MONITORING FISH AND LOW-MOBILITY VERTEBRATES ALONG A MAJOR MOUNTAIN HIGHWAY: A SNAPSHOT BEFORE CONSTRUCTION OF I-90 WILDLIFE CROSSING STRUCTURES

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ABSTRACT

We monitored low-mobility vertebrate species before construction of wildlife crossing structures on the I-90 Snoqualmie Pass East project in the Washington Cascades. Our objectives were to address connectivity patterns and habitat requirements of low-mobility wildlife species, given the likely barrier effect of I-90. Low-mobility species (defined as those with relatively small daily movements and home ranges, low dispersal capability, or restrictive habitat requirements) are particularly vulnerable to fragmentation by roads and associated human uses of adjacent habitat. Yet most wildlife monitoring efforts along roads have been devoted to larger, more mobile wildlife species. We selected a number of low-mobility focal taxa including fish (trout and salmon), amphibians (frogs, toads, salamanders), reptiles (alligator lizards), and small mammals (pikas), and also measured characteristics of several ecosystems (aquatic and terrestrial), and habitats (talus, coniferous forests, wetlands, and streams). Our overall goals were to map the current distributions of low-mobility species near the I-90 corridor, especially in designated connectivity emphasis areas, to determine where and how frequently they cross the highway, and assess habitat characteristics and requirements. We used a variety of techniques to capture, mark, and track individuals, assess habitat, and collect genetic tissue samples. Capture methods include live-trapping, pitfall trapping, transect surveying, road-cruising, and electroshocking (streams). We marked individual organisms of some species with PIT tags, ear tags, toe clips, or fin clips. Tracking methods included radio-tracking, repeat trapping of marked individuals, and PIT tag readers. Habitat measurements were collected in areas where target species were located.

Ecological connectivity for low mobility species along I-90 east of Snoqualmie Pass has not been completely interrupted by the interstate, but crossings seem to be infrequent. Several marked amphibians (frogs, toads) were documented to cross I-90, as well as nearby forest service roads. No pikas were documented crossing the highway, but pikas do occupy rock patches adjacent to the highway shoulder and stream-side rocks under highway bridges. Alligator lizards were found on the interstate shoulders. Fish were found to pass through some, but not all streams that cross under the highway.

Based on our pre-construction monitoring, we will provide recommendations for habitats built into the crossing structures and adjustments (where possible) to specific locations of some of the smaller crossing structures to link existing populations or critical habitat. The data we have gathered on habitat requirements of low-mobility vertebrates will inform engineers on which microhabitat elements should be included in the crossing structures. We will continue to monitor the movements of low-mobility species during the construction and post-construction phases of this project. Future analysis of genetic samples will allow us to determine landscape-level genetic structure for these focal populations, and assess changes to genetic structure and connectivity after wildlife crossing structures have been implemented.
INTRODUCTION

Interstate 90 (I-90) has been identified as the largest barrier to the movement of wildlife between protected federal lands in the Cascade Mountains of Washington State (Fig. 1). Federal land management plans have documented that I-90 forms a barrier to wildlife movement, and have identified the need to increase ecological connectivity across the highway (USFS 2000). Improving ecological connectivity will advance federal land management goals by reducing fish and wildlife population isolation (USFS and USFWS 1997) as well as reduce the risks to wildlife and the public from collisions between vehicles and wildlife. A 15-mile highway expansion project (I-90 Snoqualmie Pass East Project) began in 2008 with the main purpose of increasing vehicle travel safety and reducing closures due to avalanches on I-90 over Snoqualmie Pass in Washington State. Structures for wildlife passage were designed and planned at 14 major wildlife crossing areas within the project (WSDOT 2008). The wildlife crossing structures were located and designed with the purpose of increasing safety by reducing collisions between wildlife and vehicles, and to connect habitat that is currently separated by the highway. The location of the wildlife crossing structures was based on the identification of numerous Connectivity Emphasis Areas (CEA’s) that were chosen based on historical wildlife crossing areas, geographic features, or hydrologic flow.

