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Research Article

Maintaining Populations of Terrestrial Wildlife Through Land Management Planning: A Case Study

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ABSTRACT Regulations and directives associated with enabling legislation for management of national forests in the United States require maintenance of viable populations of native and desired non-native wildlife species. Broad-scale assessments that address ecosystem diversity cover assessment of viability for most species. We developed an 8-step process to address those species for which management for ecosystem diversity may be inadequate for providing ecological conditions capable of sustaining viable populations. The process includes identification of species of conservation concern, description of source habitats, and other important ecological factors, grouping species, selection of focal species, development of focal species assessment models, development of conservation strategies, and designing monitoring, and adaptive management plans. Following application of our screening criteria, we identified 209 of 700 species as species of conservation concern on National Forest System lands east of the crest of the Cascade Mountains in Oregon and Washington State, USA. We aggregated the 209 species of conservation concern into 10 families and 28 groups based primarily on habitat associations (these are not phylogenetic families). We selected 36 primary focal species (78% birds, 17% mammals, 5% amphibians) for application in northeast Washington State, USA based on risk factors and ecological characteristics. Our assessment documented reductions in habitat capability across northeast Washington State compared to historical conditions. To address such changes, for each focal species we developed conservation strategies that included habitat protection and restoration and amelioration of threats. We combined conservation strategies for individual species with other focal species and with management proposals for other resources (e.g., recreation, fire, and fuels management) to develop a multi-species, multi-resource management strategy. The information generated from our approach can be directly translated into land management planning through development of desired conditions, objectives, and standards and guidelines to improve the probability that desired population outcomes will be achieved. However, it should be noted by practitioners that a practical conservation planning process, such as ours, cannot remove all uncertainty and risk to species viability.

KEY WORDS *Accipiter gentiles*, Bayesian Belief Network models, focal species, *Gulo gulo*, habitat modeling, northern goshawk, viability, wolverine.

The National Forest Management Act of 1976 (NFMA; Public Law 94-588) and the Multiple-Use Sustained-Yield Act of 1960 (Public Law 86-517) require maintenance of diversity and sustainability of plant and animal communities on National Forest System lands throughout the United States (Marcot and Murphy 1996). Associated regulations and directives call for providing viable populations of native and desired non-native wildlife with an emphasis on those species considered to be at risk. The results of modeling viability of populations of species of concern have been suggested as appropriate measures of ecosystem sustainability (Linder et al. 2004). These analyses may be accomplished through a hierarchical approach that evaluates ecosystem diversity and species diversity. It is expected that maintaining diversity and sustainable populations across ecosystems will result in maintaining viability for most species (Hunter et al. 1988, Baydeck et al. 1999, Landres et al. 1999, Samson et al. 2003). Coarse filter ecosystem diversity evaluations generally compare existing vegetation communities to a set of reference conditions (e.g., pre-settlement, range of variability) to

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evaluate changes in disturbance regimes and as a check on adequate representation of ecological communities (Samson 2002). Much of the information and context needed for coarse filter ecosystem diversity assessments has been provided through comprehensive, broad-scale assessments that evaluated the current ecological conditions with respect to historical conditions (e.g., Thomas et al. 1993*a*,*b*; Stephenson and Calcarone 1999; Wisdom et al. 2000).

A complementary approach is necessary for those species for which ecological conditions necessary to sustain populations may not be provided by maintaining ecosystem diversity. In these cases, a species-specific approach to the analysis and establishment of plan direction may be necessary. The assessment of individual species is often referred to as the fine-filter conservation approach (Holthausen et al. 1999, Samson et al. 2003). Andelman et al. (2001) and Holthausen (2002) provided valuable suggestions on how to conduct assessments of species diversity. Identification of a full set of species for a geographic area that may be at risk from future management options is complex and a universally accepted approach has not been developed (Raphael and Marcot 1994, Holthausen et al. 1999). Numerous approaches have been applied by management agencies to classify species according to their risk of extinction at regional, national, and international scales (Millsap et al. 1990, Czech and Krausman 1997, International Union for the Conservation of Nature 2009).

Although managing species habitats and populations using a species-by-species approach has intuitive ecological merit, the sheer number of species of conservation concern often makes such an approach untenable. In many cases, the ecological understanding and resources needed to manage all species on an individual basis are not available. More importantly, attempting to manage for species of conservation concern on an individual basis may not result in holistic management of all species' needs because management focus is often fine-scale, piecemeal, and without explicit understanding of the commonalities and differences in species needs among large sets of species. Tremendous efficiencies can be gained from managing groups of species. The idea that efficiency can be gained, while maintaining effectiveness in accounting for all species needs, is a central premise to grouping approaches (Van Horne and Wiens 1991). Grouping species on the basis of $\geq$1 ecological factors provides a strong foundation for developing conservation strategies for species of conservation concern because the conservation strategies can then be ordered around ecological principles.

A focal species approach further streamlines the fine-filter assessment of ecological systems by monitoring $\geq$1 of the species in a group and can be seen as a pragmatic response to dealing with ecosystem complexity (Noon 2003, Roberge and Angelstam 2004). The key characteristic of a focal species is that its status and trend provide insights to the integrity of the larger ecological system to which it belongs (Lambeck 1997, Noss et al. 1997, Noon 2003). Focal species serve an umbrella function in terms of encompassing habitats needed for other species, are sensitive to the changes likely to occur in the area, or otherwise serve as an indicator of ecological sustainability (Lambeck 1997, Noss et al. 1997). The long-term sustainability of the focal species is assumed to be representative of a group of species with similar ecological requirements and this group is assumed to respond in a similar manner to environmental change. In addition, the focal species is assumed to have more demanding requirements for factors which may put other group members at risk of extinction (Andelman et al. 2001). Focal species are intended to represent ecological conditions that provide for sustainable populations. However, it is not expected that the population dynamics of a focal species would directly represent the population dynamics of another species.

Lindenmayer et al. (2002) pointed out some of the limitations of the focal species concept, including that the approach is data-intensive, scientific understanding is lacking for many species, and there is a lack of testing to validate the approach. Lindenmayer et al. (2002) were concerned that the focal species approach not be the only approach used to guide landscape restoration. However, the focal species approach has recently been tested for wide-ranging carnivores and birds with promising results (Carroll et al. 2001, Watson et al. 2001). In addition, Roberge and Angelstam (2004) recently reviewed the umbrella species concept and concluded that the focal species approach seems the most promising because it provides a systematic procedure for selection of umbrella species. The focal species approach is a relatively rigorous way, compared to other approaches, to deal with assessments that involve many species (Andelman et al. 2001, Roberge and Angelstam 2004).

The concept of focal species differs from the concept of management indicator species (MIS) described in the regulations written to implement the NFMA (36 CFR 219.19). The use of MIS was considered a means of evaluating the effects of management on a suite of associated species in that their population trends were assumed to reflect the changes in habitat amount and quality due to the effects of management practices. The MIS concept has been questioned in the literature over the last 2 decades (e.g., Landres et al. 1988, Andelman et al. 2001). The MIS concept evolved to the concept of surrogate species, including focal species, through the practice of conservation biology in the late 1990s (Lambeck 1997). Surrogate (focal) species are now considered a more appropriate approach in addressing species sustainability (Wiens et al. 2008).

