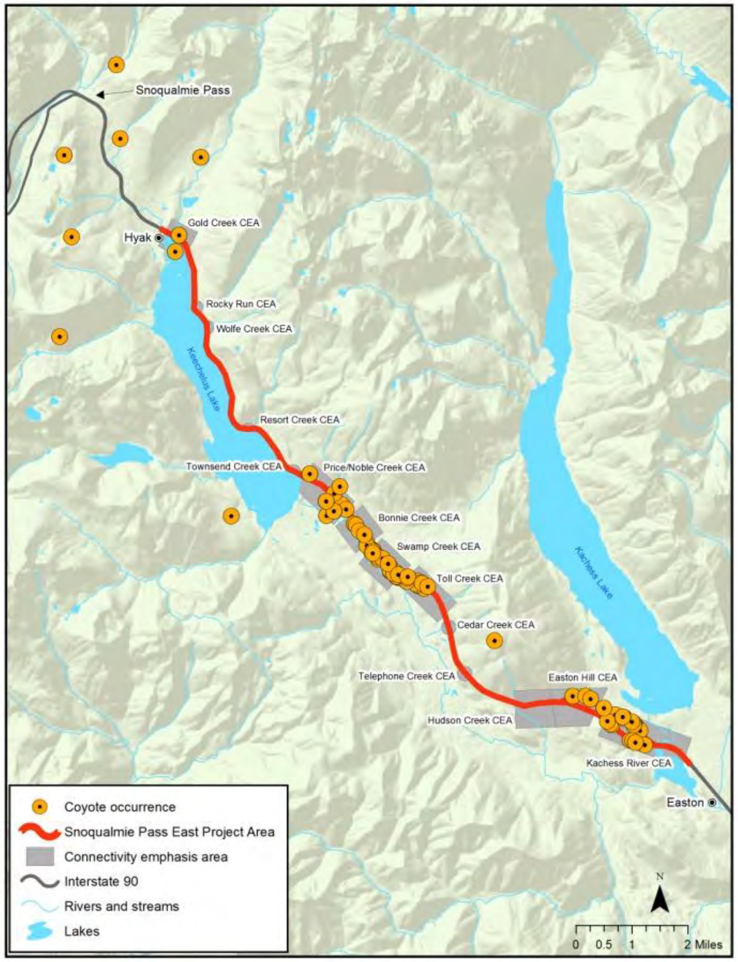


Figure 4.9. Locations where coyotes were detected via the genetic analysis of hair or scat samples, remote camera photographs, snow tracks encountered during highway snow tracking, or mud tracks encountered during track surveys of Lake Keechelus.

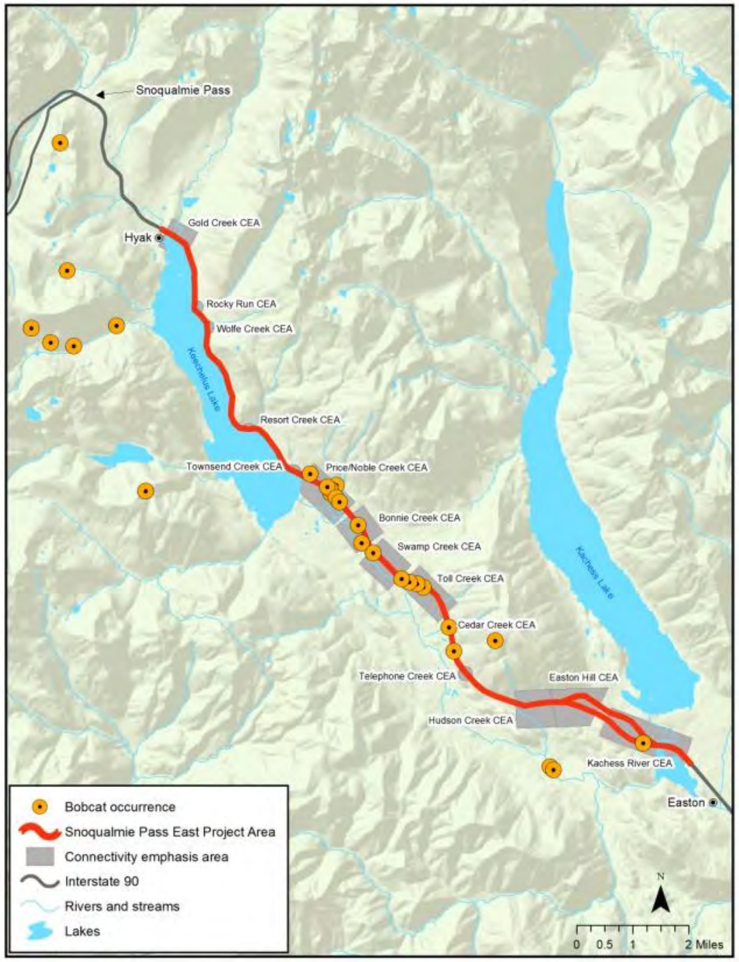


Figure 4.10. Locations where bobcats were detected via the genetic analysis of hair or scat samples, remote camera photographs, snow tracks encountered during highway snow tracking, or mud tracks encountered during track surveys of Lake Keechelus.

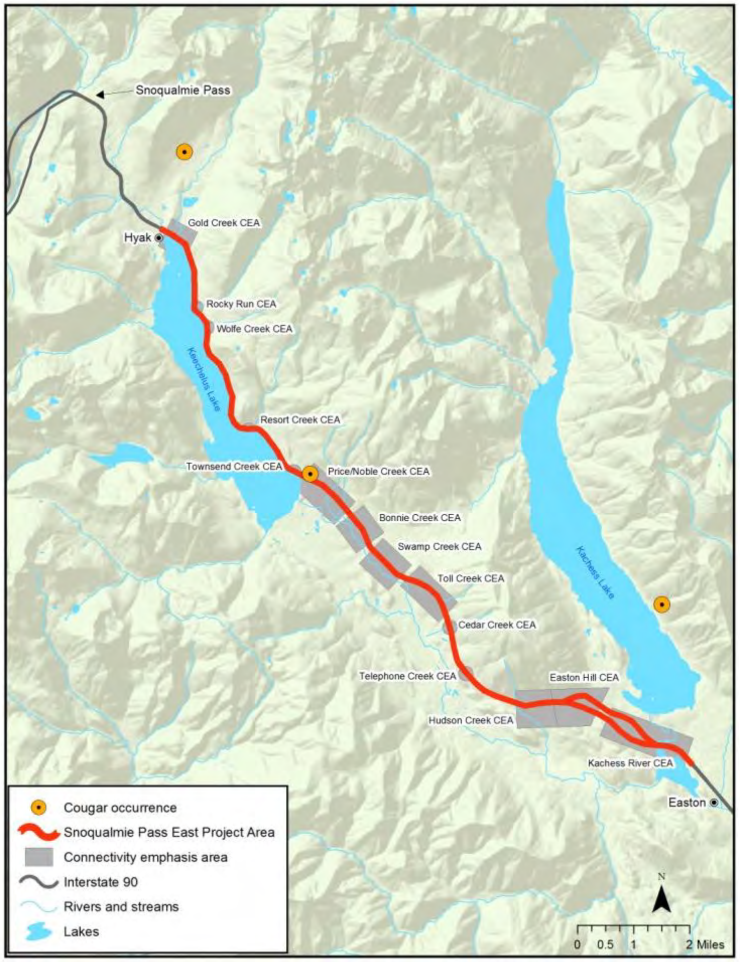


Figure 4.11. Locations where cougars were detected via the genetic analysis of hair or scat samples, or remote camera photographs.

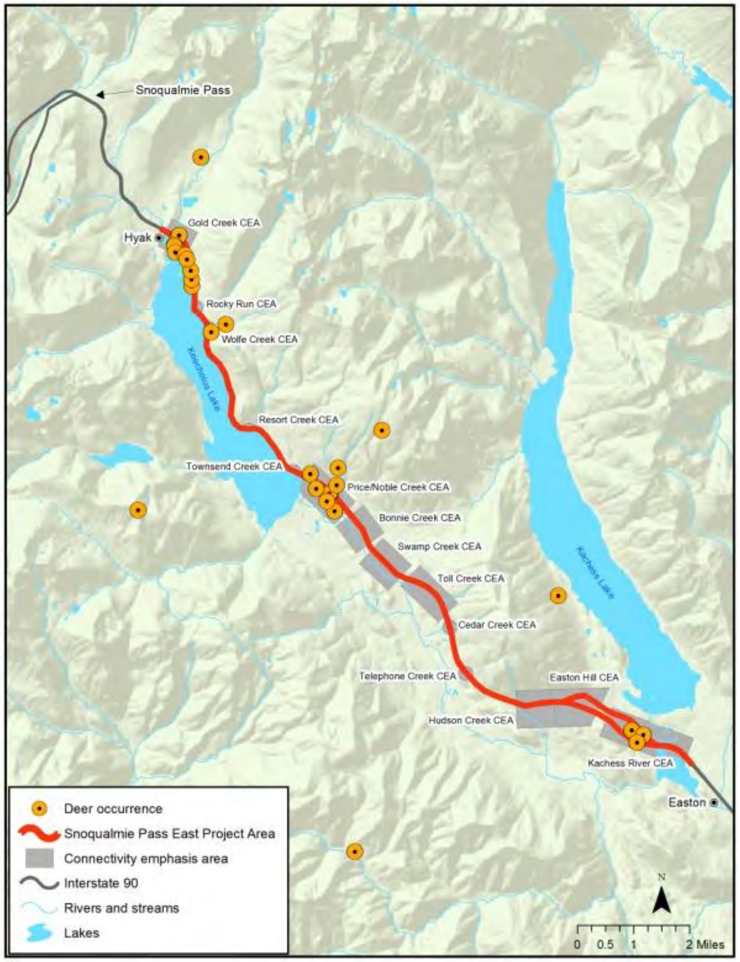


Figure 4.12. Locations where mule deer were detected via the genetic analysis of hair samples, remote camera photographs, or mud tracks encountered during track surveys of Lake Keechelus.

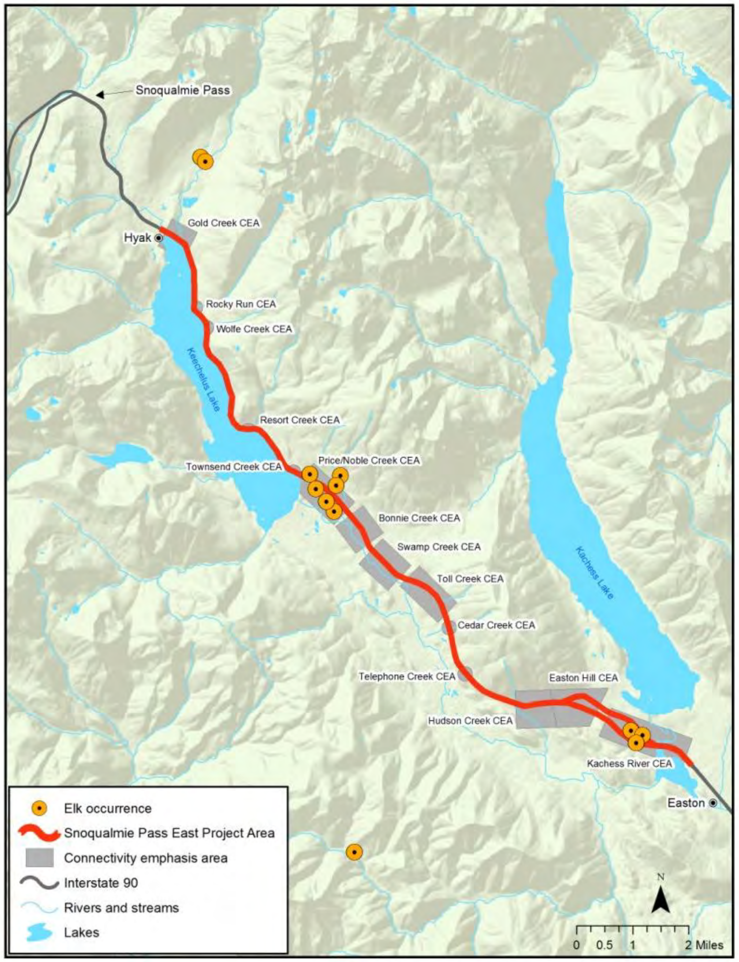


Figure 4.13. Locations where elk were detected by remote camera photographs.

Small Mammal Surveys

We captured 264 individual small mammals, with 157 recaptures and 10 mortalities (Table 4.2, Appendix 4.5). Swabs containing DNA samples from 258 unique individuals were collected and stored for potential future analysis.

Table 4.2. Summary of small mammal captures, recaptures, and mortalities by species.

Common Name	New Captures	Recaptures	Mortalities	DNA Samples
Northwestern deermouse	214	141	2	213
Townsend's chipmunk	33	15	2	33
Deermouse	6	1	0	5
Trowbridge's shrew	3	0	2	3
Northern flying squirrel	3	0	1	0
Red-backed vole	3	0	1	3
Vagrant shrew	2	0	2	1
Total Individuals	264	157	10	258

The Northwestern deermouse was the most commonly captured species, followed by Townsend's chipmunks. These two species comprised 94% of all individuals captured, with others including deermice, shrews (Trowbridge's, vagrant), northern flying squirrels, and red-backed voles. Only the Northwestern deermouse was captured at all trapping grid locations (Table 4.3)

Table 4.3. Summary of small mammal detections by species.

Common Name	Gold Creek	Price Creek	Swamp Creek	Toll Creek	Hudson Creek	Easton Hill
Northwestern deermouse	X	X	X	X	X	X
Deermouse					X	X
Trowbridge's shrew			X		X	
Vagrant shrew	X		X			
Townsend's chipmunk	X	X	X	X		
Northern flying squirrel	X					
Red-backed vole				X		X

As noted above, distinguishing between the two species of deermice is difficult in the field; thus, the genetic identification of captured individuals may prove informative.

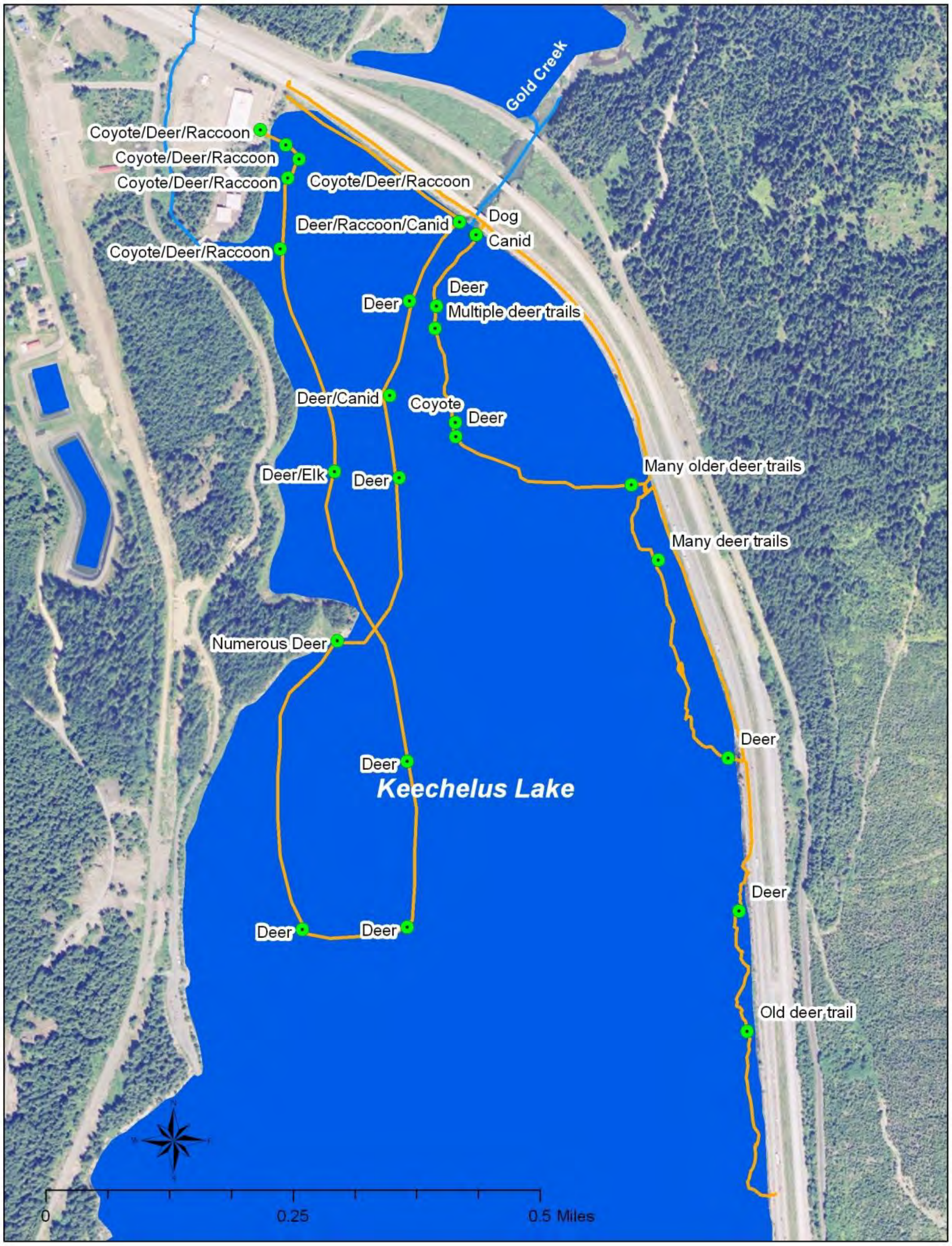
We captured two species of shrews—putatively Trowbridge's shrew and vagrant shrew. We may have misidentified the latter animals, however, which could have actually been montane shrews. Shrews are extremely difficult to identify in the field, and confirmation is best accomplished by examining skulls and dental patterns. Four of five shrew captures resulted in mortalities. Skulls from these carcasses, which were delivered to Central Washington University, could be examined for a more definitive identification.

The three captures of flying squirrels were considered incidental, as this species was not one of our target species. Adult flying squirrels are generally too large to enter the model of Sherman traps used in our surveys. Notably, all three individuals captured—with one resulting mortality—were juveniles.

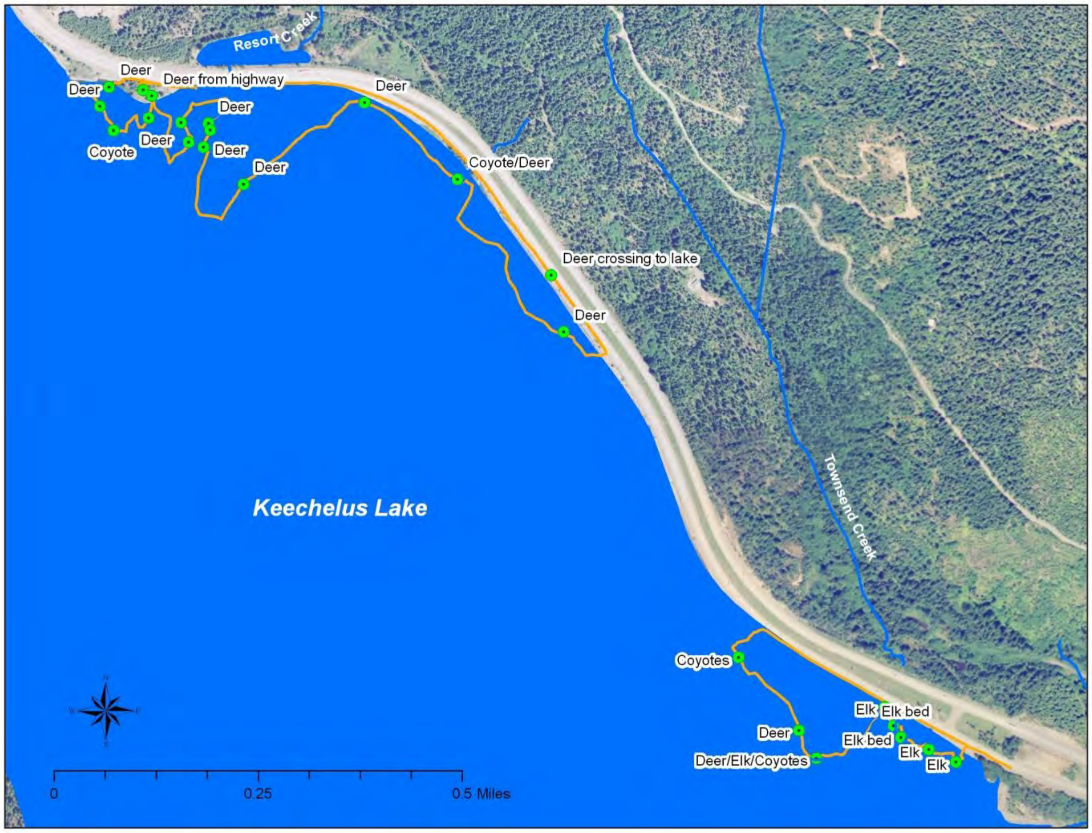
A total of ten animals died as a result of our trapping surveys—2.4% of all captures—with shrews experiencing the highest mortality rates (i.e., 40% of mortalities, and 80% of shrew captures). Shrews often experience higher mortality rates during live-trapping efforts than other species, primarily because of their high metabolic rate (Powell and Proulx 2003). After observing some mortality, we made efforts to reduce the risk of capturing shrews by stiffening the trap treadle to exclude them. This tactic appeared to be successful, as a higher number of traps were found open but with bait removed following this adjustment (and shrews were the most likely culprits due to their size). For future monitoring, alternative trapping methods for shrews should be explored, with the objective of increasing capture rates while decreasing mortality. The use of permanently placed, “non-lethal” pitfall traps may be a good option.

Keechelus Lake Track Surveys

We conducted approximately six miles of track surveys along Keechelus Lake (Fig. 4.14). All detected tracks remained alongside or within the lakebed, with the exception of a single deer track that crossed I-90 (Fig. 4.14). This animal, however, crossed from east to west (based on the direction of the track trail), and would have been presumably been precluded from accessing the highway after mitigation by wildlife fencing to be installed along the east side of the lake. Additional results, discussion, and recommendations from this monitoring effort can be found in Appendix 4.6.


Gold Creek
Coyote/Deer/Raccoon
Coyote/Deer/Raccoon
Coyote/Deer/Raccoon
Coyote/Deer/Raccoon
Coyote/Deer/Raccoon
Deer/Raccoon/Canid
Dog
Canid
Deer
Deer
Multiple deer trails
Deer/Canid
Coyote
Deer
Many older deer trails
Deer/Elk
Deer
Many deer trails
Numerous Deer
Deer
Deer
Keechelus Lake
Deer
Deer
Deer
Old deer trail
0
0.25
0.5 Miles

A.



B.

Figure 4.14. Survey routes and tracks detected during Lake Keechelus track surveys conducted on 10/5/09, 10/15/09, and 10/28/09.

Chapter 5 – Evaluating the Effects of I-90 on Northern Flying Squirrel Movement and Gene Flow

Preface

This research, collaboratively funded by WSDOT and WTI, is classified as a Tier II monitoring project because it focuses on research questions beyond the core monitoring objectives set forth in the I-90 Snoqualmie Pass East Wildlife Monitoring Plan (Clevenger et al. 2008). To help make this project possible, WSDOT funded field equipment, supplies, and a rental vehicle for two summers (2009, 2010). Meanwhile, WTI provided support for a Master's student (Joseph Smith, Montana State University [MSU] Department of Ecology), whose expenses included tuition, a stipend, and field housing at Snoqualmie Pass. In addition, the U.S. Forest Service's Pacific Northwest Research Station provided generous funding for DNA analyses, and the Washington Department of Fish and Wildlife loaned us telemetry equipment for the radio-collaring component of the project. The research described below was conducted by Joseph Smith, with oversight and assistance provided by WTI staff and several faculty members associated with MSU's Ecology department. In contrast to the other chapters in this report, we use metric units throughout this chapter because the material within was originally developed as a thesis.

Introduction

Northern flying squirrel movement is thought to be largely dependent on forest structure (e.g., tree size, canopy closure), with travel across the landscape accomplished via tree-to-tree gliding (Carey 2000). Wide gaps in forest canopy, such as those associated with large roads, may be barriers to movement for flying squirrels (Weigl et al. 2002). The maximum recorded glide distance of northern flying squirrels is 65 m (Scheibe et al. 2006), with more typical glide distances approaching 20–40 m (Vernes 2001). Although most movement takes place through the tree canopy, flying squirrels do spend some time on the ground—where they feed on hypogeous fungi (i.e., fungi with underground fruiting bodies, commonly known as truffles). Squirrel movement on the ground is slow and clumsy, however (Wells-Gosling and Heaney 1984, Maser et al. 1986), and may increase risk of predation. As the primary prey species of the northern spotted owl and an important disperser of ectomycorrhizal fungi spores, northern flying squirrels are considered a critical component of some forested ecosystems (Carey 1995, Lehmkuhl et al. 2004, Lehmkuhl et al. 2006). We selected the northern flying squirrel as a focal species for exploring potential barrier effects of I-90 and establishing baseline data that can be used to determine and monitor the overall success of mitigation measures to be implemented by WSDOT. We examined potential barrier effects using a combination of radio-telemetry and genetic analyses.

To our knowledge, this project represents the first research conducted in the Pacific Northwest regarding the response of flying squirrels to roads and/or highways. Weigl et al. (2002) studied a population of northern flying squirrels divided by a 2-lane highway in North

Carolina, and observed no crossings or crossing attempts by any of the ten radio-tracked adults over a period of two years. The width of the highway in this study averaged 38 m, which is within the gliding range of flying squirrels (Vernes 2001, Scheibe et al. 2006). These findings suggest that flying squirrels may avoid crossing roads for reasons other than physical limitations. The relationship between dispersal/movement activities and habitat configuration are poorly studied in northern flying squirrels, but have been examined in several other gliding mammals. For example, juvenile Siberian flying squirrels (*Pteromys volans*), whose gliding abilities are very similar to those of northern flying squirrels (Vernes 2001, Asari et al. 2007), tended to disperse through preferred forested habitat; open areas that could not be crossed in a single glide were almost always avoided (Selonen and Hanski 2004). In a related study, one adult male was observed to cross a field 70 m wide in a single glide several times, and a single female crossed a gap wider than 50 m (Selonen and Hanski 2003). Road crossings by squirrel gliders (*Petaurus norfolcensis*) were inhibited though not precluded by wide gaps (i.e., > 50 m) in the tree canopy created by roads and power lines (van der Ree 2006, van der Ree et al. 2010).

Study Area and Methods

Site Selection

The Study Area is described previously in detail (Chapter 1). Within the Project Area, WSDOT had previously highlighted specific highway segments that were considered to be especially important for connectivity mitigation efforts (WSDOT 2006). Fourteen of these Connectivity Emphasis Areas (CEAs) are used as reference points in our report (Fig. 5.1). We selected the Bonnie Creek, Toll Creek, Easton Hill, and Kachess River Connectivity Emphasis Areas (CEAs) as study sites for this research (Fig. 5.1). These CEA's provided sufficient habitat (i.e., late-successional forest) on both sides of the highway to enable a pairwise comparison. We live-trapped flying squirrels in June–July of 2009 and 2010.

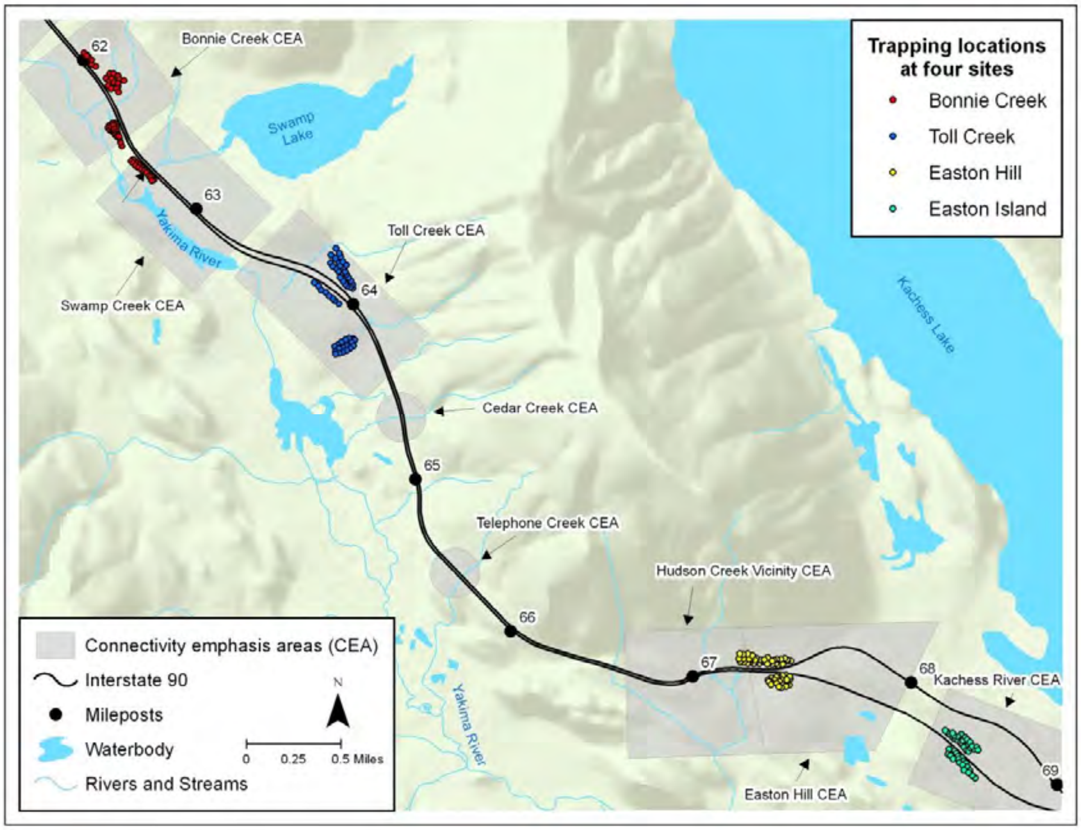


Figure 5.1. Map of study area showing live-trap locations at four trapping sites. For analyses, each site was divided into a "north" and "south" component relative to I-90.

Live Capture

We generally deployed traps within a mean home-range diameter (i.e., ~350 m) of I-90 in an effort to sample only squirrels with home ranges adjacent to or potentially overlapping the highway.

We deployed trapping sites in pairs across the highway such that crossings by trapped and marked individuals could be detected. Trap stations were located approximately 30 m apart along trap lines situated parallel to the highway, and trap lines comprised 24–36 trap stations, with a resulting effective survey area of approximately 1.8–2.7 ha. At each trap station, we placed 1 41 x 13 x 13 cm trap (Tomahawk Model 201, Tomahawk, WI) on the ground, and fixed a second trap to the bole of a nearby tree at approximately 1.25–2 m above the ground. We covered traps with tight-fitting, wax-coated cardboard boxes, and nested a small cardboard box with polyester filling within each trap to help protect trapped animals from exposure. We also covered traps with natural debris to make them less conspicuous.

We opened traps in the evening, checked them early the following morning, and then left them closed during the day to reduce captures of non-target species and minimize heat stress. We baited traps with a mixture of peanut butter, rolled oats, and molasses, and changed or supplemented bait daily. When flying squirrels were captured, we recorded their weight, sex, and reproductive status. We also collected a sample of epithelial cells for use in genetic analyses by rubbing the inside of the cheek with a cotton and/or synthetic swab, and inserted a passive integrated transponder (PIT) tag subcutaneously between the shoulder blades to permit the identification of recaptured individuals. Lastly, we fitted flying squirrels weighing >120 g with a 4 g VHF transmitter to facilitate the collection of movement and home range data.

We recorded all information, including the designated trap number and site location, onto field data forms. After we completed our processing protocol, we released squirrels at the capture location and monitored them briefly for injuries or stress. Any animal that exhibited injury or stress was cared for immediately and released after a full recovery.

Radio-Telemetry

We used radio-telemetry to track nightly movements and determine home ranges of radio-collared squirrels. To collar a given squirrel, we affixed a Holohil Model PD-2C transmitter (Holohil Systems Ltd., Carp, Ontario, Canada) around its neck with 30 lb.-test braided steel fishing line and padded the transmitter with flexible PVC tubing. We collared only squirrels weighing >120 g to guarantee that transmitter weight did not exceed the recommended maximum of 4% of the individual's weight (Cochran 1980), and thus to help ensure that gliding capabilities were not impeded by transmitters. During each tracking session, we used a radio receiver and handheld antenna (Telonics, Inc., Mesa, AZ, USA) to closely approach and record locations of radio-collared squirrels at 1-hour intervals. Once we felt that we were as close to a given squirrel as possible without disturbing its behavior, we recorded the location with a handheld global positioning system (GPS) unit. We estimated and recorded the accuracy of each location as: (1) visual confirmation or likely tree location of the squirrel; (2) within 20 m of the squirrel; (3) within 40 m of the squirrel; or (4) poor quality point, usually when we could not physically approach the squirrel or obtain a strong signal.

We monitored flying squirrel movements from late-June through late-August in 2009 and 2010. We tracked each radio-collared squirrel for 1–3 nights/week, with the resulting data consisting of several bursts of hour-spaced locations clustered temporally by individual tracking session and distributed evenly over the 2–3 month monitoring period.

Home Range and Movement Analyses

We converted pairs of sequential locations for a given squirrel into a number of movement vectors. These vectors were straight-line movement segments representing simplifications of typical movements of squirrels during approximately one hour of nightly activity. Because we were often unable to locate a squirrel or record locations at exact one-hour intervals, we relaxed this constraint slightly and used only locations separated by 50–120 minutes in the analysis. We omitted locations with level 4 accuracies from our analyses. We performed a Monte Carlo randomization procedure in R (R Core Team 2012) to assess whether movement vectors crossed the highway less frequently than expected by chance. This procedure involved:

1. selecting a random sample (without replacement) of known locations for a given squirrel equal to the number of movement vectors observed for that squirrel;

2. randomly assigning distances (sampled with replacement from observed vectors) and azimuths (sampled from a uniform distribution from 1–360) to those points to simulate random movement vectors;
3. counting the number of random vectors that would have crossed the highway.

We determined significance values by calculating the proportion of 10,000 randomized runs with crossing counts less than or equal to the observed number of crossings.

We determined home ranges by constructing simple minimum convex polygons (MCP) in ArcGIS 10 (ESRI, Redlands, CA, USA). We only calculated home range sizes for squirrels with ≥30 recorded locations.

DNA Extraction and Analysis

We stored epithelial cells from cheek swabs (cotton and/or synthetic) with silica desiccant. For extraction, we isolated genomic DNA from cheek swabs using Qiagen's Investigator Kit. We chose eleven polymorphic microsatellite loci for genotyping, and used fluorescently labeled universal M13 primer with an attached M13 sequence at the 5' end of the forward primer to view PCR amplicons. All loci shared the same PCR chemistry, which consisted of 2"L of 5X MyTaq RXN Buffer, 1"M of each primer, 0.5 Unit of MyTaq™ HS DNA Polymerase, ~50ng of DNA and enough water for a final volume of 10 "L (Bioline). Similarly, all 11 loci shared the same thermoprofile, which consisted of an activation step at 95°C for 1 min followed by 30 cycles (95°C for 15 sec, 55°C for 15 sec and 72°C for 10 sec). We performed 10 additional cycles (95°C for 15 sec, 53°C for 15 sec, and 72°C for 10 sec) to incorporate the fluorescently labeled universal M13 primer. Finally, PCR amplicons were visualized using the 3100-*Avant* Genetic Analyzer and scored with GeneMapper v3.5 (Applied Biosystems).

Population and Landscape Genetic Analyses

We screened genotypes for linkage disequilibrium and deviations from Hardy-Weinberg equilibrium using the program GENEPOP (v.4.1; Raymond and Rousset 1995, Rousset 2008), and assigned levels using sequential Bonferroni correction for multiple comparisons (Rice 1989). We also used GENEPOP to estimate allele frequency-based fixation indices (F_{ST}) between all possible pairs of trapping sites. This approach employed Weir and Cockerham's (1984) estimator θ, and pairwise individual genetic distances among all individuals using Rousset's (2000) â, which is somewhat analogous to $F_{ST}/(1-F_{ST})$ (see Rousset 1997) for assessing isolation by distance of individual squirrels. We used Mantel tests and partial Mantel tests (Mantel 1967, Smouse et al. 1986) to test for effects of geographic distance and the highway on genetic differentiation at both the site level (pairwise F_{ST}) and the individual level (â).

We assigned geographic coordinates for individual animals in one of two ways. For radio-tracked individuals, we used the center of an individual squirrel home range defined by the mean Universal Transect Mercator (UTM) easting and mean UTM northing of all recorded locations. For non radio-tracked individuals, we used the location of the capture site. We calculated the geographic coordinates of all individuals from a capture site by taking the mean UTM easting and mean UTM northing of the site. We used the natural logarithm of the

Euclidean distance (meters) between populations or individuals in evaluating isolation by distance. Mantel tests were performed in the R package ECODIST (v.1.2.3; Goslee and Urban 2010), and significance was determined with 100,000 randomizations. We used the Bayesian population assignment software STRUCTURE (v.2.3; Pritchard et al. 2000) to infer the most likely number of populations (*K*) in the study area, and to examine relationships between the inferred populations and landscape features that might affect gene flow.

STRUCTURE allows user-defined "populations" to be associated with each individual, thereby improving the program's ability to correctly assign individuals to groups when genetic structure is weak or when samples are clumped in space (Hubisz et al. 2009). We chose this approach based on the limited geographic extent of our samples and their clumped distribution. We employed model parameters recommended in the software documentation (i.e., the admixture model with correlated gene frequencies, α inferred from the data, $\lambda = 1$, a burn-in period of 10,000 iterations, and 10,000 iterations of the Markov chain), and methods described in Evanno et al. (2005) to infer the most likely value of *K* based on 5 independent runs at each value of *K* from 1 to 6 (the maximum value being the number of sites from which the samples were collected). Finally, we used program BARRIER (v.2.2; Manni et al. 2004) to identify the most likely location of a gene flow barrier. BARRIER employs Monmonier's algorithm to locate discontinuities in gene flow based on the locations of individuals and the magnitude of pairwise individual genetic distances ($\hat{a}$).

Results

Home Range and Movement

We deployed radio collars on 11 and 10 squirrels in 2009 and 2010, respectively. Three collars slipped-off or were removed by squirrels during the study. These collars were recovered and re-deployed on other squirrels. One radio-collared squirrel appeared to cease movement high in a tree after several days, and we presumed that it either died or slipped its collar. The collar was never recovered. In total, we used 548 locations from 17 individual squirrels for home range analyses (Table 5.1). Home ranges of squirrels with ≥30 locations (n = 11) ranged from 0.85 to 67.60 ha. Home range sizes of females (mean = 3.88 ha, range = 0.85–8.93 ha, n = 3) did not overlap home range sizes of males (mean = 24.99 ha, range = 10.67–67.60 ha, n = 8)(Figs. 5.2–5.5).

Table 5.1. Summary of radio-telemetry results and movement vector analysis, including squirrel identification number, sex, year monitored, and numbers of: (a) vectors; (b) tracking nights; (c) detected crossings; and (d) expected crossings (i.e., the mean of the randomization distribution). Also shown are the detected crossing rate and the *p*-value of the movement randomization test for each squirrel.

Site	Squirrel (sex)	Year monitored	Movement vectors	Tracking Nights	Detected Crossings	Expected Crossings	Crossing Rate	*p*-value
Bonnie Creek	179 (F)	2009	5	11	0	0.66	0	0.4942
	211 (F)	2009	5	5	0	0.53	0	0.5697
	120 (M)	2009	17	12	1	3.32	0.06	0.1273
	272 (M)	2009	16	11	4	3.05	0.25	0.8261
Toll Creek	091 (M)	2009	6	11	0	0.43	0	0.6452
	239 (M)	2009	14	11	0	1.96	0	0.1187
	060 (M)	2009	16	16	1	2.76	0.06	0.2057
	031 (M)	2009	16	19	2	2.21	0.13	0.6201
	300 (F)	2009	6	7	2	1.38	0.33	0.8623
Easton Hill	640 (M)	2010	28	10	0	4.45	0	0.0065
	539 (F)	2010	29	9	0	4.12	0	0.0114
	520 (M)	2010	30	10	0	4.97	0	0.0038
	680 (F)	2010	30	8	0	3.78	0	0.0188
Easton Island	818 (M)	2010	15	4	0	2.98	0	0.0362
	178 (F)	2010	32	10	0	6.47	0	0.0012
	498 (M)	2010	33	10	5	8.32	0.15	0.1236
	739 (M)	2010	35	7	16	7.64	0.46	0.9999
Pooled		2009	101	103	10	16.40	0.10	0.0493
		2010	232	68	21	42.81	0.09	<0.0001
		2009 and 2010	333	171	31	59.23	0.09	<0.0001

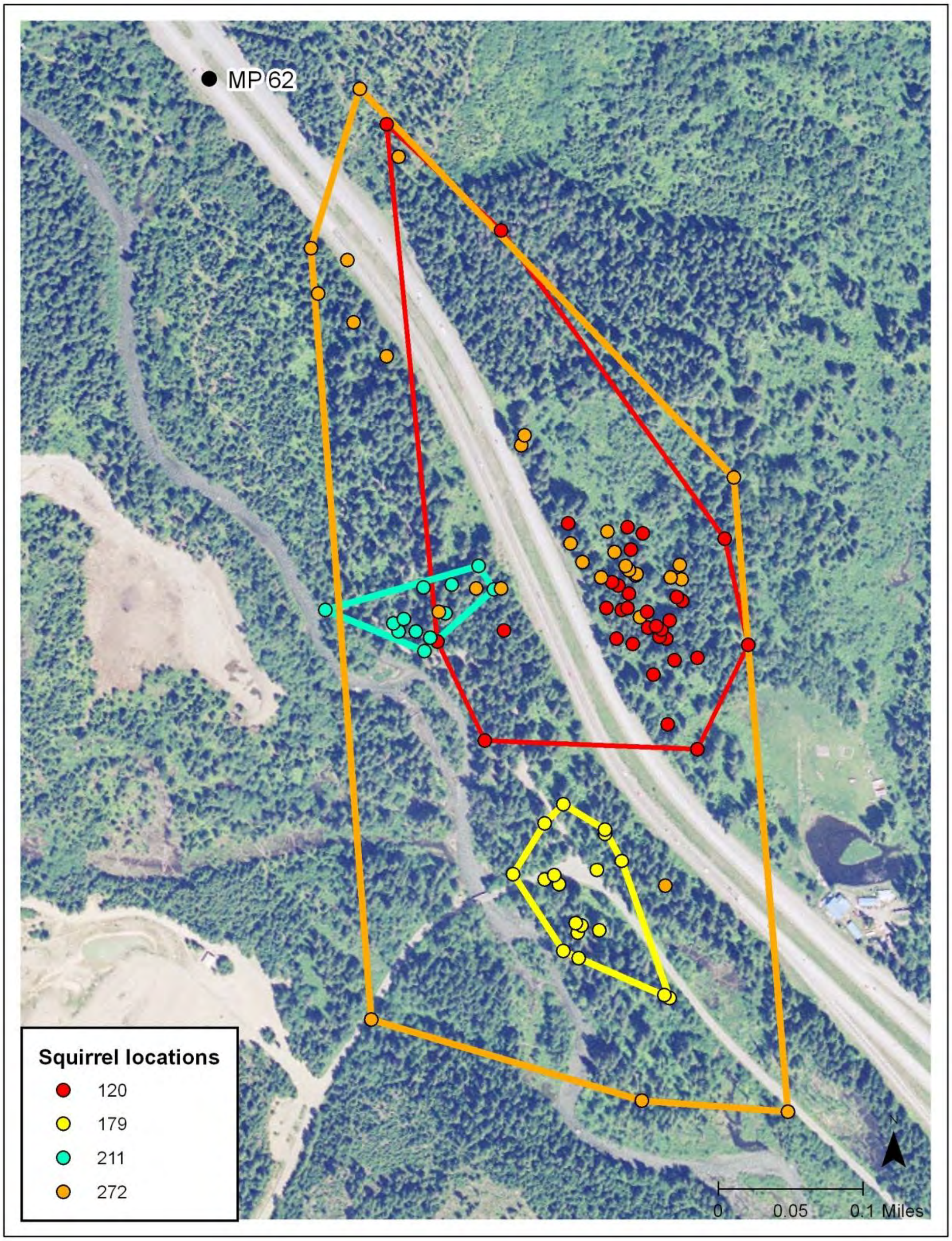


Figure 5.2. Radio-tracking locations and minimum convex polygon home ranges for four northern flying squirrels tracked at the Bonnie Creek site. The background orthophoto shows I-90, smaller paved and unpaved roads, and other landscape features.

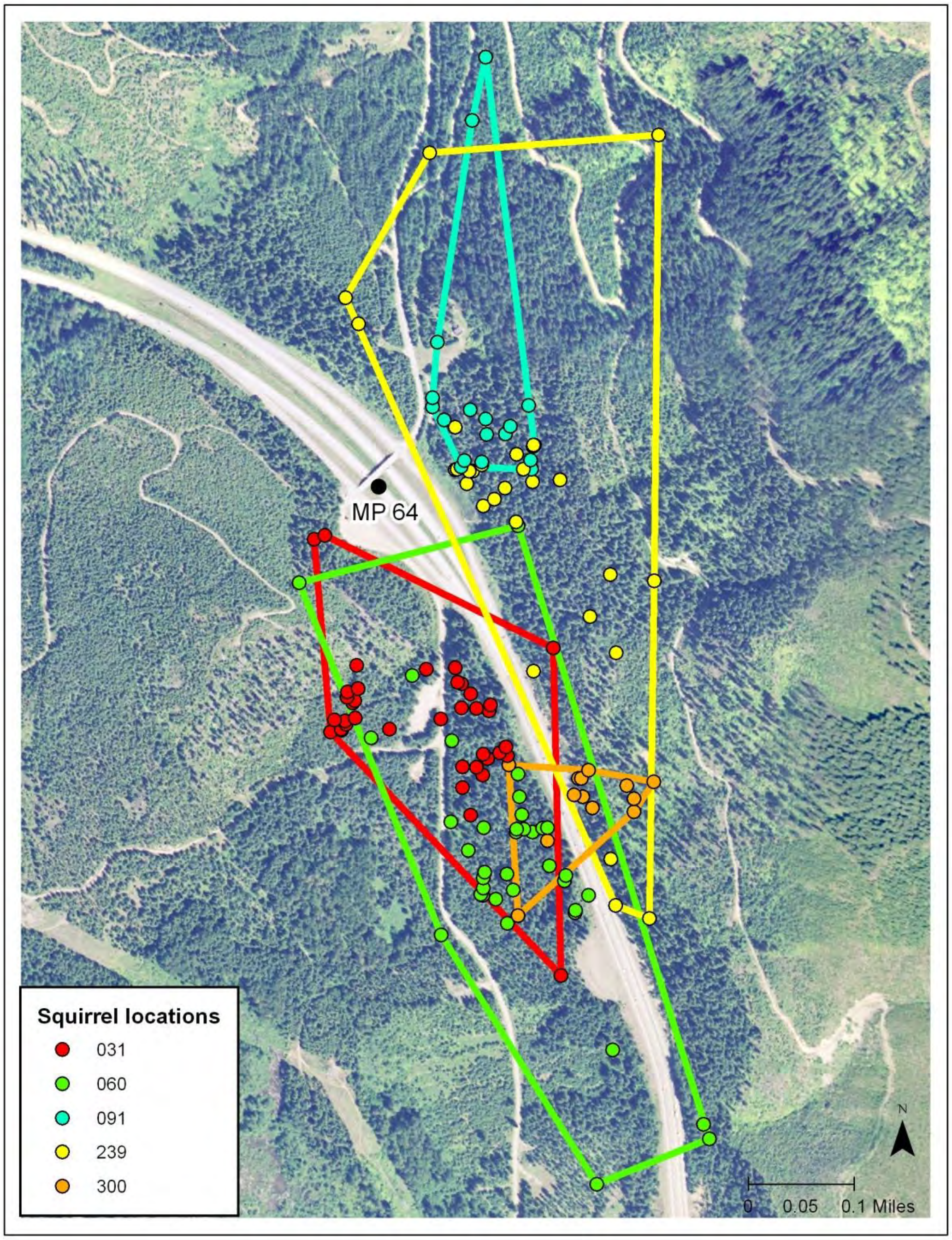


Figure 5.3. Radio-tracking locations and minimum convex polygon home ranges for five northern flying squirrels monitored at the Toll Creek site. The background orthophoto shows I-90, smaller paved and unpaved roads, and other landscape features.