A review of recent studies focusing on the effects of roads on a range of different taxa concluded that there is clear evidence for negative effects of roads at the population level (Fahrig and Rytwinski, 2009). However, the evidence for population-level effects of roads in many studies was compromised because the studies were usually not designed to evaluate the effects of roads independent of other variables (Fahrig and Rytwinski, 2009). Very few before–after–control–impact (BACI) experiments have been conducted to determine the impact of wildlife crossing structures on animal populations, yet are needed to accurately evaluate the efficacy of mitigation structures (Roedenbeck et al., 2007).

In 2008 we began a study to monitor low-mobility vertebrate species before construction of wildlife crossing structures on the I-90 Snoqualmie Pass East project. Our objectives were to address connectivity patterns and habitat requirements of populations of low-mobility wildlife species, given the likely barrier effect of I-90. We defined low-mobility species as those with relatively small daily movements and home ranges, low dispersal capability, and restrictive habitat requirements. These species are particularly vulnerable to fragmentation and isolation by roads and associated human uses of adjacent habitat. We chose vertebrate species to monitor that represented different taxonomic groups and ecological niches. The taxonomic groups represented in our study were fish (trout and salmon), amphibians (frogs, toads, salamanders), reptiles (alligator lizards), and small mammals (pikas). Choosing species that inhabited a variety of different habitats enabled us to monitor species in both aquatic and terrestrial ecosystems as well as in specific habitats such as talus, coniferous forests, wetlands, lakes, and streams. Our overall goals were to assess the current population status and map distributions of low-mobility species near the I-90 corridor, especially in designated connectivity emphasis areas where wildlife crossing structures are planned. To accomplish this goal we attempted to determine where and how frequently each species crosses the highway, as well as to assess each species’ habitat characteristics and requirements. In addition to direct measurements of individuals and...
habitats, genetic samples from each species are being collected for future analyses of the populations.

Figure 1. Map of publicly owned and managed lands within the project area in Washington State.
**METHODS**

We conducted monitoring of each taxonomic group within the 15-mile project area (Fig. 2) using a variety of techniques to capture, mark, and track individuals, assess habitat, and collect genetic tissue samples as described below in more detail for each group. Capture methods included transect surveying and road-cruising to locate and hand-capture individuals, electrofishing, live-trapping, and pitfall trapping. We marked individual organisms of some species with ear tags, toe clips, or fin clips. Passive integrated transponder (PIT) microchip tags were implanted to monitor movements of most focal species, and radio-telemetry was used to track movements of two amphibian species. Habitat measurements were made using a variety of methods depending on the habitat type. Genetic samples were collected from individual animals by removing small tissue samples from live animals, or by collecting hair samples or fecal pellets. We used handheld GPS units to record the specific locations of captured and observed animals, and to map distribution, home range, and habitats.

**Fish**

We established permanent transects in nine study streams for the collection of baseline data on stream habitat and fish populations. Baseline stream habitat conditions included measurements of instream habitat (substrate and woody debris), channel morphology, flow velocity and water temperature. Treatment reach transects were established immediately upstream and downstream of the highway and control reach transects were placed upstream out of the influence of the highway (50-100 meters) with a similar configuration of transects as though a culvert or bridge were present (Fig. 3). We monitored fish populations by conducting surveys in the treatment and control reaches using a backpack electrofisher and dipnets in eight of the streams (Swamp Creek, Bonnie Creek, Noble Creek, Price Creek, Townsend Creek, Resort Creek, Rocky Run Creek, and Coal Creek) (Fig. 2). All captured fish were identified, enumerated, measured for total length, and then released near their original capture location. We sampled Gold Creek by conducting underwater snorkel surveys rather than electrofishing due to the presence of federally-listed bull trout (*Salvelinus confluentus*). All fish encountered were identified and enumerated, and we visually estimated total length and recorded GPS location for all bull trout.
Figure 2. Map of the study area showing the locations of species monitoring sites.
We marked fish longer than 150 mm (total length) that were captured during the electrofishing surveys with a PIT tag to monitor movements and growth when recaptured. The tags were inserted using standard Biomark® implanters by first anesthetizing the specimens in a solution of MS-222 and then inserting the implanter needle just under the skin on the fish’s ventral side just anterior of the vent and allowing the tag to enter the body cavity. Each PIT-tagged fish was scanned to record the tag code prior to releasing the fish back into the stream. All captured fish were scanned to detect tags that had been implanted during previous surveys. Snorkel surveys and foot surveys were conducted in Gold Creek to determine the timing of bull trout and kokanee salmon (*Oncorhynchus nerka*) migrations as well as to delineate spawning areas. The surveys began each year in July and continued through November on a 2- to 3-week time interval. GPS coordinates were recorded where either individual bull trout or bull trout redds (nests) were found. We delineated spawning areas used by kokanee salmon in lower Gold Creek by recording GPS coordinates at the upstream and downstream limits of where spawning individuals were found.