We developed a detailed framework that incorporated focal species to assess if wildlife populations were well distributed and self sustaining. This process encompassed the following major steps: we identified species at risk and grouped those species to facilitate assessment, we identified habitats and risk-factors associated with those species, we identified focal species that represented the species groups, we developed and applied assessment models for each focal species, we developed conservation strategies for species at risk, and we provided recommendations for monitoring. To illustrate the application of this process through a case study, we applied it to a study area in central and northeast Washington State, USA.

STUDY AREA

National Forest System lands (>2 million ha) within the Okanogan-Wenatchee and Colville national forests made up the northeast Washington State assessment area (Fig. 1). This area was bounded on the west by the crest of the Cascade Range, on the north by the Canadian border, and on the east by the Idaho border.

Dominant forest cover types across the study area included 270,660 ha of subalpine forest, 803,100 ha of cold-moist forest, 138,650 ha of cold-dry forest, 103,500 ha of mesic forest, and 645,000 ha of dry forest. The remainder of the study area (approx. 100,000 ha) was composed of high elevation alpine and subalpine meadows and low elevation shrub-steppe and dry grasslands. Elevations ranged from 3,170 m along the Cascade Crest to 200 m along the Columbia River. Precipitation ranged from about 200 cm at the highest elevation mountain crests to 25 cm at low-elevation semi-desert locations (Lillybridge et al. 1995).

METHODS

Identification of Species of Conservation Concern

Our focus in this process was on native terrestrial vertebrates of regional or local conservation concern as indicated by documented threats to populations or habitats. We characterized a species as having a documented threat if it had been identified in previous reviews of species at risk in the study area. After compiling a list of all native terrestrial vertebrate species present in the study area, we evaluated each against a series of criteria to determine if those species should be considered a species of conservation concern for our evaluation process. The initial screen included species that were listed as endangered, threatened, candidate, or proposed under the United States Endangered Species Act or species that were petitioned for listing and received a determination of "may be warranted" or "warranted but precluded." Secondly, we included species listed by Oregon Department of Fish and Wildlife or Washington Department of Fish and Wildlife as threatened or endangered. We also included species considered by NatureServe to be globally or regionally at risk (i.e., G-1–G-3, T-1–T-3, S-1–S-3; NatureServe 2009). We added species on the United States Department of Interior (USDI) Fish and Wildlife Service Birds of Conservation Concern National Priority list (North American Bird Conservation Initiative U.S. Committee 2009) and species considered sensitive by the United States Department of Agriculture (USDA) Forest Service (USDA Forest Service 2008). We included bird species in the Partners in Flight Species Assessment Database with scores indicating a moderate to

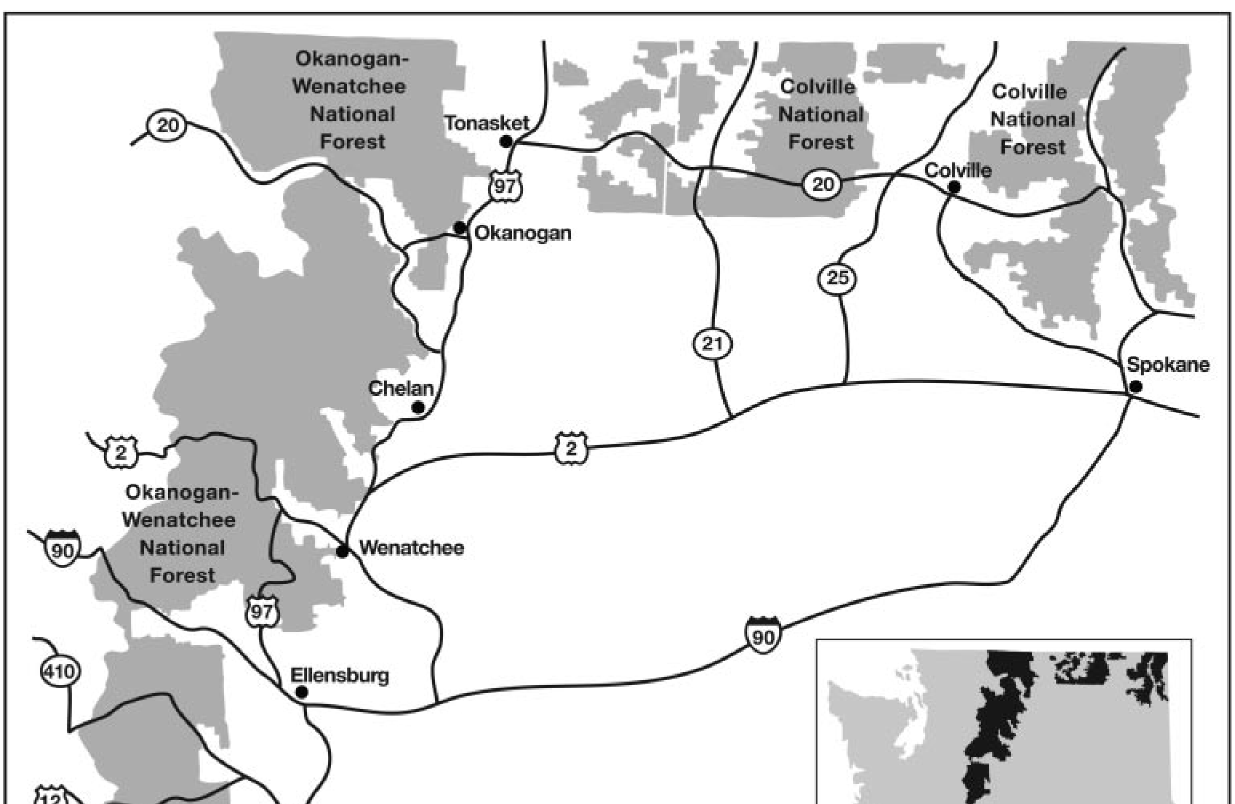

Figure 1. The study area used to develop and apply a process to assess if wildlife populations were well distributed and self sustaining in northeast Washington State, USA, 2003–2010.

large population decline or severe to extreme threats to populations (Rocky Mountain Bird Observatory 2005), as well as species similarly identified by Wisdom et al. (2000) and Raphael et al. (2001). We also added species identified in the Oregon and Washington State comprehensive wildlife conservation strategies (Washington Department of Fish and Wildlife 2005, Oregon Department of Fish and Wildlife 2006). Finally, if a species did not occur on National Forest System lands east of the crest of the Cascade Mountains in Oregon or Washington State, USA, we dropped it from consideration.

Description of Habitat Requirements for Species of Conservation Concern

We classified vegetation using a combination of cover types and structural classes (for upland forested habitats) similar to those described in Johnson and O'Neil (2001) but combined some classes to better match the vegetation classification available to national forests for planning purposes. In addition, we described 6 riparian and wetland habitat cover types and a post-fire cover type to address vegetation that occurs immediately following a stand-replacing fire. We identified source habitats (i.e., characteristics of macro-vegetation that contribute to stationary or positive population growth [Wisdom et al. 2000]) for each species using Wisdom et al. (2000), Johnson and O'Neil (2001), other published literature, and professional judgment.

