ASSESSING WILDLIFE HABITAT CONNECTIVITY IN THE INTERSTATE 90 SNOQUALMIE PASS CORRIDOR, WASHINGTON

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Abstract

An assessment of wildlife habitat connectivity the barrier effects of Interstate Highway 90 from Snoqualmie Pass to Cle Elum was initiated in January 1998 under a cooperative agreement between the Washington State Department of Transportation and the U.S. Forest Service. The assessment consists of five components: 1) GIS Aleast-cost path@ modeling of landscape patterns to identify potential linkage areas for sensitive species; 2) GIS analysis of ungulate road-kill distribution; 3) monitoring of existing highway structures that may provide crossing opportunities for wildlife; 4) automatic camera station documentation of species found near the highway; and, 5) winter snow tracking transects to document highway crossings and animal distribution along the highway. The methodology developed for this assessment will be applicable to other landscapes where the combined effects of forest management and highway corridors may be impacting habitat connectivity.

Introduction

Highways and associated developments can have substantial influence on animal movement patterns (for example Bier 1995, Gibeau and Herrero 1998, van Riper and Ockenfels 1998). Highway barrier effects can influence wildlife distribution by changing intra-territorial and dispersal movement patterns. Disruption of intra-territorial movement can contribute to a loss of available habitat (Mansergh and Scotts 1989). Disruption of dispersal movements can isolate populations and increase the probability of local extinctions (Mader 1984). In either case, highway barriers can have negative effects on some species (Andrews 1990, Reh and Seitz 1990, Foster and Humphrey 1992). Barrier effects are likely to be amplified by human disturbance and changes in habitat configuration and composition resulting from past resource management practices, residential development, and recreation (Forman 1995).

In Washington state, one area of particular concern regarding highway barrier effects is the Interstate 90 corridor over Snoqualmie Pass, east of Seattle in the central Cascades Mountains (figure 1). In 1994, the President=s Northwest Forest Plan was implemented to address forest management issues on federal lands in the Pacific Northwest (USDA Forest Service 1994). The plan designated 10 >Adaptive Management Areas= (AMAs), including the east side of Snoqualmie Pass (USDA Forest Service 1997). Late Successional Reserve (LSR) areas, to be managed for old forest characteristics, were also designated under the plan. Because of it=s keystone location in regard to federal lands, particularly those designated as LSR and wilderness areas, the Northwest Forest Plan states that the emphasis for the Snoqualmie Pass AMA is the Adevelopment and implementation Y of a scientifically credible comprehensive plan for providing late-successional forest on the checkerboard lands. This plan should recognize that the area is a critical connective link in the north-south movement of organisms in the Cascade Range@ (Record of Decision D-16, USDA Forest Service 1994)

In light of this management mandate, the U.S. Forest Service, Pacific Northwest Research Station and the Washington State Department of Transportation (WSDOT) entered into a cooperative agreement to conduct research on the effects of the Interstate 90 corridor on wildlife movement. The focus of this project is to assess the barrier effects of a major interstate highway, at multiple scales, for a variety of species, in the context of a highly fragmented landscape. A primary objective of this project is to develop methods that can be used to evaluate landscape permeability and highway barriers for wildlife in the Pacific Northwest. In this paper we will present the methods we have applied in evaluating the barrier effects of Interstate 90 and the adjacent landscape and review preliminary findings. More complete analysis of the results of each project component will be submitted for publication elsewhere.

A secondary part of the of the cooperative agreement between the PNW Research Station and WSDOT was an extensive literature review on the interactions of highways and wildlife populations. The bibliography compiled for the literature review is posted as a downloadable text file on the Wenatchee Forestry Sciences Lab web site, www.fs.fed.us/pnw/wenlab/research/projects/wildlife/index.html.

Study Area

Our study focuses on 30 miles of highway from Snoqualmie Pass, at the crest of the Cascade Mountain Range (elev. 3000 ft), to the eastern edge of contiguous forest at the town of Cle Elum (elev. 2000 ft). The study area is characterized by rugged mountainous topography. Peaks adjacent to the highway at the pass reach elevations up to 6278ft. These rugged peaks along the Cascade crest create a substantial >rain shadow= effect, with the western portion of the study area receiving 140 inches of precipitation each year and the eastern portion receiving 30 inches (USDA Forest Service 1997). Snow accumulation can reach 30ft at the pass, while snow depth rarely exceeds 3ft near Cle Elum.