Genetic samples were collected from all fish larger than 100 mm by removing a small piece of caudal fin (~ 0.5 cm²) tissue from the ventral lobe using forceps and scissors. Each tissue sample was then placed in a labeled vial containing 70% ethanol for long-term storage.

Figure 3. Map of a typical stream showing the location of permanent transects in treatment and control areas.
Amphibians

The monitoring of amphibians involved many species at many different sites and has used several approaches including radiotracking of individuals, direct monitoring of movements across roads via driving surveys, PIT tagging and marking individuals on either side of I-90 at CEA’s, and genetic sampling.

Three focal species (Cascades frogs, Western toads, Pacific Giant salamanders) were monitored with the aim of (1) characterizing the viability of these populations and (2) estimating the current rate of movement of these species across I-90, especially at three CEA’s (Gold Creek, Swamp Creek, and Toll Creek). In addition, other species were captured opportunistically, especially as they were collected in the driving surveys. Once captured, a genetic sample was collected from many individuals with an emphasis on collections north and south of the CEA’s. In order to identify locations within the vicinity of I-90 study area where Western toads were most likely to be encountered, night-time driving surveys were conducted by 1-2 people on a forest service road located ≤1 km north of the freeway. The road runs parallel to the interstate for 16 km and consists of 11 km of gravel surface with 1 km of paved surface at the eastern end and 5 km at the western terminus. Habitat surveys were conducted in areas where amphibians crossed in high numbers (“hotspots”) and adjacent control sites to identify habitat features (vegetation, canopy cover, slope, aspect, etc.) that might be influencing amphibian movements. We used radio transmitters to track populations of Western toads within the study area. These toads have been tracked from their breeding sites or summer foraging ranges, to overwintering sites and will be tracked back to breeding sites in the springtime. The study area for radio-tracking extends from Swamp Lake to Mardee Lake, with one site south of I-90 near Keechelus dam. Upon encountering a toad it was weighed and snout-to-vent length measured and a PIT tag (Biomark®) implanted into the dorsal lymph sac. A Holohil® BD-2 radio transmitter was mounted to a plastic belt made of 2.6 mm diameter surgical tubing that was custom fit to each toad’s waist with a plastic barbed connector. Toads were tracked using a Telonics® TR-4 receiver with a Telonics® RA-17 directional antenna. Individuals were tracked 2-4 times per week. Upon each encounter, we recorded GPS location, micro habitat information (percent ground cover of leaf litter, moss, rocks, grasses and sedges, herbaceous plants and shrubs), macro habitat information (cloud cover, air temperature, canopy cover, weather conditions), and time of day. Approximately twice a month, snout-to-vent length and mass were measured and the belts were examined to ensure a “good fit”, and to check for abrasions.