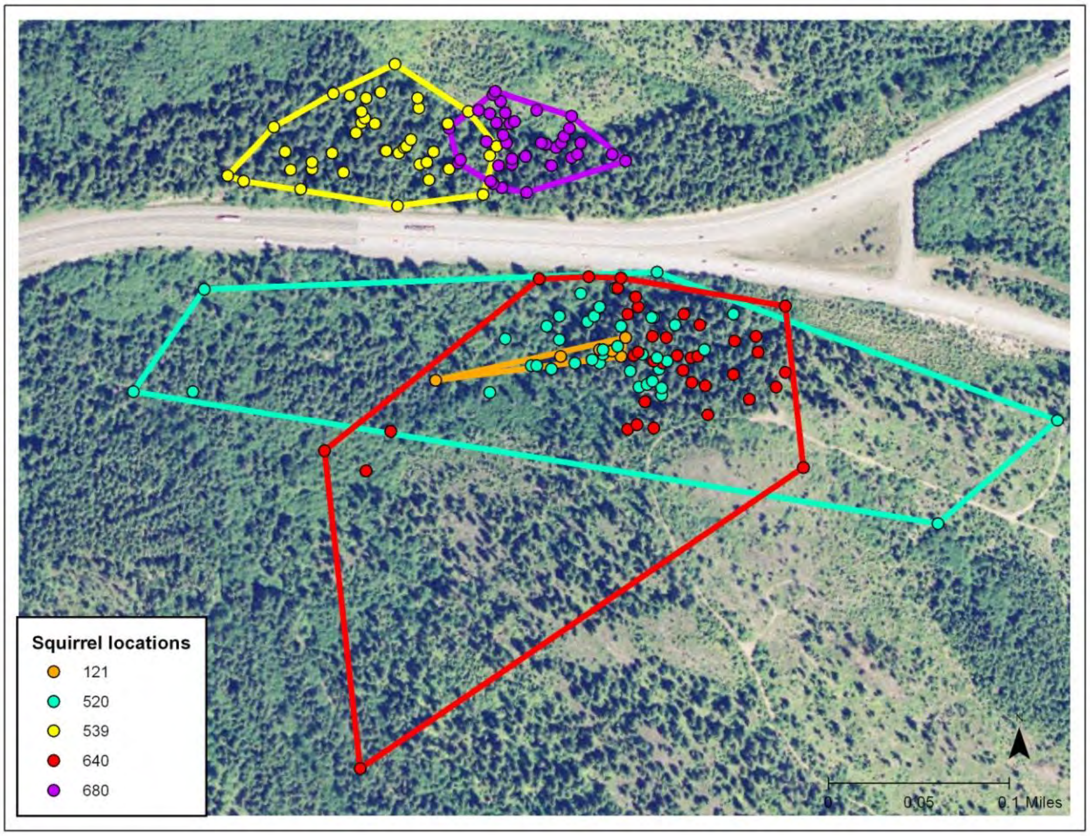


Figure 5.4. Radio-tracking locations and minimum convex polygon home ranges for five northern flying squirrels monitored at the Easton Hill site. The background orthophoto shows I-90, smaller paved and unpaved roads, and other landscape features.

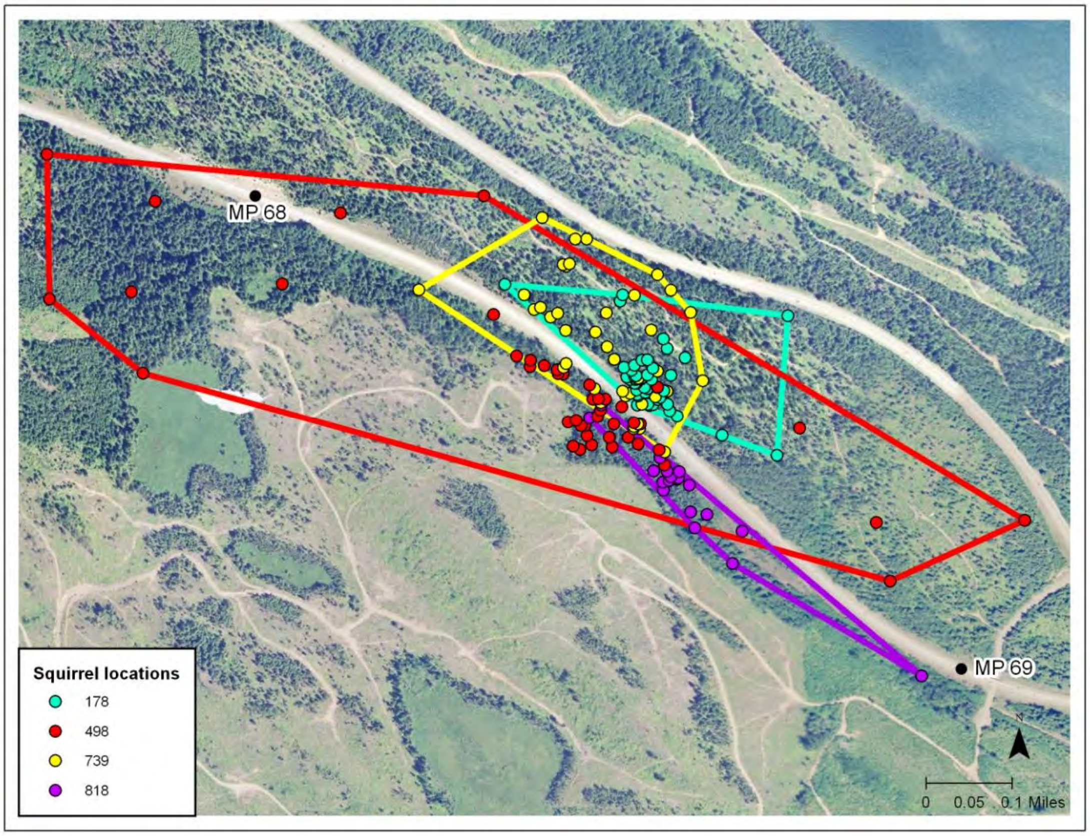


Figure 5.5. Radio-tracking locations and minimum convex polygon home ranges for five northern flying squirrels monitored at the Easton Island site. The background orthophoto shows I-90, smaller paved and unpaved roads, and other landscape features.

We detected squirrels crossing the highway at three of the four CEA's: Bonnie Creek, Toll Creek, and Easton Island (Table 5.1. Fig. 5.6). We detected no crossings at Easton Hill. We assume that squirrel crossings were achieved by gliding across the highway, from tree-to-ground or tree-to-tree (see Discussion section for more on this subject). Seven squirrels (41%) were confirmed to have crossed the highway at least once. Crossing rates (i.e., the proportion of observed vectors that crossed the highway) for squirrels that were confirmed to have crossed at least once ranged from 0.06 to 0.46. Crossing rates did not differ between males and females (exact Wilcoxon rank sum test, $W = 22.5$, $p = 0.27$). Of the four CEAs, the crossing rate was highest at Easton Island (0.18). Due to a forested median separating the east- and west-bound lanes, this site also featured the narrowest (~40 m) highway-induced gap between forest edges. In contrast, Easton Hill, where we detected no squirrel crossings, was characterized by the widest gap between forest edges (>80 m)(Fig. 5.7).

We employed a total of 333 movement vectors for the movement analysis. Highway crossings comprised about 10% of recorded movements in 2009, 9% of movements in 2010, and 9% of movements over both years combined (Table 5.1). When we pooled all squirrels over one or both years, highway crossings occurred significantly less frequently than would have been expected by chance (Monte Carlo $p < 0.0001$, all squirrels combined). These findings suggest that flying squirrels exhibited some avoidance of crossing I-90. The highway was estimated to reduce crossings by approximately 48% when all vectors were pooled for analysis (expected crossings = 59, observed crossings = 31, 95% confidence interval = 32.6–57.5% reduction).

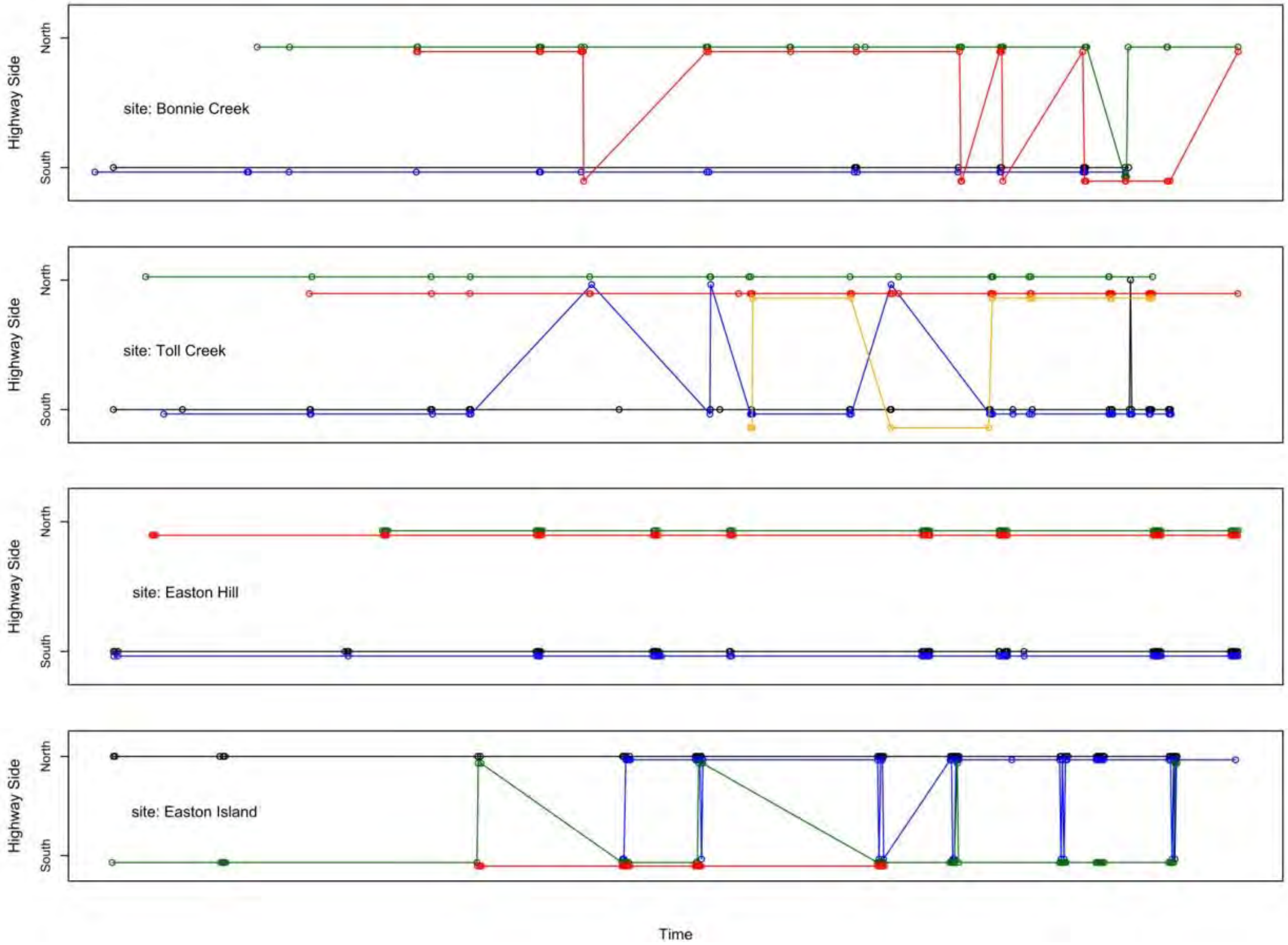


Figure 5.6. Diagram representing radio-tracked movements of collared squirrels relative to the highway. Within sites, individual squirrels are represented by different-colored lines. Site diagrams are arranged from northwest (top) to southeast.

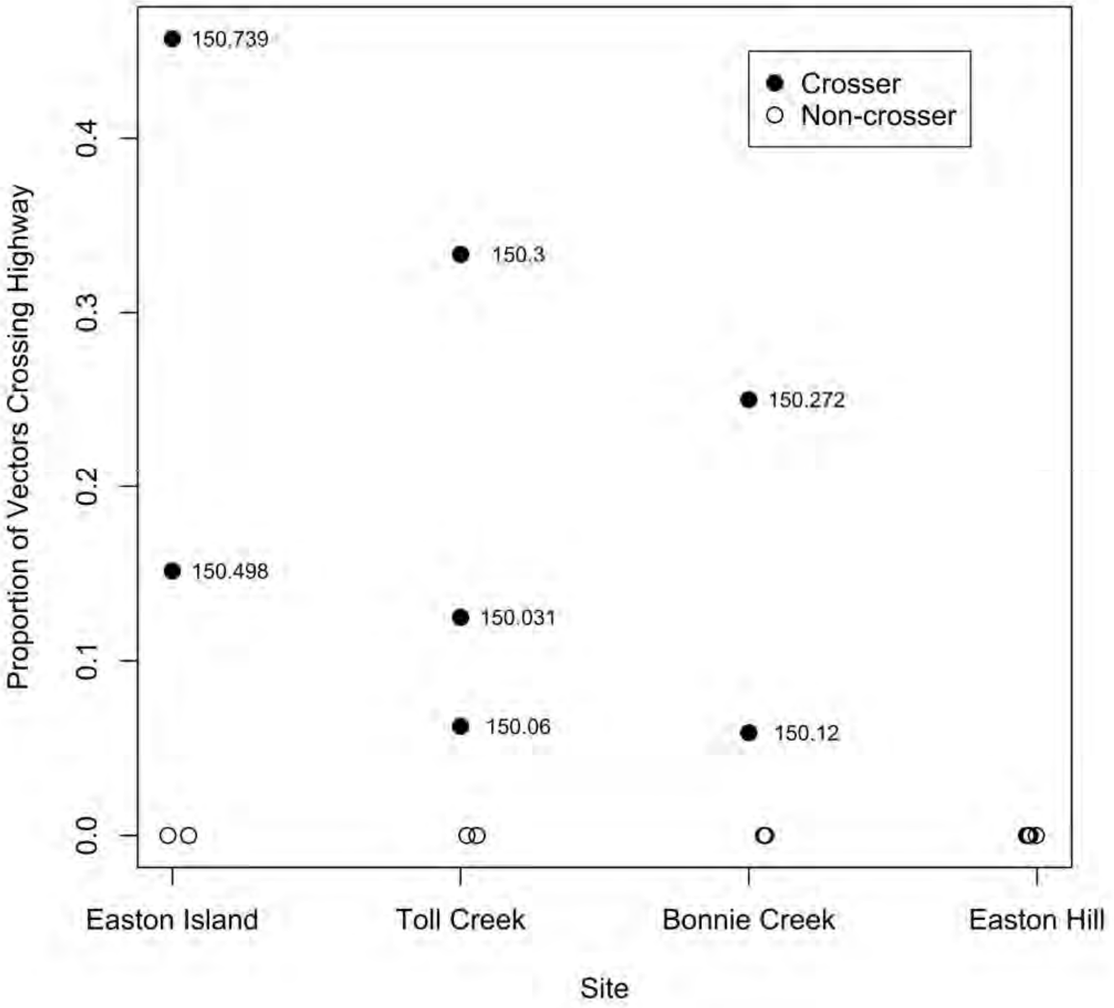


Figure 5.7. Crossing rates of all radio-tracked squirrels by site. Sites are ordered from narrowest (left) to widest average canopy gap width. Approximate average and minimum gap widths (meters): Easton Island (57, 42); Toll Creek (72, 51); Bonnie Creek (76, 64); Easton Hill (83, 65). Gaps were measured using digital orthophotos in ArcGIS 10 (Esri, Redlands, CA, USA).

Population and Landscape Genetics

We genotyped a total of 59 individuals at 11 loci (Appendix 5.1). Seven of 55 pairs of loci showed potential linkage ($p < 0.05$), but there was no evidence for gametic disequilibrium among any pairs of loci after sequential Bonferroni correction. The average number of alleles per locus was 7.73 (range 5–13). The average observed heterozygosity was 0.62. After sequential Bonferroni correction, Bonnie Creek South was the only site that deviated significantly from Hardy-Weinberg equilibrium (Fisher's method, $\chi^2 = 42.905$, d.f . = 20, $p = 0.0021$).

We detected statistically significant genetic structure between all but three pairs of sites (Table 5.2). Pairwise F_{ST} among sites on the same side of the highway (mean = 0.050, range 0.014–0.77) was very similar to pairwise F_{ST} among sites on opposite sides of the highway (mean = 0.051, range 0.011–0.91). Global F_{ST} was 0.051. There was no evidence for a correlation between pairwise F_{ST} and geographic distance (Mantel's $r = - 0.18$, $p = 0.77$) or between pairwise F_{ST} and highway presence (Mantel's $r = 0.026$, $p = 0.39$). In sum, therefore, there was no indication that the highway was a major barrier to genetic connectivity for squirrels.

Given the close proximity of individuals sampled at the same site, we chose to modify the individual-based analysis to exclude comparisons between individuals whose assigned locations were within a distance of 500 m. We took these measures because:

1. the relationship between geographic distance and genetic distance is thought to deteriorate at distances that are below the dispersal distance of individuals, σ (Rousset 1997, 2000), and the size of our trap sets resulted in clusters of individuals far below this threshold distance from one another;
2. post-hoc relatedness analyses performed in the program MLRELATE (Kalinowski et al. 2006) indicated that individuals within sites were highly related ($\bar{r}_{within} = 0.13$, $\bar{r}_{overall} = 0.06$). Pairwise comparisons between members of family groups are generally not suitable for analyzing whether a barrier is associated with genetic differences at the population scale;
3. estimated geographic distances between individuals within sites were unreliable because home ranges overlapped considerably, and any error associated with these estimates would have been magnified by the log transformation of distance.

The 500 m threshold excludes most comparisons within trapping sites and, as an approximation of dispersal distance (σ), is in close agreement with the predicted mean dispersal distance of 430 m reported for northern flying squirrels (D'Eon 2002). However, although 96% of the movement lengths we recorded were less than 500 m, we also observed squirrels moving as far as 974 m in less than 2 hours.

After we excluded comparisons of individuals below the 500 m threshold, the remaining dataset included 79% of the original dataset (n = 1355). A simple linear regression test indicated that neither geographic distance nor the barrier effect of the highway was significantly correlated with genetic distance ($t = 0.441$, df = 1454, $p = 0.659$ for geographic distance, and $t = -0.003$, df = 1454, $p = 0.998$ for barrier effect). Simple linear regression is typically not appropriate for tests such as this because non-independence among observations will always result in artificially small standard errors and, subsequently, inappropriately small *p*-values. Given this issue, the large *p*-values we observed under the simple linear regression model strongly indicated that there was no relationship between the explanatory variables—geographic distance and the highway—and genetic distances among individuals.

Table 5.2. Pairwise relatedness, geographic distances, and F_{ST} between sites. NS = not significant, * = p < 0.05, ** = p < 0.005, *** = p < 0.0001 (after sequential Bonferroni correction). Average relatedness is reported within each site (r_1 and r_2) and between sites ($r_{between}$). Bold values indicate average coefficients of relatedness consistent with first cousin or closer relationships.

Site Pair	r_1	r_2	$r_{between}$	Distance (km)	F_{ST}
BCN–BCS	**0.14**	**0.22**	0.05	0.35	0.065**
BCN–TCN	**0.14**	0.11	0.07	2.49	0.014 (NS)
BCN–TCS	**0.14**	0.12	0.05	2.81	0.063*
BCN–EHN	**0.14**	**0.17**	0.08	7.18	0.056*
BCN–EHS	**0.14**	0.08	0.07	7.89	0.011 (NS)
BCS–TCN	**0.22**	0.11	0.05	2.26	0.072***
BCS–TCS	**0.22**	0.12	0.03	2.54	0.077***
BCS–EHN	**0.22**	**0.17**	0.03	6.93	0.091***
BCS–EHS	**0.22**	0.08	0.06	7.64	0.057**
TCN–TCS	0.11	0.12	0.05	0.48	0.060***
TCN–EHN	0.11	**0.17**	0.05	4.69	0.058***
TCN–EHS	0.11	0.08	0.06	5.40	0.022 (NS)
TCS–EHN	0.12	**0.17**	0.07	4.38	0.034**
TCS–EHS	0.12	0.08	0.05	5.10	0.042***
EHN–EHS	**0.17**	0.08	0.05	0.72	0.044**

The program BARRIER identified that the most likely barrier occurred through the Easton Hill North site, perpendicular to the highway. The location of the inferred barrier did not correlate with any obvious landscape feature(s). STRUCTURE identified $K = 4$ as the most likely number of groups, but members of these inferred groups were geographically mixed. Thus, while genetic structure was evident among sampled squirrels, patterns consistent with geographically distinct groups did not emerge. Relatedness analyses in MLRELATE supported these results. We estimated relatedness coefficients of (r) ≥ 0.25 (consistent with half-sibling relationship) between squirrels in 11 of the 15 possible site pairs, including 6 of 9 possible across-highway site pairs.

Discussion

Although I-90 appeared to filter the movement of northern flying squirrels at sites where we monitored individuals, it did not appear to be an absolute barrier to movement. Almost half (41%) of the squirrels we tracked were observed to have crossed the highway at least once. Because radio-tracking occurred during hours of darkness, and flying squirrels are arboreal and use tall trees for movement, we rarely observed movement activity directly. Further, no squirrel was visually observed to cross the highway via gliding or at-grade movement (e.g., walking across the road surface). Concurrent monitoring (see Chapter 3, this report) of culverts and bridges by WTI staff indicated that no monitored culverts or bridges were used by flying squirrels to cross the highway. Further, no flying squirrels were reported in a concurrent study of wildlife-vehicle collisions and live animal sightings throughout the flying squirrel study area (see Chapter 2, this report). We assume, therefore, that highway crossings by flying squirrels detected during radio-tracking were accomplished via gliding over the highway from tree-to-tree or tree-to-ground; a phenomenon that has been documented for gliding mammals elsewhere (van der Ree 2010). We considered potential options for confirming this assumption (e.g., spotlighting, infrared cameras, covering individuals with ultraviolet-sensitive powder for visual tracking), but none was considered feasible.

Two squirrels, one from Bonnie Creek and one from Toll Creek, were only detected once on the opposite side of the highway from their respective sites of capture. For these individuals—both males—habitat on the opposite side of the highway may not have represented part of their home range as it is usually defined. Instead, we speculate that these observed crossings may have been extraterritorial “prospecting forays,” perhaps to seek out mates (Reed et al. 1999). Five other squirrels crossed the highway on a more regular basis—some almost every night they were tracked. Each of these squirrels followed similar routes on a regular basis, suggesting that their home range included territory on both sides of the highway.

Assuming maximum glide distances of approximately 65 m (Scheibe et al. 2006), and more typical glide distances of <25 m (Vernes 2001), it is reasonable to assume that some variation in crossing behavior may be attributable to among-site differences in the highway itself. Canopy gap width and crossing behavior varied predictably among the four tracking sites (Fig. Fig. 5.7). At Toll Creek and Easton Island, for example, where canopy gap was less than 50 m in places, our telemetry indicated that five of the nine crossed the highway—often on multiple occasions in a given night. In contrast, at the top of Easton Hill, where we observed no crossings, the minimum canopy gap exceeded 65 m (> 80 m along most of the length of the site). Also at Easton Hill, tall conifers were set back from the forest edge and an elevational gradient would have presumably made gliding from south to north difficult, if not impossible. The canopy gap at Bonnie Creek was also > 60 m in width, but mature, tall conifers at least 45m in height abutted the very edge of the highway on both sides. Such trees could enable >60 m glides by flying squirrels based on documented height-of-launch to glide ratios of 1:2 (Vernes 2001). Taken together, our results are consistent with the hypothesis that wide canopy gaps inhibit crossing by flying squirrels. Finer scale movement data, however, and the inclusion of several more sites along the highway, would be necessary to quantitatively address how highway characteristics and gap widths influence crossing behavior.

Given our observed rates of squirrel movement across the highway, one would expect that populations on either side are connected both demographically and genetically. The results of the molecular genetic analysis support this supposition, given the absence of a significant highway effect on genetic distances between squirrels at the landscape scale.

Simulations have shown partial Mantel tests to be sensitive to very recent barriers, and significant positive values of Mantel’s r can be expected in 1–15 generations after establishment of a complete barrier (Landguth et al. 2010). As I-90 has existed in its present form for 50–60 years, a substantial barrier effect, if present, should have been detected. Although anthropogenic barriers to dispersal may be difficult to detect in species with large population sizes (e.g. Gauffre et al. 2008), our detection of squirrels moving across the highway provides evidence that the highway is not a complete dispersal barrier. And though the highway appears to have reduced the rate of crossing events significantly (i.e., a majority of tracked squirrels were never observed crossing the highway), it is reasonable to expect that the cumulative number of individuals moving across the highway is more than sufficient to prevent genetic differentiation.

Despite our detecting no highway effect on genetic patterns, our estimates of population differentiation among sites were unexpectedly high for a vagile, non-territorial rodent—especially given the short geographic distances under consideration (Table 5.2). Our longest observed movement was 0.97 km in 83 minutes, even though we frequently observed squirrels moving at a pace that could exceed that distance in a shorter amount of time. For a species that can potentially travel 1 km/hr, one could reasonably expect dispersal distances that approach the extent of the study area. The study area was approximately 8 km in length, and distances between the centers of survey sites ranged from 0.35–7.89 km (Table 5.2). Because neither geographic distance nor the highway had a detectable effect on genetic distances between squirrels, the high degree of differentiation we observed among sites suggests that gene flow may be limited by philopatry (i.e., the tendency of an individual to locate and reproduce near where it was born) rather than dispersal limitations imposed by the landscape. This conclusion is consistent with the results of the relatedness analysis, which indicate a high number of probable parent-offspring, full sibling, and half-sibling relationships within sites. The relatively small scale at which squirrels were trapped (i.e., distances between traps were much smaller than the average home range of the radio-tracked squirrels) resulted in a sample that more closely represented a family group than a random sample of the populations of interest (i.e., squirrels occupying discrete, contiguous forest patches). Therefore, our estimates of F_{ST} were more descriptive of differences among family groups than differences among randomly mating individuals across a larger landscape. Overall, 57% of the variation in F_{ST} among pairs of sites was explained by within-site relatedness (Fig. 5.8).

Gap width (i.e., the distance between tall trees on the verges of the highway) may affect the permeability of the highway to northern flying squirrels. Although we were unable to observe highway crossings directly, the general locations of crossings lead us to believe that they were accomplished by gliding. This is also supported by the absence of any observed crossings at Easton Hill, which has the largest gap between trees on either side of the highway of all the sites we monitored. Further, we have not detected any flying squirrels crossing I-90 during our long-term monitoring of existing bridges and culverts, and only one flying squirrel has been documented inside a culvert (i.e., Price Creek), and this animal entered and turned around after moving only a few meters. Likewise, researchers studying wildlife connectivity within the I-90 Snoqualmie Pass East project area during the late 1990s never detected flying squirrels crossing the highway through existing culverts (Singleton and Lehmkuhl 2000). Given the relatively poor locomotive abilities of flying squirrels on the ground, at-grade highway crossings would be substantially more dangerous than gliding, and fewer successful crossings of this type would be expected.

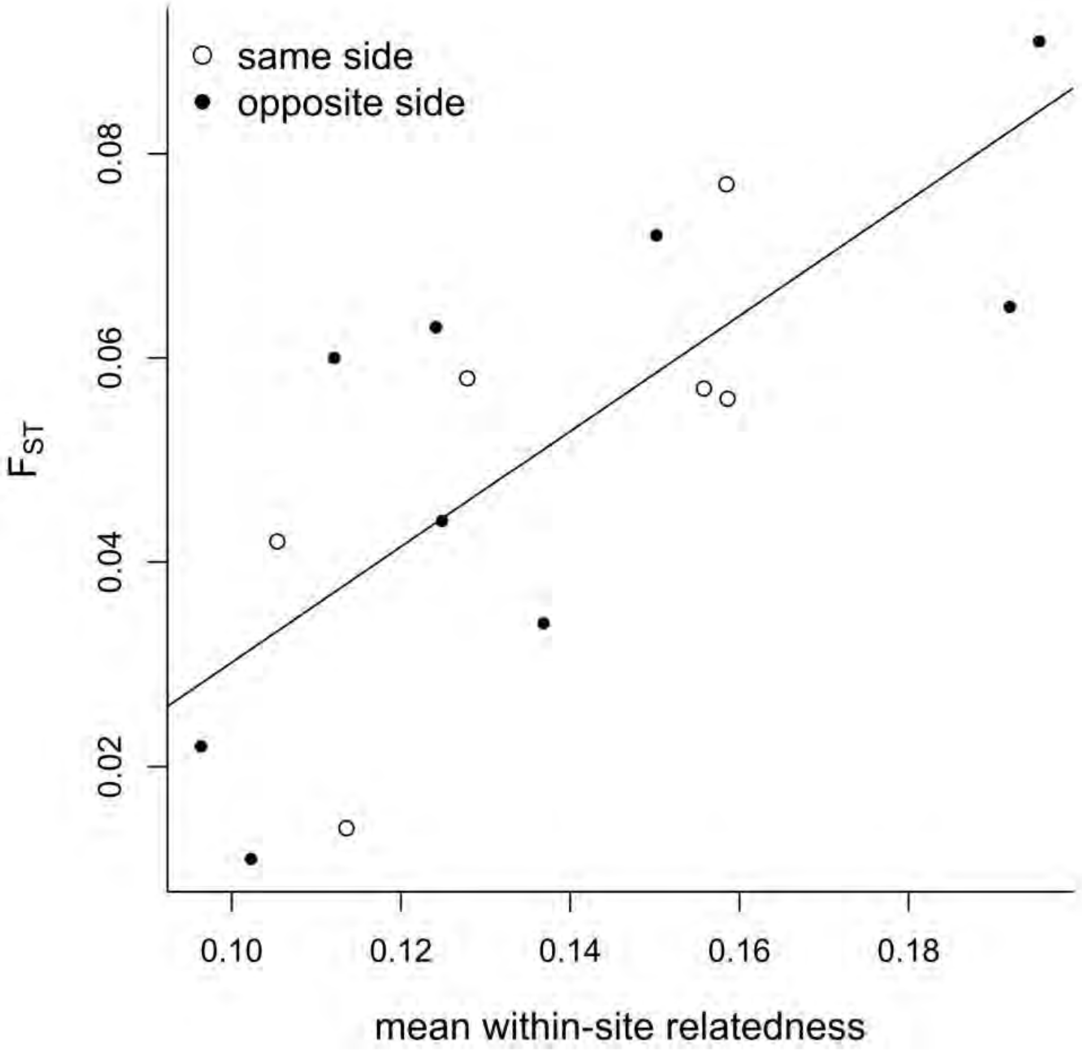


Figure 5.8. Mean within-site relatedness and pairwise F_{ST} for all pairs of sites. Higher within-site relatedness is positively associated with estimated genetic distance between sites (t = 4.14 on 13 degrees of freedom, p = 0.001). Within-site relatedness of pairs of sites explained approximately 57% of the variation in pairwise F_{ST}. Within-site relatedness at each site is reported in Table 5.2.

Management Implications and Recommendations

Results from this study suggest that habitat connectivity for flying squirrels on I-90 can be maintained if sufficiently tall trees (i.e., approximately 30 m) are present on either side of highway and canopy gaps created by the highway are limited to < ~65 m. The planned addition of new lanes via the I-90 Snoqualmie Pass East project will result in a widening of the canopy gap in most places. Mitigation measures for flying squirrels should be considered where gaps in tree canopy currently exceed the gliding ability of flying squirrels or where the addition of lanes will result in such gaps. Where highway-induced gaps in the canopy are > 65 m, potential mitigation measures could include: (1) retaining tall trees on opposite sides of the highway; (2) retaining or planting trees in the median; or (3) installing crossing poles, median poles, or suspension bridges along the highway corridor.

Crossing poles (Fig. 5.9) consist of launching platforms affixed to tall poles (e.g., 14 m; Anonymous 2010) installed on opposite sides of the road. Such poles have been successfully used to aid road crossings by endangered Australian squirrel gliders (*Petaurus norfolcensis*) in Australia (Ball and Goldingay 2008) and endangered Carolina northern flying squirrels (*Glaucomys sabrinus coloratus*) in North Carolina, USA (Anonymous 2010). Voluntary use of poles by animals has been documented in both cases. Such poles, when placed in the median (Fig. 5.10) can provide both landing and launch options to enable gliding species to cross multiple lanes of traffic (van der Ree et al. 2010). With such poles in place, gliding species are able to launch from a high point on one side of a highway, land in the median or on the median pole itself, climb to the top of the pole, and then complete the crossing by gliding across the second set of highway lanes. Alternately, suspension bridges—typically constructed of cables or rope material (R. van der Ree, personal communication; Fig. 5.11)—are affixed to trees or other structures and stretched across the highway. Such bridges could potentially provide crossing opportunities for many other species (e.g., other squirrels, smaller rodents, reptiles) as well as flying squirrels.

In conclusion, the poor locomotive capacities of flying squirrels on the ground, and the absence of tall trees in wildlife underpasses or on wildlife overpasses, will presumably make the use of I-90's future crossing structures by flying squirrels unlikely. To specifically address connectivity for northern flying squirrels within the I-90 Snoqualmie Pass East region, we would thus recommend that WSDOT consider the mitigation strategies described above.

A.

B.

Figure 5.9. (A) Glider poles deployed alongside the highway and in the median to facilitate crossing by gliding mammals in New South Wales, Australia. (B) Close-up of pole top and remote camera. (Photos: Kylie Soanes, Rodney van der Ree)

Figure. 5.10. Glider pole deployed in the median of a split highway in New South Wales, Australia (Photo: Rodney van der Ree)

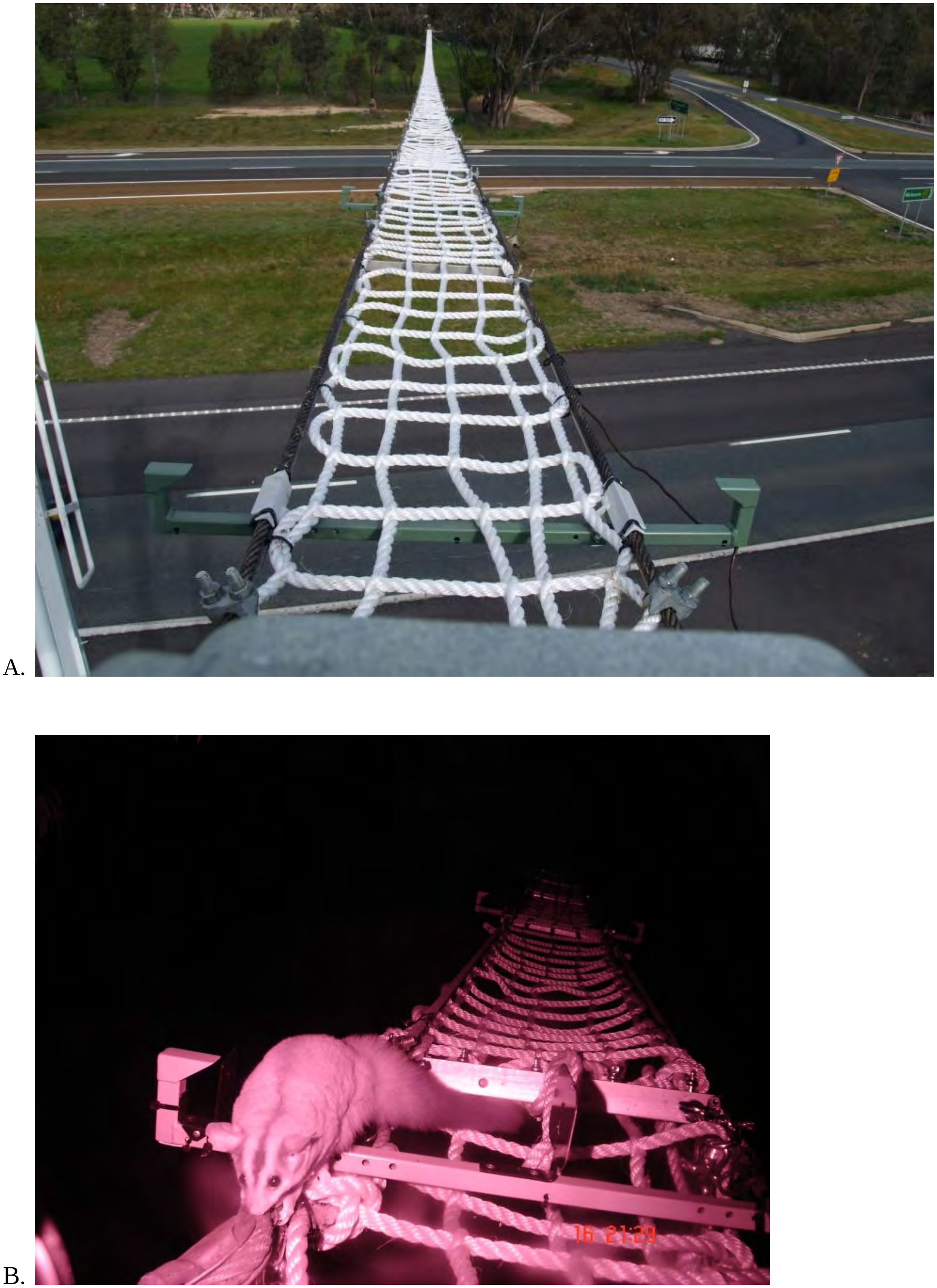


Figure. 5.11. (A) Rope bridge installed across multiple lanes of highway and median in New South Wales, Australia. (B) Squirrel glider (*Petaurus norfolcensis*) at terminus of rope bridge (Photos: Rodney van der Ree)

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Appendices

Appendix 1.1. Common and scientific names of species mentioned in this report.

Names are listed in alphabetical order and were taken from the Smithsonian National Museum of Natural History North American Mammals website (http://www.mnh.si.edu/mna/main.cfm).

Mammals
American black bear (*Ursus americanus*)
American marten (*Martes americana*)
Bobcat (*Lynx rufus*)
Bushy-tailed woodrat (*Neotoma cinerea occidentalis*)
Canada lynx (*Lynx canadensis*)
Cougar (*Puma concolor*)
Coyote (*Canis latrans*)
Deermouse (North American) (*Peromyscus maniculatus*)
Elk (*Cervus elaphus*)
Fisher (*Martes pennanti*)
Gray wolf (*Canis lupus*)
Grizzly bear (*Ursus arctos*)
Long-tailed weasel (*Mustela frenata*)
Montane shrews (Sorex monticolus)
Mountain beaver (*Aplodontia rufa*)
Mountain goat (*Oreamnos americanus*)
Mule deer (*Odocoileus hemionus*)
Northern flying squirrel (*Glaucomys sabrinus*)
Northwestern (Keen's) deermouse (*Peromyscus keeni*)
Pika (*Ochotona princeps*)
Porcupine (*Erethizon dorsatum*)
Raccoon (*Procyon lotor*)
Red-backed vole (*Clethrionomys rutilus*)
River otter (*Lutra canadensis*)
Short-tailed weasel (ermine; *Mustela erminea*)
Snowshoe hare (*Lepus americanus*)
Townsend's chipmunk (*Neotamias townsendii*)
Trowbridge's shrew (*Sorex trowbridgii*)
Vagrant shrew (*Sorex vagrans*).
Voles (*Microtus spp.*)
Wolverine (*Gulo gulo*)

Birds
American dipper (*Cinclus mexicanus*)
Canada goose (*Branta canadensis*)
Northern spotted owl (*Strix occidentalis caurina*)

Appendix 2.1. Summary report from Year 1 I-90 Wildlife Watch project. Note that internal table of contents and pages for figures and tables does not agree with pagination in this larger document.

I-90 Wildlife Watch:

A Summary Report of Year 1 Results

November 2010–November 2011

Prepared by:

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February, 2012

Project partners: I-90 Wildlife Bridges Coaltion, Washington State Department of Transportation, Washington Department of Fish and Wildlife, U.S. Forest Service, and U.S. Fish & Wildlife Service.

Visit: www.i90wildlifewatch.org

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We thank Ron Rundus (jackfig design, Seattle) for designing the gateway page for the website, and Eric Snider (WSDOT) for creating our identity package, billboards, and other outreach materials. We appreciate Amanda Sullivan's (PRR, Seattle) outreach efforts as well.

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I-90 Wildlife Watch Partners

I-90 Wildlife Watch is a collaborative project of the following entities:

MONTANA STATE UNIVERSITY
Western Transportation Institute

I-90 WILDLIFE BRIDGES COALITION
SAFE PASSAGE • HYAK TO EASTON

Washington State Department of Transportation

Washington Department of FISH and WILDLIFE

FOREST SERVICE U S DEPARTMENT OF AGRICULTURE

U.S. FISH & WILDLIFE SERVICE DEPARTMENT OF THE INTERIOR

Friends of I-90 Wildlife Watch

The organizations listed below are official *Friends of I-90Wildlife Watch*, which means that they endorse the program’s mission and help advance its visibility.

Cascade Land Conservancy
Central Washington University
Conservation Northwest
Defenders of Wildlife
Freedom to Roam
Grizzly Bear Outreach Project
The Humane Society of the United States
Mountains to Sound Greenway
Smithsonian Institution National Museum of Natural History
Western Environmental Law Center
The Wilderness Society
TransWild Alliance

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Executive Summary

Washington’s North Cascades Ecosystem (NCE) provides invaluable habitat for wildlife. Landscape-scale habitat connectivity is a critical component of wildlife conservation, with the permeability of road networks and other human development affecting the ability of animals to move and disperse. Interstate 90 (I-90) crosses the NCE at Snoqualmie Pass, where increasing traffic volumes currently average 28,000 vehicles per day. This busy transportation corridor bisects an important link in the north-south movement of wildlife in the Cascades. Washington’s Department of Transportation (WSDOT) is committed to enhancing ecological connectivity in the I-90 Snoqualmie Pass East (SPE) region, and plans to construct 24 wildlife crossing structures along the 15-mile stretch of highway between Hyak and Easton over the next several years. Coupled with wildlife fencing, these structures are intended to facilitate the safe passage of wildlife through the area.

Since 2007, researchers from the Western Transportation Institute (WTI) have been conducting pre-construction wildlife monitoring in the I-90 SPE area such that the effectiveness of the wildlife crossing structures and fencing can ultimately be evaluated. As a complement to these efforts, I-90 Wildlife Watch was launched in late 2010 to engage the public in wildlife monitoring at I-90 SPE. More specifically, motorists are encouraged to report sightings of living and road-killed wildlife on an interactive website developed by WTI. Website visitors can also view observations reported by other travelers. This program, which represents an innovative collaboration between WTI, the I-90 Wildlife Bridges Coalition, WSDOT, and other agency partners, is providing additional baseline data and promoting public participation in regional wildlife/roads issues.

The total survey area for I-90 Wildlife Watch is 41 miles, including the 15-mile section of highway between Hyak and Easton (i.e., the I-90 SPE project area), and the 26-mile stretch from Hyak west to North Bend. The latter section serves as a control area for the I-90 Wildlife Watch program.

This report summarizes Year 1 outcomes for I-90 Wildlife Watch. In its first 12 months, the website received 6,821 visits from all 50 states in the U.S.A. and 29 other countries. The vast majority of visits (83%) originated in Washington. Visitors reported 240 valid (i.e., presumed authentic) wildlife sightings made in the survey area during Year 1, comprising a total of 529 live and dead animals. Sightings included both mammals and birds, with ungulates (i.e., deer and elk) dominating the mammals list. Of 475 mammals reported, 423 were alive and 52 were dead.

The number of reports of live and dead animals in the control area (North Bend to Hyak) and the I-90 SPE project area (Hyak to Easton), respectively, were similar after removing live bird sightings and adjusting for differences in the length of the respective highway sections. The estimate of the number of live animals along the highway in the SPE project area was higher than in the control area, but estimates of the number of dead animals were similar between areas.

Background

The North Cascades Ecosystem (NCE) comprises 24,800 km^2 in Washington, with an additional 10,350 km^2 extending north into British Columbia. In the U.S., 90% of the NCE is managed by the U.S. Forest Service, the U.S. National Park Service, and the State of Washington (Fig. 1). This large network of wildlands provides valuable habitat for wildlife—including rare species such as gray wolves, Canada lynx, and wolverines (Gaines et al. 2000).