Because of the substantial elevation and precipitation gradient, the study section of the highway passes through a variety of vegetation zones and associated wildlife communities. Species of concern in this area range from highly mobile carnivores to low-mobility organisms associated with old forests. Wolverine (*Gulo gulo*) and lynx (*Lynx canadensis*) are present in the central Washington Cascades, and have been recorded on both sides of the highway (Wenatchee National Forest, Cle Elum Ranger District unpublished data). Fisher (*Martes pennanti*) were detected in the area as recently as 1976. Probable detections of grizzly bear (*Ursus horribilis*) and wolf (*Canis lupus*) have also been recorded in this area. Management directives included in the Northwest Forest Plan require surveys for a variety of species that have received little attention in the past, for example Oregon megomphix land snail (*Megomphix hemphilli*), blue-grey tail-dropper (*Prophysaon coeruleum*), keeled jumping slug (*Hemphillia burringtoni*) and others. These surveys have contributed to our understanding of late-successional forest ecosystems in this area.

The configuration of forest habitat in the Snoqualmie Pass area has been influenced by a variety of historic factors, including the land grant made by the federal government to the Northern Pacific Railway Company in the 1864. Every other square mile of land along the route of the rail line was deeded to the railroad. Most of these lands were sold to recover the cost of building the rail lines, however some mountainous forested lands were retained by the rail company and became commercial timber lands. This resulted in a checkerboard land ownership pattern across much of the Snoqualmie Pass landscape. Different management objectives between the public and private ownerships has resulted in a highly fragmented forest landscape. An extensive land exchange is presently under negotiation to consolidate land holdings in this area (USDA Forest Service 1998).

In addition to the highway and timber harvest, other features influence landscape permeability for wildlife. The study area is traversed by two high voltage electrical transmission lines and a railroad. The Yakima River valley bottom in the eastern portion of the study area is experiencing substantial suburban residential development. For the residents of urban communities around Seattle, Snoqualmie Pass is one of the most accessible areas for outdoor recreation, and there is an extensive ski resort development at the top of the pass.

Interstate 90 is a high-volume, high-speed roadway. Highway configuration in our study area ranges from 4 lanes in each direction, separated by a concrete median barrier, to 2 lanes in each direction separated by a broad forested median. Average daily traffic volume through the study area is approximately 24,400 vehicles with an average daily peak volume of 3920 vehicles per hour (including both east and west bound traffic) (Jim Mahugh, WSDOT South Central Region Traffic Office, pers. commun.). By 2018 these volumes are projected to increase to 41,400 vehicles per day with peak volumes of 6190 vehicles per hour. Highway expansion is planned to meet the increasing needs.

Despite the substantial impacts along the highway corridor, I-90 passes through a relatively narrow gap between large blocks of land managed primarily for conservation and recreation. At it=s closest point, the Alpine Lakes Wilderness Area is less than one mile north of the highway, while the Norse Peak Wilderness Area lies at least 15 miles to the south. LSR areas designated by the Northwest Forest Plan are located approximately one mile south and seven miles north of the highway.

Methods

The purpose of our project is to assess landscape permeability at multiple scales, for a variety of species, through a highly fragmented landscape. The project consists of five components; 1) landscape habitat connectivity modeling, 2) analysis of roadkill distribution, 3) monitoring animal use of existing highway structures, 4) conducting automatic camera surveys in the vicinity of the highway, and 5) winter snow tracking surveys along the highway. Our first step was to assess habitat connectivity on a landscape scale through GIS modeling. To evaluate the modeling effort, and to develop our understanding of wildlife distribution and movement patterns in the highway corridor, we conducted analysis of roadkill distribution and field monitoring of wildlife presence and highway crossings. By combining these components we have attempted to develop an understanding of wildlife distribution and movement patterns that can be incorporated into highway design to increase landscape permeability for wildlife.

<u>Landscape Modeling</u>

Our objective for the GIS linkage modeling is to evaluate landscape-scale habitat connectivity. Animals disperse in a variety of ways, but habitat characteristics are believed to influence the selection of movement routes (e.g. Bier 1995, Gustafson and Gardner 1996). We identified potential linkage areas for animal movement by analyzing landscape characteristics using GIS.

Rather than model habitat for individual species, we chose to model broad landscape characteristics that are likely to guide dispersal movements at the scale of our analysis area, such as forest cover and human disturbance. We identified four primary types of dispersers relevant to the Cascades ecoregion (table 1). Models were developed based on a literature review.

Our modeling approach is based on Aleast-cost@ path analysis conducted with the ArcInfo GRID module (ESRI 1992). Our approach uses a breeding habitat suitability model to identify areas that are likely to support source populations of the subject species, and a dispersal habitat suitability model to calculate the cumulative cost of moving from the source areas to each cell in the GIS map.