Grouping Species of Conservation Concern

We used agglomerative hierarchical cluster analysis to sequentially join species into progressively fewer groups (fewer clusters) until all species were joined in one cluster (Johnson and Wichern 2007). The result was a classification tree, which displayed the degree of similarity among groups at various points (SAS Institute Inc 2004). We developed groups primarily based on commonality of vegetation type and structural stage, as did Wisdom et al. (2000). We used 53 habitat variables in the cluster analysis consisting of combinations of 6 forest land cover classes, 5 tree size classes, and 2 canopy closure categories for forested vegetation; 3 non-forest land cover classes; 6 riparian and wetland land cover classes; and a cave category (Table 1). We sequentially examined sets of clusters with increasing numbers of clusters in each set to detect a degree of aggregation consistent with our understanding of species ecological relationships at the macrohabitat scale as done by Wisdom et al. (2000). We also evaluated similarity between species and among clusters using the Ochiai index of similarity (Legendre and

Table 1. Habitat variables we used to group species of conservation concern in eastern Oregon and Washington State, USA, 2003–2010, during our assessment to determine if wildlife populations were well distributed and self sustaining.

Variable	Description[a]
Land cover classes	
Forest	
Subalpine parkland	Mosaic of trees (10–30% canopy) and openings with grasses, forbs, or dwarf shrubs
Montane mixed conifer forest	Forest dominated by evergreen conifers (e.g., subalpine fir [*Abies lasiocarpa*], Engelmann spruce [*Picea engelmannii*])
Eastside (interior) mixed conifer forest	Montane forests and woodlands dominated by Douglas fir (*Pseudotsuga menziesii*), which may be associated with ponderosa pine (*Pinus ponderosa*), grand fir (*Abies grandis*), western red cedar (*Thuja plicata*), or western hemlock (*Tsuga heterophylla*)
Lodgepole pine forest and woodlands	Open to closed conifer forests dominated by lodgepole pine (*Pinus contorta*)
Ponderosa–white oak forest and woodlands	Woodland or Savanna (10–60% canopy) dominated by ponderosa pine with Douglas fir, western larch (*Larix occidentalis*), or Oregon white oak (*Quercus garryana*)
Juniper woodlands	Western juniper (*Juniperus occidentalis*; 10–60% canopy) with bunchgrass or shrub undergrowth
Non-forest	
Alpine	Grasses, forbs, or dwarf shrubs growing at high altitude above tree line
Shrub steppe	Arid areas with a mixture of grass and shrub vegetation (10–60% shrub canopy cover; includes sagebrush [*Artemisia* spp.])
Grasslands	Lands dominated by herbaceous or graminoid vegetation <1 m tall; tree and shrub canopy <10%
Riparian–water	
Coniferous riparian	Coniferous forests adjacent to running or standing water
Deciduous riparian	Deciduous forests adjacent to running or standing water
Wetland deciduous shrubs	Deciduous shrubs <6 m in height on wet soils but without standing water for extended periods
Marsh	Wetland principally inhabited by partially-submerged herbaceous vegetation
Wet meadow	Open grassland with waterlogged soils but without standing water for most of the year
Open water	Shallow (approx. 1 m) lakes and ponds
Tree size classes	
Large	≥53 cm dbh
Medium	≥38–<53 cm dbh
Small	≥25–<38 cm dbh
Sapling	<25 cm dbh
Seedling	Stand initiation
Tree canopy closure	
Open	<50% closure
Closed	≥50% closure
Caves	

[a] Description of forest land cover classes follow Johnson and O'Neil (2001). English and scientific nomenclature for plants followed U.S. Department of Agriculture Natural Resources Conservation Service (2010).

Legendre 1998). We chose the fewest groups that allowed aggregation while still reflecting important patterns in source habitats for species. Likewise, we placed groups of species within families (categorical, not phylogenetic) based on further similarities in habitats. Each species within a group, and each group within a family, was nested completely within each of the higher levels of grouping (i.e., we assigned each species to one group, and each group assigned to one family).

Ecological Relationships of Species of Conservation Concern

To more thoroughly describe the ecological requirements of the species of conservation concern, we complied information in addition to habitat associations on risk-factors, fine-scale habitat features, home-range size, elevation constraints on occurrence of species, and geographic range for each species of conservation concern (as per Andelman et al. 2001). We identified risk-factors that had the potential to result in reductions of habitat availability, habitat effectiveness, population size, or fitness. In addition to broad-scale habitat associations, we noted whether a species used specific fine-scale habitats such as water features (e.g., springs and seeps), topographic features (e.g., talus slopes), structure features (e.g., logs, decayed trees), or other physical features (e.g., serpentine soil; as per Johnson and O'Neil 2001). Home-range size and a species' dispersal capabilities may also play a role in determining which species may best represent ecological requirements of other species (Johnson and O'Neil 2001). Information on geographic range was helpful in determining which species best represented the ecological requirements of other species across the study area (e.g., species with non-overlapping ranges poorly represent each others' requirements). We defined a species' range as the polygon or polygons that encompassed the outer boundaries of a species' geographic occurrence within the study area.

Selection of Focal Species

Our goal was to have a manageable number of focal species (approx. 30) to assess and still achieve reliable inference to the likelihood of providing appropriate ecological conditions for the non-focal species (after Wiens et al. 2008). After we clustered species into groups based on habitat relationships and other environmental requirements, we identified a single or small set of focal species within each group using established criteria (Table 2). Whereas our intent was to select a set of species that represented the full array of potential responses of species to management activities (Raphael et al. 2001), in reality we represented the primary habitat and risk-factor categories we had identified a priori.

Development of Focal Species Assessment Models

We developed Bayesian Belief Network models using the Netica® (Norsys Software Corporation, Vancouver, British Columbia, Canada) modeling shell to provide a structured tool for integrating several sources of information to make comparisons among management alternatives on how well the conservation of focal species was addressed (Marcot et al. 2001, Raphael et al. 2001). We developed 2 models for each species analyzed, similar to the approach used in Wisdom et al. (2000). The first calculation provided an index of habitat capability for each watershed (synonymous with Hydrologic Unit Code 5) in the study area (i.e., watershed index) that ranged from 0 to 3 (low: 0 to 1, moderate: >1 to <2, high: ≥ 2). The primary variables included in the watershed index models included habitat amount, habitat quality, and risk factors. We compared the current area of source habitat for a focal species within each watershed to an estimate of the historical range of variability (HRV) for that species' source habitat. The process used to derive HRV estimates for forest vegetation was based on Hann et al. (1997), Hessburg et al. (1999), and Agee (2003).

The second model estimated a probability of the study area to support a sufficiently abundant and well-distributed population of the species of interest (i.e., population outcome). These models incorporated a watershed index score for each watershed, which we weighted by the amount of habitat in the watershed, an index of the distribution of habitat across the study area, and for some species, a habitat connectivity index that assessed how well habitats were connected across watersheds. We assumed that species with high index scores would have a high probability of having populations that are self-sustaining, viable, and well-distributed throughout their historical ranges in the study area. However, it should be noted that we did not include risks to sustainable populations from elements such as disease, catastrophic events, and interspecific interactions in this framework. These, and other factors, may confound comparisons among modeled outcomes and reality.