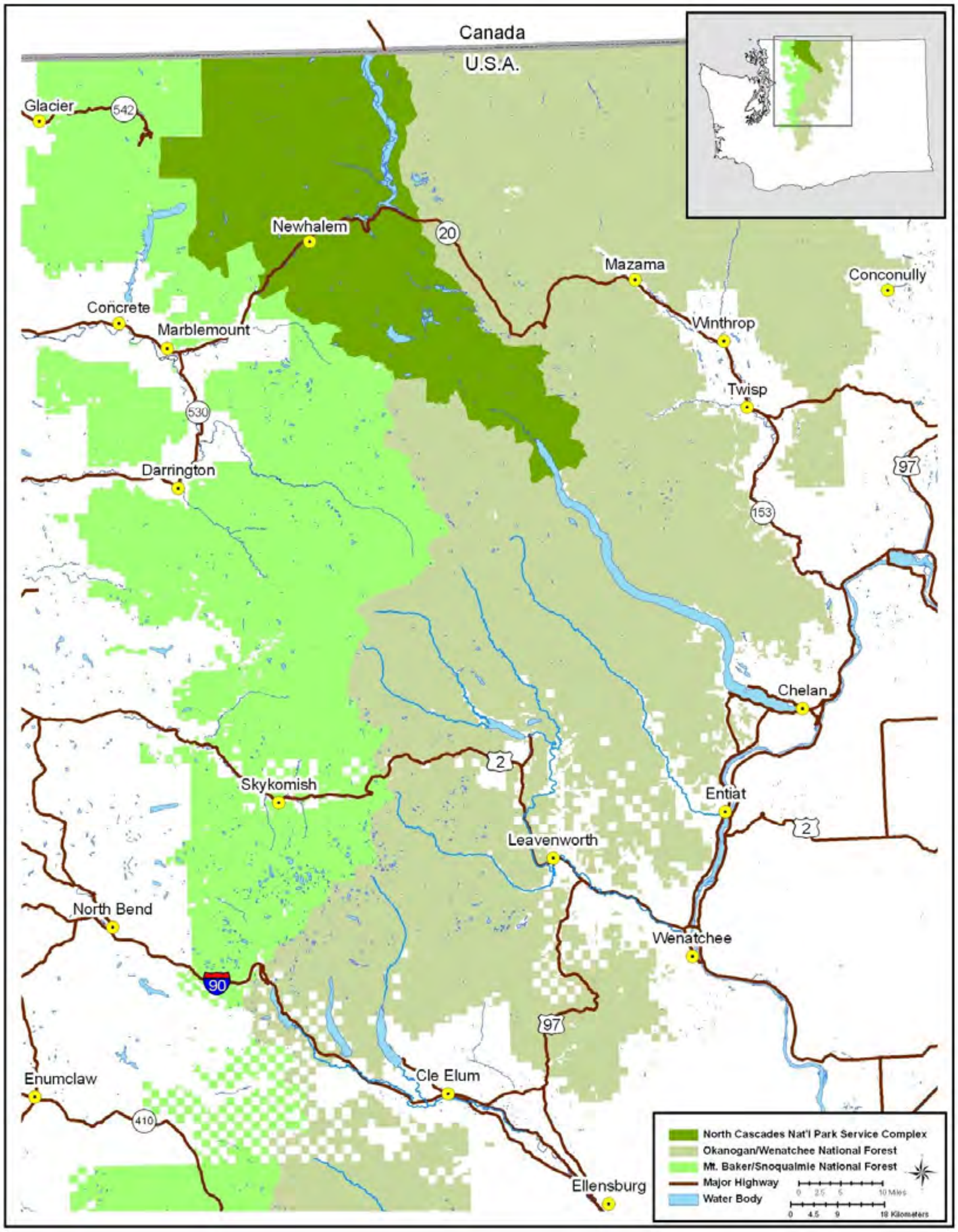


Figure 1. Washington's North Cascades Ecosystem.

Habitat connectivity allows wildlife to move freely across the landscape in search of food, mates, and other resources. Transportation corridors characterized by high road densities and substantial vehicle traffic can result in “fracture zones” that are detrimental to wildlife because they increase mortality and inhibit natural patterns of animal movement (Mace et al. 1996, Noss et al. 1996, Riley et al. 2006) (Fig. 2). This scenario may become especially problematic in the context of climate change, which will require large geographical shifts for certain wildlife populations (Parmesan 2006).

Figure 2. A coyote killed by a vehicle on I-90.
Credit: Robert Long/WTI.

Wildlife Monitoring at I-90 Snoqualmie Pass East

In Washington, Interstate 90 (I-90) crosses the NCE at Snoqualmie Pass, where traffic volumes average 28,000 vehicles per day and are increasing by ~2.1% per year (WSDOT 2008). I-90 bisects an important link in the north-south movement of wildlife in the Cascades (Singleton et al. 2002, Shirk 2009). As part of a major highway improvement project, the Washington State Department of Transportation (WSDOT) is committed to enhancing ecological connectivity in I-90’s Snoqualmie Pass East (SPE) region, and has begun construction on the first 3 of 24 wildlife crossing structures planned for the 15-mile stretch between Hyak and Easton (Figs. 3, 4).

Figure 3. Visual concept of a wildlife crossing structure near I-90 Snoqualmie Pass East. Credit: WSDOT

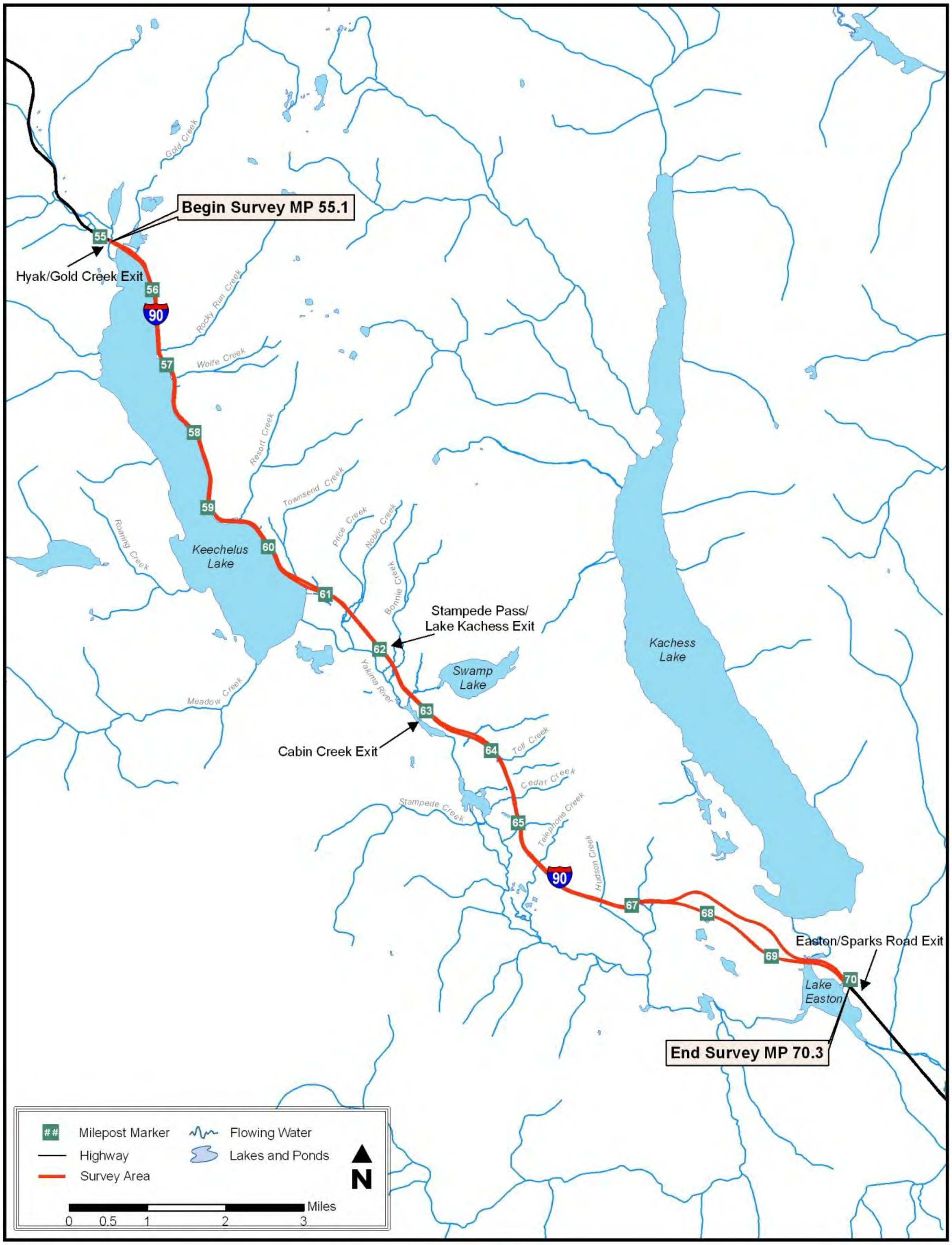


Figure 4. Map of 15-mile stretch of I-90 between Hyak and Easton.

Since 2007, researchers at the Western Transportation Institute (WTI) have been using remote cameras and other wildlife survey methods to gather pre-construction baseline data on wildlife movement in the I-90 SPE area such that the effectiveness of future crossing structures and associated wildlife fencing can be evaluated (Fig. 4). We also collaborate with WSDOT maintenance personnel to compile roadkill data with the Roadkill Observation Data Collection System (ROCS) designed by WTI. In 2010, I-90 Wildlife Watch was initiated to complement WTI's existing monitoring efforts, as well as other citizen-based and academic monitoring programs at I-90 SPE. This program, which represents an innovative partnership between WTI, the I-90 Wildlife Bridges Coalition, WSDOT, and other agency partners, is providing additional baseline data and promoting public participation in wildlife/roads issues.

In summary, the objectives of I-90 WILDLIFE WATCH are to:

1. engage citizens in wildlife monitoring at I-90 SPE;
2. inform planning for wildlife crossing structures and fencing at I-90 SPE;
3. provide additional baseline data for the future evaluation of crossing structure performance at I-90 SPE;
4. contribute to rare species management in the NCE;
5. serve as a model project for other regions.

The I-90 Wildlife Watch Website

To bring I-90 Wildlife Watch to fruition, WTI developed a website-based database (www.i90wildlifewatch.org) that allows citizens to report sightings of roadkill *and* live animals in the I-90 SPE area (Fig. 5). Observers can choose to remain anonymous. WTI had previously developed websites for similar citizen-based monitoring programs in 3 other regions (Blaine Country, Idaho; I-70 in Colorado; Bozeman Pass, Montana). The I-90 Wildlife Watch website includes a brief observation form (Fig. 6) intended to capture sighting information, and a detailed locator map that enables visitors to pinpoint sighting locations and to view observations from other observers (Figs. 7, 8).

Recent News

I-90 Wildlife Watch on billboard in Seattle
I-90 Wildlife Watch celebrates its first year
Several dead elk reported west of the Pass
I-90 Wildlife Watch in the news
Watch out for wildlife after road closures

Do you drive the Pass on a regular basis?

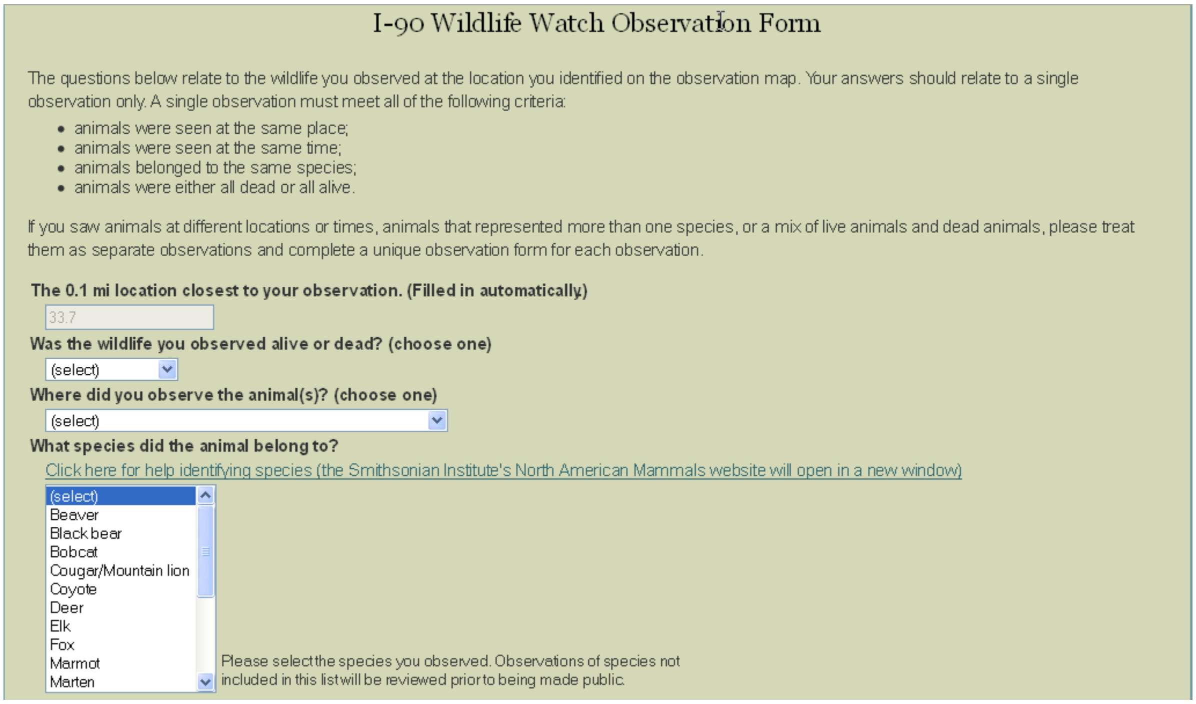
Welcome to I-90 Wildlife Watch

I-90 Wildlife Watch is a citizen-based wildlife monitoring project that invites motorists to report wildlife sightings along Interstate 90 (I-90) in the Snoqualmie Pass region of Washington.

Why is it important to collect this information?

I-90 intersects the rugged Cascade Mountains in Washington's Snoqualmie Pass region, which has been identified as a critical link in the north-south movement of wildlife. This area is also the focus of an extensive effort by the Washington State Department of Transportation to improve highway efficiency and make I-90 safer for people and wildlife. The I-90 Wildlife Bridges Coalition, the Western Transportation Institute, and other I-90 Wildlife Watch partner organizations are currently gathering information about wildlife between North Bend and Easton to help inform highway planning at Snoqualmie Pass. With your valuable assistance, we hope to reduce wildlife-vehicle collisions and enhance the safe passage of wildlife in the future.

Figure 5. The gateway page from the I-90 Wildlife Watch website.



I-90 Wildlife Watch Observation Form

The questions below relate to the wildlife you observed at the location you identified on the observation map. Your answers should relate to a single observation only. A single observation must meet all of the following criteria:

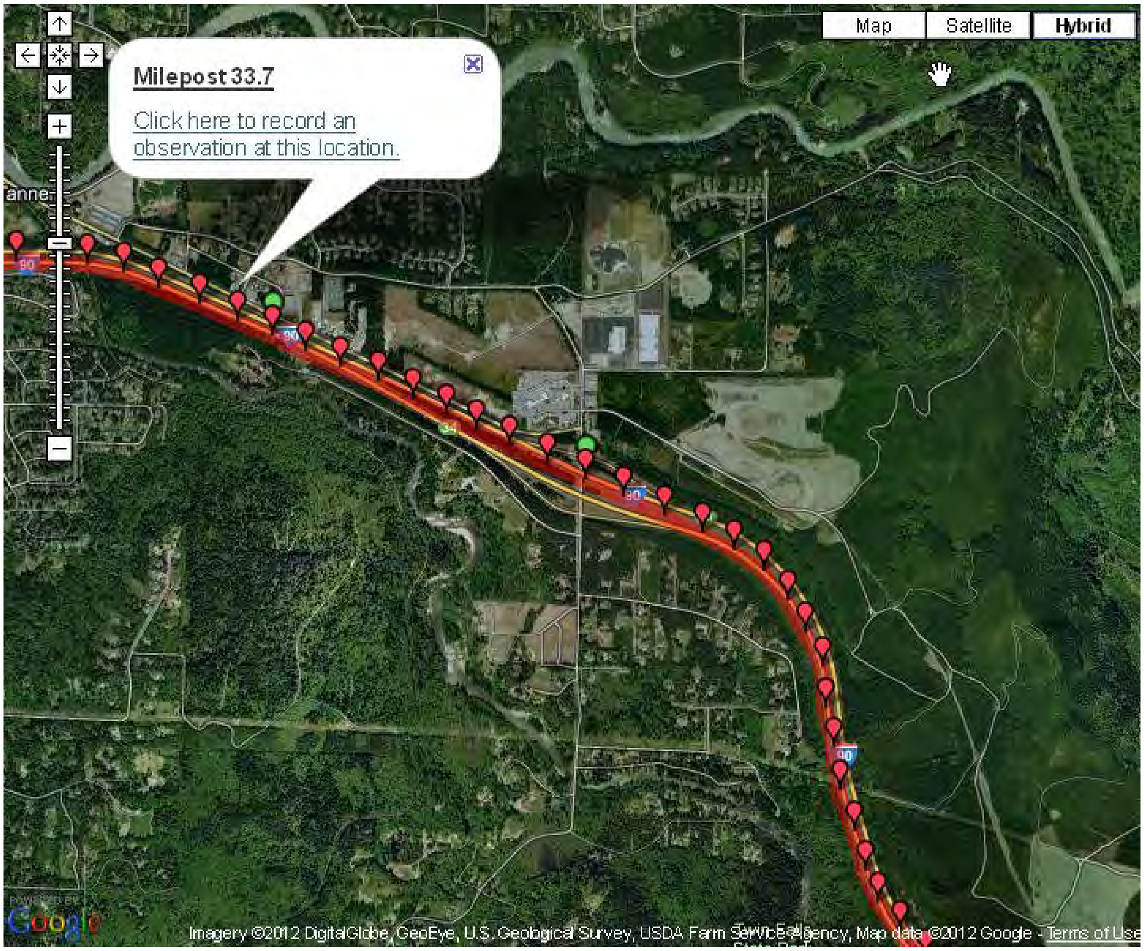
- animals were seen at the same place;
- animals were seen at the same time;
- animals belonged to the same species;
- animals were either all dead or all alive.

If you saw animals at different locations or times, animals that represented more than one species, or a mix of live animals and dead animals, please treat them as separate observations and complete a unique observation form for each observation.

The 0.1 mi location closest to your observation. (Filled in automatically)
33.7
Was the wildlife you observed alive or dead? (choose one)
Where did you observe the animal(s)? (choose one)
What species did the animal belong to?
Click here for help identifying species (the Smithsonian Institute's North American Mammals website will open in a new window)

Please select the species you observed. Observations of species not included in this list will be reviewed prior to being made public.

Figures 6. The observation form from the I-90 Wildlife Watch website.



Milepost 33.7

Click here to record an observation at this location.

Figures 7. The locator map from the I-90 Wildlife Watch website.

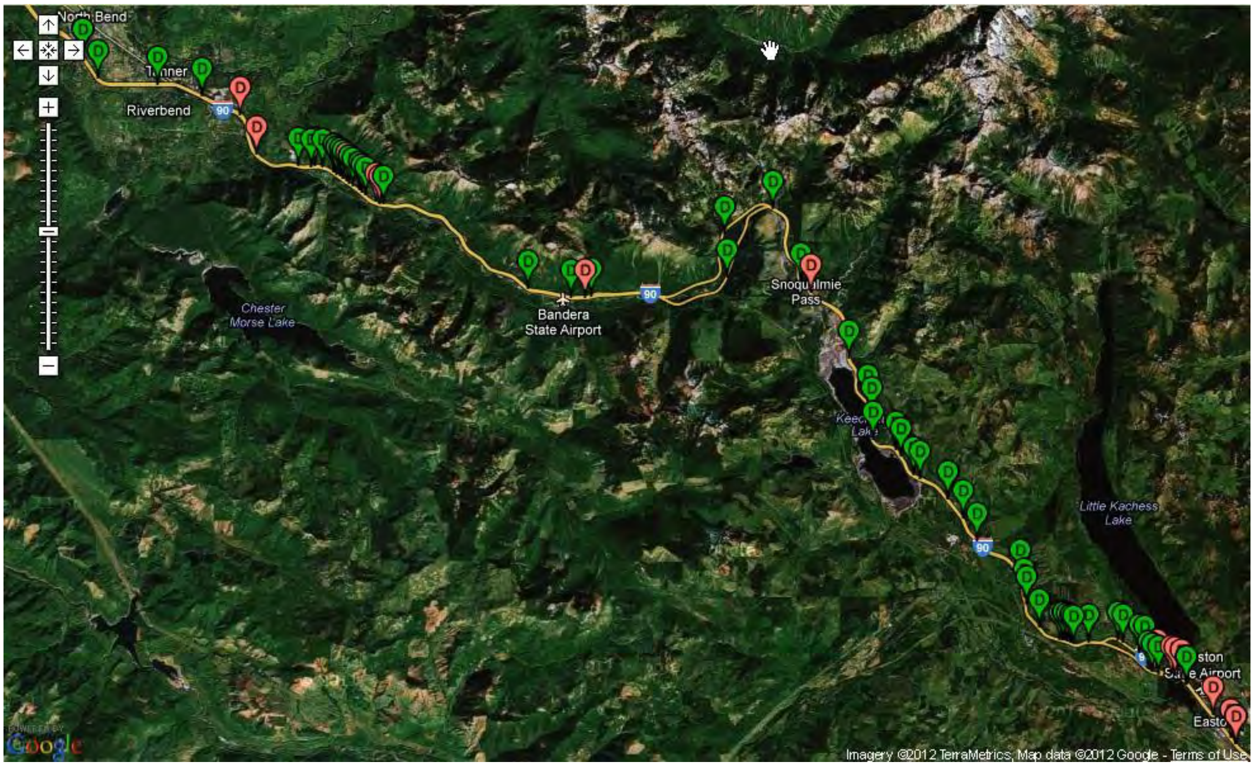


Figure 8. Website interface allowing visitors to view observations (in this case, of deer) reported by other travelers. Green markers indicated live animals; red markers indicate roadkill.

Control Area versus I-90 SPE Project Area. One of our objectives is to provide additional baseline data for evaluating the effectiveness of future crossing structures and fencing at reducing roadkill between Hyak and Easton. When attempting to evaluate change, it is beneficial to include a comparative stretch of highway to serve as a control area. Such controls permit stronger conclusions because they can help to identify broader patterns of change that might confound interpretations if results are taken only from the project area. For example, if deer roadkill rates decrease by 95% after crossing structures are installed, how can we be sure that this trend isn't due to a decline in deer populations throughout the region? I-90 Wildlife Watch includes the 26-mile section of I-90 (Hyak to North Bend) immediately west of the I-90 SPE project area to serve as a control area. The total survey area for I-90 Wildlife Watch is 41 miles.

Volunteers. Citizen reporting programs often find it challenging to quantify the amount of survey effort expended. Without such effort estimates, it is difficult to compare among different time periods or locations. Because we are interested in collecting baseline data that will be useful for comparing rates of live and dead wildlife along I-90 SPE before and after wildlife crossing structures and fencing are installed, we explored a data collection approach that would permit statistical comparisons between time periods. More specifically, we recruited several volunteers who drove I-90 on a consistent basis (i.e., 1–2 times per week) to report their wildlife observations. In addition to reporting live and dead wildlife, these volunteers also recorded trips during which they saw no wildlife. Volunteer observations of alive and dead individuals were modeled with a Poisson distribution and used to calculate Bayesian estimates of individual observation rates and associated confidence intervals for volunteers driving the survey route. Estimated rates can potentially be compared with similarly collected, post-construction rates.

Outreach

Numerous strategies were employed to inform motorists about the launch of I-90 Wildlife Watch, and to increase public awareness about the program throughout its first year. The results of these efforts are described in the Results section of this report. Outreach methods are summarized briefly below.

Building Project Identity

During website development, we contracted an independent graphic designer to design the gateway page, and to establish the site's style, color scheme, logo, and banner (Fig. 9). We then provided these elements to the technical development team at WTI such that the website would have a consistent look and feel throughout.

Figure 9. Logo and banner from I-90 Wildlife Watch website.

Soon after the project was launched, we further developed the identity package for I-90 Wildlife Watch. Key features were incorporated into all outreach materials. The American marten was selected as a charismatic wildlife ambassador to help brand the program (Fig. 10.)

Figure 10. The I-90 Wildlife Watch business card, featuring an American marten and other branding elements.

Media Communications

To officially launch I-90 Wildlife Watch, we distributed a press release to regional media outlets. We selected a launch date of November 4, 2010, to coincide with “Give Wildlife A Brake” week—a national campaign coordinated by the Humane Society of the United States. The story was picked-up by numerous media outlets, including the *Seattle Times* (Box 1). Announcements were also posted on partner websites and blogs, and the program was profiled in various other electronic venues as well (Box 1).

Box 1. Examples of media promoting I-90 Wildlife Watch

Press release: New project is launched to document wildlife sightings along I-90
November 4, 2010

Drivers encouraged to report wildlife on I-90 over Snoqualmie Pass
Seattle Times, November 4, 2010

New website lets drivers track wildlife along stretch of I-90
Seattle Times, November 6, 2010

I-90 Wildlife Watch
KOMOnews.com (radio), November 6, 2010

New web site tracks I-90 roadkill
TechFlash, November 8, 2010

Heading over I-90 Snoqualmie Pass? Keep your eyes peeled for critters big or small
WSDOT Blog, November 10, 2010

Wildlife sightings wanted from drivers on I-90
Northwest Public Radio, November 22, 2010

Help map wildlife crossings as you drive I-90 east of Snoqualmie in WA
National Geographic Global Action Atlas, March 2011

Watching for wildlife on I-90
Fall City Newsletter, April 2011 (page 4)

I-90 project to ease flow of traffic, wildlife east of Snoqualmie Pass
Seattle Times, July 7, 2011

Volunteers keep eye on wildlife along Interstate 90
Ellensburg Daily Record, July 26, 2011

We made periodic efforts to update media contacts throughout the Spring, and a second press release was distributed in July, 2011. Meanwhile, in March 2011, we broadly circulated an article about I-90 Wildlife Watch to regional newsletters, several of which published the piece (Box 1). Also in March, Defenders of Wildlife circulated an action alert to its Washington-based members. During late Summer/Fall 2011, we ran 42 PSAs on Northwest Public Radio. And an ongoing blog on the I-90 Wildlife Watch website allowed us to share periodic news with visitors.

Volunteer Recruitment

Volunteer commuters (see *Volunteers* above) were recruited by a variety of means. For example, Conservation Northwest, the umbrella organization for the I-90 Wildlife Bridges Coalition, circulated an announcement to its members. WTI notified contacts and project partners, who were asked to help spread the word. We posted flyers at a few targeted locations, and placed free ads in regional newspapers and on Craigslist. Lastly, we placed a recruitment "button" on the gateway page of the website. Once selected, volunteers were trained in how to use the volunteer interface of the website via a 1-hour telephone training with WTI personnel.

Billboard

In early March 2010, we leased a billboard (Fig. 11) on the westbound side of I-90 in Cle Elum, approximately 12 miles east of the project area. This high-profile billboard, which remains in place as of the date of this report, is within easy view of all motorists traveling toward Snoqualmie Pass from eastern Washington.

Figure 11. I-90 Wildlife Watch billboard on I-90 near Cle Elum.
Credit: P. MacKay/WTI

Print Materials

Dozens of I-90 Wildlife Watch posters (Fig. 12) were hung on public bulletin boards along the I-90 corridor in eastern and western Washington, and in the greater Seattle area. I-90 Wildlife Watch business cards (Fig. 10) were also displayed at public venues and regional conferences. Finally, WSDOT incorporated I-90 Wildlife Watch into its displays at select rest areas.

American marten
Photo courtesy of Tom Cottrell 2010

In the Snoqualmie Pass region of Washington, I-90 intersects an important wildlife corridor for animals moving north and south through the Cascades. I-90 Wildlife Watch invites motorists to report wildlife sightings along I-90 between North Bend and Easton. The data collected from this project will help inform current transportation planning efforts to reduce wildlife-vehicle collisions and enhance habitat connectivity near I-90 Snoqualmie Pass.

For more information about I-90 Wildlife Watch, to view wildlife observations made by others, and to report a wildlife sighting yourself, please visit **www.i90wildlifewatch.org**.

Printed on 100% recycled paper

Figure 12. I-90 Wildlife Watch poster.

Results and Discussion

Google Analytics indicated that there were 6,821 visits to the I-90 Wildlife Watch website between November 4, 2010 and November 4, 2011—including visits by 5,352 unique visitors. Site visitation was highest immediately after the program launched (Fig. 13), and spiked again with outreach boosts in March and July, 2011.

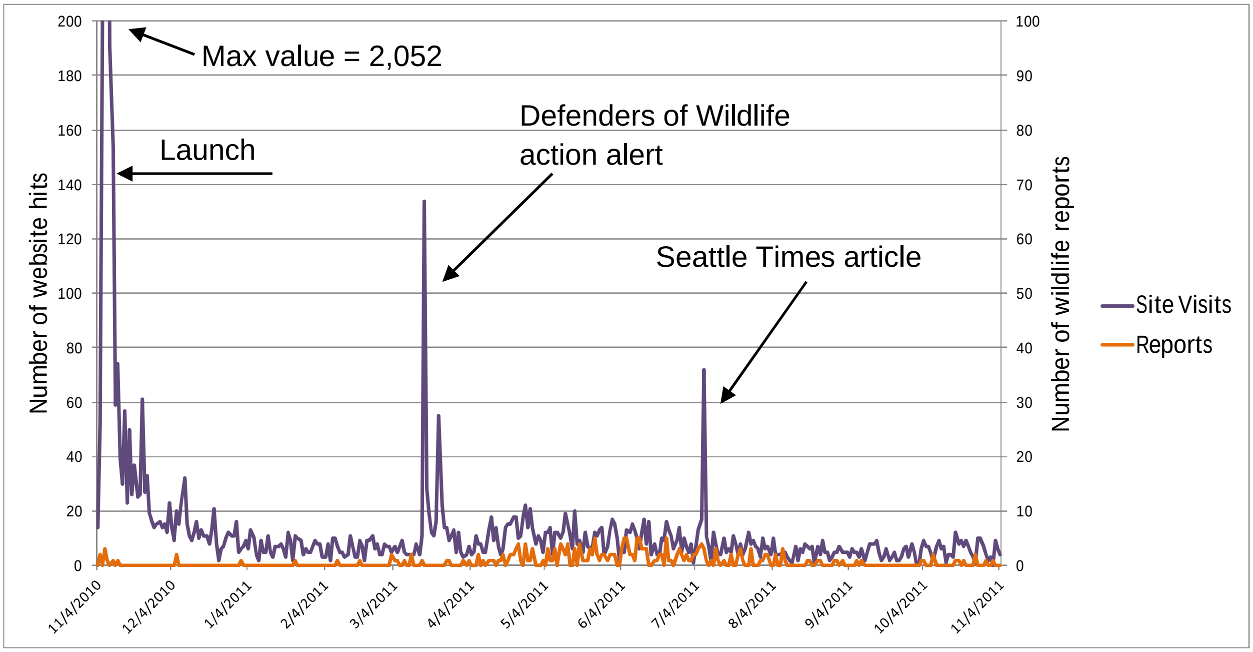


Figure 13. Number of visits to the I-90 Wildlife Watch website (blue) and wildlife reports (red) in Year 1.

Visits were reported from all 50 states of the U.S.A. and 29 other countries, with 5,627 visits (~83%) originating in Washington. Of Washington visits, ~25% were made from Seattle (Table 1). The remaining 75% of Washington visits were made from locations across the state (Fig. 14).

Table 1. Top 10 Washington cities from which website visits were documented. Source: Google Analytics

City	Visits	% Visits
Seattle	1,697	24.88%
Bellevue	418	6.13%
Spokane	307	4.50%
Ellensburg	242	3.55%
Kirkland	212	3.11%
Redmond	210	3.08%
Olympia	166	2.43%
Lynnwood	154	2.26%
Yakima	151	2.21%
Renton	134	1.96%

Figure 14. Locations of Washington-based visitors to the I-90 Wildlife Watch website. Source: Google Analytics

Wildlife Reports

The I-90 Wildlife Watch website received 268 reports during Year 1. Of these, 9 were sightings made prior to the project's launch, 7 were made outside of the survey area, and 12 were deemed fraudulent or otherwise invalid (e.g., Bigfoot, John Deere). Thus, we received a total of 240 valid reports of live and dead wildlife sighted between North Bend and Easton in the first 12 months of the program (Fig. 15). Note that many sightings included multiple individuals of the same species (e.g., deer).

For some analyses, it was important to identify reports that were likely duplicates (i.e., 2 or more reports of the same sighting). We assumed that any 2 reports of live individuals were duplicates if their locations were ≤ 0.2 mile apart and they occurred within 2 hours of each other. Similarly, we assumed dead reports were duplicates if the locations were ≤ 0.2 mile apart and they occurred within 48 hours of each other. Applying these rules, we eliminated 2 reports of live animals (4 individuals), and 9 reports of dead animals (9 individuals).

After an initial spike in reports following the program launch, relatively few reports were recorded during Winter 2010–2011 (Fig. 13). Reporting rates increased during Spring 2011, and were highest during late-Spring and Summer 2011 (Fig. 13). This trend generally corresponds with the period during which ungulates are most prevalent throughout the project area, although outreach efforts in March may have helped to increase the number of reports logged in the Spring (Fig. 13). Mammals and birds were the only species groups reported, and reports of live animals greatly outnumbered reports of dead animals (Table 2).

Table 2. Summary of live and dead individuals reported by species group (i.e., mammals, raptors, other birds, unknown group).

	Alive	Dead	Total
Mammals	423	52	475
Raptors	19	6	25
Other birds	23	4	27
Unknown	0	2	2
Total	465	64	5

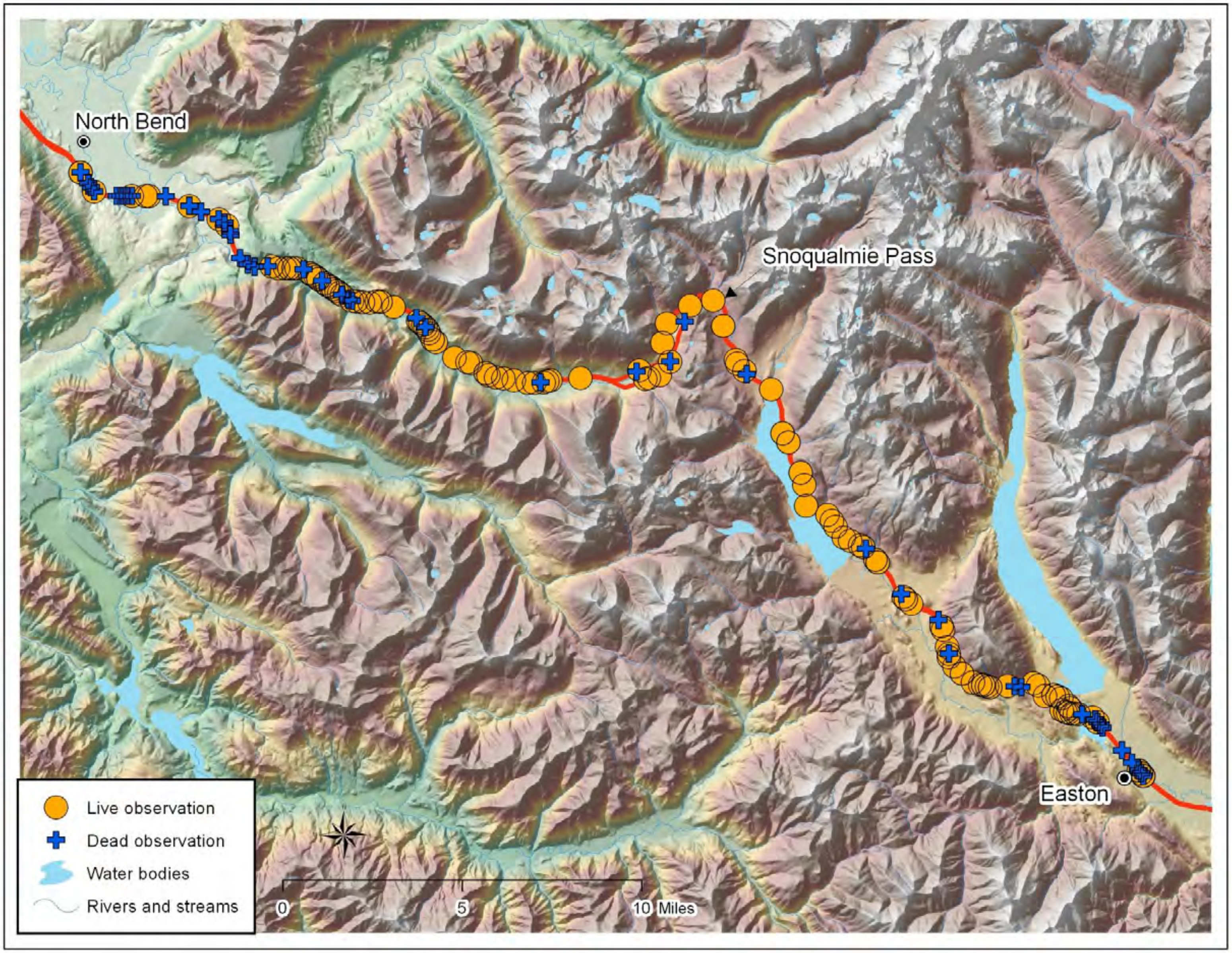


Figure 15. Locations of live and dead wildlife reports (excluding live bird sightings) across the I-90 Wildlife Watch area.

In sum, website visitors reported 529 individual animals (465 live, 64 dead). After we removed 4 live and 9 dead duplicate records from the dataset, the total number of individual animals reported was 516 (461 live; 55 dead). These reports represented 14 mammal species—including deer, elk, black bear, cougar, bobcat, coyote, otter, and others—as well as several bird species (Fig. 16, 17; see Appendix 1 for a summary of all valid reports).

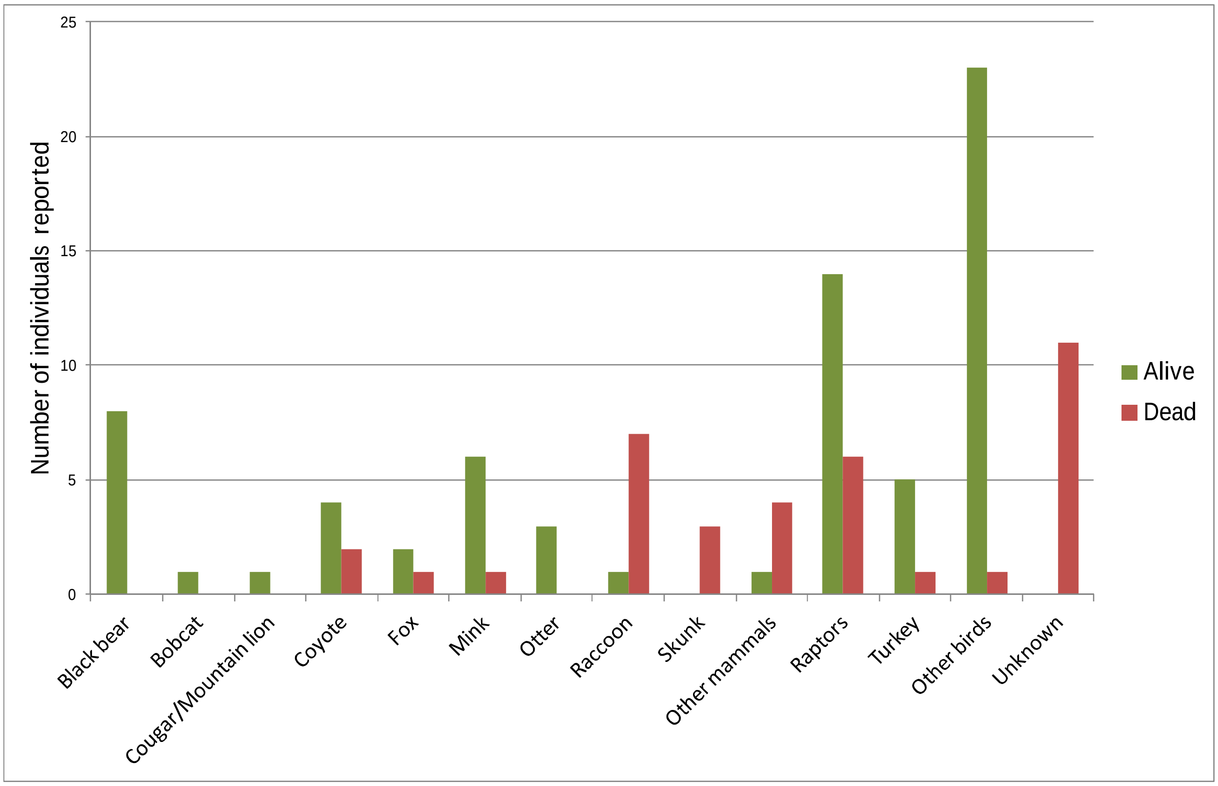


Figure 16. Number of individual animals (excluding deer and elk—see Fig. 17) reported by species or species group, duplicates removed.

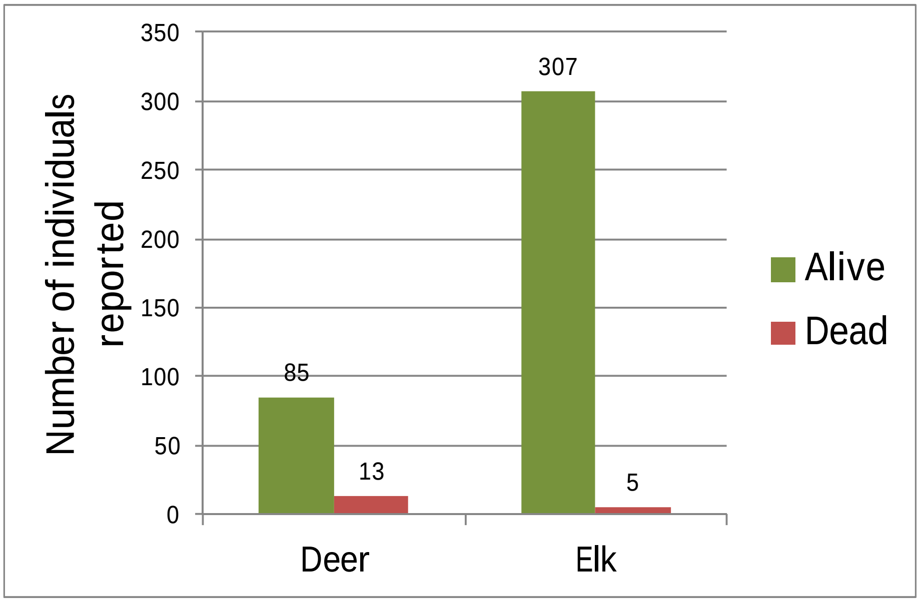


Figure 17. Number of reported deer and elk (duplicates removed).

Excluding live birds and duplicate reports, which we omitted from these analyses, most live animal sightings were clustered along the valley from North Bend east to about Exit 45 near the Bandera State Airport, and from Exit 63 (Cabin Creek) east to Easton. Another cluster occurred near Keechelus Lake dam.

Excluding duplicates, a total of 55 dead animals were recorded throughout the survey area, yielding an estimated rate of 1.34 individuals/mile (95% CI = 0.99–1.69) (Figs. 18, 19). Given the large survey area, our small sample size makes it difficult to draw any strong conclusions about hotspots for wildlife-vehicle collisions. In general, however, there were 2 regions where roadkill were recorded in the highest numbers: (1) the broad, relatively low elevation area east of North Bend, near the convergence of the Middle and South Forks of the Snoqualmie River; and (2) an area at the lowest elevation point east of Snoqualmie Pass extending from Easton Lake to the end of the project area near the town of Easton. Multiple species, including coyote, porcupine, and deer, were reported in both areas. Dead elk were reported only in the area east of North Bend, and skunks were reported only in the Easton location. We stress again, however, that small sample sizes make it impossible to make any solid inferences from these observations.

In the mammals group, the respective numbers of dead ungulates (deer and elk) and carnivores reported were almost equal (Table 3), while ungulates represented the majority (85%) of live mammal sightings. This would be expected given that ungulates congregate in groups, whereas carnivores are often solitary or occur in smaller groups. Further, carnivores tend to be more wary, and presumably spend less time near the roadway and behave more elusively when they do approach it. All dead carnivores reported were mesocarnivores (as opposed to large carnivores such as bears, mountain lions, and wolves), and included raccoons (n=7), coyotes (n=2), skunks (n=3) a fox, and a mink.

Table 3. Number of reported live and dead mammals (excluding duplicates), by species group.

	Alive	Dead	Total
Carnivore	26	14	40
Ungulate	393	19	412
Other	42	15	57
Unknown	0	7	7
Total	461	55	516

When motorists reported sightings on the website, they had the option to expand upon their observations by providing comments. Some of the comments submitted during Year 1 yielded useful information about the behavior of animals moving near or across the roadway—information that may not otherwise have been captured (Box 2).

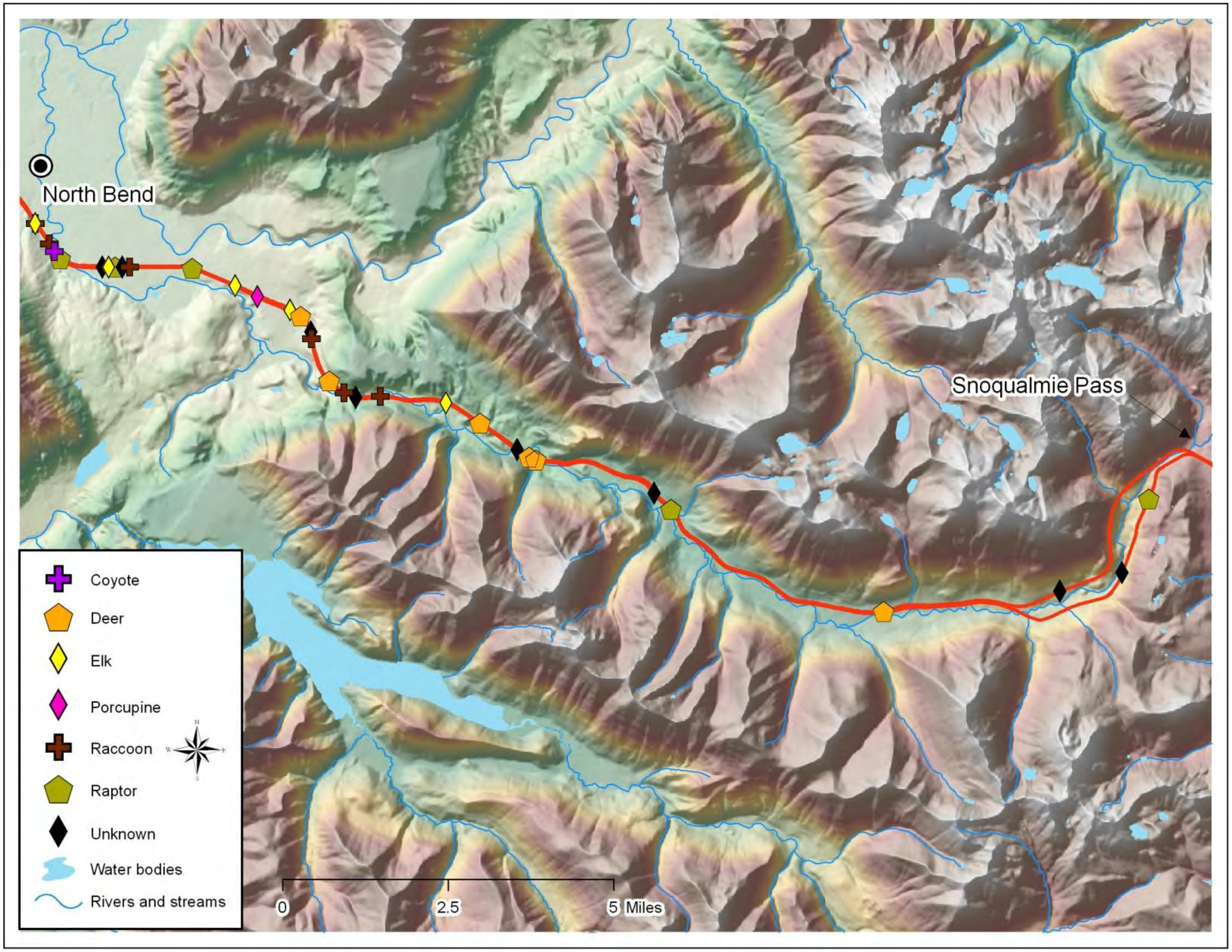


Figure 18. Locations of dead wildlife reports (duplicate reports removed) in the western portion of the survey area, from North Bend to Snoqualmie Pass.