We gathered GIS data layers from Wenatchee and Mount Baker-Snoqualmie National Forest corporate data and other sources. GIS layers we compiled included roads, buildings, slope, distance to water, forest canopy closure, and forest tree size. Forest characteristics were derived from classified Landsat imagery.

<u>Deer and Elk Roadkill Distribution</u>

We analyzed deer (*Odocoileus sp.*) and elk (*Cervus elaphus*) roadkill distribution along I-90 to identify where animal entry onto the highway constitutes a human safety concern and where animals regularly attempt to cross the highway. We expect that areas with high roadkill frequency are areas of existing or potential habitat connectivity for ungulates and other species.

Data on ungulate roadkill locations was collected by WSDOT maintenance personnel from 1990 to 1998. We imported these records on species and location of roadkills into the GIS and used a >moving window= analysis to determine the number of kills per mile along I-90.

<u>Camera Surveys</u>

We conducted automatic camera surveys and compiled existing camera survey data to evaluate wildlife, particularly carnivore, distribution in the vicinity of I-90. We attempted to address three questions; 1) what are the differences in rates of detection and species detected along I-90 compared to areas away from the highway; 2) what is the distribution of animals along the I-90 study area, and how does this compare to linkage model predictions; and 3) what are the differences between animals detected at camera stations along the highway compared to those animals detected using highway structures to cross the highway.

Camera surveys along I-90 were initiated in September 1998 and data are reported here through August 1999. Camera stations were located in forested habitat within 1 mile of I-90. TrailMaster automatic camera systems (TM500 passive infrared monitors and TM35-1 35mm cameras) were used for these surveys. The stations were baited with salmon, deer, or elk parts and predator attractant disks. The camera stations were monitored for 28 nights, following the protocol suggested by Kucera et al. (1995). We also compiled data collected during camera surveys conducted by Mt. Baker B Snoqualmie and Wenatchee National Forest personnel from September 1995 to August 1997. These stations were located 1 to 20 miles from the highway and provided useful information on the broader distribution of wildlife in the central Cascades.

<u>Snow Tracking</u>

A primary focus of field work from January to March 1999 was conducting snow tracking transects along I-90 to evaluate wildlife crossing patterns and highway encounters. Our objective was to document where animals approached the highway and where they crossed the highway surface.

We employed snow tracking techniques similar to those used by researchers in Banff National Park, Alberta (Paquet and Callaghan 1996). Snow tracking transects were laid out to sample representative portions of the highway corridor. Ten sets of transects, one mile long, were located parallel to and on both sides of the highway. Surveys were conducted by skiing or snowshoeing approximately 150m away from the highway. Surveys were generally conducted between 24 and 72 hours after the most recent snowfall. Whenever possible, two researchers in radio contact surveyed the north and south sides of the highway simultaneously. All animals larger than snowshoe hare (*Lepus americanus*) were recorded. We followed tracks in the direction of the highway to determine animal behavior in relation to the highway. When tracks were documented entering and exiting on opposite sides of the highway, within 300m, going in the same direction, a confirmed crossing was recorded.

<u>Structure Monitoring</u>

Structures associated with standard highway construction (e.g. bridges and culverts) have been documented to provide movement routes for some species (Rodriguez et al. 1996, Yanes et al. 1995, LeBlanc 1994). We monitored existing highway structures along I-90 for wildlife movements from June 24 to October 30, 1998. Our objectives were to determine what species use existing structures to cross I-90 and to evaluate the characteristics of existing highway structures used by wildlife.

We mapped all highway structures greater than 18 inches in diameter. Structure size, length, habitat conditions and other information were recorded for all structures. Culverts for monitoring were selected based on location along the highway and size class. Culverts not available for animal passage were not monitored, including those inundated with water, with perched ends, or blocked by debris grates. We also monitored all bridges that could be monitored without loosing cameras to vandalism or theft.

Monitoring techniques included automatic cameras, track plates, and tracking beds. No bait was used in any highway structures. Sooted track plates proved effective for monitoring structures less than 30 inches diameter. Automatic cameras mounted inside the passage were effective in documenting animal use of larger structures (usually concrete box culverts or bridges). Raked tracking beds were also effective for monitoring larger structures where stream banks provided a suitable tracking substrate. We did not enhance or create track beds by bringing fine sand or other material into drainage structures or stream banks because of the impacts of sedimentation in riparian habitats. Structures were monitored for a minimum of 28 days.

Results

Landscape modeling

Linkage areas predicted by our GIS models were centered on the area south and west of Kachess Lake, particularly for the moderate and high-mobility guilds (figure 2). Two broad landscape characteristics appear to define these areas; 1) the historic timber harvest patterns and associated high road density to the south and west of Keechelus Lake, and 2) residential development in the Yakima River valley bottom between the towns of Easton and Cle Elum.