To investigate Pacific Giant Salamander movements, habitat use and activity patterns we utilized radio transmitters. Tracking was conducted in and around the surrounding uplands of two streams that have been identified as harboring salamanders and cross I-90: Noble Creek and Wolf Creek. Terrestrial adult salamanders were hand-captured during night surveys in the uplands surrounding the streams. Nine individuals weighing > 40g were implanted with internal radio transmitters for tracking using standardized surgical procedures. During implantation surgery and once per season salamanders were weighed and measured. Salamanders were located every three days during the summer, fall and spring seasons, and twice per month in the winter. Salamander locations were marked with flagging and the position of the salamander (above-ground, under-cover, or under-ground) recorded. To test salamander habitat use and movement correlations we measured environmental variables (temperature, cloud cover, precipitation level), ground cover at each salamander location (1-m circular plot, visually
estimated to the nearest 5%), the decay class of woody material, size of cover object and linear distance to water. Each use location was paired with a randomly selected non-use site. Non-use site was determined by taking a random distance (between 1-12 m) and compass bearing from the salamander use location. Ground cover and wood decay class was measured in these non-use sites to test if salamanders are selecting for specific habitat features. Road crossings was recorded as ‘at grade’ or ‘below grade’ when observed. Use or avoidance of existing road crossing structures (steel culverts) was recorded. A combination of tape and compass and Topcon GPS unit were used to map the salamander locations.

Lizards

We initiated a monitoring program for the Northern Alligator lizard (*Elgaria coerulea*) near the Price-Noble CEA, a location where large terrestrial crossing structures will be built over I-90 near Snoqualmie Pass. We constructed 18 pitfall trap arrays along I-90 in upland forest near Price/Noble Creek: eight on the westbound side of the highway and eight on the eastbound side. Each pitfall array consisted of four 5-gallon buckets buried in the ground up to their rims and connected via smooth aluminum drift fences. Drift fences served to guide lizard moving through the forest into the buried pitfall buckets (Fig. 4). Pitfall arrays were checked several times/week throughout the summer of 2010. All lizards captured were marked with PIT tags (Biomark®), measured, weighed, and released. From these data, we determined the basic population structure of alligators lizards in the project area. Genetic samples were collected from Alligator lizards captured in the pitfall traps; tissue samples were also stored from many of the small mammals captured in the pitfall traps. Habitat variables (canopy cover, understory vegetation, rock abundance and sizes, slope, etc.) were recorded at each pitfall array. These same habitat features were also recorded from other sites within the project area (but outside of the pitfall arrays) where Alligator lizards were encountered. Sites where Alligator lizards were located were then compared with paired sites located randomly within the potential home range of each alligator lizard encountered. The occupied sites were then analyzed along with the random sites to identify specific habitat features associated with the presence of Alligator lizards. We used non-parametric goodness of fit tests, paired t-tests, and correlation analyses to determine specific microhabitat features associated with alligator lizards. These habitat features can then be used to inform the design and construction of future crossing structures. After the structures are built, we can then test their effectiveness by using future pitfall arrays to monitor alligator lizards in a manner similar to what we have described above.
Figure 4. Pitfall array used to capture alligator lizards along I-90 near Snoqualmie Pass, WA.

Pikas

Monitoring American pikas (Ochotona princeps) consisted of mapping suitable habitat patches (natural talus and other rocky sites), surveying for pika presence, habitat surveys, live-trapping, and collecting genetic samples. We located and mapped rocky habitats potentially suitable for pikas by aerial photos, scanning the landscape from open vantages points, driving along Forest Service Roads, and hiking across areas suspected to contain talus. We began by mapping as many talus patches as possible within approximately 1-2 miles of the interstate, along the 15-mile project area. However, during the first year, we realized that pikas also inhabited anthropogenic rocky habitats in the project area. These human-made sites include rocky fill placed along roads (I-90, Forest Service roads, and railroad beds) to stabilize slopes, and rocky riprap placed along stream banks to stabilize slopes under bridges. Thus we expanded our habitat searching to include these anthropogenic habitats. We have now mapped 94 rocky habitat patches that are potentially suitable for pikas.