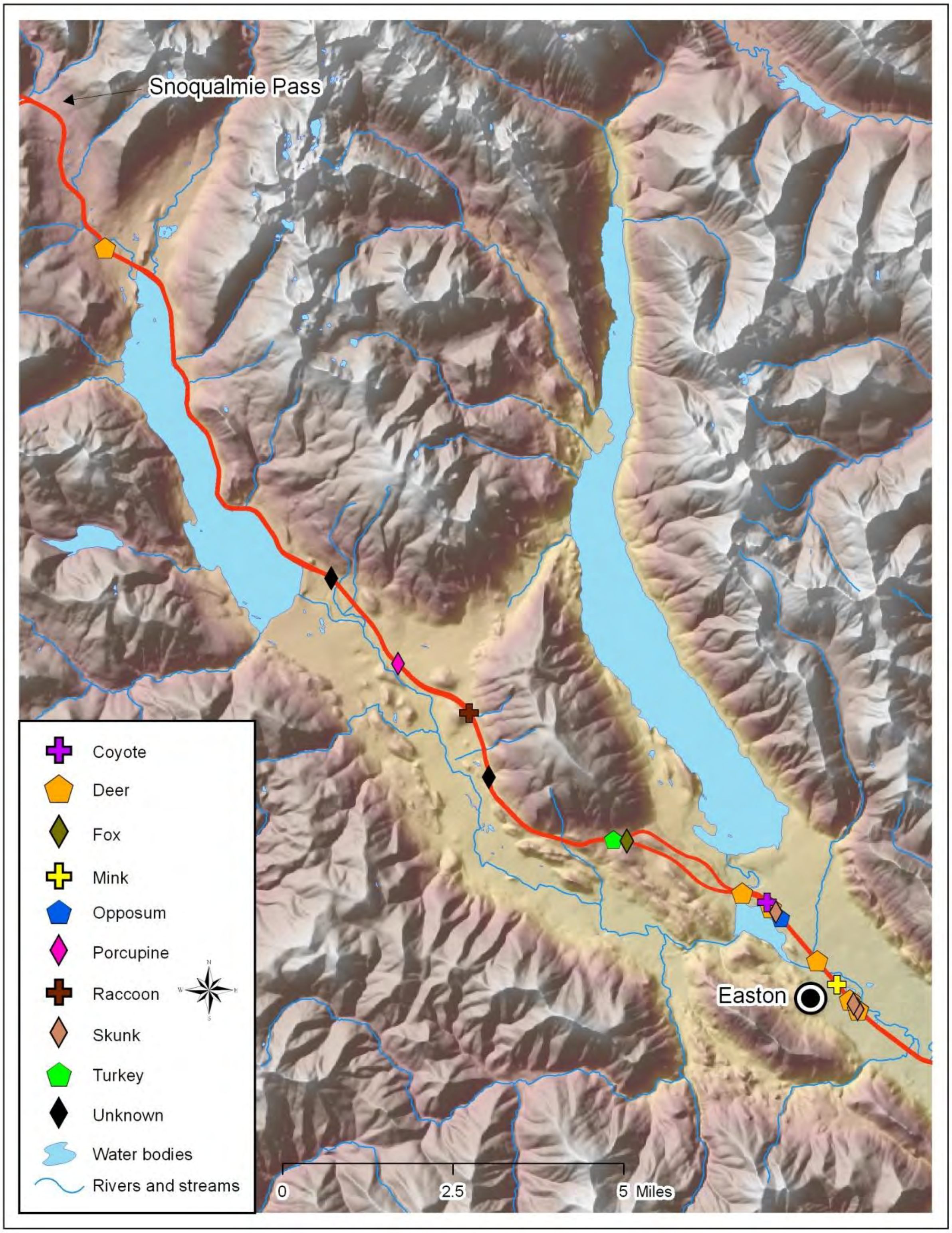


Figure 19. Locations of dead wildlife reports (duplicate reports removed) in the eastern portion of the survey area, from Snoqualmie Pass to Easton.

Box 2. Examples of comments submitted with wildlife reports

Bobcat bounded across the road in front of traffic, was really glad it wasn't hit!

The bear came running out from the side of the road out of the bushes, stopped in the second lane briefly, then turned and ran westbound in the road for 50 feet then ran back to the side of the road, then ran another 30 or 40 feet along the side of the road before I lost visual.

There were two bucks on so. side trying to cross. One turned back around the other crossed in front of us as we were doing a slow down for blasting. The one that crossed to the north, ran through the snow park.

Large female Elk, started in the median, came out onto the road way clear to the right lane before turning back and heading back into the median. My driver's side mirror barely clipped her rear end, just enough to fold my mirror back in towards my door which I adjusted back out afterwards.

Heavy traffic at this time westbound. Deer seemed to be scanning the traffic and looking for a way out (not to personalize, but little options and eyes and head were scanning back and forth). East end of the snowshed.

Spotted between MP40-42, 7:58 to 8:00pm. Animal [coyote] *crossed under guard rail on south side of WB I-90, crossed median, crossed EB, then off shoulder to the south, focusing only straight ahead, never looking at traffic. I had to slow slightly to avoid striking it. I thought only coyote with speckled coat. A passenger wondered out loud about 'wolf', thinking it was large for a coyote.*

It looked like they [elk] *were grazing alongside of the metal traffic barrier. It would have been very dangerous if not tragic if they attempted to cross the highway. With their size the barrier probably wasn't stopping them. thanks for representing the needs of the wildlife around the area.*

It [coyote] *was standing on a snow berm within several feet of the shoulder, but seemed interested in something in the snow there. It stood parallel to or facing slightly from the road and only glanced sideways at the traffic--I think there was a guard rail for the off-ramp between it and the road. Didn't appear interested in crossing the highway, at any rate.*

a young black bear crossing the freeway to get to Lake Kacheless

2-3 does, with 2-3 young, crossing all 6 lanes from north to south. Light traffic, no hits.

Control Area versus I-90 Snoqualmie Pass East Project Area

The number of reports of live and dead animals in the control area (North Bend to Hyak) and the I-90 SPE project area (Hyak to Easton) were surprisingly similar after removing live bird sightings (n=11, North Bend to Hyak; n=9, Hyak to Easton)—live bird sightings are interesting but difficult to interpret—and standardizing by dividing the number of reports by the number of miles in the area (Fig. 20). The estimated number of dead animals per mile was also similar between areas (Fig. 21). These rates will be important for ultimately evaluating the effectiveness of wildlife crossing structures and fencing at reducing roadkill. For example, because the rate of reported numbers of dead animals was similar between areas, a detected change in the post-construction rate of dead animals reported in the I-90 SPE project area without a corresponding change in the reported number of dead animals in the control area would potentially suggest that fencing and crossing structures were affecting roadkill rates. The ability to statistically detect a difference between pre- and post-construction of crossing structures, however, will ultimately depend on the number of reports submitted during post-construction roadkill surveys.

The estimated number of live animals along the highway in the I-90 SPE project area was higher than in the control area (Fig. 21). However, this result may have been caused by a few reports of large elk groups near Easton Hill—reports which likely included some of the same animals sighted at different times or locations. Because there is no way to confirm unique individuals in this research effort, the rates of live animals reported are unreliable for estimating actual numbers of animals using the I-90 Wildlife Watch project area.

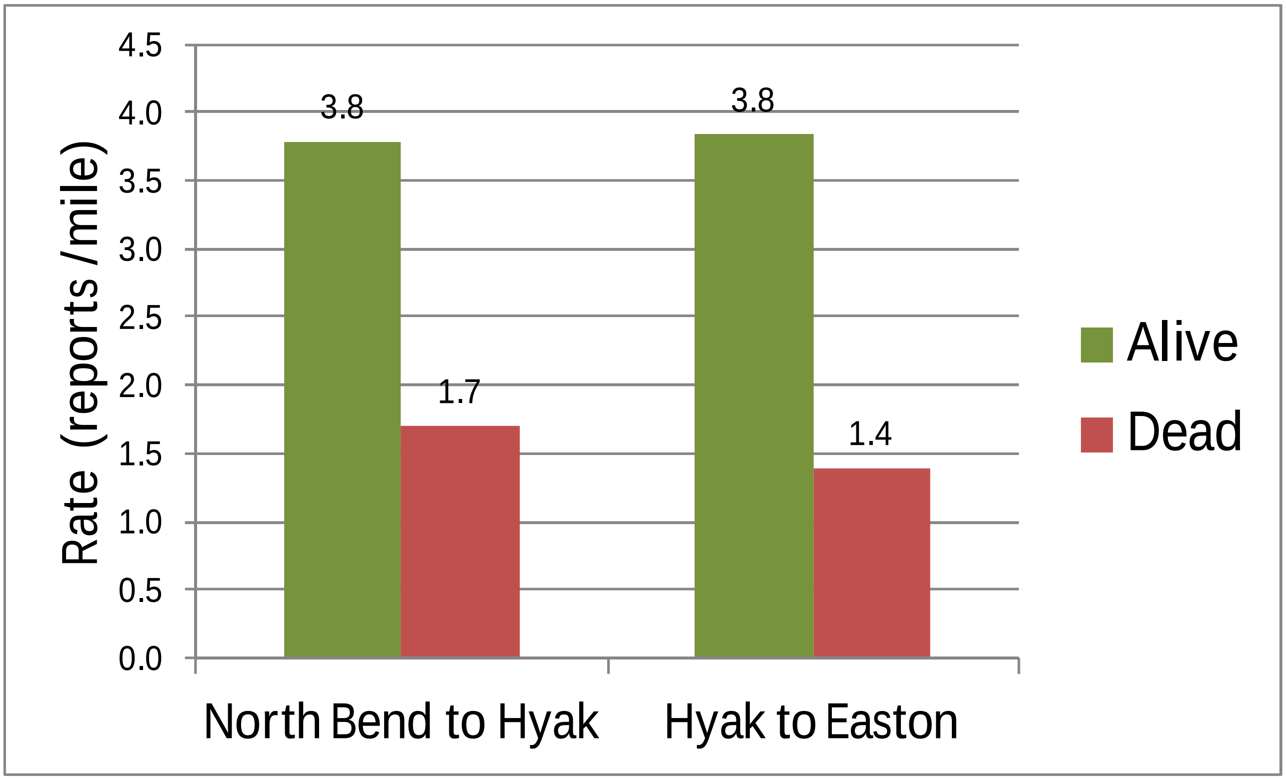


Figure 20. Actual rates of wildlife reports (reports/mile) of dead and live animals (excluding live birds) for the control area (North Bend to Hyak) and I-90 SPE project area (Hyak to Easton).

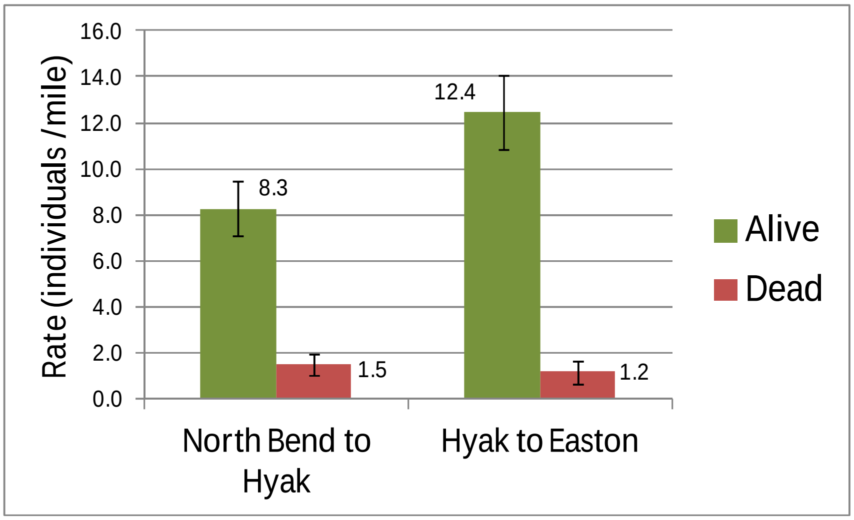


Figure 21. Poisson-based estimates and 95% confidence intervals for the number of live and dead wildlife individuals (excluding live birds and duplicates) per mile for the control area (North Bend to Hyak) and the I-90 SPE project area (Hyak to Easton).

Most reports were made under “good” driving conditions, with fewer recorded under “moderate” or “poor” conditions (Fig. 22). Note that the “poor” conditions category included all periods of darkness, when travelers would have been much less likely to observe small dead animals on the roadway or (live or dead) animals near the roadway.

<u>Volunteer Data</u>

Seven volunteers drove a combined total of 22,859 miles within the survey area, contributing 73 reports totaling 100 individual animals (live=65, dead=35). After removing miles driven in poor visibility (n=5,402) and live bird sightings (n=19), Bayesian estimates of reporting rates for live and dead individuals were 0.003 individuals/mile (95% credible interval = 0.002–0.003) and 0.002 individuals/mile (95% credible interval = 0.001–0.003), respectively. Assuming a similar effort is undertaken after wildlife fencing and crossing structures are in place, such rates—compared between time periods and between the control and I-90 SPE project areas—will contribute to post-construction evaluations of structure effectiveness.

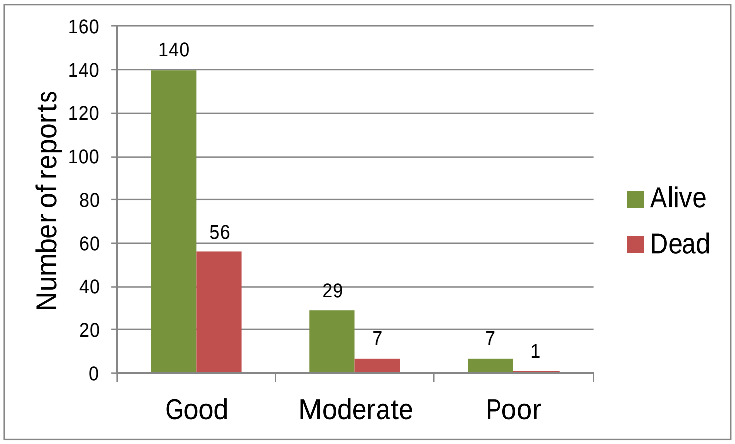


Figure 22. Visibility conditions under which observations were made.

Conclusion

I-90 Wildlife Watch was designed to harness the potential of motorists to gather information about wildlife movement in the I-90 SPE area, while also engaging the public in important conservation issues surrounding wildlife and roads. In Year 1, we achieved measurable success in developing a user-friendly website for acquiring wildlife observation data, attracting thousands of visitors to the website, and receiving 240 valid reports of live and dead wildlife sightings between North Bend and Easton. Although data of this nature should be treated judiciously—for example, animals observed by citizens traveling at high-speed along a busy highway may be prone to being misidentified—they are nonetheless a valuable complement to other wildlife monitoring efforts associated with the I-90 SPE project.

Given the success of I-90 Wildlife Watch in Year 1, we have decided to continue the project for at least one more year. Outreach will remain critical in Year 2 as we strive to maximize the number of motorists who know about and use the website. In addition to distributing print materials throughout the region, soliciting media coverage, and promoting I-90 Wildlife via billboards and WSDOT displays, we will explore other innovative opportunities for enhancing the visibility of the program. For example, we hope to reach out to truck drivers and other professionals whose work requires regular travel on I-90. As road signage on the survey route itself would be extremely helpful, we're also hoping that WSDOT will be able to advertise I-90 Wildlife Watch on its variable message signs in the future.

A second year of data will allow us to better evaluate whether reporting patterns that emerged in Year 1 (e.g., increased wildlife reports during the Spring and Summer; potential hotspots for elk and deer) reflect real patterns on the landscape. Further, after Year 2, we will have a more extensive dataset to compare with roadkill data compiled by WSDOT personnel. In the longer term, it will be vital to solicit motorist-based data again *after* wildlife crossing structures and fencing are installed, such that pre-construction and post-construction patterns and rates can be compared.

As a final note, we think it's important to emphasize the role of I-90 Wildlife Watch in building public support for enhancing habitat connectivity in the I-90 SPE region. Although this attribute may be difficult to quantify directly, it is no doubt reflected in the number of visits to our website and the observations reported. Indeed, in reading the comments provided by observers, it is clear that these individuals are concerned about wildlife on the highway (because of human safety, wildlife safety, or both), and appreciate having a forum for sharing their concerns.

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Appendix 1

Summary of all live and dead wildlife reports, including date observed, species, and number of individuals.

Date	Species	Count	Status
<u>2010</u>			
5-Nov	Elk	3	Alive
5-Nov	Deer	1	Dead
7-Nov	Deer	2	Alive
7-Nov	Raccoon	1	Alive
7-Nov	Cougar/Mountain lion	1	Alive
8-Nov	Raptor	1	Dead
10-Nov	Elk	2	Alive
12-Nov	Black bear	1	Alive
6-Dec	Raptor	1	Dead
6-Dec	Deer	1	Dead
<u>2011</u>			
1-Jan	Elk	2	Alive
23-Jan	Owl	1	Alive
9-Feb	Elk	20	Alive
18-Feb	Elk	4	Alive
3-Mar	Deer	3	Alive
3-Mar	Coyote	1	Alive
4-Mar	Raccoon	1	Dead
5-Mar	Elk	5	Alive
8-Mar	Elk	5	Alive
11-Mar	Coyote	1	Alive
11-Mar	Raven	2	Alive
15-Mar	Elk	9	Alive
25-Mar	Otter	1	Alive
26-Mar	Crow	3	Alive
1-Apr	Elk	6	Alive
3-Apr	Elk	3	Alive
7-Apr	Elk	5	Alive
7-Apr	Elk	1	Alive
9-Apr	Elk	25	Alive
11-Apr	Deer	1	Dead
12-Apr	Elk	4	Alive
13-Apr	Elk	6	Alive
15-Apr	Elk	5	Alive
16-Apr	Elk	3	Alive
17-Apr	Deer	1	Alive

17-Apr	Elk	4	Alive
19-Apr	Elk	2	Alive
20-Apr	Elk	3	Alive
20-Apr	Elk	3	Alive
21-Apr	Unknown	1	Dead
21-Apr	Elk	6	Alive
22-Apr	Deer	3	Alive
22-Apr	Elk	2	Alive
22-Apr	Elk	3	Alive
23-Apr	Porcupine	1	Dead
23-Apr	Deer	2	Alive
23-Apr	Bobcat	1	Alive
23-Apr	Elk	8	Alive
24-Apr	Elk	7	Alive
26-Apr	Elk	3	Alive
26-Apr	Elk	1	Alive
26-Apr	Elk	6	Alive
26-Apr	Mink	1	Dead
27-Apr	Elk	2	Alive
28-Apr	Skunk	1	Dead
29-Apr	Elk	4	Alive
29-Apr	Coyote	1	Alive
29-Apr	Elk	2	Alive
3-May	Elk	3	Alive
5-May	Elk	5	Alive
5-May	Elk	5	Alive
5-May	Elk	25	Alive
6-May	Elk	1	Alive
7-May	Elk	2	Alive
8-May	Deer	1	Alive
8-May	Elk	1	Alive
8-May	Elk	2	Alive
10-May	Elk	4	Alive
10-May	Elk	3	Alive
10-May	Elk	5	Alive
10-May	Unknown	1	Dead
11-May	Deer	2	Alive
11-May	Elk	2	Alive
11-May	Elk	3	Alive
12-May	Raptor	1	Alive
12-May	Mink	6	Alive
13-May	Elk	1	Alive
13-May	Elk	3	Alive
13-May	Deer	4	Alive

13-May	Elk	2	Alive
16-May	Elk	2	Alive
16-May	Hawk	1	Alive
16-May	Unknown	1	Dead
18-May	Hawk	1	Alive
18-May	Bluebird	1	Alive
18-May	Elk	2	Alive
18-May	Elk	3	Alive
19-May	Hawk	1	Dead
20-May	Elk	2	Alive
21-May	Deer	1	Alive
22-May	Deer	1	Alive
22-May	Deer	3	Alive
22-May	Elk	1	Alive
23-May	Elk	1	Alive
23-May	Elk	6	Alive
24-May	Coyote	1	Alive
24-May	Elk	2	Alive
24-May	Elk	1	Alive
24-May	Elk	3	Alive
24-May	Skunk	1	Dead
25-May	Raptor	1	Alive
25-May	Deer	4	Alive
26-May	Deer	1	Alive
27-May	Elk	20	Alive
27-May	Elk	2	Alive
28-May	Unknown	1	Dead
28-May	Elk	4	Alive
29-May	Fox	2	Alive
30-May	Elk	1	Alive
30-May	Deer	2	Alive
31-May	Elk	1	Dead
31-May	Skunk	1	Dead
1-Jun	Deer	1	Alive
1-Jun	Deer	1	Alive
4-Jun	Elk	1	Alive
4-Jun	Turkey	1	Dead
4-Jun	Turkey	5	Alive
5-Jun	Deer	1	Dead
5-Jun	Deer	1	Dead
5-Jun	Hawk	1	Alive
5-Jun	Deer	1	Alive
5-Jun	Unknown	1	Dead
6-Jun	Deer	1	Dead

6-Jun	Unknown	1	Dead
6-Jun	Unknown	1	Dead
6-Jun	Deer	2	Alive
6-Jun	Deer	1	Dead
7-Jun	Raccoon	1	Dead
7-Jun	Goose	5	Alive
8-Jun	Deer	2	Alive
8-Jun	Deer	1	Alive
9-Jun	Elk	1	Alive
10-Jun	Deer	2	Alive
10-Jun	Elk	1	Alive
10-Jun	Elk	2	Alive
10-Jun	Porcupine	1	Dead
10-Jun	Elk	1	Alive
11-Jun	Black bear	1	Alive
11-Jun	Black bear	1	Alive
11-Jun	Deer	1	Alive
11-Jun	Deer	1	Alive
11-Jun	Porcupine	1	Dead
12-Jun	Deer	1	Dead
12-Jun	Deer	1	Alive
12-Jun	Deer	1	Dead
13-Jun	Hawk	1	Alive
13-Jun	Deer	1	Alive
13-Jun	Elk	1	Alive
14-Jun	Deer	1	Alive
14-Jun	Raccoon	1	Dead
14-Jun	Deer	1	Alive
17-Jun	Black bear	1	Alive
18-Jun	Hawk	1	Dead
19-Jun	Deer	1	Alive
19-Jun	Deer	1	Alive
20-Jun	Deer	1	Alive
20-Jun	Deer	1	Alive
22-Jun	Coyote	1	Dead
22-Jun	Coyote	1	Dead
22-Jun	Elk	1	Alive
22-Jun	Elk	2	Alive
22-Jun	Goose	5	Alive
23-Jun	Coyote	1	Dead
24-Jun	Deer	2	Alive
26-Jun	Elk	7	Alive
26-Jun	Elk	6	Alive
27-Jun	Deer	1	Alive

27-Jun	Deer	1	Alive
27-Jun	Deer	1	Dead
28-Jun	Elk	1	Alive
28-Jun	Deer	1	Alive
29-Jun	Deer	1	Alive
30-Jun	Vulture	1	Alive
30-Jun	Deer	1	Alive
1-Jul	Deer	1	Alive
2-Jul	Vulture	4	Alive
3-Jul	Deer	2	Alive
3-Jul	Deer	1	Alive
4-Jul	Unknown	1	Dead
4-Jul	Elk	1	Alive
5-Jul	Elk	2	Alive
5-Jul	Black bear	1	Alive
5-Jul	Goose	2	Alive
6-Jul	Raccoon	1	Dead
6-Jul	Deer	2	Alive
6-Jul	Black bear	1	Alive
6-Jul	Deer	1	Alive
7-Jul	Raccoon	1	Dead
7-Jul	Deer	1	Alive
7-Jul	Deer	1	Alive
8-Jul	Raccoon	1	Dead
10-Jul	Black bear	1	Alive
12-Jul	Unknown	1	Dead
12-Jul	Eagle	1	Alive
12-Jul	Eagle	2	Alive
13-Jul	Deer	1	Alive
15-Jul	Deer	1	Alive
18-Jul	Deer	1	Alive
18-Jul	Deer	1	Alive
21-Jul	Deer	1	Alive
21-Jul	Deer	1	Alive
22-Jul	Deer	1	Alive
22-Jul	Coyote	1	Dead
22-Jul	Deer	1	Dead
23-Jul	Hawk	3	Alive
26-Jul	Unknown	1	Dead
26-Jul	Deer	1	Dead
26-Jul	Elk	2	Alive
30-Jul	Hummingbird	1	Dead
31-Jul	Owl	1	Dead
1-Aug	Unknown	1	Dead

1-Aug	Elk	1	Dead
2-Aug	Deer	1	Dead
2-Aug	Black bear	1	Alive
5-Aug	Deer	2	Alive
5-Aug	Deer	1	Alive
8-Aug	Unknown	1	Dead
8-Aug	Deer	1	Dead
8-Aug	Deer	1	Dead
9-Aug	Deer	1	Alive
18-Aug	Owl	1	Dead
19-Aug	Moose	1	Alive
22-Aug	Raccoon	1	Dead
23-Aug	Opossum	1	Dead
29-Aug	Deer	1	Alive
30-Aug	Deer	1	Alive
1-Sep	Fox	1	Dead
7-Sep	Otter	2	Alive
10-Sep	Deer	2	Alive
3-Oct	Deer	1	Dead
4-Oct	Osprey	1	Alive
8-Oct	Deer	3	Alive
8-Oct	Deer	1	Alive
17-Oct	Raccoon	1	Dead
18-Oct	Unknown	1	Dead
20-Oct	Elk	1	Dead
25-Oct	Elk	1	Dead
25-Oct	Elk	1	Dead
29-Oct	Raccoon	1	Dead
1-Nov	Black bear	1	Alive

Appendix 2.2. Wildlife-vehicle collision data collected by WSDOT maintenance crews from July 2008–June 2012 for the "Project" and "Control" areas as described in Chapter 2. Duplicates have been removed based on the protocol described in Chapter 2. UTM coordinates are NAD83.

Date	UTMN	UTME	Species	Count	Sex	Analysis Section
7/3/2008	5249780	622125	Canada Goose	1	Unknown	Project
7/3/2008	5250030	621743	Deer	1	Unknown	Project
7/14/2008	5253280	605801	Deer	1	Female	Control
7/14/2008	5236330	633619	Elk	1	Male	Project
7/16/2008	5246180	623286	Deer	1	Unknown	Project
7/21/2008	5250310	621133	Deer	1	Male	Project
7/21/2008	5234790	636820	Deer	1	Female	Project
7/25/2008	5243620	624962	Deer	1	Female	Project
7/25/2008	5243620	624957	Deer	1	Female	Project
7/28/2008	5240860	627677	Deer	1	Female	Project
8/27/2008	5250130	616005	Black Bear	1	Female	Control
10/8/2008	5250530	620896	Deer	1	Male	Control
10/24/2008	5257740	596676	Black Bear	1	Unknown	Control
10/25/2008	5258130	595828	Deer	1	Male	Control
10/27/2008	5250050	621711	Deer	1	Female	Project
12/3/2008	5250410	611981	Deer	1	Unknown	Control
12/4/2008	5255490	598342	Deer	1	Female	Control
12/5/2008	5250130	621660	Deer	1	Unknown	Project
12/6/2008	5257570	596860	Elk	1	Female	Control
12/6/2008	5257730	596522	Elk	1	Female	Control
2/7/2009	5256170	597988	Deer	1	Female	Control
2/13/2009	5254900	601615	Coyote	1	Unknown	Control
2/16/2009	5256200	597960	Bobcat	1	Unknown	Control
3/1/2009	5250490	615723	Black Bear	1	Female	Control
3/8/2009	5256520	597871	Deer	1	Unknown	Control
3/10/2009	5236390	632081	Deer	1	Male	Project
4/1/2009	5236590	631423	Elk	1	Female	Project
4/6/2009	5257500	597035	Elk	1	Female	Control
4/6/2009	5257520	596954	Elk	1	Female	Control
4/6/2009	5257500	597035	Elk	1	Female	Control
4/6/2009	5257520	596954	Elk	1	Female	Control
4/15/2009	5236550	631550	Elk	1	Female	Project
4/23/2009	5238150	629798	Coyote	1	Unknown	Project
4/26/2009	5257860	596193	Elk	1	Female	Control
5/4/2009	5257640	596968	Elk	1	Female	Control
5/4/2009	5236190	633995	Elk	1	Female	Project
5/28/2009	5256780	597832	Deer	1	Female	Control
6/12/2009	5250340	612954	Deer	1	Male	Control
6/19/2009	5250330	610230	Deer	1	Female	Control

7/1/2009	5254790	601641	Elk	1	Female	Control
7/2/2009	5240170	628386	Deer	1	Female	Project
7/8/2009	5240120	628369	Deer	1	Female	Project
7/10/2009	5257100	597667	Deer	1	Female	Control
7/28/2009	5253880	603051	Deer	1	Male	Control
7/28/2009	5258190	595627	Deer	1	Male	Control
11/6/2009	5248380	622519	Deer	1	Female	Project
11/12/2009	5234990	636558	Elk	1	Female	Project
12/4/2009	5253820	619546	Coyote	1	Unknown	Control
12/5/2009	5236530	632676	Elk	1	Female	Project
12/20/2009	5254650	601882	Elk	1	Female	Control
12/28/2009	5254300	602425	Elk	1	Female	Control
1/22/2010	5258350	595219	Elk	1	Female	Control
1/24/2010	5255340	600410	Elk	1	Female	Control
2/6/2010	5256600	597848	Coyote	1	Unknown	Control
2/18/2010	5258190	595616	Elk	1	Unknown	Control
3/22/2010	5254220	602494	Elk	1	Female	Control
4/7/2010	5243060	625453	Mallard Duck	1	Unknown	Project
4/7/2010	5236470	633263	Wild Turkey	1	Unknown	Project
4/16/2010	5243150	625351	Coyote	1	Male	Project
4/19/2010	5253800	603411	Elk	1	Female	Control
5/4/2010	5257640	596968	Elk	1	Female	Control
5/27/2010	5236570	631479	Elk	1	Female	Project
6/1/2010	5255810	598080	Coyote	1	Unknown	Control
6/1/2010	5253810	618337	Deer	1	Unknown	Control
6/28/2010	5250440	614608	Elk	1	Female	Control
6/30/2010	5251220	620333	Deer	1	Male	Control
6/30/2010	5255280	600784	Deer	1	Female	Control
7/11/2010	5250940	620371	Deer	1	Male	Control
7/19/2010	5236110	634583	Deer	1	Male	Project
7/20/2010	5247390	622865	Deer	1	Male	Project
7/27/2010	5252030	619996	Deer	1	Unknown	Control
8/7/2010	5235220	636115	Deer	1	Male	Project
8/12/2010	5250970	616920	Deer	1	Female	Control
10/4/2010	5253900	602978	Elk	1	Female	Control
10/11/2010	5251450	617222	Deer	1	Female	Control
10/11/2010	5250220	610818	Deer	1	Female	Control
10/11/2010	5251450	617222	Deer	1	Unknown	Control
10/11/2010	5251450	617222	Deer	1	Unknown	Control
11/7/2010	5256540	597852	Deer	1	Male	Control
11/14/2010	5237330	630784	Black Bear	1	Unknown	Project
11/14/2010	5249140	622444	Coyote	1	Unknown	Project
1/27/2011	5235320	635311	Otter	1	Unknown	Project

2/3/2011	5256920	597572	Deer	1	Female	Control
2/4/2011	5257250	597643	Deer	1	Unknown	Control
2/17/2011	5253000	619896	Coyote	1	Female	Control
2/18/2011	5258230	595495	Elk	1	Female	Control
4/17/2011	5257520	596875	Elk	1	Female	Control
5/18/2011	5257900	596277	Elk	1	Female	Control
5/31/2011	5257500	597044	Elk	1	Female	Control
6/12/2011	5255060	601337	Deer	1	Male	Control
6/16/2011	5255300	600302	Elk	1	Female	Control
6/21/2011	5255090	601334	Elk	1	Female	Control
6/27/2011	5240800	627657	Deer	1	Female	Project
8/18/2011	5240140	628462	Deer	1	Female	Project
8/18/2011	5240140	628461	Deer	1	Female	Project
8/18/2011	5240140	628464	Deer	1	Unknown	Project
9/6/2011	5242640	626385	Elk	1	Female	Project
11/29/2011	5236680	633485	Deer	1	Female	Project
12/7/2011	5253430	605374	Deer	1	Unknown	Control
12/26/2011	5252830	606250	Coyote	1	Female	Control
1/2/2012	5243280	625149	Bobcat	1	Female	Project
1/7/2012	5242050	626693	Deer	1	Unknown	Project
2/6/2012	5250890	620582	Bobcat	1	Unknown	Control
2/6/2012	5250800	620709	Bobcat	1	female	Control
2/9/2012	5255990	597990	Deer	1	Female	Control
2/12/2012	5257190	597633	Bald Eagle	1	Male	Control
2/28/2012	5246830	622814	Deer	1	Female	Project
5/21/2012	5251622	620380	Beaver	1	Unknown	Control
6/4/2012	5242187	626721	Deer	1	Female	Project
6/7/2012	5242368	626601	Deer	1	Female	Project
6/27/2012	5242963	625763	Deer	1	Male	Project

Appendix 2.3. I-90 Wildlife Watch data from November 2010–June 2012 for wildlife-vehicle collision observations for the "Project" and "Control" areas as described in Chapter 2. Duplicates have been removed based on the protocol described in Chapter 2. UTM coordinates are NAD83.

Date	Hour of Day	Mile Post	UTMX	UTMY	Species	Count	Observation Location	Travel Direction	Visibility	Analysis Section
11/5/10	15	45.9	611682	5250130	Deer	1	In Median	Eastbound	Good	Control
11/8/10	14	32.2	593000	5258520	Raptor	1	Within 10 yards South Side	Eastbound	Good	Control
12/6/10	10	36.3	598199	5255730	Deer	1	In Median	Eastbound	Good	Control
12/6/10	10	33.4	594872	5258480	Raptor	1	On Highway	Eastbound	Good	Control
3/4/11	7	32.4	593345	5258510	Raccoon	1	Within 10 yards North Side	Westbound	Moderate	Control
4/11/11	17	35.2	597509	5257310	Deer	1	Within 10 yards South Side	Eastbound	Good	Control
4/21/11	17	32	592682	5258510	Unknown	1	On Highway	Westbound	Good	Control
4/23/11	17	34.5	596458	5257800	Porcupine	1	On Highway	Westbound	Good	Control
5/10/11	19	49.8	617488	5251080	Unknown	1	On Highway	Eastbound	Good	Control
5/16/11	7	48.6	615979	5250630	Unknown	1	On Highway	Westbound	Moderate	Control
5/19/11	8	31.5	591660	5258710	Hawk	1	In Median	Westbound	Good	Control
5/28/11	10	61.2	626271	5242680	Unknown	1	Within 10 yards South Side	Eastbound	Good	Project
5/31/11	7	35	597255	5257460	Elk	1	In Median	Eastbound	Good	Control
5/31/11	7	70.1	636776	5234780	Skunk	1	Within 10 yards South Side	Eastbound	Moderate	Project
6/4/11	18	67.4	632936	5236500	Turkey	1	On Highway	Westbound	Good	Project
6/5/11	9	65.1	629993	5237970	Unknown	1	On Highway	Westbound	Good	Project
6/6/11	5	69.5	635970	5235250	Deer	1	In Median	Westbound	Good	Project
6/6/11	8	32.3	593168	5258520	Unknown	1	On Highway	Westbound	Moderate	Control
6/7/11	8	31	591051	5259570	Raccoon	1	On Highway	Westbound	Good	Control
6/10/11	17	62.8	627846	5240650	Porcupine	1	On Highway	Westbound	Moderate	Project
6/12/11	12	38.8	601874	5254710	Deer	1	On Highway	Westbound	Good	Control
6/14/11	15	64.1	629517	5239500	Raccoon	1	Within 10 yards South Side	Eastbound	Good	Project
6/18/11	8	51	618132	5252870	Hawk	1	On Highway	Eastbound	Good	Control
6/22/11	6	31.4	591521	5258890	Coyote	1	In Median	Westbound	Good	Control
7/4/11	6	36.8	598851	5255340	Unknown	1	On Highway	Westbound	Good	Control
7/6/11	15	36.6	598559	5255440	Raccoon	1	In Median	Eastbound	Good	Control
7/12/11	18	35.5	597755	5256920	Unknown	1	Within 10 yards South Side	Eastbound	Good	Control
7/22/11	7	69.9	636555	5235020	Coyote	1	In Median	Westbound	Good	Project
7/22/11	9	70	636643	5234900	Deer	1	On Highway	Westbound	Good	Project
7/26/11	23	54.7	620919	5250500	Deer	1	In Median	Eastbound	Poor	Control
7/26/11	21	39.5	602779	5254070	Unknown	1	On Highway	Eastbound	Moderate	Control
7/30/11	14	61	625995	5242830	Hummingbird	1	Within 10 yards North Side	Westbound	Good	Project
7/31/11	15	42.1	606519	5252620	Owl	1	On Highway	Eastbound	Good	Control
8/1/11	7	38.2	601048	5255210	Elk	1	Within 10 yards South Side	Eastbound	Good	Control
8/2/11	8	39.8	603225	5253820	Deer	1	In Median	Westbound	Good	Control

8/8/11	17	41.7	606108	5253020	Unknown	1	In Median	Eastbound	Good	Control
8/18/11	8	42.1	606519	5252620	Owl	1	Within 10 yards South Side	Eastbound	Good	Control
8/22/11	7	35.6	597769	5256760	Raccoon	1	Within 10 yards North Side	Westbound	Good	Control
8/23/11	7	70.2	636877	5234640	Opposum	1	Within 10 yards North Side	Westbound	Good	Project
9/1/11	14	67.6	633247	5236470	Fox	1	Within 10 yards South Side	Eastbound	Good	Project
10/3/11	7	39.7	603067	5253880	Deer	1	Within 10 yards South Side	Westbound	Good	Control
10/17/11	8	31.3	591396	5259080	Raccoon	1	Within 10 yards North Side	Westbound	Good	Control
10/18/11	7	31	591051	5259570	Unknown	1	In Median	Westbound	Good	Control
10/20/11	8	31	591051	5259570	Elk	1	Within 10 yards North Side	NA	Good	Control
10/25/11	9	34.1	595921	5258060	Elk	1	In Median	Westbound	Good	Control
10/25/11	9	32.1	592841	5258520	Elk	1	Within 10 yards South Side	Westbound	Good	Control
10/29/11	11	37.2	599449	5255360	Raccoon	1	In Median	Westbound	Good	Control
11/7/11	8	31.2	591271	5259260	Raccoon	1	Within 10 yards South Side	Eastbound	Moderate	Control
11/9/11	7	62.9	627947	5240530	Hawk	1	Within 10 yards South Side	Eastbound	Good	Project
2/27/12	19	57.8	623103	5246360	Deer	1	On Highway	Eastbound	Poor	Project
3/9/12	14	32.1	592841	5258520	Deer	1	In Median	Westbound	Good	Control
4/23/12	7	54.5	620736	5250790	Unknown	1	On Highway	Eastbound	Good	Control
5/14/12	7	36.6	598559	5255440	Raccoon	1	In Median	Eastbound	Good	Control
5/23/12	9	31	591051	5259570	Raccoon	1	On Highway	Westbound	Good	Control
5/27/12	10	54.6	620832	5250660	Black bear	1	Within 10 yards South Side	Westbound	Good	Control
5/27/12	11	60.7	625564	5243040	Raccoon	1	On Highway	Eastbound	Good	Project
5/29/12	6	63.1	628183	5240320	Raccoon	1	Within 10 yards South Side	Eastbound	Good	Project
6/4/12	6	61.7	626795	5242070	Deer	1	In Median	Eastbound	Moderate	Project
6/9/12	14	31	591051	5259570	Elk	1	In Median	Westbound	Good	Control
6/15/12	0	68.5	634558	5235870	Elk	1	On Highway	Eastbound	Moderate	Project

Appendix 2.4. I-90 Wildlife Watch data from November 2010–June 2012 for live animal observations for the "Project" and "Control" areas as described in Chapter 2. Duplicates have been removed based on the protocol described in Chapter 2. UTM coordinates are NAD83.

