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Assessing the Cumulative Effects of Linear Recreation Routes on Wildlife Habitats on the Okanogan and Wenatchee National Forests

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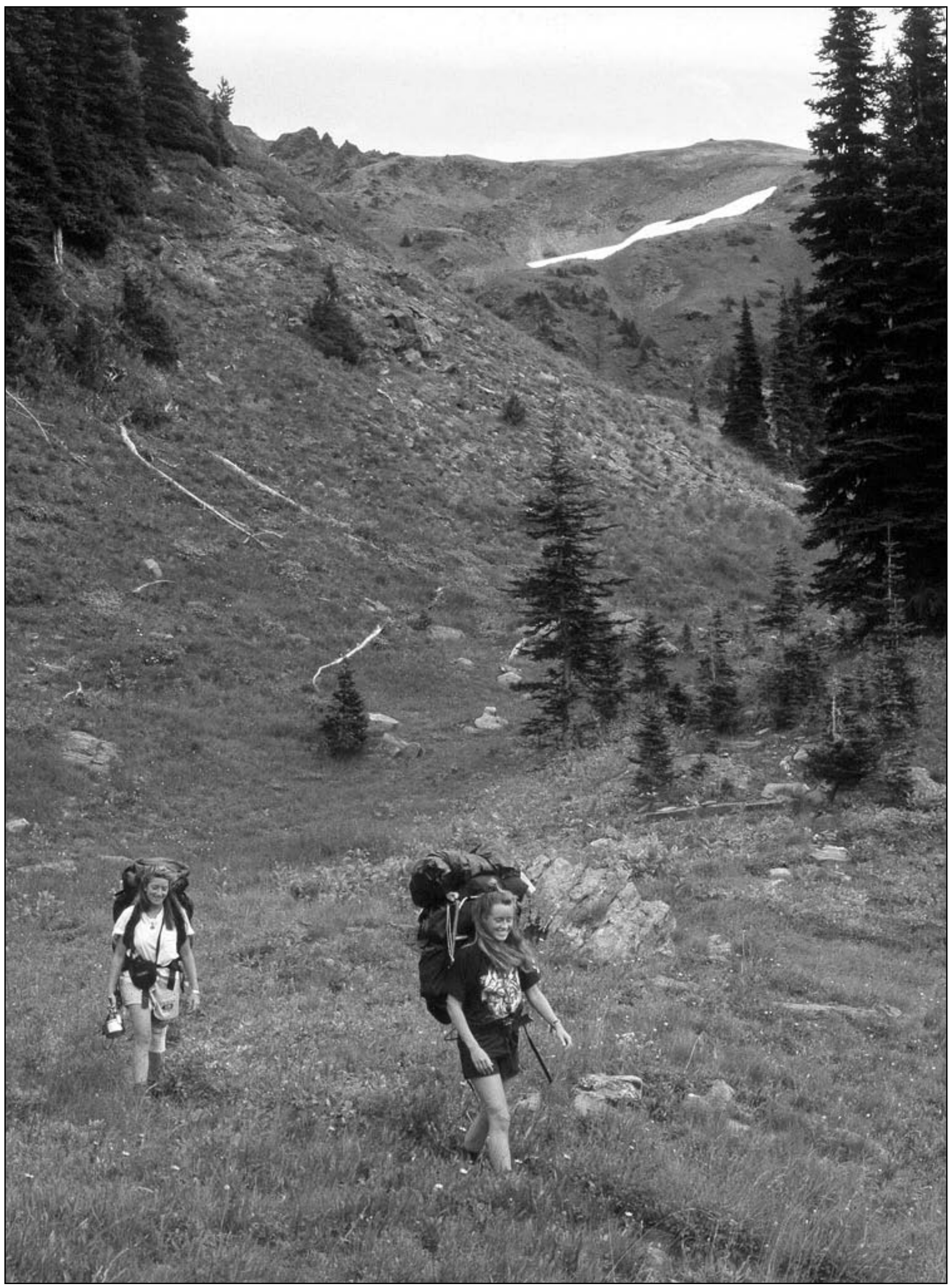

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Abstract

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We conducted a literature review to document the effects of linear recreation routes on focal wildlife species. We identified a variety of interactions between focal species and roads, motorized trails, and nonmotorized trails. We used the available science to develop simple geographic information system-based models to evaluate the cumulative effects of recreational routes on habitats for focal wildlife species for a portion of the Okanogan and Wenatchee National Forests in the state of Washington. This process yielded a basis for the consistent evaluation of the cumulative effects of roads and recreation trails on wildlife habitats, and identified information gaps for future research and monitoring. We suggest that managers use an adaptive management approach to address wildlife and recreation interactions because of the complexity and uncertainty of these issues.

Keywords: Okanogan and Wenatchee National Forests, linear recreation routes, focal wildlife species, cumulative effects.

Summary

We conducted a literature review to document the effects of linear recreation routes (roads, motorized trails, nonmotorized trails, designated and groomed ski and snowmobile routes) on wildlife and to assess the current level of human influences on focal wildlife species habitats on a portion of the Okanogan and Wenatchee National Forests in the state of Washington. The assessment consisted of seven steps: (1) identification of wildlife species and groups, (2) identification of focal species within each wildlife group, (3) identification of the road- and trail-associated factors for each focal species, (4) development of assessment processes and geographic information system (GIS) models to evaluate the influence of road- and trail-associated factors on focal species habitats, (5) application of the models to assess the current conditions of focal species habitats, (6) identification of information gaps, and (7) monitoring and adaptive management. Completion of this process yields a basis for the consistent evaluation of the cumulative effects of roads and recreation trails on wildlife habitats relative to the existing baseline conditions.

We identified 238 articles on the effects of recreation trails, roads, and related subjects on wildlife. Of these, 183 articles were used to identify the interactions between roads and recreation trails and 29 focal wildlife species. These articles included technical publications, books, agency publications, theses, and dissertations.

There is more science available to describe the interactions between focal wildlife species and roads than between focal species and recreation trails. Much of the research has been focused on wide-ranging carnivores and ungulates. Other lesser known species could benefit from additional research on the effects of roads, especially for less mobile species where roads may inhibit movements or fragment habitats. The most common reported interactions included displacement and avoidance where animals were reported as altering their use of habitats in response to roads or road networks. Disturbance at a specific site was also commonly reported and included disruption of animal nesting, breeding, or wintering areas. Collisions between animals and vehicles were commonly reported and affected a diversity of wildlife species, from large mammals to amphibians. Finally, edge effects associated with roads or road networks constructed within habitats, especially late-successional forests, were commonly identified.

Fewer wildlife species have been studied relative to their interactions with motorized trails. Ungulates and some wide-ranging carnivore species were the most studied, and many wildlife species could benefit from further research designed to identify these interactions. The most common interaction identified in the literature includes displacement and avoidance where animals altered their use of habitats in response to motorized trails or trail networks. Disturbance at a specific site also was identified and, as with roads, was usually associated with wildlife breeding or rearing young.

The most common interactions reported in the literature that we reviewed between nonmotorized trails and focal wildlife species were displacement and avoidance, which altered habitat use, and disturbance at a specific site during a critical period. The interactions of the focal species and motorized or nonmotorized trails were quite similar. Depending on the wildlife species, some were more sensitive to motorized trail use, whereas others were more sensitive to nonmotorized trail use. Based on our current understanding, both forms of recreation have effects on wildlife. Motorized trails had a somewhat greater magnitude of effects, such as longer distances in which wildlife were displaced, for a greater number of the focal species we reviewed. Additional research would be useful to further refine the interactions of specific species with motorized and nonmotorized trails.

The interactions between snowmobile routes and focal wildlife species are poorly documented for many species. These interactions need to be further refined with additional research and monitoring. The most common interactions that we documented from the literature included trapping as facilitated by winter human access, displacement and avoidance, and disturbance at a specific site, usually wintering areas. An additional interaction that occurred on winter recreation routes was the effect of snow compaction on the subnivean sites used by small mammals. Small mammals can either be suffocated as a result of the compaction, or their subnivean movements can be altered owing to impenetrable compact snow. Snow compaction associated with snowmobiling also was identified as altering the competitor/predator communities because the packed snow routes provide winter access to areas not normally available to some species.

We documented only a few interactions between ski trails and focal wildlife species because of the limited literature available on the subject. Ungulates were the most thoroughly studied group, and few others had been investigated. The most common interactions that we found in the literature included trapping facilitated by winter route access, displacement and avoidance, and disturbance at a specific site (wintering areas in this case). As with snowmobile routes, ski trails also included the interactions of snow compaction and competitor/predator community alterations.

We developed 18 simple GIS models to estimate the current level of influence of linear recreation routes on focal wildlife species habitats. Four of the models addressed winter recreation, 11 nonwinter, and 3 included winter and spring periods. Fifteen of these models were applied to a case study area on a portion of the Okanogan and Wenatchee National Forests to illustrate their use and interpretation. The application of the cumulative effects models showed that, in general, nonwinter activities had a higher level of cumulative effects than groomed and designated winter route activities. Habitats in which cumulative effects were ranked as having a high level of human influence in many analysis units included core areas for grizzly bears (*Ursus arctos*), late-successional habitats, riparian habitats, and lake and riverine habitats. The effectiveness of these habitats could be restored by using some of the approaches described in this document.

During this review, we noted information gaps that hindered our understanding of wildlife, road, and recreation trail interactions. More and better defined information of the following suggested areas of study could help fill these gaps: (1) the interactions between wildlife and nonmotorized trails, snowmobile routes, and ski trails for many wildlife species, especially those with small home ranges and limited mobility; (2) the interactions between wildlife and the intensity of human use on recreation trails (such as trail density or number of hikers per unit time); (3) the interactions between wildlife habitat use and the spatial extent (such as the proportion of a home range or watershed) of recreational activity; and (4) finally, the relation of recreation trail and wildlife interactions to the demography of a species of management interest. Adaptive management and monitoring designed to lead to greater understanding of any of these areas would greatly facilitate our management goals of conserving ecosystem processes and functions while providing recreation opportunities. These areas of study all could be accomplished through the use of an adaptive management approach and well-designed monitoring and research.

The information provided in this review, and subsequent development and application of cumulative effects models, improves the knowledge base that can be used to evaluate project proposals and make informed decisions. The findings of our review agree with the findings of other reviews. In addition, this information can be used to develop and apply mitigation tools to address the kinds of interactions that have been described for each focal wildlife species or group. Tools that have been used to mitigate recreational activities include (1) Spatial separation of humans and wildlife in key habitats. This could be used to address situations where displacement and avoidance interactions have been identified for a wildlife species of management interest. (2) Temporal separation of humans and wildlife at critical periods. This tool could be applied where the interaction of displacement at a specific site has been identified for a wildlife species of management interest. (3) Human behaviors that reduce the effects of recreation on wildlife. These can be taught through information and education programs. (4) Identification of wildlife habitat issues in the early stages of projects. The information provided in this assessment may help address habitat issues proactively through project design.

To proactively address wildlife conservation and recreation opportunities, we need to begin addressing these issues through our landscape-scale planning processes. In this manner, important habitats for wildlife and recreational opportunities for humans can be identified. This process could be accomplished by using the following approach: (1) assess the existing level of influence that recreational activities have on wildlife habitats, (2) set compatible wildlife habitat goals and recreation goals, (3) gain further knowledge about wildlife and recreation interactions through an adaptive management approach, and (4) adapt habitat and recreation goals based on new information. By using this approach, we can address the mutual goals of conserving wildlife species while providing recreation opportunities. These goals have many commonalities, not the least of which is the desire of people to experience wildlife during their recreational outings.

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The Assessment Process

Introduction

Increasing demand for recreational opportunities and facilities (Burchfield et al. 2000, USDA FS 2000b) has resulted in controversy over the potential effects of these activities on wildlife (Flather and Cordell 1995). On national forest lands, management is focused on providing recreational opportunities compatible with ecosystem processes and functions (USDA FS 2000b). Understanding how recreational activities influence ecosystem processes and functions is necessary to evaluate different management options and to make informed decisions.

As demands for recreation increase, so do cumulative effects on wildlife species and their habitats over space and time. Cumulative effects can be defined as the combined effect on a species or its habitat caused by the activity or program at hand, as well as other reasonably foreseeable events that are likely to have similar effects on the species or habitat (Weaver et al. 1987). Cumulative effects analysis assesses the effects on a system of spatial and temporal perturbations resulting from human activities (Beanlands et al. 1986). Cumulative effects analysis explicitly deals with effects and whether those effects exceed or fall short of thresholds compatible with the population or habitat goals for a given species or group of species. Hence, cumulative effects analysis and its attendant models are tools to perform proactive conservation for wildlife species and habitats (Weaver et al. 1987).

Although a considerable and growing body of research is available concerning recreation and wildlife interactions (Joslin and Youmans 1999, Knight and Gutzwiller 1995), significant gaps in our knowledge remain. Gathering reliable knowledge can be time consuming and costly because of the difficulty in controlling an array of variables that influence how wildlife reacts to human activities. Because of this, the investigation of wildlife and recreation interactions is well suited to an adaptive management approach (Gutzwiller 1993, Knight and Gutzwiller 1995).

Recreation on national forest lands includes a wide variety of activities with a correspondingly wide range of effects on wildlife. Because of this, it was necessary to narrow the scope of recreational activities considered in this assessment. Therefore, this assessment is focused on linear recreational routes; including motorized and nonmotorized trails, winter ski trails, snowmobile routes, and forest roads. These activities account for most of the recreational activities and potential effects on wildlife habitats that occur on the Okanogan and Wenatchee National Forests. Future efforts should be focused on providing a summary of the available science about other types of recreational activities and wildlife interactions such as helicopter skiing, rock-climbing, snow-play areas, and several others, which were beyond the scope and funding of this effort. The processes and methods developed in this assessment would greatly facilitate the incorporation of these other recreational activities.

This assessment has been designed with three primary objectives in mind: (1) develop a baseline of information about roads, recreation trails, and wildlife interactions through a review of relevant literature; (2) develop assessment processes and geographic information system (GIS) models for the consistent evaluation of the cumulative effects of these activities on wildlife habitats; and (3) use the processes and models to complete a case study assessment of the effects of existing roads and recreation trails on wildlife habitats for the Okanogan and Wenatchee National Forest lands located between Interstate 90 and Lake Chelan.

Methods

The assessment process consists of seven steps: (1) identify wildlife species and groups; (2) identify focal species within each wildlife group; (3) identify the road- and trail-associated factors for each focal species; (4) develop assessment processes and GIS models to evaluate the influence of road- and trail-associated factors on focal species habitats, including the development of preliminary cumulative effects thresholds; (5) apply the models to assess the current conditions of focal species habitats; (6) identify information gaps; and (7) monitor and apply adaptive management approaches. This process yields a basis for the consistent evaluation of the cumulative effects of roads and recreation trails on wildlife habitats relative to the existing baseline conditions. In addition, this process can be used to address other types of recreational activities and assess their cumulative effects on wildlife habitats.

Step 1. Identify wildlife species and groups—We used existing information about the distribution of wildlife species on the Okanogan and Wenatchee National Forests to develop a list of wildlife species and to develop groups of species based on their biology (e.g., wide-ranging carnivores, late-successional species, riparian-associated species, etc.) and interactions with road- and recreation trail-associated factors. These information sources included watershed assessments, late-successional reserve assessments (USDA FS 1997), and information from the Washington gap analysis program (GAP) (Dvornich et al. 1997, Johnson and Cassidy 1997, Smith et al. 1997).

In all, 395 species are included in this assessment (see app.). These included 9 amphibian species, 11 reptile species, 286 bird species, 84 mammal species, and 5 mollusks. These species were placed into six groups (some species occurred in more than one group and habitat generalist species were not assigned to any group), which included:

1. Wide-ranging carnivores (9 species)
2. Ungulates (6 species)
3. Late-successional forest habitat-associated species (71 species)
4. Riparian-associated species (144 species)
5. Waterfowl and colonial nesting birds (97 species)
6. Primary cavity excavators (11 species)

Step 2. Identify focal wildlife species—Many systems have been used by ecologists to evaluate or rank potential emphasis species (Kuhnke and Watkins 1999, Lambeck 1997, Lehmkuhl et al. 2001, Millsap et al. 1990, Noss et al. 1997). One approach that has been proposed is the "focal species" concept (Lambeck 1997, Noss et al. 1997) in which species that are most sensitive to a particular activity (habitat fragmentation, disturbance from a motorized trail, etc.) are used to define the acceptable levels of the activity for a group of species (such as wide-ranging carnivores). Lindenmayer et al. (2002) pointed out some of the limitations of the focal species concept, including a lack of testing to validate the approach. However, the focal species approach has recently been empirically tested for wide-ranging carnivores (Carroll et al. 2001) and birds (Watson et al. 2001) with favorable results. We, therefore, used this concept to select focal wildlife species that represented groups of wildlife species (table 1).

Focal species, as described in the federal planning regulations (CFR Vol. 65 No. 218, November 2000), are species selected for use as surrogate measures in the assessment of ecological integrity. Their distribution and abundance over time provide

Table 1—Focal wildlife species that were identified for each of the 6 wildlife groups used in this assessment

Wildlife group	Focal species
Wide-ranging carnivores	Grizzly bear, lynx, gray wolf, wolverine
Ungulates	Mule deer, elk, bighorn sheep, mountain goats
Late-successional-forest-associated species	Northern spotted owl, northern goshawk, brown creeper, American marten, fisher, northern flying squirrel, pygmy nuthatch, white-breasted nuthatch, white-headed woodpecker
Riparian associated species	Cascade frog, tailed frog, harlequin duck, bald eagle, water shrew, black-capped chickadee
Waterfowl and colonial nesters	Common loon, great blue heron, eared grebe, wood duck
Primary cavity excavators	White-headed woodpecker, three-toed woodpecker, pileated woodpecker

insights into the integrity of the larger ecological system to which they belong. We selected species that represent the range of environments within the assessment area, and that serve an umbrella function, or play key roles in maintaining community structure or processes. Therefore, we selected focal species (1) whose habitat associations represented the range of habitats associated with the wildlife group, (2) whose road- and recreation trail-associated factors were representative of the range of the group, (3) whose populations or habitats could be monitored, (4) for which viability concerns were known such as federally listed or USDA Forest Service “sensitive” species, and (5) that were relatively well studied relative to the effects of road and trails on their habitat use.

Step 3. Identify road- and trail-associated factors—Liddle (1997) provided a three-tier disturbance classification scheme for the effects recreational activities have on wildlife. Disturbance type 1 occurs when an animal sees, hears, smells, or otherwise perceives the presence of a human but no contact is made and it may or may not alter its behavior. Disturbance type 2 is when habitat is changed in some way by pathway creation, camping, the presence of food, or clearing of vegetation. Disturbance type 3 involves human actions in which there is a direct and damaging contact with the animal such as hunting, fishing, collisions with vehicles, and other accidental contact in which the results are similar to hunting. Alternatively, Knight and Cole (1995) provided a conceptual model of the responses of wildlife to recreational activities. They grouped the causes of recreation impacts to wildlife into harvest, habitat modification, pollution, and disturbance.

For this assessment, these two broad classification schemes were refined to focus on road- and recreation trail-factors that affected wildlife, based on a review of relevant literature. The road- and recreation trail-associated factors were initially based on the factors developed by Wisdom et al. (1999) and a literature review by Singleton and Lehmkuhl (1998). These reviews were expanded to include additional factors associated with winter and nonwinter human use of recreation trails. The relationship between the general classification schemes proposed by Liddle (1997) and Knight and Cole

(1995), and the road- and trail-associated factors used in this assessment are shown in table 2. Table 3 lists the road- and trail-associated factors along with their effects and groups of wildlife species that are affected by them.

Based on a review of the scientific literature, road- and recreation trail-associated factors were identified for "focal" wildlife species for which information was available. The effects of road- and recreation trail-associated factors can be direct, such as habitat loss and fragmentation, or indirect, such as displacement or avoidance of areas near roads in relation to motorized traffic and associated human activities (Blakesley and Reese 1988, Miller et al. 1998, Reed et al. 1996, Wisdom et al. 2000). Recreation trail-associated factors were identified for nonmotorized trails, motorized trails, snowmobile routes, and ski trails. In addition, the road-associated factors developed by Wisdom et al. (1999) were summarized and expanded upon.

Step 4. Processes and models—Assessment processes and models were developed to provide a consistent approach to the evaluation of the cumulative effects of roads and recreation trails on wildlife habitats. These were based on the habitat requirements of the focal species and the trail- and road-associated factors found to affect the focal species. The models and assessment processes were developed to use GIS and corresponding data layers that included roads, trails, wildlife habitats, watersheds, and subbasins. Ideally, these models would incorporate the following variables: (1) spatial extent of the immediate effect of the factor (such as distance a species was displaced from a road or trail), (2) the level of intensity of human use on a road or trail that resulted in a factor being identified as affecting the focal species (such as number of people per day or density of roads), and (3) the extent, or a threshold, of human influence (assessed by 1 and 2 above) on wildlife habitats within a given area, such as a watershed or subbasin (such as 50 percent of a watershed within a trail zone of influence with >10 people per day).

Relatively reliable information was available for many focal species concerning the immediate spatial effect, or the zone of influence, of a particular road- or trail-associated factor. Less information was available relating to the intensity of human use (number of vehicles per unit time or density of open roads) on the effect on wildlife and, consequently, it was included in only a few of the models. There was even less information on the extent of human influence (such as the proportion of a home range within a zone of influence when use by a particular species significantly changes) on focal species habitat use; this area is ripe for research.

The size of the analysis area used to evaluate cumulative effects was based on the mobility of focal species, and whether the focal species were habitat generalists or specialists. For example, wide-ranging carnivores typically have large home ranges, can travel large distances, and are habitat generalists. As a result, we chose large areas in which to address cumulative effects for these species. Conversely, several late-succession- and riparian-associated wildlife species have smaller home ranges, are less mobile, and are habitat specialists. Therefore, cumulative effects were assessed by using specific habitats within 5th-field watersheds or habitat reserves.

Because quantitative evaluation of cumulative recreation effects was not possible owing to data limitations for many species, we developed a qualitative ranking scheme. We assumed that the lower amount of roads and trails in an assessment area, the higher the probability of focal species persistence and the higher the probability that ecosystem processes and functions would be conserved (fig. 1). Consequently, we ranked cumulative linear recreation route effects to focal species as high, moderate,

Table 2—Comparison of classification schemes used to describe the effects of recreation on wildlife and the road- and trail-associated factors used in this assessment

Road- and trail-associated factors[a]	Disturbance type[b]	Recreation activity[c]	Definition of associated factors
Hunting and trapping	Disturbance type 3	Harvest	Mortality from hunting or trapping as facilitated by road and trail access
Poaching	Disturbance type 3	Harvest	Increased illegal take of animals as facilitated by trails and roads
Collisions	Disturbance type 3	Harvest	Death or injury resulting from a motorized vehicle running over or hitting an animal
Negative human interactions	Disturbance type 3	Harvest	Increased mortality of animals (euthanasia or shooting) owing to increased contact with humans, as facilitated by road and trail access
Movement barrier or filter	Disturbance type 2	Habitat modification	Interference with dispersal or other movements as posed by a road or trail itself or by human activities on or near roads, trails, or networks
Displacement or avoidance	Disturbance type 1	Disturbance	Spatial shifts in populations or individual animals away from human activities on or near roads, trails, or networks
Habitat loss and fragmentation	Disturbance type 2	Habitat modification	Loss and resulting fragmentation of habitat owing to the establishment of roads, trails, or networks, and associated human activities
Edge effects	Disturbance type 2	Habitat modification	Changes to habitat microclimates associated with the edge induced by roads or trails
Snag or downed log reduction	Disturbance type 2	Habitat modification	Reduction in density of large snags and downed logs owing to their removal near roads as facilitated by road access
Collection	Disturbance type 3	Harvest	Collection of live animals for use as pets (such as amphibians and reptiles) as facilitated by the physical characteristics of roads or trails or by road or trail access
Route for competitors and predators	Disturbance type 2	Habitat modification	A physical human-induced change in the environment that provides access for competitors or predators that would not have existed otherwise
Disturbance at a specific site	Disturbance type 1	Disturbance	Displacement of individual animals from a specific location that is being used for reproduction and rearing of young
Snow compaction	Disturbance type 3	Habitat modification	Direct mortality of animals crushed or suffocated as a result of snow compaction from snowmobile routes or groomed ski trails
Physiological response	Disturbance type 1	Disturbance	Increase in heart rate or stress hormones when near a road or trail or network of roads or trails

[a] Based in part on Wisdom et al. 1999.
[b] Disturbance type 1 occurs when an animal sees, hears, smells, or otherwise perceives the presence of a human but no contact is made and it may or may not alter its behavior. Disturbance type 2 is when habitat is changed in some way. Disturbance type 3 involves human actions in which there is direct and damaging contact with the animal. From Liddle 1997.
[c] From Knight and Cole 1995.