At most of the rocky patches we have identified and mapped, we conducted talus occupancy surveys to verify which patches were occupied by pikas each year. During 2008, we noted whether pikas were seen or heard, and whether we observed any signs of occupancy (“haypiles” of vegetation made by pikas to serve as a winter food store, and pika latrine areas where they
commonly defecate; both are signs that pikas have a territory on the patch). Because pikas are diurnal (active during the day), make foraging trips above ground, and make distinctive vocalizations, we were able to readily detect their presence. A patch was considered occupied if pikas were seen or heard, or if fresh (this year’s) haypiles or latrines were observed. During 2009 and 2010, we followed strict occupancy survey protocols using a modification of occupancy surveys developed by the California Pika Consortium (Millar 2010) and the National Park Service (NPS 2010). These involved timed focal observations for pika sightings and vocalizations, and walking transect lines across the habitat patch to search for haypiles and latrines. Not all patches were surveyed each year, but some were surveyed for two consecutive years (2008 and 2009 or 2009 and 2010) and some were surveyed all three years. In 2009 and 2010, most surveyed patches were visited in early summer and again in late summer to early fall.

We collected habitat data at a subset of the rocky patches. In 2008, we measured habitat variables at the 9 patches where we trapped pikas (and thus pikas were known to occur), and in 2009 at 4 other patches occupied by pikas. For each patch, we roughly estimated patch size (length, width) and isolation (distance to nearest other talus patch) by pacing off distances or, where possible, measuring with 30-m tapes. At four locations within each patch, we measured slope angle (with a clinometer), slope aspect (compass orientation), and percent canopy cover (with a spherical densiometer). Rock size was measured along a 10-m transect centered on the location and oriented in a random direction). Rock length, width, and height were measured for the rock closest to each meter mark along the transect.

In 2010, we initiated a specific habitat comparison of pika-occupied and unoccupied natural talus patches with anthropogenic rock patches (road-fill and riprap) to characterize the important habitat features of pika-suitable patches. Our study design was to compare 4 sites that were occupied by pikas and 4 sites not occupied by pikas for each of the 3 habitat types, for a total of 8 x 3 = 24 sites. However, most of the natural talus sites were occupied by pikas and we were able to find only 2 unoccupied sites (at elevations similar to the other sites), giving us a total of 22 sites. Most sites were within 1 mile of I-90, and all within an elevation range of 736-1220 m above sea level. At each site surveyed, we recorded GPS locations at the patch center. We recorded patch type (natural talus, road-fill, riprap), patch area, directional aspect, slope, distance from patch center to available forage, depth of deepest crevices between crolks, and distance from the patch edge to the nearest potential pika habitat (talus or other rocky habitat). We measured the size (longest dimension) of the 10 largest rocks at the patch. We also measured canopy cover using a densitometer, and visually estimated percent ground cover by rocks, lichens, mosses, ferns, grasses, forbs, shrubs, and trees in circular plots.

We selected a subset of the patches known to be occupied by pikas for live-trapping. The main objectives of live-trapping were to mark individuals to monitor any movement between patches, to monitor residency over time (between years), and to collect genetic samples. The patches selected for trapping were either near CEAs to monitor any movements of pikas close to the interstate, or where pikas were abundant (and could potentially provide more genetic samples). At each trapping location (patch), Tomahawk live-traps were placed in clusters around sites where pikas or their sign (latrines, haypiles) were seen. Fresh vegetation from the edge of the patch was used as bait. Captured pikas were weighed, marked with ear tags (in 2008-2009) or hair dye (2010), and implanted with a uniquely coded PIT tag (Biomark®) (2009-2010), then
released at the site of capture. To minimize stress, we anesthetized the animals with isoflurane before handling. We collected small ear tissue samples (from the ear tag punch or an ear notcher) from each captured animal. Trapping was typically conducted for a 3-day period at each site, during morning and evening hours. We trapped at 9 sites in 2008, 4 sites in 2009, and 2 sites in 2010.

Genetic tissue samples collected from live-trapped individuals (as described above) and stored dry in coin envelopes. We also collected fresh fecal pellets during habitat surveys, and placed them in buffer until initial DNA extractions. We also conducted a trial of hare snares at active haypiles using packing tape placed sticky-side out on a web of fishing line at the entrance to the haypile (Henry and Russello 2009).