Date	Hour of Day	Mile Post	UTMX	UTMY	Species	Count	Observation Location	Travel Direction	Visibility	Analysis Section
11/5/10	21	32.4	593345	5258510	Elk	3	On Highway	Eastbound	Moderate	Control
11/7/10	9	51.5	618384	5253590	Raccoon	1	Outside 10 yards North Side	Eastbound	Moderate	Control
11/7/10	17	52.2	619416	5253840	Cougar/Mountain lion	1	In Median	Eastbound	Good	Control
11/7/10	7	32.9	594123	5258510	Deer	2	Within 10 yards North Side	Westbound	Good	Control
11/10/10	7	37.8	600419	5255270	Elk	2	Outside 10 yards South Side	Eastbound	Good	Control
11/12/10	19	65.5	630237	5237400	Black bear	1	On Highway	Eastbound	Poor	Project
1/1/11	8	44.6	609680	5250370	Elk	2	Within 10 yards South Side	Eastbound	Good	Control
1/23/11	18	31.2	591271	5259260	Owl	1	On Highway	Westbound	Moderate	Control
2/9/11	17	69.4	635806	5235260	Elk	20	Within 10 yards South Side	Eastbound	Good	Project
2/18/11	16	35.3	597611	5257190	Elk	4	Outside 10 yards North Side	Westbound	Good	Control
3/3/11	10	54.6	620832	5250660	Coyote	1	On Highway	Eastbound	Good	Control
3/3/11	12	31.5	591660	5258710	Deer	3	Within 10 yards South Side	Eastbound	Moderate	Control
3/8/11	7	39.8	603225	5253820	Elk	5	Within 10 yards North Side	Westbound	Good	Control
3/11/11	14	63.2	628298	5240210	Coyote	1	Within 10 yards North Side	Westbound	Good	Project
3/11/11	10	69.7	636285	5235190	Raven	2	Outside 10 yards South Side	Westbound	Good	Project
3/15/11	16	64.3	629670	5239210	Elk	9	Within 10 yards North Side	Eastbound	Moderate	Project
3/25/11	15	57.1	622796	5247450	Otter	1	Outside 10 yards South Side	Eastbound	Good	Project
3/26/11	15	70.2	636877	5234640	Crow	3	Within 10 yards North Side	Westbound	Moderate	Project
4/1/11	6	42.2	606614	5252500	Elk	6	Within 10 yards North Side	Westbound	Good	Control
4/3/11	16	44.3	609210	5250570	Elk	3	Within 10 yards South Side	Eastbound	Good	Control
4/7/11	16	42.3	606686	5252350	Elk	5	Within 10 yards South Side	Eastbound	Good	Control
4/7/11	18	43.3	607820	5251250	Elk	1	Within 10 yards North Side	Westbound	Good	Control
4/12/11	19	43.8	608549	5251010	Elk	4	Within 10 yards North Side	Eastbound	Good	Control
4/13/11	6	42.5	606845	5252060	Elk	6	Within 10 yards North Side	Westbound	Moderate	Control
4/16/11	18	44.8	610021	5250320	Elk	3	Within 10 yards South Side	Eastbound	Good	Control
4/17/11	18	38.4	601336	5255050	Deer	1	Outside 10 yards North Side	Eastbound	Good	Control
4/17/11	18	40.6	604512	5253780	Elk	4	Within 10 yards North Side	Eastbound	Good	Control
4/19/11	18	40.6	604512	5253780	Elk	2	Within 10 yards North Side	Eastbound	Good	Control
4/20/11	16	38.7	601725	5254790	Elk	3	Within 10 yards South Side	Eastbound	Good	Control
4/22/11	14	41.9	606300	5252810	Elk	2	Within 10 yards South Side	Eastbound	Good	Control
4/22/11	18	37.9	600597	5255280	Deer	3	Within 10 yards South Side	Eastbound	Good	Control
4/22/11	18	42.1	606519	5252620	Elk	3	Within 10 yards South Side	Eastbound	Good	Control
4/23/11	15	48.7	616118	5250690	Bobcat	1	On Highway	Westbound	Good	Control
4/23/11	17	39.4	602649	5254160	Deer	2	Outside 10 yards North Side	Westbound	Good	Control
4/23/11	18	60.1	624915	5243680	Elk	8	Within 10 yards North Side	Eastbound	Good	Project

4/24/11	12	35	597255	5257460	Elk	7	In Median	Eastbound	Good	Control
4/26/11	6	39.1	602270	5254440	Elk	3	Within 10 yards North Side	Westbound	Moderate	Control
4/26/11	16	42	606423	5252720	Elk	1	Within 10 yards South Side	Eastbound	Good	Control
4/26/11	15	45.7	611403	5250120	Elk	6	Within 10 yards North Side	Westbound	Good	Control
4/29/11	19	41	605091	5253530	Coyote	1	On Highway	Eastbound	Good	Control
4/29/11	6	39.5	602779	5254070	Elk	4	Within 10 yards North Side	Westbound	Good	Control
4/29/11	19	63	628059	5240430	Elk	2	Within 10 yards North Side	Westbound	Good	Project
5/3/11	17	40.5	604334	5253800	Elk	3	Within 10 yards North Side	Westbound	Good	Control
5/5/11	19	40.1	603719	5253760	Elk	5	Within 10 yards North Side	Westbound	Good	Control
5/6/11	5	68.7	635034	5235970	Elk	1	Within 10 yards North Side	Westbound	Moderate	Project
5/7/11	5	32.8	593974	5258510	Elk	2	Within 10 yards South Side	Eastbound	Poor	Control
5/8/11	5	69	635349	5235630	Elk	2	Within 10 yards North Side	Westbound	Moderate	Project
5/8/11	5	64.3	629670	5239210	Elk	1	Within 10 yards North Side	Westbound	Moderate	Project
5/8/11	20	37.5	599919	5255290	Deer	1	Outside 10 yards North Side	Westbound	Good	Control
5/10/11	7	40.1	603719	5253760	Elk	3	Within 10 yards North Side	Westbound	Good	Control
5/10/11	15	38	600746	5255280	Elk	4	Within 10 yards South Side	Eastbound	Good	Control
5/10/11	7	42.6	606980	5251950	Elk	5	Within 10 yards North Side	Westbound	Good	Control
5/11/11	18	41.9	606300	5252810	Elk	3	Outside 10 yards North Side	Eastbound	Good	Control
5/11/11	7	41.8	606190	5252910	Elk	2	Within 10 yards North Side	Westbound	Good	Control
5/11/11	14	39.9	603398	5253790	Deer	2	Within 10 yards North Side	Eastbound	Good	Control
5/12/11	17	33.1	594430	5258520	Raptor	1	Within 10 yards North Side	Eastbound	Good	Control
5/13/11	8	39.2	602394	5254350	Elk	3	Outside 10 yards North Side	Westbound	Good	Control
5/13/11	18	37.7	600246	5255270	Elk	1	Within 10 yards South Side	Eastbound	Good	Control
5/13/11	22	47	613463	5250330	Elk	2	Within 10 yards North Side	Westbound	Good	Control
5/13/11	18	39.3	602524	5254260	Deer	4	Outside 10 yards North Side	Eastbound	Good	Control
5/16/11	17	42.3	606686	5252350	Hawk	1	Within 10 yards North Side	Eastbound	Moderate	Control
5/16/11	8	37.3	599617	5255360	Elk	2	Outside 10 yards North Side	Westbound	Moderate	Control
5/18/11	12	35	597255	5257460	Hawk	1	Within 10 yards North Side	Westbound	Good	Control
5/18/11	13	38	600746	5255280	Bluebird	1	Within 10 yards North Side	Westbound	Good	Control
5/18/11	12	65.2	629997	5237810	Elk	2	Within 10 yards North Side	Westbound	Good	Project
5/18/11	18	65.8	630573	5237060	Elk	3	Within 10 yards North Side	Eastbound	Good	Project
5/20/11	5	68.3	634294	5236060	Elk	2	Outside 10 yards North Side	Eastbound	Good	Project
5/21/11	7	66.5	631538	5236550	Deer	1	Within 10 yards North Side	Westbound	Good	Project
5/22/11	16	39	602129	5254510	Deer	1	Within 10 yards North Side	Westbound	Good	Control
5/22/11	19	42.5	606845	5252060	Elk	1	Within 10 yards North Side	Westbound	Good	Control
5/22/11	20	39.2	602394	5254350	Deer	3	Outside 10 yards North Side	Eastbound	Moderate	Control
5/23/11	2	61	625995	5242830	Elk	1	Within 10 yards North Side	Westbound	Poor	Project
5/23/11	11	66.2	631068	5236680	Elk	6	Within 10 yards North Side	Westbound	Good	Project
5/24/11	2	46.2	612133	5250240	Coyote	1	Within 10 yards North Side	Eastbound	Poor	Control
5/24/11	4	61.1	626137	5242770	Elk	1	Within 10 yards South Side	Eastbound	Moderate	Project
5/24/11	4	56.8	622539	5247860	Elk	2	Outside 10 yards North Side	Westbound	Moderate	Project

5/24/11	3	69	635200	5235360	Elk	3	Within 10 yards South Side	Eastbound	Poor	Project
5/25/11	7	53.6	620055	5251950	Raptor	1	Within 10 yards North Side	Westbound	Good	Control
5/25/11	5	66.6	631691	5236500	Deer	4	Within 10 yards North Side	Westbound	Moderate	Project
5/26/11	19	65.1	629993	5237970	Deer	1	Within 10 yards North Side	Westbound	Moderate	Project
5/27/11	4	63	628059	5240430	Elk	20	Outside 10 yards North Side	Westbound	Good	Project
5/27/11	20	69.1	635340	5235320	Elk	2	Within 10 yards South Side	Eastbound	Good	Project
5/28/11	5	69.3	635643	5235280	Elk	4	Outside 10 yards South Side	Eastbound	Good	Project
5/29/11	19	58	623339	5246100	Fox	2	Within 10 yards South Side	Eastbound	Good	Project
5/30/11	17	66.4	631380	5236590	Deer	2	Within 10 yards North Side	Westbound	Good	Project
5/30/11	17	61.7	626795	5242070	Elk	1	Within 10 yards South Side	Westbound	Good	Project
6/1/11	2	62.9	627947	5240530	Deer	1	Within 10 yards South Side	Eastbound	Poor	Project
6/1/11	15	38.4	601336	5255050	Deer	1	In Median	Eastbound	Good	Control
6/4/11	18	67.4	632936	5236500	Turkey	5	Outside 10 yards North Side	Westbound	Good	Project
6/4/11	21	39	602129	5254510	Elk	1	Within 10 yards South Side	Eastbound	Moderate	Control
6/5/11	10	38.2	601048	5255210	Hawk	1	Within 10 yards North Side	Westbound	Good	Control
6/5/11	18	60.5	625270	5243190	Deer	1	Within 10 yards North Side	Westbound	Good	Project
6/6/11	7	61.6	626689	5242190	Deer	2	Within 10 yards South Side	Eastbound	Good	Project
6/7/11	15	60.6	625415	5243120	Goose	5	In Median	Eastbound	Good	Project
6/8/11	8	45.5	611106	5250130	Deer	2	Outside 10 yards North Side	Westbound	Good	Control
6/9/11	8	44.3	609210	5250570	Elk	1	Within 10 yards North Side	Westbound	Good	Control
6/10/11	5	31	591051	5259570	Deer	2	Within 10 yards North Side	Westbound	Good	Control
6/10/11	5	31	591051	5259570	Elk	1	Within 10 yards North Side	Eastbound	Good	Control
6/10/11	5	46	611811	5250140	Elk	2	Within 10 yards North Side	Westbound	Good	Control
6/11/11	17	48.9	616377	5250290	Black bear	1	Outside 10 yards North Side	Eastbound	Good	Control
6/11/11	17	61.6	626689	5242190	Deer	1	Within 10 yards South Side	Eastbound	Good	Project
6/11/11	20	54.3	620496	5251000	Deer	1	Within 10 yards North Side	Westbound	Moderate	Control
6/12/11	14	44.4	609349	5250470	Deer	1	Within 10 yards North Side	Westbound	Good	Control
6/13/11	8	37.9	600597	5255280	Hawk	1	Within 10 yards North Side	Westbound	Moderate	Control
6/13/11	20	49	616533	5250340	Elk	1	Within 10 yards North Side	Eastbound	Moderate	Control
6/13/11	20	38.5	601461	5254960	Deer	1	Within 10 yards South Side	Eastbound	Moderate	Control
6/14/11	8	67.2	632611	5236520	Deer	1	Within 10 yards North Side	Westbound	Good	Project
6/14/11	15	49.8	617488	5251080	Deer	1	In Median	Eastbound	Good	Control
6/17/11	16	39	602129	5254510	Black bear	1	Outside 10 yards South Side	Eastbound	Good	Control
6/19/11	17	59.9	624747	5243940	Deer	1	Within 10 yards North Side	Westbound	Good	Project
6/19/11	17	58	623339	5246100	Deer	1	Within 10 yards North Side	Westbound	Good	Project
6/20/11	7	66.7	631839	5236450	Deer	1	Outside 10 yards North Side	Westbound	Good	Project
6/20/11	18	38.9	602008	5254600	Deer	1	Outside 10 yards North Side	Eastbound	Good	Control
6/22/11	6	59.6	624397	5244290	Goose	5	Outside 10 yards South Side	Westbound	Good	Project
6/22/11	11	38.7	601725	5254790	Elk	1	Outside 10 yards North Side	Westbound	Good	Control
6/22/11	11	45.1	610477	5250240	Elk	2	Outside 10 yards North Side	Westbound	Good	Control
6/24/11	18	38.6	601591	5254880	Deer	2	Within 10 yards North Side	Westbound	Moderate	Control

6/26/11	6	69.8	636430	5235110	Elk	6	Within 10 yards North Side	Westbound	Good	Project
6/26/11	8	38.4	601336	5255050	Elk	7	On Highway	Westbound	Good	Control
6/27/11	12	68.5	634678	5236120	Deer	1	Within 10 yards North Side	Westbound	Good	Project
6/27/11	19	65.8	630573	5237060	Deer	1	Within 10 yards South Side	Eastbound	Good	Project
6/28/11	6	40.3	604013	5253740	Elk	1	On Highway	Eastbound	Good	Control
6/28/11	5	66.7	631839	5236450	Deer	1	Within 10 yards South Side	Eastbound	Good	Project
6/29/11	11	64.9	629916	5238280	Deer	1	Within 10 yards North Side	Westbound	Good	Project
6/30/11	19	37.7	600246	5255270	Vulture	1	In Median	Eastbound	Good	Control
6/30/11	9	69.2	635499	5235290	Deer	1	Within 10 yards North Side	Eastbound	Good	Project
7/1/11	16	69	635200	5235360	Deer	1	In Median	Eastbound	Moderate	Project
7/2/11	9	38.4	601336	5255050	Vulture	4	Within 10 yards South Side	Westbound	Good	Control
7/3/11	0	58.4	623511	5245550	Deer	1	Within 10 yards North Side	Westbound	Poor	Project
7/3/11	7	56.8	622539	5247860	Deer	2	Within 10 yards North Side	Eastbound	Good	Project
7/4/11	6	43.7	608401	5251050	Elk	1	Within 10 yards North Side	Westbound	Good	Control
7/5/11	7	53.1	619867	5252680	Black bear	1	On Highway	Westbound	Good	Control
7/5/11	7	60.4	625132	5243270	Goose	2	Outside 10 yards South Side	Westbound	Good	Project
7/5/11	21	38.5	601461	5254960	Elk	2	Within 10 yards South Side	Eastbound	Moderate	Control
7/6/11	12	57.1	622796	5247450	Black bear	1	Within 10 yards North Side	Eastbound	Good	Project
7/6/11	17	60.7	625564	5243040	Deer	1	Within 10 yards North Side	Westbound	Good	Project
7/6/11	15	50.5	617340	5252800	Deer	2	Within 10 yards North Side	Eastbound	Good	Control
7/7/11	7	68.6	634870	5236060	Deer	1	In Median	Westbound	Good	Project
7/7/11	20	59	623579	5244600	Deer	1	Within 10 yards North Side	Eastbound	Good	Project
7/10/11	9	49.9	617150	5251920	Black bear	1	On Highway	Westbound	Good	Control
7/12/11	15	55.5	622025	5249830	Eagle	1	Outside 10 yards South Side	Eastbound	Good	Project
7/12/11	13	56.5	622510	5248390	Eagle	2	Outside 10 yards North Side	Eastbound	Good	Project
7/13/11	13	68.5	634678	5236120	Deer	1	In Median	Westbound	Good	Project
7/15/11	19	64.4	629718	5239050	Deer	1	Within 10 yards North Side	Westbound	Good	Project
7/18/11	7	69.1	635429	5235520	Deer	1	Within 10 yards North Side	Westbound	Good	Project
7/18/11	18	68.9	635045	5235440	Deer	1	In Median	Eastbound	Good	Project
7/21/11	7	68	633983	5236530	Deer	1	In Median	Westbound	Good	Project
7/21/11	8	46.1	611979	5250200	Deer	1	Within 10 yards North Side	Westbound	Moderate	Control
7/22/11	7	59.7	624536	5244200	Deer	1	Within 10 yards North Side	Westbound	Good	Project
7/23/11	10	48.6	615979	5250630	Hawk	3	In Median	Westbound	Good	Control
7/26/11	20	61.7	626795	5242070	Elk	2	On Highway	Westbound	Good	Project
8/2/11	8	54.2	620434	5251140	Black bear	1	On Highway	Westbound	Good	Control
8/5/11	7	34.1	595921	5258060	Deer	2	On Highway	Westbound	Good	Control
8/5/11	18	70	636643	5234900	Deer	1	Within 10 yards South Side	Eastbound	Good	Project
8/9/11	7	37.8	600419	5255270	Deer	1	Outside 10 yards North Side	Westbound	Good	Control
8/19/11	17	53.1	619867	5252680	Moose	1	Outside 10 yards North Side	Westbound	Good	Control
8/29/11	0	38.7	601725	5254790	Deer	1	On Highway	Eastbound	Moderate	Control
8/30/11	9	31	591051	5259570	Deer	1	On Highway	Eastbound	Good	Control

9/7/11	7	55.5	622025	5249830	Otter	2	In Median	Eastbound	Good	Project
9/10/11	16	67.9	633791	5236650	Deer	2	Within 10 yards South Side	Westbound	Good	Project
10/4/11	8	69.8	636430	5235110	Osprey	1	Within 10 yards North Side	Westbound	Good	Project
10/8/11	11	66.5	631538	5236550	Deer	3	Within 10 yards North Side	Westbound	Good	Project
10/8/11	11	66.5	631538	5236550	Deer	1	Within 10 yards North Side	Westbound	Good	Project
11/1/11	15	49.3	617013	5250460	Black bear	1	On Highway	Eastbound	Good	Control
11/15/11	19	38.1	600909	5255250	Deer	1	On Highway	Westbound	Poor	Control
11/29/11	14	55.4	621886	5249910	Hare	1	On Highway	Eastbound	Good	Project
12/22/11	15	31	591051	5259570	Elk	1	Within 10 yards North Side	Westbound	Good	Control
12/25/11	16	49.5	617179	5251280	Cougar/Mountain lion	1	Within 10 yards South Side	Westbound	Moderate	Control
1/2/12	14	52.1	619287	5253920	Deer	1	Within 10 yards North Side	Westbound	Good	Control
2/18/12	9	55.1	621411	5250190	Fox	1	Within 10 yards South Side	Westbound	Good	Project
2/22/12	16	38.5	601461	5254960	Coyote	1	Within 10 yards South Side	Westbound	Good	Control
2/22/12	16	36.4	598323	5255630	Elk	1	Within 10 yards North Side	Westbound	Good	Control
2/27/12	15	35.9	597899	5256250	Hawk	1	In Median	Eastbound	Good	Control
2/29/12	15	34.6	596617	5257730	Turkey	1	Within 10 yards North Side	Westbound	Good	Control
3/3/12	16	38.3	601197	5255140	Fox	1	Outside 10 yards South Side	Westbound	Good	Control
3/3/12	16	31	591051	5259570	Turkey	1	On Highway	Westbound	Good	Control
3/4/12	15	35.2	597509	5257310	Turkey	1	Within 10 yards North Side	Westbound	Good	Control
3/7/12	9	50.9	618072	5252730	Turkey	1	Within 10 yards North Side	Eastbound	Good	Control
3/20/12	8	38.2	601048	5255210	Coyote	1	On Highway	Eastbound	Good	Control
3/21/12	12	34.2	596060	5257990	Hawk	1	Within 10 yards North Side	Westbound	Good	Control
3/27/12	17	46.2	612133	5250240	Elk	5	In Median	Eastbound	Good	Control
3/28/12	0	61.8	626901	5241950	Woodrat	1	On Highway	Eastbound	Moderate	Project
3/28/12	0	34.7	596775	5257670	Elk	2	On Highway	Eastbound	Poor	Control
4/1/12	14	35.8	597836	5256420	Deer	2	Outside 10 yards North Side	Westbound	Good	Control
4/5/12	18	57.2	622863	5247280	Otter	1	Outside 10 yards South Side	Eastbound	Good	Project
4/6/12	17	35.8	597836	5256420	Deer	1	Within 10 yards South Side	Eastbound	Good	Control
4/9/12	18	41	605091	5253530	Elk	5	Within 10 yards South Side	Eastbound	Good	Control
4/10/12	19	40.4	604181	5253780	Elk	6	Within 10 yards South Side	Eastbound	Good	Control
4/10/12	18	43	607479	5251580	Elk	1	Within 10 yards South Side	Eastbound	Good	Control
4/14/12	16	42.1	606519	5252620	Elk	1	Within 10 yards South Side	Eastbound	Good	Control
4/23/12	7	42.1	606519	5252620	Elk	7	Within 10 yards South Side	Eastbound	Good	Control
4/24/12	17	44.2	609085	5250680	Elk	1	Within 10 yards North Side	Westbound	Good	Control
4/28/12	17	47.4	614109	5250390	Raccoon	1	On Highway	Westbound	Good	Control
4/29/12	19	65.1	629993	5237970	Elk	2	Within 10 yards North Side	Westbound	Good	Project
5/3/12	8	37.2	599449	5255360	Deer	1	On Highway	Eastbound	Good	Control
5/5/12	19	67.4	632936	5236500	Elk	1	Within 10 yards North Side	Westbound	Good	Project
5/6/12	18	39.1	602270	5254440	Black bear	1	Outside 10 yards North Side	Eastbound	Good	Control
5/6/12	1	47.2	613783	5250370	Elk	2	Within 10 yards South Side	Eastbound	Poor	Control
5/6/12	17	68	633874	5236250	Elk	2	Within 10 yards South Side	Eastbound	Good	Project

5/6/12	19	68.4	634438	5235970	Elk	2	Within 10 yards South Side	Eastbound	Good	Project
5/7/12	19	69.4	635806	5235260	Black bear	1	On Highway	Eastbound	Good	Project
5/7/12	19	68.8	634899	5235550	Elk	3	Within 10 yards South Side	Eastbound	Good	Project
5/8/12	8	36	597944	5256090	Elk	4	Within 10 yards South Side	Eastbound	Good	Control
5/9/12	3	43.2	607685	5251350	Elk	1	Within 10 yards South Side	Eastbound	Poor	Control
5/11/12	10	48	615048	5250100	Mouse	1	On Highway	Eastbound	Good	Control
5/15/12	13	62.1	627247	5241560	Goose	2	Within 10 yards North Side	Westbound	Good	Project
5/16/12	20	41.6	606007	5253150	Elk	3	Within 10 yards South Side	Eastbound	Moderate	Control
5/19/12	18	66.7	598559	5255440	Deer	1	Within 10 yards North Side	Westbound	Good	Control
5/19/12	18	36.6	631839	5236450	Deer	1	Within 10 yards North Side	Westbound	Good	Project
5/20/12	20	56.9	622587	5247700	Elk	2	Outside 10 yards North Side	Westbound	Good	Project
5/21/12	9	55.1	621411	5250190	Eagle	1	Outside 10 yards South Side	Eastbound	Good	Project
5/22/12	6	69	635200	5235360	Elk	1	Within 10 yards South Side	Eastbound	Good	Project
5/26/12	10	57.5	622858	5246780	Deer	1	Within 10 yards North Side	Westbound	Good	Project
5/26/12	17	66.9	632155	5236380	Deer	1	Within 10 yards North Side	Westbound	Good	Project
5/29/12	6	44.5	609507	5250410	Deer	1	In Median	Westbound	Good	Control
6/1/12	8	68.1	620055	5251950	Elk	1	Within 10 yards North Side	Westbound	Good	Control
6/1/12	8	67.4	634107	5236450	Deer	1	Within 10 yards North Side	Westbound	Good	Project
6/1/12	9	61.8	632936	5236500	Deer	2	Within 10 yards North Side	Eastbound	Good	Project
6/1/12	11	63.5	626901	5241950	Deer	2	Within 10 yards South Side	Westbound	Good	Project
6/1/12	17	53.6	628720	5240010	Deer	1	Within 10 yards North Side	Westbound	Moderate	Project
6/4/12	6	68.9	635045	5235440	Deer	1	Outside 10 yards South Side	Eastbound	Moderate	Project
6/24/12	20	66.5	631538	5236550	Deer	1	On Highway	Eastbound	Good	Project
6/27/12	18	68.3	634294	5236060	Deer	1	Outside 10 yards North Side	Eastbound	Good	Project
6/28/12	12	67	632309	5236430	Deer	1	Within 10 yards North Side	Westbound	Good	Project
6/28/12	13	61.6	626689	5242190	Deer	2	Outside 10 yards South Side	Eastbound	Good	Project
6/28/12	17	63.4	628572	5240060	Deer	2	Within 10 yards North Side	Westbound	Good	Project
6/29/12	18	52.7	619963	5253280	Deer	1	Within 10 yards North Side	Westbound	Good	Control
6/30/12	23	40.5	604334	5253800	Cougar/Mountain lion	1	On Highway	Eastbound	Moderate	Control

Appendix 3.1. Conditions and representative crossing photos from 12 structures monitored during 2008–2012.

Gold Creek Bridges

Gold Creek Bridge NE (right bank) and NW (left bank). (Photo: WSDOT)

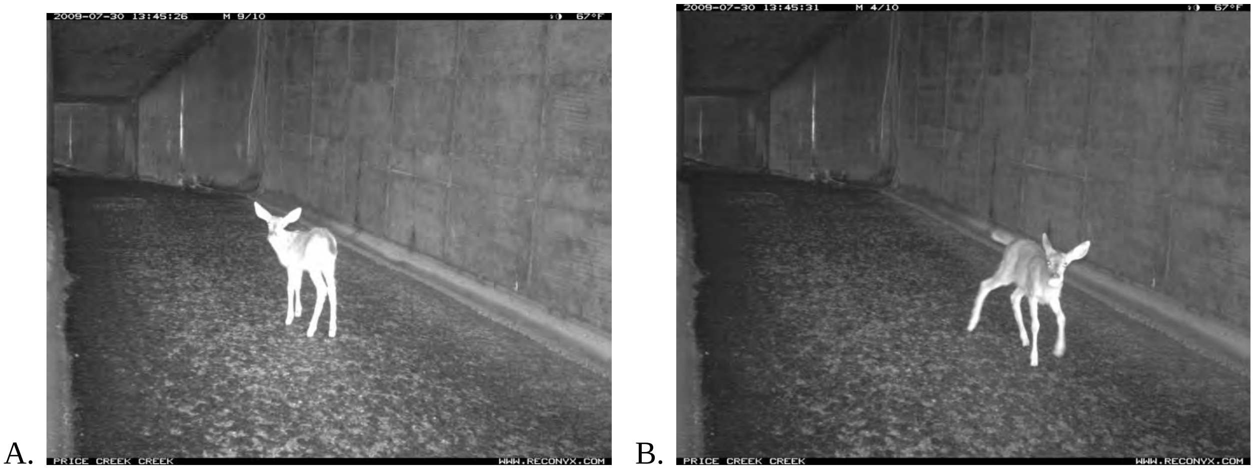
(A) Coyote crossing from north to south under eastbound lanes of I-90 on west bank of Gold Creek.
(B) Deer crossing from south to north under westbound lanes of I-90 on east bank of Gold Creek.
(Photos: WTI)

An adult deer and fawn pass from north to south under the Gold Creek North Bridge. (Photo: WTI)

Price Creek Culvert

Price Creek Culvert south entrance. (Photo: WTI)

Price Creek Culvert north entrance. (Photo: WTI)



A deer (A) enters the Price Creek Culvert, but (B) turns around and does not complete the crossing. (Photos: WTI)

A bobcat—the first to cross in this culvert and only the second to cross in any monitored culvert—crosses through the Price Creek Culvert. (Photo: WTI)

The first (and only) black bear detected using culverts monitored by WTI. This individual crossed through the Price Creek Culvert three times within a span of a week, but was detected moving only from north to south. We thus suspect that s/he crossed back to the north over the highway. (Photo: WTI)

A mink venturing into the Price Creek Culvert during high water flow. The mink, the first detected in this culvert, aborted two apparent crossing attempts within a 30-minute period. (Photo: WTI)

Bonnie Creek Culvert

Bonnie Creek Culvert south entrance (A) and opening to median (B). (Photo: WTI)

A mink pauses in the Bonnie Creek Culvert. The mink, the first detected in this culvert, aborted the crossing just after this photo was taken. (Photo: WTI)

Swamp Creek Culverts


South entrance of paired Swamp Creek Culverts. (Photo: WTI)


North entrance of Swamp Creek West Culvert. (Photo: WTI)

Otter in Swamp Creek West Culvert. (Photo: WTI)

Otters in Swamp Creek East Culvert. (Photo: WTI)

Three otters, one carrying a fish, in the Swamp Creek West Culvert. (Photo: WTI)

Raccoon in Swamp Creek East Culvert, with bats overhead. (Photo: WTI)

Ducks in Swamp Creek East Culvert. (Photo: WTI)

Mink in Swamp Creek East Culvert. (Photo: WTI)

Cedar Creek Culvert

Cedar Creek Culvert south entrance with dropoff. (Photo: WTI)

Cedar Creek Culvert north entrance. (Photo: WTI)

A bobcat passing through the Cedar Creek Culvert. (Photo: WTI)

A weasel passing through the Cedar Creek Culvert. (Photo: WTI)

Unnamed Creek Culvert

Unnamed Creek Culvert north entrance. (Photo: WTI)

A bobcat—the first and only detected at this culvert— tentatively moves into the Unnamed Creek Culvert. The individual aborted the crossing just after the photo was taken. (Photo: WTI)

A mountain beaver in the Unnamed Creek Culvert. (Photo: WTI)

Telephone Creek Culvert

Telephone Creek Culvert south entrance with dropoff. (Photo: WTI)

American dipper inside the Telephone Creek Culvert. (Photo: WTI)

Hudson Creek Culvert

Hudson Creek Culvert south entrance with dropoff. (Photo: WTI)

Raccoons cross through Hudson Creek Culvert. (Photo: WTI)

Sparks Underpasses

Sparks Road Bridge South. (Photo: WSDOT)

Sparks Road Bridge North. (Photo: WSDOT)

A deer passes under the Sparks Road Bridge North, moving from south to north and exiting the “island” between east and westbound lanes west of Easton. (Photo: WTI)

A deer looks up at traffic as it approaches Sparks Road Bridge North. (Photo: WTI)

A deer crosses under the Sparks Road Bridge South. (Photo: WTI)

A bull elk near the Sparks Road Bridge North. (Photo: WTI)

Appendix 3.2. Crossings recorded for species-of-interest (i.e., large mammals) including location, camera number, date, time, period-of-day (as defined in Chapter 3; Day, Night, C-DA=crepuscular day, C-DU=crepuscular dusk), species, number of individuals, and heading (N=north, S=south).

Location Name	Camera	Date	Time	Period	Species	Number	Heading
Sparks_S	RC60-1	6/3/08	16:26	Day	Deer	1	N
Sparks_N	RC60-2	6/8/08	16:48	Day	Deer	1	N
Sparks_N	RC60-2	6/8/08	20:11	C-DU	Deer	1	S
Sparks_N	RC60-2	6/10/08	15:36	Day	Deer	1	S
Sparks_S	RC60-1	6/15/08	5:17	C-DA	Deer	1	N
Sparks_N	RC60-2	6/19/08	9:07	Day	Deer	1	S
Sparks_S	RC60-1	6/19/08	9:32	Day	Deer	1	S
Swamp_Creek	IR-3	6/28/08	15:54	Day	Beaver	1	S
Sparks_S	RC60-1	7/6/08	5:44	C-DA	Deer	1	N
Swamp_Creek_E	IR-3	7/18/08	10:34	Day	Mink	1	N
Swamp_Creek_W	IR-6	7/18/08	3:25	Night	Raccoon	1	S
Swamp_Creek_E	IR-3	7/19/08	3:01	Night	River_otter	2	S
Swamp_Creek_E	IR-3	7/20/08	4:31	C-DA	Raccoon	1	N
Swamp_Creek_W	IR-6	7/21/08	8:42	Day	River_otter	1	N
Sparks_S	RC60-1	7/31/08	9:13	Day	Deer	1	N
Sparks_N	RC60-2	8/8/08	10:59	Day	Deer	1	S
Sparks_S	RC60-1	10/9/08	23:08	Night	Coyote	1	S
Gold_Creek_NE	RC60-3	10/12/08	22:08	Night	Deer	1	S
Swamp_Creek_E	IR-3	10/12/08	23:34	Night	Raccoon	1	S
Gold_Creek_NE	RC60-3	11/2/08	0:19	Night	Deer	1	N
Gold_Creek_NW	RC60-1	1/19/09	4:50	Night	Coyote	1	S
Gold_Creek_NW	RC60-1	2/10/09	3:19	Night	Coyote	2	S
Swamp_Creek_W	IR-6	3/20/09	20:51	Night	Raccoon	1	N
Swamp_Creek_E	IR-3	3/21/09	12:02	Day	River_otter	1	N
Swamp_Creek_E	IR-3	3/22/09	15:32	Day	Mink	1	N
Swamp_Creek_E	IR-3	3/27/09	21:20	Night	Mink	1	N
Swamp_Creek_E	IR-3	3/28/09	16:19	Day	Mink	1	N
Bonnie_Creek	IR-1	4/4/09	10:52	Day	Weasel	1	N
Swamp_Creek_E	IR-3	4/5/09	22:19	Night	Mink	1	N
Swamp_Creek_E	IR-3	4/7/09	22:08	Night	Mink	1	N
Cedar_Creek	IR-5	4/8/09	22:38	Night	Bobcat	1	N
Swamp_Creek_E	IR-3	4/11/09	20:47	C-DU	Mink	1	N
Swamp_Creek_E	IR-3	4/15/09	22:35	Night	Beaver	1	S
Gold_Creek_NW	RC60-1	4/21/09	16:59	Day	Beaver	1	N
Swamp_Creek_E	IR-3	4/24/09	4:26	Night	Beaver	1	N
Swamp_Creek_E	IR-3	4/28/09	23:28	Night	Raccoon	1	N
Swamp_Creek_E	IR-3	4/30/09	8:51	Day	Mink	1	N
Swamp_Creek_E	IR-3	5/3/09	3:32	Night	Beaver	1	N
Swamp_Creek_E	IR-3	5/3/09	3:57	Night	Beaver	1	S

Swamp_Creek_W	IR-6	5/16/09	8:24	Day	Mink	1	N
Bonnie_Creek	IR-1	5/20/09	22:52	Night	Weasel	1	N
Sparks_N	RC60-2	5/22/09	9:21	Day	Deer	1	S
Sparks_N	RC60-2	5/27/09	8:15	Day	Deer	1	S
Swamp_Creek_E	IR-3	5/27/09	4:43	C-DA	Raccoon	1	S
Swamp_Creek_E	IR-3	6/1/09	6:44	Day	Beaver	1	S
Gold_Creek_NW	RC60-1	6/3/09	1:28	Night	Beaver	1	S
Sparks_N	RC60-2	6/13/09	13:46	Day	Deer	1	N
Swamp_Creek_E	IR-3	6/14/09	7:26	Day	Beaver	1	N
Swamp_Creek_E	IR-3	6/19/09	1:11	Night	Mink	1	N
Swamp_Creek_E	IR-3	6/25/09	12:29	Day	Mink	1	N
Gold_Creek_NW	RC60-1	6/27/09	9:42	Day	Beaver	1	N
Sparks_S	RC60-4	6/29/09	20:00	Day	Deer	1	S
Swamp_Creek_E	IR-3	6/29/09	4:45	C-DA	Raccoon	1	N
Swamp_Creek_E	IR-3	6/29/09	23:52	Night	Raccoon	1	N
Sparks_N	RC60-2	6/30/09	5:56	C-DA	Deer	1	S
Swamp_Creek_E	IR-3	6/30/09	5:02	C-DA	Raccoon	1	S
Swamp_Creek_E	IR-3	6/30/09	23:50	Night	Raccoon	1	S
Sparks_N	RC60-2	7/1/09	7:53	Day	Deer	1	N
Sparks_N	RC60-2	7/1/09	11:44	Day	Deer	1	N
Swamp_Creek_E	IR-3	7/1/09	7:29	Day	Raccoon	1	S
Swamp_Creek_E	IR-3	7/5/09	2:10	Night	Raccoon	1	N
Swamp_Creek_E	IR-3	7/5/09	22:52	Night	Raccoon	1	S
Gold_Creek_NW	RC60-1	7/6/09	4:48	C-DA	Deer	1	N
Sparks_S	RC60-4	7/7/09	8:35	Day	Deer	1	N
Swamp_Creek_E	IR-3	7/8/09	8:15	Day	Raccoon	1	S
Sparks_N	RC60-2	7/12/09	6:40	Day	Deer	1	N
Sparks_N	RC60-2	7/12/09	8:19	Day	Deer	1	S
Sparks_S	RC60-4	7/12/09	8:36	Day	Deer	1	S
Sparks_N	RC60-2	7/13/09	18:28	Day	Deer	1	N
Swamp_Creek_E	IR-3	7/13/09	2:52	Night	Raccoon	1	N
Gold_Creek_NE	RC60-2	7/14/09	3:28	Night	Deer	2	S
Gold_Creek_NE	RC60-2	7/14/09	3:37	Night	Deer	2	N
Gold_Creek_NE	RC60-2	7/14/09	8:27	Day	Deer	1	S
Sparks_N	RC60-2	7/16/09	4:28	C-DA	Deer	1	S
Sparks_N	RC60-2	7/16/09	21:58	Night	Deer	1	N
Sparks_S	RC60-4	7/16/09	9:47	Day	Deer	1	N
Swamp_Creek_E	IR-3	7/16/09	4:15	Night	Raccoon	1	S
Swamp_Creek_E	IR-3	7/19/09	7:57	Day	Raccoon	1	S
Sparks_N	RC60-2	7/20/09	20:33	C-DU	Deer	1	N
Swamp_Creek_W	IR-6	7/23/09	12:52	Day	River_otter	3	S
Swamp_Creek_W	IR-6	7/26/09	11:48	Day	River_otter	3	S

Swamp_Creek_E	IR-3	7/27/09	9:43	Day	Weasel	1	N
Swamp_Creek_E	IR-3	7/28/09	5:51	C-DA	Raccoon	1	S
Swamp_Creek_E	IR-3	7/30/09	5:14	C-DA	Raccoon	1	S
Sparks_N	RC60-2	7/31/09	21:16	C-DU	Deer	1	N
Sparks_N	RC60-2	8/1/09	5:50	C-DA	Deer	1	S
Swamp_Creek_E	IR-3	8/1/09	5:44	C-DA	Raccoon	1	S
Hudson_Creek	RM45-1	8/3/09	4:09	Night	Raccoon	1	N
Swamp_Creek_E	IR-3	8/3/09	12:02	Day	Raccoon	1	S
Gold_Creek_NE	RC60-2	8/4/09	20:36	C-DU	Deer	1	N
Sparks_N	RC60-2	8/4/09	10:12	Day	Deer	1	S
Swamp_Creek_E	IR-3	8/7/09	5:45	C-DA	Raccoon	1	S
Sparks_N	RC60-2	8/11/09	8:57	Day	Deer	1	N
Sparks_N	RC60-2	8/12/09	9:11	Day	Deer	1	N
Sparks_N	RC60-2	8/12/09	16:09	Day	Deer	1	S
Gold_Creek_NE	RC60-2	8/13/09	19:32	C-DU	Deer	2	S
Hudson_Creek	RM45-1	8/13/09	23:32	Night	Raccoon	1	S
Cedar_Creek	IR-5	8/16/09	8:59	Day	Weasel	1	N
Swamp_Creek_W	IR-6	8/16/09	1:37	Night	Weasel	1	N
Swamp_Creek_E	IR-3	8/17/09	12:56	Day	Weasel	1	N
Swamp_Creek_E	IR-3	8/18/09	13:56	Day	Mink	1	N
Price_Creek	IR-4	8/18/09	3:23	Night	Raccoon	1	S
Swamp_Creek_E	IR-3	8/19/09	17:17	Day	Mink	1	N
Bonnie_Creek	IR-1	8/20/09	18:14	Day	Weasel	1	N
Sparks_N	RC60-2	8/21/09	7:25	Day	Deer	1	N
Swamp_Creek_E	IR-3	8/21/09	21:20	Night	Raccoon	1	N
Gold_Creek_NE	RC60-2	8/22/09	9:28	Day	Deer	1	S
Swamp_Creek_E	IR-3	8/22/09	11:41	Day	Weasel	1	N
Sparks_N	RC60-2	8/24/09	9:34	Day	Deer	1	S
Sparks_N	RC60-2	8/24/09	23:44	Night	Deer	1	N
Swamp_Creek_E	IR-3	8/25/09	2:45	Night	Raccoon	1	S
Bonnie_Creek	IR-1	8/25/09	14:31	Day	Weasel	1	N
Bonnie_Creek	IR-1	8/25/09	15:14	Day	Weasel	1	S
Bonnie_Creek	IR-1	8/25/09	17:15	Day	Weasel	1	N
Sparks_N	RC60-2	8/26/09	7:18	Day	Deer	1	N
Swamp_Creek_W	IR-6	8/26/09	11:34	Day	River_otter	1	S
Swamp_Creek_W	IR-6	8/27/09	22:23	Night	River_otter	2	S
Sparks_N	RC60-2	8/29/09	20:38	C-DU	Deer	1	N
Bonnie_Creek	IR-1	8/29/09	11:38	Day	Weasel	1	N
Swamp_Creek_E	IR-3	8/30/09	4:32	Night	Mink	1	N
Bonnie_Creek	IR-1	8/30/09	9:32	Day	Weasel	1	N
Swamp_Creek_E	IR-3	8/31/09	8:09	Day	Weasel	1	N
Bonnie_Creek	IR-1	9/1/09	12:57	Day	Weasel	1	S

Swamp_Creek_E	IR-3	9/3/09	3:31	Night	Mink	1	N
Sparks_S	RC60-4	9/6/09	0:03	Night	Deer	1	N
Sparks_S	RC60-4	9/7/09	0:00	Night	Deer	1	N
Sparks_N	RC60-2	9/8/09	20:15	C-DU	Deer	1	N
Swamp_Creek_E	IR-3	9/10/09	0:00	Night	Weasel	1	N
Price_Creek	IR-4	9/11/09	2:57	Night	Raccoon	1	S
Swamp_Creek_E	IR-3	9/11/09	23:15	Night	Raccoon	1	N
Cedar_Creek	IR-5	9/12/09	4:59	Night	Weasel	1	N
Cedar_Creek	IR-5	9/12/09	5:41	C-DA	Weasel	1	S
Swamp_Creek_E	IR-3	9/13/09	12:17	Day	Mink	1	N
Sparks_N	RC60-2	9/13/09	7:09	C-DA	Deer	1	S
Sparks_N	RC60-2	9/16/09	20:16	Night	Deer	1	N
Cedar_Creek	IR-5	9/16/09	21:52	Night	Weasel	1	N
Sparks_N	RC60-2	9/19/09	6:30	C-DA	Deer	1	S
Swamp_Creek_E	IR-3	9/26/09	12:56	Day	Weasel	1	N
Bonnie_Creek	IR-1	9/27/09	13:29	Day	Weasel	1	S
Swamp_Creek_W	IR-6	10/2/09	11:41	Day	River_otter	1	S
Cedar_Creek	IR-5	10/9/09	21:25	Night	Raccoon	1	S
Cedar_Creek	IR-5	10/10/09	20:03	Night	Raccoon	1	N
Swamp_Creek_E	IR-3	10/13/09	21:27	Night	Raccoon	1	N
Swamp_Creek_W	IR-6	10/15/09	23:11	Night	Beaver	1	N
Swamp_Creek_W	IR-6	10/15/09	23:47	Night	Beaver	1	S
Sparks_N	RC60-2	10/15/09	6:40	C-DA	Deer	1	N
Sparks_N	RC60-2	10/15/09	6:43	C-DA	Deer	1	N
Swamp_Creek_E	IR-3	10/15/09	6:41	C-DA	Raccoon	1	N
Swamp_Creek_W	IR-6	10/17/09	3:34	Night	Beaver	1	N
Swamp_Creek_E	IR-3	10/17/09	20:11	Night	Mink	1	N
Swamp_Creek_W	IR-6	10/18/09	3:35	Night	Beaver	1	N
Bonnie_Creek	IR-1	10/19/09	8:16	C-DA	Weasel	1	S
Swamp_Creek_W	IR-6	10/20/09	23:00	Night	Beaver	1	N
Swamp_Creek_E	IR-3	10/20/09	5:00	Night	Raccoon	1	N
Bonnie_Creek	IR-1	10/20/09	11:02	Day	Weasel	1	N
Swamp_Creek_W	IR-6	10/21/09	1:37	Night	Beaver	1	S
Swamp_Creek_W	IR-6	10/21/09	20:51	Night	Beaver	1	N
Swamp_Creek_W	IR-6	10/22/09	23:13	Night	Raccoon	1	N
Swamp_Creek_E	IR-3	10/26/09	4:54	Night	Mink	1	N
Swamp_Creek_W	IR-6	10/26/09	11:17	Day	River_otter	1	S
Swamp_Creek_W	IR-6	10/27/09	9:11	Day	Beaver	1	N
Swamp_Creek_W	IR-6	10/31/09	19:59	Night	Beaver	1	S
Swamp_Creek_E	IR-3	11/1/09	2:31	Night	Beaver	1	N
Swamp_Creek_W	IR-6	11/1/09	3:17	Night	Beaver	1	N
Swamp_Creek_E	IR-3	11/6/09	10:41	Day	River_otter	4	S

Swamp_Creek_E	IR-3	11/8/09	20:03	Night	Beaver	1	N
Bonnie_Creek	IR-1	11/9/09	21:25	Night	Weasel	1	N
Swamp_Creek_E	IR-3	11/10/09	20:06	Night	Mink	1	N
Swamp_Creek_E	IR-3	11/12/09	22:42	Night	Raccoon	1	S
Swamp_Creek_E	IR-3	11/14/09	22:25	Night	Raccoon	1	N
Cedar_Creek	IR-5	11/23/09	20:31	Night	Weasel	1	N
Swamp_Creek_E	IR-3	11/30/09	23:47	Night	Raccoon	1	S
Swamp_Creek_E	IR-3	12/1/09	5:48	Night	Raccoon	1	N
Gold_Creek_NW	PC90-2(HO)	12/7/09	19:01	Night	Coyote	2	S
Cedar_Creek	IR-5	12/15/09	22:38	Night	Weasel	1	N
Cedar_Creek	IR-5	12/20/09	4:31	Night	Weasel	1	N
Gold_Creek_NW	PC90-2(HO)	12/26/09	2:29	Night	Coyote	1	N
Cedar_Creek	IR-5	1/5/10	23:07	Night	Weasel	1	N
Cedar_Creek	IR-5	1/7/10	1:26	Night	Weasel	1	N
Swamp_Creek_E	IR-3	1/12/10	4:43	Night	Raccoon	1	S
Swamp_Creek_E	IR-3	1/12/10	21:38	Night	Raccoon	1	N
Cedar_Creek	IR-5	1/13/10	0:27	Night	Weasel	1	N
Swamp_Creek_E	IR-3	1/23/10	22:26	Night	Mink	1	N
Swamp_Creek_E	IR-3	1/28/10	0:33	Night	Raccoon	1	N
Swamp_Creek_E	IR-3	2/6/10	23:16	Night	Raccoon	1	S
Swamp_Creek_E	IR-3	2/13/10	21:59	Night	Raccoon	1	S
Swamp_Creek_E	IR-3	2/15/10	22:38	Night	Raccoon	1	S
Swamp_Creek_E	IR-3	2/16/10	4:04	Night	Raccoon	1	N
Swamp_Creek_E	IR-3	2/16/10	19:12	Night	Raccoon	1	S
Swamp_Creek_E	IR-3	2/17/10	4:38	Night	Raccoon	1	S
Cedar_Creek	IR-5	2/19/10	3:37	Night	Weasel	1	N
Cedar_Creek	IR-5	3/11/10	4:00	Night	Weasel	1	N
Cedar_Creek	IR-5	3/20/10	10:48	Day	Weasel	1	N
Swamp_Creek_E	IR-3	3/26/10	7:22	C-DA	Mink	1	N
Swamp_Creek_E	IR-3	3/28/10	12:59	Day	Mink	1	N
Swamp_Creek_E	IR-3	3/30/10	20:25	C-DU	Mink	1	N
Swamp_Creek_E	IR-3	4/14/10	2:02	Night	Raccoon	1	S
Swamp_Creek_E	IR-3	5/4/10	21:55	Night	Mink	1	N
Swamp_Creek_W	IR-6	5/4/10	21:44	Night	Mink	1	N
Bonnie_Creek	IR-1	5/5/10	23:52	Night	Weasel	1	N
Swamp_Creek_E	IR-3	5/9/10	4:15	Night	Raccoon	1	S
Sparks_N	RC60-6	5/14/10	9:59	Day	Deer	1	S
Sparks_S	RC60-4	5/15/10	6:11	C-DA	Deer	1	S
Price_Creek	IR-4	5/16/10	4:04	Night	Beaver	1	N
Sparks_N	RC60-6	5/18/10	5:04	C-DA	Deer	1	S
Sparks_S	RC60-4	5/18/10	7:09	Day	Deer	2	S
Sparks_S	RC60-4	5/18/10	7:12	Day	Deer	2	N

Swamp_Creek_E	P-1	5/20/10	22:48	Night	Beaver	1	S
Sparks_S	RC60-4	5/21/10	6:42	Day	Deer	1	N
Sparks_S	RC60-4	5/21/10	7:31	Day	Deer	1	S
Swamp_Creek_E	P-1	5/22/10	13:09	Day	Beaver	1	S
Sparks_N	RC60-6	5/22/10	6:10	C-DA	Deer	3	S
Sparks_N	RC60-6	5/22/10	7:49	Day	Deer	2	N
Gold_Creek_NE	RC60-2	5/24/10	22:26	Night	Deer	1	S
Sparks_N	RC60-6	5/24/10	21:56	Night	Deer	1	N
Gold_Creek_NW	PC90-2(HO)	5/25/10	20:23	C-DU	Deer	1	N
Sparks_N	RC60-6	5/25/10	8:19	Day	Deer	1	S
Sparks_N	RC60-6	5/26/10	5:48	C-DA	Deer	1	N
Sparks_N	RC60-6	5/26/10	19:26	Day	Deer	1	N
Sparks_N	RC60-6	5/26/10	20:47	C-DU	Deer	1	S
Sparks_S	RC60-4	5/27/10	9:56	Day	Deer	1	N
Sparks_N	RC60-6	5/28/10	10:31	Day	Deer	1	S
Sparks_S	RC60-4	5/29/10	20:33	C-DU	Deer	1	S
Sparks_S	RC60-4	5/29/10	21:27	C-DU	Deer	1	N
Sparks_N	RC60-6	5/30/10	18:07	Day	Deer	1	S
Sparks_S	RC60-4	5/30/10	8:34	Day	Deer	2	N
Swamp_Creek_E	P-1	5/30/10	22:32	Night	Raccoon	1	S
Swamp_Creek_E	IR-3	5/30/10	23:25	Night	Raccoon	1	N
Swamp_Creek_E	IR-3	5/30/10	23:46	Night	Raccoon	1	S
Swamp_Creek_E	P-1	5/31/10	2:44	Night	Raccoon	1	N
Sparks_N	RC60-6	6/1/10	4:49	C-DA	Deer	1	N
Sparks_S	RC60-4	6/1/10	17:55	Day	Deer	1	S
Swamp_Creek_W	IR-6	6/2/10	2:26	Night	Beaver	1	S
Sparks_N	RC60-6	6/4/10	13:58	Day	Deer	2	S
Sparks_N	RC60-6	6/4/10	20:27	C-DU	Deer	1	N
Sparks_S	RC60-4	6/4/10	8:28	Day	Deer	1	N
Sparks_N	RC60-6	6/7/10	15:26	Day	Deer	1	S
Sparks_S	RC60-4	6/7/10	6:29	Day	Deer	3	S
Swamp_Creek_E	IR-3	6/8/10	23:20	Night	Mink	1	N
Swamp_Creek_E	P-1	6/8/10	5:19	C-DA	Raccoon	1	N
Swamp_Creek_E	IR-3	6/9/10	22:43	Night	Raccoon	1	N
Sparks_N	RC60-6	6/12/10	9:54	Day	Deer	1	N
Sparks_N	RC60-6	6/12/10	19:43	Day	Deer	1	N
Gold_Creek_NW	PC90-2(HO)	6/15/10	11:16	Day	Beaver	1	S
Sparks_N	RC60-6	6/15/10	11:16	Day	Deer	1	N
Sparks_N	RC60-6	6/15/10	11:24	Day	Deer	2	S
Sparks_N	RC60-6	6/15/10	19:35	Day	Deer	1	N
Swamp_Creek_E	IR-3	6/16/10	22:49	Night	Raccoon	1	S
Sparks_N	RC60-6	6/17/10	18:47	Day	Deer	2	S