The models predict that the high-mobility habitat generalist guild experiences a lower minimum cost for traversing the landscape than the low-mobility late successional riparian forest associates. Least-Cost path analysis identifies the best connected areas relative to the rest of the analyzed landscape. Despite the fact that relatively broad areas are shown to have the best linkage for riparian forest associates compared to the rest of the landscape, the models predict that the linkage areas are still rather difficult for these species to traverse.

Roadkill distribution analysis

Four roadkill concentration areas were identified based on the analysis of 490 deer and 194 elk kills (figure 3). One area, Easton Hill, was also highlighted in the GIS modeling. Quantitative analysis of landscape characteristics of collision locations has not yet been conducted. However, roadkill distribution appears to be affected by landforms that channel animal movement (e.g. lakes, rivers, and steep mountain sides) and by human development and disturbance patterns.

Automatic Camera Surveys

To date, we have compiled data for 99 camera stations in the vicinity of the I-90 study area (48 stations within one mile of the highway and 51 away from the highway). Fifteen species of mammals were detected, including coyote (*Canis latrans*), elk, porcupine (*Erithizon dorsatum*), mountain lion (*Felis concolor*), northern flying squirrel (*Glaucomys sabrinus*), snowshoe hare, bobcat (*Lynx rufus*), American marten (*Martes americana*), striped skunk (*Mephitis mephitis*), weasels (*Mustela sp.*), bushy-tailed woodrat (*Neotoma cinerea*), deer, Douglas squirrel (*Tamiasciurus douglasi*), black bear (*Ursus americana*), and spotted skunk (*Spilogale putorius*). There are no substantial differences between species detected more than a mile from the highway compared to those detected within a mile of the highway. Elk, deer, flying squirrel and Douglas squirrel are well distributed within the highway corridor, while bobcat, coyote, and black bear detections near the highway were concentrated west of the town of Easton. American marten were detected at six stations, including two within a 0.25 miles of the highway. All stations with marten detections were near the summit of Snoqualmie Pass.

Snow Tracking

Wildlife species detected during tracking transects were coyote, elk, porcupine, bobcat, striped skunk, deer, raccoon (*Procyon lotor*), and red fox (*Vulpes fulva*). Thirty-seven highway crossings were recorded during snow tracking. Two of the crossings were made by raccoons crossing under a small bridge in the eastern portion of the study area. All other crossings were over the highway surface. Sixty-two percent of the crossings were recorded along Easton Hill, the same area identified as a potential linkage area in GIS modeling and roadkill analysis. Seventy-six percent of all crossings were made by coyotes. Four crossings by bobcat were recorded, three along Easton Hill, and one in the eastern portion of the study area. The bobcat crossing in the eastern portion of the study area was made while the highway was closed for avalanche control.

Structure monitoring

We mapped 58 culverts and 21 bridges and underpasses in the study section. Thirty structures (24 culverts and 6 bridges) were monitored for animal use. Duration of monitoring varied with detection method. Structures with cameras were monitored an average of 38 nights (N = 15, range 23 to 57 nights), track plates for an average 86 nights (N = 12, range 66 to 103 nights), and bridges with tracking beds were monitored for the entire field season (N = 3, 124 nights).

We recorded 1554 detections and 324 crossings (including humans and pets) in 1983 monitoring-nights. Of these, 1132 detections and 264 crossings were wild mammals (table 2). Twenty-four species or groups of species were detected, including humans, dogs, cats, snakes, lizards, and frogs. Amphibians and reptiles were not identified to species and no crossings were documented for these taxa. Wild mammals were detected in 87% of the monitored structures and crossed through 66%. On average, wild mammals were detected in structures in the first 16 nights of monitoring (range 1 to 110 nights).

Five taxa constituted 68% of all detections and 81% of the crossings. These taxa are mice (*Peromyscus sp.*) (23% of detections), chipmunks (*Tamias sp.*) (14%), Douglas squirrels (14%), striped skunks (9%), and humans (9%). The small mammal taxa (chipmunks, mice, and squirrels) were detected in all structures monitored with tracking techniques (beds and plates) and consisted of 74% of the crossings recorded for wild mammals. Trapping within culverts during August 1999 found that deer mice (*Peromyscus maniculatus* and *P. keeni*) constituted 86% of captures within culverts, and were the only species captured whose tracks would have been identified as mice on track plates. No species were trapped in culverts that had not been identified on track plates.