Table 2. Criteria we used to select focal species for eastern Oregon and Washington State, USA, 2003–2010, during our assessment to determine if wildlife populations were well distributed and self sustaining.

Criterion	Description
Source habitats	If we noted differences in source habitat use within a species group, we selected >1 focal species to represent the full array of source habitats used by the group or family
Risk factors	We selected species that represented all or key combinations of risk factors identified for the group or family
Fine scale habitats	We selected species that used fine scale habitat features identified for the group or family (e.g., if some species within the habitat-based group used snags, we selected a species with the most demanding or limiting snag requirements as a focal species)
Home range and dispersal	Lambeck (1997) recommended that species with the most demanding requirements be selected as focal species. We attempted to choose species with the largest home range, which is a more limiting requirement than species with smaller home ranges. Knowledge of dispersal capabilities was lacking for most species, although, where possible, we considered species with the most limited dispersal capability as focal species
Species range	We gave species with the widest distribution across the study area priority within groups or families

We developed and applied focal species assessment models for wolverine (*Gulo gulo*; Fig. 2, Table 3) and northern goshawk (*Accipiter gentiles*; Fig. 3, Table 4) for our case study to demonstrate changes in amount and quality of habitat (see Gaines et al. in press for a more thorough description of these focal species assessment models and their application).

Evaluation of Focal Species Assessment Models

We evaluated the watershed index models using location data on species occurrences within the study area from the Washington Department of Fish and Wildlife Heritage Database (e.g., northern goshawk: 674 records, wolverine: 64 records; Washington Department of Fish and Wildlife 2006). We compared watershed index scores associated with points of occurrence for each species to an equal number of random locations. Our assumption was that mean watershed index values from the occurrence points would be greater than mean watershed index values generated from the random points if our models were operating as designed. We used 2-sample t-tests for unequal variances to compare the average values of the watershed index scores associated with the species occurrence data to those of the random points (Snedecor and Cochran 1989).

Development of Conservation Strategies

Wisdom et al. (2002) described a process for assessing habitat conditions for groups of species to identify a habitat network for terrestrial wildlife in the interior Columbia basin. We modified this approach to integrate information from multiple focal species into overall conservation strategies. For each focal species, we determined the condition of the habitat in each watershed, which led to a conservation emphasis for each focal species in each watershed (i.e., habitat protection, habitat restoration, develop or enhance connectivity of habitats, or combinations of these). We then created a matrix of all focal species and conservation measures that addressed their habitat and risk factors to identify key conservation strategies that would benefit multiple species.

The multi-species strategies provided a basis for including management practices designed to restore or maintain well-distributed, self-sustaining populations into management strategies that incorporated multiple resources (e.g., fisheries, fuels, recreation). Because compromises in the multi-species strategies were often required during development of the multi-resource strategies, we evaluated the resulting modeled landscapes again with the focal species assessment models to ensure suitable progress was made toward restoring or maintaining sustainable populations. If we determined through that analysis that conditions needed for well-distributed, self-sustaining populations were not adequately restored or maintained, we revised the multi-resource strategies to address the limiting factors.

Monitoring and Adaptive Management

When dealing with complex management questions and high levels of uncertainty, monitoring and adaptive management become vital tools (Busch and Trexler 2003). Assessing sustainability of focal species is complex and involves uncertainties. The primary assumptions made in the development

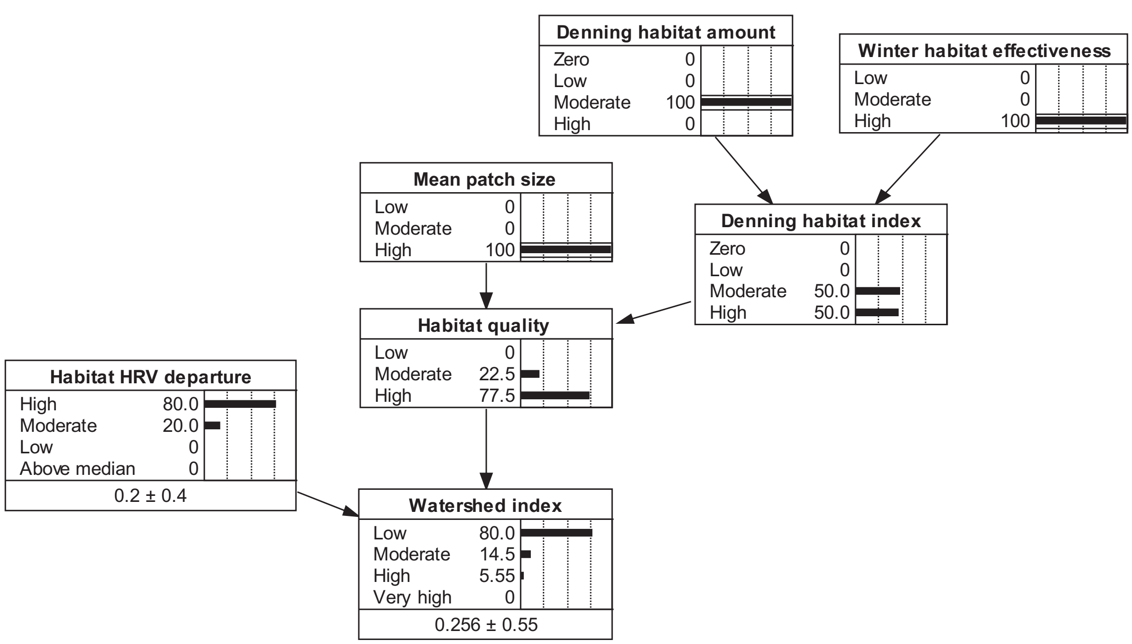

Figure 2. Focal species assessment model for wolverines expressed as a Bayesian Belief Network. This figure illustrates running the model for a specific watershed in northeast Washington State, USA, 2003–2010 with a moderate amount of denning habitat, high effectiveness of winter habitat, large patch size, and a large negative departure from the historical range of variability in the amount of source habitat. Characterization of the values of variables within the nodes grades from negative effect at the top to positive effect at the bottom. For example, within the habitat historical range of variability (HRV) departure node, high loss in the amount of source habitat from the historical range of variability had a negative effect on amount and distribution of habitat. Even though there was evidence that habitat present in the watershed was of high quality, the effect of loss of habitat from historical conditions resulted in a low overall watershed index. Values by the solid bars are probabilities; for example, the model predicted an 80% probability that this watershed had a low index value for wolverines. Numbers below the boxes are mean and standard deviation (assuming a Gaussian error distribution); we scaled index values from zero (habitat not present) to 3 (high habitat quality; thus, 0.256 denotes evidence of low habitat quality for wolverines in this watershed).

Table 3. Focal species assessment model for wolverine developed and applied in northeast Washington State, USA, 2003–2010.