Sparks_N	RC60-6	6/17/10	19:03	Day	Deer	2	N
Sparks_N	RC60-6	6/18/10	0:07	Night	Deer	2	N
Swamp_Creek_E	IR-3	6/19/10	2:16	Night	Beaver	1	S
Swamp_Creek_E	IR-3	6/20/10	1:38	Night	Beaver	1	N
Swamp_Creek_E	IR-3	6/20/10	1:46	Night	Beaver	1	S
Sparks_N	RC60-6	6/21/10	23:28	Night	Deer	1	N
Swamp_Creek_W	IR-6	6/23/10	14:52	Day	Mink	1	N
Sparks_N	RC60-6	6/23/10	7:33	Day	Deer	2	S
Sparks_N	RC60-6	6/23/10	11:27	Day	Deer	1	N
Sparks_N	RC60-6	6/23/10	17:32	Day	Deer	1	S
Sparks_N	RC60-6	6/24/10	0:19	Night	Deer	2	S
Sparks_N	RC60-6	6/24/10	6:15	Day	Deer	1	N
Sparks_N	RC60-6	6/25/10	20:20	C-DU	Deer	1	S
Swamp_Creek_W	IR-6	6/25/10	22:09	Night	Raccoon	1	N
Sparks_N	RC60-6	6/26/10	3:41	Night	Deer	2	N
Gold_Creek_NW	PC90-2(HO)	6/27/10	22:18	Night	Beaver	1	S
Swamp_Creek_E	IR-3	6/29/10	22:33	Night	Raccoon	1	S
Swamp_Creek_E	IR-3	6/30/10	13:04	Day	Mink	4	N
Hudson_Creek	RM45-1	6/30/10	21:55	C-DU	Raccoon	1	S
Sparks_N	RC60-6	7/2/10	21:11	C-DU	Deer	1	S
Sparks_N	RC60-6	7/3/10	1:17	Night	Deer	1	N
Swamp_Creek_E	P-1	7/3/10	22:04	Night	Weasel	5	N
Swamp_Creek_E	P-1	7/4/10	18:32	Day	Mink	4	S
Swamp_Creek_E	IR-3	7/10/10	11:15	Day	Mink	4	S
Gold_Creek_NE	RC60-2	7/10/10	4:29	C-DA	Deer	1	S
Swamp_Creek_E	P-1	7/15/10	13:17	Day	Mink	1	N
Swamp_Creek_E	IR-3	7/15/10	13:58	Day	Mink	4	N
Swamp_Creek_E	P-1	7/15/10	14:21	Day	Mink	1	S
Swamp_Creek_E	P-1	7/16/10	18:49	Day	Mink	1	S
Gold_Creek_NE	RC60-2	7/16/10	21:23	C-DU	Deer	1	S
Sparks_N	RC60-6	7/16/10	5:35	C-DA	Deer	1	S
Sparks_N	RC60-6	7/16/10	6:37	Day	Deer	2	S
Sparks_N	RC60-6	7/16/10	20:01	C-DU	Deer	2	S
Sparks_N	RC60-6	7/16/10	23:08	Night	Deer	2	N
Swamp_Creek_E	P-1	7/16/10	2:25	Night	Raccoon	1	N
Gold_Creek_NE	RC60-2	7/17/10	21:31	C-DU	Deer	1	N
Gold_Creek_NW	PC90-2(HO)	7/17/10	21:31	C-DU	Deer	1	N
Sparks_N	RC60-6	7/17/10	21:02	C-DU	Deer	1	S
Bonnie_Creek	IR-1	7/17/10	23:21	Night	Raccoon	1	N
Swamp_Creek_W	IR-6	7/17/10	7:13	Day	River_otter	3	N
Gold_Creek_NW	PC90-2(HO)	7/18/10	10:22	Day	Deer	1	N
Gold_Creek_NW	PC90-2(HO)	7/18/10	21:37	C-DU	Deer	1	N

Swamp_Creek_E	IR-3	7/20/10	10:41	Day	Mink	1	S
Swamp_Creek_W	IR-6	7/21/10	10:56	Day	River_otter	2	N
Gold_Creek_NW	PC90-2(HO)	7/24/10	11:00	Day	Deer	1	S
Gold_Creek_NW	PC90-2(HO)	7/24/10	23:08	Night	Deer	3	S
Gold_Creek_NE	RC60-2	7/25/10	15:51	Day	Deer	1	N
Gold_Creek_NW	PC90-2(HO)	7/25/10	2:39	Night	Deer	2	N
Gold_Creek_NW	PC90-2(HO)	7/25/10	6:07	C-DA	Deer	1	N
Gold_Creek_NW	PC90-2(HO)	7/25/10	15:51	Day	Deer	1	N
Sparks_S	RC60-1	7/25/10	22:51	Night	Deer	1	S
Unnamed_Creek	IR-2	7/26/10	17:09	Day	Weasel	1	S
Gold_Creek_NE	RC60-2	7/27/10	4:12	Night	Deer	1	S
Gold_Creek_NE	RC60-2	7/27/10	22:17	Night	Deer	1	S
Gold_Creek_NW	PC90-2(HO)	7/27/10	4:12	Night	Deer	1	S
Gold_Creek_NW	PC90-2(HO)	7/27/10	22:18	Night	Deer	1	S
Gold_Creek_NE	RC60-2	7/29/10	22:43	Night	Deer	1	S
Gold_Creek_NW	PC90-2(HO)	7/29/10	22:48	Night	Deer	1	N
Sparks_N	RC60-6	7/29/10	23:57	Night	Deer	1	S
Gold_Creek_NW	PC90-2(HO)	7/30/10	21:09	C-DU	Deer	1	S
Sparks_N	RC60-6	7/30/10	5:32	C-DA	Deer	1	S
Swamp_Creek_E	IR-3	7/31/10	23:34	Night	Raccoon	2	N
Gold_Creek_NW	PC90-2(HO)	8/1/10	15:45	Day	Deer	1	N
Gold_Creek_NW	PC90-2(HO)	8/2/10	21:12	C-DU	Deer	1	S
Gold_Creek_NW	PC90-2(HO)	8/2/10	21:43	Night	Deer	1	N
Swamp_Creek_E	IR-3	8/2/10	13:11	Day	Weasel	1	N
Swamp_Creek_E	P-1	8/4/10	16:23	Day	Mink	1	N
Gold_Creek_NW	PC90-2(HO)	8/4/10	1:53	Night	Deer	1	S
Gold_Creek_NW	PC90-2(HO)	8/4/10	22:41	Night	Deer	1	S
Gold_Creek_NE	RC60-2	8/5/10	0:22	Night	Deer	1	N
Swamp_Creek_E	IR-3	8/6/10	2:06	Night	Raccoon	1	S
Sparks_N	RC60-6	8/7/10	18:58	Day	Deer	1	S
Sparks_S	RC60-1	8/7/10	8:16	Day	Deer	2	N
Sparks_S	RC60-1	8/7/10	8:19	Day	Deer	1	S
Sparks_S	RC60-1	8/7/10	19:22	Day	Deer	1	S
Gold_Creek_NW	PC90-2(HO)	8/9/10	6:06	C-DA	Deer	1	N
Sparks_S	RC60-1	8/11/10	6:12	C-DA	Deer	2	N
Sparks_S	RC60-1	8/11/10	17:20	Day	Deer	2	S
Price_Creek	IR-4	8/13/10	9:44	Day	Bobcat	1	N
Gold_Creek_NE	RC60-2	8/14/10	23:20	Night	Deer	1	S
Gold_Creek_NW	PC90-2(HO)	8/14/10	23:20	Night	Deer	1	S
Sparks_S	RC60-1	8/17/10	8:30	Day	Deer	2	N
Sparks_S	RC60-1	8/17/10	18:54	Day	Deer	2	S
Cedar_Creek	IR-5	8/17/10	22:18	Night	Weasel	1	N

Swamp_Creek_E	IR-3	8/20/10	0:06	Night	Raccoon	3	S
Swamp_Creek_E	IR-3	8/20/10	11:31	Day	Weasel	1	N
Gold_Creek_NW	PC90-2(HO)	8/22/10	1:14	Night	Deer	1	N
Swamp_Creek_E	IR-3	8/25/10	16:44	Day	Mink	1	N
Swamp_Creek_W	IR-6	8/25/10	12:45	Day	River_otter	4	N
Cedar_Creek	IR-5	8/27/10	16:57	Day	Weasel	1	N
Sparks_N	RC60-6	8/28/10	7:51	Day	Deer	1	N
Gold_Creek_NW	PC90-2(HO)	8/30/10	3:07	Night	Deer	1	N
Hudson_Creek	RM45-1	8/31/10	10:31	Day	Weasel	1	S
Swamp_Creek_E	IR-3	9/3/10	10:37	Day	Mink	1	N
Hudson_Creek	RM45-1	9/3/10	14:33	Day	Weasel	1	S
Hudson_Creek	RM45-1	9/3/10	15:00	Day	Weasel	1	N
Swamp_Creek_E	P-1	9/3/10	12:50	Day	Weasel	1	N
Gold_Creek_NW	PC90-2(HO)	9/4/10	5:41	C-DA	Deer	1	N
Sparks_S	RC60-1	9/4/10	17:54	Day	Deer	1	S
Cedar_Creek	IR-5	9/4/10	15:50	Day	Weasel	1	N
Swamp_Creek_E	P-1	9/12/10	14:24	Day	Mink	1	S
Sparks_N	RC60-6	9/12/10	18:22	C-DU	Deer	2	S
Unnamed_Creek	IR-2	9/12/10	11:39	Day	Weasel	1	S
Gold_Creek_NW	PC90-2(HO)	9/13/10	6:05	C-DA	Deer	1	S
Sparks_N	RC60-6	9/13/10	10:11	Day	Deer	2	N
Swamp_Creek_E	IR-3	9/18/10	22:59	Night	Beaver	1	N
Swamp_Creek_E	IR-3	9/20/10	8:29	Day	Mink	1	N
Price_Creek	IR-4	9/24/10	4:44	Night	Raccoon	1	S
Cedar_Creek	IR-5	9/24/10	22:35	Night	Weasel	1	N
Swamp_Creek_E	IR-3	9/26/10	20:45	Night	Raccoon	1	N
Swamp_Creek_E	P-1	9/30/10	11:10	Day	Mink	1	N
Swamp_Creek_E	IR-3	10/4/10	0:21	Night	Raccoon	1	S
Price_Creek	IR-4	10/5/10	17:29	Day	Black_bear	1	S
Cedar_Creek	IR-5	10/6/10	14:18	Day	Weasel	1	N
Price_Creek	IR-4	10/7/10	3:01	Night	Black_bear	1	S
Bonnie_Creek	IR-1	10/7/10	22:04	Night	Raccoon	1	S
Bonnie_Creek	IR-1	10/7/10	23:36	Night	Raccoon	1	S
Swamp_Creek_E	P-1	10/8/10	5:37	Night	Raccoon	2	S
Swamp_Creek_W	IR-6	10/8/10	7:03	C-DA	River_otter	3	S
Swamp_Creek_E	IR-3	10/10/10	0:11	Night	Raccoon	2	N
Price_Creek	IR-4	10/14/10	13:32	Day	Black_bear	1	S
Swamp_Creek_E	IR-3	10/14/10	15:01	Day	Mink	1	N
Hudson_Creek	RM45-1	10/14/10	23:59	Night	Weasel	1	S
Swamp_Creek_E	IR-3	10/19/10	16:39	Day	Mink	1	N
Swamp_Creek_E	IR-3	10/20/10	4:32	Night	Raccoon	1	S
Swamp_Creek_E	IR-3	10/20/10	22:26	Night	Raccoon	1	N

Unnamed_Creek	IR-2	10/21/10	16:30	Day	Weasel	1	S
Swamp_Creek_E	IR-3	10/25/10	0:58	Night	Raccoon	1	S
Swamp_Creek_E	P-1	10/29/10	20:25	Night	Raccoon	1	N
Swamp_Creek_E	IR-3	11/3/10	8:33	C-DA	Mink	1	S
Swamp_Creek_E	IR-3	11/10/10	4:40	Night	Raccoon	1	N
Sparks_N	RC60-6	11/16/10	19:33	Night	Deer	1	S
Gold_Creek_NW	RC60HO-5	2/3/11	4:54	Night	Coyote	1	N
Swamp_Creek_E	RC55-1	2/9/11	20:55	Night	Raccoon	1	S
Swamp_Creek_E	RC55-1	3/12/11	3:06	Night	Raccoon	1	S
Swamp_Creek_E	RC55-1	3/22/11	20:36	Night	Raccoon	1	N
Swamp_Creek_E	RC55-1	3/27/11	21:00	Night	Raccoon	1	S
Swamp_Creek_E	RC55-1	3/28/11	0:02	Night	Raccoon	1	N
Swamp_Creek_E	RC55-1	4/5/11	2:17	Night	Raccoon	1	S
Swamp_Creek_E	RC55-1	4/11/11	1:32	Night	Beaver	1	S
Swamp_Creek_E	RC55-1	4/13/11	23:21	Night	Beaver	1	S
Cedar_Creek	IR-5	5/1/11	23:18	Night	Weasel	1	N
Swamp_Creek_E	IR-3	5/2/11	2:00	Night	Raccoon	1	S
Swamp_Creek_E	IR-3	5/5/11	0:43	Night	Raccoon	1	S
Swamp_Creek_E	IR-3	5/13/11	0:18	Night	Mink	1	N
Sparks_N	RC60-6	5/18/11	5:15	C-DA	Deer	1	S
Sparks_N	RC60-6	5/23/11	20:16	C-DU	Deer	1	N
Sparks_N	RC60-6	5/24/11	3:42	Night	Deer	1	S
Unnamed_Creek	IR-6	5/30/11	8:36	Day	Weasel	1	S
Swamp_Creek_E	RC55-1	6/2/11	2:07	Night	Beaver	1	N
Bonnie_Creek	IR-1	6/3/11	9:01	Day	Mink	1	S
Bonnie_Creek	IR-1	6/3/11	9:39	Day	Mink	1	N
Bonnie_Creek	IR-1	6/4/11	10:44	Day	Mink	1	S
Bonnie_Creek	IR-1	6/4/11	12:39	Day	Mink	1	N
Bonnie_Creek	IR-1	6/6/11	18:16	Day	Mink	1	S
Bonnie_Creek	IR-1	6/26/11	10:29	Day	Mink	1	N
Bonnie_Creek	IR-1	6/28/11	7:20	Day	Mink	1	S
Swamp_Creek_E	IR-3	6/28/11	8:38	Day	Mink	1	N
Bonnie_Creek	IR-1	7/3/11	8:34	Day	Mink	1	S
Swamp_Creek_E	IR-3	7/6/11	15:14	Day	Mink	1	N
Bonnie_Creek	IR-1	7/8/11	15:38	Day	Mink	1	S
Bonnie_Creek	IR-1	7/9/11	10:18	Day	Mink	1	N
Swamp_Creek_W	P-1	7/10/11	23:31	Night	Raccoon	1	N
Bonnie_Creek	IR-1	7/12/11	16:05	Day	Mink	1	N
Bonnie_Creek	IR-1	7/13/11	13:52	Day	Mink	1	N
Swamp_Creek_E	IR-3	7/13/11	12:48	Day	Mink	1	N
Swamp_Creek_E	RC55-1	7/13/11	3:10	Night	Raccoon	1	S
Swamp_Creek_E	IR-3	7/15/11	4:05	Night	Beaver	1	S

Gold_Creek_NW	RC60HO-5	7/21/11	1:39	Night	Deer	1	S
Gold_Creek_NW	RC60HO-5	7/21/11	1:41	Night	Deer	1	N
Swamp_Creek_W	P-1	7/24/11	12:03	Day	River_otter	1	S
Swamp_Creek_W	P-1	7/24/11	15:55	Day	River_otter	3	N
Swamp_Creek_E	IR-3	7/25/11	4:26	Night	Raccoon	1	N
Swamp_Creek_E	IR-3	7/27/11	11:14	Day	Mink	1	S
Swamp_Creek_E	RC55-1	7/27/11	13:37	Day	Raccoon	1	S
Swamp_Creek_W	P-1	7/27/11	2:23	Night	Raccoon	1	N
Gold_Creek_NE	RC60-2	7/29/11	5:16	C-DA	Deer	1	S
Gold_Creek_NE	RC60-2	7/30/11	4:44	C-DA	Deer	2	N
Swamp_Creek_E	IR-3	7/30/11	9:22	Day	River_otter	3	N
Swamp_Creek_W	P-1	7/30/11	9:28	Day	River_otter	2	S
Swamp_Creek_W	P-1	7/30/11	12:19	Day	River_otter	1	N
Swamp_Creek_E	IR-3	8/2/11	21:04	C-DU	Mink	1	N
Bonnie_Creek	IR-1	8/7/11	1:04	Night	Raccoon	1	S
Gold_Creek_NW	RC60HO-5	8/8/11	21:19	C-DU	Deer	1	S
Gold_Creek_NW	RC60HO-5	8/9/11	5:23	C-DA	Deer	1	N
Bonnie_Creek	IR-1	8/9/11	22:28	Night	Weasel	1	N
Sparks_S	RC60-1	8/13/11	6:56	C-DA	Deer	1	N
Bonnie_Creek	IR-1	8/16/11	21:14	C-DU	Raccoon	1	S
Bonnie_Creek	IR-1	8/16/11	8:41	Day	Weasel	1	N
Gold_Creek_NW	RC60HO-5	8/20/11	8:24	Day	Deer	1	N
Gold_Creek_NW	RC60HO-5	8/20/11	20:52	C-DU	Deer	1	S
Swamp_Creek_E	IR-3	8/20/11	21:08	Night	Raccoon	1	S
Swamp_Creek_W	P-1	8/20/11	15:36	Day	River_otter	3	N
Swamp_Creek_E	IR-3	8/21/11	9:52	Day	Mink	1	N
Bonnie_Creek	IR-1	8/22/11	14:42	Day	Weasel	1	N
Bonnie_Creek	IR-1	8/26/11	13:49	Day	Weasel	1	S
Swamp_Creek_E	IR-3	8/27/11	23:25	Night	Mink	1	N
Gold_Creek_NW	RC60HO-5	8/27/11	3:16	Night	Deer	3	N
Bonnie_Creek	IR-1	8/29/11	5:12	Night	Raccoon	1	N
Bonnie_Creek	IR-1	8/30/11	5:02	Night	Raccoon	1	S
Bonnie_Creek	IR-1	9/2/11	14:40	Day	Weasel	1	S
Price_Creek	IR-4	9/3/11	10:33	Day	Mink	1	N
Gold_Creek_NW	RC60HO-5	9/4/11	4:35	Night	Deer	2	S
Bonnie_Creek	IR-1	9/6/11	21:44	Night	Raccoon	1	N
Hudson_Creek	RC55-2	9/14/11	23:58	Night	Raccoon	1	N
Swamp_Creek_W	P-1	9/18/11	11:11	Day	Beaver	1	S
Swamp_Creek_E	IR-3	9/18/11	20:34	Night	Mink	1	N
Swamp_Creek_W	P-1	9/18/11	6:03	C-DA	Raccoon	1	S
Swamp_Creek_W	P-1	9/19/11	6:23	C-DA	Beaver	1	N
Swamp_Creek_E	IR-3	9/22/11	21:16	Night	Mink	1	N

Swamp_Creek_E	IR-3	9/25/11	4:51	Night	Raccoon	1	N
Swamp_Creek_W	P-1	9/27/11	3:35	Night	Raccoon	1	S
Swamp_Creek_W	P-1	9/28/11	11:03	Day	River_otter	2	N
Swamp_Creek_E	IR-3	9/29/11	15:14	Day	Mink	1	N
Swamp_Creek_W	P-1	9/30/11	3:50	Night	Raccoon	1	S
Hudson_Creek	RC55-2	10/1/11	23:22	Night	Raccoon	1	S
Bonnie_Creek	IR-1	10/3/11	19:46	Night	Mink	1	N
Sparks_N	RC60-8	10/4/11	0:02	Night	Deer	1	S
Bonnie_Creek	IR-1	10/6/11	9:43	Day	Mink	1	N
Bonnie_Creek	IR-1	10/6/11	20:36	Night	Raccoon	1	S
Cedar_Creek	IR-5	10/9/11	1:13	Night	Weasel	1	N
Price_Creek	IR-4	10/10/11	21:15	Night	Raccoon	1	S
Price_Creek	IR-4	10/15/11	7:51	C-DA	Mink	1	S
Cedar_Creek	IR-5	10/18/11	19:19	Night	Weasel	1	N
Swamp_Creek_W	P-1	10/25/11	21:25	Night	Beaver	1	N
Swamp_Creek_E	IR-3	10/27/11	22:20	Night	Raccoon	1	S
Swamp_Creek_W	P-1	10/28/11	13:13	Day	Mink	1	N
Hudson_Creek	RC55-2	10/28/11	4:27	Night	Raccoon	2	N
Hudson_Creek	RC55-2	10/28/11	4:36	Night	Raccoon	2	S
Swamp_Creek_W	P-1	10/30/11	22:55	Night	Beaver	1	S
Cedar_Creek	IR-5	10/30/11	20:38	Night	Weasel	1	N
Swamp_Creek_W	P-1	10/31/11	3:58	Night	Beaver	1	N
Swamp_Creek_E	IR-3	11/4/11	19:31	Night	Raccoon	1	N
Swamp_Creek_W	P-1	11/6/11	5:49	Night	Raccoon	1	S
Swamp_Creek_W	P-1	11/7/11	4:44	Night	Raccoon	1	N
Swamp_Creek_W	P-1	11/7/11	13:44	Day	River_otter	3	N
Swamp_Creek_W	P-1	11/7/11	16:30	C-DU	River_otter	1	S
Swamp_Creek_W	P-1	11/9/11	5:00	Night	Raccoon	1	S
Unnamed_Creek	IR-6	11/24/11	5:27	Night	Weasel	1	S
Bonnie_Creek	IR-1	11/25/11	4:36	Night	Weasel	1	N
Swamp_Creek_E	IR-3	11/26/11	20:29	Night	Raccoon	1	S
Bonnie_Creek	IR-1	12/15/11	20:15	Night	Raccoon	1	S
Cedar_Creek	IR-5	12/20/11	3:22	Night	Weasel	1	N
Swamp_Creek_E	IR-3	1/6/12	5:36	Night	Raccoon	1	S
Swamp_Creek_W	P-1	1/21/12	4:31	Night	Raccoon	1	S
Swamp_Creek_E	IR-3	3/4/12	2:25	Night	Mink	1	N
Swamp_Creek_E	IR-3	3/12/12	0:00	Night	Beaver	1	N
Swamp_Creek_E	IR-3	3/18/12	20:27	Night	Beaver	1	N
Swamp_Creek_E	IR-3	3/18/12	8:17	Day	Mink	1	N
Swamp_Creek_W	P-1	3/19/12	23:04	Night	Beaver	1	N
Swamp_Creek_E	IR-3	3/19/12	1:35	Night	Mink	1	N
Swamp_Creek_E	IR-3	3/19/12	1:40	Night	Mink	1	N

Swamp_Creek_E	IR-3	3/19/12	2:06	Night	Mink	1	N
Swamp_Creek_E	IR-3	3/23/12	4:20	Night	Beaver	1	N
Bonnie_Creek	IR-2	3/23/12	4:00	Night	Weasel	1	N
Swamp_Creek_E	IR-3	3/25/12	0:23	Night	Mink	1	N
Swamp_Creek_E	IR-3	3/25/12	0:57	Night	Mink	1	N
Swamp_Creek_E	IR-3	3/28/12	0:11	Night	Mink	1	N
Price_Creek	IR-4	4/1/12	9:35	Day	Mink	1	N
Swamp_Creek_E	IR-3	4/7/12	10:47	Day	Mink	1	N
Bonnie_Creek	IR-2	4/7/12	21:11	Night	Raccoon	1	N
Swamp_Creek_E	IR-3	4/10/12	2:54	Night	Beaver	1	N
Price_Creek	IR-4	4/10/12	15:02	Day	Mink	1	N
Swamp_Creek_E	IR-3	4/14/12	23:44	Night	Beaver	1	N
Swamp_Creek_E	IR-3	4/20/12	0:32	Night	Beaver	1	N
Bonnie_Creek	IR-2	4/21/12	12:55	Day	Mink	1	N
Bonnie_Creek	IR-2	4/21/12	18:27	Day	Mink	1	S
Bonnie_Creek	IR-2	5/16/12	22:23	Night	Raccoon	1	S

Appendix 4.1. Individual black bears identified within the greater I-90 SPE Project Area, including DNA source, sex, date of sampling, side of highway, and location of sample collection (UTM NAD83).

Unique Individual	Source	Sex	Date Collected	Hwy Side	UTM X	UTM Y
URAM101468	Scat	M		North	638381	5236793
URAM101474	Scat	M	9/26/2008	North	638353	5236755
URAM101478	Scat	F		North	636376	5255584
URAM101488	Hair	M	8/6/2009	South	626991	5239246
URAM101490	Hair	M	8/26/2009	South	623714	5241766
URAM101496	Hair	F	8/26/2009	South	620908	5242022
URAM130508	Hair	M	5/26/2010	North	635960	5239304
URAM130536	Hair	M	10/13/2009	North	628341	5248013
URAM130632	Hair	F	9/18/2009	North	630677	5241939
URAM130635	Hair	M	9/18/2009	North	624350	5249358
URAM144800	Hair	F	9/2/2010	North	635326	5261079
URAM144803	Hair	M	9/3/2010	North	638699	5262507
URAM144804	Hair	M	9/3/2010	North	638699	5262507
URAM144805	Hair	F	9/14/2010	South	612284	5247689
URAM144809	Hair	F	9/17/2010	South	658327	5218574
URAM144811	Hair	F	9/17/2010	South	658327	5218574
URAM144828	Hair	F	9/30/2010	South	615823	5223282
URAM161877	Scat	F	10/17/2008	North	642503	5252916
URAM161881	Scat	F	10/17/2008	North	642270	5253166
URAM166883	Hair	F	8/25/2011	South	619229	5231571
URAM167752	Hair	M	9/5/2008	South	632825	5234847
URAM167759	Hair	F	9/5/2008	South	632825	5234847
URAM167765	Hair	M	8/21/2008	South	632825	5234847
URAM167767	Hair	F	7/28/2008	North	632978	5239556
URAM167806	Hair	M	7/8/2008	North	620017	5254108
URAM167809	Hair	F	8/8/2008	North	626767	5243171
URAM167812	Hair	M	8/19/2008	South	621324	5244046
URAM167821	Hair	M	9/17/2008	North	623887	5253814
URAM167825	Hair	M	10/10/2008	South	627127	5234637
URAM173807	Hair	F	7/9/2010	South	657157	5222728
URAM173811	Hair	M	6/25/2010	South	654691	5222012
URAM173818	Hair	F	7/16/2010	South	647302	5222075
URAM173823	Hair	F	7/16/2010	South	647302	5222075
URAM173850	Hair	F	9/2/2010	North	635326	5261079
URAM173851	Hair	M	9/3/2010	North	636107	5263589
URAM173853	Hair	f(m)	9/14/2010	South	612284	5247689
URAM173854	Hair	M	9/1/2010	North	642478	5262134

URAM173855	Hair	f	9/1/2010	North	642478	5262134
URAM173856	Hair	M	9/1/2010	North	642478	5262134
URAM191970	Hair	M	8/12/2010	South	640536	5227202
URAM194205	Hair	M	9/9/2008	North	625138	5245964
URAM194208	Hair	M	9/10/2008	South	618434	5246781
URAM194211	Hair	M	9/12/2008	North	627752	5244019
URAM197590	Hair	M	8/6/2009	North	627605	5241846
URAM900101	Hair	M	9/22/2011	South	617633	5235091
URAM901248	Hair	F	10/20/2011	North	654312	5241023
URAM902584	Hair	M	8/25/2011	South	636467	5223268
URAM902587	Hair	F	8/25/2011	South	616060	5230280
URAM902787	Hair	M	9/22/2011	South	616344	5237139
URAM902788	Hair	F	9/22/2011	South	616344	5237139
URAM902790	Hair	F	9/22/2011	South	616344	5237139
URAM902791	Hair	M	9/21/2011	North	611744	5251423
URAM902792	Hair	F	9/21/2011	North	611744	5251423
URAM902816	Hair	M	9/1/2011	North	615377	5255014
URAM902836	Hair	M	9/1/2011	North	616583	5253387
URAM903004	Hair	F	7/12/2011	North	615699	5271285
URAM903011	Hair	F	7/27/2011	North	613128	5271042
URAM903020	Hair	F	8/25/2011	South	632663	5223463
URAM903038	Hair	F	7/20/2011	South	630157	5226280
URAM903045	Hair	M	7/21/2011	South	618503	5239359
URAM903046	Hair	M	7/21/2011	South	618503	5239359
URAM903051	Hair	M	9/8/2011	South	636467	5223268
URAM903064	Hair	M	9/8/2011	South	616060	5230280
URAM903086	Hair	F	9/8/2011	South	636432	5219667
URAM903088	Hair	F	7/22/2011	South	651286	5217913
URAM903143	Hair	F	10/20/2011	North	654312	5241023
URAM903144	Hair	F	10/20/2011	North	654312	5241023
URAM903168	Hair	F	10/20/2011	North	655245	5241739
URAM903191	Hair	F	8/4/2011	South	622901	5227707
URAM903219	Hair	M	8/4/2011	South	622901	5227707
URAM903225	Hair	F	8/4/2011	South	618503	5239359
URAM903226	Hair	M	8/5/2011	South	651286	5217913
URAM903229	Hair	F	9/21/2011	South	620456	5269513
URAM903231	Hair	F	9/22/2011	South	621387	5275352
URAM903240	Hair	F	8/19/2011	North	611047	5269780
URAM903241	Hair	M	8/19/2011	North	613128	5271042
URAM903274	Hair	M	9/21/2011	South	620456	5269513

Appendix 4.2. Raw results of genetic analyses for black bears. including number of loci successfully identified and locus-specific values for 20 microsatellite markers. Each 6-digit value represents 2, 3-digit alleles. Missing locus values or those containing fewer than six digits represent a failed analysis at that locus.

		Locus																			
Unique Individual	# Loci Complete	G10B	G10H	G10J	G10L	MU23	MU59	G1D	G10C	G1A	G10M	G10P	CXX110	CXX20	MSUT-6	145P07	CPH9	D123	D1a	G10O	MSUT-2
URAM101468	18	158162	237245	201205	137159	187195	237241	176176	205215	192194	210217	165165	139141	139143	178180	165171	45145	141147	181183	6208	203203
URAM101474	15	158160	239239	205207	135165	195195	243243	72174	15215	90194	212212	15357	141155	131135	180180	171172	143147	145147	177179	9898	201203
URAM101478	19	160162	243263	187199	137159	191195	239243	172176	199207	192194	212216	153153	15359	131131	180180	163165	143143	145147	179179	196196	199203
URAM101488	20	160164	239241	205205	159165	191191	239243	172176	199205	184192	212213	161161	147157	131139	180180	163165	143147	145147	163181	196196	197199
URAM101490	20	158164	239241	187187	149159	187191	243243	174176	199215	184194	210212	153157	155157	131139	176176	163165	143143	145145	177179	156198	197199
URAM101496	20	162164	237239	187205	157159	191195	243243	172178	199205	184186	213218	153157	145153	131139	180180	165171	143143	141143	157177	150192	203203
URAM130508	20	160164	239243	187205	159165	187187	239239	176176	203215	190196	212217	155157	151155	139143	178180	163171	145145	141143	177179	196208	197203
URAM130536	20	160164	239259	199201	135155	187187	237241	174176	203203	190192	210212	159161	141151	139143	178180	163163	145145	145147	177181	198200	197207
URAM130632	20	156158	237239	205207	149165	187195	231243	172178	199215	184194	210218	153165	153157	131135	178180	163169	145147	141147	177181	192208	199207
URAM130635	20	160162	245245	187197	159165	187191	239239	174176	215215	190192	210212	157165	151157	137143	180184	163165	141143	141151	181181	196198	191209
URAM144800	20	156162	239263	199199	155165	191191	241243	172172	207215	184192	210216	159161	141153	131131	180180	157165	143143	145145	165177	192196	207209
URAM144803	20	160160	237243	195199	137159	187191	241243	176176	203203	194194	210212	161165	141157	131139	178180	169171	145147	147147	163181	196196	203209
URAM144804	20	156164	245245	187195	159169	191191	245245	176178	203205	184194	210220	157165	149157	131131	180180	165171	145145	145147	157179	150198	203207
URAM144805	20	158162	237239	187187	151171	191197	243243	176176	199203	194198	214218	157159	151157	131131	180180	165165	147147	141143	179181	200200	203209
URAM144809	20	162164	235239	187207	159163	191199	239241	172172	199199	194198	212212	157161	147155	135143	180180	169172	141143	147147	163181	196198	197199
URAM144811	20	164164	235237	187205	161163	191195	241241	172172	199203	194198	212218	157161	147157	143143	180180	165172	141147	145147	163177	150198	191199
URAM144828	20	156160	237245	195201	151159	191191	239243	172172	203205	190194	213216	157161	157157	139143	168176	157163	143145	141147	179185	150208	199203
URAM161877	20	158164	237243	187199	155159	191193	239241	172176	211215	190192	212213	153165	141151	135135	176176	163169	145147	141145	177179	198198	199207
URAM161881	19	162164	239243	205207	165169	187187	239243	172174	199199	184192	212212	153165	155155	139143	180182	165171	145145	145153	17981	154154	195199
URAM166883	20	156158	237239	205205	161165	191191	239243	172178	203211	186194	216218	153153	153153	131139	176180	163169	145145	141147	167177	196208	203209
URAM167752	20	158160	241249	199201	157159	191197	239239	172172	199203	192194	210212	157161	141157	131131	180180	163165	145147	145145	179181	196200	197201
URAM167759	20	158162	239241	195207	135159	191191	237239	172182	199215	192192	212213	153157	149153	131137	176178	163169	143145	141143	177177	196198	203203
URAM167765	20	156160	239249	201205	159159	199199	241243	172178	199199	192194	212212	155157	151151	131131	176180	163163	145149	141145	175179	198208	203203
URAM167767	20	156160	239259	207207	165169	191191	243245	172178	199215	194198	210210	153159	153157	135139	176178	165169	145145	145151	179181	198208	199209
URAM167806	20	160162	239245	195201	171171	195199	239241	178178	199215	192194	210210	157159	151155	131131	168180	165171	143147	141145	177179	196196	203203

URAM167809	20	160164	237239	199207	137165	191191	243243	176178	205215	194194	210210	159165	139153	131135	178180	165169	145145	141145	179181	208208	199199
URAM167812	6	158158	237249	189201	159161	191195	241243														
URAM167821	20	160162	245259	195197	165169	191191	239241	176176	205215	194194	212216	159159	141141	131139	180180	159171	145145	145147	157177	196196	203203
URAM167825	20	160160	239239	195205	159169	199199	239243	172178	199203	194194	212218	157165	151155	131131	180180	163172	145149	145147	175179	198208	203203
URAM173807	20	156162	237245	187205	159163	195199	243243	172178	199199	192194	212214	155157	141147	131139	180182	171172	145145	145147	175179	150198	199209
URAM173811	20	156162	237255	197205	151159	191195	239243	172176	203203	188198	214214	153157	141155	131135	180182	165165	145145	141145	179181	154156	203209
URAM173818	20	156160	239239	205207	159165	191195	243243	172176	199211	192194	213214	153155	151159	131131	180180	163165	145145	145147	181181	196198	203209
URAM173823	20	156160	243243	205207	159159	191195	243243	176176	203213	192192	208212	155157	141141	131139	176180	157165	145145	145147	175181	150154	201209
URAM173850	20	162164	239245	199205	159159	187187	237239	174176	203203	190198	210217	161161	141153	143147	178180	163165	145145	143147	181181	154198	209209
URAM173851	17	164164	243259	187199	159165	191195	239239	176176	199203	192194	212217	165165	141159	13141139	176180	157165	43143	141141	163177	150198	19703
URAM173853	16	160160	239239	199205	155169	191195	243243	72178	315	192194	212218	161161	145155	135137	176180	163171	47147	145147	179181	154196	
URAM173854	20	160160	237263	195199	159165	191191	241243	176176	203211	184194	212216	161161	147157	131131	180180	163169	143147	145147	181181	150196	209209
URAM173855	17	160162	243263	199199	159165	191199	241243	176178	707	18496192	212216	155161	147159	131131	180180	157163	143143	141145	179181	150198	20709
URAM173856	20	160164	245259	187187	161169	191191	239245	176176	199199	194194	212217	153165	151159	131139	182184	165171	143147	143143	177181	198198	199203
URAM191970	20	160162	239239	197205	135159	191191	233243	172178	199211	194194	213217	161161	147155	131143	180182	165167	145145	145151	157177	150196	199203
URAM194205	20	158164	237255	199201	155165	187187	243245	174176	203205	192194	210210	161165	139153	135141	176180	163167	143145	141141	177183	196208	199203
URAM194208	20	160164	239245	187187	155159	187199	239243	172176	199203	194194	210210	153153	155157	131139	176176	163171	143145	145145	179179	198198	199203
URAM194211	20	160164	237243	197197	137159	187191	239243	176176	205215	192194	210212	157165	141157	131137	176184	165171	143145	141147	181181	196208	191203
URAM197590	20	156158	237239	195205	149161	191195	231231	172176	199215	184194	213218	157165	141157	131131	180184	163165	143147	145147	177177	192192	207209
URAM900101	20	160162	245249	199205	159165	191199	243243	172178	199205	186194	210212	157157	151151	131131	180182	163165	143149	141141	157179	154198	203203
URAM901248	20	160162	237239	187205	159159	187191	239243	176178	199207	192194	212216	157161	155155	131139	180180	163171	143145	145147	179183	196208	197199
URAM902584	20	160160	239239	201205	159163	191191	241243	172176	211215	194194	212216	161163	155155	131139	180182	165167	143145	141147	177177	150150	203207
URAM902587	20	164164	237237	201205	159171	191195	237239	172176	199203	188198	214216	153161	155157	135139	176180	165165	145145	145145	177181	150192	203203
URAM902787	20	162164	241245	187189	159171	191191	231239	172172	199215	194194	212213	157159	151157	139139	180180	163165	143145	145147	177179	192196	203203
URAM902788	20	162162	239241	201205	165171	191195	231239	176176	199203	184198	212216	159159	157159	131139	180180	157169	143145	141145	177179	198198	203207
URAM902790	20	154162	239245	187189	159165	191195	231243	172176	199215	194194	212213	157159	151157	139139	180180	163165	143145	143145	177179	196200	203203
URAM902791	20	158160	239245	201201	169171	191195	239241	174178	203215	194198	210214	153159	147151	131139	180180	165171	143147	141145	177179	196198	199203
URAM902792	20	158160	239245	195199	169171	191199	241241	174178	199203	192192	210216	155157	147151	131139	180180	171171	145147	141145	177179	198206	199203
URAM902816	20	156164	239249	201205	161171	195199	231239	172172	215215	194194	213216	155157	151157	131131	180184	165165	145147	145145	177179	192196	203209
URAM902836	20	160162	237245	201203	165171	191193	239243	172174	207215	192194	210214	153157	147153	139141	176182	165171	143145	141145	179179	196198	203203

URAM903004	20	164164	237239	187201	137137	191195	241243	178184	203207	192194	214216	157159	153153	141141	180180	163165	143143	145145	177179	156196	191203
URAM903011	20	158162	239255	203207	151159	191195	241243	178178	203203	194194	212214	157165	153155	131139	180180	165171	143147	145145	175179	196200	203207
URAM903020	20	156160	245263	197201	165165	187191	239243	172172	203207	194198	212212	161161	151153	131139	176180	163171	145145	141143	177179	150196	199207
URAM903038	20	158160	239245	197199	151159	191195	243243	172172	199203	184190	212217	151161	155157	131135	176178	171173	145147	145147	177177	150198	199209
URAM903045	20	164164	237239	187205	159171	187195	231243	172176	203215	192194	210213	157159	153153	131139	180182	157171	143145	143147	177181	192198	197203
URAM903046	20	162164	255261	195205	159159	191191	231239	176178	199199	184194	210216	153159	153155	139139	180180	163165	143145	145147	177177	150150	197203
URAM903051	20	156160	235237	197197	159159	191195	239243	172172	203207	194194	212214	157161	147157	139143	176180	157171	145145	145145	177179	150198	199203
URAM903064	20	158160	239249	201201	159169	187191	245245	176176	199203	192194	212212	157157	151159	131139	180182	163163	143145	147147	177179	196198	191203
URAM903086	20	158164	239239	187205	149159	191195	243243	172172	199205	184190	212214	161161	151157	131143	176180	163171	145145	145145	177181	150182	195199
URAM903088	20	160162	239245	187205	159159	191191	239241	172176	203203	194194	212214	155157	141157	131143	180182	163165	145147	145147	163181	150208	195199
URAM903143	20	158160	243259	187205	155159	187191	239243	172176	199207	192196	210216	153153	157159	131131	180180	167171	145145	143143	163179	150198	203203
URAM903144	20	158160	243245	187197	155159	191195	231239	174178	199207	192194	212216	153153	157159	131131	180180	163165	145145	145145	163179	150198	199209
URAM903168	20	156158	245263	201207	155163	195195	237245	172176	199215	192198	212213	153155	137161	131139	180180	163163	145145	143147	177181	198208	191203
URAM903191	20	156158	237237	205207	159161	191191	241243	172172	199211	194194	216218	153161	141153	131141	176182	163171	145151	141141	177177	208208	207209
URAM903219	20	160162	239261	205205	151171	191195	239241	172172	203205	192194	212218	157163	157159	139141	178180	163171	145151	143147	177177	196208	195199
URAM903225	20	158162	237249	205207	157171	191199	243243	172176	205215	186194	212218	153157	141145	131131	182182	165167	143145	141143	157183	192200	197203
URAM903226	20	158162	239245	205205	159165	191191	239243	178178	199203	190194	212212	161161	153157	131139	182182	171173	145145	145145	157177	150150	203203
URAM903229	20	156160	239255	205205	159159	191195	241243	172176	199203	194198	210212	153157	141159	131139	180180	165165	143147	145145	175177	200208	203207
URAM903231	20	156160	237241	205205	157159	191195	243245	176178	203215	192194	210214	153165	141153	131131	180180	157165	143143	141147	177179	192198	203209
URAM903240	20	154164	239245	187187	137159	191195	231245	172178	203203	184194	210210	157161	137155	139141	180182	161163	143143	145145	157179	196198	203209
URAM903241	20	160164	245245	201205	151165	191199	241241	176178	199211	194198	216218	153153	151159	139139	180180	159173	145147	145145	177179	196198	203207
URAM903274	20	160160	239239	187205	159159	191191	241243	176176	203205	194198	210212	153157	159159	139139	176180	165165	145147	143145	157177	198208	203207

Appendix 4.3. Individual martens identified within the greater I-90 SPE Project Area, including DNA source, sex, date of sampling, side of highway, and location of sample collection (UTM NAD83).

Unique Individual	Source	Sex	Date Collected	Hwy Side	UTM X	UTM Y
MAAM101497	Hair	M	2/9/2010	North	627970	5245076
MAAM130602	Hair	M	4/4/2009	North	620285	5254827
MAAM130631	Hair	F	10/22/2009	North	620455	5255151
MAAM130782	Hair	M	3/4/2010	North	618388	5256330
MAAM130803	Hair	F	2/23/2010	North	626415	5246528
MAAM130825	Hair	M	2/23/2010	North	627051	5246870
MAAM144834	Hair	F	1/27/2012	North	624307	5247865
MAAM160755	Hair	M	1/13/2011	North	624912	5248045
MAAM167847	Hair	M	3/21/2009	North	619933	5254494
MAAM193642	Hair	F	3/4/2010	North	616992	5257191
MAAM197587	Hair	M	5/8/2009	North	631343	5237791
MAAM900005	Hair	M	3/17/2012	South	618458	5251190
MAAM900781	Hair	M	2/13/2011	North	620294	5253235
MAAM900992	Hair	M	1/27/2012	North	620570	5255247
MAAM903034	Hair	M	2/3/2012	North	618928	5256090
MAAM903342	Hair	M	1/27/2012	North	624912	5248045
MAAM903351	Hair	M	2/10/2012	North	631024	5238034
MAAM903471	Hair	M	1/23/2012	North	616700	5253637

Appendix 4.4. Raw results of genetic analyses for martens, including number of loci successfully identified and locus-specific values for 12 microsatellite markers. Each 6-digit value represents 2, 3-digit alleles. Missing locus values represent a failed analysis at that locus.

		Locus											
Unique Individual	# Loci Complete	MP55	MP114	MP175	MP197	MP59	MP85	MA-10	MA-7	MA-9	MP0227	MP0182	MP0144
MAAM101497	12	106108	154166	130130	235235	141141	127127	166168	189191	140140	116118	153155	157157
MAAM130602	12	106108	162170	130130	235235	141143	133133	168169	185191	141141	118118	155155	157157
MAAM130631	12	106106	166166	130130	235235	141141	127127	168169	189191	140141	118122	155155	157157
MAAM130782	12	106108	166170	130130	231235	141141	127133	166168	187189	140140	118122	153155	157157
MAAM130803	12	106106	158166	130130	231235	141143	127133	166166	187189	140140	118118	153153	157157
MAAM130825	12	106106	166166	130130	235235	141141	127127	168169	189189	140140	116118	155155	157157
MAAM144834	10	106106			235235	141141	127127	168169	185187	140141	116116	153153	
MAAM160755	10	106106			231235	135141	127127	166169	185187	140141	118122	153155	
MAAM167847	12	106106	158166	130130	231231	141141	127133	169169	187189	140140	118118	155155	157157
MAAM193642	12	106106	162166	130130	231235	141141	127133	168169	189191	140141	118118	155155	157157
MAAM197587	12	106108	158166	130130	235239	141143	127133	169170	185187	141142	118118	155155	157157
MAAM900005	10	106106			231231	141143	125127	166170	187189	140140	118118	153153	
MAAM900781	11	106108	162166		231235	141141	127133	168168	185189	140140	118118	153155	157157
MAAM900992	10	106108			231235	135141	127135	168169	185189	140140	118118	153155	
MAAM903034	10	106106			231235	141143	125127	166168	187189	140140	118118	153155	
MAAM903342	10	106108			231235	141141	127133	168169	185191	141141	118118	155155	
MAAM903351	10	106106			227231	141141	127133	168170	185187	140140	118118	153153	
MAAM903471	10	106106			231235	141141	125127	169169	187189	140140	118122	155155	

Appendix 4.5. Raw results of small mammal trapping effort, including grid-specific captures and recaptures by species. "Result" codes are as follows: CLGA=red-backed vole; ESCP=animal escaped during handling; GLSA=northern flying squirrel; GONE=trap missing; NOBT=trap open but bait removed; PEKE=Northwestern deermouse; PEMA=deermouse; SOTR=Trowbridge's shrew; SOVA=vagrant shrew; SPRG=trap closed but trap empty; STCK=trap door sprung but door stuck ajar; TATO= Townsend's chipmunk.