Table 3—Recreation trail- and road-associated factors with documented effects on habitat or populations of wildlife species, and the affected wildlife species groups

Road- and trail-associated factors	Effects of the factors	Wildlife group affected
Hunting and trapping	Mortality from hunting or trapping as facilitated by road and trail access	Wide-ranging carnivores Ungulates Waterfowl
Poaching	Increased illegal take of animals, as facilitated by trails and roads	Wide-ranging carnivores Ungulates Waterfowl
Collisions	Death or injury resulting from a motorized vehicle running over or hitting an animal	Wide-ranging carnivores Late successional Riparian associated Ungulates
Negative human interactions	Increased mortality of animals (e.g., euthanasia or shooting) owing to increased contact with humans, as facilitated by road and trail access	Wide-ranging carnivores Ungulates Late successional
Movement barrier or filter	Alteration of dispersal or other movements as posed by a road or trail itself or by human activities on or near a road or trail or network	Wide-ranging carnivores Late successional Riparian associated Ungulates
Displacement or avoidance	Spatial shifts in populations or individual animals from a road or trail or network in relation to human activities on or near a road or trail or network	Wide-ranging carnivores Late successional Riparian associated Ungulates
Habitat loss and fragmentation	Loss and resulting fragmentation of habitat owing to the establishment of roads and trails, road and trail networks, and associated human activities	Wide-ranging carnivores Late successional Riparian associated Ungulates Primary cavity excavators
Edge effects	Changes to habitat microclimates associated with the edge induced by roads or trails	Late successional
Snag or downed log reduction	Reduction in density of large snags and downed logs owing to their removal near roads or campsites, as facilitated by road access	Late successional Riparian associated Primary cavity excavators
Collection	Collection of live animals for use as pets (such as amphibians and reptiles), as facilitated by the physical characteristics of roads and trails or by road and trail access	Late successional Riparian associated
Route for competitors or predators	A physical human-induced change in the environment that provides access for competitors or predators that would not have existed otherwise	Wide-ranging carnivores Late successional Riparian associated Primary cavity excavators
Disturbance at a specific site	Displacement of individual animals from a specific location that is being used for reproduction and rearing young	Wide-ranging carnivores Late successional Riparian associated Ungulates
Snow compaction	Direct mortality of animals crushed or suffocated as a result of snow compaction from snowmobile routes or groomed ski trails	Late successional Riparian associated
Physiological response	Changes in heart rate or level of stress hormones as a result of proximity to a road or trail	Ungulates Late successional

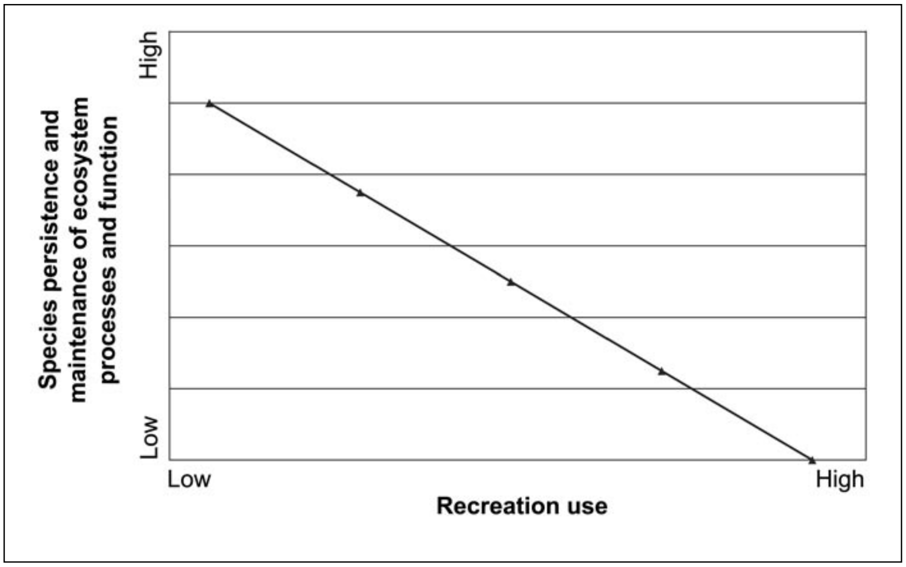

Figure 1—Hypothetical example showing the assumed relationship between increasing recreational use within wildlife habitats and the probability of focal species persistence and maintenance of ecosystem processes and functions.

or low depending largely on the extent of influence that these activities had on wildlife habitats within a given analysis area. Where possible, we linked these rankings to biological thresholds derived from our literature review. Where these data were lacking, we generally split the effects levels into quartiles to assign relative ranks.

The assessment processes and models described in the document were designed to address broad-scale issues, such as cumulative effects, and to provide information that could be used to evaluate project-level effects. These models could best be viewed as working hypotheses about the interactions between roads, trails, and wildlife. As such, wildlife responses should be monitored and models adapted as new information becomes available.

Step 5. Assess the current condition—We applied the assessment processes and models to evaluate the current condition of wildlife habitats for each of the effects of associated factors of the recreation activities (table 2) associated with roads and recreation trails. To complete this assessment, district recreation specialists updated GIS-based road and trail maps and attributed each trail or trail segment with information on trail use levels. This was completed for all the recreation trails that occurred in the assessment area.

Step 6. Identify information gaps—The literature review, model-building exercises, and pilot study allowed for the identification of information gaps. These were summarized and prioritized, and potential research topics were identified for each group of wildlife species.

Step 7. Monitor and apply adaptive management approaches—Because of our incomplete knowledge about many of the road, recreation trail, and wildlife interactions, assumptions were made to complete the assessment. Appropriate monitoring was identified to test the validity of our assumptions and to make management adjustments based on monitoring results.

Document Organization

The next section of this document focuses on different types of linear recreational routes and the documented effects they have on focal wildlife species. This overview is provided for different types of recreational routes, highlights the most common road- and trail-associated factors, and describes how pervasive these effects are across focal species. This section provides the reader with an idea of the range of road- and trail-associated factors and their likelihood of affecting focal species.

The six sections (beginning on page 13) following the overview shifts the focus to wildlife species groups and focal wildlife species within each group. We describe documented specific effects of linear recreation routes on species groups and focal species to provide insights into how severe effects are likely to be when they occur. In these sections, we present assessment models and tools for specific focal species and species groups.

Taken together, the overview and following sections for each species group provide information about the likelihood and magnitude of effects that is necessary to estimate cumulative effects. Examples of how these work together are presented for a case study area by using a portion of the Okanogan and Wenatchee National Forests, and includes interpretations of model outputs. The final section of this document discusses monitoring and adaptive management, and provides a hypothetical example of how these concepts can be applied to learn from recreation projects that could influence wildlife habitats.

Overview of Interactions Between Focal Wildlife Species and Linear Recreation Routes

Here we provide an overview of the road- and trail-associated factors that were documented in the literature between the five types of linear recreation routes and 29 focal wildlife species (table 1). We provide this overview to illustrate the frequency with which various road- and trail-associated factors were documented in the literature and to summarize the relative status of our scientific understanding of how each of the five types of linear recreation routes affect focal wildlife species.

Literature Review

We reviewed 238 articles on the effects of recreation trails and roads on wildlife. Of these, 183 articles were used to identify the interactions between roads, recreation trails, and focal wildlife species. These articles included technical publications, books, agency publications, theses, and dissertations. Many of these references came from previous reviews (Boyle and Samson 1985, Joslin and Youmans 1999, Knight and Gutzwiller 1995, Liddle 1997).

Road and focal wildlife species interactions—The science available to describe the interactions between focal wildlife species and roads is more developed than that available to describe the interactions between focal wildlife species and recreation trails. Much of the research has been focused on wide-ranging carnivores and ungulates. Other lesser known species could benefit from additional research on the effects of roads; this is especially true for less mobile species where roads may inhibit movements or fragment habitats.

The most commonly reported interactions included displacement or avoidance where animals were reported as altering their use of habitats in response to roads or road networks (Cassier and Groves 1990, Hutto 1995, Johnson et al. 2000, Klein 1993, Mace et al. 1996, 1998) (fig. 2). Disturbance at a specific site was also commonly reported and included disruption of animal nesting, breeding, or wintering areas (Linnell et al. 2000, Papouchis et al. 2001, Skagen et al. 1991). Collisions between animals and vehicles were commonly reported and affected a diversity of wildlife species, from large mammals (Gibeau and Heuer 1996, Lehnert et al. 1996) to amphibians (Ashley

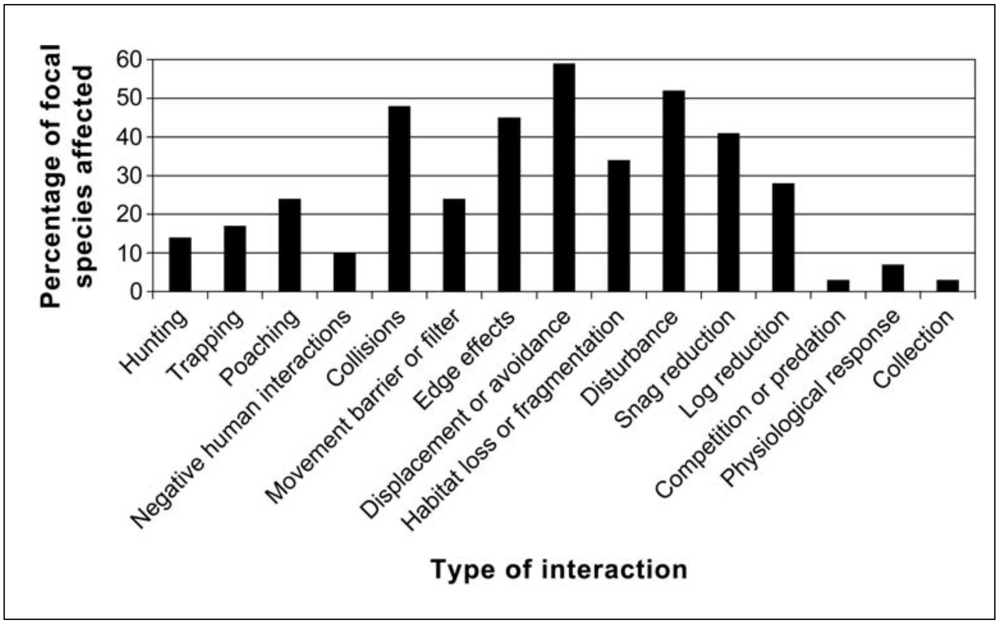

Figure 2—Interactions between the 29 focal wildlife species and roads documented from the literature review.

and Robinson 1996). Finally, edge effects associated with roads or road networks constructed within habitats, especially late-successional forests, were commonly identified (Hickman 1990, Miller et al. 1998).

Motorized trails and focal wildlife interactions—Fewer wildlife species have been studied relative to the interactions with motorized trails compared to studies that have investigated wildlife and road interactions. Ungulates and some wide-ranging carnivore species were the best studied, and many wildlife species could benefit from further research designed to identify common factors involved in these interactions.

One of the most common interactions identified in the literature includes displacement or avoidance where animals altered their use of habitats in response to motorized trails or trail networks (Kasworm and Manley 1990, Mace et al. 1996) (fig. 3). Disturbance at a specific site also was identified and, as with roads, was usually associated with breeding or rearing young (Foppen and Reijnen 1994, Phillips and Alldredge 2000).

Nonmotorized trail and focal wildlife species interactions—The most common interactions reported in the literature that we reviewed between nonmotorized trails and focal wildlife species were displacement and avoidance, which altered habitat use (Kasworm and Manley 1990, Klein 1993, Miller et al. 1998, Swarthout and Steidl 2001), and disturbance at a specific site during a critical period (Ashley 1994, Cassier and Groves 1989) (fig. 4). The interactions of focal species and motorized or nonmotorized trails were quite similar. Depending on the wildlife species, some were more sensitive to motorized trail use, whereas others were more sensitive to nonmotorized trail use. Based on our current level of understanding, both forms of recreation have effects on wildlife. Motorized trails had a somewhat greater magnitude of effects, such

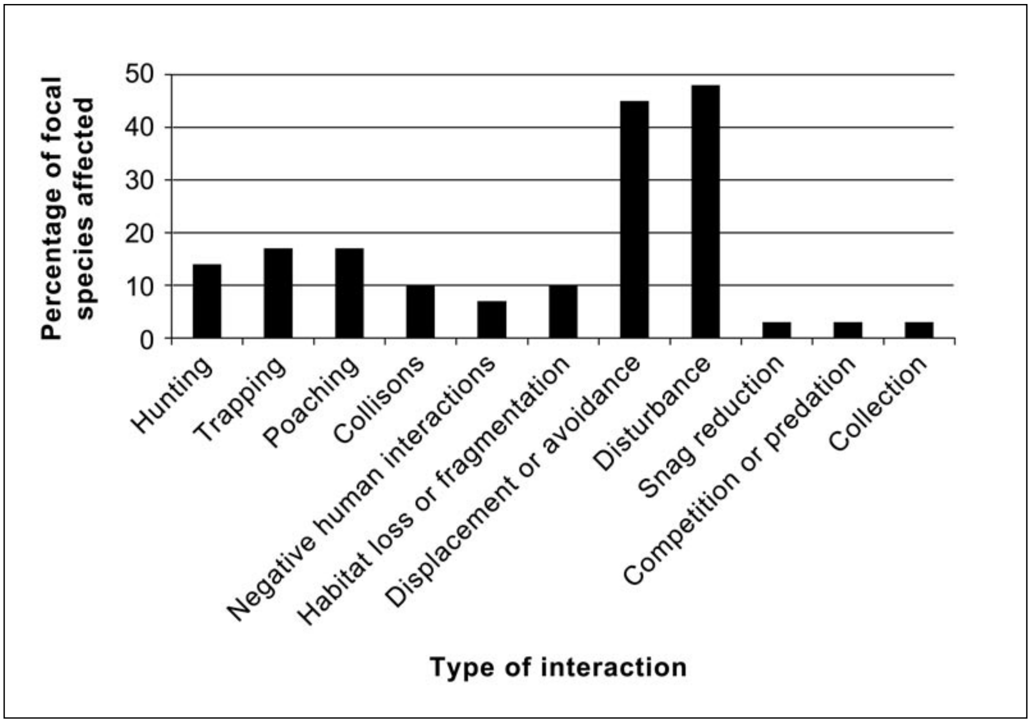

Figure 3—Interactions between the 29 focal wildlife species and motorized trails documented from the literature review.

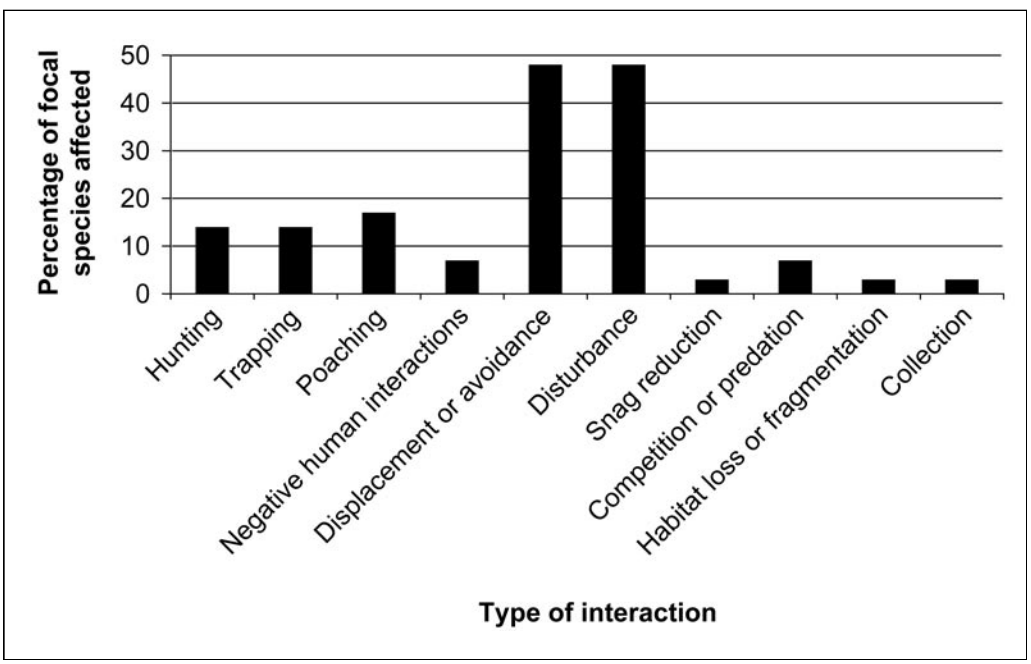

Figure 4—Interactions between the 29 focal wildlife species and nonmotorized trails documented from the literature review.

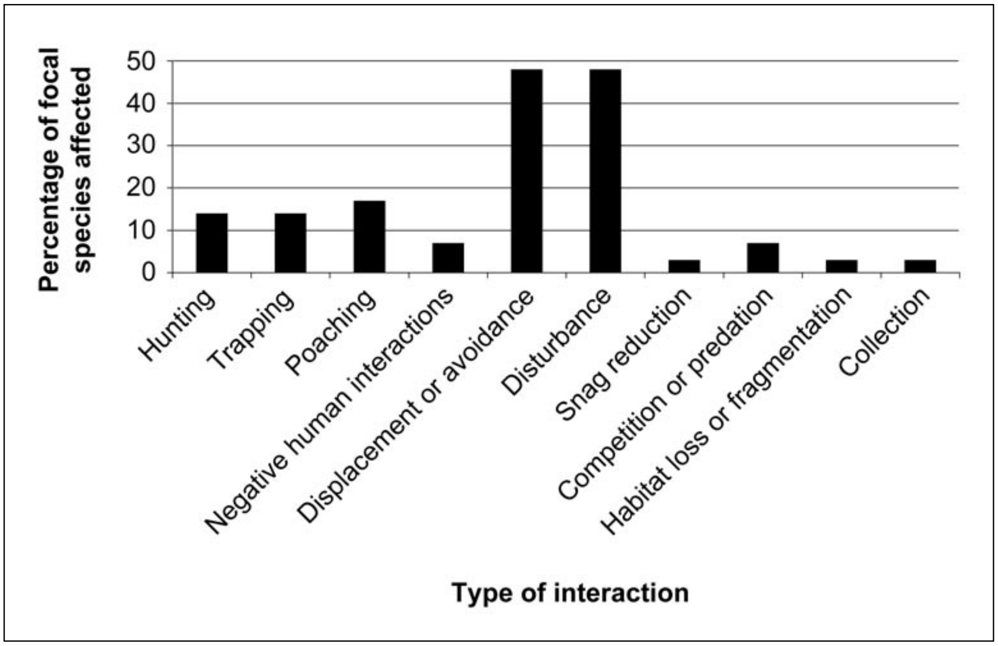

Figure 5—Interactions between the 29 focal wildlife species and snowmobile routes documented from the literature review.

as longer distances in which wildlife were displaced, for a greater number of the focal species we reviewed. Additional research would be useful to further refine the interactions of specific species with motorized and nonmotorized trails.

Snowmobile route and focal wildlife species interactions—The interactions between snowmobile routes and focal wildlife species are poorly documented for many species. These interactions need to be further refined with additional research and monitoring. The most common interactions that we documented from the literature included trapping and poaching facilitated by winter human access (Claar et al. 1999, Wisdom et al. 2000), displacement and avoidance (Cassier et al. 1992), and disturbance at a specific site (Copeland 1996, Hornocker and Hash 1981, Jonkel 1980, Linnell et al. 2000, Reynolds et al. 1986), usually wintering areas (fig. 5). An additional interaction that occurred for winter recreation routes was the effect that snow compaction has on the subnivean sites used by small mammals (Schmid 1972). Small mammals can either be suffocated as a result of the compaction, or their subnivean movements can be altered owing to impenetrable compact snow. Snow compaction associated with snowmobiling also was identified as altering the competitor/predator communities because the packed snow routes provide winter access to areas not normally available to some species (Buskirk 1999, Koehler and Aubry 1994, Ruediger et al. 2000).

Ski trails and focal wildlife interactions—We documented only a few interactions between ski trails and focal wildlife species owing to the limited literature available on the subject. Ungulates were the most thoroughly studied group, and few others had been investigated. The most common interactions that we found in the literature included trapping facilitated by winter route access (Claar et al. 1999), displacement and avoidance (Ferguson and Keith 1982, Freddy et al. 1986), and disturbance at a

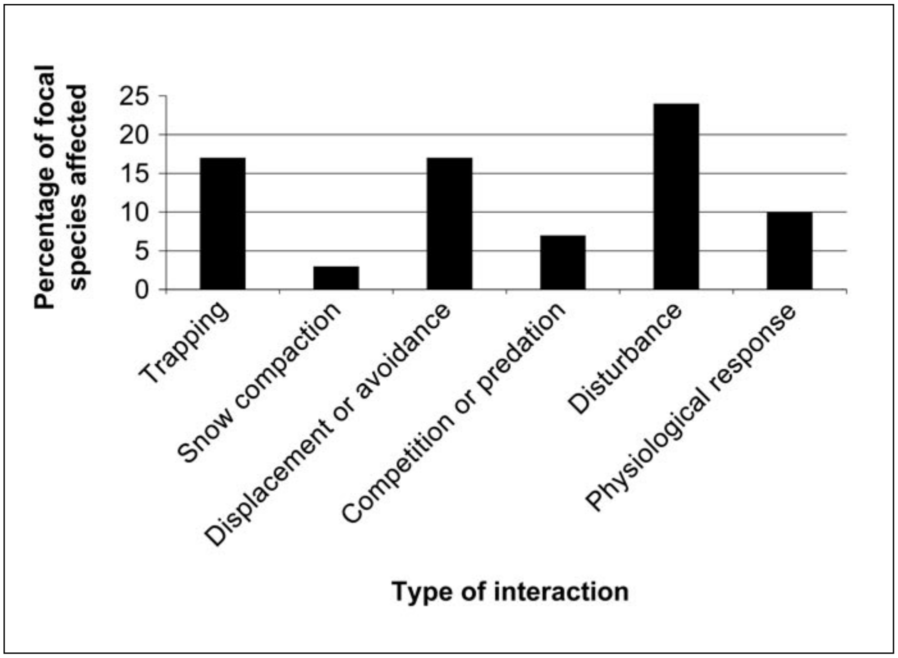

Figure 6—Interactions between the 29 focal wildlife species and ski trails documented from the literature review.

specific site, such as wintering areas (Canfield et al. 1999, Freddy et al. 1986) (fig. 6). As with snowmobile routes, ski trails also included the interactions of snow compaction and competitor/predator community alterations (Buskirk 1999, Koehler and Aubry 1994, Ruediger et al. 2000).

Information Gaps

Over the course of this review, we kept track of information gaps that hindered our understanding of wildlife, road, and recreation trail interactions. Further research in the following suggested areas of study, which can be accomplished through the use of an adaptive management approach and well-designed monitoring and research (Gaines et al. 1999; Gutzwiller 1991, 1993), would help improve our understanding of wildlife, road, and recreation trail interactions.

- The interactions between wildlife, nonmotorized trails, snowmobile routes, and ski trails for many wildlife species, especially those with small home ranges and limited mobility.
- The interactions between wildlife and the intensity of human use on recreation trails (such as trail density or number of hikers per unit time).
- The interactions between wildlife habitat use and the spatial extent (such as the proportion of a home range or watershed) of recreational activity.
- The relation of recreation trail and wildlife interactions to the demography of particular species of management interest.

Adaptive management and monitoring designed to lead to greater understanding of any of these areas would greatly facilitate our management goals of conserving ecosystem processes and functions while providing recreation opportunities (see “Monitoring and Adaptive Management” on page 51).

The following sections of this document are designed to provide managers with some tools that can be used to evaluate wildlife habitats for various focal wildlife species. In addition, a framework for how to approach adaptive management and monitoring is provided. This information will help address the mutual goals of conserving wildlife species while providing recreation opportunities. These goals have many commonalities, not the least of which is the desire of people to experience "wildlife" during their recreational outings.

Wide-Ranging Carnivore Habitat Assessment

Introduction and Focal Species Selection

There were nine wildlife species that were included in the wide-ranging carnivore group (see app.). The species that met the criteria of a focal species for this group included the grizzly bear (*Ursus arctos*), Canada lynx (*Lynx canadensis*), gray wolf (*Canis lupus*) and wolverine (*Gulo gulo*). These four species were representative of the habitat requirements of the other species in the group and were sensitive to an array of road- and trail-associated factors. In addition, three of these species are federally listed, and the other, wolverine, has been petitioned (Biodiversity Legal Foundation 2000) for listing and is under review.

Summary of Recreation Route-Associated Factors for Focal Species

Mammalian carnivores have responded variously to human recreation. Some species, such as coyotes, have adapted to the presence of humans and to human activities (Crabtree and Sheldon 1999). For others, human recreational activities are documented or suspected to have significant adverse impacts (Claar et al. 1999). Because they are listed under the Endangered Species Act and have been the subjects of considerable research, evidence of such impacts is most compelling for grizzly bears and gray wolves (Claar et al. 1999). For several other carnivore species, such as black bear (*Ursus americanus*), mountain lion or cougar (*Felis concolor,* now *Puma concolor*), lynx, bobcat (*Lynx rufus*), wolverine, fisher (*Martes pennanti*), and marten (*Martes americana*), research has been focused on the demographic effects of hunting or trapping and not on the effects of other recreational activities on their habitats.

Several studies have documented displacement of grizzly bears from trails (motorized and nonmotorized) and roads (Archibald et al. 1987; Kasworm and Manley 1990; Mace and Waller 1996, 1998; Mace et al. 1996, 1999; Mattson et al. 1987; McLellan and Shackleton 1988, 1989) (table 4). Factors related to human access include increased potential for poaching, collisions with vehicles, and chronic negative human interactions at campgrounds and campsites that are accessed by roads and trails (Claar et al. 1999, Wisdom et al. 2000) (table 4). Winter recreational activities have been documented to disturb bears in winter dens (Jonkel 1980, Linnell et al. 2000, Reynolds et al. 1986) and are of special concern if they occur within 200 m of a den site (Linnell et al. 2000). However, because we could not model grizzly bear denning habitat at this broad scale, project-level analyses should consider the direct and indirect effects of winter recreational activities in areas where grizzly bear denning is an issue. Finally, grizzly bear mortalities as a result of collisions with vehicles have been documented (Gibeau and Heuer 1996) (table 4).

Few studies have been conducted on the effects of recreational activities on lynx (Ruediger et al. 2000). Other focal carnivores appear to be more sensitive to the effects of roads and trails (McKelvey et al. 2000); therefore, lynx was selected as a focal species because of concerns about the potential effects of winter recreational activities (Buskirk 1999, Koehler and Aubry 1994, Ruediger et al. 2000). Specifically, snow compaction associated with grooming for snowmobiling and cross-country skiing may provide travel routes for competitors and predators such as coyotes (*Canis latrans*), bobcats, and mountain lions (Buskirk 1999, Koehler and Aubry 1994,

Table 4—Road- and recreation trail-associated factors for wide-ranging carnivores

Focal species	Road-associated factors	Motorized trail-associated factors	Nonmotorized trail-associated factors	Snowmobile route-associated factors	Ski trail-associated factors
Grizzly bear[a]	Poaching Collisions Negative human interactions Displacement or avoidance	Poaching Negative human interactions Displacement or avoidance	Poaching Negative human interactions Displacement or avoidance	Disturbance at a specific site	Disturbance at a specific site
Lynx[b]	Down log reduction Trapping Collisions Disturbance at a specfic site	Disturbance at a specific site Trapping	Disturbance at a specific site	Route for competitors or predators Trapping Disturbance at a specific site	Route for competitors or predators Disturbance at a specific site
Gray wolf[c]	Trapping Poaching Collisions Negative human interactions Disturbance at a specific site Displacement or avoidance	Trapping Disturbance at a specific site	Trapping Disturbance at a specific site	Trapping Physiological response	
Wolverine[d]	Down log reduction Trapping Disturbance at a specific site Collisions	Trapping Disturbance at a specfic site	Trapping Disturbance at a specific site	Trapping Disturbance at a specific site	Trapping Disturbance at a specific site

[a]Sources: Archibald et al. 1987; Claar et al. 1999; Hood and Parker 2001; Jonkel 1980; Kasworm and Manley 1990; Linnell et al. 2000; Mace and Waller 1996, 1998; Mace et al. 1996, 1999; Mattson et al. 1987; McLellan and Shackleton 1988, 1989; Puchlerz and Servheen 1998; Weaver et al. 1987; Wisdom et al. 2000.
[b]Sources: Banci 1994, Buskirk 1999, Claar et al. 1999, Koehler and Aubry 1994, McKelvey et al. 2000, Ruediger et al. 2000.
[c]Sources: Boyd and Pletscher 1999; Claar et al. 1999; Creel et al. 2002; De Vos 1948; Harrison and Chapin 1998; Jensen et al. 1986; Mech et al. 1988, 1991; Mladenoff and Sickley 1998; Mladenoff et al. 1995, 1997; Thiel 1985; Thurber et al. 1994.
[d]Sources: Banci 1994, Claar et al. 1999, Copeland 1996, Hornocker and Hash 1981, Koehler and Aubry 1994.