Factor	Variable	Background	Quantification
Habitat	Departure in amount of habitat from historical conditions	Effects of roads on wolverines and their habitat and have been documented (Wisdom et al. 2000, Carroll et al. 2001, Raphael et al. 2001, Rowland et al. 2003, Copeland et al. 2007, Krebs et al. 2007). Carroll et al. (2001) found areas with road densities <0.6 km/km^2 to be strongly correlated with presence of wolverines. Wisdom et al. (2000) modeled source habitat for wolverines by including cover types and structural stages in montane forest, subalpine forest, and alpine tundra.	Roads: areas with road densities <0.6 km/km^2; we calculated densities within each watershed in the assessment area. Cover types: alpine, parkland, subalpine fir, pacific silver fir (*Abies amabilis*), Engelmann spruce, western hemlock, western red-cedar, mountain hemlock (*Tsuga mertensiana*), lodgepole pine, western larch, mixed conifer, Douglas fir, and grand fir.
	Mean patch size	Banci (1994) identified the need for large areas of appropriate vegetation types with low human use to provide for conservation of wolverine. We evaluated the relative size of the areas of source habitat within a watershed by computing a mean patch size.	Low: <5 km^2 mean patch size of source habitat for the watershed Moderate: 5–10 km^2 mean patch size of source habitat for the watershed High: >10 km^2 mean patch size of source habitat for the watershed
	Amount of denning habitat	Natal dens are typically above or near treeline, require snow depths of 1–3 m that persist into spring, and are near rocky areas such as talus slopes or boulder fields (Copeland 1996). The predictive model developed by Carroll et al. (2001) was improved when alpine cirque habitat was added as a variable. We modeled potential den habitat by using landtype associations that described alpine and subalpine boulder fields and talus slopes.	Zero = 0 ha of potential den habitat Low = >0–1,500 ha of potential den habitat Moderate = >1,500–3,500 ha of potential den habitat High = >3,500 ha of potential den habitat
Human disturbance	Winter habitat effectiveness	Copeland (1996) documented the potential for disturbance to wolverine dens as a result of late-winter to spring snowmobile and other winter recreation activities. We assessed the potential effects of winter recreation on wolverine habitat by overlaying groomed and designated winter routes onto wolverine habitat and assessing the density of these routes.	Low: >25% of habitat with winter route densities >3.2 km/2.6 km^2 Moderate: >25% of habitat with winter route densities >1.6 km/2.6 km^2 High: <25% of habitat with winter route densities <1.6 km/2.6 km^2

and implementation of this process included: species' assessment models provided a conceptual outline of the primary habitat and risk factors that influence the sustainability of focal species, the assessment models provided a reasonable and scientifically credible structural approximation of the species niche in the ecosystem that can be used to identify key monitoring elements, the selected focal species represented the species group in a manner that provided insights into the capability of the habitat to support other species in the group, and thus species with high index scores would have a high probability of having populations that are self-sustaining, viable, and well-distributed throughout their historical ranges in the study area.

These assumptions guided development of specific monitoring and research questions that varied for each focal species. Because of the number of focal species we selected to represent various habitats and risk factors, it was not possible to monitor all focal species in a rigorous manner due to cost and impracticality. Therefore, we developed a process to prioritize focal species monitoring based on the likelihood of restoring or maintaining well-distributed, self-sustaining populations of each focal species; whether source habitat and risk factors that influenced sustainability for each species were likely to increase, decrease, or remain the same; and the degree of uncertainty associated with predictions of the relationship between each focal species and their risk factors.

RESULTS

Species of Conservation Concern

We evaluated >700 species (67% birds, 23% mammals, 5% amphibians, 5% reptiles) documented to occur in Oregon and Washington State, USA. Following application of the screening criteria, we identified 209 species of conservation concern on National Forest System lands east of the crest of the Cascade Mountains in these states. We aggregated these species into 10 habitat families and 28 habitat groups based on habitat associations (Table 5). We identified 52 focal species (67% birds, 17% mammals, 14% amphibians, 2% reptiles) based on risk factors and ecological characteristics; we selected 34 for use in northeast Washington State, USA (Table 6).

To provide examples of the application of our process we chose to present our findings for wolverine and northern goshawk. Wolverines are habitat generalists sensitive to risk factors that can cause disturbance (Gaines et al. 2003, Copeland et al. 2007, Krebs et al. 2007). Increasing human disturbance, especially in the form of winter recreation, could potentially affect wolverine denning habitats (Banci 1994, Krebs et al. 2007). Northern goshawks use a complex mosaic of landscape conditions to meet various life history requirements for nesting, post-fledgling, and foraging, including mature and older forests in eastern Oregon and Washington State, USA (Reynolds et al. 1992, McGrath et al. 2003). Fire exclusion within these habitats has reduced their sustainability and resulted in increased susceptibility to stand-replacing fires (Everett et al. 2000, McGrath et al. 2003). These species' source habitats and their associated risk factors

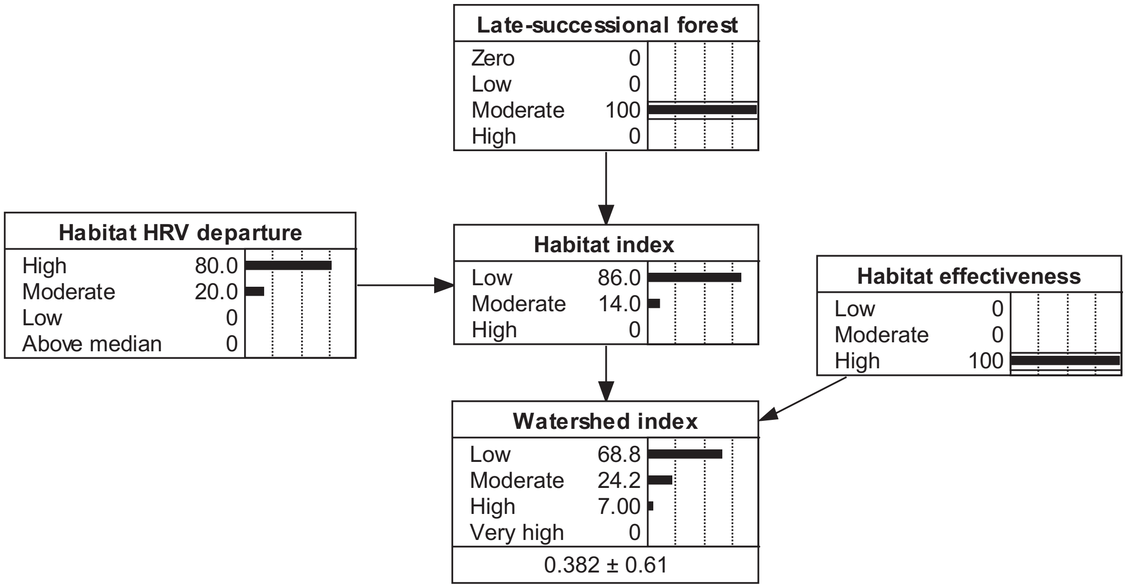

Figure 3. Focal species assessment model for northern goshawks expressed as a Bayesian Belief Network. This figure illustrates running the model for a specific watershed in northeast Washington State, USA, 2003–2010 with a moderate amount of late successional forest, high effectiveness of habitat, and a large negative departure from the historical range of variability in the amount of source habitat. Characterization of the values of variables within the nodes grades from negative effect at the top to positive effect at the bottom. For example, within the habitat HRV departure node, high loss in the amount of source habitat from the historical range of variability had a negative effect on amount and distribution of habitat. Values by the solid bars are probabilities; for example, the model predicts an approximate 69% probability that this watershed had a low index value for northern goshawks. Numbers below the boxes are mean and standard deviation (assuming a Gaussian error distribution); we scaled index values from zero (habitat not present) to 3 (high habitat quality; thus, 0.382 denotes evidence of low habitat quality for northern goshawks in this watershed).

involve them in 2 of the most complex issues currently facing land managers in North America, increasing human recreation and management of fire and fuels.