DATE	GRID	TRAP	RESULT	SAMPLE	RECAPTURE	SEX	WEIGHT	MORTALITY	COMMENTS
9/16/2008	PRICE_CREEK_NORTH	A1	TATO	A593734B		M	N/A		
9/16/2008	GOLD_CREEK_NORTH	B4	TATO	A593703B		M	N/A		
9/16/2008	GOLD_CREEK_SOUTH	C1	TATO	A593701B		M	N/A		
9/16/2008	GOLD_CREEK_NORTH	C5	TATO	A593741B		M	N/A		
9/16/2008	GOLD_CREEK_SOUTH	A5	STCK						
9/16/2008	PRICE_CREEK_NORTH	B1	STCK						
9/16/2008	GOLD_CREEK_NORTH	B3	STCK						
9/16/2008	GOLD_CREEK_NORTH	B5	STCK						
9/16/2008	PRICE_CREEK_SOUTH	C1	STCK						
9/16/2008	PRICE_CREEK_SOUTH	C2	STCK						
9/16/2008	PRICE_CREEK_SOUTH	D3	STCK						
9/16/2008	GOLD_CREEK_NORTH	E2	STCK						
9/16/2008	GOLD_CREEK_NORTH	E3	STCK						
9/16/2008	PRICE_CREEK_SOUTH	E3	STCK						
9/16/2008	PRICE_CREEK_NORTH	E4	STCK						
9/16/2008	GOLD_CREEK_NORTH	D4	SPRG						
9/16/2008	PRICE_CREEK_SOUTH	A1	PEKE	A593737B		F	14		
9/16/2008	GOLD_CREEK_NORTH	A3	PEKE	A593704B		M	17		
9/16/2008	GOLD_CREEK_SOUTH	A4	PEKE	A593747B		F	13.5		
9/16/2008	GOLD_CREEK_NORTH	A4	PEKE	A593702B		M	16		
9/16/2008	PRICE_CREEK_NORTH	A4	PEKE	A593735B		M	16		
9/16/2008	PRICE_CREEK_NORTH	A5	PEKE	A593736B		F	17		
9/16/2008	GOLD_CREEK_SOUTH	B1	PEKE	A593750B		M	17		
9/16/2008	GOLD_CREEK_NORTH	B2	PEKE	A593705B		F	17		

9/16/2008	PRICE_CREEK_SOUTH	B2	PEKE	A593708B		M	15	
9/16/2008	PRICE_CREEK_NORTH	B3	PEKE	A593729B		M	15	SEX UNCERTAIN
9/16/2008	GOLD_CREEK_SOUTH	C2	PEKE	A593749B		F	20	
9/16/2008	GOLD_CREEK_SOUTH	C3	PEKE	A593748B		F	14	
9/16/2008	PRICE_CREEK_SOUTH	C5	PEKE	A593707B		M	12.5	
9/16/2008	PRICE_CREEK_NORTH	C5	PEKE	A593727B		F	22	
9/16/2008	PRICE_CREEK_SOUTH	D1	PEKE	A593738B		M	15	
9/16/2008	PRICE_CREEK_NORTH	D1	PEKE	A593733B		F	16.5	
9/16/2008	GOLD_CREEK_NORTH	D2	PEKE	A593706B		M	21	
9/16/2008	PRICE_CREEK_SOUTH	D2	PEKE	A593709B		F	19	
9/16/2008	GOLD_CREEK_SOUTH	D4	PEKE	A593746B		F	24	
9/16/2008	PRICE_CREEK_SOUTH	D4	PEKE					NO SAMPLE TAKEN
9/16/2008	PRICE_CREEK_NORTH	D4	PEKE	A593728B		M	16	
9/16/2008	GOLD_CREEK_SOUTH	D5	PEKE	A593743B		M	21	
9/16/2008	PRICE_CREEK_SOUTH	E1	PEKE	A593739B		F	18	
9/16/2008	PRICE_CREEK_NORTH	E1	PEKE	A593732B		F	21	
9/16/2008	PRICE_CREEK_NORTH	E2	PEKE	A593731B		F	16	
9/16/2008	PRICE_CREEK_NORTH	E3	PEKE	A593730B		F	16	
9/16/2008	GOLD_CREEK_SOUTH	E4	PEKE	A593745B		M	17.5	
9/16/2008	GOLD_CREEK_NORTH	E4	PEKE	A593740B		F	15.5	
9/16/2008	GOLD_CREEK_SOUTH	E5	PEKE	A593744B		M	15	
9/16/2008	GOLD_CREEK_NORTH	E5	PEKE	A593742B		F	15	
9/16/2008	PRICE_CREEK_NORTH	E5	PEKE	A593726B		M	20	
9/16/2008	GOLD_CREEK_SOUTH	E1	ESCP					MOST LIKELY A PEKE
9/17/2008	GOLD_CREEK_SOUTH	C2	TATO	A593724B		F	N/A	
9/17/2008	GOLD_CREEK_SOUTH	D1	TATO	A593725B		F	N/A	
9/17/2008	GOLD_CREEK_NORTH	D4	TATO	A593712B		M	N/A	
9/17/2008	GOLD_CREEK_NORTH	D5	TATO		X	M	N/A	
9/17/2008	GOLD_CREEK_SOUTH	E3	STCK					
9/17/2008	GOLD_CREEK_SOUTH	A3	SPRG					

9/17/2008	GOLD_CREEK_NORTH	B1	SPRG				
9/17/2008	GOLD_CREEK_NORTH	B4	SPRG				
9/17/2008	PRICE_CREEK_NORTH	C3	SPRG				
9/17/2008	GOLD_CREEK_NORTH	E1	SPRG				
9/17/2008	PRICE_CREEK_NORTH	E5	SPRG				
9/17/2008	GOLD_CREEK_SOUTH	A1	PEKE		X	M	16
9/17/2008	PRICE_CREEK_SOUTH	A1	PEKE		X	F	14.5
9/17/2008	PRICE_CREEK_NORTH	A2	PEKE	A197502B		M	14
9/17/2008	GOLD_CREEK_NORTH	A3	PEKE		X	M	18
9/17/2008	GOLD_CREEK_SOUTH	A4	PEKE	A593723B		M	21
9/17/2008	GOLD_CREEK_NORTH	A5	PEKE	A593720B		M	21
9/17/2008	GOLD_CREEK_SOUTH	B1	PEKE		X	F	21
9/17/2008	PRICE_CREEK_NORTH	B1	PEKE	A197550B		F	14
9/17/2008	GOLD_CREEK_SOUTH	B2	PEKE	A593710B		F	15.5
9/17/2008	PRICE_CREEK_SOUTH	B2	PEKE	A593716B		M	16
9/17/2008	PRICE_CREEK_SOUTH	B3	PEKE		X	N/A	15
9/17/2008	PRICE_CREEK_NORTH	B4	PEKE	A197545B		F	18
9/17/2008	GOLD_CREEK_SOUTH	B5	PEKE		X	M	21
9/17/2008	GOLD_CREEK_NORTH	B5	PEKE		X	M	18
9/17/2008	PRICE_CREEK_NORTH	B5	PEKE	A197544B		F	13
9/17/2008	GOLD_CREEK_SOUTH	C3	PEKE		X	M	20
9/17/2008	PRICE_CREEK_SOUTH	C4	PEKE	A593718B		F	14
9/17/2008	PRICE_CREEK_NORTH	C4	PEKE		X	F	18
9/17/2008	GOLD_CREEK_SOUTH	C5	PEKE		X	F	18
9/17/2008	GOLD_CREEK_NORTH	C5	PEKE		X	M	18
9/17/2008	PRICE_CREEK_SOUTH	C5	PEKE	A593719B		F	18
9/17/2008	PRICE_CREEK_NORTH	C5	PEKE	A197543B		M	17
9/17/2008	PRICE_CREEK_SOUTH	D1	PEKE	A593714B		M	15
9/17/2008	PRICE_CREEK_SOUTH	D2	PEKE	A593715B		M	15.5
9/17/2008	GOLD_CREEK_SOUTH	D3	PEKE	A593711B		M	16

9/17/2008	GOLD_CREEK_NORTH	D3	PEKE		X	M	21		
9/17/2008	PRICE_CREEK_SOUTH	D3	PEKE		X	F	21		
9/17/2008	GOLD_CREEK_SOUTH	D4	PEKE		X	F	16		
9/17/2008	PRICE_CREEK_SOUTH	D4	PEKE	A593717B		M	16		
9/17/2008	GOLD_CREEK_SOUTH	D5	PEKE	A593721B		F	17		SEX UNCERTAIN
9/17/2008	PRICE_CREEK_NORTH	D5	PEKE		X	M	17		
9/17/2008	PRICE_CREEK_NORTH	E1	PEKE	A197549B		F	14.5		
9/17/2008	PRICE_CREEK_NORTH	E2	PEKE	A197548B		M	13		
9/17/2008	PRICE_CREEK_NORTH	E3	PEKE	A197547B		M	14.5		
9/17/2008	GOLD_CREEK_SOUTH	E4	PEKE		X	F	22		
9/17/2008	GOLD_CREEK_NORTH	E4	PEKE	A593713B		M	18		
9/17/2008	PRICE_CREEK_NORTH	E4	PEKE	A197546B		M	17		
9/17/2008	GOLD_CREEK_SOUTH	E5	PEKE	A593722B		M	20		
9/17/2008	GOLD_CREEK_NORTH	D1	GLSA						RELEASED
9/17/2008	PRICE_CREEK_NORTH	A3	ESCP						TATO
9/17/2008	GOLD_CREEK_SOUTH	C1	ESCP						TATO
9/18/2008	GOLD_CREEK_NORTH	A1	TATO	A197538B		F	N/A		
9/18/2008	GOLD_CREEK_NORTH	A5	TATO	A197539B		M	N/A		
9/18/2008	PRICE_CREEK_NORTH	C5	TATO		X	M	N/A		
9/18/2008	GOLD_CREEK_NORTH	D4	TATO						
9/18/2008	PRICE_CREEK_SOUTH	E3	TATO	A197536B		M	N/A		
9/18/2008	GOLD_CREEK_SOUTH	C1	SPRG						
9/18/2008	GOLD_CREEK_NORTH	C1	SPRG						
9/18/2008	GOLD_CREEK_NORTH	C3	SPRG						
9/18/2008	GOLD_CREEK_NORTH	D2	SPRG						
9/18/2008	GOLD_CREEK_NORTH	D1	SOVA			N/A	5	X	MAYBE SOMO(?)
9/18/2008	GOLD_CREEK_SOUTH	A4	SOTR	A197541B		N/A	7		SPECIES WRONG?
9/18/2008	PRICE_CREEK_SOUTH	A5	PEKE		X	F	16		
9/18/2008	GOLD_CREEK_SOUTH	B1	PEKE		X	F	17		
9/18/2008	PRICE_CREEK_SOUTH	B2	PEKE		X	F	16		

9/18/2008	PRICE_CREEK_SOUTH	B3	PEKE	A197537B		M	18	
9/18/2008	GOLD_CREEK_SOUTH	B4	PEKE		X	F	14	
9/18/2008	GOLD_CREEK_NORTH	B4	PEKE		X	M	16	SHRT TAIL, <103mm
9/18/2008	PRICE_CREEK_NORTH	B4	PEKE		X	M	16	
9/18/2008	GOLD_CREEK_NORTH	B5	PEKE	A197540B		F	17	
9/18/2008	PRICE_CREEK_SOUTH	C1	PEKE		X	M	14	
9/18/2008	GOLD_CREEK_SOUTH	C2	PEKE	A197542B		M	18	
9/18/2008	PRICE_CREEK_NORTH	C3	PEKE		X	F	14	
9/18/2008	GOLD_CREEK_SOUTH	C4	PEKE		X	F	15	
9/18/2008	PRICE_CREEK_SOUTH	C4	PEKE	A197505B		M	16	
9/18/2008	PRICE_CREEK_NORTH	C4	PEKE		X	M	17	
9/18/2008	PRICE_CREEK_SOUTH	D1	PEKE		X	M	16	
9/18/2008	PRICE_CREEK_NORTH	D1	PEKE		X	F	19	
9/18/2008	PRICE_CREEK_SOUTH	D2	PEKE					
9/18/2008	GOLD_CREEK_SOUTH	D3	PEKE		X	F	15	
9/18/2008	PRICE_CREEK_SOUTH	D3	PEKE		X	M	14.5	
9/18/2008	GOLD_CREEK_SOUTH	D4	PEKE		X	M	17	TWO IN TRAP
9/18/2008	GOLD_CREEK_SOUTH	D4	PEKE		X	F	20	TWO IN TRAP
9/18/2008	PRICE_CREEK_SOUTH	D4	PEKE	A197504B		F	15	
9/18/2008	GOLD_CREEK_SOUTH	D5	PEKE		X	M	18	
9/18/2008	GOLD_CREEK_SOUTH	E1	PEKE		X	M	17	
9/18/2008	PRICE_CREEK_SOUTH	E1	PEKE		X	M	16	
9/18/2008	PRICE_CREEK_NORTH	E3	PEKE	A197507B		F	15	
9/18/2008	GOLD_CREEK_SOUTH	E4	PEKE	A197503B		M	18	TAIL <103mm PEMA?
9/18/2008	GOLD_CREEK_NORTH	E4	PEKE		X	M	N/A	TAIL <103mm PEMA?
9/18/2008	PRICE_CREEK_NORTH	E4	PEKE	A197506B		M	15	TAIL < 103mm PEMA?
9/18/2008	GOLD_CREEK_SOUTH	E5	PEKE		X	F	21	
9/18/2008	PRICE_CREEK_NORTH	A5	NOBT					
9/18/2008	PRICE_CREEK_NORTH	C1	NOBT					
9/18/2008	PRICE_CREEK_SOUTH	C2	NOBT					

9/18/2008	PRICE_CREEK_SOUTH	E2	NOBT						
9/18/2008	GOLD_CREEK_SOUTH	A5	GLSA					X	
9/18/2008	GOLD_CREEK_SOUTH	B2	ESCP						TATO
9/18/2008	GOLD_CREEK_SOUTH	D2	ESCP						
9/19/2008	PRICE_CREEK_SOUTH	A1	TATO	A197512B		M	N/A		
9/19/2008	PRICE_CREEK_NORTH	B1	TATO		X	F	N/A		
9/19/2008	GOLD_CREEK_SOUTH	B2	TATO		X	F	N/A		
9/19/2008	GOLD_CREEK_NORTH	B5	TATO		X	M	N/A		
9/19/2008	GOLD_CREEK_SOUTH	D1	TATO	A197508B		F	N/A		
9/19/2008	GOLD_CREEK_NORTH	D2	TATO	A197511B		F	N/A		
9/19/2008	GOLD_CREEK_SOUTH	D3	TATO		X	F	N/A		
9/19/2008	PRICE_CREEK_SOUTH	E1	TATO		X	M	N/A		
9/19/2008	PRICE_CREEK_SOUTH	D1	STCK						
9/19/2008	GOLD_CREEK_NORTH	B4	SPRG						
9/19/2008	PRICE_CREEK_SOUTH	C1	SPRG						
9/19/2008	PRICE_CREEK_SOUTH	A3	PEKE		X	F	19		
9/19/2008	PRICE_CREEK_NORTH	A3	PEKE	A197513B		F	17		
9/19/2008	GOLD_CREEK_SOUTH	A5	PEKE	A197509B		F	19		
9/19/2008	PRICE_CREEK_NORTH	A5	PEKE	A197514B		F	19		
9/19/2008	GOLD_CREEK_SOUTH	B1	PEKE		X	M	18		
9/19/2008	PRICE_CREEK_SOUTH	B2	PEKE		X	F	N/A		
9/19/2008	GOLD_CREEK_SOUTH	B4	PEKE		X	M	18		
9/19/2008	PRICE_CREEK_SOUTH	B4	PEKE		X	M	14		
9/19/2008	PRICE_CREEK_NORTH	B4	PEKE		X	F	19		
9/19/2008	GOLD_CREEK_SOUTH	B5	PEKE	A197535B		M	17		
9/19/2008	PRICE_CREEK_NORTH	C1	PEKE	A197515B		M	16		
9/19/2008	GOLD_CREEK_NORTH	C2	PEKE	A197510B		F	16		
9/19/2008	PRICE_CREEK_NORTH	C2	PEKE	A197534B		M	12		
9/19/2008	GOLD_CREEK_SOUTH	C3	PEKE		X	M	17		
9/19/2008	GOLD_CREEK_NORTH	C3	PEKE		X	F	18		

9/19/2008	PRICE_CREEK_SOUTH	C3	PEKE		X	F	16	
9/19/2008	PRICE_CREEK_NORTH	C3	PEKE		X	F	16	
9/19/2008	GOLD_CREEK_SOUTH	C4	PEKE			F	16	
9/19/2008	PRICE_CREEK_SOUTH	C5	PEKE		X	M	14	
9/19/2008	PRICE_CREEK_NORTH	C5	PEKE	A197517B		M	15	
9/19/2008	PRICE_CREEK_SOUTH	D4	PEKE		X	N/A	N/A	ESCAPE B/F SEX/WT
9/19/2008	GOLD_CREEK_SOUTH	D5	PEKE		X	F	22	
9/19/2008	PRICE_CREEK_NORTH	D5	PEKE		X	F	17	
9/19/2008	PRICE_CREEK_NORTH	E2	PEKE					
9/19/2008	PRICE_CREEK_NORTH	E3	PEKE	A197516B		F	17.5	
9/19/2008	GOLD_CREEK_SOUTH	E4	PEKE		X	F	20	
9/19/2008	PRICE_CREEK_NORTH	E4	PEKE		X	M	17	
9/19/2008	GOLD_CREEK_SOUTH	E5	PEKE		X	M	15.5	
9/19/2008	PRICE_CREEK_NORTH	A1	NOBT					
9/19/2008	GOLD_CREEK_SOUTH	A2	NOBT					
9/19/2008	GOLD_CREEK_NORTH	A2	NOBT					
9/19/2008	PRICE_CREEK_NORTH	A2	NOBT					
9/19/2008	GOLD_CREEK_SOUTH	D2	NOBT					
9/19/2008	PRICE_CREEK_NORTH	D2	NOBT					
9/19/2008	GOLD_CREEK_NORTH	D5	NOBT					
9/19/2008	GOLD_CREEK_SOUTH	E2	NOBT					
9/19/2008	GOLD_CREEK_NORTH	E2	NOBT					
9/19/2008	PRICE_CREEK_SOUTH	E2	NOBT					
9/19/2008	GOLD_CREEK_SOUTH	E3	NOBT					
9/19/2008	PRICE_CREEK_SOUTH	E4	NOBT					
9/19/2008	PRICE_CREEK_NORTH	E5	NOBT					
9/19/2008	GOLD_CREEK_NORTH	B3	GLSA					RELEASED
9/19/2008	GOLD_CREEK_NORTH	E4	ESCP					SOVA(?) ESCAPED
9/23/2008	SWAMP_CREEK_SOUTH	D1	TATO	A197532B		M	N/A	
9/23/2008	SWAMP_CREEK_NORTH	B1	STCK					

9/23/2008	SWAMP_CREEK_SOUTH	B5	STCK					
9/23/2008	SWAMP_CREEK_SOUTH	D2	STCK					
9/23/2008	SWAMP_CREEK_SOUTH	B2	SPRG					
9/23/2008	SWAMP_CREEK_SOUTH	C5	SPRG					
9/23/2008	SWAMP_CREEK_NORTH	A1	PEKE	A197528B		F	21	
9/23/2008	SWAMP_CREEK_NORTH	A2	PEKE	A197527B		M	17	
9/23/2008	SWAMP_CREEK_SOUTH	A2	PEKE	A197518B		F	19	
9/23/2008	SWAMP_CREEK_SOUTH	B1	PEKE	A197533B		F	21	
9/23/2008	SWAMP_CREEK_SOUTH	C1	PEKE	A197519B		M	17	TAIL < 103MM, PEMA?
9/23/2008	SWAMP_CREEK_SOUTH	D3	PEKE	A197520B		M	15	
9/23/2008	SWAMP_CREEK_SOUTH	E1	PEKE	A197521B		M	25	
9/23/2008	SWAMP_CREEK_SOUTH	E2	PEKE	A197531B		M	20	
9/23/2008	SWAMP_CREEK_SOUTH	E4	PEKE	A197530B		M	15	
9/23/2008	SWAMP_CREEK_SOUTH	E5	PEKE	A197529B		M	18	
9/24/2008	SWAMP_CREEK_SOUTH	A5	TATO	A197526B		F	N/A	
9/24/2008	SWAMP_CREEK_SOUTH	B4	TATO	A197524B		F	N/A	
9/24/2008	SWAMP_CREEK_SOUTH	C3	TATO	A197650B		M	N/A	
9/24/2008	SWAMP_CREEK_SOUTH	D2	TATO	A197649B		F	N/A	
9/24/2008	SWAMP_CREEK_NORTH	B1	PEKE		X	M	17	
9/24/2008	SWAMP_CREEK_SOUTH	B1	PEKE		X	M	17	
9/24/2008	SWAMP_CREEK_SOUTH	B2	PEKE	A197522B		M	20	
9/24/2008	SWAMP_CREEK_NORTH	B5	PEKE	A197605B		M	19	
9/24/2008	SWAMP_CREEK_SOUTH	B5	PEKE	A197525B		F	18	
9/24/2008	SWAMP_CREEK_SOUTH	C1	PEKE		X	F	21	
9/24/2008	SWAMP_CREEK_SOUTH	C2	PEKE	A197523B		F	18	
9/24/2008	SWAMP_CREEK_SOUTH	C5	PEKE	A197601B		M	16	
9/24/2008	SWAMP_CREEK_SOUTH	D3	PEKE		X	M	16	
9/24/2008	SWAMP_CREEK_SOUTH	D4	PEKE	A197602B		M	19	
9/24/2008	SWAMP_CREEK_SOUTH	E1	PEKE	A197603B		F	19	
9/24/2008	SWAMP_CREEK_SOUTH	E2	PEKE		X	F	20	

9/24/2008	SWAMP_CREEK_SOUTH	E4	PEKE		X	N/A	18		ESCAPED
9/24/2008	SWAMP_CREEK_SOUTH	E5	PEKE	A197604B		M	17		
9/24/2008	SWAMP_CREEK_SOUTH	A1	NOBT						
9/24/2008	SWAMP_CREEK_SOUTH	C4	NOBT						
9/24/2008	SWAMP_CREEK_SOUTH	D1	NOBT						
9/24/2008	SWAMP_CREEK_SOUTH	D5	NOBT						
9/24/2008	SWAMP_CREEK_SOUTH	E3	NOBT						
9/25/2008	SWAMP_CREEK_SOUTH	A2	TATO	A197607B		F	N/A		
9/25/2008	SWAMP_CREEK_NORTH	A4	TATO	A197611B		M	N/A		
9/25/2008	SWAMP_CREEK_SOUTH	B3	TATO		X	F	N/A		
9/25/2008	SWAMP_CREEK_SOUTH	C5	TATO	A197645B		N/A	N/A		FORGOT TO SEX
9/25/2008	SWAMP_CREEK_SOUTH	D2	TATO		X	F	N/A		
9/25/2008	SWAMP_CREEK_SOUTH	D4	TATO	A197644B		N/A	N/A		FORGOT TO SEX AGAIN
9/25/2008	SWAMP_CREEK_SOUTH	E2	TATO	A197641B		F	N/A		
9/25/2008	SWAMP_CREEK_SOUTH	E4	TATO	A197640B		M	N/A		
9/25/2008	SWAMP_CREEK_SOUTH	E5	TATO		X	F			
9/25/2008	SWAMP_CREEK_SOUTH	E3	SPRG						
9/25/2008	SWAMP_CREEK_NORTH	B1	SOVA	A197639B		N/A	5	X	SPECIES UNCERTAIN
9/25/2008	SWAMP_CREEK_SOUTH	A3	SOTR	A197608B		N/A	4.5	X	SPECIES UNCERTAIN
9/25/2008	SWAMP_CREEK_SOUTH	A1	PEKE	A197606B		F	19		
9/25/2008	SWAMP_CREEK_SOUTH	A4	PEKE		X	F	18		
9/25/2008	SWAMP_CREEK_SOUTH	B2	PEKE	A197648B		F	15.5		
9/25/2008	SWAMP_CREEK_NORTH	B4	PEKE		X	M	17.5		
9/25/2008	SWAMP_CREEK_SOUTH	C1	PEKE	A197609B		F	17.5		TWO ANIMALS IN TRAP
9/25/2008	SWAMP_CREEK_SOUTH	C1	PEKE	A197647B		F	16		TWO ANIMALS IN TRAP
9/25/2008	SWAMP_CREEK_SOUTH	C2	PEKE	A197646B		M	17		
9/25/2008	SWAMP_CREEK_NORTH	C5	PEKE	A197610B		M	18		
9/25/2008	SWAMP_CREEK_SOUTH	D1	PEKE	A197643B		F	24		

9/25/2008	SWAMP_CREEK_SOUTH	E1	PEKE	A197642B		F	19	
9/25/2008	SWAMP_CREEK_NORTH	A1	NOBT					
9/25/2008	SWAMP_CREEK_NORTH	A5	NOBT					
9/25/2008	SWAMP_CREEK_SOUTH	A5	NOBT					
9/25/2008	SWAMP_CREEK_SOUTH	B1	NOBT					
9/25/2008	SWAMP_CREEK_SOUTH	B4	NOBT					
9/25/2008	SWAMP_CREEK_SOUTH	B5	NOBT					
9/25/2008	SWAMP_CREEK_SOUTH	C3	NOBT					
9/25/2008	SWAMP_CREEK_SOUTH	C4	NOBT					
9/25/2008	SWAMP_CREEK_SOUTH	D3	NOBT					
9/25/2008	SWAMP_CREEK_SOUTH	D5	NOBT					
9/25/2008	SWAMP_CREEK_NORTH	D5	ESCP					PEKE
9/26/2008	SWAMP_CREEK_NORTH	A4	TATO	A197615B		F	N/A	
9/26/2008	SWAMP_CREEK_SOUTH	B3	TATO		X	F		
9/26/2008	SWAMP_CREEK_SOUTH	B5	TATO		X	F	N/A	
9/26/2008	SWAMP_CREEK_SOUTH	C3	TATO	A197637B		M	N/A	
9/26/2008	SWAMP_CREEK_SOUTH	C5	TATO		X	M	N/A	
9/26/2008	SWAMP_CREEK_SOUTH	E1	TATO	A197612B		M	N/A	
9/26/2008	SWAMP_CREEK_SOUTH	E2	TATO		X	M		
9/26/2008	SWAMP_CREEK_SOUTH	A1	SPRG					
9/26/2008	SWAMP_CREEK_SOUTH	B1	SPRG					
9/26/2008	SWAMP_CREEK_NORTH	C1	SPRG					
9/26/2008	SWAMP_CREEK_SOUTH	C1	SPRG					
9/26/2008	SWAMP_CREEK_NORTH	C2	SPRG					
9/26/2008	SWAMP_CREEK_SOUTH	C2	SPRG					
9/26/2008	SWAMP_CREEK_NORTH	D3	SPRG					
9/26/2008	SWAMP_CREEK_SOUTH	D3	SPRG					
9/26/2008	SWAMP_CREEK_SOUTH	E4	SPRG					
9/26/2008	SWAMP_CREEK_NORTH	A2	PEKE		X	F	17	
9/26/2008	SWAMP_CREEK_SOUTH	A3	PEKE	A197638B		M	18	

9/26/2008	SWAMP_CREEK_NORTH	A5	PEKE		X	M	17	
9/26/2008	SWAMP_CREEK_SOUTH	B2	PEKE		X	F	21	
9/26/2008	SWAMP_CREEK_SOUTH	C4	PEKE	A197636B		F	22	
9/26/2008	SWAMP_CREEK_NORTH	C5	PEKE	A197614B		F	16	
9/26/2008	SWAMP_CREEK_NORTH	E4	PEKE	A197613B		M	19	
9/26/2008	SWAMP_CREEK_SOUTH	A2	NOBT					
9/26/2008	SWAMP_CREEK_SOUTH	A4	NOBT					
9/26/2008	SWAMP_CREEK_SOUTH	A5	NOBT					
9/26/2008	SWAMP_CREEK_NORTH	B4	NOBT					
9/26/2008	SWAMP_CREEK_SOUTH	B4	NOBT					
9/26/2008	SWAMP_CREEK_SOUTH	D1	NOBT					
9/26/2008	SWAMP_CREEK_SOUTH	D2	NOBT					
9/26/2008	SWAMP_CREEK_SOUTH	D4	NOBT					
9/26/2008	SWAMP_CREEK_SOUTH	D5	NOBT					
9/26/2008	SWAMP_CREEK_NORTH	E1	NOBT					
9/26/2008	SWAMP_CREEK_NORTH	E3	NOBT					
9/26/2008	SWAMP_CREEK_SOUTH	E3	NOBT					
9/26/2008	SWAMP_CREEK_NORTH	E5	NOBT					
9/26/2008	SWAMP_CREEK_SOUTH	E5	NOBT					
9/30/2008	TOLL_CREEK_NORTH	A2	TATO	A197736B		M	N/A	
9/30/2008	TOLL_CREEK_NORTH	E5	TATO	A197733B		M	N/A	
9/30/2008	TOLL_CREEK_NORTH	B2	SPRG					
9/30/2008	TOLL_CREEK_SOUTH	C2	SPRG					
9/30/2008	TOLL_CREEK_NORTH	D1	SPRG					DAMAGED BY BEAR
9/30/2008	TOLL_CREEK_NORTH	A1	PEKE	A197737B		M	20	
9/30/2008	TOLL_CREEK_SOUTH	A1	PEKE	A197726B		M	17	
9/30/2008	TOLL_CREEK_SOUTH	A3	PEKE	A197729B		M	17	
9/30/2008	TOLL_CREEK_NORTH	A5	PEKE	A197735B		M	16	
9/30/2008	TOLL_CREEK_SOUTH	B2	PEKE	A197727B		M	18	
9/30/2008	TOLL_CREEK_NORTH	B5	PEKE	A197734B		M	19	

9/30/2008	TOLL_CREEK_SOUTH	C4	PEKE	A197730B		M	16	
9/30/2008	TOLL_CREEK_SOUTH	C5	PEKE	A197731B		M	15	
9/30/2008	TOLL_CREEK_SOUTH	D1	PEKE	A197725B		F	18	
9/30/2008	TOLL_CREEK_SOUTH	D2	PEKE	A197728B		M	17	
9/30/2008	TOLL_CREEK_SOUTH	D5	PEKE	A197732B		F	18	
9/30/2008	TOLL_CREEK_NORTH	E1	PEKE	A197738B		M	19	
9/30/2008	TOLL_CREEK_SOUTH	E3	PEKE	A197724B		F	17	
9/30/2008	TOLL_CREEK_NORTH	E4	PEKE	A197740B		F	20	
9/30/2008	TOLL_CREEK_NORTH	C5	NOBT					
9/30/2008	TOLL_CREEK_NORTH	D5	NOBT					
9/30/2008	TOLL_CREEK_SOUTH	E1	NOBT					
9/30/2008	TOLL_CREEK_NORTH	E3	CLGA	A197739B		UNK	14	X
10/1/2008	TOLL_CREEK_NORTH	D1	STCK					
10/1/2008	TOLL_CREEK_SOUTH	C1	SPRG					
10/1/2008	TOLL_CREEK_NORTH	A1	PEKE	A197703B		M	15	
10/1/2008	TOLL_CREEK_SOUTH	A3	PEKE	A197745B		M	17	
10/1/2008	TOLL_CREEK_NORTH	A4	PEKE	A197702B		F	17	
10/1/2008	TOLL_CREEK_SOUTH	A4	PEKE	A197746B		M	16	
10/1/2008	TOLL_CREEK_SOUTH	A5	PEKE	A197747B		M	17	
10/1/2008	TOLL_CREEK_NORTH	B1	PEKE		X	M	19	
10/1/2008	TOLL_CREEK_NORTH	B2	PEKE	A197705B		F	17	
10/1/2008	TOLL_CREEK_SOUTH	C2	PEKE	A197743B		M	16	
10/1/2008	TOLL_CREEK_NORTH	C3	PEKE	A197706B		F	16	
10/1/2008	TOLL_CREEK_SOUTH	C3	PEKE		X	M	19	
10/1/2008	TOLL_CREEK_SOUTH	C4	PEKE		X	M	18	
10/1/2008	TOLL_CREEK_SOUTH	D1	PEKE	A197742B		F	20	
10/1/2008	TOLL_CREEK_NORTH	D2	PEKE	A197704B		F	18	
10/1/2008	TOLL_CREEK_SOUTH	D2	PEKE		X	F	18	
10/1/2008	TOLL_CREEK_SOUTH	D3	PEKE	A197744B		M	18	
10/1/2008	TOLL_CREEK_SOUTH	D4	PEKE		X	M	17	

10/1/2008	TOLL_CREEK_SOUTH	E1	PEKE	A197741B		F	17	
10/1/2008	TOLL_CREEK_NORTH	E3	PEKE		X	F	21	
10/1/2008	TOLL_CREEK_SOUTH	E4	PEKE	A197701B		F	18	
10/1/2008	TOLL_CREEK_NORTH	A2	NOBT					
10/1/2008	TOLL_CREEK_SOUTH	A2	NOBT					
10/1/2008	TOLL_CREEK_NORTH	A5	NOBT					
10/1/2008	TOLL_CREEK_NORTH	B4	NOBT					
10/1/2008	TOLL_CREEK_NORTH	C5	NOBT					
10/1/2008	TOLL_CREEK_SOUTH	C5	NOBT					
10/1/2008	TOLL_CREEK_NORTH	D4	NOBT					
10/1/2008	TOLL_CREEK_NORTH	D5	NOBT					
10/1/2008	TOLL_CREEK_NORTH	E2	NOBT					
10/1/2008	TOLL_CREEK_NORTH	E4	NOBT					
10/1/2008	TOLL_CREEK_NORTH	E5	NOBT					
10/1/2008	TOLL_CREEK_SOUTH	E5	NOBT					
10/2/2008	TOLL_CREEK_NORTH	A4	TATO	A197719B		F	N/A	
10/2/2008	TOLL_CREEK_NORTH	C5	TATO		X	M	N/A	
10/2/2008	TOLL_CREEK_NORTH	E2	STCK					
10/2/2008	TOLL_CREEK_SOUTH	A5	SPRG					
10/2/2008	TOLL_CREEK_NORTH	D1	SPRG					
10/2/2008	TOLL_CREEK_SOUTH	D1	SPRG					
10/2/2008	TOLL_CREEK_NORTH	E1	SPRG					
10/2/2008	TOLL_CREEK_SOUTH	E5	SPRG					
10/2/2008	TOLL_CREEK_SOUTH	A3	PEKE		X	M	16	
10/2/2008	TOLL_CREEK_SOUTH	A4	PEKE		X	M	18	
10/2/2008	TOLL_CREEK_NORTH	B2	PEKE	A197707B		F	17	
10/2/2008	TOLL_CREEK_SOUTH	B3	PEKE	A197723B		M	18	
10/2/2008	TOLL_CREEK_SOUTH	B4	PEKE		X	F	15	
10/2/2008	TOLL_CREEK_NORTH	C1	PEKE		X	UNK	16	ESCAPED BEFORE SEXING
10/2/2008	TOLL_CREEK_SOUTH	C1	PEKE		X	M	17	

10/2/2008	TOLL_CREEK_NORTH	C2	PEKE		X	M	16		
10/2/2008	TOLL_CREEK_SOUTH	C2	PEKE		X	F	16		
10/2/2008	TOLL_CREEK_NORTH	C4	PEKE	A197717B		F	16		
10/2/2008	TOLL_CREEK_SOUTH	C4	PEKE		X	M	15		
10/2/2008	TOLL_CREEK_SOUTH	C5	PEKE	A197722B		F	18		
10/2/2008	TOLL_CREEK_SOUTH	D2	PEKE		X	F	18		
10/2/2008	TOLL_CREEK_SOUTH	D4	PEKE						
10/2/2008	TOLL_CREEK_NORTH	D5	PEKE	A197720B		M	16		
10/2/2008	TOLL_CREEK_NORTH	E3	PEKE		X	F	17		
10/2/2008	TOLL_CREEK_NORTH	E4	PEKE		X	F	19		
10/2/2008	TOLL_CREEK_NORTH	E5	PEKE	A197721B		F	18		
10/2/2008	TOLL_CREEK_SOUTH	A2	NOBT						
10/2/2008	TOLL_CREEK_NORTH	A3	NOBT						
10/2/2008	TOLL_CREEK_NORTH	A5	NOBT						
10/2/2008	TOLL_CREEK_NORTH	B1	NOBT						
10/2/2008	TOLL_CREEK_SOUTH	B1	NOBT						
10/2/2008	TOLL_CREEK_NORTH	B5	NOBT						
10/2/2008	TOLL_CREEK_SOUTH	B5	NOBT						
10/2/2008	TOLL_CREEK_SOUTH	C3	NOBT						
10/2/2008	TOLL_CREEK_NORTH	D3	NOBT						
10/2/2008	TOLL_CREEK_SOUTH	D5	NOBT						
10/2/2008	TOLL_CREEK_SOUTH	E1	NOBT						
10/2/2008	TOLL_CREEK_SOUTH	E3	NOBT						
10/2/2008	TOLL_CREEK_SOUTH	E4	NOBT						
10/2/2008	TOLL_CREEK_SOUTH	D3	ESCP						
10/2/2008	TOLL_CREEK_NORTH	D4	ESCP						TATO
10/2/2008	TOLL_CREEK_NORTH	B4	CLGA	A197708B					
10/3/2008	TOLL_CREEK_NORTH	C5	TATO	A197753B		F	N/A	X	
10/3/2008	TOLL_CREEK_NORTH	E1	TATO	A197754B		F	N/A		
10/3/2008	TOLL_CREEK_NORTH	E4	TATO	A197755B		M	N/A		

10/3/2008	TOLL_CREEK_NORTH	E5	TATO		X	M	N/A
10/3/2008	TOLL_CREEK_NORTH	E3	SPRG				
10/3/2008	TOLL_CREEK_SOUTH	A1	PEKE	A197751B		F	20
10/3/2008	TOLL_CREEK_SOUTH	A2	PEKE	A197716B		F	16
10/3/2008	TOLL_CREEK_SOUTH	A4	PEKE		X	F	19
10/3/2008	TOLL_CREEK_SOUTH	A5	PEKE		X	F	16
10/3/2008	TOLL_CREEK_NORTH	B2	PEKE		X	M	16
10/3/2008	TOLL_CREEK_SOUTH	B2	PEKE	A197752B		M	17
10/3/2008	TOLL_CREEK_SOUTH	B3	PEKE		X	M	17
10/3/2008	TOLL_CREEK_SOUTH	B4	PEKE	A197715B		F	16
10/3/2008	TOLL_CREEK_NORTH	C1	PEKE	A197713B		M	18
10/3/2008	TOLL_CREEK_SOUTH	C1	PEKE		X	F	16
10/3/2008	TOLL_CREEK_SOUTH	C4	PEKE	A197714B		F	19
10/3/2008	TOLL_CREEK_SOUTH	C5	PEKE		X	M	16
10/3/2008	TOLL_CREEK_SOUTH	D3	PEKE		X	F	17
10/3/2008	TOLL_CREEK_SOUTH	E4	PEKE		X	M	19
10/3/2008	TOLL_CREEK_SOUTH	E5	PEKE		X	M	20
10/3/2008	TOLL_CREEK_NORTH	A2	NOBT				
10/3/2008	TOLL_CREEK_NORTH	A3	NOBT				
10/3/2008	TOLL_CREEK_NORTH	A4	NOBT				
10/3/2008	TOLL_CREEK_NORTH	A5	NOBT				
10/3/2008	TOLL_CREEK_NORTH	B1	NOBT				
10/3/2008	TOLL_CREEK_SOUTH	B1	NOBT				
10/3/2008	TOLL_CREEK_NORTH	B3	NOBT				
10/3/2008	TOLL_CREEK_NORTH	B5	NOBT				
10/3/2008	TOLL_CREEK_SOUTH	B5	NOBT				
10/3/2008	TOLL_CREEK_NORTH	C3	NOBT				
10/3/2008	TOLL_CREEK_NORTH	D1	NOBT				
10/3/2008	TOLL_CREEK_NORTH	D2	NOBT				
10/3/2008	TOLL_CREEK_SOUTH	D2	NOBT				

10/3/2008	TOLL_CREEK_NORTH	D3	NOBT			
10/3/2008	TOLL_CREEK_NORTH	D4	NOBT			
10/3/2008	TOLL_CREEK_SOUTH	D4	NOBT			
10/3/2008	TOLL_CREEK_NORTH	D5	NOBT			
10/3/2008	TOLL_CREEK_SOUTH	D5	NOBT			
10/3/2008	TOLL_CREEK_NORTH	E2	NOBT			
10/3/2008	TOLL_CREEK_SOUTH	E2	NOBT			
10/3/2008	TOLL_CREEK_SOUTH	E3	NOBT			
10/7/2009	HUDSON_SOUTH	B1	SPRG			
10/7/2009	HUDSON_NORTH	A1	PEKE	A197801B	F	16
10/7/2009	HUDSON_SOUTH	A2	PEKE	A197756B	F	19
10/7/2009	HUDSON_NORTH	A3	PEKE	A197806B	F	19
10/7/2009	HUDSON_NORTH	A4	PEKE	A197812B	F	18
10/7/2009	HUDSON_SOUTH	A4	PEKE	A197850B	M	17
10/7/2009	HUDSON_SOUTH	A5	PEKE	A197813B	M	19
10/7/2009	HUDSON_NORTH	B1	PEKE	A197802B	F	16
10/7/2009	HUDSON_NORTH	B3	PEKE	A197807B	F	19
10/7/2009	HUDSON_SOUTH	B5	PEKE	A197757B	M	17
10/7/2009	HUDSON_NORTH	C1	PEKE	A197803B	F	23
10/7/2009	HUDSON_SOUTH	C1	PEKE	A197759B	F	18
10/7/2009	HUDSON_NORTH	C3	PEKE	A197808B	F	19
10/7/2009	HUDSON_NORTH	C5	PEKE	A197811B	M	25
10/7/2009	HUDSON_SOUTH	C5	PEKE	A197758B	F	18
10/7/2009	HUDSON_NORTH	D1	PEKE	A197804B	F	17
10/7/2009	HUDSON_NORTH	D2	PEKE	A197805B	M	20
10/7/2009	HUDSON_SOUTH	D2	PEKE	A197844B	M	19
10/7/2009	HUDSON_NORTH	D4	PEKE	A197810B	F	17
10/7/2009	HUDSON_NORTH	D5	PEKE	A197809B	M	18
10/7/2009	HUDSON_SOUTH	E1	PEKE	A197848B	F	20
10/7/2009	HUDSON_SOUTH	E4	PEKE	A197843B	M	19

10/7/2009	HUDSON_NORTH	E1	NOBT					
10/8/2009	HUDSON_NORTH	B4	SPRG					
10/8/2009	HUDSON_SOUTH	B5	SPRG					BEAR DAMAGE
10/8/2009	HUDSON_SOUTH	C5	SPRG					
10/8/2009	HUDSON_SOUTH	E5	SPRG					
10/8/2009	HUDSON_SOUTH	E2	PEMA	A197815B		M	16	UNCERTAIN WITH SPECIES ID, SHORT TAIL
10/8/2009	HUDSON_NORTH	A1	PEKE	A197760B		F	18	
10/8/2009	HUDSON_SOUTH	A2	PEKE		X	M	18	
10/8/2009	HUDSON_NORTH	A3	PEKE		X	M	19	
10/8/2009	HUDSON_NORTH	A4	PEKE		X	F	21	
10/8/2009	HUDSON_NORTH	A5	PEKE		X	F	18	
10/8/2009	HUDSON_SOUTH	A5	PEKE		X	M	19	
10/8/2009	HUDSON_NORTH	B1	PEKE	A197761B		F	22	
10/8/2009	HUDSON_NORTH	B2	PEKE	A197849B		F	18	
10/8/2009	HUDSON_SOUTH	B2	PEKE		X	F	21	
10/8/2009	HUDSON_NORTH	C1	PEKE		X	M	21	
10/8/2009	HUDSON_NORTH	C3	PEKE	A197711B		F	16	
10/8/2009	HUDSON_SOUTH	C4	PEKE		X	F	19	
10/8/2009	HUDSON_NORTH	D1	PEKE	A197846B		F	17	
10/8/2009	HUDSON_NORTH	D2	PEKE	A197847B		F	16	
10/8/2009	HUDSON_NORTH	D3	PEKE	A197712B		M	21	
10/8/2009	HUDSON_SOUTH	D3	PEKE	A197816B		F	19	
10/8/2009	HUDSON_NORTH	D4	PEKE	A197814B		M	18	
10/8/2009	HUDSON_NORTH	D5	PEKE		X	M	20	
10/8/2009	HUDSON_SOUTH	D5	PEKE	A197817B		M	20	
10/8/2009	HUDSON_NORTH	E1	PEKE		X	M	16	
10/8/2009	HUDSON_NORTH	E2	PEKE	A197845B		M	17	
10/8/2009	HUDSON_NORTH	E3	PEKE	A197710B		M	19	
10/8/2009	HUDSON_NORTH	E4	PEKE	A197709B		M	16	

10/8/2009	HUDSON_NORTH	B5	NOBT						
10/8/2009	HUDSON_NORTH	C2	NOBT						
10/8/2009	HUDSON_SOUTH	C3	NOBT						
10/8/2009	HUDSON_NORTH	C4	NOBT						
10/8/2009	HUDSON_NORTH	C5	NOBT						
10/9/2009	HUDSON_SOUTH	C2	SPRG						
10/9/2009	HUDSON_NORTH	D1	SOTR	A197819B		UNK	4.5	X	UNCERTAIN WITH SPECIES ID
10/9/2009	HUDSON_NORTH	A1	PEKE		X	M	19		
10/9/2009	HUDSON_SOUTH	A1	PEKE	A197825B		M	17		
10/9/2009	HUDSON_NORTH	A2	PEKE		X	M	18		
10/9/2009	HUDSON_SOUTH	A2	PEKE		X	F	20		
10/9/2009	HUDSON_NORTH	A3	PEKE	A197821B		F	16		
10/9/2009	HUDSON_NORTH	A4	PEKE	A197824B		M	19		
10/9/2009	HUDSON_NORTH	A5	PEKE			F	18		
10/9/2009	HUDSON_NORTH	B1	PEKE		X	F	15		
10/9/2009	HUDSON_NORTH	B2	PEKE		X	F	17		
10/9/2009	HUDSON_SOUTH	B2	PEKE		X	F	19		
10/9/2009	HUDSON_NORTH	B3	PEKE		X	M	18		
10/9/2009	HUDSON_NORTH	B4	PEKE	A197823B		M	20		
10/9/2009	HUDSON_SOUTH	B4	PEKE		X	F	20		
10/9/2009	HUDSON_NORTH	B5	PEKE		X	M	23		
10/9/2009	HUDSON_NORTH	C1	PEKE	A197818B		M	19		
10/9/2009	HUDSON_NORTH	C2	PEKE	A197820B		M	17		
10/9/2009	HUDSON_NORTH	C3	PEKE	A197822B		M	19		
10/9/2009	HUDSON_NORTH	D2	PEKE		X	M	17		
10/9/2009	HUDSON_SOUTH	D3	PEKE		X	M	19		
10/9/2009	HUDSON_NORTH	D5	PEKE		X	F	19		
10/9/2009	HUDSON_SOUTH	D5	PEKE		X	M	19		
10/9/2009	HUDSON_NORTH	E4	PEKE		X	M	19		
10/9/2009	HUDSON_NORTH	C4	NOBT						