Ruediger et al. 2000) (table 4). Other associated factors include disturbance of den sites during the period of rearing young (Claar et al. 1999) (table 4), which is a site-specific issue that should be addressed during project-level analysis and planning. Lynx mortalities associated with collisions with vehicles have been documented on other areas (Gibeau and Heuer 1996).

Gray wolves and wolverines are sensitive to road-associated factors but are not particularly affected by summer recreation trails (Banci 1994, Boyd and Pletscher 1999, de Vos 1948, Mech et al. 1988, Paquet and Callahan 1996, Thurber et al. 1994) (table 4). For gray wolves, both Mech et al. (1988) and Thiel (1985) found that when road densities exceed about 1.6 km/0.9-km-radius circle (1 mi/mi^2), wolves avoided or were displaced from areas. Mladenoff et al. (1995) found road density to be the major predictor of wolf pack location. Jensen et al. (1986) reported that road densities >0.6 km/km^2 were apparent barriers to wolf dispersal. In Yellowstone, Voyageurs, and Isle Royale National Parks, Creel et al. (2002) found levels of stress hormones in wolves to be higher in areas with snowmobiles than in areas without snowmobiles. The implications of these elevated levels of stress hormones to gray wolf population dynamics are not currently well understood. Gray wolves have been documented to abandon den sites if disturbed by humans (Mech et al. 1991) (table 4). However, it was not possible to identify potential wolf denning habitat at the broad scale for this assessment, although it should be addressed at the project level. Both wolves and wolverines have been documented to be killed by collisions with vehicles (Gibeau and Heuer 1996, Paquet and Callahan 1996) (table 4).

Winter recreational activities may displace wolverines from important natal dens in subalpine cirques (Copeland 1996, Hornocker and Hash 1981) (table 4). The effects of recreation trails on potential wolverine denning habitat will be addressed in this assessment process because of the ability to model potential denning habitat by using GIS (Copeland 1996).

Assessment Processes for Focal Species

Grizzly bear assessment model—Cumulative effects models have been developed for grizzly bears (Gibeau 1998, Hood and Parker 2001, Puchlerz and Servheen 1998, Weaver et al. 1987). The model we recommend for use on the Wenatchee and Okanogan National Forests (Puchlerz and Servheen 1998) identifies areas of relatively low human use, called core areas, which provide refugia for grizzly bears, within bear management units (BMUs). The BMUs have been identified for the portion of the Okanogan and Wenatchee National Forests within the grizzly bear recovery zone (USFWS 1997). These areas are generally large enough to provide a variety of seasonal habitats, making them appropriately sized to address cumulative effects.

Core areas are identified by buffering high-use trails and open roads by 500 m on each side. The 500-m buffer was based on a considerable body of research that shows displacement of grizzly bears from habitats adjacent to roads and high-use trails (Kasworm and Manley 1990, Mace and Waller 1996, Mace et al. 1996, Mattson et al. 1987, McLellan and Shackelton 1988) (table 5) and has been used in other cumulative effects models (Hood and Parker 2001, Puchlerz and Servheen 1998). Definitions of high-use trails and open roads are provided in table 6. To use this model, roads and trails must be assigned attributes by using these definitions and linked to GIS for spatial analysis.

This model should be applied to assess the effects of roads and recreation trails on grizzly bear habitat on a seasonal basis. Seasons appropriate to the Okanogan and Wenatchee National Forests are early-season—15 March or den emergence to 31 May; middle season—1 June to 15 July; and late season—July 16 to 31 October or den entrance (NCETT 1999). Outputs of this model include (1) the amount of core area within the analysis area, (2) the vegetation types that are represented within the core areas, (3) the effects of trails on the amount of core area, and (4) the effects of roads on the amount of core area.

Once the amount of core area has been determined for the BMU or subbasin influenced by the proposed project, then a relative rating of the level of influence of human activities on grizzly bear habitat can be made. The relative scale is as follows: <55 percent core area = high level of human influence on the habitat, 55 to 70 percent core area = moderate level of human influence on the habitat, and >70 percent core area = low level of human influence on the habitat. These levels of core area are similar to

Table 5—Effects of roads and trails on grizzly bears and gray wolves

Human activity	Focal species	Distance at which use is less than expected [a]	Road density at which use is less than expected [b]	References
		Meters	*Kilometers per square kilometer*	
Roads	Grizzly bear	500		Mattson et al. 1987
Roads	Grizzly bear	100		McLellan and Shackleton 1988
Roads	Grizzly bear	200 through spring 100 through summer 400 through autumn		Aune and Kasworm 1989
Roads	Grizzly bear	914		Kasworm and Manley 1990
Roads	Grizzly bear	500		Mace et al. 1996
Roads and trails	Grizzly bear	500		Hood and Parker 2001
Trails	Grizzly bear	813 through spring 878 through summer 1,129 through autumn		Mace and Waller 1996
Trails	Grizzly bear	122 through spring and fall		Kasworm and Manley 1990
Roads	Gray wolf		0.7	Harrison and Chapin 1998
Roads	Gray wolf		.4	Mladenoff et al. 1995
Roads	Gray wolf		.6	Mech et al. 1988
Roads	Gray wolf		.7	Thiel 1985
Roads	Gray wolf		.6	Jensen et al. 1986

[a] Distance from a linear recreation route in which use by an animal was statistically significantly less than expected.
[b] Density of roads at which use by an animal was statistically significantly less than expected.

what has been prescribed in other areas where grizzly bears and human access are being managed, and provide reasonable estimates of cumulative effects thresholds (Gibeau 1998, Hood and Parker 2001, Puchlerz and Servheen 1998, USFWS 1993).

Canada lynx assessment model—We have a rudimentary understanding of the effects of recreational activities on Canada lynx (Ruediger et al. 2000). Canada lynx were selected as a focal species to address the potential for snowmobiling and ski trails to provide routes for competitors such as coyotes, bobcats, and cougars to access lynx habitat (Buskirk 1999, Koehler and Aubry 1994). For lynx, which have relatively narrow habitat preferences (Koehler 1990, McKelvey et al. 2000), lynx analysis units (LAUs) have been identified. These areas have been identified with adequate suitable habitat to support resident lynx (Ruediger et al. 2000) and are an appropriate spatial scale for addressing cumulative effects.

To assess the effects of recreational activities on lynx habitat, the density of groomed or commonly used snowmobile routes and ski trails should be determined by using LAUs as the area of analysis. Determine the density of groomed ski and snowmobile routes in an LAU by using current GIS data layers for spatial analysis. The outputs of this analysis include the proportion of the LAU with route density <1.6 km/0.9-km-radius circle (<1 mi/mi^2), 1.6 to 3.2 km/0.9-km-radius circle (1 to 2 mi/mi^2), and >3.2 km/0.9-km-radius circle (>2 mi/mi^2).

Table 6—Definitions of roads and trails used in the core area analysis to determine the level of influence of road and recreation trails on grizzly bear habitat

Road or trail type	Definition	Effect to core area
Impassable roads	Roads not reasonably or prudently passable by conventional four-wheeled passenger vehicles, motorcycles, or all-terrain vehicles	Any road classified as impassable during a bear analysis season would be included as core area for that season.
Restricted roads	Roads that are restricted with gates or berms but receive occasional administrative use	Any road classified as restricted during a bear analysis season would be included as core area for that season.
Open roads	Roads open to motorized use during any portion of an active bear season, or information is not available to verify the effectiveness of a gate or berm	Any road classified as open during a bear analysis season would not be included as core area for that season.
Open motorized trail	Trails that are passable by motorcycles or all-terrain vehicles and are not legally restricted	Any trail classified as open motorized during a bear analysis season would not be included as core area for that season.
Open nonmotorized rail	Trails that are not reasonably or prudently passable by motorcycles or all-terrain vehicles, but are not legally restricted, or any trail that is legally restricted to allow only nonmotorized use	Any trail classified as open nonmotorized during a bear analysis season would be included as core area for that season unless it is a high-use trail.
High-use trail	Any nonmotorized trail that receives an average of 20 or more parties per week during the grizzly bear season being assessed	Any trail categorized as high use during a season would not be included as core area for that season.

Based on the above information, the relative level of human influence on lynx habitat can then be rated. The rating scheme is as follows: <25 percent of the LAU with ski and snowmobile route densities of <1.6 km/0.9-km-radius circle (<1 mi/mi^2) = low level of human influence on lynx habitat, >25 percent with route densities 1.6 km/0.9-km-radius circle (>1 mi/mi^2) to 3.2 km/0.9-km-radius circle (2 mi/mi^2) = a moderate level of human influence on lynx habitat, and >25 percent with route densities >3.2 km/0.9-km-radius circle (>2 mi/mi^2) = a high level of human influence on lynx habitat. This rating scheme is intended to provide a means of making comparisons among the relative levels of human influence within LAUs. Additional research is needed to determine how increases in groomed ski and snowmobile route density affect lynx habitat use and to define cumulative effects thresholds.

Gray wolf and wolverine assessment model—An assessment of the effects of roads and trails on gray wolves and wolverines should be based on an area that approximates their extensive home ranges (Banci 1994, Boyd et al. 1995, Mech 1970). Therefore, to address cumulative effects, BMUs should be used for assessments within the grizzly bear recovery zone and 4th-field subbasins for areas outside of the grizzly bear recovery zone.

To address the road- and trail-associated factors identified for gray wolves and wolverines (table 4), three analyses should be conducted to assess the cumulative effects. These include an assessment of the current level of road and motorized trail access within available habitat, the effects of snowmobile routes and ski trails that occur on deer and elk winter ranges (see “Ungulate Winter and Summer Habitat Assessment”), and the effects of snowmobile routes and ski trails on potential wolverine denning habitat. No model is currently available to predict wolf denning habitat on the Okanogan and Wenatchee National Forests.

A moving windows road and motorized trail density analysis using a 0.9-km-radius circular window should be used to classify areas as follows: areas with no open roads or motorized trails, areas with densities from >0 to 1.6 km/0.9-km-radius circle (>0 to 1.0 mi/mi^2), and areas with densities that are >1.6 km/0.9-km-radius circle (>1 mi/mi^2) within a 4th-field subbasin or a BMU. Outputs of this model for each BMU or subbasin include (1) the amount and location of areas with no open roads or motorized trails, (2) the amount and location of areas with open road and motorized trail densities >0 to 1.6 km/0.9-km-radius circle (>0 to 1.0 mi/mi^2), and (3) the amount and location of areas with open road and motorized trail densities >1.6 km/0.9-km-radius circle (>1 mi/mi^2). Areas with open road densities <1.6 km/0.9 km (<1 mi/mi^2) are referred to as security habitats.

Based on the above information, the relative level of human influence on gray wolf and wolverine habitat can then be rated. The rating scheme we used was <50 percent of a BMU or subbasin in security habitat = a high level of human influence on wolf and wolverine habitat, 50 to 70 percent security habitat = a moderate level of human influence on wolf and wolverine habitat, >70 percent security habitat = a low level of human influence on wolf and wolverine habitat.

Potential wolverine denning habitat—The effects of snowmobile routes and ski trails on potential wolverine denning habitat could be assessed by using the following model. Current GIS data layers with snowmobile routes and ski trails would be overlaid onto the land type associations (LTAs) (USDA FS 2000a) that correspond to alpine cirques with the type of structure typically used by wolverines for natal dens (Copeland 1996). These include LTAs Ha7, Ha8, Hb9, and Hi9. The density of snowmobile and ski trails would then be calculated for the potential denning habitat located within a BMU or subbasin. The outputs of this model include potential wolverine denning habitat with groomed winter route densities >1.6 km/0.9-km-radius circle (>1 mi/mi^2), and areas with densities >3.2 km/0.9-km-radius circle (>2 mi/mi^2).

A relative rating of the level of influence of winter recreation routes on potential wolverine denning habitat can then be made by using the following scale. A high level of human influence on potential wolverine denning habitat = >25 percent of the potential habitat within a BMU or subbasin with winter route densities >3.2 km/0.9-km-radius circle (>2 mi/mi^2), a moderate level of human influence = >25 percent of the potential habitat within a BMU or subbasin with winter route densities >1.6 km/0.9-km-radius circle (>1 mi/mi^2) and <3.2 km/0.9-km-radius circle (<2 mi/mi^2), and a low level of human influence = <25 percent of the potential denning habitat within a BMU or subbasin with winter route densities >1.6 km/0.9-km-radius circle (>1 mi/mi^2).

Information Gaps and Research Needs

Research is needed to validate the applicability of the bear and wolf models for use on the Okanogan and Wenatchee National Forests as they are based on research conducted in other ecosystems. Specifically, the response of grizzly bears and gray wolves to different levels of human use on trails and roads needs further study (Claar et al. 1999). Research needs to be conducted to determine the direct and indirect effects of recreation on wolverines (Banci 1994) and lynx (Koehler and Aubry 1994, Ruediger et al. 2000), including how snow compaction alters interference competition among lynx, bobcats, and coyotes (Koehler and Aubry 1994). The results of this research could then be used to adapt the assessment models.

Monitoring and Adaptive Management

Habitat-effectiveness monitoring—Periodic application of the assessment models for wide-ranging carnivores across the Okanogan and Wenatchee National Forests would establish baseline conditions and allow comparisons of habitat effectiveness over time. Information on road and trail status and use levels should be updated at the project level and fed into a forest-wide GIS for landscape-scale assessment. Monitoring information can then be used to guide adaptive ecosystem management as new science becomes available about the interactions between wide-ranging carnivores and recreation.

Population-level monitoring—Presently, the numbers of grizzly bears, gray wolves, and wolverines may be too low (Almack et al. 1993; Gaines et al. 1995, 2000a, 2000b) to effectively monitor their populations. Lynx on the Okanogan National Forest could provide a situation where numbers are high enough for population monitoring. Population monitoring methods for lynx are currently being developed and implemented (McKelvey et al. 1999).

Ungulate Winter and Summer Habitat Assessment

Introduction and Focal Species Selection

There are six wildlife species included in the ungulate group: mule deer (*Odocoileus hemionus*), white-tailed deer (*O. virginianus*), elk (*Cervus elaphus*), moose (*Alces alces*), bighorn sheep (*Ovis canadensis*), and mountain goats (*Oreamnos americanus*). The focal species selected to represent the effects of roads and recreational activities on ungulates include mule deer, elk, bighorn sheep, and mountain goats. These species were selected because their habitat needs and response to recreation trails and roads were representative of the group, and because habitat effects are possible to monitor. Additionally, the bighorn sheep is listed as a “sensitive” species.

Summary of Recreation Route-Associated Factors for Focal Species

In general, ungulates respond to recreational activities by avoiding areas near roads, recreation trails, and other types of human activities (tables 7 and 8) (Cassier et al. 1992, Ferguson and Keith 1982, Freddy et al. 1986, Leslie and Douglas 1980, MacArthur et al. 1982, Papouchis et al. 2001, Rowland et al. 2000). Human activities are of particular concern for ungulates when they occur on their winter ranges or where young are reared (Canfield et al. 1999). The direct and indirect effects of recreation on rearing areas may be best evaluated at the site-specific project level owing to the difficulty in identifying them at the broad scale of this assessment.

Several studies have been conducted on the effects of linear recreation routes on mule deer. For example, ski trails seem to displace mule deer to greater distances than occurs along snowmobile routes (table 8) (Cassier et al. 1992, Freddy et al. 1986). Freddy et al. (1986) reported that mule deer displacement by skiers was independent of skier numbers or group size. Perry and Overly (1977) showed that deer were displaced up to 800 m from roads.

Elk responded to persons on foot by moving away from trails, and the distance of this displacement was quite variable among study areas (Cassier et al. 1992, Ferguson and Keith 1982, Schultz and Bailey 1978) (table 8). Elk moved away from ski trails only when use was >8 persons per day (Ferguson and Keith 1982). Creel et al. (2002) reported elevated levels of stress hormones in elk in Yellowstone National Park when they were exposed to snowmobile activity. In addition, Millspaugh et al. (2001) reported that increased levels of stress hormones were associated with vehicle use on

Table 7—Road- and recreation trail-associated factors for ungulate focal species

Focal species	Road-associated factors	Motorized trail-associated factors	Nonmotorized trail-associated factors	Snowmobile route-associated factors	Ski trail-associated factors
Mule deer[a]	Hunting Poaching Collisions Displacement or avoidance Disturbance at a specific site	Hunting Poaching Displacement or avoidance Disturbance at a specific site	Hunting Poaching Displacement or avoidance Disturbance at a specific site	Displacement or avoidance Disturbance at a specific site	Displacement or avoidance Disturbance at a specific site
Elk[b]	Hunting Poaching Collisions Displacement or avoidance Disturbance at a specific site	Hunting Poaching Displacement or avoidance Disturbance at a specific site	Hunting Poaching Displacement or avoidance Disturbance at a specific site	Displacement or avoidance Disturbance at a specific site Physiological response	Displacement or avoidance Disturbance at a specific site
Bighorn sheep[c]	Hunting Poaching Collisions Displacement or avoidance Disturbance at a specific site Physiological response	Hunting Poaching Displacement or avoidance Disturbance at a specific site	Hunting Poaching Displacement or avoidance Disturbance at a specific site	Displacement or avoidance Disturbance at a specific site Physiological response	Displacement or avoidance Disturbance at a specific site
Mountain goat[d]	Hunting Poaching Collisions Displacement or avoidance Disturbance at a specific site Movement barrier or filter	Hunting Poaching	Hunting Poaching		

[a] Sources: Canfield et al. 1999, Cassier et al. 1992, Freddy et al. 1986, Johnson et al. 2000, Ward et al. 1980.
[b] Sources: Canfield et al. 1999, Cassier et al. 1992, Cole et al. 1997, Creel et al. 2002, Ferguson and Keith 1982, Johnson et al. 2000, Lyon 1983, Millspaugh et al. 2001, Phillips and Alldredge 2000, Roloff 1998, Roloff et al. 2001, Rowland et al. 2000, Schultz and Bailey 1978, Ward 1976, Ward et al. 1980.
[c] Sources: Canfield et al. 1999; Hicks and Elder 1979; King and Workman 1986; Leslie and Douglas 1980; MacArthur et al. 1979, 1982; Papouchis et al. 2001; Smith et al. 1991.
[d] Sources: Joslin 1986, Pedevillano and Wright 1987, Singer 1978, Singer and Doherty 1985.

Table 8—Displacement distances and mean distance from roads reported for ungulate focal species

Human activity	Focal species	Distance displaced[a]	Mean distance[b]	References
		- - - - - - - - - - - - - *Meters*	- - - - - - - - - - - - -	
Hiking	Mule deer	191		Freddy et al. 1986
Snowmobiling	Mule deer	133		Freddy et al. 1986
Hiking	Mule deer	200		Ward et al. 1980
Hiking	Elk	86		Schultz and Bailey 1978
Skiing	Elk	650		Cassier et al. 1992
Skiing	Elk	Moved away from high-use (>8 persons per day) trail		Ferguson and Keith 1982
Hiking	Bighorn sheep	50		MacArthur et al. 1982
Hiking	Bighorn sheep	Did not affect sheep movements		Hicks and Elder 1979
Hiking	Bighorn sheep		200 at which sheep first responded	Papouchis et al. 2001
Roads and trails <500 visitors per year	Bighorn sheep	100		Smith et al. 1991
Roads and trails >500 visitors per year	Bighorn sheep	150		Smith et al. 1991
Road driving ≤1 vehicle per day	Bighorn sheep		354	Papouchis et al. 2001
Road driving 5 to 13 vehicles per day	Bighorn sheep		490	Papouchis et al. 2001
Road driving	Elk	400		Ward 1976
Road driving	Mule deer	800		Perry and Overly 1977
Road driving (closed to vehicles but open to all-terrain vehicles)			268 to 280	Johnson et al. 2000
Road driving (low traffic 0 to 1 vehicle per 12 hours)	Elk		869 to 890	Johnson et al. 2000
Road driving (medium traffic 2 to 4 vehicles per 12 hours)	Elk		909 to 1032	Johnson et al. 2000
Road driving (high traffic >4 vehicles per 12 hours)	Elk		1103 to 1560	Johnson et al. 2000

[a] Average distance at which animals reacted to human activities and were displaced from the area.

[b] Distance that radio-collared animals were located from roads.

primary roads and the density of primary roads. Presently, the relationship between stress hormones and population dynamics of elk is not well understood, and these results should be interpreted with caution (Millspaugh et al. 2001). Johnson et al. (2000) showed that as the volume of traffic increased on roads, the mean distance that elk were located from roads also increased (table 8). Hayes et al. (2002) reported that mortality of elk during hunting season increased when total road density increased. In addition, elk reproductive success has been shown to decrease following human disturbance to calving areas (Phillips and Alldredge 2000). Cole et al. (1997) showed that road closures are successful in reducing the effects of habitat displacement and increasing elk survivorship.

Bighorn sheep also have been reported to respond to human disturbance (Hicks and Elder 1979; King and Workman 1986; Leslie and Douglas 1980; MacArthur et al. 1979, 1982; Papouchis et al. 2001; Smith et al. 1991) (table 8). MacArthur et al. (1979) showed that the heart rate of bighorn sheep varies inversely with distance from a road. MacArthur et al. (1982) reported that sheep are affected by a human approaching within 50 m, and Papouchis et al. (2001) found that bighorn sheep respond to hikers at an average distance of 200 m. They also showed that avoidance of roads is greater for high-use (5 to 13 vehicles per hour) versus low-use (1 vehicle per hour) roads. On average, radio-collared sheep were 490 m from high-use roads compared to 354 m from low-use roads (Papouchis et al. 2001). Smith et al. (1991) developed a habitat suitability model for bighorn sheep and considered areas within 100 m of low to moderate human use (<500 visitors per year) trails and roads as unsuitable, and areas within 150 m of high human use (>500 visitors per year) trails and roads as unsuitable.

Limited research has been conducted on the effects of recreational activities on mountain goats, although concern has been expressed about the interactions between recreation and goats (Sachet 1988). Highways have been documented to cause difficulty for crossing goats, resulting in avoidance or temporary displacement (Singer 1978, Singer and Doherty 1985). People walking on the highway to observe goats increased goat crossing time and altered crossing routes (Pedevillano and Wright 1987). In Montana's Rocky Mountain front, mountain goat reproduction was lower in a herd exposed to human activity (ski area, energy exploration, developed recreation), compared to a herd in a more remote area (Joslin 1986). No studies on the effects of forest roads or recreation trails were found in this review. Rodrick and Milner (1991) recommended that recreational activities (roads and hiking trails) that occur within 1.6 km of winter ranges from 1 November to 30 June be evaluated.

Assessment Processes for Focal Species

Mule deer and elk winter habitat disturbance index—The cumulative effects of roads and recreation trails on mule deer and elk should be assessed during winter when disturbance has the potential to be the most detrimental (Canfield et al. 1999). This means evaluating the effects of roads, ski trails, and snowmobile routes on the winter ranges for these species. Winter ranges for mule deer and elk on the Okanogan and Wenatchee National Forests generally occur at lower elevations and are usually distinct units separated by private lands and higher elevation nonwinter habitats. To address cumulative effects, the entire unit of winter range habitat should be evaluated, and the area should be at least 800 to 1200 ha (Lyon 1983).

An index of habitat effectiveness applied to the winter range habitat unit can be calculated by using GIS with current data layers showing plowed roads, ski trails, and snowmobile routes. Because of the differing effects of these activities, different buffers would be applied to each to evaluate the amount of affected habitat. For roads, the zone of influence would be 800 m on each side of a plowed road; for ski trails that receive use >8 persons per day, the zone of influence would be 200 m on each side; and for snowmobile routes, the zone would be 150 m on each side of the route. The zone of influence may be modified based on the topography adjacent to the linear recreation route. The proportion of the winter range that is influenced by winter recreation is determined. Model outputs include the proportion of winter range influenced by roads, ski trails, and snowmobile routes.

Table 9—The zone of influence applied to each side of a trail or road based on road type and use level for the bighorn sheep summer and winter habitat influence indices

Trail or road type and status	Zone of influence[a]
	Meters
Nonmotorized trail (ski or hiking)	200
Motorized trail	350
Road ≤1 vehicle per day	350
Road >1 vehicle per day	500

[a] Zone of influence distance may be modified by topographic features.

The summed relative effects of these activities are then rated by using the following scale: >70 percent of the winter range outside of a zone of influence rates as a low level of human influence on deer and elk winter range, 50 to 70 percent of the winter range outside of a zone of influence is classified as a moderate level of human influence, and <50 percent outside of the zone of influence rates as a high level of human influence.

Bighorn sheep summer or winter habitat disturbance index—To assess the effects of road- and recreational trail-associated factors on bighorn sheep, a summer and winter range habitat-effectiveness index is calculated. To calculate this index, GIS maps of bighorn sheep winter and summer ranges are needed. For the winter index, GIS layers of current roads and their use levels, ski trails, and snowmobile routes are used. For the summer index, GIS layers of roads and their use levels, motorized trails, and nonmotorized trails are used. Roads that receive <1 vehicle per day and other motorized routes are buffered by a 350-m zone of influence and those with >1 vehicle per day a 500-m zone of influence (table 9). Groomed ski trails and hiking trails are buffered by 200 m on each side (table 9). The zone of influence may be modified based on the topography adjacent to the linear recreation route. The proportions of the summer and winter ranges that are influenced by road and trail recreation activities are then determined. Model outputs include the proportion of summer or winter range influenced by roads, the proportion of summer or winter range influenced by trails, and the proportion of summer or winter range influenced by motorized trail routes.