Wolverine.—We selected this focal species from species of conservation concern that were habitat generalists and that were sensitive to risk factors that can cause disturbance (i.e., peregrine falcon [*Falco peregrines*], gray wolf [*Canis lupus*], grizzly bear [*Ursus arctos*]; Gaines et al. 2003, Copeland et al. 2007, Krebs et al. 2007). Reports of wolverines within the planning area have been steadily increasing since the 1960s (Johnson 1977, Edelmann and Copeland 1999, Aubry et al. 2007). At the time of our analysis their distribution appeared to include the Cascade, Kettle Range, and Selkirk mountains, though wolverine density was likely low (Edelmann and Copeland 1999, Aubry et al. 2007).

Northern goshawk.— We selected this focal species from species of conservation concern associated with a wide range of forest types that had a habitat component of large trees (i.e., dusky grouse [*Dendragapus obscures*], band-tailed pigeon [*Patagioenas fasciata*], long-eared owl [*Asio otus*], great gray owl [*Strix nebulosa*]). Goshawks were reported to be widely distributed across the forested portions of the study area (Smith et al. 1997).

Habitat Models

Wolverine.— Application of the focal species assessment model for wolverine indicated that 5 (7%) watersheds in the study area had high watershed index values. The remaining watersheds had moderate watershed index values. Moderate scores were largely due to the influence of roads on habitat effectiveness for wolverines. In our model, roads reduced the availability of source habitat to wolverines and reduced mean patch size of source habitats within watersheds. The population outcome we calculated for the whole study area indicated that suitable environments for wolverines were broadly distributed and of high abundance, but there were gaps where suitable environments were absent or only present in low abundance. However, the disjunct areas of suitable environments were typically large and close enough to permit dispersal among subpopulations and to allow the species to potentially interact as a metapopulation. Historically, suitable environments for wolverines were likely more broadly distributed and of higher abundance. In addition, the suitable environments may have been better connected, allowing for enhanced intraspecific interactions. Our analysis indicated that a reduction in the availability of suitable environments for wolverines may have occurred in the study area compared to the historical distribution and condition of their habitats.

We derived mean watershed index values from 64 wolverine occurrence points, which we compared with watershed index values from 63 random points. Mean watershed index value for the occurrence points (2.01) was higher ($t = 1.98$, $P \leq 0.001$) than the mean derived from the random points (1.58).

Northern goshawk.—Application of the focal species assessment model for northern goshawks indicated that 31 (43%) watersheds in the study area had high watershed index values. Eleven percent (8) of watersheds in the study area had moderate watershed index values; the remaining 32 (46%) watersheds had low values. Our assessment showed that the amount of source habitat had the most influence on the index values. Fifty percent of watersheds had less than the historical median of source habitat. The population outcome

Table 4. Focal species assessment model for northern goshawk developed and applied in northeast Washington State, USA, 2003–2010.

Factor	Variable	Background	Quantification
Habitat	Departure in amount of habitat from historical conditions	Northern goshawks use a complex mosaic of landscape conditions to meet various life history requirements for nesting, post-fledgling, and foraging (Reynolds et al. 1992). Goshawk nesting habitat in eastern Washington and Oregon is generally composed of mature and older forests (McGrath et al. 2003). Nest stands are typically composed of a many large trees, high canopy closure (>50%), multiple canopy layers, and many snags and downed wood (McGrath et al. 2003).	Forest types: dry forest, mesic forest, cold-moist forest Tree size and forest structure: single or multistory, >38 cm dbh (quadratic mean diameter) Canopy closure: >50%
	Late successional forest	Goshawks forage in a variety of forest types, however several studies have shown the importance of mid to late successional forests as foraging habitat for goshawks (Finn et al. 2002*a*,*b*, Drennan and Beier 2003, Desimone and DeStefano 2005). Beier and Drennan (1997) supported the hypothesis that goshawk morphology and behavior are adapted for hunting in moderately dense, mature forests, and that prey availability (as determined by the occurrence of favorable vegetation structure) is more important than prey density in habitat selection.	Zero = 0% of source habitat in late-successional forest Low = > 0–20% of source habitat in late-successional forest Moderate = > 20–50% of source habitat in late-successional forest High = > 50% of source habitat in late-successional forest
Human disturbance	Habitat effectiveness	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). To address this we used the late-successional forest habitat disturbance index described in Gaines et al. (2003).	Low: <50% of source habitat outside zone of influence. Moderate: 50–70% of source habitat outside zone of influence High: >70% of source habitat outside zone of influence

calculated for the whole study area indicated that suitable environments for northern goshawks were broadly distributed and of high abundance, but there were gaps where suitable environments were absent or only present in low abundance. These gaps were typically not large enough to prevent the species from interacting as a metapopulation. Historically, suitable environments for northern goshawks were likely more broadly distributed and of higher abundance. In addition, suitable environments may have been better connected, allowing for enhanced intraspecific interactions. Our analysis indicated that a reduction in the availability of suitable environments for northern goshawks may have occurred in the study area compared to the historical distribution and condition of their habitats.

We compared mean watershed index values derived from 674 occurrence points to the mean watershed index derived from 674 random points. Mean watershed index for the occurrence points (1.72) was higher ($t = 1.96$, $P \leq 0.001$) than the mean we derived from the random points (1.56).

Conservation strategies.— We used the information from individual focal species assessments to identify 10 broad conservation strategies that addressed habitat conservation and risk factors for multiple focal species. These strategies provided a biological foundation from which integration with other resources during forest planning occurred. The multi-species strategies include 2 parts: specific conservation measures and a prioritized list of watersheds for habitat treatments. We developed specific conservation strategies to address aquatic and riparian habitats, snags and downed wood, late-successional forests, dry forest restoration, post-fire timber harvest, human access management, domestic livestock grazing, invasive species, wildland fire use, and unique habitats.