Discussion

Highway crossing rates are nearly impossible to quantify without radio telemetry or other markBrecapture methods. Such techniques are, however, expensive and usually require selection of one or a few study species. By evaluating habitat configuration, animal distribution in the transportation corridor, and animal crossing patterns, relative permeability of different portions of the transportation corridor can be evaluated and strategies for improving permeability for wildlife can be developed.

Together, the five components applied on Snoqualmie Pass provide useful insights on wildlife movements in the I-90 corridor. Landscape linkage modeling, roadkill distribution analysis, and snow tracking all identified Easton Hill as an important connectivity area. Roadkill distribution patterns and snow tracking also identified the north and south ends of Keechelus Lake as linkage areas. Ideally the techniques we have applied on

Snoqualmie Pass should be combined with single species genetic analysis and telemetry or intensive surveys to better understand the interaction of habitat modification, human disturbance, and physical highway barriers in influencing population isolation for carnivores and old forest species.

It is important to note that the species we have detected during snow tracking and camera surveys in this area have not been species modeled for in the GIS linkage analysis. However, more common species have been proposed as surrogates for the study of the ecology of rarer species (e.g. Foster & Humphrey 1992). Identification of barriers and linkage areas for bobcat may provide insights useful for planning highway permeability for lynx.

Highway structure monitoring has highlighted the importance of maintaining landscape permeability at multiple scales. Use of drainage culverts for crossing by mice and other small mammals indicates that consideration for such structures should be incorporated into highway design throughout the study area, though particular attention should be paid to areas where forested habitat exists adjacent to the highway. Although species most frequently detected using drainage structures to cross the highway are relatively common (e.g. deer mice and chipmunks), maintaining their movement through the highway corridor serves many important ecological functions including the dispersal of seeds and fungal spores (Maser et al. 1978). It is also important to note the lack of detections of medium and large carnivores (i.e. bobcat, coyote, and bear) using these structures. While drainage structures provide landscape permeability for smaller animals, other crossing opportunities need to be provided for medium and large carnivores, particularly as traffic volumes increase, roadway characteristics change and existing permeability may be lost.

Transportation corridors obviously exist within a broader landscape. Multi-scale assessment of highway and landscape characteristics is critical for understanding the ecosystem effects of highway barriers. Permeable roadway characteristics or crossing structures do not contribute to landscape permeability if habitat conditions do not allow the species in question to approach the roadway. In this project we have attempted to develop techniques that address these multi-scale issues.

Acknowledgements

This project was made possible by funding and support from the Washington State Department of Transportation, U.S. Forest Service, Region 6, and the Pacific Northwest Research Station. James Schafer, Marion Carey and Paul Wagner from the WSDOT Environmental and Research Offices have been instrumental in project development and review. Katie Cecil, Keith Kistler, James Bagley, and Sue Reffler were energetic field technicians on this project. Boise Cascade Corporation provided classified Landsat imagery from their Teanaway Ecosystem Management Project that was used in our GIS landscape linkage analysis. Thanks to Bill Noble, Bill Gaines, and Susan Piper for reviewing this manuscript.