The relative effects of these activities are then rated by using the following scale: >70 percent of the range outside of a zone of influence rates as a low level of human influence on bighorn sheep summer or winter range, 50 to 70 percent of the summer or winter range outside of a zone of influence is classified as a moderate level of human influence, and <50 percent outside of the zone of influence rates as a high level of human influence.

Mule deer and elk summer habitat disturbance index—Previous generations of deer and elk habitat-effectiveness models have used road density as an index for summer ranges. However, Roloff (1998) and Rowland et al. (2000) suggested that a spatially explicit roads variable, based on distance to open roads, may be more appropriate. In addition, Johnson et al. (2000) showed that different levels of traffic can have different degrees of influence on deer and elk habitat use. Therefore, to evaluate the

Table 10—The zone of influence applied to each side of a motorized trail or road based on road type and use level for the deer and elk summer habitat influence index

Trail or road type and status	Zone of influence[a]
	Meters
Motorized trails	300
Closed road (no vehicular traffic but open to all-terrain vehicles)	300
Low traffic open road (>0 to 1 vehicle per 12 hours)	900
Moderate traffic open road (>2 to ≤4 vehicles per 12 hours)	1000
High traffic open road (>4 vehicles per 12 hours)	1300

[a] Zone of influence distance may be modified by topographic features.

cumulative effects of road and motorized trails on deer and elk summer ranges, roads and motorized trails would be buffered by the distances shown in table 10. These buffers would be applied to all the roads in a 5th-field watershed, and the proportion of the habitat in the watershed would be determined. The zone of influence may be modified based on the topography adjacent to the linear recreation route. This becomes the portion of the watershed that is influenced by roads. This number is then divided by the total area in the watershed to estimate the percentage within a zone of influence.

A relative ranking of the level of road and trail influences on deer and elk summer range is then applied as follows: >70 percent of the summer range outside of a zone of influence is ranked as a low level of human influence on deer and elk summer range, 50 to 70 percent of the summer range outside of a zone of influence is ranked as a moderate level of human influence, and <50 percent outside of the zone of influence is ranked as a high level of human influence.

Mountain goat winter habitat disturbance index—To assess the influence of recreation routes on mountain goats, two sources of information are needed for each 5th-field watershed in which a project or related projects may occur. A map of mountain goat winter range is overlaid with roads, trails, snowmobile routes, and ski trails, and each is buffered by a 500-m zone of influence. The zone of influence may be modified based on the topography adjacent to the linear recreation route. The proportion of winter range outside a zone of influence is then determined for each watershed. A relative index is then applied: >70 percent of the range outside of a zone of influence is ranked as a low level of human influence on mountain goat winter range, 50 to 70 percent of the winter range outside of a zone of influence is classified as a moderate level of human influence, and <50 percent outside of the zone of influence is ranked as a high level of human influence.

Information Gaps and Research Needs

Additional research is needed on the effects of roads and snowmobiles on bighorn sheep and mountain goats during winter. The most efficient method to accomplish this would be through the use of telemetry or observational studies conducted during winter. All ungulate focal species could benefit from research that links the effects of recreation trails and roads to the demography of the focal species. Research on this subject has been most intensively focused on elk, and other species would benefit from similar efforts.

Monitoring and Adaptive Management

Habitat monitoring—Periodic application of the assessment models would allow trends of habitat effectiveness to be tracked over time. In addition, monitoring could be used to validate the zone of influence estimates with site-specific conditions (Roloff et al. 2001). This could be done by using radio-telemetry (White and Garrott 1990), snow tracking, or pellet group indices (Wemmer et al. 1996).

Population monitoring—Population monitoring of ungulates is generally carried out by state agencies relying on aerial counts conducted during winter when animals are concentrated on their winter ranges. These data provide information on general trends of ungulate populations.

Late-Successional Forest Habitat Assessment

Introduction and Focal Species Selection

A total of 71 species was included in the late-successional forest habitat species group (see app.). The focal species that were selected for this group include species associated with mixed-conifer late-successional forests such as the northern spotted owl (*Strix occidentalis caurina*), northern goshawk (*Accipiter gentilis*), brown creeper (*Certhia americana*), American marten, fisher, and the northern flying squirrel (*Glaucomys sabrinus*). Additional species were selected that are associated with old ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) forests and they include the pygmy nuthatch (*Sitta pygmaea*), white-breasted nuthatch (*Sitta carolinensis*), and white-headed woodpecker (*Picoides albolarvatus*). These species were selected because they represent an array of road- and recreation trail-associated factors, and late-successional habitats (table 11).

Summary of Recreation Route-Associated Factors for Focal Species

There is limited information available concerning the effects of winter recreation routes on many of the wildlife species associated with late-successional habitats. More studies have documented the effects that roads and nonwinter recreation routes can have on these species.

Northern spotted owls could be affected by the edge effects that roads can have when they fragment suitable habitat, or mortality as a result of collisions with vehicles (USDA FS 1997). In addition, linear recreation routes can result in physiological stress responses in owls and may result in displacement of owls by certain types of recreational activities. For example, Wasser et al. (1997) found that stress hormone levels were significantly higher in male northern spotted owls (but not females) when they were located <0.41 km from a major logging road compared to spotted owls in areas >0.41 km from a major logging road. The potential effects of elevated stress hormones on spotted owl population dynamics are not well understood. However, chronic high levels of stress hormones (corticosterone) may have negative consequences on reproduction or physical condition in birds (Marra and Holberton 1998). Additional evidence of recreation effects on spotted owls was reported by Swarthout and Steidl (2001) who found that the closely related Mexican spotted owl (*Strix occidentalis lucida*) was affected by hikers. They reported that juveniles and adults were unlikely to flush at distances ≥12 m and ≥24 m from hikers, respectively. Finally, although not a study of

Table 11—Road- and trail-associated factors for late-successional habitat-associated focal species

Focal species	Road-associated factors	Motorized trail-associated factors	Nonmotorized trail-associated factors	Snowmobile route-associated factors	Ski trail-associated factors
Northern goshawk[a]	Edge effects Habitat loss or fragmentation Disturbance at specific site Collection	Disturbance at a specific site Collection	Disturbance at a specific site Collection		
Northern spotted owl[b]	Edge effects Snag reduction Disturbance at a specific site Collisions Physiological response	Disturbance at a specific site	Disturbance at a specific site		
Brown creeper[c]	Snag reduction Edge effects Displacement or avoidance Habitat loss or fragmentation Route for competitors or predators	Route for competitors or predators Displacement or avoidance	Route for competitors or predators Displacement or avoidance	Route for competitors or predators	Route for competitors or predators
American marten[d]	Snag reduction Down log reduction Edge effects Trapping Collisions Habitat loss or fragmentation Movement barrier or filter	Trapping	Trapping	Trapping	Trapping
Fisher[e]	Snag reduction Down log reduction Edge effects Trapping Collisions Habitat loss or fragmentation Movement barrier or filter Displacement or avoidance	Trapping	Trapping	Trapping Displacement or avoidance	Trapping

Table 11—Road- and trail-associated factors for late-successional habitat-associated focal species (continued)

Focal species	Road-associated factors	Motorized trail-associated factors	Nonmotorized trail-associated factors	Snowmobile route-associated factors	Ski trail-associated factors
Northern flying squirrel[f]	Snag reduction Down log reduction Edge effects Habitat loss or fragmentation Movement barrier or filter				
Pygmy nuthatch[g]	Snag reduction Edge effects Displacement or avoidance	Displacement or avoidance	Displacement or avoidance		
White-breasted nuthatch[h]	Snag reduction Edge effects Displacement or avoidance	Displacement or avoidance	Displacement or avoidance		
White-headed woodpecker[i]	Snag reduction Edge effects				

[a]Sources: Beier and Drennan 1997, Daw and DeStefano 2001, Erdman et al. 1998, Grubb et al. 1998, Hamann et al. 1999, Jones 1979, Reynolds et al. 1992, Wisdom et al. 2000.
[b]Sources: Delaney et al. 1999, Swarthout and Steidl 2001, USDA FS 1997, Wasser et al. 1997.
[c]Sources: Brand and George 2001, Foppen and Reijnen 1994, Gutzwiller et al. 2002, Hickman 1990, Hutto 1995, Keller and Anderson 1992, Miller et al. 1998.
[d]Sources: Buskirk and Ruggiero 1994; Claar et al. 1999; Powell 1979, 1982; Weaver 1993; Wisdom et al. 2000.
[e]Sources: Claar et al. 1999; Heinenmeyer and Jones 1994; Powell 1979, 1982; Rosenburg and Raphael 1986; Weaver 1993; Wisdom et al. 2000.
[f]Sources: Carey 1991, 1995, 2000; Carey et al. 1997, 2002; Wisdom et al. 2000.
[g]Sources: Foppen and Reijnen 1994, Gutzwiller et al. 2002, Miller et al. 1998, Wisdom et al. 2000.
[h]Sources: Foppen and Reijnen 1994, Gutzwiller et al. 2002, Miller et al. 1998, Wisdom et al. 2000.
[i]Sources: Hamann et al.1999, Miller et al. 1998, Wisdom et al. 2000.

recreational effects, Delaney et al. (1999), studied the effects of chainsaw and helicopter noise on Mexican spotted owls. They found that no spotted owls flushed when noise stimuli were >105 m away. This study further shows that spotted owls may be sensitive to some types of noise disturbance.

Some types of human disturbances to goshawk nests have been a suspected cause of nest abandonment (Reynolds et al. 1992). In addition, roads and trails may facilitate access for falconers to remove young from nests (Erdman et al. 1998). Grubb et al. (1998) reported that vehicle traffic from roads caused no discernable behavioral response by goshawks at distances >400 m from nest sites in forested habitats with noise levels <54 decibels. Critical times for human disturbance to be evaluated include the nesting period and postfledgling periods for goshawks. The postfledgling area is an area of concentrated use from the time the young leave the nest until they are no longer dependent on the adults for food. Jones (1979) recommended a 400- to 500-m radius buffer around goshawk nest sites to protect them from disturbance during 1 March to 30 September. Forest road-associated factors include the fragmentation or loss of goshawk habitat as a result of roads, or more likely, road networks (Wisdom et al. 2000). Goshawks have been shown to be sensitive to changes in canopy closure and habitat fragmentation (Beier and Drennan 1997, Daw and DeStefano 2001) such as could result from a road network.

Recreation routes have been shown to affect forest birds. For example, roads may result in the loss or fragmentation of habitat for brown creepers (table 11). Hutto (1995) found that brown creepers were twice as likely to occur in habitats that were more than 100 m from a road, and both Keller and Anderson (1992) and Brand and George (2001) found that brown creepers were associated with larger forest patches. Foppen and Reijnen (1994) found that roads and motorized trails reduced forest bird reproduction up to a distance of 200 m. In addition, roads and recreation trails may break up forest patches and increase nest predation and parasitism rates by species such as cowbirds (*Molothrus* spp.) (Hickman 1990, Miller et al. 1998). Gutzwiller et al. (2002) found that human intrusion, in the form of hiking, increased the probability of gray jay (*Perisoreus canadensis*) recurrence, which may increase nest predation on other bird species. Trails used for hiking also can influence forest bird habitat use. Miller et al. (1998) reported a zone of influence of 100 m for some forest bird species.

Fisher and marten are known for their vulnerability to trapping and susceptibility to overharvest (Heinenmeyer and Jones 1994; Powell 1979, 1982; Weaver 1993). Roads and trails, especially snowmobile trails, developed for recreation also are used by trappers and, therefore, increase vulnerability of these species to trapping mortality (Claar et al. 1999). Other road- and trail-associated factors included snag and downed log reduction, edge effects, collisions, and habitat loss or fragmentation (table 11) (Buskirk and Ruggiero 1994, Claar et al. 1999, Rosenberg and Raphael 1986, Wisdom et al. 2000).

Northern flying squirrels play important ecological roles in late-successional forests (Carey 1991, 1995) and are therefore included as a focal species. The road-associated factors for the northern flying squirrel included snag and downed log reduction, edge effects, and habitat loss or fragmentation (table 11) (Wisdom et al. 2000). Several studies have shown that forest management can influence den site availability (Carey et al. 1997), food abundance (Carey et al. 2002), and northern flying squirrel densities (Carey 2000). Presumably, roads, and especially road networks, could have similar influences. No trail-associated factors were identified in the literature we reviewed.

Pygmy nuthatch, white-breasted nuthatch, and white-headed woodpecker are affected by the removal of snags along roads for firewood and safety, and the edge effects of roads to their habitats (table 11) (Wisdom et al. 2000). No recreation trail-associated factors were identified for white-headed woodpeckers (Hamann et al. 1999). Roads and recreation trails may influence pygmy nuthatch and white-breasted nuthatch habitat use (Miller et al. 1998). For example, Foppen and Reijnen (1994) found that roads and motorized trails influenced forest bird reproduction to a distance of 200 m. Miller et al. (1998) reported a zone of influence of 75 to 100 m along trails used for hiking for some forest bird species

Assessment Processes for Focal Species

Habitat for late-successional-associated species within the range of the northern spotted owl is managed within a network of reserves (USDA FS 1994). On the Wenatchee and Okanogan National Forests, these reserves are called late-successional reserves (LSRs) and managed late-successional areas (MLSAs). This network of reserves was designed to provide for the viability of late-successional species (Thomas et al. 1993). When projects are proposed within one of these reserves, the cumulative effects of roads and trails on habitat effectiveness within the reserve should be assessed (USDA FS 1997). Reserves should be at least 4000 ha to adequately address cumulative effects. Reserves smaller than this can be grouped by including adjacent reserves until an adequately sized area is reached. Projects that are not located in a reserve but could affect late-successional habitats and species should be addressed by using late-successional habitat within a 5th-field watershed as the analysis area.

In the Wenatchee National Forest LSR assessment (WNFLSRA), two indices to assess habitat effectiveness within LSRs and MLSAs were identified (USDA FS 1997). These included the overall open road density within the LSR and the amount of security habitat. Security habitat was defined as areas that were greater than 500 m from an open road. The WNFLSRA did not consider the effects of recreation trails within LSRs and MLSAs on habitat effectiveness for late-successional species. However, as a result of this review, the assessment model that is described below includes recreation trails, both winter and nonwinter, and should be viewed as an update to the security habitat model originally developed in the WNFLSRA (USDA FS 1997).

Late-successional nonwinter habitat influence index—The assessment process to evaluate roads and recreational trails on habitat effectiveness for late-successional species should be divided into winter and nonwinter periods. For the nonwinter period, a habitat influence index and security habitat index should be calculated for the late-successional habitat in an LSR, MLSA, or 5th-field watershed in which the project is located. The habitat influence index is designed to address edge effects, snag and downed log reduction, and habitat loss and fragmentation resulting from road-associated factors. This index is calculated by using GIS with a current open roads data layer and late-successional habitat layer. Open roads are buffered by 50 m on both sides, and the area within this buffer is determined for the entire LSR, MLSA, or late-successional habitat in a 5th-field watershed. This number is then divided by the total amount of late-successional habitat in the LSR, MLSA, or in a 5th-field watershed to determine the proportion of late-successional habitats that could be influenced by open roads.

Once the habitat influence index has been calculated, then the relative level of influence of road-associated factors on late-successional habitat can be determined. The scale used to determine the level of influence is as follows: <30 percent within habitat influence buffer is ranked as a low level of human influence on late-successional habitats, 30 to 50 percent is ranked as a moderate level of influence on late-successional habitats, and >50 percent is ranked as a high level of influence on late-successional habitats.

Late-successional nonwinter security habitat—The second nonwinter index is a modification of the security habitat index described in the WNFLSRA (USDA FS 1997). This index is used to evaluate the effects of displacement and avoidance, disturbance, and human access that can lead to trapping. This index is calculated by using GIS and current trail and open road data layers. Open roads and motorized trails are buffered by 200 m (Foppen and Reijnen 1994, Hamann et al. 1999, Hutto 1995), and nonmotorized trails are buffered by 100 m (Hamann et al. 1999, Miller et al. 1998).

The area outside this buffer, referred to as security habitat, is determined for late-successional habitat in an LSR, MLSA, or in a 5th-field watershed. This number is then divided by the total area in late-successional habitat in an LSR, MLSA, or 5th-field watershed to determine the proportion that is in security habitat and may provide refugia for some late-successional-associated species.

Once the amount of late-successional security habitat has been determined for the LSR, MLSA, or 5th-field watershed, then a relative rating of the level of influence of human activities on late-successional habitat can be made. This scale is as follows: <50 percent security habitat is ranked as high level of human influence on the late-successional habitat, 50 to 70 percent security habitat is ranked as moderate level of human influence on late-successional habitat, and >70 percent security habitat is ranked as low level of human influence on late-successional habitat.

Late-successional winter security habitat—To evaluate the effects of winter recreation trails, a winter security habitat index should be calculated. This index is calculated by using GIS and a current data layer attributed with plowed roads, ski trails, and snowmobile routes within the late-successional habitat in an LSR, MLSA or 5th-field watershed. Plowed roads, ski trails, and snowmobile routes are buffered by 200 m on each side, and the area outside of this buffer is referred to as winter security habitat. This number is then divided by the total area of late-successional habitat in the LSR, MLSA, or 5th-field watershed to determine the proportion of the late-successional habitat in the LSR, MLSA, or 5th-field watershed that is late-successional winter security habitat.

Once the amount of late-successional winter security habitat has been determined for the LSR, MLSA, or 5th-field watershed, then a relative rating of the level of influence of human activities on late-successional habitat can be made. This scale is as follows: <50 percent winter security habitat is ranked as high level of human influence on late-successional habitat, 50 to 70 percent winter security habitat is ranked as moderate level of human influence on late-successional habitat, and >70 percent winter security habitat is ranked as low level of human influence on late-successional habitat

Information Gaps and Research

There is currently a lack of information on the effects of recreational trails on many of the wildlife species associated with late-successional habitats. This makes it difficult to develop good management strategies or to assess the effects of projects on these species. Specifically, the influence of recreation trails on space-use patterns of late-successional species at different levels of recreation use and for different types of uses needs to be studied. Research that links the effects of recreational activities to the demography of late-successional species would be especially valuable.

Monitoring and Adaptive Management

Until additional research becomes available, the assessment processes identified should be considered as working hypotheses on which monitoring could be designed to test their validity. For example, the influence that roads have on the availability of late-successional habitat structure adjacent to roads as a result of snag cutting and tree felling for firewood or traffic safety could be monitored to determine the validity of the habitat loss index. In addition, the concept of security habitat could be evaluated by monitoring the demography of focal late-successional species in areas identified as security habitat compared to those in areas that are not security habitat.

Habitat effectiveness monitoring—The habitat influence index and the security habitat indices could be used to establish baseline levels of habitat effectiveness within LSR, MLSAs, and late-successional habitat in a 5th-field watershed. Periodic application of these models could show trends in habitat effectiveness over time.

Population monitoring—Monitoring within LSRs and MLSAs could be used to track habitat effectiveness in relation to species abundance. For example, protocols have been developed to survey and locate goshawk nest sites and monitor their productivity (Watson et al. 1999). Brown creepers, pygmy nuthatches, white-breasted nuthatches, and white-headed woodpeckers can be monitored by using point counts (Ralph et al. 1993), or nest searches could be conducted to evaluate productivity (Ralph et al. 1993). American marten and fisher populations can be indexed by using track plate surveys (Zielinski and Kucera 1995). These protocols could be used to monitor focal late-successional species populations within different late-successional habitats.

Northern spotted owl population monitoring has been ongoing on the Wenatchee and Okanogan National Forests for the past 10 years (Forsman et al. 1996, Van Deusen et al. 1998). These monitoring efforts have indicated a stable to declining population but have not been able to reveal any causal factors at this time. An additional research proposal is being developed that may provide additional insights into causes of the population decline and address how some types of recreational activities may influence spotted owl habitat use and reproduction.

Riparian Habitat Assessment

Introduction and Focal Species Selection

There were 144 wildlife species in the riparian habitat species group (see app.). The focal species identified for this group includes the Cascades frog (*Rana cascadae*), tailed frog (*Ascaphus truei*), harlequin duck (*Histrionicus histrionicus*), bald eagle (*Haliaeetus leucocephalus*), water shrew (*Sorex palustris*), and black-capped chickadee (*Parus atricapillus*). These species were selected because they represent a diversity of riparian habitats and were sensitive to a variety of road- and trail-associated factors (table 12).

Summary of Recreation Route-Associated Factors for Focal Species

Wildlife species associated with riparian habitats are particularly vulnerable to the effects of recreational activities on their habitats because of the concentration of these activities in riparian areas. Riparian habitats occur in a linear configuration within watersheds and are often traversed by roads and trails. In addition, riparian habitats are used by a variety of wildlife species and are used disproportionately more than they are available (Thomas et al. 1979).

The road- and trail-associated factors for the Cascades frog and tailed frog were derived from studies of a variety of amphibian species and included collisions, habitat loss or fragmentation, and movement barriers and filters (table 12) (Ashley and Robinson 1996, DeMaynadier and Hunter 2000, Fahrig et al. 1995, Gibbs 1998, Rei and Seitz 1990, Welsh and Ollivier 1998, Wisdom et al. 2000, Yanes et al. 1995).

Studies have shown that harlequin ducks are sensitive to human disturbances during the breeding season (Cassier and Groves 1989, Hamann et al. 1999, Wallen and Groves 1989). Ashley (1994) found that Harlequin ducks use stream habitats inaccessible to humans more than expected. Wallen (1987) reported that fishing along trails seems more disruptive than hiking. Harlequins avoided humans on the bank or in the streambed and would typically swim or dive downstream past people, remaining partially submerged and watchful while moving out of the area. Fishing also has a direct effect on harlequin ducks as birds have been found entangled in fishing line

Table 12—Road- and trail-associated factors for riparian associated focal species

Focal species	Road-associated factors	Motorized trail-associated factors	Nonmotorized trail-associated factors	Snowmobile route-associated factors	Ski trail-associated factors
Cascades frog[a]	Collisions Habitat loss or fragmentation Movement barrier or filter	Collisions Habitat loss or fragmentation			
Tailed frog[b]	Collisions Habitat loss or fragmentation Edge effects Movement barrier or filter	Collisions Habitat loss or fragmentation			
Harlequin duck[c]	Downed log reduction Disturbance at a specific site Displacement or avoidance Habitat loss or fragmentation Negative human interactions	Disturbance at a specific site Displacement or avoidance Negative human interactions	Disturbance at a specific site Displacement or avoidance Negative human interactions		
Bald eagle[d]	Poaching Disturbance at a specific site Displacement or avoidance	Disturbance at a specific site	Disturbance at a specific site Displacement or avoidance	Disturbance at a specific site	Disturbance at a specific site
Water shrew[e]	Collisions Movement barrier or filter Habitat loss or fragmentation Downed log reduction	Collisions		Snow compaction Displacement or avoidance	Snow compaction
Black-capped chickadee[f]	Displacement or avoidance Habitat loss or fragmentation	Displacement or avoidance Habitat loss or fragmentation	Displacement or avoidance Habitat loss or fragmentation		

[a] Sources: Ashley and Robinson 1996, DeMaynadier and Hunter 2000, Fahrig et al. 1995, Gibbs 1998, Rei and Seitz 1990, Welsh and Ollivier 1998, Wisdom et al. 2000, Yanes et al. 1995.

[b] Sources: Ashley and Robinson 1996, DeMaynadier and Hunter 2000, Fahrig et al. 1995, Gibbs 1998, Rei and Seitz 1990, Welsh and Ollivier 1998, Wisdom et al. 2000, Yanes et al. 1995.

[c] Sources: Ashley 1994, Clarkson 1992, Hamann et al. 1999, Wallen 1987, Wisdom et al. 2000.

[d] Sources: Fletcher et al. 1999, Hamann et al. 1999, Harmata and Oakleaf 1992, Skagen et al. 1991, Stalmaster and Newman 1978.

[e] Sources: Baldwin and Stoddard 1973, Cole and Landres 1995, Hickman 1990, Knight and Cole 1991, Randgaard 1998, Schmid 1972.

[f] Sources: Belisle et al. 2001, Blakesley and Reese 1988, Garton et al. 1977.

(Ashley 1994, Clarkson 1992). The road- and recreation-trail associated factors that were identified for the harlequin duck include snag reduction, disturbance at a specific site (nest site), displacement and avoidance, and habitat loss and fragmentation from roads (table 12) (Hamann et al. 1999, Wisdom et al. 2000). Cassier and Groves (1990) recommended that trails and roads be located at least 50 m from streams used by harlequin ducks.

The response of bald eagles to human activities is variable. Reported responses have included spatial avoidance of activity and reproductive failure (Anthony et al. 1995, Buehler et al. 1991, Hamann et al. 1999, McGarigal et al. 1991, Watson 1993), although in some cases, eagles tolerate human disturbances (Harmata and Oakleaf 1992). The road- and recreation-trail associated factors that were identified in this review included poaching, disturbance at a specific site, and avoidance and displacement (table 12) (Skagen et al. 1991, Stalmaster and Newman 1978). Bald eagles seem to be more sensitive to humans afoot than to vehicular traffic (Grubb and King 1991, Hamann et al. 1999, Skagen et al. 1991, Stalmaster and Newman 1978). Fletcher et al. (1999) reported that the abundance of bald eagles was lower in riparian habitats with nonmotorized trails compared to riparian habitats without trails. Montopoli and Anderson (1991) developed a cumulative-effects model for bald eagles that included human disturbances associated with recreational boating. No model has been developed for assessing the cumulative effects of linear recreation routes on bald eagle habitats. Recommended buffer distances to reduce the potential for disturbance to eagles during the nesting period have ranged from 300 to 800 m (Anthony and Isaacs 1989, Fraser et al. 1985, McGarigal 1988, Stalmaster 1987). Grubb and King (1991) evaluated the influence of pedestrian traffic and vehicle traffic on bald eagle nesting activities and recommended buffers of 550 m for pedestrians and 450 m for vehicles.