DISCUSSION

Our results, though based on finer-scale data, were similar to those reported for wolverines in Raphael et al. (2001). Both assessments showed trends of reduced habitat availability compared to historical conditions across broad areas. Wolverines were included in the conservation strategy developed for human access management, which called for: 1) managing winter recreation for no net increase in groomed and designated snow routes that create snow compacting conditions (e.g., Ruediger et al. 2000), 2) reducing the negative impacts of roads on focal species' source-habitats by reducing overall road density and reducing the amount of area within a zone of influence of a road (Gaines et al. 2003), 3) using Singleton et al. (2002) and permeability information from our assessment to identify unroaded areas or areas with low-road densities to serve as stepping-stones to enhance habitat permeability, and 4) managing road construction activities to either maintain or enhance landscape permeability. This strategy also required that human activities adjacent to highways be managed so that wildlife could access any crossing structures. Among other focal species assumed to have benefited from this conservation strategy were American marten (*Martes americana*), Canada lynx (*Lynx canadensis*), and bighorn sheep (*Ovis canadensis*). All of these

Table 5. Number of species of conservation concern and focal species by habitat family, habitat group, and taxa in eastern Oregon and Washington State, USA, 2003–2010.

Habitat			Number of species							
			Birds		Mammals		Amphibians		Reptiles	
Family	Group	Habitat description	Total	Focal	Total	Focal	Total	Focal	Total	Focal
Alpine–boreal	Alpine	Non-forested habitats above tree-line	1	1						
	Boreal forest	Mid- to high-elevation mosaic of dense and open stands as well as larger and smaller trees	4	2	5	3				
Forest mosaic	All forest communities	Multiple forest habitats from low to high elevations with a mix of dense forest and openings	5	1						
Medium and large trees	All forest communities	Variety of forest communities across elevational gradients; tree dbh ≥38 cm; large snags are used by some of the species in this group; usually associated with late-successional forests	7	1	5					
	Cool and moist forests	Cool and moist forests occurring at mid- to high-elevations as source habitat; several species use large snags or defective trees for nesting or foraging; large hollow trees are important for a few species; usually associated with late-successional forests.	10	1	3	1	1	1		
	Dry forest	Dry forests at lower elevations (primarily ponderosa pine, sometimes Douglas fir); most species use cavities, sloughing bark, or crevices in large snags for nesting or roosting; some species use open, single-story stands whereas others use more closed canopy, multi-story stands	5	1	1					
Open forest	All forest communities	Open canopied (<50%) forested ecosystems across a range communities and elevational gradients; tree size is not necessarily important (i.e., species will use small- to large-tree structure stages)	6	1	3	1			2	
	Early succession	Early succession forest in all community types	3	2						
	Pine–oak (medium to large tree)	Ponderosa pine woodlands with a component of Oregon white oak; large snags or defective trees	1	1	1	1			1	1
	Post-fire habitat	Post-fire habitats with abundant snags; most species also occur in other groups, at lower densities, when post-fire habitat is not available	6	2						
Upland grassland	Upland grassland	Natural grassy openings within forest matrix (i.e., not within the shrub steppe matrix)	1	1						
Human disturbance	Habitat generalist	Species sensitive to human disturbance; require remote areas	1	1	3	1				
Woodland–grass–shrub	Woodland–grass–shrub	Woodland, grassland, and shrubs	9	2	4				4	
	Juniper woodland	Open juniper woodlands with or without a shrub understory	3	1						
	Woodland–shrub	Shrub steppe and juniper woodland; (i.e., shrublands with scattered juniper and juniper savannah)	3	1	1				2	
	Shrub	Shrub steppe and dwarf shrub habitats dominated by sagebrush and bitterbrush (*Purshia tridentata*) outside of the forest matrix (i.e., not shrub dominated seral stages of forest types)	5	2	2		1			
	Grass–shrub	Grasslands and shrublands outside the forest matrix	6		9	1	1	1		
	Grassland	Grasslands outside the forest matrix (i.e., not small, natural openings within forests)	4	3						
Chambers–caves	Chambers–caves	Chambers, including caves and human-made structures			2	1				
Riparian	Conifer	Coniferous forests adjacent to running or standing water	1	1			1	1		
	Large tree or snag–open water	Tree and snag cavities and large trees adjacent to water	8	3						
	Shrubby–deciduous	Shrubs adjacent to running or standing water; may or may not be part of deciduous forest	13	2	1					
	Marsh with adjacent large trees	Water with emergent vegetation for foraging, and adjacent large trees for nesting.	4	1						
	Pond–small lake–slough	Small, shallow water bodies with limited water flow	1				5	4	2	
	Banks	Stream banks with exposed soil for nest excavations	1	1						
Wetland	Marsh	Water with emergent vegetation	8	1						
	Marsh–wet meadow	Water with emergent vegetation or meadows with standing water	11	1						
	Marsh–open water	Water with emergent vegetation and open water	22	1						
		Total	149	35[a]	40	9[b]	8	7[c]	12	1[d]

[a] 4 species had localized populations confined to specific habitats, we analyzed these species only where they occurred and not across the assessment area; 7 species were alternates that may be used to better address specific regional issues.
[b] 3 species had localized populations confined to specific habitats, we analyzed these species only where they occurred and not across the assessment area; 1 species was an alternate that may be used to better address specific regional issues.
[c] 4 species had localized populations confined to specific habitats, we analyzed these species only where they occurred and not across the assessment area; 2 species were alternates that may be used to better address specific regional issues.
[d] 1 species had a localized population confined to specific habitats, we analyzed that species only where it occurred and not across the assessment area.

Table 6. Focal species by habitat family and group identified for eastern Oregon and Washington State, USA, 2003–2010.