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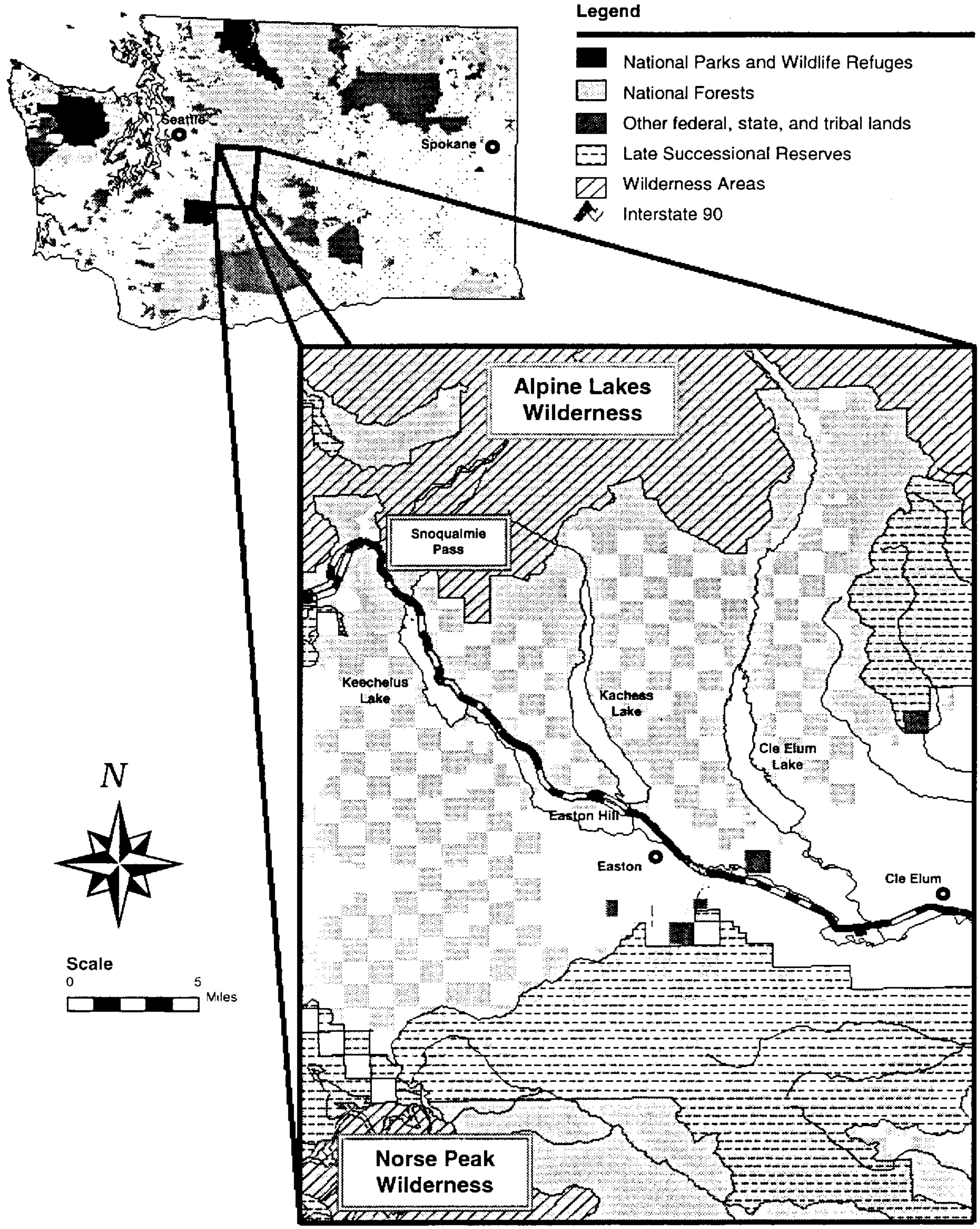

Figure 1. Land ownership and management status in the I-90 Snoqualmie Pass study area. Checkerboard land ownership, Interstate 90, and other developments may constitute a barrier between lands managed for biological diversity in the central Cascade Mountains of Washington.

Table 1. Summary of GIS connectivity models used in the Snoqualmie Pass linkage assessment.

	Guild			
	High-mobility dispersal habitat generalists	**Moderate-mobility late successional forest associates**	**Low-mobility late successional forest associates**	**Low-mobility late successional riparian forest associates**
Description	These species include highly mobile animals whose dispersal movements within the study area are likely to be more influenced by human disturbance than by forest habitat characteristics.	This guild includes medium sized animals associated with old forest characteristics. These species typically prefer to move within closed canopy older forest and, in some cases, are sensitive to human disturbance.	These are small animals closely tied to old forest characteristics. These species are often dependent on large down logs and a multi-layered forest canopy.	These species are found in wet, old forest habitats, often along streams, and may be dependent on large down logs and other habitat characteristics found in older forests.
Examples of species in guild	Wolverine, grizzly bear, lynx, and wolf.	American marten, fisher, spotted owl, northern flying squirrel, and brown creeper.	Trowbridge's shrew, shrew-mole, red-backed vole, Oregon megomphix land snail, and keeled jumping slug.	Tailed frog, pacific water shrew, Puget Oregonian land snail, and warty jumping slug.
Model description	Source habitat for these species was identified based on large roadless areas, and dispersal habitat was modeled based on indicators of human disturbance (road and building density) as well as hiding cover (canopy closure).	Source areas for this guild were areas with the largest concentrations of closed canopy, large tree forests with low road density. Dispersal habitat was evaluated based on forest canopy closure, tree size, Road density, building density, and slope	Source areas were located by identifying the largest contiguous closed canopy, large tree forest stands. Dispersal habitat was evaluated based on forest characteristics (canopy closure and tree size), as well as roads.	Relatively large patches of closed canopy, large tree forest along streams were considered source habitat. Dispersal habitat was identified based on closed canopy forest along streams.