The water shrew is known to be associated with riparian habitats and occurs at high enough densities to make it a good candidate for monitoring (Peffer 2001). The road- and recreation-trail associated factors for the water shrew include collisions, movement barriers and filters, habitat loss and fragmentation, downed log reduction, displacement and avoidance, and snow compaction (table 12), based on effects documented for other small mammal species as well (Baldwin and Stoddard 1973, Cole and Landres 1995, Knight and Cole 1991, Randgaard 1998, Schmid 1972). Snow compaction from snowmobiling and ski trail grooming has been cited to cause mortality and to present barriers to small mammal movements in subnivean spaces (Schmid 1972).

Some forest birds, such as American robins (*Turdus migratorius*), that are associated with riparian habitats are attracted to campgrounds that occur within riparian areas along roads and trails (Blakesley and Reese 1988, Marzluff 1997). Others, such as the black-capped chickadee, fox sparrow (*Passerella iliaca*) and song sparrow (*Melospiza melodia*) are negatively associated with campgrounds (Blakesley and Reese 1988, Garton et al. 1977, Marzluff 1997). In addition, Odell and Knight (2001) showed that black-capped chickadee densities increased with increasing distance from exurban housing developments. Belisle et al. (2001) found that the movement patterns of black-capped chickadees were influenced by forest cover removal. We included the black-capped chickadee as a focal species to address the displacement or avoidance factor that occurs when roads or trails provide access to campgrounds (table 12) and to address the removal of forest cover for roads and campgrounds.

Assessment Processes for Focal Species

To evaluate the cumulative effects of roads and recreation trails on riparian-associated species, the evaluation area should be the 5th-field watershed in which the proposed project is located. Riparian reserves (RR) or riparian habitat conservation areas (RHCAs) are management allocations designed to provide a variety of functions for aquatic and terrestrial species (USDA FS 1994). For terrestrial species, these include providing habitat and connectivity between habitat patches (USDA FS 1994). The assessment processes to evaluate the effects of roads and recreational trails on riparian habitats should be divided into winter and nonwinter periods. We created five GIS models to evaluate the influences of winter recreation routes; three models provide a general index to the overall level of human influence on riparian habitats, and two models are species specific. Any or all of these models can be applied depending on the species being addressed and the issues identified for a project.

Riparian nonwinter habitat influence index—For the nonwinter period, a habitat influence index should be calculated for all the RRs or the RHCAs within the watershed. The habitat influence index is designed to address edge effects, and snag and downed log reduction road-associated factors. This index is calculated by using GIS and a current open-roads data layer. Open roads are buffered by 60 m on both sides, and the area within this buffer is determined for the entire area that is within RRs or RHCAs in a watershed. The 60-m buffer is based on information presented in Hamann et al. (1999) on the degree of habitat affected by woodcutting along roads. The area within the buffer is then divided by the total area within RR or RHCA in the watershed to determine the proportion of the riparian habitat influenced by open roads.

We calculated a relative rating to determine the extent that recreation activities influence riparian habitats. The relative rating is as follows: <30 percent of the RR or RHCA in an open road buffer is ranked as a low level of human influence on riparian habitats, 30 to 50 percent is ranked as a moderate level, and >50 percent is ranked as a high level of human influence on riparian habitats.

Riparian habitat nonwinter route density index—In addition to the habitat influence index, the density of open roads within RRs or RHCAs should be calculated for the watershed by using a moving window analysis with a 0.9-km-radius circular window. This index is used to evaluate the potential for collisions, habitat loss and fragmentation, and edge-effect road-associated factors to influence wildlife habitats. A high level of human influence on riparian habitat = >25 percent of the riparian habitat within a watershed has route densities >3.2 km/0.9-km-radius circle (>2 mi/mi^2), a moderate level of human influence = >25 percent of the riparian habitat within watershed with route densities >1.6 km/0.9-km-radius circle (>1 mi/mi^2) and <3.2 km/0.9 km-radius circle (<2 mi/mi^2), and a low level of human influence = <25 percent of the riparian habitat within a watershed with route densities >1.6 km/0.9-km-radius circle (>1 mi/mi^2).

Riparian habitat winter recreation route density index—For the winter period, the density of plowed roads, groomed ski trails, and snowmobile routes within RRs or RHCAs in the watershed should be calculated by using a moving window analysis with a 0.9-km-radius circular window. This provides an index of the effects of winter recreation routes on riparian habitats. A high level of human influence on riparian habitat = >25 percent of the riparian habitat within a watershed that has route densities >3.2 km/0.9-km-radius circle (>2 mi/mi^2), a moderate level of human influence = >25 percent of the riparian habitat within a watershed with route densities >1.6 km/

0.9-km-radius circle (>1 mi/mi^2), and a low level of human influence = <25 percent of the riparian habitat within a watershed with route densities >1.6 km/0.9-km-radius circle (>1 mi/mi^2).

Bald eagle nesting habitat disturbance index—To evaluate the potential influences of human activities on bald eagle nesting habitat, the bald eagle nesting habitat disturbance index should be applied. This index should be applied to potential nesting habitat within a 5th-field watershed for activities that occur during the nesting period, which is February through August (Rodrick and Milner 1991). A 550-m zone of influence is applied to each side of nonmotorized trails and 450 m to motorized trails and roads. The zone of influence may be modified based on the topography adjacent to the linear recreation route. The proportion of potential nesting habitat within a zone of influence is then calculated and the following relative ranking is applied: <30 percent of the potential nesting habitat in a watershed in a zone of influence is ranked as a low level of human influence, 30 to 50 percent is ranked as a moderate level, and >50 percent is ranked as a high level of human influence on bald eagle nesting habitats.

Harlequin duck nesting habitat disturbance index—This index can be used to evaluate the level of human influence on harlequin duck nesting habitats during their nesting period. The nesting period on the Okanogan and Wenatchee National Forests is from February through August. This index is based on the amount of potential nesting habitat within a 5th-field watershed. A 50-m zone of influence is then applied to each side of roads, motorized trails, and nonmotorized trails. The proportion of the potential nesting habitats that occurs within a zone of influence is then determined for each watershed. A relative ranking can then be applied to compare the relative levels of human influence among watersheds. The relative rankings are <30 percent of the potential nesting habitat in a watershed in a zone of influence is ranked as a low level of human influence, 30 to 50 percent is ranked as a moderate level, and >50 percent is ranked as a high level of human influence on harlequin duck nesting habitats.

Information Gaps and Research

Research is needed to develop a thorough understanding of the influences of road- and trail-associated factors on riparian species, particularly research that links human uses to effects on animal population demographics. Specifically, research needs to be conducted to determine the extent to which roads and recreation trails serve as dispersal barriers or filters for amphibians and small mammals. A more complete understanding of the influences that road and recreation trails have on harlequin duck reproduction and survival is needed. For example, a better understanding of the relationship between the intensity of human use and its effects on harlequin duck reproduction would be helpful to design effective management strategies.

Monitoring and Adaptive Management

Habitat monitoring—Application of the assessment models for riparian-associated species could be applied periodically to assess trends in the influence of roads and recreation trails on riparian habitats. Validation monitoring needs to be implemented to determine the validity of the assessment models and link them to population demographics of the focal riparian species.

Population monitoring—Populations of Cascades frogs and small mammals (such as water shrews) could be monitored by using pitfalls traps (Jones et al. 1996) within riparian habitats that are influenced by road- and trail-associated factors, and compared to areas not influenced (to serve as controls). Specific locations where frogs disperse across roads should be monitored for road-specific mortality and to determine if management changes are needed. Populations of harlequin ducks could be surveyed following the Forest Service survey protocol and a comparison made between areas with roads and recreation trails compared to those without. A few bald eagle nest sites have been located on the Okanogan and Wenatchee National Forests, and they are being monitored as part of forest plan monitoring. Monitoring of black-capped chickadees in campground and noncampground sites could be accomplished by using point counts (Ralph et al. 1993) and following the methods of Blakesley and Reese (1988).

Waterfowl and Colonial Nesting Bird Habitat Assessment

Introduction and Focal Species Selection

A total of 97 wildlife species is in this group (see app.). Focal species that were selected included the common loon (*Gavia immer*), great blue heron (*Ardea herodias*), eared grebe (*Podiceps nigricolis*), and wood duck (*Aix sponsa*). Loons use large rivers and lakes as nesting habitat and are listed as a "sensitive" species. The eared grebe uses ponds and lakes up to the ponderosa pine zone and also is listed as a "sensitive" species. Great blue herons use lowland rivers, and wood ducks nest in cavities adjacent to small ponds and lakes. Together, these species represent a variety of habitats, and road- and trail-associated factors (table 13).

Summary of Recreation Route-Associated Factors for Focal Species

Human disturbance is known to negatively affect waterfowl and colonial waterbirds (Anderson 1988; Belanger and Bedard 1989, 1990; Boellstorff et al. 1988; Gotmark and Ahlund 1984; Havera et al. 1992; Henson and Grant 1991; Madsen 1985; Owens 1977; Pierce and Simons 1986; Tremblay and Ellison 1979). These studies have shown that human disturbances associated with recreational activities can affect productivity in many ways including nest abandonment, egg mortality owing to exposure, increased predation of eggs and hatchlings, depressed feeding rates on wintering and staging grounds, and avoidance of otherwise suitable habitat.

The common loon, great blue heron, eared grebe, and wood duck were selected as focal species and can be influenced by several forms of human activities (Hamann et al. 1999, Klein 1993, Titus and VanDruff 1981). The road and recreation trail factors associated with these species included disturbance during nesting, and displacement from habitat (table 13) (Ashley 1994, Hamann et al. 1999, Kelly 1992, Klein 1993, Markham and Brechtel 1979, McEneaney 1994, Rodgers and Smith 1995, Titus and VanDruff 1981, Vos et al. 1985, Wallen 1987, Werschkul et al. 1976). No ski- or snowmobile route-associated factors were identified for these species as winter recreation generally occurs outside of the nesting and rearing periods when they are the most susceptible.

Titus and VanDruff (1981) reported that population characteristics, nest and egg production, nest and egg losses, flushing distances, and hatching and brood rearing success for common loons was influenced by human activities such as hiking and boating, but there were no significant differences between areas of high and low human use. Vermeer (1973) showed an inverse relationship between numbers of breeding pairs of loons and the level of human disturbance. Ream (1976) reported that campers and canoeists displaced loons from their nests.

Klein (1993) reported that great blue heron responses to humans in vehicles and afoot varied from no response to flying away, and that they reacted more to humans on foot than in vehicles. Rodgers and Smith (1995) reported that great blue herons flushed at a mean distance of 32.0 ± 12.3 m in response to persons approaching on foot. They recommended a 100-m setback to limit disturbance to nesting colonies. Skagen et al. (2001) found a reduction in the number of great blue heron nests when they were

Table 13—Road- and recreation trail-associated factors for waterfowl and colonial nesting focal species

Focal species	Road-associated factors	Motorized trail-associated factors	Nonmotorized trail-associated factors	Snowmobile route-associated factors	Ski trail-associated factors
Common loon[a]	Disturbance at a specific site Displacement or avoidance	Disturbance at a specific site Displacement or avoidance	Disturbance at a specific site Displacement or avoidance		
Great blue heron[b]	Disturbance at a specific site Displacement or avoidance	Disturbance at a specific site Displacement or avoidance	Disturbance at a specific site Displacement or avoidance Route for competitors		
Eared grebe[c]	Disturbance at a specific site Displacement or avoidance	Disturbance at a specific site Displacement or avoidance	Disturbance at a specific site Displacement or avoidance		
Wood duck[d]	Snag reduction Disturbance at a specific site Displacement or avoidance	Disturbance at a specific site Displacement or avoidance Snag reduction	Disturbance at a specific site Displacement or avoidance Snag reduction		

[a] Sources: Hamann et al. 1999, Ream 1976, Titus and VanDruff 1981, Vermeer 1973.
[b] Sources: Klein 1993, Rodgers and Smith 1995, Skagen et al. 2001.
[c] Source: Hamann et al. 1999.
[d] Source: Hamann et al. 1999.

exposed to humans on foot. In addition, she reported an increase in competition between great blue herons and cormorants, as cormorants were more tolerant of human activities.

Wood ducks nest in cavities and can be affected by the loss of snag habitat associated with firewood gathering and felling of snags for safety when roads are near nesting habitat (Hamann et al. 1999).

Assessment Processes for Focal Species

Waterfowl and colonial nester habitat disturbance index—To evaluate the cumulative effects of roads and recreation trails on nesting and habitat use, the assessment model described below would be applied at the 5th-field watershed scale. Potential nesting habitats such as lakes, rivers, and ponds should be identified within a watershed and put into GIS. A 250-m habitat zone is then placed around each of the identified habitats, and the area within this zone is summed for the watershed. These habitats are overlaid with roads, motorized trails, and nonmotorized trails. Roads and recreation trails are then buffered by a 250-m zone of influence on each side. The proportion of the habitat zone that lies outside of a zone of influence of a road or trail is then determined. The 250-m zone of influence is based on distances at which birds have been observed to be affected by human disturbances (Hamann et al. 1999, Kelly 1992, Markham and Brechtel 1978, Rodgers and Smith 1995, Vos et al. 1985).

Outputs of this model include the proportion of potential habitat in a watershed affected by road-associated factors, motorized trails and nonmotorized trails, and the overall influence of roads and trails.

Hamann et al. (1999) reported that when over half of the available habitat around a lake was disturbed by human activities, loons did not nest. This estimate was used to establish a preliminary cumulative effects threshold and to rank the level of human influence on these habitats within a watershed. The relative ranking is as follows: <50 percent of the potential habitat outside of the zone of influence of a road or trail is ranked as high level of human influence, 50 to 70 percent of the potential habitat in a zone of influence is ranked as moderate level of human influence, and >70 percent is ranked as a low level of human influence.

Information Gaps and Research Needs

Additional research is needed to relate road- and trail-associated factors to demographic responses of the focal species. In addition, research that explores how different types and intensities of road and trail uses affect focal waterfowl and colonial nester species would allow for the refinement of the cumulative effects models.

Monitoring and Adaptive Management

Habitat-effectiveness monitoring—The cumulative effects model described for these focal species could be used to establish baseline conditions for their habitats within watersheds. These models could then be periodically applied to monitor trends in human influences on habitat over time.

Population monitoring—The numbers and productivity of the focal species in this group could be monitored by selecting representative lakes, ponds, and rivers that have different levels of human activities adjacent to them. In this manner, population trends could be monitored, and these trends could be correlated to different levels of human activity.

Primary Cavity Excavator Habitat Assessment

Introduction and Focal Species Selection

A total of 11 species was included in the primary cavity excavator (PCE) group (see app.). The species selected as focal species included the white-headed woodpecker, three-toed woodpecker (*Picoides tridactylus*), and pileated woodpecker (*Dryocopus pileatus*) (table 14). The white-headed woodpecker was selected because of its association with old ponderosa pine forests, three-toed woodpeckers with subalpine fir forests, and pileated with mixed-conifer forests.

Summary of Recreation Route-Associated Factors for Focal Species

Only road-associated factors were identified for these species as the available literature did not suggest that recreation trail-associated disturbances presented a problem for primary cavity excavators (Hamann et al. 1999). Recreational activity is unlikely to be focused around the nest sites of these species and, by design, woodpeckers and other cavity users are relatively more secure from nest predation than any other group of forest birds (Hamann et al. 1999). Therefore, at present, recreational disturbance is not known to be a major limiting factor.

The road-associated factors included the negative edge effects of roads on PCE habitat and snag and down log reduction resulting from wood cutting and safety practices along roads (table 14) (Bull and Holthausen 1993, Hitchcox 1996, Hutto 1995, Milne and Hejl 1989, Raphael and White 1976). The distances in which woodcutters can harvest snags from roads differ according to terrain. Distances reported by Hamann et al. (1999) ranged from 65 to 200 m.

Table 14—Road- and trail-associated factors for primary cavity excavator focal species

Focal species	Road-associated factors	Motorized trail-associated factors	Nonmotorized trail-associated factors	Snowmobile route-associated factors	Ski trail-associated factors
White-headed woodpecker[a]	Snag reduction Edge effects				
Three-toed woodpecker[a]	Snag reduction Edge effects				
Pileated woodpecker[a]	Snag reduction Down log reduction Edge effects				

[a] Sources: Bull and Holthausen 1993, Hamann et al. 1999, Hitchcox 1996, Hutto 1995, Milne and Hejl 1989, Raphael and White 1976.

Assessment Processes for Focal Species

Primary cavity excavator habitat influence index—The assessment processes to evaluate the cumulative effects of road-associated factors on primary cavity excavators would be applied to the 5th-field watershed. Open roads that occur within forested habitats (>10 percent tree cover) are buffered by 60 m on each side to determine the potential influence on cavity excavator habitat. The amount of forested habitat within this buffer is then determined and divided by the total amount of forested habitat within the watershed. In this manner, an index to the proportion of primary cavity excavator habitat influenced by roads within a watershed is derived. A relative ranking is then determined based on the following scale: <30 percent of forested habitat in an open road buffer is ranked as a low level of human influence on primary cavity excavator habitat, 30 to 50 percent is ranked as a moderate level of influence, and >50 percent is ranked as a high level of influence.

Information Gaps and Research

Research is needed to link road-associated factors to the demography of the focal species for this wildlife group. Additional research is needed to validate the assumption that recreation trails are not a limiting factor for primary cavity excavator populations.

Monitoring and Adaptive Management

Habitat monitoring—The habitat influence index for primary cavity excavators could be applied periodically to determine baseline conditions and track the changes to habitat over time. Monitoring needs to be completed to validate the zone of influence along roads in primary cavity excavator habitat. This could be done by sampling habitat structure at varying distances from roads in a variety of forested habitat types.

Population monitoring—Populations of primary cavity excavators could be monitored by using point counts (Bull et al. 1990, Huff et al. 2001) established in a variety of habitats and in areas with and without road- and recreation trail-associated factors.

Application of the Recreation Route Cumulative Effects Models: A Case Study

This section illustrates how cumulative effects of linear recreation routes on wildlife habitats can be assessed by using the GIS models developed in the previous sections. This section is intended to display current conditions relative to the influences that linear recreation routes have on various wildlife habitats, which in turn provides a baseline of information for planning efforts. Finally, this section discusses the results and management implications of applying the proposed cumulative effects models.

Assessment Area

The assessment area includes all of the lands that lie to the east of the crest of the North Cascade Range between Lake Chelan and the Interstate 90 Highway corridor, extending east to the Columbia River. This area provides a diversity of winter and nonwinter recreation opportunities and a diversity of wildlife habitats making it an excellent area to "test drive" the proposed cumulative effects process. The area includes 11 BMUs, 22 LAUs, 9 ungulate winter range units, 15 LSRs (including MLSAs), and 19 5^{th}-field watersheds.

Assessment Models Applied

We applied 15 of the 18 GIS cumulative effects assessment models to evaluate wildlife habitats within the case study area (table 15). Four of the models were used to evaluate winter recreational activities on wildlife habitats; 10 models were for the nonwinter periods, and one model, the wolverine denning model, included winter and spring periods. The three models that were not applied included the deer and elk summer habitat effectiveness model, bald eagle nesting habitat disturbance model, and Harlequin duck nesting habitat disturbance model. These models were not run at this time because of either limited computing power or a lack of information about the habitat of a focal species.

Results and Discussion

Wide-ranging carnivore habitats—During the early season, 36 percent of the BMUs were rated as a high level of human influence, 27 percent as moderate, and 36 percent as low (table 16). During the mid and late seasons, trails became snow free and received enough use to be classified as high-use trails resulting in a higher proportion of BMUs with a high level of human influence. Sixty-four percent of the BMUs were ranked as high level of human influence, 18 percent as moderate, and 18 percent as low during the mid and late seasons (table 16).

This analysis suggests that cumulative effects are more of an issue for grizzly bear habitats during the mid and late seasons within the assessment area. Cumulative effects could be reduced through access management, and these opportunities could be identified during roads analysis (USDA FS 2000c). Seasonally important habitats to be considered for inclusion in core areas have been identified for each of these BMUs in the North Cascades ecosystem grizzly bear habitat assessment (NCETT 2001).

During the nonwinter period, 36 percent of the analysis areas for gray wolf and wolverine habitats were ranked as having a high level of human influence, 36 percent as moderate, and 27 percent as low (table 17). Cumulative effects were more of an issue during the nonwinter season based on this analysis. Habitat effectiveness could be restored through road access management, and opportunities could be identified during roads analysis (USDA FS 2000c). During winter, all the assessment areas were ranked as having a low level of human influence from groomed and designated winter recreation routes (table 18). This assessment did not include winter routes that are not groomed or officially designated, such as snowmobile routes or snow-play areas. These have the potential to result in additional cumulative effects.

Table 15—Species groups, focal species, cumulative effects indices, and assessment areas used in the cumulative effects of roads and recreation trails on wildlife habitats case study

Species group	Focal species	Index	Analysis unit
Wide-ranging carnivores	Grizzly bear	Grizzly bear assessment model	Bear management unit
Wide-ranging carnivores	Gray wolf and wolverine	Gray wolf and wolverine assessment model	Bear management unit
Wide-ranging carnivores	Wolverine	Potential denning habitat model	Potential denning habitat within bear management units
Wide-ranging carnivores	Lynx	Lynx assessment model	Lynx analysis unit
Ungulates	Deer and elk	Winter habitat disturbance index	Winter range unit
Ungulates	Bighorn sheep	Summer or winter habitat disturbance index	Summer or winter range unit
Ungulates	Deer and elk	Summer habitat disturbance index	Fifth-field watersheds
Ungulates	Mountain goat	Winter habitat disturbance index	Fifth-field watersheds
Late successional	Northern spotted owl, goshawk, brown creeper, American marten, fisher, flying squirrel, pygmy nuthatch, white-breasted nuthatch, white-headed woodpecker	Nonwinter habitat influence index	Late-successional habitat in reserves or fifth-field watersheds
Late successional	Northern spotted owl, goshawk, brown creeper, American marten, fisher, flying squirrel, pygmy nuthatch, white-breasted nuthatch, white-headed woodpecker	Nonwinter security habitat	Late-successional habitat in reserves or fifth-field watersheds
Late successional	Northern spotted owl, goshawk, brown creeper, American marten, fisher, flying squirrel, pygmy nuthatch, white-breasted nuthatch, white-headed woodpecker	Winter security habitat	Late-successional habitat in reserves or fifth-field watersheds
Riparian	Cascades frog, tailed frog, harlequin duck, bald eagle, water shrew	Nonwinter habitat influence index	Riparian reserves within fifth-field watersheds
Riparian	Cascades frog, tailed frog, harlequin duck, bald eagle, water shrew	Nonwinter road density index	Riparian reserves within fifth-field watersheds
Riparian	Cascades frog, tailed frog, harlequin duck, bald eagle, water shrew	Winter recreation route density index	Riparian reserves within fifth-field watersheds
Riparian	Bald eagle	Nesting habitat disturbance index	Nesting habitat within fifth-field watersheds
Riparian	Harlequin duck	Nesting habitat disturbance index	Nesting habitat within fifth-field watersheds
Waterfowl and colonial nesters	Common loon, great blue heron, eared grebe, wood duck	Habitat disturbance index	Habitats within fifth-field watersheds
Primary cavity excavators	White-headed woodpecker	Habitat influence index	Forested habitats within fifth-field watersheds

Table 16—Cumulative effects of roads and trails on grizzly bear habitat within bear management units (BMUs) in the case study area

BMU	Early season core	Relative ranking[a]	Mid and late season core	Relative ranking[a]
	Percent		*Percent*	
Upper Chelan	87	Low	82	Low
Lower Chelan	62	Moderate	53	High
Upper Entiat	40	High	47	High
Lower Entiat	19	High	18	High
Chiwawa	60	Moderate	55	Moderate
Upper Wenatchee	73	Low	61	Moderate
Lower Wenatchee	38	High	39	High
Icicle	82	Low	73	Low
Peshastin	35	High	36	High
Swauk	63	Moderate	20	High
Cle Elum	81	Low	33	High

[a] High level of human influence = <55 percent core area per BMU, moderate level of human influence = 55 to 70 percent core area per BMU, and low level of human influence = >70 percent core area per BMU.

Table 17—Cumulative effects of roads and motorized trails on gray wolf and wolverine habitat within bear management units (BMUs) in the case study area

BMU	Areas with no roads	Areas with road densities >0 and <1.6 km/ 0.9-km-radius circle	Areas with road densities >1.6 km/0.9-km-radius circle	Relative ranking[a]
	- - - - - - - -	*Percent*	- - - - - - - -	
Upper Chelan	100	0	0	Low
Lower Chelan	57.3	9.9	32.8	Moderate
Upper Entiat	50.2	8.6	41.2	Moderate
Lower Entiat	6.7	9.1	84.2	High
Chiwawa	58.2	5.2	36.6	Moderate
Upper Wenatchee	67.1	6.8	26.1	Low
Lower Wenatchee	31.1	9.5	59.4	High
Icicle	84.3	4.0	11.7	Low
Peshastin	28.6	10.0	61.3	High
Swauk	13.9	8.7	77.3	High
Cle Elum	46.5	7.9	45.6	Moderate

[a] High level of human influence = <50 percent of a BMU with an open road/trail density of 3.2 km/0.9-km radius circle (<1 mi/mi^2), moderate level of human influence = 50 to 70 percent of a BMU with an open road/trail density of between 1.6 and <3.2 km/0.9-km radius circle (<1 mi/mi^2 and <2), and low level of human influence = >70 percent of a BMU with an open road/trail density of >1.6 km/0.9-km radius circle (<1 mi/mi^2).

The assessment of cumulative effects of groomed and designated winter recreation routes on lynx habitats showed that 4 percent of the LAUs had a high level of human influence, 20 percent had a moderate level, and 76 percent had a low level (table 19). Based on this analysis, cumulative effects are a significant issue within the Cascade crest LAU in the assessment area. This assessment did not include winter routes that are not groomed or officially designated, such as snowmobile routes or snow play areas. These have the potential to result in additional cumulative effects.