RESULTS AND DISCUSSION

Fish

Based on direct observations of certain fish species as well as the recapture of tagged fish we found that the highway is not a barrier to fish passage in some streams, but may be a barrier in others. In Swamp Creek we found juvenile Chinook salmon in 2008, 2009, and 2010 upstream of a concrete culvert under I-90. The nearest spawning area for Chinook salmon is about 200 meters downstream in the mainstem Yakima River, so the juveniles likely migrated upstream into Swamp Creek during the moderate stream flows in early summer when passage through the culvert is possible.

In contrast to Swamp Creek, we found no movement of cutthroat trout (*Oncorhynchus clarki*) tagged with PIT tags in Rocky Run Creek. We recaptured 13 cutthroat trout in 2010 out of 50 that had been tagged in 2009 (26% recapture rate), however, all of the recaptured fish were found in their original capture/release location with no evidence of any fish moving through the culvert under I-90. We also found that both bull trout and kokanee salmon were able to move past the I-90 bridges in Gold Creek (Fig. 5) to make successful spawning migrations. Bull trout redds were found several kilometers upstream from I-90, and kokanee salmon used the areas immediately under and adjacent to the I-90 bridges for their redds.

New bridges are currently being constructed over both Rocky Run Creek and Gold Creek to make the span longer and allow the streams to create a more natural channel. The pre-construction data on seasonal cutthroat trout movements in several of the study streams as well as bull trout and kokanee salmon spawning migration patterns in Gold Creek will be compared to similar data collected following the completion of the new bridges to evaluate the efficacy of the structures for improving ecological connectivity. A genetic analysis of the fish populations in each stream prior to and following construction of stream-crossing structures will also help to assess any changes in ecological connectivity.

Pre-construction stream habitat data will be compared to similar data collected following the completion of stream-crossing structures to assess habitat responses when culverts are replaced with bridges. Channel shape, flow regime, substrate composition and woody debris are variables that are likely to change when stream channels are allowed to flow unrestricted instead of
through culverts. The highway construction project includes plans to replace culverts and short bridges over several streams of varying channel widths with bridges of varying span lengths, so post-construction data will be useful in determining which streams and associated bridges respond positively with respect to instream habitat, fish passage, and overall stream health.

Figure 5. Map showing the area in lower Gold Creek where kokanee salmon were observed spawning during October 2011.
Amphibians

Among focal amphibians, Cascades Frogs are relatively abundant throughout the study area and adult recapture rates were 74% at Gold Creek with all tagged individuals were recovered at Swamp and Toll Creek. Cascades frogs tend to occupy stream channels, wetlands, or riparian areas. The high frequency of tagged individuals allowed us to detect movements across I-90, suggesting limited connectivity for amphibians at Toll Creek and Swamp Creek. At Swamp Creek, we detected 7 and 5 Cascade frogs move across I-90 through a box culvert in 2009 and 2010, respectively. Similarly at Toll Creek, we detected 2 and 3 individuals move through a pipe culvert in 2009 and 2010, respectively. Detections at Toll Creek were made with an automated PIT detector that was installed in Toll Creek. For the Gold Creek CEA, movement of amphibians across I-90 may be constrained by the Gold Creek bridge and the parallel forest service bridge. We expect permeability in this region to increase with the construction of a raised bridge and restoration of Gold Creek to a more natural flow regime. Western toad detection at these sites was low. However, tracking of toads by radio telemetry suggests they can move long distances and spend most of their in the uplands outside of breeding the seasons.

We tracked 25 different Western toads from the fall of 2009 to the spring of 2010. Toads were observed mostly using burrows and tunnels in roadside ditches and hillsides less than 3 m from Forest Service Road 4832. Further, they frequently cross FS Road 4832 and were routinely found during nighttime road surveys on the surface of the road. Three of the radioed toads were run over by cars on FS Road 4832 during 2010. However, Toads do appear to avoid I-90 and were only rarely observed coming with 3 m of the roadway.

Terrestrial Coastal Giant salamanders (N=7) were radiotracked from the spring of 2010 until spring 2011. All of these salamanders were encountered on or within 1 m of Forest Service road 4832 during rainy spring nights. Three tracked salamanders were observed crossing FS Road 4832 at grade. One salamander travelled to within 1 m of I-90 but made movements parallel to the highway.