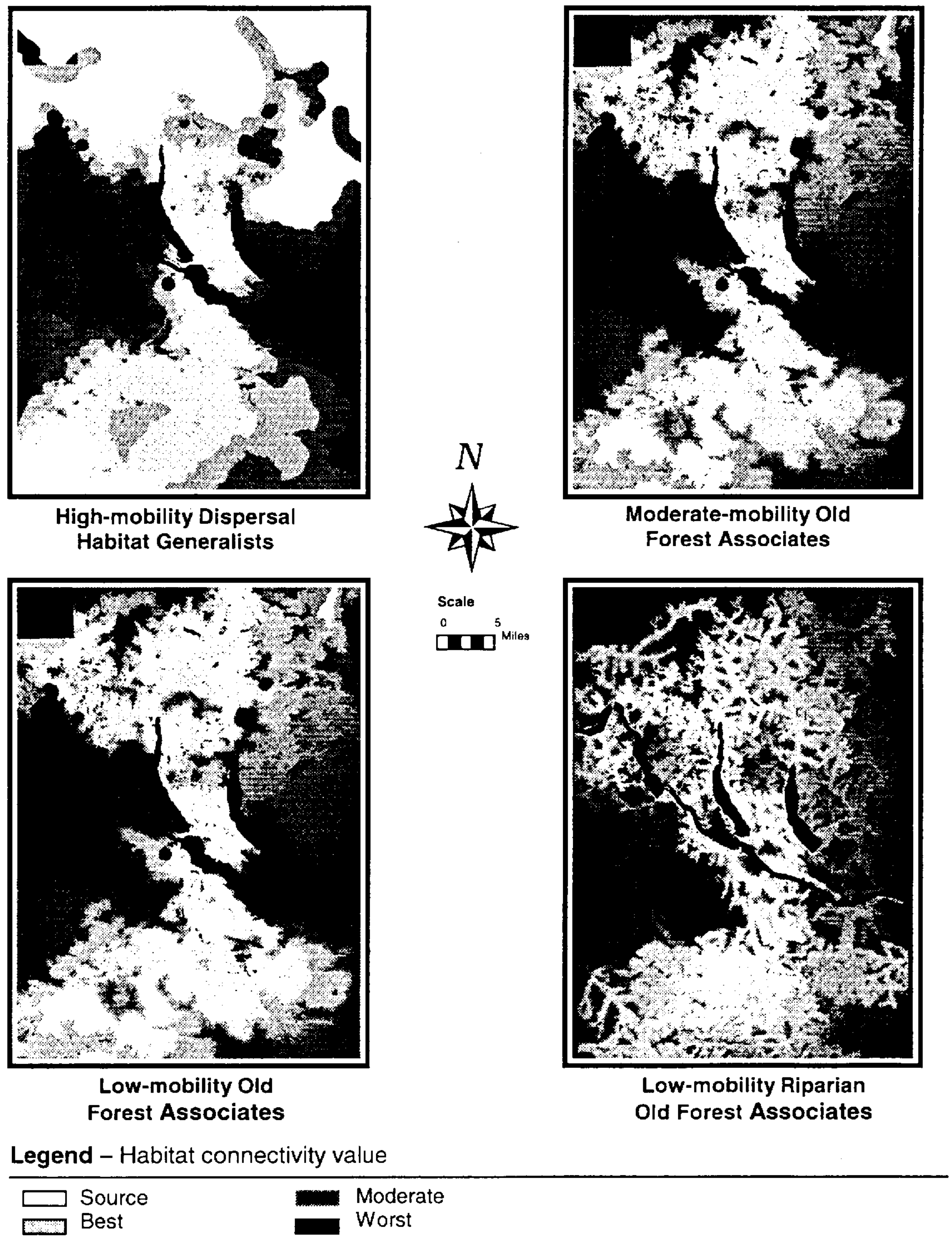

Figure 2. Results of landscape linkage GIS model for the Interstate 90 Snoqualmie Pass study area. Linkage models are summarized in table 1.