Table 18—Cumulative effects of groomed and designated winter recreation routes on potential wolverine denning habitat within bear analysis units (BMUs) in the case study area

BMU	Denning habitat	Proportion of denning habitat with road densities >1.6 km/0.9-km-radius circle	Proportion of denning habitat with road densities >3.2 km/0.9-km-radius circle	Relative ranking[a]
	Hectares	- - - - - - - - - - - - *Percent*	- - - - - - - - - - -	
Upper Chelan	283	0	0	Low
Lower Chelan	1124	0	0	Low
Upper Entiat	1761	0	0	Low
Lower Entiat	162	0	0	Low
Chiwawa	332	0	0	Low
Upper Wenatchee	1014	0	0	Low
Lower Wenatchee	1500	0.1	0	Low
Icicle	3119	0	0	Low
Peshastin	143	0	0	Low
Swauk	793	0	0	Low
Cle Elum	793	0	0	Low

[a] High level of human influence = >25 percent of the BMU with route densities 3.2 km/0.9-km radius circle (>2 mi/mi^2), moderate level of human influence = >25 percent of the BMU with route densities between 1.6 and <3.2 km/0.9-km radius circle (>1 mi/mi^2 and >2), and low level of human influence = <25 percent of the BMU with route densities >1.6 km/0.9-km radius circle (>1 mi/mi^2).

Table 19—Cumulative effects of groomed winter recreation routes within lynx analysis units (LAUs) in the case study area

LAU	Proportion of the LAU with groomed route densities <1.6 km/ 0.9-km-radius circle	Proportion of the LAU with groomed route densities 1.6 to 3.2 km/ 0.9-km-radius circle	Proportion of the LAU with groomed route densities >3.2 km/ 0.9-km-radius circle	Relative ranking[a]
Cascade Crest	19.5	23	57.5	High
Cooper Mountain	100	0	0	Low
Ferry Basin	100	0	0	Low
Hungry Ridge	100	0	0	Low
Indian Head Basin	100	0	0	Low
Copper Peak	100	0	0	Low
Upper Entiat	100	0	0	Low
Pyramid	99.9	.1	0	Low
Lake Basin	82.9	13.9	3.2	Low
Chiwawa	93.2	6.8	0	Low
Garland	92.7	7.2	.1	Low
Cougar	86.6	8.7	4.7	Low
Chumstick Mountain	70.7	10.8	18.5	Moderate
White River	99.4	.4	.2	Low
Little Wenatchee	100	0	0	Low
Nason	85.1	8.3	6.6	Low
Icicle Ridge	99.9	.1	0	Low
Upper Icicle	98.6	1.0	0.4	Low
Enchantment	99.8	.2	0	Low
Table Mountain	72.2	14	13.8	Moderate
Teanaway	83.6	11.1	5.3	Low
Waptus	92.6	6.2	1.2	Low
Sasse Ridge	73.1	10.8	16.1	Moderate
Silver	77.1	14	8.9	Moderate
Keechelus Ridge	63.9	13.1	23	Moderate

[a] High level of human influence = >25 percent of the LAU with route densities 3.2 km/0.9 km (>2 mi/mi^2), moderate level of human influence = >25 percent of the LAU with route densities between 1.6 and <3.2 km/0.9-km radius circle (>1 mi/mi^2), and low level of human influence = <25 percent of the LAU with route densities >1.6 km/0.9 km-radius circle (>1 mi/mi^2).

Table 20—Cumulative effects of groomed and designated winter recreation routes on deer and elk winter ranges within watersheds in the case study area

Watershed	Hectares of winter range	Percentage outside of a zone of influence	Relative ranking[a]
Chelan	3584	92.4	Low
Entiat	5893	95.9	Low
Columbia River-Antoine	2466	63.6	Moderate
Wenatchee	9358	92.9	Low
Columbia River-Navarre	2142	87.9	Low
Columbia River-Swakane	5360	98.7	Low
Mission	5216	87.7	Low
Columbia River-Stemilt	1158	97.8	Low
Swauk-Naneum	2134	95.4	Low

[a] Low = >70 percent outside a zone of influence, moderate = 50 to 70 percent outside a zone of influence, and high = <50 percent outside a zone of influence.

Table 21—Cumulative effects of nonwinter recreation routes on bighorn sheep summer ranges in the case study area

Bighorn sheep summer range	Percentage outside zone of influence	Relative ranking[a]
Lake Chelan	55.4	Moderate
Swakane	33.8	High

[a] Low = >70 percent outside a zone of influence, moderate = 50 to 70 percent outside a zone of influence, and high = <50 percent outside a zone of influence.

Table 22—Cumulative effects of groomed and designated winter recreation routes on bighorn sheep winter ranges in the case study area

Bighorn sheep winter range	Hectares	Percentage outside zone of influence	Relative ranking[a]
Lake Chelan	15 461	93.7	Low
Swakane	3 352	95.0	Low

[a] Low = >70 percent outside a zone of influence, moderate = 50 to 70 percent outside a zone of influence, and high = <50 percent outside a zone of influence.

Ungulate winter habitats and bighorn sheep nonwinter habitats—During winter, groomed and designated winter recreation routes had lower levels of cumulative effects. None of the winter ranges had a high level of human influence on deer and elk, 10 percent had a moderate level, and 90 percent had a low level (table 20). This same trend occurred for bighorn sheep. Assessment units for nonwinter bighorn sheep habitats showed one with a high level and one with a moderate level of human influence (table 21), whereas during winter, both ranked as low levels (table 22).

The cumulative effects of nonwinter recreation routes on deer and elk habitat could be reduced through management of roads. Opportunities to enhance deer and elk habitat effectiveness through road management could be addressed during roads analysis (USDA FS 2000c). Only groomed and designated routes were considered in this assessment. Other routes may occur and could contribute to additional cumulative effects.

Late-successional forest habitats—The results of applying the cumulative effects models to late-successional habitats within LSRs and MLSAs showed that nonwinter recreation routes currently ranked as a low level of direct habitat loss (table 23). However, nonwinter recreation routes had a high level of human influence on habitat effectiveness within 31 percent of the LSRs and MLSAs, a moderate level in 56 percent, and a low level in 13 percent (table 24). Habitat effectiveness could be improved through human access management, and opportunities could be identified during roads analysis (USDA FS 2000c) and project-level analyses. Groomed and designated winter recreation routes had a low level of human influence on winter habitat effectiveness of late-successional habitats (table 25). Other winter routes that are not groomed or designated were not considered in this assessment and may result in additional cumulative effects.

Riparian habitats—The analysis of cumulative effects of nonwinter recreation routes on riparian habitat effectiveness showed that 95 percent of the assessment units had a high level of human influence, and 5 percent had a low level (table 26). This analysis showed that roads have the greatest cumulative effect on riparian habitat effectiveness. Opportunities to restore habitat effectiveness for riparian habitats could be identified during roads analysis (USDA FS 2000c).

The riparian habitat influence index estimates the cumulative effects that roads have on habitat loss within riparian habitats. This assessment showed that 26 percent had a moderate level, and 74 percent had a low level (table 27). Opportunities to restore riparian habitats through road management could be identified through roads analysis (USDA FS 2000c).

The winter route density index provides an estimate of the cumulative effects of winter recreation routes on riparian habitat effectiveness. This assessment showed that 5 percent of the assessment areas ranked as a high level of human influence, 26 percent as a moderate level, and 68 percent as a low level (table 28).

The assessments of riparian habitats showed that cumulative effects of linear recreation routes had the greatest impact from nonwinter recreation routes, reducing habitat effectiveness. Habitat effectiveness of riparian habitats could be restored through route access management and restoration opportunities identified through roads analysis (USDA FS 2000c). Riparian areas provide habitat for a large number of wildlife species (Thomas et al. 1979) and therefore should receive high priority for restoration.

Waterfowl and colonial nesting bird habitats—The cumulative effects analysis for waterfowl and colonial nesting bird habitats showed that 68 percent of the assessment areas had a high level of human influence, 21 percent had a moderate level, and 10 percent had a low level (table 29). Based on this assessment, cumulative effects on these habitats are relatively high. These areas provide habitat for a large number of

Table 23—Habitat influence index for late-successional forest habitats within late-successional reserves (LSRs) and managed late-successional areas (MLSAs) in the case study area

LSR/MLSA	Percentage inside zone of influence	Relative ranking[a]
Slide Peak	10.1	Low
Icicle	17.7	Low
Boundary Butte	24.5	Low
Sawtooth	0	Low
Shady Pass	10.8	Low
Chiwawa	14.0	Low
Lake Wenatchee	14.2	Low
Deadhorse	15.3	Low
Teanaway	6.4	Low
Swauk	23.9	Low
Eagle	22.8	Low
Twin Lake	3.6	Low
Tumwater	16.3	Low
Camas	22.0	Low
Sand Creek	12.4	Low
Natapoc	24.7	Low

[a] Low = <30 percent of the habitat in a zone of influence, moderate = 30 to 50 percent, and high = >50 percent.

Table 24—Cumulative effects of nonwinter recreation routes on late-successional forest habitat effectiveness for late-successional reserves (LSRs) and managed late-successional areas (MLSAs) in the case study area

LSR/MLSA	Percentage outside zone of influence	Relative ranking[a]
Slide Peak	41.7	High
Icicle	56.5	Moderate
Boundary Butte	46.1	High
Sawtooth	59.9	Moderate
Shady Pass	63.6	Moderate
Chiwawa	56.3	Moderate
Lake Wenatchee	63.9	Moderate
Deadhorse	58.9	Moderate
Teanaway	56.3	Moderate
Swauk	38.1	High
Eagle	42.7	High
Twin Lake	82.8	Low
Tumwater	58.6	Moderate
Camas	42.7	High
Sand Creek	54.4	Moderate
Natapoc	49.2	Low

[a] Low = <30 percent of the habitat in a zone of influence, moderate = 30 to 50 percent, and high = >50 percent.

Table 25—Cumulative effects of groomed and designated winter recreation routes on late-successional forest habitat effectiveness for late-successional reserves (LSRs) and managed late-successional areas (MLSAs) in the case study area

LSR/MLSA	Percentage outside zone of influence	Relative ranking[a]
Slide Peak	66.7	Low
Icicle	100.0	Low
Boundary Butte	99.0	Low
Sawtooth	100.0	Low
Shady Pass	98.3	Low
Chiwawa	84.2	Low
Lake Wenatchee	94.8	Low
Deadhorse	93.2	Low
Teanaway	96.0	Low
Swauk	84.8	Low
Eagle	10.0	Low
Twin Lake	100.0	Low
Tumwater	86.2	Low
Camas	100.0	Low
Sand Creek	100.0	Low
Natapoc	93.9	Low

[a] Low = <30 percent of the habitat in a zone of influence, moderate = 30 to 50 percent, and high = >50 percent.

Table 26—Nonwinter recreation route density index for riparian habitats in the case study area

Watershed	Percentage with recreation route densities <1.6 km/ 0.9-km-radius circle	Percentage with recreation route densities 1.6 to 3.2 km/ 0.9-km-radius circle	Percentage with recreation route densities >3.2 km/ 0.9-km-radius circle	Relative ranking[a]
Chelan	48.3	22.7	29.0	High
Chiwawa	24.6	26.2	49.2	High
Entiat	17.5	23.7	58.7	High
White-Little Wenatchee	39.8	19.5	40.7	High
Columbia River-Antoine	0	70.7	29.3	High
Mad	7.2	15.6	77.1	High
Columbia River-Navarre	40.2	9.4	50.4	High
Wenatchee	18.6	21.5	60.0	High
Nason	17.4	21.0	61.7	High
Columbia River-Entiat	84.3	8.9	6.8	Low
Icicle	30.4	30.0	39.5	High
Columbia River-Swakane	38.0	33.2	28.8	High
Cle Elum	25.0	20.9	54.2	High
Peshastin	11.1	18.1	70.9	High
Mission	33.9	19.5	46.5	High
Yakima	14.7	24.2	61.1	High
Columbia River-Stemilt	22.9	7.8	69.3	High
Peshastin	16.9	31.6	51.5	High
Swauk-Nanuem	6.8	5.2	88.0	High

[a] High level of human influence = >25 percent of the watershed with 3.2 km/0.9-km radius circle (>2 mi/mi^2), moderate level of human influence = >25 percent of the watershed with between 1.6 and <3.2 km/0.9-km radius circle (>1 mi/mi^2 and >2), and low level of human influence = <25 percent of the watershed with 1.6 km/0.9-km radius circle (>1 mi/mi^2).

Table 27—Nonwinter riparian habitat influence index for watersheds located in the case study area

Watershed	Hectares of riparian habitat	Percentage of riparian habitats in a zone of influence	Relative ranking[a]
Chelan	19 972	5.6	Low
Chiwawa	8 240	13.0	Low
Entiat	11 830	21.9	Low
White-Little Wenatchee	11 428	9.9	Low
Columbia River-Antoine	4	0	Low
Mad	3 803	22.7	Low
Columbia River-Navarre	753	35.3	Moderate
Wenatchee	11 361	33.9	Moderate
Nason	3 932	20.9	Low
Columbia River-Entiat	426	.9	Low
Icicle	8 493	6.7	Low
Columbia River-Swakane	1 261	23.6	Low
Cle Elum	11 328	11.0	Low
Peshastin	4 757	31.8	Moderate
Mission	2 768	20.1	Low
Yakima	7 228	14.9	Low
Columbia River-Stemilt	453	33.5	Moderate
Peshastin	4 829	14.6	Low
Swauk-Naneum	5 087	39.3	Moderate

[a] Low level of human influence = <30 percent of the habitat in the watershed within a zone of influence, moderate level of human influence = 30 to 50 percent of the habitat in the watershed within a zone of influence, and high level of human influence = >50 percent of the habitat in the watershed within a zone of influence.

Table 28—Winter recreation route density index for riparian habitats in the case study area

Watershed	Percentage with recreation route densities <1.6 km/ 0.9-km-radius circle	Percentage with recreation route densities 1.6 to 3.2 km/ 0.9-km-radius circle	Percentage with recreation route densities >3.2 km/ 0.9-km-radius circle	Relative ranking[a]
Chelan	92.9	6.3	1	Low
Chiwawa	69.6	20	11	Moderate
Entiat	87	12	1	Low
White-Little Wenatchee	91.2	4	4	Low
Columbia River-Antoine	100	0	0	Low
Mad	77.8	8.8	13.4	Low
Columbia River-Navarre	87.4	12.6	0	Low
Wenatchee	75.5	17.3	7.3	Moderate
Nason	63.8	20.2	16	Moderate
Columbia River-Entiat	59.4	40.6	0	Low
Icicle	98.7	1.3	0	Low
Columbia River-Swakane	95.8	4.2	0	Low
Cle Elum	73	13	14	Moderate
Peshastin	83.1	16.8	1	Low
Mission	98.2	1.8	0	Low
Yakima	54.8	20.5	25	High
Columbia River-Stemilt	83	7.8	9	Low
Peshastin	86.3	9.3	5	Low
Swauk-Naneum	52.2	23.2	25	High

[a] High level of human influence = >25 percent of the watershed with 3.2 km/0.9-km radius circle (<1 mi/mi^2), moderate level of human influence = >25 percent of the watershed with between 1.6 and <3.2 km/0.9-km radius circle (<1 mi/mi^2 and <2) and low level of human influence = <25 percent of the watershed with >1.6 km/0.9-km radius circle (<1 mi/mi^2).

Table 29—Cumulative effects analysis for waterfowl and colonial nesting bird habitats for watersheds in the case study area

Watershed	Percentage of habitat within a zone of influence	Relative ranking[a]
Chelan	34	Moderate
Chiwawa	55.1	High
Entiat	62.9	High
White-Little Wenatchee	55	Moderate
Columbia River-Antoine	0	Low
Mad River	74.4	High
Columbia River-Navarre	50.5	High
Wenatchee River	68.3	High
Nason Creek	65.9	High
Columbia River-Entiat	4.4	Low
Icicle	55.9	High
Columbia River-Swakane	41.9	Moderate
Cle Elum	55.7	High
Peshastin	77.8	High
Mission Creek	46.5	Moderate
Yakima	58.4	High
Columbia River-Stemilt	67.8	High
Peshastin	66.7	High
Swauk-Naneum	81.4	High

[a] High level of human influence = .50 percent of the habitat in the watershed outside a zone of influence, moderate level of human influence = 30 to 50 percent of the habitat in the watershed outside a zone of influence, and low level of human influence = <30 percent of the habitat in the watershed outside a zone of influence.

wildlife species and should be given high restoration priority. Opportunities to restore these habitats could be identified during roads analysis (USDA FS 2000c) and considered in project-level evaluations.

Primary cavity excavator habitats—The cumulative effects analysis of roads on habitats for primary cavity excavators showed that 90 percent of the assessment units ranked as a low level of human influence, and 10 percent ranked as a moderate level of human influence (table 30). Relative to other focal species habitats, cumulative effects do not seem to be a significant issue for primary cavity excavators within the assessment area.

Management Implications

This section provides information on the current condition of wildlife habitat for focal species relative to the cumulative effects of linear recreation routes. This information can be used to determine the significance of cumulative effects as an issue at the project scale. For example, if a project is proposed within an assessment area ranked as currently having a high level of human influence, then cumulative effects would be an important issue to address. This issue could be addressed by using the assessment models described in this document. This section also provides an evaluation of baseline conditions to which project-level assessments can be tiered. Finally, this information can be used to identify priorities for restoration of important habitats. The most notable restoration needs based on this assessment are core areas for grizzly bears, late-successional habitat effectiveness, riparian habitat effectiveness, and wetland habitat effectiveness.

Table 30—Cumulative effects analysis for primary cavity excavator habitats for watersheds located in the case study area

Watershed	Percentage of habitat within a zone of influence	Relative ranking[a]
Chelan	6.7	Low
Chiwawa	13.6	Low
Entiat	21.0	Low
White-Little Wenatchee	7.8	Low
Columbia River-Antoine	6.5	Low
Mad River	29.2	Low
Columbia River-Navarre	45.1	Moderate
Wenatchee River	26.7	Low
Nason Creek	17.4	Low
Columbia River-Entiat	22.6	Low
Icicle	4.1	Low
Columbia River-Swakane	24.1	Low
Cle Elum	13.3	Low
Peshastin	28.9	Low
Mission Creek	15.3	Low
Yakima	23.9	Low
Columbia River-Stemilt	27.0	Low
Peshastin	9.2	Low
Swauk-Naneum	47.5	Moderate

[a] Low level of human influence = <30 percent of the habitat in the watershed within a zone of influence, moderate level of human influence = 30 to 50 percent of the habitat in the watershed within a zone of influence, and high level of human influence = >50 percent of the habitat in the watershed within a zone of influence.

Some tools that can be used to restore habitat effectiveness are described in general terms below and are based on Knight and Gutzwiller (1995) and Colorado State Parks (1998).

- Spatial separation of humans and wildlife in key habitats. This approach could be used to address situations where displacement/avoidance interactions have been identified for a wildlife species of management interest.
- Temporal separation of humans and wildlife at critical periods. This tool could be applied where the interaction of displacement at a specific site has been identified for a wildlife species of management interest.
- Human behaviors that reduce the effects of recreation on wildlife can be taught through information and education programs.
- Facilities designed with wildlife habitat values in mind. If wildlife habitat issues are identified in the early stages of projects, they can be addressed proactively through project design. Hopefully, the information provided in this assessment will help accomplish this.

To proactively address wildlife conservation and recreation opportunities, we need to begin addressing these issues through our landscape-scale planning processes, such as forest-level planning. This will help in identifying important habitats for wildlife and recreational opportunities for humans. This process could be accomplished by using the following approach:

- Assess the existing level of influence that recreational activities have on wildlife habitats by applying the GIS models and establishing baseline conditions.
- Set compatible wildlife habitat goals and recreation goals through an interdisciplinary planning process.
- Gain further knowledge about wildlife and recreation interactions through an adaptive-management approach. This will require a high level of collaboration between managers and researchers to jointly develop scientifically credible monitoring.
- Adapt habitat and recreation goals based on new information.

The following section provides a framework for how to approach adaptive management and monitoring. This framework will allow us to address the mutual goals of conserving wildlife species while providing recreation opportunities. These goals have many commonalities, not the least of which is the desire of people to experience wildlife during their recreational outings.

Monitoring and Adaptive Management

Monitoring has been identified as an integral part of an adaptive-management approach to natural resource conservation (Christensen 1997; Christensen et al. 1996; Everett et al. 1994; Gaines et al. 1999; Gutzwiller 1991, 1993; Noss and Cooperrider 1994). Monitoring is defined as the collection and analysis of repeated observations or measurements to evaluate changes in condition and progress toward meeting a management objective (Elzinga et al. 1998). Adaptive management is a systematic process for continually improving management policies and practices by learning from the outcomes of operational programs (Nyberg 1998). Adaptive management blends methods of scientific investigation with deliberate manipulations of managed systems. Adaptive management embodies a simple imperative: **policies are experiments and we must learn from them** (Lee 1993).

Adaptive management shares much of its theoretical basis with similar concepts from other fields. Examples include the continuous improvement process in business (Deming 1986, Walton 1986), adaptive control process theory in engineering, and operations research and management (McLain and Lee 1996). An adaptive management approach is particularly useful when dealing with complex management questions and high levels of uncertainty (Nyberg 1998, Walters 1986), both of which confront natural resource managers. One set of complex issues fraught with uncertainty is the management dilemma of balancing recreational opportunities with the conservation of ecological functions and processes. It would seem that using an adaptive-management approach, coupled with credible monitoring, is critical to address these issues.

Scientists can play an important role in adaptive management (Walters 1986), but it is the local resource professionals who must become “adaptive managers” if the promise of the concept is to be realized through its application to natural resource management issues (Nyberg 1998). As part of their everyday jobs, resource managers must be able to design and implement studies that produce reliable information about complex natural resource issues.

An Adaptive-Management and Monitoring Process

The process for designing and implementing an adaptive management project involves seven steps (based on Elzinga et al. 1998): (1) complete background tasks, (2) develop objectives, (3) design and implement management, (4) design the monitoring methods, (5) implement monitoring, (6) report and use results, and (7) adapt management in light of monitoring results. These seven steps are described in detail below.

Step 1. Background tasks—This step involves compiling and reviewing existing information, including relevant management direction. Important decisions to be made at this step include what the priorities are for monitoring (e.g., focal species habitat or population), what resources are available for monitoring, appropriate temporal and spatial scales, and the intensity of the monitoring efforts.

Step 2. Develop clear, well-defined objectives—At this step, general management goals and objectives are defined, and monitoring indicators are selected. The desired direction of change (e.g., a 10-percent increase in habitat effectiveness) is described, and specific timeframes for achieving the desired direction are identified.

Step 3. Design and implement management—At this step, the project is implemented. It is important that monitoring be considered an integral part of the initial project design as opposed to an afterthought.

Step 4. Design the monitoring method—This critical step involves identifying the sampling objectives and methods, defining sampling units, estimating the number of sampling units required, noting sampling frequency, and identifying the resources needed to carry out the monitoring. Randomization, stratification, and replication are important concepts to integrate into the monitoring methods and have implications for the types of statistical methods that can be used in data analyses. Identifying the likely statistical methods that will be used in analysis is also important at this step. Seeking peer review of the monitoring and statistical methods is very important and should be an integral part of this step. This step must be completed along with project design so that project and monitoring objectives are integrated.

Step 5. Implement monitoring—This step includes the collection of field data, analysis of data after each measurement cycle, and evaluation of monitoring results. Periodic analysis after measurement cycles allows for adjustments to be made in the monitoring methods.

Step 6. Report and use results—For monitoring and adaptive management to be successful, the results, and their applications, must be displayed to managers, interested parties, and decisionmakers. In addition, it is important to leave tracks for successors, as some monitoring may be long term. Seeking peer review of the analysis methods and results is very important and should be an integral part of this step.

Step 7. Adapt management approaches given the monitoring results—If monitoring is irrelevant to how resources are managed, then this step is not useful. However, if monitoring is carried out in a way that views management approaches as experimental, is designed into projects at their inception, and is done in a scientifically rigorous manner, then it can be used to guide management of natural resources.

A Hypothetical Adaptive-Management Plan

Step 1. Background—There is a proposal to build a trail for motorized use in order to separate motorized from nonmotorized trail recreation. The project occurs in a roadless area designated for motorized and nonmotorized trail recreation and in a habitat reserve that emphasizes late-successional habitat for species associated with late-successional forest. The land allocations have two goals: provide recreation trail opportunities and maintain security habitat for late-successional species. The specific security habitat goals were described in the reserve assessment (USDA FS 1997), which called for managing toward a goal of a "high" level of security habitat, which is defined as >70 percent security habitat in the reserve. Application of the late-successional habitat cumulative effects models (as presented in this document) resulted in a concern by the interdisciplinary team (IDT) in meeting recreation needs and maintaining habitat effectiveness for wildlife. This prompted the IDT to propose an adaptive management approach for this project.

The focal species selected for monitoring include breeding birds associated with late-successional forests (brown creeper, pygmy nuthatch, white-breasted nuthatch, white-headed woodpecker) and the American marten.

Step 2. Objectives—The management goal is to maintain or improve security habitat for species associated with late-successional forest while providing for trail recreation opportunities. The objective is to determine (1) if motorized trail use decreases habitat effectiveness for the focal species, and (2) if nonmotorized trail use decreases habitat effectiveness for the focal species. The indicators that will be monitored include (1) population indices for late-successional breeding bird species and American marten along the proposed motorized trail, along a nonmotorized hiking trail, and in an area with no trails; and (2) the zone of influence at which focal species may be affected by motorized and or nonmotorized trails, compared to control (trailess) areas.

Monitoring will be implemented for two field seasons following construction of the trail. Monitoring could lead to several possible management changes. First, monitoring may indicate that cumulative effects models need to be revised. Second, if monitoring results in modifications to the cumulative effects models, then the cumulative effects of the current conditions (baseline conditions) will be reassessed based on the new information. Finally, monitoring results will be applied to the evaluation of any future project to assess habitat effectiveness for late-successional focal species in the habitat reserve.

Step 3. Project design and implementation—Because the IDT wants to take an adaptive-management approach, they will craft the decision notice to implement the project in three phases. Phase 1 would construct the trails beginning the first field season following a final decision. Phase 2 will be the monitoring of focal species during two field seasons immediately after completion of the trail construction. Phase 3 would include a final evaluation of the monitoring information and appropriate management adjustments to the cumulative effects model and reevaluation of the trail network within the habitat reserve to assess attainment of security habitat goals. This example shows how management decisions can be crafted to incorporate adaptive management.