Habitat[a]			
Family	Group	Focal species[b]	Focal type[c]
Alpine–boreal	Alpine	Gray-crowned rosy-finch (*Leucosticte tephrocotis*)	Secondary
	Boreal forest	Spruce grouse (*Falcipennis canadensis*)	Alternate
		Boreal owl (*Aegolius funereus*)	Alternate
		Canada lynx[d] (*Lynx canadensis*)	Alternate
		Water vole[d] (*Microtus richardsoni*)	Primary
		Northern bog lemming[d] (*Synaptomys borealis*)	Secondary
Forest mosaic	All forest communities	Northern goshawk[d] (*Accipiter gentilis*)	Primary
Medium and large trees	All forest communities	Cassin's finch[d] (*Carpodacus cassinii*)	Primary
	Cool and moist forests	Pileated woodpecker[d] (*Dryocopus pileatus*)	Primary
		American marten[d] (*Martes americana*)	Primary
		Larch mountain salamander[d] (*Plethodon larselli*)	Secondary
	Dry forest	White-headed woodpecker[d] (*Picoides albolarvatus*)	Primary
Open forest	All forest communities	Western bluebird[d] (*Sialia mexicana*)	Primary
		Fringed myotis[d] (*Myotis thysanodes*)	Primary
	Early succession	Fox sparrow[d] (*Passerella iliaca*)	Alternate
		Townsend's solitaire (*Myadestes townsendi*)	Alternate
	Pine–oak (medium to large tree)	Acorn woodpecker (*Melanerpes formicivorus*)	Secondary
		Western gray squirrel[d] (*Sciurus griseus*)	Secondary
		California mountain kingsnake (*Lampropeltis zonata*)	Secondary
	Post-fire habitat	Lewis's woodpecker[d] (*Melanerpes lewis*)	Primary
		Black-backed woodpecker[d] (*Picoides arcticus*)	Primary
Upland grassland	Upland grassland	Upland sandpiper (*Bartramia longicauda*)	Primary
Human disturbance	Habitat generalist	Peregrine falcon[d] (*Falco peregrines*)	Primary
		Wolverine[d] (*Gulo gulo*)	Primary
Woodland–grass–shrub	Woodland–grass–shrub	Golden eagle[d] (*Aquila chrysaetos*)	Primary
		Lark sparrow[d] (*Chondestes grammacus*)	Primary
	Juniper woodland	Ash-throated flycatcher (*Myiarchus cinerascens*)	Primary
	Woodland–shrub	Loggerhead shrike (*Lanius ludovicianus*)	Primary
	Shrub	Greater sage-grouse (*Centrocercus urophasianus*)	Alternate
		Sage thrasher[d] (*Oreoscoptes montanus*)	Alternate
	Grass–shrub	Bighorn sheep[d] (*Ovis canadensis*)	Primary
		Tiger salamander[d] (*Ambystoma tigrinum*)	Secondary
	Grassland	Northern harrier[d] (*Circus cyaneus*)	Alternate
		Swainson's hawk (*Buteo swainsoni*)	Alternate
		Grasshopper sparrow (*Ammodramus savannarum*)	Alternate
Chambers–caves	Chambers–caves	Townsend's big-eared bat[d] (*Corynorhinus townsendii*)	Secondary
Riparian	Conifer	Black swift (*Cypseloides niger*)	Secondary
		Inland tailed frog[d] (*Ascaphus truei*)	Primary
	Large tree or snag–open water	Wood duck[d] (*Aix sponsa*)	Primary
		Harlequin duck[d] (*Histrionicus histrionicus*)	Secondary
		Bald eagle[d] (*Haliaeetus leucocephalus*)	Primary
	Shrubby–deciduous	Red-naped sapsucker[d] (*Sphyrapicus nuchalis*)	Primary
		MacGillivray's warbler[d] (*Oporornis tolmiei*)	Primary
	Marsh with adjacent large trees	Black-crowned night-heron (*Nycticorax nycticorax*)	Primary
	Pond–small lake–slough	Woodhouse's toad (*Bufo woodhousii*)	Secondary
		Cascades frog (*Rana cascadae*)	Secondary
		Oregon spotted frog (*Rana pretiosa*)	Alternate
		Columbia spotted frog[d] (*Rana luteiventris*)	Alternate
	Banks	Northern rough-winged swallow (*Stelgidopteryx serripennis*)	Primary
Wetland	Marsh	Marsh wren[d] (*Cistothorus palustris*)	Primary
	Marsh–wet meadow	Wilson's snipe[d] (*Gallinago delicate*)	Primary
	Marsh–open water	Eared grebe[d] (*Podiceps nigricollis*)	Primary

[a] See Table 5 for descriptions of habitat families and groups.
[b] Common and scientific nomenclature for birds followed American Ornithologists' Union (1983); mammals followed Wilson and Reeder (2005); amphibians and reptiles followed Crother et al. (2000).
[c] We evaluated primary focal species throughout the assessment area when the habitat family and group was present; we evaluated $\geq$1 of the alternate species throughout the assessment area when the associated habitat families and groups were present; secondary species had localized populations confined to specific habitats, we analyzed these species only where they occurred and not across the assessment area.
[d] Focal species selected for use in northeast Washington State, USA. If a habitat group was not represented with a focal species it did not occur in the assessment area or management activities were not proposed for that habitat group.

species are sensitive to human pressures associated with increased access facilitated by roads (e.g., Robitaille and Aubry 2000, Gaines et al. 2003, Bayne et al. 2008) and would benefit from management of roads to limit human access to source habitats.

Wisdom et al. (2000) assessed viability for northern goshawks across the Columbia Basin and reported reductions in available habitat for both the North Cascades and Northern Glaciated ecological reporting units, areas that roughly correspond to our assessment area. Our results, though based on finer-scale data, showed trends similar to those of Wisdom et al. (2000). Northern goshawks were included in the conservation strategies we developed for snags and down wood, late successional forest, dry forest restoration, and human access management. These strategies provided recommendations to: 1) provide historical densities of snags and down wood (Harrod et al. 1998, Mellen-McLean et al. 2009), 2) manage to protect or restore late-successional forest habitat conditions to approximate historical conditions (Hessburg et al. 2000, Wimberly et al. 2000, Agee 2003, USDI Fish and Wildlife Service 2008), 3) restore the historical distribution and sizes of habitat patches (Hessburg et al. 2007), and 4) maintain old-forest conditions in forest stands with active northern goshawk nests (Wisdom et al. 2000). Among other focal species assumed to have benefited from these conservation strategies were golden eagle (*Aquila chrysaetos*), bald eagle (*Haliaeetus leucocephalus*), and pileated woodpecker (*Dryocopus pileatus*). All of these species are sensitive to declines in amount and patch size of source habitats (e.g., Menkens and Anderson 1983, Anthony and Isaacs 1989, Kochert et al. 2002, Bull et al. 2007) and would benefit from management designed to protect or restore late-successional forest habitat conditions and the historical distribution and sizes of habitat patches.

The conservations strategies we summarized for wolverines and northern goshawks and those we developed for the other focal species are being incorporated into management plans for the national forests in northeast Washington State, USA. The process we described provides the basis for viability assessments in the Pacific Northwest Region of the USDA Forest Service for national forests in eastern Oregon and Washington State, USA undergoing revisions of their land management plans (USDA Forest Service 2010).

MANAGEMENT IMPLICATIONS

Management objectives are generally temporally and spatially explicit actions taken during the life of a land management plan to move toward an identified desired condition. Objectives for focal species may be derived from the conservation strategies developed during application of this process to enhance species sustainability and may be made spatially explicit by identifying the anticipated amount of habitat that is expected to improve and in which priority watershed(s) the activity will occur. For example, an objective from the human access management strategy could be to reduce the amount of habitat influenced by roads by 500 ha within specific priority watersheds. The amount and location of these activities would be agreed to through an interdisciplinary planning process and hopefully meet multiple resource objectives (e.g., also restore fish habitat).

Applying this process to our study area provided an example of how to address a wide variety of species with conservation concerns. The application of the focal species approach allowed us to evaluate a subset of species that we then used to develop a wide range of conservation strategies and measures. The information generated from our approach can be directly translated into land management planning through development of desired conditions, objectives, and standards and guidelines to improve the probability that desired population outcomes will be achieved, not only for the focal species, but also for a broad array of species as well. In addition, development of assessment models provided a consistent and repeatable approach that can be used to evaluate and compare management options. Although we based this approach on current science, it should be noted by practitioners that any practical conservation planning process cannot remove all uncertainty and risk to species viability. Therefore, it will be important that a rigorous monitoring program be implemented to test the key assumptions: 1) assessment models provided a conceptual outline of the primary habitat and risk-factors that affected sustainability of focal species; 2) assessment models provided a reasonable and credible approximation of species' ecological requirement that may be used to identify key monitoring elements; and 3) focal species represented their respective species group in a manner that provided insights into the capability of habitat to support other species in the group.

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