10/9/2009	HUDSON_NORTH	C5	NOBT					
10/9/2009	HUDSON_NORTH	E1	NOBT					
10/9/2009	HUDSON_NORTH	E2	NOBT					
10/9/2009	HUDSON_NORTH	E3	NOBT					
10/9/2009	HUDSON_SOUTH	B5	GONE					REPLACED
10/9/2009	HUDSON_SOUTH	E5	GONE					REPLACE
10/10/2009	HUDSON_NORTH	D1	STCK					
10/10/2009	HUDSON_SOUTH	B1	SPRG					
10/10/2009	HUDSON_SOUTH	C4	SPRG					
10/10/2009	HUDSON_SOUTH	C5	SPRG					
10/10/2009	HUDSON_NORTH	A5	PEMA	A197833B		M	13	
10/10/2009	HUDSON_NORTH	C5	PEMA	A197831B		F	15	
10/10/2009	HUDSON_NORTH	D4	PEMA	A197830B		M	15	SPECIES UNCERTAIN, SHORT TAIL
10/10/2009	HUDSON_NORTH	A1	PEKE		X	M	19	
10/10/2009	HUDSON_SOUTH	A1	PEKE		X	M	19	
10/10/2009	HUDSON_NORTH	A2	PEKE		X	M	17	
10/10/2009	HUDSON_NORTH	A3	PEKE		X	M	18	
10/10/2009	HUDSON_SOUTH	A3	PEKE		X	M	20	
10/10/2009	HUDSON_NORTH	A4	PEKE		X	F	17	
10/10/2009	HUDSON_NORTH	B1	PEKE	A197826B		M	17	
10/10/2009	HUDSON_SOUTH	B2	PEKE		X	F	18	
10/10/2009	HUDSON_NORTH	B4	PEKE		X	F	20	
10/10/2009	HUDSON_SOUTH	B4	PEKE		X	F	17	
10/10/2009	HUDSON_NORTH	B5	PEKE	A197832B		F	18	
10/10/2009	HUDSON_SOUTH	B5	PEKE		X	F	18	
10/10/2009	HUDSON_NORTH	C1	PEKE	A197827B		M	18	
10/10/2009	HUDSON_SOUTH	C3	PEKE		X	F	22	
10/10/2009	HUDSON_NORTH	D2	PEKE	A197828B		M	18	
10/10/2009	HUDSON_NORTH	D3	PEKE		X	M	17	
10/10/2009	HUDSON_SOUTH	D3	PEKE		X	M	19	

10/10/2009	HUDSON_NORTH	D5	PEKE		X	F	17
10/10/2009	HUDSON_SOUTH	D5	PEKE	A197835B		M	20
10/10/2009	HUDSON_SOUTH	E1	PEKE	A197834B		F	23
10/10/2009	HUDSON_NORTH	E5	PEKE	A197829B		F	16
10/10/2009	HUDSON_SOUTH	E5	PEKE	A197836B		F	19
10/10/2009	HUDSON_NORTH	B2	NOBT				
10/10/2009	HUDSON_NORTH	B3	NOBT				
10/10/2009	HUDSON_NORTH	C2	NOBT				
10/10/2009	HUDSON_NORTH	C3	NOBT				
10/10/2009	HUDSON_NORTH	C4	NOBT				
10/10/2009	HUDSON_SOUTH	D4	NOBT				
10/10/2009	HUDSON_NORTH	E1	NOBT				
10/10/2009	HUDSON_NORTH	E2	NOBT				
10/10/2009	HUDSON_NORTH	E3	NOBT				
10/14/2009	EASTON_HILL_SOUTH	A4	SPRG				
10/14/2009	EASTON_HILL_SOUTH	B1	SPRG				
10/14/2009	EASTON_HILL_SOUTH	D2	SPRG				
10/14/2009	EASTON_HILL_NORTH	E3	SPRG				
10/14/2009	EASTON_HILL_SOUTH	A1	PEKE	A197838B		F	22
10/14/2009	EASTON_HILL_NORTH	A3	PEKE	A197839B		F	16
10/14/2009	EASTON_HILL_NORTH	B3	PEKE	A197841B		F	20
10/14/2009	EASTON_HILL_NORTH	B4	PEKE	A197842B		F	17
10/14/2009	EASTON_HILL_NORTH	C2	PEKE	A197766B		F	18
10/14/2009	EASTON_HILL_NORTH	C3	PEKE	A197762B		F	18
10/14/2009	EASTON_HILL_NORTH	C4	PEKE	A197788B		M	17
10/14/2009	EASTON_HILL_NORTH	C5	PEKE	A197840B		M	17
10/14/2009	EASTON_HILL_SOUTH	D1	PEKE	A197837B		F	17
10/14/2009	EASTON_HILL_NORTH	D3	PEKE	A197763B		M	16
10/14/2009	EASTON_HILL_NORTH	D5	PEKE	A197790B		M	18
10/14/2009	EASTON_HILL_NORTH	E1	PEKE	A197765B		F	19

10/14/2009	EASTON_HILL_NORTH	E2	PEKE	A197764B		F	17		
10/14/2009	EASTON_HILL_NORTH	E5	PEKE	A197789B		M	19		
10/14/2009	EASTON_HILL_NORTH	B5	NOBT						
10/14/2009	EASTON_HILL_NORTH	C1	NOBT						
10/15/2009	EASTON_HILL_NORTH	A1	PEKE	A197768B		M	20		
10/15/2009	EASTON_HILL_NORTH	B4	PEKE	A197786B		M	18		
10/15/2009	EASTON_HILL_NORTH	C1	PEKE	A197785B		F	17		
10/15/2009	EASTON_HILL_NORTH	C2	PEKE		X	M	17	X	
10/15/2009	EASTON_HILL_SOUTH	C4	PEKE	A197767B		F	18		
10/15/2009	EASTON_HILL_NORTH	C4	PEKE	A197769B		F	17		
10/15/2009	EASTON_HILL_NORTH	C5	PEKE		X	M	18		
10/15/2009	EASTON_HILL_SOUTH	E4	PEKE	A197787B		M	20		
10/15/2009	EASTON_HILL_SOUTH	A1	NOBT						
10/15/2009	EASTON_HILL_SOUTH	B1	NOBT						
10/15/2009	EASTON_HILL_NORTH	B3	NOBT						
10/15/2009	EASTON_HILL_NORTH	B5	NOBT						
10/15/2009	EASTON_HILL_NORTH	D1	NOBT						
10/15/2009	EASTON_HILL_NORTH	D4	NOBT						
10/15/2009	EASTON_HILL_NORTH	E1	NOBT						
10/15/2009	EASTON_HILL_NORTH	E2	NOBT						
10/15/2009	EASTON_HILL_NORTH	A4	ESCP						PEKE
10/16/2009	EASTON_HILL_NORTH	A4	SPRG						BEAR DAMAGE
10/16/2009	EASTON_HILL_SOUTH	C5	SPRG						
10/16/2009	EASTON_HILL_NORTH	B4	PEMA		X	F	18		SPECIES ID UNCERTAIN, SHORT TAIL
10/16/2009	EASTON_HILL_NORTH	A2	PEKE		X	F	21		
10/16/2009	EASTON_HILL_SOUTH	B1	PEKE		X	M	19		
10/16/2009	EASTON_HILL_NORTH	B2	PEKE	A197784B		F	19		
10/16/2009	EASTON_HILL_SOUTH	C3	PEKE		X	F	20		
10/16/2009	EASTON_HILL_SOUTH	D2	PEKE		X	F	22		

10/16/2009	EASTON_HILL_SOUTH	D3	PEKE	A197770B		M	19	
10/16/2009	EASTON_HILL_NORTH	E2	PEKE		X	M	18	
10/16/2009	EASTON_HILL_SOUTH	A1	NOBT					
10/16/2009	EASTON_HILL_SOUTH	A3	NOBT					
10/16/2009	EASTON_HILL_NORTH	A3	NOBT					
10/16/2009	EASTON_HILL_NORTH	B1	NOBT					
10/16/2009	EASTON_HILL_NORTH	B3	NOBT					
10/16/2009	EASTON_HILL_NORTH	B5	NOBT					
10/16/2009	EASTON_HILL_NORTH	C4	NOBT					
10/16/2009	EASTON_HILL_NORTH	C5	NOBT					
10/16/2009	EASTON_HILL_NORTH	D1	NOBT					
10/16/2009	EASTON_HILL_NORTH	D4	NOBT					
10/16/2009	EASTON_HILL_SOUTH	D5	NOBT					
10/16/2009	EASTON_HILL_NORTH	E1	NOBT					
10/16/2009	EASTON_HILL_NORTH	E4	NOBT					
10/16/2009	EASTON_HILL_NORTH	E5	NOBT					
10/16/2009	EASTON_HILL_SOUTH	E4	CLGA	A197783B		M	16	
10/17/2009	EASTON_HILL_SOUTH	E5	PEMA	A197773B		F	15	UNCERTAIN WITH SPECIES ID, SHORT TAIL
10/17/2009	EASTON_HILL_SOUTH	A1	PEKE		X	F	21	
10/17/2009	EASTON_HILL_NORTH	A3	PEKE	A197771B		M	18	
10/17/2009	EASTON_HILL_NORTH	A5	PEKE		X	M	17	
10/17/2009	EASTON_HILL_NORTH	B1	PEKE	A197782B		F	17	
10/17/2009	EASTON_HILL_SOUTH	B3	PEKE		X	F	16	
10/17/2009	EASTON_HILL_SOUTH	C5	PEKE	A197774B		M	19	
10/17/2009	EASTON_HILL_NORTH	C5	PEKE		X	M	17	
10/17/2009	EASTON_HILL_NORTH	D1	PEKE	A197772B		M	17	
10/17/2009	EASTON_HILL_SOUTH	D2	PEKE		X	M	17	
10/17/2009	EASTON_HILL_NORTH	E2	PEKE		X	F	17	
10/17/2009	EASTON_HILL_NORTH	A1	NOBT					

10/17/2009	EASTON_HILL_SOUTH	A3	NOBT
10/17/2009	EASTON_HILL_NORTH	A4	NOBT
10/17/2009	EASTON_HILL_NORTH	B4	NOBT
10/17/2009	EASTON_HILL_NORTH	B5	NOBT
10/17/2009	EASTON_HILL_NORTH	C1	NOBT
10/17/2009	EASTON_HILL_SOUTH	C2	NOBT
10/17/2009	EASTON_HILL_NORTH	D2	NOBT
10/17/2009	EASTON_HILL_SOUTH	D4	NOBT
10/17/2009	EASTON_HILL_NORTH	D4	NOBT
10/17/2009	EASTON_HILL_NORTH	E1	NOBT
10/17/2009	EASTON_HILL_NORTH	E4	NOBT
10/17/2009	EASTON_HILL_NORTH	E5	NOBT

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Appendix 4.6. Report from track survey of Lake Keechelus.

DATE: 6 November 2009
TO: WSDOT
THRU:
FROM: Western Transportation Institute

SUBJECT: Keechelus Lake shoreline wildlife fencing recommendations memo.

Attachment: Exhibits 1-11
cc:

Western
Transportation
Institute

Introduction

This memo addresses questions regarding wildlife fencing on the proposed eastbound embankment along Keechelus Lake. Specifically, we sought to address whether fencing this section of I-90 is necessary, given observed patterns of wildlife vehicle collisions (WVCs), wildlife tracks, and conditions that will be present after the construction of wildlife crossing structures and wildlife fencing on the eastern side of I-90. We also discuss whether the proposed embankment should deter wildlife (mainly ungulates), and if not, what options exist for wildlife fencing given the proposed conditions.

Review of Current and Proposed Condition and Existing Data—Mileposts 51.2-61.0

We evaluated existing WVC data along this section of I-90, as well as conducting track surveys along Lake Keechelus and on the lakebed during drawdown. Here we summarize these data in relation to lake levels, lake drawdown periods, and likely post-construction condition.

Current Condition

Lake Keechelus is typically at or near full pool (elevation 2,517 feet) during May-July, and drawn-down considerably during all other months. These drawdown periods result in exposure of the lakebed over much of the northern part of the lake (Exhibit 1), as well as exposing portions of shoreline adjacent to the dam at the south end (Exhibit 1). In these locations, during the drawdown period, it is possible for terrestrial wildlife species to approach the highway from west to east. Currently, a steep, rocky embankment drops off the west side of the eastbound highway shoulder (Exhibit 2a, b). At full pool this embankment descends directly into Lake Keechelus along most of the section, resulting in almost no shoreline availability for terrestrial wildlife. During drawdown this embankment still presents an obstacle to animals attempting to access the roadway from the lakebed, although access is possible for animals approaching directly off of the lakebed. Snow levels are generally high along this section from January through March, with snow depth averaging between 40 and 65 inches (NWAC

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http://www.nwac.us/media/uploads/pdfs/Annual%20Northwest%20Snowdepths%20by%20Location.pdf). During winter, most large species such as deer (*Odocoileus* spp.) and elk (*Cervus elaphus*) are at lower elevations and are not encountered in this section.

Proposed Post-construction Condition

Lake drawdown will be similar to the current condition in timing and extent after construction, as will expected snow depths. A steep, 1.5:1 or 2:1 engineered Select Rock Embankment (SRE) composed of 18” or smaller riprap will extend to the lakebed along the highway section, but no wildlife fencing is currently proposed along this side of the highway. A key difference will be that wildlife fencing will be installed throughout the entire section along the east side of I-90, east of the westbound lanes, and large wildlife underpasses (varying in size) will be installed at Gold Creek, Rocky Run Creek, Wolfe Creek, Resort Creek, and Townsend Creek. These underpasses will allow wildlife to cross under the highway and exit on the opposite side, heading either east into forest, or west onto the lakeshore or lakebed.

WVC Data

WVC data have been systematically collected via electronic/GPS data entry by WSDOT maintenance crews with oversight by Western Transportation Institute (WTI) since May 2007. To date, 18 WVCs have been recorded between mileposts 51.2 and 61.5 (Exhibit 1, Exhibit 3). Sixteen were mule deer (*Odocoileus hemionus*), one was a beaver (*Castor canadensis*), and one was a Canada goose (*Branta Canadensis;* not included on map or in table). Most WVCs involving mule deer were located near the WSDOT Maintenance Building at the northernmost end of the lake (5), at Rocky Run Creek (3), and just south of the dam at the southernmost end of the lake (3). Two others were located near the snowshed, and 3 more in the section north of the dam (Exhibit 1, Exhibit 3).

Twelve of the 16 deer WVCs occurred during periods when the lake was at full pool (Exhibit 1, Exhibit 3). These animals were, therefore, almost certainly traveling from east to west (i.e., from the upland forest towards the lake), and would have been stopped by the wildlife fencing on the east side of the highway. Of the 4 WVCs that occurred when the lake was drawn down, 2 were just north of the lake at the WSDOT maintenance facility. This is a location where a terrestrial wildlife underpass will be installed. The remaining 2 WVCs occurred at the same time and location, and were in a location that could have been accessed from the lakebed, but which would have been unlikely given the pattern of lake drawdown and access points to this location. These deer, therefore, likely accessed the roadway from the east.

Track Data

Two WTI staff surveyed for wildlife tracks along the west side of the eastbound lanes of I-90 between mileposts 55.1 and 56.6, 59.2 and 60.0, and 60.4 and 60.8 during 3 visits (10/5/09, 10/15/09, and 10/28/09) (Exhibit 4a, b). The purpose was to detect any tracks or animal use areas that approached the roadway from the lakeside. The surveys also included parts of the lakebed, and the western lakeshore (Exhibit 4a, b). These are areas available to terrestrial wildlife from the west during periods of lake drawdown.

A total of approximately 6 miles of surveys were conducted. While some wildlife tracks were detected (Exhibit 4a, b), all stayed along or within the lakebed except for a single deer track that crossed the road. This animal, however, crossed from east to west (based on the direction of the track trail), and would have likely been stopped by the wildlife fencing on the east side of the roadway.

Remote Camera Data

Two remote digital cameras have been deployed near mile 55 under the westbound Gold Creek bridges (one on each shoreline) since October 2008. To date, 6 mule deer crossings have been recorded under the bridge on the north shore. Only one of these crossings was a directional west-to-east movement, and this was during drawdown. Along the south shore, a single mule deer was detected and crossed heading east during full pool. Four coyote detections also occurred, but only one individual was heading east (during drawdown). Three beavers were also detected crossing through this structure, with 2 heading east—1 during drawdown. These data suggest that some animals are crossing the highway in an easterly direction during both full pool and drawdown. The Gold Creek bridge is, however, the most readily accessible from the west of all the structures between mileposts 51.2 and 61.5, given it’s proximity to terrestrial habitats to the north, and major exposure of the lakebed during drawdown in this location. Further, after construction of the Gold Creek crossing structure and associated terrestrial crossing structure just to the north, this location will be highly permeable to both aquatic and terrestrial wildlife, and the outlets to the west and north will make it easy for individual animals to move away from the highway after crossing. Given this, we would not expect to see excessive attempts by animals to reenter the highway from the west after exiting the structure on the west side.

Literature Review of Fencing and Fencing Alternatives

Function

Highway fencing is designed to keep wildlife away from roadways, to lead animals to wildlife crossings, and to permit safe travel under or above the highway (Clevenger and Huijser 2009). Fences should be impermeable to wildlife movement in order to keep traffic-related mortality to a minimum, and to ensure that wildlife crossings are used. Defective or permeable fences result in reduced use of the wildlife crossings and increased risk of wildlife–vehicle collisions. The latter is a cause for concern for transportation agencies after making substantial investments in infrastructure to reduce WVCs.

Little research or best management practices exist regarding effective fence designs or other innovative solutions to keep wildlife away from roads. We were unable to find any literature regarding technical design or performance of fences of any type in areas of high snowfall or steep terrain. Despite a general paucity of literature on highway fence design for wildlife exclusion, several studies have reported on their effectiveness in reducing wildlife-vehicle collisions and associated property damage (Reed et al. 1982, Foster and Humprey 1995, Clevenger et al. 2001, Huijser et al. 2009).

Standard Fencing Description

Fencing design used to mitigate road impacts depends on several variables associated with the specific location, primarily adjacent land use, traffic volumes and terrain. Both sides of the road are typically fenced. Fence ends must line up across the road (symmetric) and not be offset or staggered. Partial fencing at the opening of wildlife crossing structures is termed “wing wall” fencing. This type of fencing is intended to funnel animals to crossing structures. It is generally used in areas where land use does not permit continuous fencing. The length of wing wall fencing from crossing structures varies from 50 m (165 ft) to nearly 200 m (655 ft) and is dependent on the individual site, focal species and local terrain.

Fencing Challenges

Fencing can be fraught with problems related to maintenance, integrity, and, ultimately, performance under different site conditions. Automobile collisions, rockslides, and tree fall are just some of the issues that challenge successful fencing efforts. Naturally occurring problems associated with high snow loads, steep terrain and interceptions with watercourses (e.g., creeks, rivers) have yet to be properly resolved or addressed with best management practices.

Snow-load problems such as failing fence posts and fencing material may be an issue in the upper section of the I-90 SPE project area. Fence type testing is currently taking place to determine the most suitable design for these extreme site conditions (Urlich et al. 2009). Further, guidelines currently being used in high snow load areas in Norway - with regard to fence mesh size, poles, distance between poles and fence height - are found in Appendix A of Clevenger (2005; Fencing specifications for high snowfall areas).

Fence Height Determination

Standard height for wildlife exclusion fencing is 2.4 m (8 ft) high. The height appears to be effective for most wildlife species and all ungulates in North America (e.g., elk, deer, bighorn sheep [*Ovis canadensis*], mountain goats [*Oreamnos americanus*], pronghorn [*Antilocapra americana*]).

Fencing Alternatives

There are some alternatives to standard fencing that can successfully deter wildlife from highways and direct them to crossing structures. Raised mechanically stabilized earth (MSE) retaining walls may be an option in places where the walls can effectively function as fences (see Exhibit 5). MSE walls are typically used in areas where the highway right-of-way is limited, or to protect areas of special conservation concern.

Fences invariably intersect other linear features that allow for movement of people or transport materials. This can include access roads, but also people (e.g., recreations trails) and water (e.g., creeks, streams). These breaks or interceptions in the fence require special modifications to limit the number of wildlife intrusions into the right-of-way.

Boulder walls or riprap barriers are a substitute for wildlife fencing in some areas where there rock material is abundant. We are aware of one location where such substrate was used as a substitute for wildlife fencing (US 95 in northern Idaho; Exhibits 6, 7). In this case, the 1.8-2 m (7-8 ft) high rock wall composed of 30-45 cm (12-18 in) boulders was not entirely effective. Deer and elk were able to cross the highway by “picking their way through the boulders, finding footholds on rock surfaces” and walking over the wall (Wayne Wakkinen, Idaho Department of Fish and Game, personal communication). Even on some steep-sloped highway sections, elk were still able to climb through the boulder walls and cross the highway. Given the failure of the boulder wall to prevent elk and deer movements, Idaho Department of Transportation subsequently constructed wildlife fencing behind the wall and installed escape ramps (see Exhibit 8) at regular intervals for the elk and deer that occasionally accessed the right-of-way through the fence ends (Wayne Wakkinen, Idaho Department of Fish and Game, personal communication).

On some highways large boulders have been placed in the right-of-way, outside of the clear zone, as an alternative to wildlife fencing. Large boulders are thought to make it difficult for animals, especially ungulates, to walk across an area. Boulders have been used for this purpose along State Route 260 in Arizona (Terry Brennan, U.S. Forest Service, personal communication; Norris Dodd, Arizona Game and Fish Department, personal communication)(Exhibit 9). The boulder barrier was not extended through areas with steep slopes, as it was thought that wildlife would not move through steep sections. Observations after construction, however, suggest that animals continue to travel through these areas. The barrier is thought to be effective except for some access through the gaps occurring in steep areas. (Norris Dodd, Arizona Game and Fish Department, personal communication).

Boulder barriers are typically constructed of subangular, quarried rock, ranging in size from 20-60 cm (10-25 in). To be most effective, however, most rocks should be larger than 30 cm (12 in) and project about 20-30 cm (10-12 in) above ground surface (see Exhibit 10). Clevenger et al. (2007) found a boulder barrier to be effective at keeping most ungulates from gaining access inside the fence line. Winter snow and ice, however, can render boulder barriers ineffective, as the surface becomes level and compacted by snow and ice.

Natural terrain, in some instances, may be steep enough that wildlife movement is minimal if not impossible. Cliffs and steep cut-slopes adjacent to roads may serve as an alternative to fencing. Particularly if the habitat near the road is not suitable to most wildlife.

Concerns and Recommendations

Concerns

Based on the existing data, the movement of terrestrial wildlife from west to east (i.e., across the lakebed at the northern part of Lake Keechelus, or from the dam and along the shoreline at the southern end of Lake Keechelus) within the section of interest appears to be minimal. Uncertainty still exists, however, regarding the behavior of animals that cross the highway from east to west via the crossing structures that will be installed at Gold Creek, Rocky Run Creek, Wolfe Creek, Resort Creek, and Townsend Creek. When these animals exit the structures on the lakeshore there is some probability that they will attempt to access the westbound lanes of the roadway. This probability will likely be higher at times when the lake is at full pool, and movement away from the structure directly to the west is not possible. This risk will be lower near Gold Creek and Townsend Creek, because animals will be able to use lakeshore routes to the north and south, respectively, to move away from the crossing structure. This risk will likely be higher at Rocky Run Creek, where the proposed highway realignment calls for a graded, forested slope west of the highway and above full pool that may attract animals that exit the western side of the structure. The proposed SRE should deter some highway access, but may not be completely successful at deterring all species. During winter, fencing on either side of the highway may be rendered ineffective due to snow accumulation. During these periods, however, very large species (e.g., deer and elk) are unlikely to be present in this section.

Recommendations

Even the most rigorous mitigation measures will not eliminate wildlife-vehicle collisions entirely. On the most well-designed and effective mitigation projects, wildlife-vehicle collisions are reduced substantially, but some collisions with wildlife still occur. These collisions generally result when animals climb fences, move through gaps or open gates, or travel over cattle guards. Here we address whether fencing is necessary along the lakeside of this section of highway. We also make some suggestions that should help to minimize WVCs.

Wildlife exclusion fencing. We recommend that wildlife exclusion fencing along the west side of I-90 is not necessary between Mileposts 51.2 - 61.0. The WVC and tracking data presented earlier suggest that there are few movements by large wildlife species in a west-to-east direction across I-90. Most movement is observed to be in the east-to-west direction. The majority of east-to-west movement took place while Lake Keechelus was at full pool. Animals traveling east-to-west post-construction will intercept the wildlife fence on the east side of I-90 and be funneled to the five crossing structures noted above. Animals passing through the crossing structures and encountering Lake Keechelus at full pool will either: (a) reverse their direction of travel and return through the crossing structure or (b) travel along the edge of the lake until running out of space, and will either move upslope and attempt to cross I-90 or return to the crossing structure. The proposed SRE barrier may prevent some upslope movement in the event of (b). We also recognize that during high snow periods no fencing option will likely deter species active during the winter months.

SRE-type barriers are not completely effective at deterring wildlife access to roads. The proposed 1.5:1 or 2:1 SRE barrier will be unlikely to completely prevent movement of wildlife intent on traveling from west-to-east. For this particular section of I-90, however, suboptimal habitat adjacent to the highway and relatively few crossing attempts across the proposed SRE barrier are expected. After construction of crossing structures, it is expected that some animals will attempt to cross west-to-east and will hopefully be deterred by the SRE barrier. For those animals that reach the right-of-way, escape ramps will need to be installed adjacent to the proposed crossing structures in addition to opportune locations between structures as a safety measure for motorists and wildlife (see Exhibit 8; Bissonette and Hammer 2000; Clevenger and Huijser 2009).

Fencing at wildlife crossing structures. There is some concern that wildlife will move through the crossing structures, encounter the lakebed, and then attempt to access I-90 across the SRE (i.e., option [b] described above). To reduce the likelihood of this occurring, retaining walls should be constructed that flare out from the crossing structures. Most wildlife underpass structures are built with some form of retaining wall (see

Exhibit 11). In this instance, we recommend that the underpass retaining walls be extended at least 100 m (165 ft) on both sides to minimize the chances of animals moving across I-90 via the SRE barrier once out of the crossing structures. As mentioned above, the risk of animals exiting the west end of a crossing structure and attempting to move back towards the highway may be highest at the Rocky Run Creek structure because of the graded and forested slope that will be installed along the western side of the highway immediately south of the structure exit. At this location we strongly recommend that fencing be installed from the structure and to the south that would deter entries into the highway zone. This fencing should be installed as close to the high water zone (i.e., away from the highway) as possible. This will both help deter animals from being attracted to the forested area, and will provide a refuge—and possibly a location for a jumpout—for animals that do end up on the highway.

An untested alternative to the wing wall extension described above would be to ‘armor’ the SRE barrier with chain-link fence material. The small mesh size of chain-link fencing attached to a rocky and irregular surface such as the SRE may be an effective combination that deters animal movement across. We are unaware of this type of design being used with the purpose of deterring animal movement. Chain-link or other heavy woven-wire and woven-cable meshes, however, are routinely used by transportation agencies to retain debris fall on steep hillsides and cut slopes. Chain-link is relatively inexpensive. The aesthetics of this application would not be an issue because it will occur below grade and out of sight of motorists. Post-construction test sections could be compared with control areas (without chain-link application) of similar length, in terms of their association with reported WVCs and live wildlife occurrences.

Median barriers. The above recommendations are based on best management practices and professional judgment. They have been carefully prepared taking into consideration available field data, experience, and logic. Inevitably, some animals will be able to access the I-90 right-of-way by one or more means. The placement of median (i.e., Jersey) barriers is typically discouraged because the concrete barriers can block wildlife movement across roads. On this section of I-90, however, we recommend that tall median barriers be installed to keep wildlife to one side of the highway should they access the right-of-way. This would keep wildlife movement across I-90 to a minimum (i.e., only 3 lanes of traffic could be crossed rather than all 6 lanes), and would encourage wildlife to return to the lakeshore and crossing structures via the escape ramps provided for this purpose.

Additional monitoring. We suggest that additional track surveys be conducted during winter, full pool, and drawdown to further evaluate whether animals are attempting to access the roadway from the lake side.

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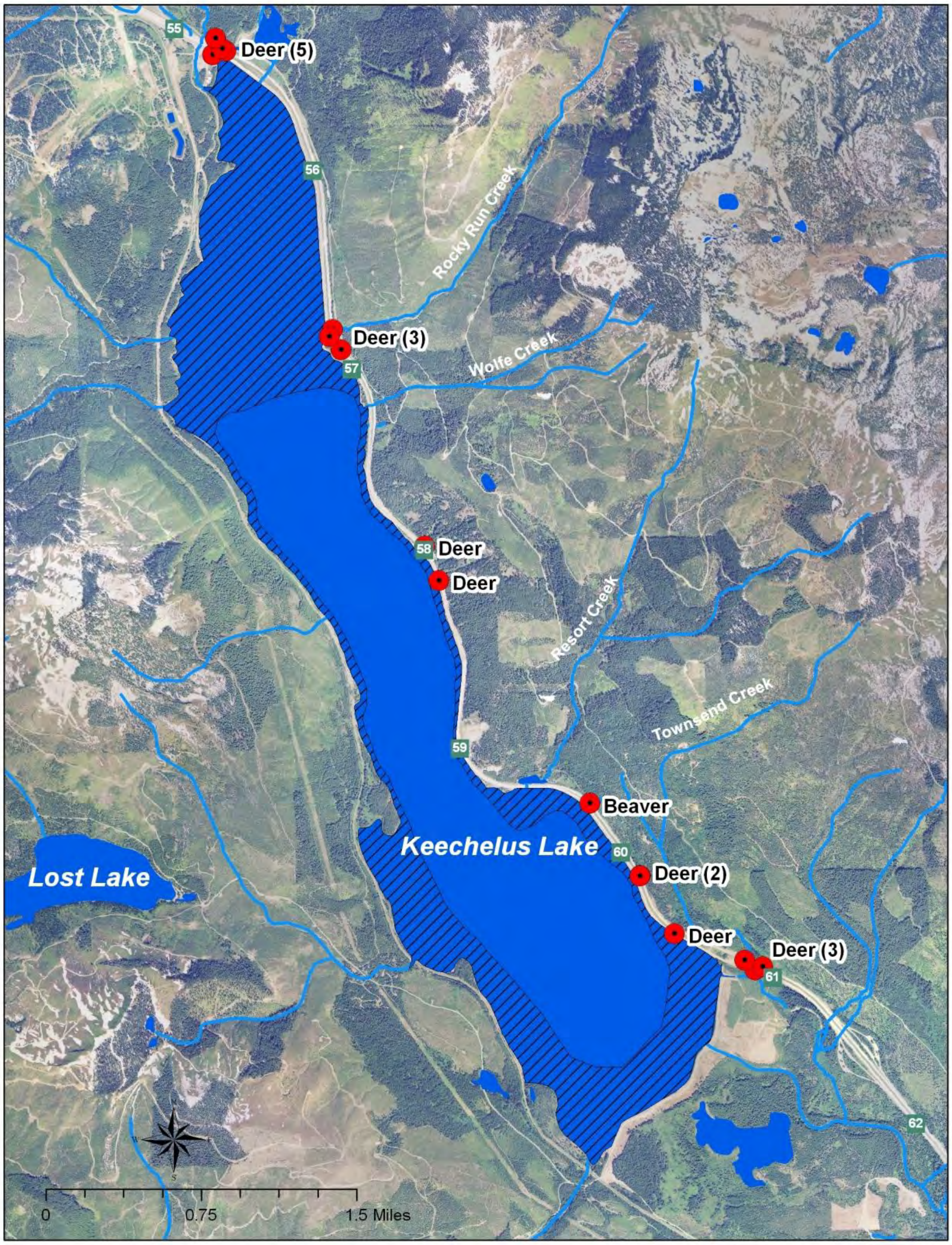

Exhibit 1. Documented wildlife vehicle collisions detected between milepost 51.2 and 60.0 from May 2007 to present. Cross-hatching shows estimated lakebed exposure during drawdown periods.

a.

b.

Exhibit 2. Current condition embankment along the eastbound lanes of I-90.

Date	Species	Approximate Milepost	Lake Level
5/26/2007	Mule deer	56.9	Full pool
5/28/2007	Mule deer	60.9	Full pool
6/20/2007	Mule deer	56.9	Full pool
5/29/2008	Mule deer	60.9	Full pool
6/19/2008	Mule deer	55.2	Full pool
6/23/2008	Mule deer	60.9	Full pool
6/24/2008	Mule deer	56.9	Full pool
6/27/2008	Mule deer	58.2	Full pool
6/30/2008	Mule deer	55.2	Full pool
6/30/2008	Mule deer	60.5	Full pool
6/30/2008	Beaver	59.7	Full pool
7/3/2008	Mule deer	55.2	Full pool
7/16/2008	Mule deer	58.1	Full pool
7/25/2008	Mule deer	60.1	Drawn down
7/25/2008	Mule deer	60.1	Drawn down
10/27/2008	Mule deer	5.3	Drawn down
12/5/2008	Mule deer	5.2	Drawn down

Exhibit 3. Wildlife vehicle collisions including date, species, location, and lake level.

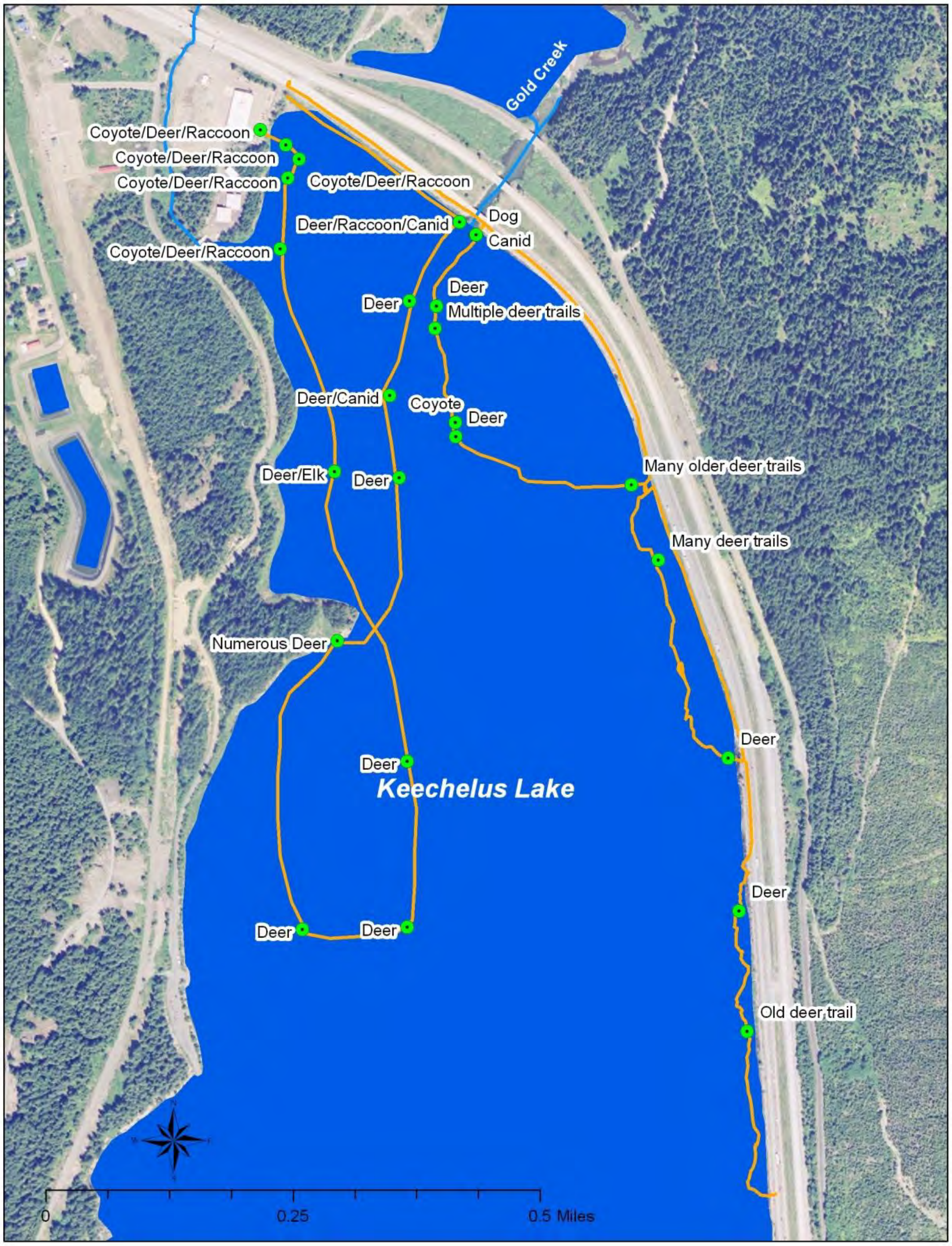

Exhibit 4a. Survey routes and tracks detected during northern Lake Keechelus track surveys on 10/5/09, 10/15/09, and 10/28/09.

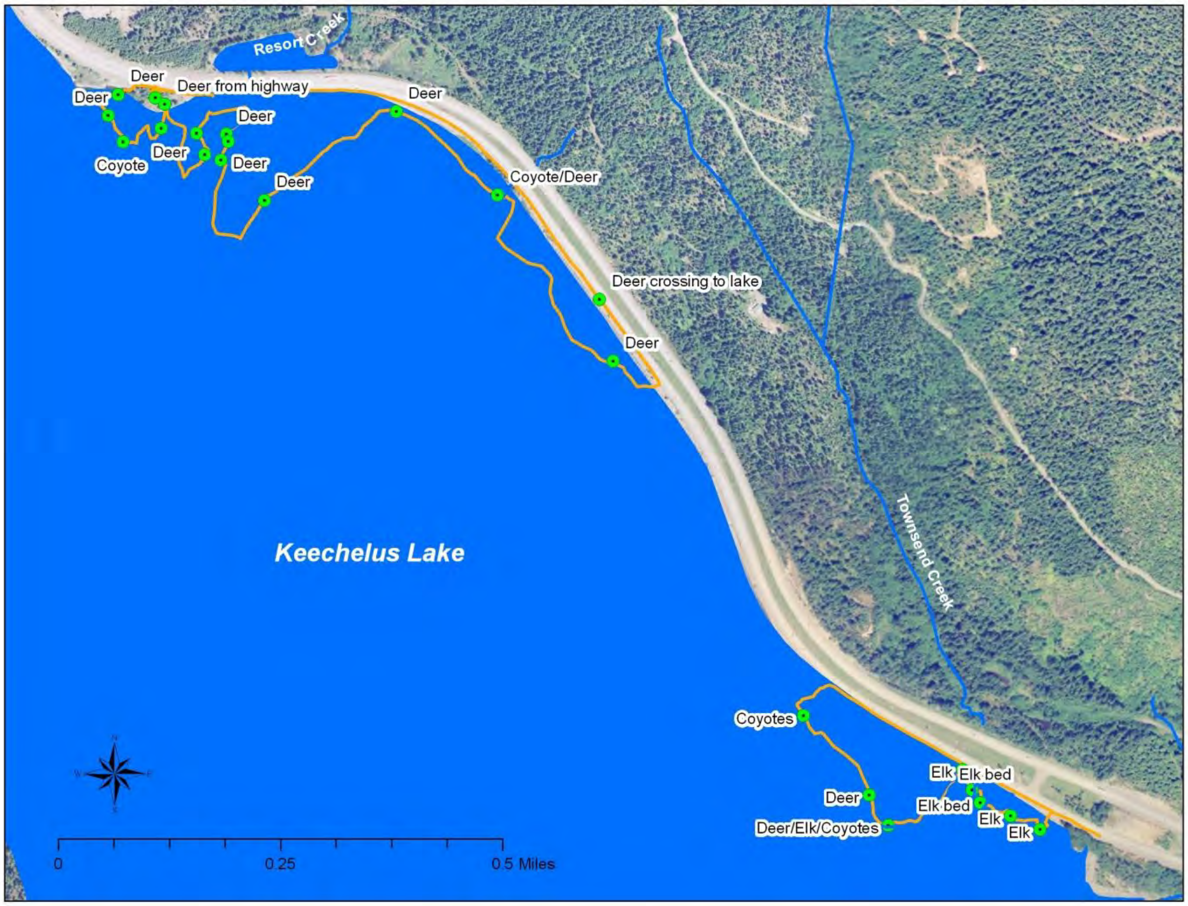

Exhibit 4b. Survey routes and tracks detected during northern Lake Keechelus track surveys on 10/5/09, 10/15/09, and 10/28/09.

Exhibit 5. Mechanically stabilized earth (MSE) retaining wall along the Trans-Canada Highway in Banff National Park, Alberta. (copyright: Tony Clevenger)

Exhibit 6. Boulder wall substituted for wildlife exclusion fence on eastside of US 95, near Bonners Ferry, Idaho. (copyright: Tony Clevenger)

Exhibit 7. Wing wall at wildlife underpass and connection to large boulders, substituted for wildlife exclusion fence on west-side of US 95, near Bonners Ferry, Idaho. (copyright: Tony Clevenger)

a.

b.

Exhibit 8. Escape ramps on US 95 near Bonners Ferry, Idaho. (a) Lateral view of escape ramp fitted into boulder wall on downhill side of highway; (b) elevated view of escape ramp under construction with landing pad in place. (copyright: Tony Clevenger [a] and Wayne Wakkinen [b])

Exhibit 9. Large boulders placed in the right of way as a barrier to elk and deer along State Route 260 in Arizona (copyright: Marcel Huijser).

Exhibit 10. Boulder field at termination of wildlife fence on Trans-Canada Highway, near Canmore, Alberta (copyright: Tony Clevenger).

Exhibit 11. Retaining wall at wildlife underpass on US 95 near Bonners Ferry, Idaho. (copyright: Tony Clevenger).

Appendix 5.1. Northern flying squirrel genotypes including individual and capture grid.

		Locus										
Individual	Capture	194	1367	2035	2565	4185	4361	4732	5265	5430	6777	7299
A101487B	BCN	987987	995997	106106	148152	113115	188176	115117	232234	109110	238238	000000
A144818B	BCN	993995	989993	106106	148152	113115	176176	115117	232234	109110	237239	112114
A144819B	BCN	993109	993997	106110	150152	113115	176176	117117	234236	109110	237239	108112
A197570B	BCN	993997	993993	106106	148150	115115	178176	117117	232236	110110	236236	106110
A197573B	BCN	993997	995997	106106	152154	113115	176176	117117	234240	110110	234237	112114
A197574B	BCN	993997	993993	106106	148150	115115	176176	117117	232236	110110	236236	106110
A197792B	BCN	981993	993993	106106	150154	113115	176176	115115	234236	106112	237240	112114
A101511B	BCS	981981	989989	106106	147148	113115	176188	117117	236236	106112	236238	114114
A101512B	BCS	981987	993993	106106	152152	115115	176186	117117	236240	109114	238240	000000
A159854B	BCS	993993	993993	106106	148148	111113	186176	113117	234234	106110	237240	000000
A159855B	BCS	981987	993993	106106	152152	115115	176186	117117	236240	109114	238241	112116
A197568B	BCS	981981	989989	106106	147148	113115	176188	117117	236236	106112	236238	114114
A197569B	BCS	981981	993993	106106	150152	111111	176186	117117	236240	109110	238240	112112
A197571B	BCS	981993	989993	106106	152152	113115	176176	117117	236240	112114	238240	110116
A197572B	BCS	981987	993993	106106	150152	115115	176186	115117	234236	109110	238242	112114
A197779B	BCS	981101	993993	106106	150152	111111	176186	117117	236240	109110	238240	112112
A197791B	BCS	987995	993997	106106	150152	113113	178186	111117	234234	109114	237239	112112
A101486B	TCN	993105	993993	106106	148150	113115	176190	115117	238240	110110	236241	112112
A101508B	TCN	105107	993998	106106	150150	113122	176178	115117	234236	109110	238238	112112
A101513B	TCN	987103	993997	106106	148150	113113	176176	117121	236236	112112	235238	114116
A101514B	TCN	993999	993995	106106	148152	113115	176176	115115	230232	110112	237239	114116
A144820B	TCN	987993	989991	106110	148150	115115	176178	117117	234238	110112	240241	112114
A144821B	TCN	993993	993993	106106	148148	113113	176186	113117	234236	110112	236236	106114
A144822B	TCN	987993	993993	106106	148150	113113	176186	117117	234240	110112	236238	106116
A144825B	TCN	993997	991993	106110	147150	115115	167188	115117	234234	110114	238238	110112
A144827B	TCN	993993	989995	106110	148150	113113	176176	117117	232234	110112	240240	106116
A144829B	TCN	993105	993998	106106	148152	113115	176186	115117	232236	105112	234240	106110
A191969B	TCN	993993	993993	106106	148150	113113	176186	117117	234236	110112	236240	106114
A191973B	TCN	981993	989993	106106	148152	113113	176176	115117	232234	109112	238239	112114
A101484B	TCS	103109	989993	106106	152154	111115	176178	117117	234236	110110	238239	000000
A101485B	TCS	981981	993993	106106	150154	113113	176176	107117	232234	109110	237242	112114

A173828B	TCS	981993	989997	106108	148150	113113	176190	115117	234236	106110	236238	997112
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A173830B	TCS	981981	993997	108112	148152	113113	176190	117117	234236	106109	238239	114114
A173831B	TCS	981993	989993	106112	148150	113113	176190	117117	234234	109110	236238	997114
A173834B	TCS	981981	995997	106108	152152	113113	176176	117117	234236	000000	239239	112114
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A173840B	TCS	981993	989995	106106	148152	113113	176176	113117	232236	106110	239239	114114
A173841B	TCS	981993	993995	106110	148152	113113	176176	117119	236236	106106	239239	112114
A197567B	TCS	981105	989993	106112	148150	113122	176178	113117	234236	109110	236238	112112
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A173839B	EHN	981101	102105	106106	150150	113115	176176	115117	236236	110110	238240	112116
A173886B	EHN	993105	995997	106106	150152	113113	176176	115117	232234	106109	236242	110114
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A173558B	EHS	981993	989993	106110	152152	113120	176178	113117	234236	106110	236239	112112
A173881B	EHS	987993	991993	108114	150152	113115	176188	115117	234236	109110	238238	108112
A173884B	EHS	995101	993993	106106	147150	113115	176186	117117	232234	110110	236240	112112
A173885B	EHS	981981	989989	106110	150152	113113	176182	117117	234236	110116	236241	116116
A173899B	EHS	997997	993993	106106	150150	115115	176176	115117	236236	109110	238238	110112
A173902B	EHS	981993	993993	106110	148152	113113	176176	115115	234236	109110	236238	112112
A173904B	EHS	993993	989993	106106	147152	113124	176176	109117	232236	110110	236239	110114