Step 4. Monitoring methods—Monitoring of birds would take place during two breeding seasons immediately following completion of trail construction. Methods will be based on Hickman (1990) and Miller et al. (1998) and include bird point count stations (Ralph et al. 1993) located on and at various distances from motorized and nonmotorized trails, and areas with no trails. A total of 72 point count stations will be located in similar habitats. A total of nine 150-m segments would be monitored, three each along the motorized, nonmotorized, and no-trail areas. Table 31 summarizes the number of bird point count stations at various distances from the trails that would be monitored.

Monitoring of the American marten would rely on the track plate method from Zielinski and Kucera (1995) as modified by Foresman and Pearson (1998). Track plate monitoring would occur at various distances from the trails (table 31) and would include a total

Table 31—Monitoring efforts for the hypothetical adaptive management trail project to address the effects of motorized and nonmotorized recreation trails on late-successional focal species

	No trail				Nonmotorized trail				Motorized trail			
Distance from trail (meters)	0	100	200	300	0	100	200	300	0	100	200	300
Bird point count stations (number)	6	6	6	6	6	6	6	6	6	6	6	6
Marten track plate stations (number)		6	6	6		6	6	6		6	6	6

of 54 monitoring stations conducted during two summer field seasons following trail construction. A total of nine 150-m segments within similar habitats would be monitored; three each along the motorized, nonmotorized, and no-trail areas.

Analysis of variance will be used to compare the detection rates of the focal species at each distance from the trail and for each trail type. Alpha for significance testing would be set at 0.05.

Step 5. Implement and monitor—District recreation specialists and wildlife biologists would work cooperatively to implement and monitor the trail projects as described in the adaptive-management plan and decision notice.

Step 6. Report and use—The district biologists and recreation specialists would summarize their monitoring results and present them to the district leadership team. The monitoring results and report will be peer reviewed and published to assure accuracy and objectivity, and to make them available for others to use.

Step 7. Management adjustments—Based on the monitoring results, the district leadership team will review the cumulative effects model and trail network within the habitat reserve to make adjustments to meet the goals for habitat effectiveness for late-successional wildlife species and to provide recreation opportunities.

Conclusion

Monitoring that is well thought out can be used to validate the assumptions of the cumulative effects models developed in this assessment, and to gain a better understanding of the interactions between wildlife and recreation. The use of adaptive management allows managers to acknowledge uncertainties and information gaps but still move forward with project design and implementation. To implement an adaptive approach, researchers and managers will have to work closely together. But by learning as we go, through the use of monitoring for adaptive management, we will have a higher probability of accomplishing the mutual objectives of providing a highly effective wildlife habitat and offering recreation opportunities.

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English Equivalents

When you know:	Multiply by:	To find:
Meters (m)	3.28	Feet
Kilometers (km)	.62	Miles (mi)
Square kilometers (km^2)	.38	Square miles (mi^2)
Hectares (ha)	2.47	Acres

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Appendix

	Wildlife groups						Road-associated factors														
	Riparian-associated	Late successional	Primary cavity excavator	Waterfowl (lakes, ponds, etc.)	Ungulates	Wide-ranging carnivores	Snag reduction	Down log reduction	Edge effects	Hunting	Trapping	Poaching	Collection	Disturbance at a specific site	Collisions	Negative human interactions	Movement barrier filter	Displacement/avoidance	Habitat loss/fragmentation	Physiological response	Route for competitors/predators
Amphibians																					
Northwestern salamander	X	X													X		X		X		
Long-toed salamander	X														X		X		X		
Pacific giant salamander	X	X													X		X		X		
Larch Mountain salamander		X																			
Roughskin newt	X	X													X		X		X		
Western toad	X														X		X		X		
Pacific treefrog	X														X		X		X		
Tailed frog*	X	X							X						X		X		X		
Cascade frog*	X														X		X		X		
Spotted frog	X														X		X		X		
Reptiles																					
Northern alligator lizard															X				X		
Western fence lizard	X														X				X		
Western skink															X				X		
Rubber boa															X				X		
Racer	X														X				X		
Sharptail snake								X					X		X				X		
Night snake															X				X		
Gopher snake	X														X				X		
Western terrestrial garter snake	X														X				X		
Common garter snake	X														X				X		
Western rattlesnake															X				X		
Birds																					
Arctic loon				X																	
Common loon*				X										X				X			
Yellow-billed loon				X																	
Pied-billed grebe				X																	
Horned grebe				X																	
Red-necked grebe				X																	
Eared grebe*				X										X				X			
Western grebe				X																	
American white pelican				X																	
Double-crested cormorant				X																	
American bittern				X											X						
Great blue heron*				X										X				X			
Great egret				X																	
Cattle egret				X																	
Green-backed heron				X																	
Black-crowned night heron				X																	
Tundra swan				X																	
Trumpeter swan				X																	
Greater white-fronted goose				X																	
Snow goose				X																	
Canada goose				X											X						

	Nonmotorized trail-associated factors												Motorized trail-associated factors												
	Hunting	Snag reduction	Trapping	Poaching	Collection	Edge effects	Disturbance at a specific site	Negative human interactions	Movement barrier	Displacement/avoidance	Habitat loss/fragmentation	Route for competitors/predators	Hunting	Snag reduction	Trapping	Poaching	Collection	Edge effects	Collisions	Disturbance at a specific site	Negative human interactions	Movement barrier	Displacement/avoidance	Habitat loss/fragmentation	Route for competitors/predators
Amphibians																									
Northwestern salamander																			X					X	
Long-toed salamander																			X					X	
Pacific giant salamander																			X					X	
Larch Mountain salamander																									
Roughskin newt																			X					X	
Western toad																			X					X	
Pacific treefrog																			X					X	
Tailed frog*																			X					X	
Cascade frog*																			X					X	
Spotted frog																			X					X	
Reptiles																									
Northern alligator lizard																			X					X	
Western fence lizard																			X					X	
Western skink																			X					X	
Rubber boa																			X					X	
Racer																			X					X	
Sharptail snake																			X					X	
Night snake																			X					X	
Gopher snake																			X					X	
Western terrestrial garter snake																			X					X	
Common garter snake																			X					X	
Western rattlesnake																			X					X	
Birds																									
Arctic loon																									
Common loon*							X			X										X			X		
Yellow-billed loon																									
Pied-billed grebe																									
Horned grebe																									
Red-necked grebe																									
Eared grebe*							X			X										X			X		
Western grebe																									
American white pelican																									
Double-crested cormorant																									
American bittern																									
Great blue heron*							X			X		X								X			X		
Great egret										X															
Cattle egret										X															
Green-backed heron										X															
Black-crowned night heron										X															
Tundra swan																									
Trumpeter swan										X															
Greater white-fronted goose																									
Snow goose										X															
Canada goose																									

	Winter recreation/ snowmobiling									Winter rec./ skiing & snowshoeing						
	Trapping	Direct mortality	Route for competitors/predators	Disturbance at a specific site	Movement barrier	Displacement/avoidance	Habitat loss/fragmentation	Physiological response	Snow compaction	Trapping	Route for competitors/predators	Disturbance at a specific site	Movement barrier	Displacement/avoidance	Habitat loss/fragmentation	Snow compaction
Amphibians																
Northwestern salamander																
Long-toed salamander																
Pacific giant salamander																
Larch Mountain salamander																
Roughskin newt																
Western toad																
Pacific treefrog																
Tailed frog*																
Cascade frog*																
Spotted frog																
Reptiles																
Northern alligator lizard																
Western fence lizard																
Western skink																
Rubber boa																
Racer																
Sharptail snake																
Night snake																
Gopher snake																
Western terrestrial garter snake																
Common garter snake																
Western rattlesnake																
Birds																
Arctic loon																
Common loon*																
Yellow-billed loon																
Pied-billed grebe																
Horned grebe																
Red-necked grebe																
Eared grebe*																
Western grebe																
American white pelican																
Double-crested cormorant																
American bittern																
Great blue heron*																
Great egret																
Cattle egret																
Green-backed heron																
Black-crowned night heron																
Tundra swan																
Trumpeter swan																
Greater white-fronted goose																
Snow goose																
Canada goose																

Birds (continued)	Wildlife groups						Road-associated factors														
	Riparian-associated	Late successional	Primary cavity excavator	Waterfowl (lakes, ponds, etc.)	Ungulates	Wide-ranging carnivores	Snag reduction	Down log reduction	Edge effects	Hunting	Trapping	Poaching	Collection	Disturbance at a specific site	Collisions	Negative human interactions	Movement barrier filter	Displacement/avoidance	Habitat loss/fragmentation	Physiological response	Route for comptetitors/predators
Wood duck*				X			X											X			
Green-winged teal				X																	
American black duck				X																	
Mallard				X											X						
Northern pintail				X																	
Blue-winged teal				X																	
Cinnamon teal				X																	
Northern shoveler				X																	
Gadwall				X																	
Eurasian wigeon				X																	
American wigeon				X																	
Canvasback				X																	
Redhead				X																	
Ring-necked duck				X																	
Greater scaup				X																	
Lesser scaup				X																	
Harlequin duck*	X	X		X				X						X		X		X	X		
Oldsquaw				X																	
Surf scoter				X																	
White-winged scoter				X																	
Common goldeneye				X																	
Barrow's goldeneye		X		X																	
Bufflehead		X		X																	
Hooded merganser		X		X																	
Common merganser		X		X											X						
Red-breasted merganser				X																	
Ruddy duck				X																	
Turkey vulture																					
Osprey	X																				
Bald eagle*	X	X										X		X				X			
Northern harrier																					
Sharp-shinned hawk		X																			
Cooper's hawk		X																			
Northern goshawk*		X							X				X	X					X		
Swainson's hawk																					
Red-tailed hawk																					
Ferruginous hawk												X		X	X			X			
Rough-legged hawk																		X			
Golden eagle																		X			
American kestrel																		X			
Merlin																		X			
Peregrine falcon																		X			
Gray falcon																					
Prairie falcon																					
Gray partridge																					
Chukar																					

Birds (continued)	Nonmotorized trail-associated factors												Motorized trail-associated factors												
	Hunting	Snag reduction	Trapping	Poaching	Collection	Edge effects	Disturbance at a specific site	Negative human interactions	Movement barrier	Displacement/avoidance	Habitat loss/fragmentation	Route for comptetitors/predators	Hunting	Snag reduction	Trapping	Poaching	Collection	Edge effects	Collisions	Disturbance at a specific site	Negative human interactions	Movement barrier	Displacement/avoidance	Habitat loss/fragmentation	Route for comptetitors/predators
Wood duck*		X					X			X				X						X			X		
Green-winged teal																									
American black duck																									
Mallard																									
Northern pintail																									
Blue-winged teal																									
Cinnamon teal																									
Northern shoveler																									
Gadwall																									
Eurasian wigeon																									
American wigeon																									
Canvasback																									
Redhead																									
Ring-necked duck																									
Greater scaup																									
Lesser scaup																									
Harlequin duck*							X	X		X										X	X		X		
Oldsquaw																									
Surf scoter																									
White-winged scoter																									
Common goldeneye																									
Barrow's goldeneye																									
Bufflehead																									
Hooded merganser																									
Common merganser																									
Red-breasted merganser																									
Ruddy duck																									
Turkey vulture																									
Osprey							X													X					
Bald eagle*							X			X										X					
Northern harrier							X													X					
Sharp-shinned hawk							X													X					
Cooper's hawk							X													X					
Northern goshawk*					X		X										X			X					
Swainson's hawk							X													X					
Red-tailed hawk							X													X					
Ferruginous hawk							X			X										X					
Rough-legged hawk							X			X										X					
Golden eagle							X			X										X					
American kestrel										X															
Merlin										X															
Peregrine falcon							X			X										X					
Gray falcon							X													X					
Prairie falcon							X													X					
Gray partridge																									
Chukar																									

Birds (continued)	Winter recreation/ snowmobiling									Winter rec./ skiing & snowshoeing						
	Trapping	Direct mortality	Route for comptetitors/predators	Disturbance at a specific site	Movement barrier	Displacement/avoidance	Habitat loss/fragmentation	Physiological response	Snow compaction	Trapping	Route for comptetitors/predators	Disturbance at a specific site	Movement barrier	Displacement/avoidance	Habitat loss/fragmentation	Snow compaction
Wood duck*																
Green-winged teal																
American black duck																
Mallard																
Northern pintail																
Blue-winged teal																
Cinnamon teal																
Northern shoveler																
Gadwall																
Eurasian wigeon																
American wigeon																
Canvasback																
Redhead																
Ring-necked duck																
Greater scaup																
Lesser scaup																
Harlequin duck*																
Oldsquaw																
Surf scoter																
White-winged scoter																
Common goldeneye																
Barrow's goldeneye																
Bufflehead																
Hooded merganser																
Common merganser																
Red-breasted merganser																
Ruddy duck																
Turkey vulture																
Osprey																
Bald eagle*				X								X				
Northern harrier																
Sharp-shinned hawk																
Cooper's hawk																
Northern goshawk*																
Swainson's hawk																
Red-tailed hawk																
Ferruginous hawk																
Rough-legged hawk																
Golden eagle																
American kestrel																
Merlin																
Peregrine falcon																
Gray falcon																
Prairie falcon																
Gray partridge																
Chukar																

Birds (continued)	Wildlife groups						Road-associated factors														
	Riparian-associated	Late successional	Primary cavity excavator	Waterfowl (lakes, ponds, etc.)	Ungulates	Wide-ranging carnivores	Snag reduction	Down log reduction	Edge effects	Hunting	Trapping	Poaching	Collection	Disturbance at a specific site	Collisions	Negative human interactions	Movement barrier filter	Displacement/avoidance	Habitat loss/fragmentation	Physiological response	Route for comptetitors/predators
Ring-necked pheasant																					
Spruce grouse		X																			
Blue grouse														X							
White-tailed ptarmigan																					
Ruffed grouse	X																				
Sage grouse														X							
Sharp-tailed grouse												X		X							
Northern bobwhite																					
California quail	X																				
Mountain quail	X													X							
Virginia rail	X														X						
Sora				X																	
American coot				X											X						
Sandhill crane				X																	
Black-bellied plover				X																	
Semi-palmated plover				X																	
Killdeer				X											X						
Mountain plover				X																	
Black-necked stilt				X																	
American avocet				X																	
Greater yellowlegs				X																	
Lesser yellowlegs				X																	
Solitary sandpiper				X																	
Willet				X																	
Spotted sandpiper				X																	
Upland sandpiper				X																	
Whimbrel				X																	
Long-billed curlew				X																	
Bar-tailed godwit				X																	
Marbled godwit				X																	
Ruddy turnstone				X																	
Red knot				X																	
Sanderling				X																	
Semi-palmated sandpiper				X											X						
Western sandpiper				X																	
Least sandpiper				X																	
White-rumped sandpiper				X																	
Baird's sandpiper				X																	
Pectoral sandpiper				X																	
Dunlin				X																	
Stilt sandpiper				X																	
Buff-breasted sandpiper				X																	
Short-billed dowitcher				X											X						
Long-billed dowitcher				X																	
Common snipe	X														X						
Wilson's phalarope				X																	

Birds (continued)	Nonmotorized trail-associated factors												Motorized trail-associated factors												
	Hunting	Snag reduction	Trapping	Poaching	Collection	Edge effects	Disturbance at a specific site	Negative human interactions	Movement barrier	Displacement/avoidance	Habitat loss/fragmentation	Route for comptetitors/predators	Hunting	Snag reduction	Trapping	Poaching	Collection	Edge effects	Collisions	Disturbance at a specific site	Negative human interactions	Movement barrier	Displacement/avoidance	Habitat loss/fragmentation	Route for comptetitors/predators
Ring-necked pheasant																									
Spruce grouse																									
Blue grouse																									
White-tailed ptarmigan																									
Ruffed grouse																									
Sage grouse							X			X										X			X		
Sharp-tailed grouse																									
Northern bobwhite																									
California quail																									
Mountain quail																									
Virginia rail																									
Sora																									
American coot										X															
Sandhill crane																									
Black-bellied plover																									
Semi-palmated plover																									
Killdeer																									
Mountain plover																									
Black-necked stilt																									
American avocet																									
Greater yellowlegs																									
Lesser yellowlegs																									
Solitary sandpiper																									
Willet																									
Spotted sandpiper																									
Upland sandpiper																									
Whimbrel																									
Long-billed curlew																									
Bar-tailed godwit																									
Marbled godwit																									
Ruddy turnstone																									
Red knot																									
Sanderling																									
Semi-palmated sandpiper																									
Western sandpiper																									
Least sandpiper																									
White-rumped sandpiper																									
Baird's sandpiper																									
Pectoral sandpiper																									
Dunlin																									
Stilt sandpiper																									
Buff-breasted sandpiper																									
Short-billed dowitcher																									
Long-billed dowitcher																									
Common snipe																									
Wilson's phalarope																									

Birds (continued)	Winter recreation/ snowmobiling									Winter rec./ skiing & snowshoeing						
	Trapping	Direct mortality	Route for comptetitors/predators	Disturbance at a specific site	Movement barrier	Displacement/avoidance	Habitat loss/fragmentation	Physiological response	Snow compaction	Trapping	Route for comptetitors/predators	Disturbance at a specific site	Movement barrier	Displacement/avoidance	Habitat loss/fragmentation	Snow compaction
Ring-necked pheasant																
Spruce grouse																
Blue grouse																
White-tailed ptarmigan																
Ruffed grouse																
Sage grouse																
Sharp-tailed grouse																
Northern bobwhite																
California quail																
Mountain quail																
Virginia rail																
Sora																
American coot																
Sandhill crane																
Black-bellied plover																
Semi-palmated plover																
Killdeer																
Mountain plover																
Black-necked stilt																
American avocet																
Greater yellowlegs																
Lesser yellowlegs																
Solitary sandpiper																
Willet																
Spotted sandpiper																
Upland sandpiper																
Whimbrel																
Long-billed curlew																
Bar-tailed godwit																
Marbled godwit																
Ruddy turnstone																
Red knot																
Sanderling																
Semi-palmated sandpiper																
Western sandpiper																
Least sandpiper																
White-rumped sandpiper																
Baird's sandpiper																
Pectoral sandpiper																
Dunlin																
Stilt sandpiper																
Buff-breasted sandpiper																
Short-billed dowitcher																
Long-billed dowitcher																
Common snipe																
Wilson's phalarope																

Birds (continued)	Wildlife groups						Road-associated factors														
	Riparian-associated	Late successional	Primary cavity excavator	Waterfowl (lakes, ponds, etc.)	Ungulates	Wide-ranging carnivores	Snag reduction	Down log reduction	Edge effects	Hunting	Trapping	Poaching	Collection	Disturbance at a specific site	Collisions	Negative human interactions	Movement barrier filter	Displacement/avoidance	Habitat loss/fragmentation	Physiological response	Route for comptetitors/predators
Red-necked phalarope				x																	
Long-tailed jaeger				x																	
Franklin's gull				x																	
Bonaparte's gull				x																	
Ring-billed gull				x											x						
California gull				x																	
Herring gull				x																	
Glaucous-winged gull				x																	
Glaucous gull				x																	
Sabine's gull				x																	
Iceland gull				x																	
Caspian tern				x																	
Common tern				x																	
Forster's tern				x																	
Black tern				x																	
Marbled murrelet		x																			
Rock dove															x						
Band-tailed pigeon	x																				
Mourning dove	x														x						
Yellow-billed cuckoo	x														x						
Barn owl	x																				
Flammulated owl		x	x				x		x												
Western screech-owl	x																				
Great horned owl	x																				
Snowy owl																					
Northern hawk-owl																					
Northern pygmy-owl	x	x																			
Burrowing owl												x		x							
Northern spotted owl*		x					x		x					x	x						
Barred owl	x	x																			
Great gray owl		x					x														
Long-eared owl	x																				
Short-eared owl	x												x		x		x				
Boreal owl							x		x												
Northern saw-whet owl	x														x						
Common nighthawk																					
Common poorwill																					
Black swift	x																				
Vaux's swift	x	x					x		x												
White-throated swift	x																				
Black-chinned hummingbird	x																				
Anna's hummingbird	x																				
Calliope hummingbird	x																				
Rufous hummingbird	x																				
Belted kingfisher	x														x						
Lewis's woodpecker			x				x							x							

Birds (continued)	Nonmotorized trail-associated factors												Motorized trail-associated factors												
	Hunting	Snag reduction	Trapping	Poaching	Collection	Edge effects	Disturbance at a specific site	Negative human interactions	Movement barrier	Displacement/avoidance	Habitat loss/fragmentation	Route for comptetitors/predators	Hunting	Snag reduction	Trapping	Poaching	Collection	Edge effects	Collisions	Disturbance at a specific site	Negative human interactions	Movement barrier	Displacement/avoidance	Habitat loss/fragmentation	Route for comptetitors/predators
Red-necked phalarope																									
Long-tailed jaeger																									
Franklin's gull																									
Bonaparte's gull																									
Ring-billed gull																									
California gull																									
Herring gull																									
Glaucous-winged gull																									
Glaucous gull																									
Sabine's gull																									
Iceland gull																									
Caspian tern																									
Common tern																									
Forster's tern																									
Black tern																									
Marbled murrelet																									
Rock dove																									
Band-tailed pigeon																									
Mourning dove																									
Yellow-billed cuckoo																									
Barn owl																									
Flammulated owl																									
Western screech-owl																									
Great horned owl																									
Snowy owl																									
Northern hawk-owl																									
Northern pygmy-owl																									
Burrowing owl							x													x					
Northern spotted owl*							x													x					
Barred owl																									
Great gray owl																									
Long-eared owl																									
Short-eared owl																									
Boreal owl																									
Northern saw-whet owl										x															
Common nighthawk																									
Common poorwill																									
Black swift																									
Vaux's swift																									
White-throated swift																									
Black-chinned hummingbird																									
Anna's hummingbird																									
Calliope hummingbird																									
Rufous hummingbird																									
Belted kingfisher																									
Lewis's woodpecker																									

Birds (continued)	Winter recreation/ snowmobiling									Winter rec./ skiing & snowshoeing						
	Trapping	Direct mortality	Route for comptetitors/predators	Disturbance at a specific site	Movement barrier	Displacement/avoidance	Habitat loss/fragmentation	Physiological response	Snow compaction	Trapping	Route for comptetitors/predators	Disturbance at a specific site	Movement barrier	Displacement/avoidance	Habitat loss/fragmentation	Snow compaction
Red-necked phalarope																
Long-tailed jaeger																
Franklin's gull																
Bonaparte's gull																
Ring-billed gull																
California gull																
Herring gull																
Glaucous-winged gull																
Glaucous gull																
Sabine's gull																
Iceland gull																
Caspian tern																
Common tern																
Forster's tern																
Black tern																
Marbled murrelet																
Rock dove																
Band-tailed pigeon																
Mourning dove																
Yellow-billed cuckoo																
Barn owl																
Flammulated owl																
Western screech-owl																
Great horned owl																
Snowy owl																
Northern hawk-owl																
Northern pygmy-owl																
Burrowing owl																
Northern spotted owl*																
Barred owl																
Great gray owl																
Long-eared owl																
Short-eared owl																
Boreal owl																
Northern saw-whet owl																
Common nighthawk																
Common poorwill																
Black swift																
Vaux's swift																
White-throated swift																
Black-chinned hummingbird																
Anna's hummingbird																
Calliope hummingbird																
Rufous hummingbird																
Belted kingfisher																
Lewis's woodpecker																

Birds (continued)

Wildlife groups

Birds	Riparian-associated	Late successional	Primary cavity excavator	Waterfowl (lakes, ponds, etc.)	Ungulates	Wide-ranging carnivores
Red-breasted sapsucker		X	X			
Williamson's sapsucker		X	X			
Downy woodpecker			X			
Hairy woodpecker		X	X			
White-headed woodpecker*		X	X			
Three-toed woodpecker*		X	X			
Black-backed woodpecker		X	X			
Northern flicker		X	X			
Pileated woodpecker*		X	X			
Olive-sided flycatcher	X					
Say's phoebe						
Western wood-pewee						
Willow flycatcher	X					
Least flycatcher	X					
Hammond's flycatcher	X	X				
Dusky flycatcher	X					
Gray flycatcher	X					
Western flycatcher	X	X				
Ash-throated flycatcher	X					
Western kingbird	X					
Eastern kingbird	X					
Horned lark						
Tree swallow	X					
Violet-green swallow	X					
Northern rough-winged swallow	X					
Bank swallow	X					
Cliff swallow	X					
Barn swallow	X					
Gray jay						
Stellar's jay	X					
Scrub jay						
Pinyon jay						
Clark's nutcracker						
Black-billed magpie						
American crow	X					
Common raven	X					
Black-capped chickadee*	X					
Mountain chickadee						
Chestnut-backed chickadee		X				
Bushtit						
Red-breasted nuthatch		X				
White-breasted nuthatch*		X				
Pygmy nuthatch*		X				
Brown creeper*		X				
Rock wren						
Canyon wren						

Road-associated factors

Birds	Snag reduction	Down log reduction	Edge effects	Hunting	Trapping	Poaching	Collection	Disturbance at a specific site	Collisions	Negative human interactions	Movement barrier filter	Displacement/avoidance	Habitat loss/fragmentation	Physiological response	Route for comptetitors/predators
Red-breasted sapsucker															
Williamson's sapsucker	X		X												
Downy woodpecker															
Hairy woodpecker															
White-headed woodpecker*	X		X												
Three-toed woodpecker*	X		X												
Black-backed woodpecker	X		X												
Northern flicker															
Pileated woodpecker*	X	X	X												
Olive-sided flycatcher															
Say's phoebe															
Western wood-pewee															
Willow flycatcher			X						X						
Least flycatcher															
Hammond's flycatcher			X												
Dusky flycatcher															
Gray flycatcher															
Western flycatcher															
Ash-throated flycatcher	X														
Western kingbird															
Eastern kingbird									X						
Horned lark															
Tree swallow									X						
Violet-green swallow															
Northern rough-winged swallow															
Bank swallow									X						
Cliff swallow									X						
Barn swallow									X						
Gray jay															
Stellar's jay															
Scrub jay															
Pinyon jay															
Clark's nutcracker															
Black-billed magpie															
American crow															
Common raven															
Black-capped chickadee*												X	X		
Mountain chickadee															
Chestnut-backed chickadee	X		X										X		
Bushtit															
Red-breasted nuthatch													X		
White-breasted nuthatch*	X		X									X			
Pygmy nuthatch*	X		X									X			
Brown creeper*	X		X									X	X		X
Rock wren															
Canyon wren															