Overall, there is limited connectivity of Cascade frogs across I-90. However, Western Toads and Coastal Giant salamanders appear to avoid I-90. However, they do interact with a forest service that runs parallel to I-90.

Lizards

Northern Alligator lizards are relatively abundant on both sizes of I-90 in the vicinity of the Price/Noble connectivity emphasis area (CEA). Pitfall arrays were successful in sampling not only Alligator lizards, but also small mammal species such as shrews. Several amphibians (frogs, toads, and *Ensatina* salamanders) were also captured in the pitfall arrays. The Alligator lizard population structure, based on preliminary data from the first field season, suggests a robust population with varies age classes (juveniles, early reproductive adults, and larger adults) well represented in the population. The age and sex of individuals that are active in the population varies seasonally, with females more active in the summer and males and juveniles more active in the early fall. This suggests that the timing of sampling is important; an incomplete understanding of population characteristics might result from a limited sampling period. Very few individuals were recaptured during our first year of sampling with pitfall traps. As more individuals become marked in the population, and subsequent seasons are added
to our analysis, we should obtain more recaptures and be able to more accurately estimate the population density of Alligator lizards at the connectivity emphasis area.

Certain microhabitat features of sites used by Alligator lizards differed significantly from random locations within the connectivity emphasis area. Alligator lizards selected microhabitats with relatively low forest canopy cover (30-60%) and moderate rock cover (6-15%) and more medium (10-30 cm) to large-sized (>60cm) rocks. Sites occupied by Alligator lizards varied in understory vegetation, with low-growing kinnikinnick (*Arctostaphylos uva-ursi*) being the most abundant. However, we found no significant differences in understory vegetation between Alligator lizard sites and random sites during this first field season.

The information from this study will facilitate design of wildlife crossing structures to include microhabitat features that enhance movements of low mobility species in this area. Our results are only preliminary; additional field seasons are necessary for a valid sample size and to capture inevitable annual variation. Based on our preliminary results for Alligator lizards, moderate understory rock cover (6-15%), a variety of rock sizes (especially intermediate-sized rocks, 10-60 cm in diameter), and 30-60% forest canopy cover may be important microhabitat features to design into the crossing structure at Price/Noble CEA. A more complete picture of understory vegetation requirements and Alligator lizard movements will come with additional field seasons.

Studies should be continued during and after construction to determine the effectiveness of the bridges as sources of habitat for wildlife migration. As future terrestrial crossing structures are built, pitfall trapping arrays can be incorporated into those structures to monitor their use and effectiveness in enhancing connectivity of low mobility terrestrial vertebrates.

**Pikas**

We have mapped 94 rocky habitat patches that are potentially suitable for pikas within the project area (Figure 6). Pikas occupy 80-95% of suitable rock patches in the study area, including anthropogenic habitats such as patches of rocky road-fill along the shoulders of highways and Forest Service roads and riprap along streams. The high occupancy rate suggests that, despite the strong tendency of adult pikas to stay in established territories and disperse infrequently (Barash 1973; Tapper 1973; Smith and Ivins 1983), pikas (perhaps the young?) are able to disperse among patches on one side of the interstate or the other side. This is supported by genetic analyses of pikas in fragmented habitats suggesting that gene flow does occur among patches in fragmented habitats (Peacock and Smith, 1997).

Our preliminary data do not yet allow us to evaluate whether pikas are currently able to cross the interstate. So far, we have no observations of pikas moving across the interstate at grade level or of being killed on the highway, and no records of PIT-tagged individuals being recaptured on the opposite side. Pikas have been seen running across small gravel forest service roads on at least two occasions in the past three years by our field crews, but these are much narrower roadways with a more natural surface, often overhanging vegetation (shrubs or trees), and very little traffic. Given the susceptibility of pikas to heat stress and predation (Smith and Weston 1990), the likelihood of them successfully crossing multiple lanes of highway (often with high traffic volumes) is probably quite low. However, pikas do occupy rock riprap under highway bridges at one site (Gold Creek), and there is no apparent barrier to them moving across the highway below grade level at that location.
Figure 6. Rocky habitat patches potentially suitable for pikas, including natural talus (NT) and human-made patches (rocky fill along roads or railroads, RF, and riprap, RR). M = mixed types.