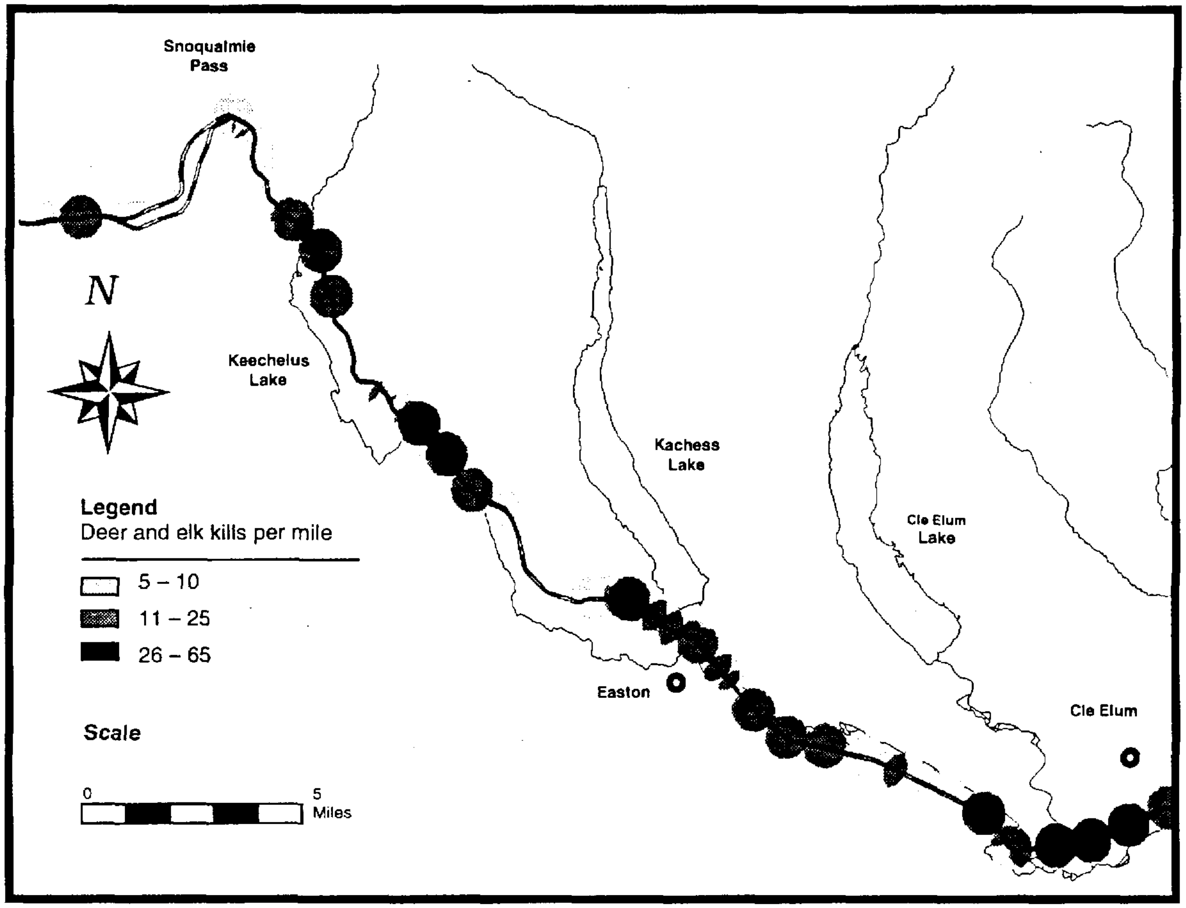

Figure 3. Deer and elk roadkill distribution along Interstate 90 in the Snoqualmie Pass area. Data were collected by Washington State Dept. of Transportation maintenance personnel from 1990 through 1998.

Table 2. Total detections and documented highway crossings in all structures, and the frequency of detections and crossings in different types of structures along Interstate 90 recorded in 1983 monitoring-nights from June to October 1998. Detection methods included automatic cameras, tracking plates, and tracking beds. Small mammal species identification was confirmed by live trapping in culverts in August 1999.

	Total detections for all structures		Number of structures by size class								
			0.4-0.6m n = 8		0.6-1.1m n = 4		>1.1m n = 12		Bridges* n = 6	Total n = 30	
Species	Detections	Crossings	Detections	Crossings	Detections	Crossings	Detections	Crossings	Crossings	Detections	Crossings
Deer Mice *(Peromyscus sp.)*	351	78	8	7	4	3	2		3	17	13
Chipmunks *(Tamias sp.)*	217	55	8	8	4	3	3	2	3	18	16
Douglas Squirrel *(Tamiasciurus douglasi)*	213	48	8	5	4		2	1	3	17	9
Striped Skunk *(Mephitis mephitis)*	139	36	6	4	3	2	1		2	12	8
Pacific Jumping Mouse *(Zapus trinotatus)*	63	15	6	5	2		1		1	10	6
Bushy-tailed Woodrat *(Neotoma cinerea)*	51	16	3	2	1	1	3	2		7	5
Mule Deer *(Odocoileus hemionus)*	46	5					1		5	6	5
Racoon *(Procyon lotor)*	16	2	1		1		3	1	2	7	3
Weasels *(Mustela sp.)*	13	5	5	1	1		4	3	1	11	5
Snowshoe Hare *(Lepus americanus)*	5	1					2	1		2	1
Opposum *(Didelphus marsupialis)*	2	0					1			1	0
River Otter *(Lutra lutra)*	1	1					1	1		1	1
Porcupine *(Erethizon dorsatum)*	1	0							1	1	0

*Three bridges were monitored with track beds and the rest with cameras. Track beds were much more effective for documenting small mammals than cameras.