Nonmotorized trail-associated factors

Birds	Hunting	Snag reduction	Trapping	Poaching	Collection	Edge effects	Disturbance at a specific site	Negative human interactions	Movement barrier	Displacement/avoidance	Habitat loss/fragmentation	Route for comptetitors/predators
Red-breasted sapsucker												
Williamson's sapsucker												
Downy woodpecker												
Hairy woodpecker												
White-headed woodpecker*												
Three-toed woodpecker*												
Black-backed woodpecker												
Northern flicker												
Pileated woodpecker*												
Olive-sided flycatcher												
Say's phoebe												
Western wood-pewee										X		
Willow flycatcher						X						
Least flycatcher												
Hammond's flycatcher												
Dusky flycatcher												
Gray flycatcher												
Western flycatcher												
Ash-throated flycatcher												
Western kingbird												
Eastern kingbird												
Horned lark												
Tree swallow												
Violet-green swallow												
Northern rough-winged swallow												
Bank swallow												
Cliff swallow												
Barn swallow												
Gray jay												
Stellar's jay												
Scrub jay												
Pinyon jay												
Clark's nutcracker												
Black-billed magpie												
American crow												
Common raven												
Black-capped chickadee*										X	X	
Mountain chickadee												
Chestnut-backed chickadee												
Bushtit												
Red-breasted nuthatch												
White-breasted nuthatch*										X		
Pygmy nuthatch*										X		
Brown creeper*										X		X
Rock wren												
Canyon wren												

Motorized trail-associated factors

Birds	Hunting	Snag reduction	Trapping	Poaching	Collection	Edge effects	Collisions	Disturbance at a specific site	Negative human interactions	Movement barrier	Displacement/avoidance	Habitat loss/fragmentation	Route for comptetitors/predators
Red-breasted sapsucker													
Williamson's sapsucker													
Downy woodpecker													
Hairy woodpecker													
White-headed woodpecker*													
Three-toed woodpecker*													
Black-backed woodpecker													
Northern flicker													
Pileated woodpecker*													
Olive-sided flycatcher													
Say's phoebe													
Western wood-pewee													
Willow flycatcher						X							
Least flycatcher													
Hammond's flycatcher													
Dusky flycatcher													
Gray flycatcher													
Western flycatcher													
Ash-throated flycatcher													
Western kingbird													
Eastern kingbird													
Horned lark													
Tree swallow													
Violet-green swallow													
Northern rough-winged swallow													
Bank swallow													
Cliff swallow													
Barn swallow													
Gray jay													
Stellar's jay													
Scrub jay													
Pinyon jay													
Clark's nutcracker													
Black-billed magpie													
American crow													
Common raven													
Black-capped chickadee*											X	X	
Mountain chickadee													
Chestnut-backed chickadee													
Bushtit													
Red-breasted nuthatch													
White-breasted nuthatch*											X		
Pygmy nuthatch*											X		
Brown creeper*											X		X
Rock wren													
Canyon wren													

Winter recreation/snowmobiling and **Winter rec./skiing & snowshoeing**

Birds	Snowmobiling: Trapping	Snowmobiling: Direct mortality	Snowmobiling: Route for comptetitors/predators	Snowmobiling: Disturbance at a specific site	Snowmobiling: Movement barrier	Snowmobiling: Displacement/avoidance	Snowmobiling: Habitat loss/fragmentation	Snowmobiling: Physiological response	Snowmobiling: Snow compaction	Skiing & snowshoeing: Trapping	Skiing & snowshoeing: Route for comptetitors/predators	Skiing & snowshoeing: Disturbance at a specific site	Skiing & snowshoeing: Movement barrier	Skiing & snowshoeing: Displacement/avoidance	Skiing & snowshoeing: Habitat loss/fragmentation	Skiing & snowshoeing: Snow compaction
Red-breasted sapsucker																
Williamson's sapsucker																
Downy woodpecker																
Hairy woodpecker																
White-headed woodpecker*																
Three-toed woodpecker*																
Black-backed woodpecker																
Northern flicker																
Pileated woodpecker*																
Olive-sided flycatcher																
Say's phoebe																
Western wood-pewee																
Willow flycatcher																
Least flycatcher																
Hammond's flycatcher																
Dusky flycatcher																
Gray flycatcher																
Western flycatcher																
Ash-throated flycatcher																
Western kingbird																
Eastern kingbird																
Horned lark																
Tree swallow																
Violet-green swallow																
Northern rough-winged swallow																
Bank swallow																
Cliff swallow																
Barn swallow																
Gray jay																
Stellar's jay																
Scrub jay																
Pinyon jay																
Clark's nutcracker																
Black-billed magpie																
American crow																
Common raven																
Black-capped chickadee*																
Mountain chickadee																
Chestnut-backed chickadee																
Bushtit																
Red-breasted nuthatch																
White-breasted nuthatch*																
Pygmy nuthatch*																
Brown creeper*			X								X					
Rock wren																
Canyon wren																

Birds (continued)	Wildlife groups						Road-associated factors														
	Riparian-associated	Late successional	Primary cavity excavator	Waterfowl (lakes, ponds, etc.)	Ungulates	Wide-ranging carnivores	Snag reduction	Down log reduction	Edge effects	Hunting	Trapping	Poaching	Collection	Disturbance at a specific site	Collisions	Negative human interactions	Movement barrier filter	Displacement/avoidance	Habitat loss/fragmentation	Physiological response	Route for comptetitors/predators
Bewick’s wren	X																				
House wren																					
Winter wren		X					X	X	X										X		
Marsh wren	X																				
American dipper	X																				
Golden-crowned kinglet		X							X						X				X		
Ruby-crowned kinglet																					
Western bluebird							X														
Mountain bluebird																					
Townsend’s solitaire																					
Veery									X										X		
Swainson’s thrush	X														X				X		
Hermit thrush		X													X						
American robin	X														X						
Varied thrush		X																	X		
Gray catbird															X						
Northern mockingbird																					
Sage thrasher									X												
American pipit																					
Bohemian waxwing																					
Cedar waxwing	X														X						
Northern shrike																					
Loggerhead shrike															X						
European starling	X														X						
Solitary vireo	X								X												
Warbling vireo	X	X							X												
Red-eyed vireo	X								X												
Orange-crowned warbler	X																				
Nashville warbler	X																				
Yellow warbler	X								X						X						
Yellow-rumped warbler	X								X												
Black-throated gray warbler																					
Townsend’s warbler																			X		
Hermit warbler		X							X												
Palm warbler															X						
Black-and-white warbler	X								X												
American redstart									X												
Northern waterthrush																					
Macgillivray’s warbler	X																				
Common yellowthroat	X								X						X						
Wilson’s warbler	X	X																			
Yellow-breasted chat	X								X												
Western tanager	X																				
Black-headed grosbeak	X																				
Lazuli bunting	X																				
Spotted towhee	X																				

Birds (continued)	Nonmotorized trail-associated factors												Motorized trail-associated factors												
	Hunting	Snag reduction	Trapping	Poaching	Collection	Edge effects	Disturbance at a specific site	Negative human interactions	Movement barrier	Displacement/avoidance	Habitat loss/fragmentation	Route for comptetitors/predators	Hunting	Snag reduction	Trapping	Poaching	Collection	Edge effects	Collisions	Disturbance at a specific site	Negative human interactions	Movement barrier	Displacement/avoidance	Habitat loss/fragmentation	Route for comptetitors/predators
Bewick’s wren																									
House wren																									
Winter wren																									
Marsh wren																									
American dipper																									
Golden-crowned kinglet																									
Ruby-crowned kinglet																									
Western bluebird																									
Mountain bluebird																									
Townsend’s solitaire										X															
Veery						X												X							
Swainson’s thrush																									
Hermit thrush																									
American robin																									
Varied thrush																									
Gray catbird																									
Northern mockingbird																									
Sage thrasher						X												X							
American pipit																									
Bohemian waxwing																									
Cedar waxwing																									
Northern shrike																									
Loggerhead shrike																									
European starling																									
Solitary vireo						X				X								X							
Warbling vireo						X												X							
Red-eyed vireo						X												X							
Orange-crowned warbler																									
Nashville warbler																									
Yellow warbler						X												X							
Yellow-rumped warbler						X												X							
Black-throated gray warbler																									
Townsend’s warbler																									
Hermit warbler																									
Palm warbler																									
Black-and-white warbler						X												X							
American redstart						X												X							
Northern waterthrush																									
Macgillivray’s warbler																									
Common yellowthroat						X												X							
Wilson’s warbler																									
Yellow-breasted chat						X												X							
Western tanager																									
Black-headed grosbeak																									
Lazuli bunting																									
Spotted towhee																									

Birds (continued)	Winter recreation/ snowmobiling									Winter rec./ skiing & snowshoeing						
	Trapping	Direct mortality	Route for comptetitors/predators	Disturbance at a specific site	Movement barrier	Displacement/avoidance	Habitat loss/fragmentation	Physiological response	Snow compaction	Trapping	Route for comptetitors/predators	Disturbance at a specific site	Movement barrier	Displacement/avoidance	Habitat loss/fragmentation	Snow compaction
Bewick’s wren																
House wren																
Winter wren																
Marsh wren																
American dipper																
Golden-crowned kinglet																
Ruby-crowned kinglet																
Western bluebird																
Mountain bluebird																
Townsend’s solitaire																
Veery																
Swainson’s thrush																
Hermit thrush																
American robin																
Varied thrush																
Gray catbird																
Northern mockingbird																
Sage thrasher																
American pipit																
Bohemian waxwing																
Cedar waxwing																
Northern shrike																
Loggerhead shrike																
European starling																
Solitary vireo																
Warbling vireo																
Red-eyed vireo																
Orange-crowned warbler																
Nashville warbler																
Yellow warbler																
Yellow-rumped warbler																
Black-throated gray warbler																
Townsend’s warbler																
Hermit warbler																
Palm warbler																
Black-and-white warbler																
American redstart																
Northern waterthrush																
Macgillivray’s warbler																
Common yellowthroat																
Wilson’s warbler																
Yellow-breasted chat																
Western tanager																
Black-headed grosbeak																
Lazuli bunting																
Spotted towhee																

Birds (continued)	Wildlife groups						Road-associated factors														
	Riparian-associated	Late successional	Primary cavity excavator	Waterfowl (lakes, ponds, etc.)	Ungulates	Wide-ranging carnivores	Snag reduction	Down log reduction	Edge effects	Hunting	Trapping	Poaching	Collection	Disturbance at a specific site	Collisions	Negative human interactions	Movement barrier filter	Displacement/avoidance	Habitat loss/fragmentation	Physiological response	Route for comptetitors/predators
American tree sparrow																					
Chipping sparrow	X								X						X						
Clay-colored sparrow																					
Brewer's sparrow									X												
Vesper sparrow																					
Lark sparrow																					
Sage sparrow									X												
Savannah sparrow															X						
Grasshopper sparrow																					
Fox sparrow	X																	X			
Song sparrow	X								X						X			X			
Lincoln's sparrow	X																				
White-throated sparrow															X						
Golden-crowned sparrow	X																				
White-crowned sparrow																					
Harris's sparrow																					
Dark-eyed junco	X																				
Lapland longspur	X																				
Snow bunting	X																				
Bobolink	X																				
Red-winged blackbird	X														X						
Western meadowlark																X					
Yellow-headed blackbird	X																				
Brewer's blackbird	X								X						X						
Brown-headed cowbird	X														X						
Northern oriole (Bullock's)	X																				
Rosy Finch																					
Pine grosbeak																					
Purple finch	X																				
Cassin's finch	X																				
House finch	X														X						
Red crossbill		X																			
White-winged crossbill															X						
Common redpoll																					
Pine siskin															X						
American goldfinch									X												
Evening grosbeak	X																				
House sparrow	X														X						
Mammals																					
Virginia opossum															X						
Masked shrew	X																X				
Merriam shrew	X														X		X		X		
Trowbridge shrew	X																X				
Dusky shrew	X																X				
Montane shrew	X																X				

Birds (continued)	Nonmotorized trail-associated factors												Motorized trail-associated factors												
	Hunting	Snag reduction	Trapping	Poaching	Collection	Edge effects	Disturbance at a specific site	Negative human interactions	Movement barrier	Displacement/avoidance	Habitat loss/fragmentation	Route for comptetitors/predators	Hunting	Snag reduction	Trapping	Poaching	Collection	Edge effects	Collisions	Disturbance at a specific site	Negative human interactions	Movement barrier	Displacement/avoidance	Habitat loss/fragmentation	Route for comptetitors/predators
American tree sparrow																									
Chipping sparrow						X				X								X							
Clay-colored sparrow																									
Brewer's sparrow						X												X							
Vesper sparrow																									
Lark sparrow																									
Sage sparrow						X												X							
Savannah sparrow																									
Grasshopper sparrow																									
Fox sparrow										X													X		
Song sparrow						X				X								X					X		
Lincoln's sparrow																									
White-throated sparrow																									
Golden-crowned sparrow																									
White-crowned sparrow																									
Harris's sparrow																									
Dark-eyed junco																									
Lapland longspur																									
Snow bunting																									
Bobolink																									
Red-winged blackbird																									
Western meadowlark																									
Yellow-headed blackbird																									
Brewer's blackbird						X												X							
Brown-headed cowbird																									
Northern oriole (Bullock's)																									
Rosy Finch																									
Pine grosbeak																									
Purple finch																									
Cassin's finch																									
House finch																									
Red crossbill																									
White-winged crossbill																									
Common redpoll																									
Pine siskin																									
American goldfinch						X												X							
Evening grosbeak																									
House sparrow																									
Mammals																									
Virginia opossum																									
Masked shrew																									
Merriam shrew							X			X	X								X					X	
Trowbridge shrew																									
Dusky shrew																									
Montane shrew																									

Birds (continued)	Winter recreation/ snowmobiling									Winter rec./ skiing & snowshoeing						
	Trapping	Direct mortality	Route for comptetitors/predators	Disturbance at a specific site	Movement barrier	Displacement/avoidance	Habitat loss/fragmentation	Physiological response	Snow compaction	Trapping	Route for comptetitors/predators	Disturbance at a specific site	Movement barrier	Displacement/avoidance	Habitat loss/fragmentation	Snow compaction
American tree sparrow																
Chipping sparrow																
Clay-colored sparrow																
Brewer's sparrow																
Vesper sparrow																
Lark sparrow																
Sage sparrow																
Savannah sparrow																
Grasshopper sparrow																
Fox sparrow																
Song sparrow																
Lincoln's sparrow																
White-throated sparrow																
Golden-crowned sparrow																
White-crowned sparrow																
Harris's sparrow																
Dark-eyed junco																
Lapland longspur																
Snow bunting																
Bobolink																
Red-winged blackbird																
Western meadowlark																
Yellow-headed blackbird																
Brewer's blackbird																
Brown-headed cowbird																
Northern oriole (Bullock's)																
Rosy Finch																
Pine grosbeak																
Purple finch																
Cassin's finch																
House finch																
Red crossbill																
White-winged crossbill																
Common redpoll																
Pine siskin																
American goldfinch																
Evening grosbeak																
House sparrow																
Mammals																
Virginia opossum																
Masked shrew																
Merriam shrew		X		X		X	X									
Trowbridge shrew																
Dusky shrew																
Montane shrew																

Mammals (continued)

Mammals	Wildlife groups: Riparian-associated	Late successional	Primary cavity excavator	Waterfowl (lakes, ponds, etc.)	Ungulates	Wide-ranging carnivores	Road-associated factors: Snag reduction	Down log reduction	Edge effects	Hunting	Trapping	Poaching	Collection	Disturbance at a specific site	Collisions	Negative human interactions	Movement barrier filter	Displacement/avoidance	Habitat loss/fragmentation	Physiological response	Route for comptetitors/predators
Northern water shrew	X																X				
Pygmy shrew	X																X				
Vagrant shrew	X																X				
Water shrew*	X							X							X		X		X		
Shrew-mole	X	X															X				
Coast mole (Pacific)	X																X				
Little brown myotis	X	X													X				X		
Yuma myotis	X	X										X		X					X		
Keen myotis	X	X												X					X		
Long-eared myotis	X	X					X					X		X					X		
Fringed myotis	X	X					X					X		X					X		
Long-legged myotis	X	X					X					X		X					X		
California myotis	X	X																	X		
Silver-haired bat	X	X					X												X		
Small footed pipistrel	X																		X		
Big brown bat	X	X																	X		
Hoary bat		X					X												X		
Townsend's big-eared bat (western)												X		X				X	X		
Black bear						X				X					X	X		X			
Grizzly bear*						X						X			X	X		X			
Raccoon															X						
Marten*		X					X	X	X		X				X		X		X		
Fisher*		X					X	X	X		X				X		X	X	X		
Ermine (shorttail weasel)	X														X		X				
Longtail weasel	X														X		X				
Mink	X										X			X	X		X	X	X		
Wolverine*						X		X			X			X	X						
River otter	X										X			X	X		X	X	X		
Badger															X						
Western spotted skunk															X						
Striped skunk	X														X						
Coyote						X									X	X		X			
Gray wolf*						X					X	X		X	X	X		X			
Red fox						X						X			X		X				
Mountain lion						X				X					X	X		X			
Lynx*		X				X		X			X			X	X						
Bobcat						X															
Mountain beaver	X																		X		
Yellowbelly marmot																	X				
Hoary marmot																	X				
California ground squirrel																	X				
Townsend ground squirrel																	X				
Golden-mantled ground squirrel																	X				
Least chipmunk															X		X				
Townsend chipmunk		X													X		X				
Yellow pine chipmunk	X														X		X				

Mammals	Nonmotorized trail-associated factors: Hunting	Snag reduction	Trapping	Poaching	Collection	Edge effects	Disturbance at a specific site	Negative human interactions	Movement barrier	Displacement/avoidance	Habitat loss/fragmentation	Route for comptetitors/predators	Motorized trail-associated factors: Hunting	Snag reduction	Trapping	Poaching	Collection	Edge effects	Collisions	Disturbance at a specific site	Negative human interactions	Movement barrier	Displacement/avoidance	Habitat loss/fragmentation	Route for comptetitors/predators
Northern water shrew																									
Pygmy shrew																									
Vagrant shrew																									
Water shrew*																			X						
Shrew-mole																									
Coast mole (Pacific)																									
Little brown myotis																									
Yuma myotis																									
Keen myotis																				X					
Long-eared myotis																									
Fringed myotis																				X					
Long-legged myotis																									
California myotis																									
Silver-haired bat																									
Small footed pipistrel																									
Big brown bat																									
Hoary bat																									
Townsend's big-eared bat (western)																				X					
Black bear	X							X		X			X								X		X		
Grizzly bear*				X				X		X						X					X		X		
Raccoon																									
Marten*			X												X										
Fisher*			X												X										
Ermine (shorttail weasel)																									
Longtail weasel																									
Mink			X				X		X		X				X					X	X			X	
Wolverine*			X				X								X					X					
River otter			X				X		X		X				X					X	X			X	
Badger																									
Western spotted skunk																									
Striped skunk																									
Coyote								X													X				
Gray wolf*			X				X								X					X					
Red fox																									
Mountain lion	X							X					X								X				
Lynx*							X								X					X					
Bobcat																									
Mountain beaver																									
Yellowbelly marmot							X																		
Hoary marmot							X																		
California ground squirrel																									
Townsend ground squirrel																									
Golden-mantled ground squirrel																									
Least chipmunk																									
Townsend chipmunk																									
Yellow pine chipmunk																									

Mammals	Winter recreation/snowmobiling: Trapping	Direct mortality	Route for comptetitors/predators	Disturbance at a specific site	Movement barrier	Displacement/avoidance	Habitat loss/fragmentation	Physiological response	Snow compaction	Winter rec./skiing & snowshoeing: Trapping	Route for comptetitors/predators	Disturbance at a specific site	Movement barrier	Displacement/avoidance	Habitat loss/fragmentation	Snow compaction
Northern water shrew																
Pygmy shrew																
Vagrant shrew																
Water shrew*									X							X
Shrew-mole																
Coast mole (Pacific)																
Little brown myotis																
Yuma myotis																
Keen myotis																
Long-eared myotis																
Fringed myotis																
Long-legged myotis																
California myotis																
Silver-haired bat																
Small footed pipistrel																
Big brown bat																
Hoary bat																
Townsend's big-eared bat (western)																
Black bear				X								X				
Grizzly bear*				X								X				
Raccoon																
Marten*	X									X						
Fisher*	X									X						
Ermine (shorttail weasel)						X										
Longtail weasel																
Mink																
Wolverine*	X			X						X		X				
River otter																
Badger																
Western spotted skunk																
Striped skunk																
Coyote																
Gray wolf*	X							X								
Red fox																
Mountain lion																
Lynx*	X		X	X							X	X				
Bobcat																
Mountain beaver																
Yellowbelly marmot																
Hoary marmot																
California ground squirrel																
Townsend ground squirrel																
Golden-mantled ground squirrel																
Least chipmunk																
Townsend chipmunk																
Yellow pine chipmunk																

Mammals (continued)	Wildlife groups						Road-associated factors														
	Riparian-associated	Late successional	Primary cavity excavator	Waterfowl (lakes, ponds, etc.)	Ungulates	Wide-ranging carnivores	Snag reduction	Down log reduction	Edge effects	Hunting	Trapping	Poaching	Collection	Disturbance at a specific site	Collisions	Negative human interactions	Movement barrier filter	Displacement/avoidance	Habitat loss/fragmentation	Physiological response	Route for comptetitors/predators
Western gray squirrel									X			X					X	X			
Douglas squirrel (chickaree)		X															X				
Northern flying squirrel*		X					X	X	X								X		X		
Northern pocket gopher		X															X				
Great Basin pocket mouse															X		X		X		
Beaver	X										X			X				X	X		
Western harvest mouse	X																X				
Deer mouse	X	X													X		X				
Bushytail woodrat	X														X		X	X			
Heather vole (mtn. phenacomys)																	X				
Redback vole (boreal)	X	X															X				
Meadow vole															X		X				
Water vole (Richardson vole)	X																X				
Creeping vole (Oregon vole)																	X				
Longtail vole	X																X				
Sagebrush vole																X	X				
Muskrat	X										X			X				X	X		
Norway rat																	X				
House mouse	X														X		X				
Western jumping mouse	X																X				
Pacific jumping mouse	X																X				
Porcupine	X																				
Nutria	X																				
Pika																	X				
Whitetail jackrabbit																					
Snowshoe hare																	X				
Blacktail jackrabbit																					
Moose					X													X			
Cottontail (mountain)																					
Rocky mountain elk*		X			X					X		X		X	X			X			
Mule deer*					X					X		X		X	X			X			
Whitetail deer					X					X											
Mountain goat*					X					X		X		X	X		X	X			
Bighorn sheep*					X					X		X		X	X			X		X	
Mollusks																					
Warty jumping slug		X													X		X				
Blue-gray taildropper		X													X		X				
Papillose taildropper		X													X		X				
Chelan mountain snail		X													X		X				
Columbia pebblesnail		X													X		X				

Mammals (continued)	Nonmotorized trail-associated factors												Motorized trail-associated factors												
	Hunting	Snag reduction	Trapping	Poaching	Collection	Edge effects	Disturbance at a specific site	Negative human interactions	Movement barrier	Displacement/avoidance	Habitat loss/fragmentation	Route for comptetitors/predators	Hunting	Snag reduction	Trapping	Poaching	Collection	Edge effects	Collisions	Disturbance at a specific site	Negative human interactions	Movement barrier	Displacement/avoidance	Habitat loss/fragmentation	Route for comptetitors/predators
Western gray squirrel																									
Douglas squirrel (chickaree)																									
Northern flying squirrel*																									
Northern pocket gopher																									
Great Basin pocket mouse							X			X	X								X					X	
Beaver			X				X		X		X				X					X	X			X	
Western harvest mouse																									
Deer mouse																									
Bushytail woodrat																									
Heather vole (mtn. phenacomys)																									
Redback vole (boreal)																									
Meadow vole																									
Water vole (Richardson vole)																									
Creeping vole (Oregon vole)																									
Longtail vole																									
Sagebrush vole																									
Muskrat			X				X		X		X				X					X	X			X	
Norway rat																									
House mouse																									
Western jumping mouse																									
Pacific jumping mouse																									
Porcupine																									
Nutria																									
Pika																									
Whitetail jackrabbit																									
Snowshoe hare																									
Blacktail jackrabbit																									
Moose										X															
Cottontail (mountain)																									
Rocky mountain elk*	X			X			X			X			X			X				X			X		
Mule deer*	X			X			X			X			X			X				X			X		
Whitetail deer	X												X												
Mountain goat*	X			X			X						X			X									
Bighorn sheep*	X			X			X			X			X			X				X			X		
Mollusks																									
Warty jumping slug																									
Blue-gray taildropper																									
Papillose taildropper																									
Chelan mountain snail																									
Columbia pebblesnail																									

Mammals (continued)	Winter recreation/ snowmobiling									Winter rec./ skiing & snowshoeing						
	Trapping	Direct mortality	Route for comptetitors/predators	Disturbance at a specific site	Movement barrier	Displacement/avoidance	Habitat loss/fragmentation	Physiological response	Snow compaction	Trapping	Route for comptetitors/predators	Disturbance at a specific site	Movement barrier	Displacement/avoidance	Habitat loss/fragmentation	Snow compaction
Western gray squirrel																
Douglas squirrel (chickaree)																
Northern flying squirrel*																
Northern pocket gopher																
Great Basin pocket mouse		X		X		X	X									
Beaver																
Western harvest mouse																
Deer mouse																
Bushytail woodrat																
Heather vole (mtn. phenacomys)																
Redback vole (boreal)																
Meadow vole																
Water vole (Richardson vole)																
Creeping vole (Oregon vole)																
Longtail vole																
Sagebrush vole																
Muskrat																
Norway rat																
House mouse																
Western jumping mouse																
Pacific jumping mouse																
Porcupine																
Nutria																
Pika																
Whitetail jackrabbit																
Snowshoe hare						X										
Blacktail jackrabbit																
Moose																
Cottontail (mountain)																
Rocky mountain elk*						X		X				X		X		
Mule deer*				X		X		X				X		X		
Whitetail deer						X						X				
Mountain goat*																
Bighorn sheep*				X		X		X				X		X		
Mollusks																
Warty jumping slug																
Blue-gray taildropper																
Papillose taildropper																
Chelan mountain snail																
Columbia pebblesnail																

* indicates species that were used as focal species.

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