Our habitat analyses suggest substantial overlap in habitat features of natural talus and anthropogenic rocky patches occupied by pikas. However, some differences do exist among patch types and between occupied and unoccupied patches, such as in patch size, number of vertical rock layers, canopy cover, and maximum rock size. We will be able to provide recommendations to WSDOT on habitat features to incorporate into crossing structures where pikas are a likely candidate for crossing (i.e., structures that incorporate rock piles or other talus-like habitat). We can also use the habitat data to suggest engineering specifications (such as rock size, depth of rocks) for rocky road-fill along the highway and riprap under bridges where encouraging pika colonization is considered beneficial.
To date, we have collected genetic samples from 52 individuals north of I-90, 45 individuals south of I-90, and 14 directly under I-90 (riprap sites). We will continue to build the tissue collection, and will conduct landscape-level analyses to see if I-90 has likely been a barrier to pika movement in the past. Genetic samples collected in the future after wildlife crossing structures are implemented can be used to compare with current levels of genetic structuring in pika populations, and hopefully evaluate the effectiveness of the crossing structures in improving connectivity.

CONCLUSIONS

Our data on these low-mobility species suggests that their ecological connectivity has not been completely interrupted by I-90 east of Snoqualmie Pass, but crossings seem to be infrequent. Some amphibians (frogs and toads) were documented to cross I-90, as well as nearby forest service roads. Alligator lizards occur along the highway shoulders at Price-Noble. No pika were documented crossing the highway, but pikas do occupy rock patches adjacent to the highway shoulder and stream-side rocks under highway bridges. Fish passage under the interstate occurs in some, but not all, streams that cross under the highway.

Based on our pre-construction monitoring, we have and will continue to provide recommendations to the state department of transportation for habitats built into the crossing structures. In addition, our mapping of habitats and species occurrences will allow us to recommend adjustments (where possible) to specific locations of some of the smaller crossing structures (e.g., culverts) to link existing populations or critical habitat. The data we have gathered on habitat requirements for these low-mobility vertebrate species will inform engineers on which microhabitat elements should be included in the crossing structures.

Monitoring multiple focal species of small vertebrates across highways presents multiple challenges in study design and logistics. We were able to solve many of these issues in the first three years of pre-construction monitoring, but in some cases low sample size (due to logistics and budgetary constraints) continues to make robust data analysis and conclusions a challenge. For many of these smaller vertebrates, direct observations of animal movement across the highway are difficult, thus our reliance on indirect measures in most cases. Highway crossings by amphibians and fish seem to be easier to detect, at least in part because PIT-tag antenna arrays have been installed in smaller culverts and under highway bridges.

Studies of this nature encompassing a variety of species and approaches, and attempting to provide data needed by the state department of transportation, require a high level of cooperation among researchers and agencies. Our biological work has been supported by positive interactions with the regional land management agency involved in permitting the I-90 construction (the US Forest Service, Okanogan-Wenatchee National Forest, Cle Elum Ranger District) and by the highway agency (WSDOT). We highly recommend developing cooperative interagency agreements and interactions.

Future Work

Results collected to date will help us fine-tune pre-construction monitoring protocols for the next 10-mile section of the Snoqualmie Pass East Project, which has not yet been funded. We will
continue to monitor the movements of low-mobility species during the construction and post-construction phases of this project.

We plan some experimental manipulations to test ideas generated from observational monitoring data. Field experiments will be especially useful for testing specific aspects of habitat that our monitoring study suggest may be requirements for some of our focal species. For example, pre-construction monitoring has indicated that patch size, number of vertical rock layers, and maximum rock size may be important for pikas. We are designing experiments to create replicated rock patches with different combinations of habitat variables and hope to monitor pika colonization of these new patches.

We will continue to collect genetic samples. Analysis of genetic samples will allow us to determine landscape-level genetic structure for these focal populations, and assess changes to genetic structure and connectivity after wildlife crossing structures have been implemented.

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REFERENCES


